INDUCTIVE LOGIC

FOR

Intermediate Students

NOTE.

Students of the Punjab University who have to take the Intermediate Examination in Philosophy in 1937 **are not expected to read** *the following chapters in this book :—*

Chapter VIII.—Scientific Induction. (I) Mill's Methods.

Chapter IX.—Scientific Induction. (II) The Deductive Method of Investigation.

PUBLISHED BY

A. H. I. BOOK DEPOT.

Brandreth Road, Lahore.

Scientific explanation moving between the two extremes of most particular and the most general. The following mark the limit of explanation

INDUCTIVE LOGIC

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Intermediate Students

BY

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First Edition.

1935.

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Analogy cannot take the place of Complete Induction where the later is attainable analogy can only be treated as a Process through which further suggestions for the establishment of Scientific laws are available. As Mill said, Analogy has the highest Scientific value when it is used as mere 'guide post' pointing out the direction in which more rigorous investigations should be prosecuted. Boyce Gibson has rightly pointed out that the true place of Analogy is in the service of Scientific Induction. It plays an important part in the Logic of Discovery but has no place in the Logic of Verification. It is never Complete proof but a stage on the Road to exact [illegible] monstration.

(1) Fundam[illegible] ons are their own e[illegible] not be explained further. [illegible] ling of Smell Colour, are ultimate & unique.
(2) Certain Ultimate Principle cannot be explained atom, matter, Inertia, gravity, energy.
(3) Individual Peculiarities of particular objects cannot be explained

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Pages.

while Induction by Simple enumeration merely states a fact of universal but fails to deal with apparent exceptions to a generalisation. Scientific Induction overcomes the difficulty by attempting

a thorough going analysis to establish a universal law of causal connexion.

Induction by Simple enumeration

Scientific Induction :- It goes beyond the factual relation established on the strength of mere enumeration, and aims at establishing a universal Law whose validity may be independent of the citation of Instances. The certainty of Proposition follows more from establishing a causal relation. Thus Scientific explanation which is based on the discovery of Laws of causal connexion is only possible through this type of Induction.

The essential steps in Scientific Induction are :-

(1) Preliminary observation of Facts.
(2) Supposition as to their cause.
(3) Verification of the Hypothesis.
(4) Explanation of the Law.
(5) Application of the established Law.

Scientific Induction undertakes to discover Principles of Universal Connexation through the analysis & Comparison of instances. Sometimes even a single instance is enough to establish a Causal relation; all depends on the Completeness & adequacy of our analysis. The Proper function of Scientific Induction is to explain the 'how' and not merely the 'that' of Phenomena. The statement of the fact of a uniform Connexion is not enough for purposes of Science. That Connexion itself must be explained.

Induction by Simple enumeration Consists in establishing a Universal truth on the ground of mere enumeration of instances, without any attempt at Causal explanation. It differs from Perfect Induction (based on Complete enumeration) in that its Conclusion is not a mere summing up of the known facts but is much more general. This type of Induction is based on the Principle that the future will probably resemble the Past. This admits Probability & not Certainty. It can only state a fact of Universal Connexion but cannot establish any Causal con...

CHAPTER I.

INDUCTION.

I. **What is it?**—Suppose that I desire to buy one hundred mangoes for a feast. I go to the fruit market. I am shown several heaps and baskets of mangoes. How am I to decide which mangoes are the best? I cannot merely guide myself by observing their odour or colour. I must taste some mangoes. The grocer points out one basket which, he says, should suit me. I taste some of these mangoes and find them sweet. I jump to the conclusion that the remaining mangoes of that basket must also be sweet. This is an induction, but a very risky and bad induction. Why? Because, when on my return home the mangoes are eaten, several turn out to be sour. The grocer had placed the bad mangoes at the bottom of the basket!

What should I have done? I should have mixed all the mangoes of the basket thoroughly. Then I should have tasted one or two mangoes from the top, one or two from the centre, one or two from the sides, and one or two from the bottom of the basket. I should thus have selected, say ten mangoes, from the basket (or the heap). This selection would have been a very *fair sample* of the lot. If on tasting these ten mangoes I had found them all to be sweet, I could have very correctly inferred that the remaining mangoes would also be sweet. Had I found that eight out of ten mangoes were sweet I could, again very correctly, have inferred that the percentage of good mangoes in the basket would be 80. This process would have been a scientific induction, and the probability of the truth of its conclusion would have been great.

What, then is the difference between a good induction and a bad induction, as depicted by the foregoing examples ? It is that the sample in the good induction was a fair one in the sense that (1) the selection was made after the mangoes had been *thoroughly mixed*; (2) that the selection represented all sides of the heap or basket equally well; and, (3) that the selection was *random* (*i.e.*, I had picked up whatever mangoes came to my hands from the various sides).

Let us take another example of scientific induction on the basis of these three points. Suppose that you want to buy wheat on a large scale. You go to the market. What procedure must you adopt to get the best value for your money ? You have not the time or energy to examine minutely all the various stocks of wheat lying in the market. Obviously you must take samples. Suppose that you select one particularly good-looking heap. You take a handful from the top. It *is* good. But this is not evidence enough. Have another handful from the right, still another from the left, etc. Now thrust your arm inside the heap and bring out handfuls from the various sides. In short, try to get a sample which may represent all the cubic space occupied by the wheat. Now examine the lot. If it is still good wheat you are justified in buying up the whole heap. This would be a good induction.

What, then, is induction ? It is (1) a form of *inference.* We have certain data and from them we derive a certain conclusion. (2) This inference is *concerned with* the objects which we find in *the world of nature* around us, *i.e.*, material objects. (3) The distinguishing character of induction—its differentia—is that *by examining* a few or some individuals, *i.e.*, *a part of a class, we can infer something about the whole class.* Herein lies the great utility of induction: it saves our time and energy, simplifies our labour, and enables us to *infer the nature of the unknown from that which is known.* From a few to the many—this is induction. (4) The *conclusion* of an inductive inference must be *a general or a universal proposition.* This, of course, follows from (3).

In this sense induction is a very common form of inference for all of us. Our daily life supplies scores of examples. The only thing that Inductive Logic does is to make this form of inference systematic and thorough-going. It tells us how to change our bad inductions into good ones.

II. Contrast with Deduction.—(1) Deductive inference is *formal*, almost symbolic, in nature. We say: if x is y, and y is z, then x is z, whatever x, y and z may be. Thus if they be 'John, man and mortal,' respectively, then the inference is: 'John is a man, and man is mortal, therefore, John is mortal.' This is valid and true. But if x, y, and z be 'cats, dogs and apples.' respectively, then the inference is: 'cats are dogs, and dogs are apples, therefore, cats are apples.' This inference is also quite valid (formally), but absurd and false. Deductively considered, both are equally valid.

Why? Because the formula is the same, *i.e.*, if x is y, and y is z, then x is z, whatever x, y and z may be. Now *Induction must also be formally valid, but in addition to this, it must be true to Nature; i.e.*, the statements of inductive inference must not be contradicted by facts, as we find them around us. This difference is expressed by saying that "the criterion of Deduction is mere formal consistency, whereas that of Induction involves Truth (consistency with Nature) in addition to formal consistency."

(2) Formal consistency depends on certain laws and postulates, such as the Three Laws of Thought, the Dictum of Aristotle, etc. Induction, like every other science, must conform to these laws. (They provide the skeleton of a science). But it must look to Nature for facts. These facts of Nature are its subject-matter. Induction studies these facts from its own point of view. It tries to discover what facts are connected with what other facts in such a way that if the former occur, the latter are sure to follow—*i.e.*, what facts are causes and what effects.

(3) One very important form of deductive inference is the syllogism. It is based on Aristotle's Dictum: "What is affirmed or denied of a whole class can be affirmed or denied of a part of that class". Can we have a parallel dictum or axiom for induction? Here is one which does bring out the essential nature of inductive reasoning: "*What belongs, or does not belong, to all the (observed) constituent parts, belongs or does not belong, to the constituted whole.*" The attribute 'mortality' belongs to observed members

of the class 'man'; hence it also belongs to the whole class 'man'. Similarly, the attribute 'rationality' does not belong to the observed members of the class 'goats'; hence it cannot belong to the entire class 'goats.'

(4) It is sometimes said that induction is *analytic* in nature whereas deduction is *synthetic* in nature. This is not an accurate statement. Both induction and deduction have to employ analysis as well as synthesis. In fact, every science requires the aid of these two processes.

(5) Induction and Deduction, as forms of inference, are complementary to each other. One cannot do without the other. Deduction gives us the laws which govern all formal reasoning. Induction (like every other sciene) must conform to these laws. But if we desire to use these laws in the search for Truth, we must have recourse to experience—to Induction. Induction leads to the discovery of 'general propositions' or universal truths which later on form the basis of (by serving as major premisses in) deductive syllogisms. Both together would form a whole—the science of Logic.

III. Kinds of Inductive Inference.—There are two main forms of inductive inference :—(*i*) *imperfect* and (*ii*) *scientific.* Imperfect Induction has two sub-forms: (*a*) induction by *simple enumeration* and *analogy*. Scientific Induction has several sub-forms: it comprises, for instance, the five *Experimental Methods* of Mill, the *Deductive Method of Scientific Investigation* (also called the method of Rational Induction), and *Hypothesis.* Imperfect inductions prepare the way for and take the place of scientific induction where the latter is not possible. The most important preliminary process of inductive investigation is *Classification*, by means of which the data (facts) are methodically arranged and tabulated and thus are made available for systematic study. Classification requires the assistance of scientific *Nomenclature* and *Terminology*.

How are the facts—the data of induction—got hold of? By means of *Observation* and *Experiment*. These form the method of inductive study. The facts are worked over in various ways by the inductive processes mentioned above and laws of function and structure are deduced. There laws are so many general propositions about the events which comprise Nature.

IV. Inductions Wrongly so-called.—There are certain processes, however, which look like Induction but are really different from it. There are three such forms of inference. (*i*) *Perfect Induction*, (*ii*) *Parity of Reasoning* and (*iii*) *Colligation of Facts*. It is necessary to distinguish these processes from induction proper because in essence they are entirely distinct from it.

A. Perfect Induction.—Suppose that I have a basket of mangoes, say one hundred. I want to judge whether the contents of this basket are sweet or not. If, now, I begin to taste each and every mango and find it sweet, and judge that all the mangoes in the basket are sweet, the judgment would be called a Perfect Induction. Perfect Induction, in other words, is that process of reasoning, in which, after examining each and every member of a group of objects, we deduce something about the group as a whole. The facts before us are exhausted and nothing is left to chance or probability. The result obtained has been verified in each and every case. Since in this form of inference the whole evidence is exhausted, the mediaeval logicians called the process a Perfect Induction.

This, however, is, not the modern view. Perfect Induction, instead of being perfect is, strictly speaking, no induction at all; and for the following reasons:—

(*a*) The essence of induction is the discovery of a general law or universal proposition as the result of the examination of a certain limited number of individuals belonging to that class. If I taste, say, ten mangoes at random from the basket, find them sweet, and then infer that the remaining mangoes must also be sweet, I am having a true induction. In this case I *go beyond the evidence*. My conclusion covers the facts studied, but goes beyond them and embraces the whole class. This is not so in Perfect Induction because the whole evidence is exhausted and the conclusion tells us nothing *new*. The conclusion is nothing but a summarized statement of the facts observed.

(*b*) Since in a real induction the conclusion always goes beyond the facts studied, there is always an element of *risk* present. The inductive conclusion can only be probable and not certain. Now in a Perfect Induction we have no risk but certainty because no unexamined facts remain. The conclusion embraces the same area as the facts which form its basis.

(*c*) Induction proceeds from a part to the whole of a class, but Perfect Induction exhausts the whole class and is limited by it. It has no generalization; no reference to the future. It is merely limited to the circle of facts which form its basis.

B. Parity of Reasoning.—Suppose that I have a triangle before me. I find that the sum of any two of its angles is greater than the third. Since I find this to be true in the case of one triangle, I infer that it shall also be true in every other triangle. Why? Because all triangles conform to, and are illustrations of, one and the same definition. This definition gives us the essential attributes of all triangles and the law referred to above is merely a corollary from that definition. The examination of only one triangle is sufficient to establish and test the law. We argue that since the one triangle examined established this conclusion, it must be true of all other triangles too, simply because they are triangles and conform to, or are illustrations of, the same definition. In other words, there is a parity in the nature of all triangles and what is true of one is for that very reason true of all. Now is such reasoning inductive? No, because:—

(*a*) In induction we examine several cases out of a class of objects, and on the basis of this examination, decide that what is true of these cases will probably be true of the remaining unexamined cases of that class. In Parity of Reasoning, on the other hand, we examine only one case and this suffices to establish the result beyond the shadow of a doubt.

(*b*) In Parity of Reasoning the established conclusion follows from the very definition of (the objects) of that class. This is not so in induction where the very nature of the class itself is the problem under discussion.

(c) The element of *risk*, which is inseparable from the inductive process is entirely missing in Parity of Reasoning.

C. Colligation of Facts.—Suppose that I want to find out the layout or plan of a certain town. One method, of course, would be to mount up into the sky and have a bird's-eye view. But when this is not practicable, I shall have to chart out piecemeal the various sides of the town. These side-views could then be pieced together and a general view of the whole town obtained. This method is that of Colligation of Facts. But is it inductive in nature? No, and for the following reasons: –

(*a*) In induction we study some members of a group or class, and then infer or generalise about the whole class. In Colligation, on the other hand, we have only one fact before us and the ultimate result does not go beyond it. It is entirely limited to it and by it.

(*b*) In induction each member, out of a group, is studied as individually complete, but in Colligation the *one* fact before us is broken up and studied piecemeal.

(*c*) The element of *risk* which is a feature of the inductive inference is absent in Colligation.

(*d*) The result of a Colligation is merely the summation of the various parts into a whole; there is no going from the known to the unknown.

Exercises.

1. What is the general nature of Induction? Explain by means of examples.

2. In what way does inductive reasoning differ from deductive reasoning? Distinguish between these two methods of inference

3. Of what use is inductive inference? Does it perform a function which deductive inference cannot perform?

4. What is meant by saying that "deduction and induction are continuous operations"? Examine this view.

5. Discuss: "Induction is really the inverse process of Deduction."

6. Define induction and describe its aim.

7. Name the various forms and subforms of induction.

8. What processes look like induction but are not inductions in reality? Give examples.

9. Write short notes on:—Perfect Induction; Parity of Reasoning; and Colligation of Facts. Mention in each case why the process is not really an induction.

CHAPTER II

FACT, PHENOMENON AND THEORY.

I. Introductory.—The words *fact* and *phenomenon* are often used as synonyms; while *fact* and *theory* are very often regarded as opposed in their significance. It is necessary to know the exact scientific connotation of each of these terms before entering into a detailed discussion of the problems of induction.

*To begin with, we remind ourselves of the truth that all inductive sciences deal with Nature (in its various aspects) as revealed to us by our *experience*. Nature does not come to 'us' except through the channels of sense, *viz.*, our sense-organs. These sense-organs are themselves only outposts of our nervous system, and especially of that most important part of it, known as 'the brain'. The sense-organs receive impressions from objects outside us; but every impression that irritates a sense-organ is *not* received by it: the organ selects some and rejects others. These selected impressions are worked over by the central nervous system, especially the brain, and then in some mysterious way we have a *sensation*—*i.e.*, an exceedingly simple or elementary mental process. This is not all! We do not receive sensations simply and singly: we receive them 'in lumps, by the gross and arranged in the most diverse patterns'. Our mental processes at any single moment are very complex and have for their elements not sensations merely, but also feelings and images. This vast network

*This paragraph may be omitted if the class has had no grounding in the elements of Psychology.

of simple mental processes worked over by more complex processes (cognitive processes) like association, memory, imagination and thought; (conative processes like) instinct and will; and (affective processes like) emotion and sentiment,—constitutes our *experience*.

All this must be very obscure to the reader unacquainted with the elements of Psychology. But even without understanding it, one can realise the complexity of the processes which go to make up our experience.

We realise, then, that *experience* is (1) the extremely complex sumtotal of different kinds of *mental processes*; (2) that it is initiated by *impressions* or stimuli or irritations received *by our sense-organs* from objects outside 'us'; (3) that our own body (being a material object) can give rise to sense-impressions which serve to enrich our experience; and (4) that the mental processes which make up experience are *selective* through and through. So far we have considered that experience whose origin is in impressions from external objects. But we have our own (5) *spiritual experiences* too whose seat is 'within us'; *e.g.*, the joy of the mystic in his contemplation of the divine; the joy of the artist or the poet who sees beauty where others see it not; the creative impulse of the genius who gives 'life and form' to clay or bronze or marble, or infuses fire and spirit into words, or formulates judgments and laws undreamt of by his duller fellow-mortals. Such 'spiritual experiences' seem to well up from within the inmost recesses of our own souls; but as they assume the patterns of our mental processes, we must call them experiences.

The *selectivity* of experience is best illustrated by a homely example. What happens when I pass through a crowded street? There are sounds, sights, odours, strains and movements of the most diverse sorts. They impinge upon my ears, eyes, nose, limbs, etc. But do I give equal attention to all of them? Certainly not! I see a friend, and he is selected out of the crowd. The other objects drop behind. Do I see everything about the person of my friend? Again, no. I look at his face and have the merest glance for the rest of his body. Do I see his face with care? No, I am far too busy now talking to him to do so. Do I give equal attention to every word of his? No, some words interest me more than others. In short, there is selection every moment and at every step.

Outside Reality or *Nature* is more or less common for all minds. But the *selection* made by each mind, each personality, *is different.* Each one of us lives in a different world of his own devising, and though each of these 'private worlds' of ours is a glimpse and construction out of the same Nature in which we all 'live and move and have our being', yet the selectors being different, no two such glimpses are absolutely alike. You and I perceive the same rose and declare that we like it. Yet the perception and liking of both of us are different.

II. Definitions.—We are now in a better position to understand the significance and mutual relationship of fact, phenomenon and theory. Let us define each. ***Fact***: A fact is that which is *given* in experience—*a* data

datum of experience. This datum of experience is to be distinguished from the experience of which it is a datum. (1) In other words, *it is independent of the mind which perceives it*: it is *objective*. (2) Secondly, it should be *immediate*. (3) Thirdly there should be nothing hypothetical or unreal about it: it should be *actual*, *i.e.*, something existing in our experience.

In the light of what we have said above about the nature of experience, it should be evident that however objective a *fact* might be, *it is a result of mental activity*, 'a mental construction.' The rose on the bush is a fact; it exists outside of me; it is not a figment of my or somebody else's imagination; even if I and every other perceiving mind were to die *it* would. exist; etc. All this is very true. But it is also true that if every perceiving mind were to disappear, the rose could not be known. It would cease to be a fact in anybody's experience. This aspect of the fact is called *Phenomenon.*

A ***Phenomenon*** is any occurence in nature as revealed to us by our experience. It is always *relative to us*. It is an object or event in our time and our space, and as such we can observe it and describe it. We receive it through the impressions of our senses, and it has no existence apart from our mental activity. It is an aspect of realitv or nature in so far as nature depends upon us, and we distinguish it from the *thing-in-itself*—*i.e.*, from nature in so far as it is independent of us and of our mental activity.

In fine, the same object or event in our experience is a *fact* when we emphasise its *objectiveness* or independence of our mental activity; and is a *phenomenon* when we emphasise its *subjectiveness* or dependence on our mental activity. The rose, in so far as it exists in its own peculiar reality, in its own private right, that is to say—is a fact. But in so far as the rose is *known* to me or to other perceiving minds, *i.e.*, in so far as it starts certain mental processes in certain minds (and but for these processes would not exist for those minds)—it is a *phenomenon*. The objective Sun that we all perceive and refer to is a *fact*, but my perception of the Sun (different in some slight way from your perception of it) is a *phenomenon*. If all perceiving minds were to disappear, the Sun as phenomenon would also disappear, but as fact it would remain and continue to exist in solitary majesty.

There is, then, the distinction of 'objective and subjective' between fact and phenomenon. In the rest of this book, however, we shall use these terms interchangably, except, of course, where it might be necessary to distinguish between them.

Theory. Facts or phenomena must be explained. In themselves they do not mean much. Only when brought into relationship with other facts or phenomena do they become significant and scientifically important. Explanation consists in thus linking facts with other facts or with laws. Now the principle or formula which is devised for the purpose of explaining facts, is called a *theory*. Should this explanatory principle or formula be very provisional and insecure in its basis, it is sometimes called an *hypothesis*. A theory is distinguished in the sense that it has a larger measure of plausibility, *i.e.*, has a greater probability of being true. Further, a theory which has stood the test of criticism and is firmly established, is sometimes called a *law*.

Now a theory is entirely the work of the intellect. In this sense, it is quite 'subjective' in its nature.

III. Fact and Theory: mutual relationship.—The business of science is twofold: (1) to find facts; and (2) to explain them by satisfactory theories. Facts are the raw material of science; theory is the architect that gives shape to it and arranges it in the form of a scientific structure. Both hang together. Facts, by themselves, are meaningless and valueless; but when systematized by means of a theory, they assume significance and their hidden import is revealed. Similarly, a theory divorced from facts is the idle play of the imagination, a mere form without content. Each is necessary for the other.

Since a theory is devised to explain the facts of a certain class, it follows that when facts conflict with it, it should be modified, or if that is not possible, entirely rejected. Facts have primary importance and 'scientific honesty' consists not only in incessant search for all relevant facts, but also in attaching due value to every fact even though it happen to conflict with our most cherished theory.

Every fact has a many-sided reference. A piece of paper is a fact: it exists. But it is white; it has weight; it has value; it is combustible; it is a manufactured article; it is meant to write on; etc. There are so many aspects of its existence and every aspect is important from some point of view. Now it is impossible for any single theory to satisfy every feature of the facts with which it deals. Hence a *theory must needs be more simple than the facts on which it is based*, and which it tries to explain. One should, therefore, be very cautious in drawing the extreme consequences of even the best theory.

For this very reason, *every theory is subject to criticism*. It cannot satisfy all demands. But facts are independent of criticism and are there to accept, systematise and explain. Hence it is easier to find facts than to theorise on them.

There is another difficulty. It is not always possible to distinguish between facts and theory. Both being 'mental constructions', there may be no special attributes to mark off the one from the other. Whewell says, "Facts are phenomena apprehended by the aid of conceptions and mental acts, as Theories also are. We commonly call our observations Facts, when we apply, without effort or consciousness, conceptions perfectly familiar to us; while we speak of Theories, when we have previously contemplated the Facts and the connexion conception separately and have made the connexion by a conscious mental act." "Is it a Fact or a Theory that the planet Mars revolves in an ellipse about the Sun? To Kepler, employed in endeavouring to combine the separate observations by the conception of an Ellipse, it is a Theory; to Newton, engaged in inferring the law of force from a knowledge of the elliptical motion, it is a Fact." *

IV. Kinds of Facts.—All facts are not of the same kind. We have already said that one and the same fact may have a manifold reference. Different sciences have different points of view and select those facts and those aspects of facts which are relavant to their special point of view.

Facts may broadly be classified into two great groups:—

(*A*) *Material*, and (*B*) *Non-material*. The latter are psychical, mental and spiritual phenomena. *Material* facts can be sub-divided into three chief classes:—(1) *Physical facts* which deal with matter, its laws and properties and such facts as those of 'mechanics, dynamics, light, heat, sound, electricity and magnetism'. (2) *Chemical facts* which deal with the 'different kinds of matter of which the globe is composed, and the nature, laws of combination, and mutual actions of the properties of matter, and the properties of the compounds they form'. (3) *Biological facts, i.e.*, facts which deal with the phenomena of life or of living matter; or facts pertaining to the life of animals and plants and other living organisms generally, 'their morphology, physiology, origin, development and distribution.'

Non-material facts are either (4) *psychical* in so far as they involve some mental processes, conscious,

* *Novum Oganon Renovatum*—p. 116.

sub-conscious, unconscious, etc.; (5) *mental* when the processes are of a clearly conscious or self-conscious and more or less normal character; (6) *spiritual* when the processes, in addition to being mental, involve unmistakable attributes of awe, reverence, humility, prayer, etc., towards a Diety or any Mysterious Power which is believed to be divine and the basis, life and goal of all that is highest and noblest in man.

It is evident that no one science can concern itself with all of these facts or all aspects of any one fact. The different sciences are based on the working principle of a division of labour. Each science must needs have a one-sided outlook and its results, being confessedly partial and limited, can never have the finality of ultimate truth. Only when the results of different scientific disciplines are brought together to form a systematic whole, *i.e.*, only when a comprehensive System of Philosophy takes up the threads of investigation where they are left hanging by the various sciences and weaves them into the pattern of a higher synthesis, do we come near to a truer vision of Reality. But we should not forget that the noblest and most comprehensive System of Philosophy is also a 'human construction' and suffers from the limitations of the intellect. Man cannot jump out of his own shadow.

Exercises.

1. What is meant by *experience*? How does it grow?

2. What part do our sense-organs play in the growth of our experience?

3. What is meant by saying that experience is *selective* through and through? Illustrate by reference to your own experience.

4. What is meant by Nature or Outside Reality?

5. Can two people perceive the same object in the same way? If not, why not?

6. Distinguish carefully between Fact and Phenomenon. Give examples. Define both.

7. What is the relationship between a *phenomenon* and the *mind* which perceives it?

8. 'Facts are objective but phenomena are subjective in nature'. What does this statement mean?

9. What is meant by Theory?

10. What is the mutual relationship between 'facts' and 'theory?' Explain fully.

11. What would you do if some facts conflict with a good theory?

12. Can one and the same theory explain facts in all their aspects? If not, why not?

13. What is meant by saying that the theory is simpler than the facts on which it is based?

14. What is meant by a *mental construction*?

15. Is it always possible to distinguish between a fact and a theory? Give examples to support your answer.

16. Mention with examples the various kinds of facts enumerated in this chapter.

17. Can any theory explain all possible facts? If not, why not?

18. Can any theory be finally true?

CHAPTER III.

METHOD OF INDUCTION: OBSERVATION, EXPERIMENT AND TESTIMONY.

I. Introductory.—Induction, as we have seen, is concerned in a way with the discovery of Truth. Now, Truth is not to be had for the asking. Like grains of gold in a mine which are mingled with clods of earth, Truth comes to us all-enmeshed in a mass of irrelevant facts. The method by which Truth can be sifted out of this irrelevant mass is Scientific Observation.

It must not be supposed, however, that observation alone can suffice in the search after Truth. Besides observation (and Experiment, which is only another form of observation) we require the processes of Inference and Hypothesis. These processes enable us to arrange the facts in a proper way so that we can examine them in the light of a possible Explanation.

II. What is Observation?—Observation is a *form of experience.* We can observe that which our senses reveal to us. In this sense, observation is a form of Perception. Now, what is Perception?

We may roughly define *perception* as the process of obtaining knowledge of an object in the outside world by the help of all the sense organs that might be necessary for this purpose. Suppose that a child sees an orange for the first time. The orange is taken up in the hand, smelt, tasted, felt, etc.—in short, *perceived.* After the experience of some oranges, let the child enter a room where, on a table, he sees an object which *looks* like an orange. At once he makes for it. But alas! it is only a clay orange—a toy. The child was deceived in his judgment that the object was an orange. Why was he deceived? Simply because he had pronounced his judgment on the basis of only one kind of sensations—*viz.*, sight sensations. He had not waited to supplement this knowledge by using his other sense-organs. He took a short-cut to knowledge and he was deceived. This misleading short-cut to knowledge resulted, not in a true, but in a *false perception*—*i.e.*, in an *illusion.*

The *good observer* is one who *avoids such misleading short-cuts*; *i.e.*, he does not pronounce his judgments until he is sure of his ground.

III. Difficulties of Observation.—Correct observation of phenomena (natural events) is not an easy affair. Observation is an art. One must *have* the gift. Mere practice cannot create it though it certainly does perfect it. The ordinary man is liable to be misled in his observations for the following reasons:—

1. *Observation requires effort and attention.* But most of us are disinclined to do so. A good observer becomes good after years of hard work and practice. Even a Sherlock Holmes or an Houdini would require years of apprenticeship before he can perform the wonders of his trade. Houdini, for example, had trained himself to observe more than a hundred objects at a glance. At first he could not observe even twenty.

2. When we observe something in which we are interested we are sure to have a *bias or prejudice in favour of it or against* it. To be good and reliable observers, we

should first purge our minds of these prejudices. And this is not an easy thing to do. Betzelius, the great Dutch chemist, once told his students that not one of them was a good observer. The students protested and challanged him to examine them. He told them that in order to observe a chemical substance, say, they had not merely to look at it, but also to smell it, taste it, touch it, etc. As an example, he took hold of a bottle containing a liquid, removed the stopper, smelt the liquid, thrust one finger into it, and licked it. Next he asked each student to come up to the table and do exactly what he had observed him do. Each student came in turn, looked at the liquid, smelt it, tasted it, and went back spitting and disgusted. The liquid seemed to have an evil taste but Betzelius had not suffered at all. When all had had their turn, he declared that his contention was proved because not one of the students had proved himself a good observer. What *he* had done was to dip *one* finger and lick *another*. The students had licked the same finger that they had dipped. The reason was that their minds were so full of their teacher's remarks about tasting that they had mis-observed him.

3. Another difficulty is that *very often we do not know what to observe.* The habit of fixing one's attention on relevant and important facts takes long to acquire. Here also the influence of our previously formed views and intentions becomes apparent. If our aims are different, the same fact which in one case is of the greatest importance might dwindle into insignificance in another. To decide *what* to look for depends to a great extent on the

motive *why* are we looking for it. The appearance of a comet might be quite irrelevant as the cause of the sudden death of a king, but it might have a great deal to do with the atmospheric disturbances which appeared at the same time as that event.

This difficulty makes itself felt in another way too. Ask a young student to observe a drop of water under a microscope. He is confused. He strains his eyes but does not seem to secure any tangible result. Only when the instructer tells him *what* to look for and *where* to look for it, does he get anything out of his observation. The trained observer would feel quite at home in the presence of a tangled mass of phenomena which utterly bewilder a beginner.

4. Lastly, observation becomes extremely difficult when one has to deal not with things but with *processes*. Things are relatively stable and unchanging, and can be observed at leisure. One can observe now one side and then the other. Repeated acts of observation help to fill in the sketch we are forming. But *processes change every moment*. When we have noticed one aspect, several others have passed by unnoticed. *Continuous and rapid change bewilders us.*

All of these difficulties can be overcome. '*Patience and practice*', as Titchener says, help a lot in doing so.

IV. Cautions to bear in mind.—The following points are worth noting:—

1. Observation always demands *active attention*. Now, *attention is always selective*. When we attend to a phenomenon we note only some aspects or qualities and

by that very act we over-look others. We note, say, qualities *a*, *b*, *c*, because at the time these qualities are useful for our purpose. Had our inquiry been of a different order, qualities *p*, *q*, *r*,—also present in the same phenomenon—might have been attended to instead of *a*, *b*, *c*. This means that *our observation is always guided by the purpose or aim of our inquiry*. Now, what determines our purpose? Obviously, the hypothesis or theory that we are trying to test.

2. When we observe a group of phenomena, we should try to make sure that our *investigation* is as *exhaustive* as possible. As Welton says, "non-observation does not prove the non-existence of a phenomenon unless its existence would certainly involve its observation." For this reason, our *negative evidence*, *i e.*, evidence which would tend to prove the non-existence of a certain phenomenon, or of some of its qualities, should be as exhaustive as possible. The non-discovery (till very recent times) of the gas Argon as a constituent of the atmospheric air is a case in point.

3. Observation is carried on by means of our sense-organs. But the sense organs are, after all, very imperfect. We can see or hear ordinary objects and sounds. But anything out of the way, things very big or very small, very near or very far away, are beyond the ken of our sense-organs. In such cases the organs require artificial help by means of instruments. Telescopes and microscopes, *e.g.*, are such artificial aids to our sense-organs. They increase their *efficacy* and *range*. But the use of such

instruments does not mean that we are performing experiments: they are different in nature.

4. Again, *every scientific instrument embodies the results of previous investigations.* Knowledge previously gained gets crystalised in these instruments, and they in their turn help later investigation. By means of a thermometer I can measure the degree of heat at any moment. But the thermometer itself is a record of the discovery that heat is a measurable quantity and that mercury and temperature vary together. "Thus, not only the matter which is observed, but the accuracy of the observation depends on previous knowledge; and such accuracy is always a matter of inference from the application of such knowledge." (Welton).

(5) Lastly, it must be remembered that *good observers are born, not made.* Given a knack for the thing, practice and training can perfect it. But they cannot create it out of nothing. *Correct observation is an art, not a science.* The good observer must know what he wants and have the skill, the knack, to search for it in the right place. *Further,* he should have the ability to put the observed facts together and *infer something new* about them. This element of inference is *the* thing in the development of man's knowledge. Millions had noticed the ebb and flow of tides, the fall of unsupported bodies, etc. But it was left to Newton to infer the Law of Gravitation, and thus to explain them all. "The true 'seer' indeed, is the rarest of all discoverers; but *the true seer is one who brings to his observation more than he finds in it.* The drudgery of the patient interrogator of nature is made

divine only when it is inspired by ideas which are not objects of observation."*

V. Observation and Experiment.—*Experiment is observation under artificial and standard conditions; i.e.,* conditions controlled and determined *by* us (and not *for* us by nature). Observation is more or less accurate inspection of phenomena under nature's conditions. But nature does not always, or even often, give us phenomena carefully delimited from irrelevant circumstances. Again, many natural processes are so slow and minute that they altogether escape ordinary observation. For this reason we require observation where the conditions are entirely determined by us in order that we can *control, vary,* or *modify* them according to our requirements. Such *controlled observation* is called Experiment.

Experiment and Observation, then, differ from each other not in kind but in *degree*. The latter is only carried to its farthest limit under self-imposed conditions. Both are forms of experience. But (1) observation is rather *passive* experience as contrasted with experiment which is *active* both in its inception and in its execution. (2) In observation we study phenomena under nature's conditions, whereas in experiment we *prepare* our own conditions. (3) Observation, thus, is *finding* a fact, while experiment is *making* a fact.

" While ordinary observation is more or less, casual perception, experimental perception is planned, designed, and deliberate, and therefore, of superior value as evidence."

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*Mackenzie: *Social Philosophy.*

Relative Merits.— Experiment has certain advantages over ordinary observation:—

(1) By experiment the phenomenon under consideration can be *reproduced* as often as we like; whereas in observation we have to wait until nature presents it before us. In experiment the phenomenon is under our control.

(2) In experiment we can vary the phenomenon as often as we like. In this way new light is thrown on the problem. New results are obtained with each variation. *Further,* we can obtain the precise sort of variation that we require. This is not possible in observation; *e.g.*, observation can tell me that quinine cures malaria. But how much of it would be necessary for a child, or for an adult, or what should be the dose under different circumstances?—these are questions that require exact and quantitative variations which only experiment can give.

(3) *Elimination of irrelevant circumstances* is rendered much easier by experiment. *Isolation* of the phenomenon under consideration from others which might accidentally be found present along with it, enables us to judge exactly and definitely what conditions or causes are responsible for which effects. For instance, incantations or magic formulas and a little arsenic occuring together are found to have resulted in the death of a man. But experiment tells us that arsenic alone is sufficient to kill a living being. Incantations, therefore, were useless and irrelevant. Mere observation could not have eliminated the irrelevant factors.

(4) Since an experiment depends on our own efforts and not on the courtesy of nature, and since, further, we

can always repeat it in case of necessity, it follows that *we can study the phenomenon with far greater coolness, accuracy and precision* than can be possible with observation alone. In the latter case one has to hurry the pace, since at any moment nature might snatch the interesting object away from us. In sciences like Astronomy, which do not allow of experimentation, this defect of observation is made most manifest. Witness the prolonged preparations, years ahead of the event, for a three or four minutes' view of the Solar Eclipse. The consequent agitation at the critical time does not make for the best results.

(5) Lastly, an experiment can always be *repeated* by other investigators. This ensures co-operation and community of work. Results can be verified or corrected, if necessary.

The above considerations should not be taken to mean that pure observation plays no part at all in scientific investigation. It has its own advantages :—

(1) Observation is the sole instrument of knowledge in sciences which do not allow of experimentation. Astronomy, Metereology, Geology (to a great extent), Sociology, Economics, etc., are observational sciences. One cannot experiment upon the heavenly bodies, nor can one control the tides, the winds, or the strata of the earth. Even the facts of social and economic life are, to a great extent, beyond our control.

(2) Observation helps both in the search for causes as well as for effects. Experiment can only help in the latter case. Given an effect, to go *back* to the cause is only possible by patient observation.

Both observation and experiment, therefore, are useful in the search after Truth. The two methods are complimentary and not antagonistic. Each has its proper place in the investigation of phenomena. But wherever observation can be changed into or supplemented with experiment, we should do so. Sometimes nature herself performs an experiment. A solar or lunar eclipse, for example, is a natural experiment. The study of such phenomena might be regarded as a sort of intermediate stage between pure observation and pure experiment.

VI. Testimony : What is it ?—All that we know is not the result of our own investigations. It would be no exaggeration to say that 99·9% of the average human being's knowledge is based on the reports and records (oral as well as written) of others. Such reports and records form *testimony*. Now these 'others' on whose records and reports we base our knowledge are not all alive : the great majority of them died long ago. Their testimony has come down to us, not at second-hand but at hundredth or thousandth hand. We should, therefore, have some criterion or standard of judgment by means of which we can decide in every case what part of a certain record or report is to be accepted as true and accurate, and what part is to be rejected as false and inaccurate.

Should the person whose testimony is received by us be alive and the facts reported by him be such as can be repeated, it would be possible for us to verify the truth or otherwise of the report. But when neither the facts are available nor is the reporter alive, the necessity of a very thorough sifting of the testimony becomes urgent. The best of us do commit serious errors of observation. How much greater is the probability of such errors in the case of those observers who had no scientific training in methods of observation; or whose good faith as honest reporters cannot be established; or whose competence to report accurately was doubtful; or whose poetic flights of imagination made it well-nigh impossible for them to separate truth from fiction! The risk of error becomes overwhelming when we consider that the records of the earliest times have been transmitted to us by persons whose very names are not known. And yet it is on such flimsy foundations that the so-called science of Ancient History is based.

The risk of error in the oral transmission of a report is very well illustrated by a popular parlour game. Seat some people in a circle. Write out a story and whisper it accurately to your righthand neighbour. He should next repeat it to *his* neighbour and so on until your left-hand neighbour relates it to you. The story is altered almost beyond recognition! We can well imagine the modifications which a tradition must suffer when passed *uncritically* from generation to generation.

VII. How should Testimony be critically examined before it is accepted as true?—We have seen above that any and every testimony cannot be accepted. We should first subject it to severe tests. The reporter whose testimony is to be accepted should be (1) *impartial* *i.e.*, free from bias; (2) he should give his testimony in *good faith*; (3) he should be *competent to observe*; (4) he should be a *contemporary* of the events reported; (5) he should have written down his record *immediately after* the occurrence of the event; and (6) his record should be *accurate* and precise. Very rarely are all of these conditions rigidly satisfied, but they give us the criteria in terms of which we should determine the value or otherwise of any particular case of testimony. We shall now say a few words about each of these conditions.

(1) *Impartiality.*--This condition has already been explained and illustrated in the discussion of observation. Our prejudices are many and very seldom are we even conscious of them. Modern Psychology has thrown a flood of light on the workings of the 'sub-conscions' mind and we now know that our real motives to action are often quite obscure and unrevealed. Hence a man may be prejudiced without knowing that he is. The best-intentioned parent who happens to witness his son's mix-up in a street brawl, will not be able to confess that the boy was really to blame. In fact, too much of conscientiousness in such a case may make the parent's report really unjust to the boy: in trying not to be partial to the boy he may end by being partial against him. The Caliph Omar was once distributing booty, consisting of pearls, among his soldiers. To each person was given a handful. Hundreds were served like that, but his own son who had long been waiting for his share was continually overlooked. A soldier who had just got his share exclaimed, "Omar! you are unjust to your own son! Why do you not give him his share? He was one of the first to come." Omar answered that he was afraid lest his handful becomes unconsciously larger when he plunged it into the heap for his son's sake. "Let him have my

share," retorted the Arab soldier, "and now give me a handful for mine."

(2) *Good Faith.*—The reporter should believe in the accuracy and truthfulness of his own account. He should be sincere in his assertions. The reader may perhaps wonder why should this condition be specifically mentioned. There is great need for it, however, especially in these days of newspaper reporters. So-called eye-witnesses or 'special correspondents' are supposed to contribute reports of the various happenings of the day. Yet the reporter may not have been an eye-witness at all or may have written his report even *before* the event actually occurred! When the testimony is unsupported by other witnesses or records, the question of sincerity is important. We should then ask "whether falsehood would appear to bring any personal advantage to the witness, whether he is likely to be swayed by fear, vanity, sympathy, antagonism, the desire to please, or the wish to astonish or amuse. We should be inclined to suspect all rhetorical flourishes, all dramatic detail, expecially when any considerable time has elapsed between the occurrence of the event and the record of it."* Mere good faith or sincerity, however, would not suffice to make the testimony valuable. Good faith should also be supported by *accuracy* of record.

(3) *Competence to observe.*—The historian, for instance, may be a bad observer of chemical changes in a test tube; and conversely, the chemist may be unfit to unravel and report the complexity of motives which create a social or

*Welton: *Logical Basis of Education*—p. 157.

political upheaval. Briefly, only the expert in a certain line is competent enough to report with any accuracy the events of his particular department. Again, one may be a good enough observer but a bad reporter. People with vivid imaginations (unless, of course, when they subject themselves to the most rigorous discipline) are prone to exaggeration. Poets, orators, politicians, etc., are often very bad reporters. Historians with strong 'literary bias' can seldom give us accounts free from the figments of their own vivid imaginations. The good reporter, in short, is he who gives us a *word-photograph* of the event reported and not a *word-painting* of it. Here we must also refer to the gross exaggerations and actual falsehood of much of so-called *propaganda*, the broadcasting of untruths on the principle that a falsehood oft-repeated comes to be believed in by the people. This principle is, unfortunately, only too true.

(4) *Contemporaneousness.*—In the last resort, all testimony should be based on the account of an *eye-witness.* 'Personal observation' (our own or somebody else's) is the ultimate foundation of all inductive sciences. When this condition is not satisfied, we can have no criterion to distinguish fact from fiction. Hence *anonymous* testimony cannot be accepted, for when the reporter is unknown one cannot judge his impartiality, good faith, competence, etc. Many ancient historical records on which vast structures of history are based suffer from this defect. And the legends of a country belong to the same category. Their great value is that "they embody a people's ideas,

but they cannot be appealed to as records of facts."*

(5) *Immediacy of record.*—The observer or witness should have written down his report *immediately after* the event. This condition is necessary in view of the fact that our memory and imagination play all sorts of tricks on us. We often believe what we *wish* to believe. We tend to forget unpleasant experiences especially when we do not show off well in them. We suffer from lapses of memory and these are later on filled in by imagination and inference. Recent developments in the psychology of the 'unconscious or subconscious mind,' and especially the perfection of the methods of hypnotism, psycho-analysis, and free-association in the study and cure of mental diseases, other abnormal mental states, dreams, etc., have made it impossible to overrate the part played by 'memory and imagination' in the health and hygiene of the mind. Most of the dreams of the night, for instance, are forgotten in the morning. And it is now a rule with psychologists to consider no record of a dream as accurate which was not written down *a few minutes after* its occurrence. Records of historical events, written years after their occurrence are, therefore, more than suspect. Here again we see revealed the shaky foundation on which most 'history' is based.

(6) *The accuracy and precision of the record.*—This point does not need labouring over. Accuracy and precision are of the essence of scientific honesty. Only the trained observer, however, can fulfil this condition. To be accurate he should know which facts are relevant to the

*Welton: *ibid*—p. 164.

record and which are not; while to be precise he should be experienced in the right choice of words. The observer should know *what* to record and also *how* to record it.

VIII. The Interpretation of Testimony.—So far we have been concerned with those conditions which every witness should fulfil before his testimony can be accepted. But granted the fulfilment of all these conditions, does it follow that the testimony is going to be properly evaluated by the person receiving it? Certainly not. The *interpreter* of the testimony is exposed to an important *fallacy*: *he may read into the testimony what is only in his own mind.* The probability of the occurrence of this error of interpretation is the greater the farther removed in time is the witness where testimony is to be interpreted. We are said to live, for instance, in an 'age of democracy.' Now suppose that we read that a certain ancient society had a democratic form of government. We are liable to jump to the false conclusion that the 'democracy' of to-day is exactly similar to the 'democracy' of that ancient people. Identity of words may mislead us to ascribe to them an identity of significance and background even though centuries stand between the ancient writer and his present-day interpreter.

The difficulties of interpretation increase manifold when one has to deal with anonymous documents and ancient historical records about whose authors very little is known. In such cases, we should rely on the following methods:--(1) There should be a *cross-examination of documents* in the light of one another. This is possible only in those cases where different documents deal with the same event or events. If they are written by people of different temperaments, different prejudices or different walks of life, and still they agree in certain general features and details, then it is very probable that the facts on which they all agree did happen. (2) Historical documents whose authenticity is doubtful should also be tested by means of *internal criticism*, *i.e.*, a detailed and internal examination of the peculiarities of style and structure of the text. If, for example, we are told that a certain document was written by a certain historian (who lived, say, in the 12th Cen. A. D.), and if we further find that the document contains words, expressions, phrases, idioms or metaphers which originated in the 13th Cen., then we may be sure that the document in question is not genuine. (3) Should different ancient documents reporting the same events reveal similar mistakes, we may infer with great probability that their origin was the same, and that they are not really independent documents, but the work of different scribes who copied from a common source.

IX. To sum up.—Testimony is indispensible but often full of errors. These errors multiply as we go back into past ages. The value of testimony depends not only on the reliability of the reporter but also on the intelligence of the interpreter. For both of these purposes we should have rigid tests. But when all is said and done, the fact remains that much of what we know about the remote past is based on extremely flimsy foundations; that much of what we are supposed to know of the occurrences of to-day is itself full of errors, thanks to the frailties of human observation and the powers of *propaganda*; and that the real sifting of testimony is possible only in scientific circles where nothing is accepted which has not been subjected to the severest tests.

To these difficulties must be added another, *viz.*, that what we do know about the past is as nothing to what we do *not* know. How many events must have occurred of which we have no records? How many facts may have existed in the past and may still exist about which we have nobody's testimony? To make sure that an event simply did not take place in the past, we should first make sure that it should certainly have been observed and recorded by some one in some place had it actually occurred. "In all other cases we can only suspend judgment and confess our ignorance."*

Exercises.

1. Define observation and explain its nature.

2. Observation is difficult. Why? How would you overcome these difficulties?

3. What cautions would you bear in mind to ensure accuracy of observation?

4. What is meant by Experiment? Explain its nature. How does it differ from Observation?

5. Mention the relative advantages and defects of observation and experiment.

6. What is meant by Testimony? Why do we require testimony?

7. How should Testimony be critically examined before it is accepted as true? Discuss in detail.

8. Give examples to show how Testimony can be false.

*Welton: *Op. Cit.*—*p.* 165.

9. How should testimony be interpreted?

10. In what way is observation helped by the use of instruments?

11. Would the mere use of instruments change an observation into an experiment? If not, why not?

12. Compare observation and experiment as means for the collection of data for scientific investigation. (P. U. 29).

13. In what way does experiment differ from observation? Why is experiment more useful in science than observation? (P. U. 28).

14. Distinguish between observation and experiment. Mention and illustrate some of the fallacies incident to observation. What are the advantages of experiment over observation? (P. U. 23).

15. How does experiment differ from observation? Experiment is always preferable to observation. Why? What precautions must be taken in observation and experiment to avoid error? (P. U. 34).

16. Define and discuss the value of Testimony. Is all Testimony reliable? If not, why not? Mention with illustrations the principles of its criticism.

17. Discuss the place of Observation in Inductive Logic, and the advantage of Experiment over Observation in certain sciences. In those sciences where Experiment is difficult or impossible, what methods are used? Give examples. (P. U. 34).

CHAPTER IV.

POSTULATES OF INDUCTION (I).

THE UNITY AND UNIFORMITY OF NATURE.

I. Introductory: What is meant by Nature's Unity and Uniformity?—Is there order or disorder in nature? To the primitive man, the savage, the child, sometimes even to the rustic, nature very often seems to be 'one, big, blooming buzzing, confusion,' *i.e.*, with no regularities, and no order. Everything looks freakish and strange. The world for them is a *chaos*, disordered and puzzling. If there is a thundercloud, the rain-god is angry and must be appeased by sacrifice and offering. If his shaft of lightning sears a tree or a hill-side, the god is very angry indeed. 'Why should the god be angry at all'? is a question which may not arise. The brute fact is that he jolly well is, and that one has got to mollify him. Every day of the savage's life is passed in this state of terror, perplexity and insecurity. The gods who rule his little world are more freakish and tyrannical than any human ruler that he has experience of.

But even in the midst of this seeming disorder he begins to be dimly aware of some events which happen again and again, events whose appearance he can sometimes predict. The seasons follow one another in a certain order. The stars shift their places with a regularity which can be observed night after night. The sun-god, dear fellow, is so very regular in his appearance and exit, morning and evening. In short, even for the most primitive savage there is no such thing as *pure* *disorder.* That is only possible in a badly managed lunatic asylum.

When the primitive man settles down to a particular locality, and, most especially, when he takes up agriculture for his means of livelihood, the regular course of the little world in which he 'lives and moves and has his being' becomes patent. At this stage his mind gets so used to the regularity in the events of nature that the *irregularities* alone upset and terrify him. When the expected rain does not materialize; when his seed does not sprout; when he wakes up from his sleep with what we call a cramp or a chill due to a damp grass-bed, but what to *him* is only the work of an evil spirit; when the lightning suddenly kills his comrade or child; when his rough canoe suddenly capsizes on the calm surface of the lake; when he gets a bumper crop though little was expected; when fortune drives a sleek deer to his very door; - when, in short, the *unexpected* happens, does he feel that his gods are pleased or displeased with him, as the case may be. With the growth of knowledge and civilisation, the rule of order in the world is found to extend indefinitely. Hidden connections are discovered where they were least expected. Predictions of the future are continually verified, and the wise men of the community succeed in determining with precision the ordered revolutions of the heavenly bodies. As science develops, the realm of nature is found to be a system of laws, regular and uniform in its workings; a *cosmos*, in other words, and not a chaos. Where laws are not yet discovered, the hope of doing so in the near or remote future continues to animate all endeavour. Predictions of the future, span not years or decades or centuries, but ages and melleniums and infinity itself. 'Order' becomes the rule and 'disorder' the exception, an exception that is explained away as due to our limited knowledge.

Two things, then, continue to strike the mind with ever greater force as man's knowledge grows:—(1) *the uniform behaviour of nature, i.e.*, the regular course of the various classes of natural events; and (2) *the oneness of nature, i.e.*, the intimate relationship between the various events and phenomena of nature.

(1) We expect that the water which quenched our thirst yesterday will do so to-day and in future too; that the fire which burnt a piece of wood yesterday will do the same thing over again when opportunity offers; that the food which appeased our hunger yesterday will continue to do so on similar occasions in the future; etc. It is not man alone who works in the light of this belief in the uniformity of nature. Animal behaviour justifies the same conclusion. Feed some animals (birds, dogs, fishes, etc.) at a certain hour for a week or so without break. They will in future turn up for the expected meal at the *right* time. An experimenter tied a dry bone to an invisible thread whose other end was in the next room. His dog lay in a corner of the room dozing half-awake after a comfortable meal. He watched the bone but it had no attractions for him. The master in the other room now began to pull the bone gently by means of the invisible thread. The dog watched the proceedings for a while and then ran out whining piteously. His terror is

easily explained His experience was that bones, dry or fresh, never moved of their own accord. This one did move; but he could not perceive any one moving it. The object had not 'behaved' as he had expected it to behave. Such '*habits of expectation*' are set up as the *result* of the regular and uniform behaviour of events of a certain type. As Hume says, our expectations of the future are based on our memories of past experiences.

The above-mentioned examples illustrate the *regularity or uniformity* of nature. Let us now illustrate its *unity*. (2) There is interconnection between the various parts of nature. Objects which seem to be entirely different may reveal the most intimate connections between themselves. "Cut open the heart of the molecule," says Iqbal, "and behold! the life-blood of the sun spurt out."—Why do the oceans suffer the rhythmic ebb and flow of the tides? Because of the gravitational pull of the sun and the moon. Why does the earth revolve round the sun, the moon round the earth, etc.? Because of the Law of Gravitation.—Why do we in India have monsoon rains? Because of the climatic changes in the Indian Ocean and the coast lands of Eastern Africa.—Some years ago, an enterprising French engineer suggested a plan to irrigate the Sahara and thus to turn it into a vast paradise of trees, crops and fruits. The scheme was severely criticised by others on the ground that if the Sahara changed as was proposed, the greater part of Central and Northern Europe would soon be unfit for human habitation: there would be arctic cold and snow almost all the year round. It is the heat of the Sahara which guarantees the temperate climate of Central and Southern Europe.

To conclude.—We live in a vast world whose boundaries (if any) are not yet known to man. The 'primitive man' looked upon this world as (1) a *chaos*—an aggregate of unconnected parts—in which there was no order or regularity. But even the primitive man soon began to find traces of regularity in the course of events which caught his attention from day to day. As knowledge and experience grew and the foundations of civilized progress were laid, man's attention was caught more and more by the regularity of natural events and the mutual relationship of the various parts of nature. Nature ceased to be looked upon as a chaos but as a (2) *cosmos* or a *universe*; *i.e.*, as a system of inter-related parts where everything is regular and subject to law. This cosmos or universe may itself be looked upon in two ways:—either as (*a*) a *mechanism, e g.*, a watch; or as (*b*) an *organism, e.g.*, plant, animal, man. In both cases, there is a whole made up of parts. There is a oneness and there is a manyness. Both form a complex system, a unity in the midst of diversity. In both, the parts and the whole which they make, are intimately connected. But there is also a vital difference between the two. A part of a mechanism, say a watch, can become a member of more than one whole (for instance, a wheel of one watch can be placed and worked in another) and still preserve its identity or individuality: that is, the whole is for the parts but the parts are not entirely or merely for the whole. In an organism, on the other hand, the whole is for the parts and the parts are for the whole in the most intimate sense. The arm which has been lopped from the living body ceases to be an arm. It is dead and useless, and only *looks* like an arm. Nor can we insert it in another body and work it there, just as we can insert a wheel of one watch in another. The organism, then, differs from a mechanism in that its relationship of 'parts and whole' is unique. It is gifted with 'life' and grows and decays, but all the time it preserves its unique oneness.

Now, it is neither possible nor fortunately necessary for us to decide whether the 'unity' of Nature is the unity of a mechanism or the unity of an organism. It suffices if we realise that Nature *is* a unity and that it is very regular and uniform in its workings.

II. Different Kinds of Uniformity.—Human intellect is limited in its power and reach, and it is, as yet, not possible for it to see the unity in *all* nature. *That* is the ideal towards which it continually strives. Similarly, the general Uniformity of Nature is presented to us only in the various aspects or departments of Nature, and we then infer that there must be a wider uniformity to embrace them all. Carveth Read mentions the following as distinct branches of the general uniformity:—

(1) The Three Laws of Thought.

(2) Mathematical Axioms and the Axiom of the Syllogism.

(3) The Uniformity of Time and Space.

(4) The Persistence of Matter and Energy.

(5) Uniformities of Sequence or Succession. (Causation).

(6) Uniformities of Co-existence.

Mill considers the uniformities of Sequence (Causation) and Co-existence as the most important. Inductive science is, however, more interested in causation than in co-existence. Let us now say a word about 'sequence,' 'co-existence' and 'persistence.'

A. Uniformities of Sequence (Causation).—If the event *X* is invariably followed by the event *Y*, then *X* is regarded as the cause of *Y*. Such uniformities are of the greatest importance for scientific purposes. Very often, scientific explanation is nothing but the discovery of the causes of given effects and the effects of given causes; *i. e.*, the discovery of the relation of uniform sequence or succession between certain events or classes of events. A detailed discussion of causation follows in the next chapter.

B. Uniformities of Co-existence.—In some animals certain qualities or characteristics always occur together (*co-exist*) and we do not know why they should do so. For instance, animals which chew the cud also divide the hoof; blue-eyed cats are dumb; scarlet flowers have no scent; negroes are snub-nosed and curly haired; etc. Such coexistences are unexplained. We do not know why these qualities should be found together in the same individual. It is quite possible that the key to some or all of these riddles may be discovered later on. Suppose that qualities, *p* and *q*, always occur together in individuals of a certain class. This is a uniformity of co-existence so long as we do not know why '*p* and *q*' should occur together. If, later on, it is found that '*p* and *q*' are really joint-effects of another quality, *X*, then the uniformity of co-existence is changed into one of sequence or causation. The ambition of the scientist is to change these uniformities of co-existence into those of causation.

C. Uniformities of Persistence.—We expect that in the absence of conflicting (counteracting) causes things will continue to possess their attributes or characteristics. For example, I leave my pencil on the table and go out of the room. On my return I find that the pencil is diminished in size. I infer that somebody has used it, because left to itself, it should have *persisted* (remained) in its original condition. If we leave a fire burning in the hearth and on our return after six hours find it as bright as when we left, we are naturally surprised because the characteristic of fire is to exhaust itself. Since this particular fire is not exhausted, we infer that somebody has fed it in our absence. Whenever our belief in a uniformity of persistence is violated, it is a signal for us to search for some hidden or unknown cause to explain the change. Thus the violation of a uniformity of persistence is a step towards the discovery of a uniformity of causation.

III. Inductive Reasoning and Uniformity of Nature.—Inductive reasoning consists in inferring something about a *whole* class from the study of some members of that class. For example, we study the physical and climatic conditions of certain parts of the country where good mangoes grow in abundance. We find that certain conditions are common to all these areas. We infer that anybody who desires to plant a mango-grove should select that area for cultivation which fulfils those conditions. This is the application of an induction. But what *right* have we to argue in this wise? We have no other right than our implicit belief in the Uniformity of Natnre, *viz.*, *that what has been found to be true of anything will continue to be found true of the same sort of thing.* This is the Law or Postulate of the Uniformity of Nature which forms the basis of all inductive reasoning. We may put the law in a more exact form:—"If under the conditions p, q, r, the event X has been followed by the event Y, then in future also the event X_1 shall be followed by the event Y_1, provided that the conditions p_1, q_1, r_1, are present!"

Mill says that *every induction may be thrown into the form of a syllogism by supplying a major premiss.* This major premiss is always an expression in some form of the principle of Unity and Uniformity of Nature. For example, we infer that 'all the mangoes of this basket are sweet', because this, that and the other eight mangoes we picked out of it have all been sweet. The syllogism would be:—

What is true of this, that and the other eight mangoes is true of all mangoes in this basket; Sweetness is true of this, that and the other eight mangoes;

therefore, sweetness is true of all the mangoes in this basket.

It is evident that a belief in the Uniformity of Nature is the ultimate ground of all reasoning about the future on the basis of the study of the present and the past. This belief of ours is the *subjective* ground of induction. and the facts that *actually* (*i.e.*, as revealed by experience) Nature is uniform and that our predictions of the future are verified, together form its *objective* ground.

IV. Theories of the Origin of the Belief that Nature is Uniform?—How does this belief arise in our minds? That we do believe that nature is uniform is a fact. Our belief may not be expressed in words; it may not eve[n] be conscious, but it is there, and we all act on it. Anim[al] behaviour is understandable on the same basis. We should now discuss the *origin* of this belief in our minds. There are three views :—

A. The Intuitionist or a priori View.—The belief in the uniformity of Nature is in-born or innate in us. It is not the result of our experience. It is a truth that we cannot help believing in. It is true *a priori*, *i.e.*, prior to all experience, and a fundamental principle of human nature. Experience cannot explain it because it is itself explained by it. Experience only helps to awaken this belief in the mind where it was latent from the beginning. If the baby pokes its hand into the fire, this *one* experience is enough to prevent it from repeating the experiment.

B. The Empiricist or Experiential View.—The belief in the uniformity of Nature is not innate but *founded on experience.* All that we know is the result of experience. Mind, to begin with, is a *tabula rasa*—a blank tablet—on which accumulating experiences leave their traces. We have repeated experiences of a certain class of phenomenon and gradually '*a habit of expectation*' is set up. Oft-repeated experiences lead us to believe that 'food nourishes', 'fire burns', etc.—minor uniformities. Ultimately, we come to believe in a *general* uniformity of nature which embraces all these particular cases of uniformity. This view has been so very severely criticised that we may consider it as exploded. It is wrong to say that the mind of the new-born child is a blank tablet. Modern Psychology has long since disproved this notion. This is not all! As mentioned above, the burnt child's one experience of fire is enough to keep him from it in future. On the empiricist view he should allow himself to be burnt again and again before 'a habit of expectation about fire' can be set up.

C. *The Evolutionist View.*—There is an element of truth in each of the above-mentioned views, though the first is a more correct statement of facts if we interpret it in the light of modern Biology and Psychology. The evolutionist view says that the belief in the uniformity of Nature is *now instinctive in each man.* It is in-born and inherited, being the result of the accumulated experiences of countless generations. But the race originally learnt it by experience. The result of the experiences of 'early man' and his pre-human ancestors has become instinctive for the succeeding generations.

The above is a very brief and rough statement of the three views. It is not necessary for us to decide here which one of them is the best. What we have to realise is that we all do believe in a general uniformity of Nature and that we all act on this belief.

Exercises.

1. What is meant by the Unity and Uniformity of Nature?

2. Why does primitive man regard the world as 'one big blooming buzzing confusion'? How does his mind move on to the idea of a regularity in the course of natural events?

3. Formulate the Law of the Uniformity of Nature. Illustrate the application of the law.

4. Why is the belief in the Uniformity of Nature called a *postulate* of Induction? Can Induction be possible without a uniformity in the course of Nature? If not, why not?

5. What is meant by calling the world *a cosmos* or *a universe*? What is meant by *a chaos*?

6. Is the world a *mechanism* or an *organism*? Explain the meaning of these terms.

7. Mention and illustrate the different kinds of the Uniformity of Nature.

8. Explain and give two examples of each of the following:—(*a*) Uniformities of sequence, (*b*) Uniformities of co-existence, and (c) Uniformities of persistence.

9. What is meant by saying that the Law of the Uniformity of Nature is the ultimate ground or major premiss of all inductive reasoning? Explain and illustrate.

10. What are the three theories of the origin of the belief in the Uniformity of Natuie? Briefly discuss each view. Which of these views do you consider to be the best explanation of the facts?

11. On what grounds are we justified in inferring that what

is true in some cases is probably true in all similar cases? Discuss the nature of this assurance. (P. U. 29).

12. Explain what is meant by the Uniformity of Nature and show how Induction is related to this postulate. (P. U. 21).

13. What is meant by the principle of the Uniformity of Nature?—The Uniformity of Nature is the ultimate major premiss of all Induction. Explain his statement. (P. U. 26).

14. What is meant by the Uniformities of Nature? Discuss whether it is right to call Nature a unity and indicate the importance of this discussion for Inductive Logic. (P. U. 33).

15. Critically examine the view that once we accept the law of Causation and the principle of Uniformity of Nature, every inductive inference is turned into deductive. (P. U. 22).

CHAPTER V.

POSTULATES OF INDUCTION (II).

CAUSATION.

I. Introductory.—Inductive Science is concerned withthe discovery of more or less permanent (causal) connections between the various events in nature. In this respect, Induction is just the scientific development of an attitude common to both men and animals. Pull your dog's tail and he will at once turn round to discover who is responsible for the prank. Produce a strange sound and your fowls will stretch their necks to look for the cause of the disturbance. Say something to a child and he will at once accost you with an 'how' or a 'why'. Let anything strange happen and everybody will be asking questions about the cause of the phenomenon.

The inductive scientist differs from the ordinary man in that he tries to discover the causes not only of the more or less strange occurrences of nature but *also* of the so-called familiar ones. For him everything that happens must have a discoverable cause. He may not be able to find out *the* cause in any one particular case, but his ideal is to reduce the different phenomena of nature to various inter-connected chains, the links of which are the stages in the general causal process which forms our universe (our cosmos). As J. S. Mill says: "To ascertain what are the laws of causation which exist in nature; to determine the effect of every cause and the cause of all effects, is the main business of

Induction; and to point out how this is done is the chief object of Inductive Logic."

The study of Induction is, therefore, the study of the 'why' and 'wherefore' of phenomena, and the only way to satisfy inquiry is to supply answers to these questions. Now this inquiry may be met in one of two ways. Suppose that the question is 'Why has rain fallen to-day'? I may answer it by saying that 'God willed it so', or 'that the atmospheric conditions demanded it'. The human spirit cannot be long content with answers of the first type, *i.e.*, answers supplying supernatural causes for natural phenomena. We begin to demand *natural causes for natural effects.* But this process turns out to be a long and arduous one. At every stage the question 'why' still stands. We can push back the inquiry only as far back as our knowledge at any particular stage allows us to do. But *final answers to causal questions are really impossible* to give.

II. History of the Concept of Causation*—What is meant by 'cause'? Different thinkers have answered this question in different ways. Some of the more important of these answers are briefly indicated below:--

(1) Aristotle distinguished four aspects of causation. The potter makes a pot. What is the cause of the pot? Firstly, there must be clay. This is the *material* cause. Next is the energy spent (or effort exerted) by the potter in making the pot. This is the *efficient*

*It would be better if the teacher first discusses the problem orally in the class and then enters into an explanation of the text.

cause. Then there is the form which the potter imparts to the lump of clay in order to make it a pot and not something else. This is the *formal* cause. Lastly, there is the purpose for which the pot is made—the *final* cause. The four make up *the* cause of the pot.

(2) Later thinkers in Europe emphasised the ***efficiency*** aspect of the cause. They looked upon the cause as that something which has the *power* to produce the effect. To say, *e.g.*, that 'heat expands bodies' would mean for them that heat has the *power* to produce this effect of expansion.

(3) ***The Sequence View of Causation.***—Hume, a famous British philosopher of the 18th century, denied that there is anything like 'power' in the constitution of the cause. 'Power,' he said, is simply an illusion. To prove this he undertook an analysis of the different types of causal relationship, and declared that he could not find any trace of 'efficiency' or power in any one of the different forms:—(*i*) Suppose that a physical event produces another physical event; (*ii*) or that a mental event produces a physical event; (*iii*) or that a mental event produces another mental event. (*i*) *E.g.*, we let fall a ball of lead. A stone on the floor on which the ball falls, is crushed to pieces. Do we find any trace of any 'power' exerted by the ball on the stone? The order of events is:—1stly, lead ball in my hand; 2ndly, ball falling on stone; and lastly, stone crushed. If a person on the planet Mars, say, had observed this order of events he could not have observed any trace of 'power'. (*ii*) Now

suppose that I resolve (mental event) to lift my arm. It is lifted (physical event). Is it not, we may ask, a case of 'power'? I willed to do something and I have succeeded in doing it. Hume denies the presence of 'power' in this case, too. My willing, he says, is merely a group of sensations, and the sense of power that I have is only an illusion. Let my arm be struck with paralysis. Would any amount of will-power on my part result in the actual lifting of it? Not at all! This proves that the sense of power has really nothing to do with the lifting of the arm: at the most, it is an illusory and ineffectual accompaniment. Similarly, (*iii*) if I will to have the image of my friend in my mind's eye (mental event), and I do succeed in calling it up (another mental event), I should not suppose that I had some mysterious 'power' which was responsible for this phenomenon. The cause is merely that I am so made that when certain changes take place in my brain, certain other changes in the brain follow as a matter of course.

Hume, then, believed that the *sense of efficiency* in causation is quite an *illusion*. He explained the idea of causation by saying that (*a*) it is entirely *subjective*, *i.e.*, merely a state of our own mind; and that (*b*) it is nothing but a *feeling of expectation due to custom*. At the first appearance of an event we cannot say what it will lead to, *i.e.*, what effect it will produce. But when the same event, *X*, has been several times observed to be followed by another event, *Y*, we are led to expect *Y*'s appearance after the next appearance of X. "Expectation is memory reversed". The future must resemble the past. Hence we expect that the order of events observed in the past (custom and habit) shall be verified in the future. "After a repitition of similar instances, the mind is carried by habit, upon the appearance of an event, to expect its usual attendant, and to believe that it will exist ....When we say, therefore, that one object is connected with another, we mean only that they have acquired a connection in our thought." Thus *cause* "is an object followed by another and whose appearance always conveys the thought of that other."* Modern Science agrees with Hume in his refutation of *efficiency* as any part of the cause; but it rejects both his doctrine of the subjectivity of Causation, and his view that the causal relation is established only by repeated observations in the past (custom and habit). In other words, Hume's doctrine is false in these two respects, because (*i*) science rests on the belief that the material is real, *i.e.*, is real whether any sentient being is there to perceive it or not. The world is real whether you and I who observe it live or die. It is not a figment of our imagination, but possesses an independent status. Hence, causation is not (as for Hume) "a principle of connection among ideas," but rather between events in a material world. (*ii*) Again, Hume is wrong in supposing that only repeated observation of several similar instances in the past leads us to expect a similar connection in the future. For a scientist, on the other hand, a single experience (or

*Quotations from Hume.

experiment) of causal connection, if observed or performed under standard and verifiable conditions, is enough to establish it beyond the shadow of a doubt.

(4) J. S. Mill accepted Hume's view that the cause is the invariable antecedent of the effect. Cause is that event which always comes before, or precedes, the effect. X is the cause of Y, if whenever X is, Y is after it. The event which *always* comes first in time is the cause; that which follows it is the effect. But whereas Hume regarded the *cause* as just one event, Mill looks upon it *as the sum-total or a group of events or conditions.* Suppose that a lighted match-stick is applied to a piece of paper. The paper burns. What, now, is the cause of the burning of the paper? The ordinary man would say: the lighted match-stick. Not so, says Mill. The real cause is the lighted match-stick *plus* the combustability of the paper, the presence of oxygen in the atmosphere, the relative absence of moisture and of strong wind, etc. Some conditions must be *present*, and some other conditions must be *absent*, if the paper is to burn. And the *cause is the sum-total of all* of these *positive and negative conditions.* (The positive conditions are those which must be present, and the negative conditions are those which must be absent, if the effect is to appear). Briefly, the cause is the sum-total of all the essential antecedents or conditions.

But this is not all. The cause should not merely be the invariable group of essential antecedents: it should also be *unconditional.* The idea of 'unconditional' implies *necessity* in the causal relation. "What *must* be means that which will be whatever supposition we may make in regard to all other things", says Mill. *X* is the cause of *Y*, if *X always, invariably* and *unconditionally* preceeds *Y*.

Mill's doctrine of causation is itself full of contradictions. He goes on to say that one and the same effect can be produced by different causes working independently of each other, *i.e.*, at different times. But this position of his cannot be reconciled with his doctrine that the cause is the sum-total of essential and invariable antecedents. This point, however, shall be discussed in detail later on under 'Plurality of Causes'.

Briefly, then, Mill is right in analysing the Cause into a set of positive and negative conditions; but he is wrong in his belief that more than one cause can produce the same effect.*

III. Phenomenon, Antecedent and Condition.— It will help the student in his study of the discussion

*It is said that the cause must precede the effect. This is roughly true. But in this connection much time has been wasted on the problem:—'When does the cause end and the effect begin?' This question is idle. The causal process is *continuous* and it all depends on practical considerations where exactly should we put the hypothetical dividing line between the two. Really there is no gap between cause and effect. "The problem is, how to divide and describe this continuous process in a way that grasps its essence, by exhibiting some characters in it which formally imply others." (Eaton: *General Logic*—*p.* 510).

of causation to bear in mind the scientific significance of the terms mentioned above.

Phenomenon.—An occurrence in nature, if perceived or capable of being perceived, is called a phenomenon. 'Nature' includes both the world of matter and of mind, *i.e.*, objective reality as well as subjective reality. Any perceived happening or change in Nature (in this wide sense) would be called a phenomenon. In this sense, the universe presented to our *senses*, the universe as it is *perceived* by us, is nothing but a mighty system of phenomena. The interplay of ideas in your mind, the fall of my pencil, "the starry heavens above and the moral law within," the cricket match, the experiment in the test tube, etc., are all phenomena. 'Any fact or occurrence presented to our observation, either in the external world or in the human mind' is a phenomenon. (*See Chap. II.*)

Antecedent and Consequent.—If some phenomena succeed each other in time, then that which comes first is called the antecedent while that which succeeds it is called the consequent. Let the order of events be : *l*—*m*—*n* . . , then *l* is the antecedent of *m*, and *m* that of *n*. Similarly, *m* is the consequent of *l*, and *n* that of *m* ; *m* is antecedent for *n*, but consequent for *l* ; *e.g.*, you are hungry ; you eat something ; and you then feel satisfied. Now, hunger is the antecedent of eating, while eating is the antecedent of the feeling of satisfaction.

Condition.—If a phenomenon simply cannot happen unless another happen before it, then this latter phenomenon will be its *indispensable antecedent* or *condition.* All antecedents of a phenomenon cannot be its conditions, because some of them may be quite irrelevant. Only the relevant and indispensable antecedents are conditions.

Now these conditions are of two sorts: some are *positive, viz.*, those without the *presence* of which the phenomenon could not have occurred; and some are *negative, viz.*, those without the *absence* of which the phenomenon could not have occurred. *E.g.*, a house was on fire. What were the conditions of this phenomenon? The positive conditions were, say, carelessness of the servant who did not put out the fire in the kitchen before going to bed; the presence of kerosine oil and wood near the fire; the presence of oxygen in the atmosphere; and the fact that all the inmates of the house were asleep. The negative conditions were, say, the absence of heavy rain and of the local fire-brigade at the time; the delay in giving the alarm, etc. The fire was caused by both the positive and the negative conditions. This totality of positive and negative conditions is the cause.

IV. Popular and Scientific Views of Causation.—*The Popular View.* (*a*) The ordinary man does not care to distinguish between the positive and negative conditions of a phenomenon. For him there is only *one* important fact in the whole list of conditions (many of which never occur to his mind). He is satisfied if he can lay his finger on that one (to him most important) point. This point is generally some vivid or prominent factor in the antecedents of that phenomenon. *E.g.*, why was the house on fire?

He answers at once;—'because the servant left a fire about in the kitchen.' He overlooks entirely the part played by the other conditions (positive and negative) in the production of that phenomenon. Why, *e.g.*, has the labourer fallen from the ladder? 'Because his foot slipped.' It is overlooked that the foot slipped because of many factors: the ladder was slippery on account of last night's rain; the earth's gravitational pull on his body; the fact that he was mounting the rungs in a hurry; the fact that he was talking to other people all the time; the fact that there was nothing on the ladder to stay his sudden fall*; etc. The factor selected by the popular mind has really no closer relation to the effect than has any other condition. *All* essential conditions must be mentioned if the real and complete cause is to be discovered.

(*b*) Another mistake committed by the ordinary man in his view of causation is his *wrong distinction* between the *agent* and the *patient*. A heavy ball of lead, say, falls upon and crushes a stone. The lead-ball is called the agent and the stone the patient. It is supposed that the lead-ball (the agent) has some mysterious power to crush the stone. The ball is falsely regarded as the more active party of the two and hence is called the agent. The stone is crushed because it was so made that it could be crushed; *i. e.*, the effect, 'crushed stone', depended on the activity and co-operation of both the stone and the lead-ball.

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*This illustration is borrowed from Stock's *Logic*.

In nature all things are equally active, and the distinction between the agent (as that which produces or causes some change in another) and the patient (as that which suffers some change through the activity of another) is mistaken. It depends solely on the way we look at the phenomenon concerned. A 'patient' is either a co-operating or a counteracting agent. The stone was crushed because it was *ready* (metaphorically speaking) to be crushed. "The attributes *both* of the agent and the object acted upon are essential elements in determining the character of the change which is effected". It is for this reason that the same object (or phenomenon) produces different effects according to the nature of the object acted upon: "The twilight which sends the hens to roost, sets the fox to prowl; and the lion's roar which gathers the jackals, scatters the sheep".*

The Scientific View.—This view is distinguished from that of the man in the street in that it *analyses both* the *antecedents* (which form the cause) and the *consequents* (which form the effect). Let X be the group of relevant antecedents and Y the group of relevant consequents. On analysis it is found that X consists of $a,b,c,$ (positive conditions) and $p,q,r,$ (negative conditions). The man in the street does not mention all of these positive and negative conditions. He selects *one positive* condition—say a—and glorifies it into *the* cause. The remaining positive and negative conditions are generally not noted by him at all, and even if they are noted, they are regarded as of no importance.

*Ward, *Psychological Principles.*

(*a*) The scientific mind cannot be content with this summary treatment of the cause. It should mention *all* those conditions which by their presence or absence (as the case may be) made it possible for *Y* to appear. The term 'cause' is only a short or convenient name to embrace those conditions. The scientist would even like to discard this name altogether, and merely content himself by *describing how* a certain group of positive and negative conditions or occurrences is always followed by *Y*.

(*b*) Now go a step further. What exactly is *Y* ? Here again the popular mind is satisfied with *one* prominent sign or aspect or character of the resulting phenomenon and glorifies *that* into *the* effect. Of course, the scientist must differ. He carries on his analysis until he simply cannot go further. He finds that just as the supposedly single and simple 'cause', *X*, turned out to be a very complex affair, similarly the supposedly single and simple 'effect', *Y*, is a very complex something. It can be analysed into, say, *l,m,n,o* ; but since *m* has a popular appeal or has somehow caught people's attention or is an unusual occurrence, the popular mind comes to regard it as *the* effect. It is really only one aspect or one character out of the several which together form 'the effect'. Like 'cause', the 'effect' also is a shorthand formula, a convenient term to label the resulting phenomenon with. The scientist would be pleased to discard this term also from his dictionary. He would merely say that 'when a certain group or pattern of qualities or events, *abc,pqr*, occurs, another pattern or group of qualities or events, *lmno*, always follows it. He would discard the terms 'cause', and 'produce'.

Suppose that we hear that our acquaintance, Mr. Sickbody, has died. Of what' ?—we naturally ask. 'Of fever', we are told. Then 'the fever' becomes for us, in the popular sense, the cause, and 'death' the effect. Fever means for the ordinary mind such qualities as high temperature, thirst, weakness, etc. Death means, similarly, cessation of breath, permanent loss of 'life' and consciousness, and a passage out of the 'world.' 'Fever caused Mr. Sickbody's death' is, then, for the popular mind, quite a satisfactory account of the matter. But can the scientist be satisfied with this account ? He cannot be. Why did Mr. Sickbody die of fever when others who had fever of an equally high or even higher temperature did not die ? Because fever was not the sole antecedent of death. Mr. Sickbody was weak in body ; he had long been ill ; the fever had affected some vital brain centres ; he was worried about his financial affairs ; there was a sudden fall in temperature some hours before his death, etc.—positive conditions. Further, his long illness had reduced his body's resisting power ; there was no good medical advice at the beginning of his illness ; he had ceased to assimilate any diet ; he had no good nursing ; there was very little of real sanitation in his neighbourhood, etc.—negative conditions. The combination of these different positive and negative conditions was followed by Mr. Sickbody's death. Was 'death' a simple phenomenon ? No. His death means that the body has lost its animal heat ; does not breathe ;

the blood has ceased to flow; there are no responses if we shout or touch or pinch his body; his eyes are dilated and lustreless; the internal organs and brain centres have ceased to function; etc. Instead of having to mention these characters in their entirety, the popular mind contents itself with the one magic word 'death.' The scientist, however, has got to mention all these factors of which the effect is composed.

V. Causation and Conservation of Energy.—So far we have been concerned with the *qualitative* aspect of causation. But science requires exact and *quantitative* fomulations of its laws. To achieve this end, modern Physics developed the famous doctrine of 'Conservation of Energy.' Energy is defined as capacity to do work. All energy is either latent (passive) or actual (active); or in technical language, either *potential* or *kinetic*. When a body is at rest, its energy is latent or potential, *i.e.*, *possible* because of its position. When a body is in motion, its energy is actual or kinetic.

Now the doctrine of Conservation makes two suppositions:—(*a*) that one form of energy can be transformed into another; and (*b*) that the total amount of energy in the universe is constant, *i.e.*, there is neither increase nor decrease. This implies (*c*) that energy can never be destroyed: where it seems that energy has been lost, we should look for its presence or appearance in another form. (*d*) Work means the transmutation (change) of energy from one form into another.

For example, a stone is lying on a wooden plank in the street. I pick it up and carry it to the top of a tall building. In carrying it I have done work, *i.e.*, spent energy. Where has that energy gone to? To the stone, mostly! But it is the 'same stone' still. What has happened is that my kinetic energy has become potential in the stone. Now I let the stone fall from the roof. It falls on the plank and smashes it. The energy that was potential in the stone has become kinetic—has worked. Similarly, if I burn a roll of paper, I should not say that the potential energy of that roll of paper is lost to the universe. It changes into light, heat, smoke, ashes, etc.

If, now, we describe the causal relation in terms of the Law of Conservation, we shall have to say that when a certain group or pattern of characters (*abc*, *pqr*) is uniformly followed by another pattern of characters (*lmno*), the total energy of the former is transformed into the latter. $E(abc, pqr) = E(lmno)$. Cause and effect may, therefore, be regarded as two stages in a continuous chain of transmutations.

All this is very theoretical, and it should be noted that human knowledge at the present stage of its development is so very rudimentary that quantitative exactness in most departments of our thought and conduct is still only an ideal. Perhaps it can never be attained in certain cases. In fact, the Law of Conservation is as yet more or less of an *hypothesis*. It has, of course, a very high degree of probability of being true in the world of non-living matter; though even here it is not yet completely verified. Its range of application is limited to the realms of Physical Science, and it is not possible to say when, if ever, it will be applied with any hope of success to the study of the phenomena of *living* matter—the province of the Biological Sciences. Lastly, its value becomes extremely doubtful when we deal with *psychological* phenomena, *i.e.*, those phenomena of living matter where *mind* plays the most important part.

VI. Definition of Cause.—We may now sum up this discussion of causation in the words of Carveth Read. "The cause of any event, when exactly discernable, has five marks: it is (quantitatively) *equal* to the effect and is (qualitatively) its *immediate, unconditional, invariable antecedent.*" 'Antecedent' here means the entire set of positive and negative conditions.

VII. Doctrine of Plurality of Causes.—(Also known as 'Vicariousness of Causes' and 'Alternativity of Causes).—It is commonly believed that one and the same effect may be produced *on different occasions* by different causes. For instance, death may be caused by opium poisoning, a gun-shot wound, malarial fever, drowning, etc.; or light may be produced by the sun, the stars, fire, electricity, etc. Mill defends this view:—"It is not true that one effect must be connected with only one cause, or assemblage of conditions; that each phenomenon can be produced only in one way. There are often several independent modes in which the same phenomenon could have originated. One fact may be consequent in several invariable sequences; it may follow with equal uniformity any one of several antecedents or collections of antecedents. Many causes may produce motion: many causes may produce some kinds of sensation: many causes may produce death. A given effect may really be produced by a certain cause, and yet be perfectly capable of being produced without it."*

The doctrine of Plurality of Causes implies that the causal relation is *not* reciprocal. In other words, since *A*, *B*, *C* and *D* can, *independently of each other*, produce the same effect, *X*, we infer that—if *A*, then *X*; if *B*, then *X*; if *C*, then *X*; if *D*, then *X*; but we *cannot* infer in any particular case what has been the cause, if *X* is present. We can infer the effect from the cause, but we cannot infer the cause from the effect. Thus the causal relation must remain hypothetical if this doctrine is true. *But is it true?* It is *not*, and for the following reasons:—

Criticism of the doctrine.—(*a*) This doctrine looks very probable as long as we do not move beyond the popular notion of the causal relation. The analysis of the cause, however accurate it may be, would not by itself suffice to shake our belief in the possibility of several different causes, at different times, producing the same effect. But when we *analyse the effect*, just as we analyse the cause, the bottom is knocked out of the doctrine. The popular mind selects one character out of the several which jointly make up the effect. This one character is found to be present in several other cases. It stands as the 'symbol' of the effect, and is mistakenly believed to be the whole effect. The different kinds of effect, all agreeing in their generic characters, are confused, and their *specific* differences are overlooked. But when the constituent elements in the total effect are enumerated as accurately and exhaustively as we enumerate the

*Mill's *Logic*, I.—*p.* 468.

constituent elements in the total cause, the possibility of a plurality of causes disappears. As Venn says: -"We say, for instance, that death may be brought about in a variety of different ways, and we call all these ways 'causes,' and thence deduce the doctrine of plurality of causes. It may be produced by suicide, in any particular case, by disease, and that of various kinds; by murder; and so forth. But all these alternative suppositions are only rendered possible because the 'death' is a single element in the sense above described, that is, it has been abstracted from a number of other characterising circumstances. Had we introduced these other elements or characterising circumstances, only one of these causes would have been left possible. The conditions of the organs would have precluded such and such form of disease; the position of the body and the nature of the wounds would have precluded the alternative of suicide; and so on with each alternative in turn. So clearly is all this recognised whenever it becomes important to take it into consideration that the whole procedure of a trial for murder, or in any coroner's court, rests upon the assumption that if we are particular enough in our assignment of the effect there is no possibility left open for any plurality of causes."* In brief, there can be no plurality of causes if the scientific view of causation is correct.

(*b*) The Law of Causation taken by itself would not preclude the possibility of a plurality of causes. The law only says that *every event must have a*

*Venn, *Empirical Logic—p.* 62.

cause. But it does not say that the same cause produces the same effect and that the same effect is produced by the same cause. These propositions are valid and necessary only when to the Law of Causation we add the belief in the Uniformity of Nature. As far as the Law of Causation is concerned, any event, *X*, may cause any other event, *Y*; and therefore, at times, one and the same event, *Y*, may have been caused by different events *X*, *M*, *N*; just as, at times, one and the same event, *X*, may cause different events *P*, *Q*, *R*. But a belief in the Uniformity of Nature restricts us to a reciprocal relation: if *X* produces *Y*, then *Y* can only be produced by *X*.

(*c*) Mill's defence of 'Plurality' is inconsistent even with his own view of causation. He defines the cause as the *invariable and unconditional* antecedent of a phenomenon. This implies that a particular cause and its effect are rigidly bound to each other.

(*d*) As pointed out above (*a*), the doctrine of Plurality is quite consistent with the popular view of Causation. And it is at this stage that it is both useful and important. Human knowledge is so imperfect that exact quantitative equivalence between cause and effect, and perfect analysis of both into their ultimate constituent factors, are seldom possible. Hence, as a *working hypothesis* in any particular case it is always useful, *i. e.*, in the absence of exact knowledge to the contrary, to suppose a plurality of causes. This is inevitable in the realm of practical affairs and in those scientific investigations which deal with Life and Mind.

With the growth of exact knowledge, the sphere of such suppositions will continue to contract. The 'scientific view' provides us only with the ideal towards which causal investigation should travel.

VIII. Intermixture of Effects.—Mr. X is ill. He is advised by his physician to go up to a hill-station for a change. He uses the medicine prescribed for him; follows a properly arranged diet-programme; is looked after by a qualified nurse; breathes the fresh and pure air of the pine-covered hills; indulges in mild physical exercise morning and evening; lives in a comfortable house with a beautiful valley spreading out underneath; forgets for the time being the cares and worries of his business or official life; enjoys domestic peace and quiet; etc. The result is that he is restored to health within a short time. 'Restoration to health', then, is the joint-effect of all these causes or conditions which have together been in operation. It is a case, in short, of a 'Conjunction of Causes' or of an *Intermixture of Effects.*

When several causes operate all together and their effects get blended or fused into one, the total phenomenon is called an Intermixture of Effects. Now there are *two* possibilities:—

(1) It may happen that the nature of the joint-effect is the same in quality as that of the effect of each cause had it worked independently of others; *i. e.,* 'the separate effects of all the causes continue to be produced, but are compounded with one another and disappear in one total'. *E. g.,* a railway train is

ving at a certain speed. An additional locomotive (additional cause) is then attached. The speed will appreciably increase. *Or*, consider the *parallogram of forces*: an object *P* occupies a certain position in space. It is attracted by a force on one side of it. But at the same time another force of equal intensity and at right angles to the first is pulling *P* from an equal distance. The joint effect of these two attractions is that *P* now moves along a line at an angle of 45° between these two forces. Now both in the case of *P* and in that of the railway train, the *joint-effect* of the several causes is *qualitatively the same* as the effect of each cause had it worked independently of others. This type of Intermixture is called *Homogeneous* or *Mechanical.*

(2) In other cases, however, as for instance in the case of 'restoration to health', the joint effect of the several causes is different in quality from the effects of those very causes had they worked independently of one another. For example, water, sugar, tea-leaves, heat and milk have different effects and characteristics. But when they operate all together, their joint-effect is 'tea' with its peculiar flavour. *Or*, consider the composition of water. It can be analysed into hydrogen and oxygen. Hydrogen is a combustible gas and one of the lightest known. Oxygen is not combustible but supports combustion and life. But their joint-effect, water, is neither combustible nor does it support combustion. It does support life but in a way different from oxygen. This kind of Intermixture is called *Heterogeneous* or (sometimes) *Chemical.* In this case the separate effects cease entirely

and are succeeded by phenomena altogether different and are governed by different laws'.

In homogeneous intermixture or mechanical causation we have a sort of *summation of stimuli*; while in heterogeneous intermixture or chemical causation we have a *transformation of stimuli*. The former is a *union of forces*; the latter a *union of substances*.

Tendency.– The physical maxim that 'effects are proportional to their causes' is true only of mechanical causation. In this case, the joint-effect of the operative forces is equal to the sum of their separate effects. But the different effects may be so opposed that we fail to notice them at all or may consider them to be destroyed. In a well-balanced tug-of-war match, for instance, there may be no movement either way though there is a maximum of force exerted. Similarly, when a body is at rest, it is so because all the forces of nature operative on it have reached a state of 'equilibrated tension.' The effect of one force is being counteracted by that of another. But the *counteracted force* is not lost: it is said *to exist in tendency*.

IX. Progressive Effects.– Suppose that a cause continues to act in a more or less permanent way. The series of effects to which it is giving rise continues to gather force as time passes on account of the accumulated influence of the cause. The effect of such a cause would be called a *progressive effect*. (1) It may be *invariable*, *e.g.*, the gravitation of the earth is a permanent cause; but the velocity with which unsupported bodies fall on the earth does not remain the same: it is augmented every moment. The body falls 16 ft. in the first second, 48 in the second, etc. Here the permanent cause produces *more and more* of the same effect. (2) Again, the progressive effect may sometimes be *variable*, *i.e.*, the intensity of the cause may itself be increased by its continued action: *e.g.*, heat increases as summer advances; or, the anger of a man increases the more he gives vent to it. Progressive effects are regarded by Mill as of the type of homogeneous intermixture of effects.

X. Mutuality of Cause and Effect.—Two phenomena may be so related that each in turn can act as cause and effect. The causal relation is reciprocal in such a case. For example, good government leads to a good system of education in the country which, in its turn, leads to better government, and so on. Drink leads to crime which, again, leads to a larger consumption of drink and so on in a vicious circle. Similarly, the industry and wealth of a country have this mutual causal relation. "Habits of study may sharpen the understanding, and the increased acuteness of the understanding may afterwards increase the appetite for study. So an excess of population may, by impoverishing the labouring classes be the cause of their living in bad dwellings; and again bad dwellings, by deteriorating the moral habits of the poor, may stimulate population. The general intelligence and good sense of a people may promote its good government, and the goodness of the government may, in its turn, increase the intelligence of the people, and contribute to the formation of sound opinions among them. Drunkenness is in general the consequence of a low degree of intelligence, as may be observed both among savages and in civilised countries. But in turn, a habit of drunkenness prevents the cultivation of the intellect, and strengthens the cause out of which it grows. As Plato remarks, education improves nature, and nature facilitates education. National character, again, is both effect and cause: it reacts on the circumstances from which it arises. The national peculiarities of a people, its race, physical structure, climate, territory, etc.,. form originallv a certain character which tends to create certain institutions, political and domestic, in harmony with that character. These institutions strengthen, perpetuate and reproduce the character out of which they grow, and so on in succession, each new effect becoming, in its turn, a new cause. Thus a brave, energetic, restless nation, exposed to attack from neighbours, organises military institutions: these institutions promote and maintain a warlike spirit: this warlike spirit, again, assists the development of the military organization, and it is further promoted by territorial conquests and success in war, which may be its result—each successive effect thus adding to the cause out of which it sprung,"*

Sometimes this mutuality is transformable; *e.g.*, water is analysed into oxygen and hydrogen which again can be combined to produce water.

*Sir G. C. Lewis: *On Methods of Observation and Reasoning in Politics., Vol.* I—*p.* 375.

Exercises.

1. What is meant in Science by the cause of an event? Explain the difference between the practical (*i.e.*, popular) and the scientific senses of the term cause. (P. U. 1932).

2. State exactly the meaning of cause in science. Point out the importance of causa tion in Scientific Induction. (P. U. 30).

3. Define cause and dis cuss the view that the same effect may be produced by different causes. (P. U. 25, 27, 28, 33).

4. Explain clearly what is meant by cause in Science. Discuss the view that one and the same effect may proceed from a number of Alternative causes. (P. U. 27).

5. Explain and criticise the doctrine referred to in the following lines :—

> 'A different cause', says Dr. Sly,
> 'The same effect may give,
> Poor Lubin weeps lest he should die,
> His wife lest he should live.' (P. U. 28).

6. Carefully formulate the conception of cause as underlying the process of Inductive Inference. (P. U. 22).

7. Define the notion of cause and explain in what sense, if any, cause and effect are reciprocal. (P. U. 21).

8. In what different senses has the term 'Cause' been used by the following thinkers :—Aristotle, David Hume and J. S. Mill?

9. What is the significance of 'cause' in the light of the Doctrine of Conservation of Energy?

10. Explain these terms :—Antecendent, consequent, positive and negative conditions, and phenomenon.

11. What is the *sequence* view of Causation? How was it developed by Hume and Mill?

12. Examine the Doctrine of Plurality of Causes? In what way is it defective? Is it useless?

13. What is meant by Intermixture of Effects ? What is its other name ? Why ? Give examples of 'intermixture'.

14. Differentiate between Homogeneous and Heterogeneous Intermixture. Give two examples of each.

15. What is meant by 'Tendency'?

16. What is meant by 'Progressive Effects.' Give examples.

17. What is meant by the 'Mutuality of Cause and Effect'? Give examples.

CHAPTER VI

CLASSIFICATION, NOMENCLATURE AND TERMINOLOGY.

(A). CLASSIFICATION.

I. What is it?—Suppose that I possess one thousand books. Should I lump them in shelves without system and method, or should I arrange them in some order? Suppose that I leave them in a confused mass. What happens then? I want a particular book. I hunt up one almirah after another, and still I cannot trace it. I do not know where it is lying. No book has a fixed place. The result is that in my hurry I needlessly spoil other books, waste my time, forego the benefits that I should have derived from that book, and, in short, do not get that value out of my library that one ought to get. But if I arrange my books in a systematic way, classify them according to the language they are written in, place those books together which deal with the same subject, subdivide into the branches of each subject, arrange them further according to the names of the authors in alphabetical order, etc:—in short, if I *classify* my books, I shall have a library in the real sense of the term. Here we have an example of the nature and value of classification.

Classification is the process according to which we arrange a number of objects into various kinds and groups according as these objects possess certain common features, properties, characteristics, attributes, etc. It is *the systematic arrangement of objects in groups* *according to certain points of similarity and difference.* This definition is slightly inaccurate. We cannot always have objects before us to classify or arrange. Suppose that we wish to classify all animals. Can we have them all in actual concreteness before us? Surely such a thing is impossible. But we can classify our ideas or notions of these animals. Hence classification is not always *actual or concrete.* The classification of books in a library or of curios in an art-museum is, of course, actual; but the classification of animals or plants or men would be *mental.* Hence Jevons defines *classification* as "the arrangement of things, or our notions of them, according to their resemblances or identities."

II. The Principle and Forms of Classification.— According to Mill, "the requisites of a Classification intended to facilitate the study of a particular phenomenon are, first to bring into one class all kinds of things which exhibit that phenomenon, in whatever variety of forms or degrees; and secondly to arrange these kinds in a series according to the degree in which they exhibit it, beginning with those which exhibit most of it, and terminating with those which exhibit it least."* This shows that all classification is with reference to some special *purpose.* Now these purposes can be of two sorts. Either the classification is one of *general or scientific* intent; or one of *special or practical* intent. The former is meant to increase the boundaries of knowledge; the latter to serve some practical or momentary end.

*Mill, *Logic*—II—*p.* 289.

Thus we have two chief forms of classification :— (*a*) ***scientific*** and (*b*) ***artificial.***

(*a*) In *scientific or general classification* objects are grouped together according to *important* or prominent *qualities*. Those objects form one group which possess in common the most important and most numerous points of community or similarity. Scientific classification is also called *natural* because 'these important points of community' (resemblance) which form the basis of the classification are real points of affinity or kinship characterising a group as 'fixed by Nature.' Mill calls such groups *Natural Kinds*. (*b*) In *special or artificial classification* we group objects according to some passing or practical intent. We select some quality or characteristic *arbitrarily* as the basis of our classification.

For instance, we may group animals according to their colour. Such a classification serves no permanent scientific interest, and is never very useful. But if we group animals according to their structure or origin, the classification would be scientific because in this case we can assert a large number of important characteristics of all the animals included in a group. Hence the most *important or fundamental qualities* for a scientific classification are those which *are causes or sure signs of many other properties*. Artificial classification only serves a passing practical interest; a natural classification, on the contrary, helps scientific investigation and extends the boundaries of knowledge. Artificial classification suffers from an additional defect in that it may group objects and individuals together which are really dis-similar, and separate other objects into different groups although they possess the closest similarity. If, for instance, we classify animals on the basis of 'yellow colour', then a yellow sparrow, a yellow lion, a yellow panther and a yellow eagle shall have to be grouped together.

In this sense, the *alphabetical classification* of words in a dictionary is artificial, although it is helpful in some respects.

A natural classification is complete only when it is supplemented by a ***classification by series.*** The objects or individuals are arranged in groups, and these groups are then themselves arranged in a series or hierarchy. Thus we have a sort of graduated scale according to the variation in degree of some feature or group of features. Such serial classifications help in the discovery of laws by the employment of the Method of Concomitant Variations (see Methods of Mill in Chapter VIII.) A complete classification of the animal kingdom, for instance, would be a sort of genealogical tree in which we can go from the simplest to the most complex as well as from the earliest to the most recently developed organisms.

III. *Classification in the light of the Theory of Evolution.—The Theory of Evolution, as ordinarily understood, declares that all living beings had their origin in a common ancestor—*protoplasm, i.e.,* matter endowed with life. Out of protoplasm originated, first of all, the very lowest forms of organism and later on through a variety of causes (some known and many yet unknown)

*The teacher should first discuss this section orally in the class.

the various species of plant and animal sprang into being. This process of the 'Origin of Species' took an almost incalculably long time to reach the forms of life known to us now. According to C. Darwin, the most famous exponent of this theory in the second half of the 19th Century, the evolution of animals and man came about through the two processes of *natural selection* and *sexual selection*. The different species have always been at war with one another in a *struggle for existence*. This continual warfare had a twofold motive, to secure food (self-preservation) and to secure mates or wives (race-preservation). The fittest animals survived in this struggle. The unfit were those which could not adapt themselves to their surroundings and they were killed off by those which could, 'the fit.' Their world was governed according to

> "The good old rule, the golden plan,
> That they should take who have the power,
> And they should keep who can."

This was the mode of *natural selection*. And now about the other process at work:—The fit propagated their kind; *i.e.*, they succeeded in getting 'wives' and in begetting children. This was *sexual selection*. Among the 'children' the same two processes continued to work, and, in this wise, the grim struggle continued for countless generations.

Every surviving generation of a species (and its various individuals) had some feature or characteristic which distinguished it from its ancestors and from those species which it had succeeded in killing or driving off. These 'peculiar characteristics' of each species were somehow '*spontaneously generated*,' *i.e.*, they appeared by the merest accident. They appeared one knows not how. They 'emerged' at various stages of the evolutionary process and each such '*emergence*' marked a distinct rise in the scale of life.

According to the evolutionists, then, the world of life has common roots, and, therefore, any system of classification that overlooks this factor is artificial. "Community of descent is the hidden bond which naturalists have been unconsciously seeking, and not some unknown plan of creation, or the enunciation of general properties, and the mere putting together and separating objects more or less alike."* The complete classification of plants and animals would thus be 'the Tree of Life,' a genealogical tree, a look at which would tell us the natural relationships of the various classes which would form the branches and sub-branches and off-shoots and twigs. From this point of view, the natural classification of organic beings is one founded on *descent with modification.*

Consider *languages*! How have they differentiated? Darwin says! "If we possessed a perfect pedigree of mankind, a genealogical arrangement of the races of man would afford the best classification of the various languages now spoken throughout the world; and if all extinct languages and all intermediate and slowly changing dialects, were to be included, such an arrangement would be the only possible one. Yet it might be that some ancient languages had altered very little and had

*Darwin, *Origin of Species*, p. 369.

given rise to few new languages, whilst others had altered much owing to the spreading, isolation, and state of civilization of the several co-descended races, and had thus given rise to many new dialects and languages. The various degrees of difference between the languages of the same stock, would have to be expressed by groups subordinate to groups: but the proper or even the only possible arrangement would still be the genealogical; and this would be strictly natural, as it would connect together all languages, extinct or recent, by the closest affinities, and would give the filiation and origin of each tongue." *

IV. Should Classification be by Definition or by Type? – What should be the method of classification? Should we first *define* each class, *i.e.*, enumerate its essential attributes, and then group those objects or individuals together which happen to possess those attributes? Or, should we first select some particular individual as the *type* of a class, and taking it as the centre or nucleus of the class, group all those objects or individuals together which conform to it most closely? Each of these views has its advocates.

J. S. Mill considered *Definition* to be the basis of classification. The members of the class or group should be selected according as they possess the essential qualities which form the connotation (or definition) of the group. Mere type, he says, will not do. How do we get the type at all? Only because it possesses certain attributes or characteristics in prominent degree. Type

*Darwin, *Origin of Species*, p. 371.

implies definition; and we should, therefore, start with the latter. Each class should first be defined by the invariable presence of certain common attributes. Thus classification, for Mill, in a sort of pigeonholing of individuals according as they fit in one compartment or the other as determined by definition.

Whewell, on the other hand, was a prominent advocate of classification *by Type*. "The Type of each genus should be that species in which the characters of its group are best exhibited and most evenly balanced;" *e.g.*, the cat represents the class *felidae*: the dog the class *canine*, etc. "Natural Groups are best described, not by any Definition which makes their boundaries, but by a Type which makes their centre. The Type of any natural group is an example which possesses in a marked degree all the leading characters of the class. A Natural Group is steadily fixed, though not precisely limited; it is given in position though not circumscribed; it is determined, not by a boundary without, but by a central point within;—not by what it strictly excludes, but by what it eminently includes;— by a Type, not by a Definition." *

Joseph holds the same view: "A classification attempts to establish types; it selects some particular characteristics in determining the type of any species; these characteristics should be (*a*) of the same general kind for each type within one genus, or,......variations upon the same theme, in order to exhibit the mutual relations of agreement and divergence among the various types: (*b*) important, or, as one might say, pervasive: that

*Whewell, *Novum Organon Renovatum*, p. 21-22.

is, they should connect themselves in as many ways as possible with other characters of the species. It will be the description of the type, drawn up on such principles as these, that will serve for definition. It is avowedly a mere extract from all that would need to be said, if we were to define (upon the supposition that we could define) any species of plant or animal completely."*

The trouble with definitions is that they can never be final. Every day the boundaries and depth of scientific knowledge are increasing. Further, what might *now* seem an important characteristic in an organism may be utterly unimportant for its classification on an evolutionary basis; and, conversely, characters which *now* appear to be unimportant in 'the scheme of life' may really be fundamental for a really scientific classification of living beings. As Darwin says: "It might have been thought (and was in ancient times thought) that those parts of the structure which determined the habits of life, and the general place of each being in the economy of nature, would be of very high importance in classification. Nothing can be more false. No one regards the external similarity of a mouse to a shrew, of a dugong to a whale, of a whale to a fish as of any importance".† Again "organs in a rudimentary condition plainly show that an early progenitor had the organ in a fully developed condition; and this, in some cases, implies an enormous amount of modification in the descendents."‡

*Joseph, *In Introduction to Logic*, *p.* 103.
†*Origin of Species*, *p.* 365.
‡*Op Cit.*, *p.* 424,

It would seem, then, that in the opinion of experts the *classification of organic beings*, at least, *should always be by Type* rather than by Definition. The latter depends on the former.

V. Rules of Classification.—The following rules are regarded as important for classification. It is understood that only an expert in a particular science is competent enough to classify the objects with which his science deals. Inductive Logic can only suggest the method.

(1) Those objects or individuals should be grouped together which possess in common the most numerous and the most important characters. With the Type as the centre or nucleus, the individuals most resembling it should form a particular class.

(2) Smaller groups, which though distinct, have yet close affinities, should be placed together under a common genus; while those groups which, though possessing certain characters in common with others are yet marked off from them by other and more important points of difference, should be classed separately from them. Birds and raptiles are thus placed differently even though they possess several characters in common.

(3) There should be a gradual transition from the lower to the higher (*i.e.*, wider) classes. The gradation should continue until we reach a comprehensive group which includes all minor classes and groups, and shows their respective affinities and distinctions. The nearness of each minor class with reference to others should be determined according to their mutual resemblances; and their distance (from each other in the general

scheme) according to their mutual differences, or the degree of their variation from an originally common stock. In a scientific classification of to-day, the divisions and sub-divisions are so numerous that the 'genus and species' of Aristotalian Logic cannot suffice. Hence the gradation of classes in the declining order of their generality is as follows: Kingdom, Sub-kingdom, Class, Sub-class, Division, Order, Section or Family, Genus, Species, Variety.

VI. Distinction between Classification and Division.—Perhaps the nature of Classification will be thrown into greater relief if we briefly contrast it with Division.

(1) Division is a deductive process while classification is an inductive process. This sums up the difference between the two. The former indicates the downward, the latter the upward trend in the arrangement of things. In Division we proceed from higher to lower classes, while in Classification we start with particular individuals and go upwards, sorting them into groups, and then these groups into higher groups, and so forth.

(2) Division is a formal process while classification is a concrete process. Division is based on knowledge already acquired, while classification tries to extend our knowledge by the grouping of individuals into diverse classes on the basis of mutual resemblances and differences.

(3) Both are concerned with Denotation. They deal not with the attributes of objects and classes, but with their *thinghood* or individuality, so to speak. Definition, which deals with Connotation, does help but is not of primary importance in either case.

VII. Uses of Classification.—Inductive Science attempts to explain phenomena. This is possible when we know the *causal connections* obtaining between the various events which require to be explained. Now, causal connections are not always discovered or understood. What should science do in such cases? It is at this stage in the development of a positive science that classification proves useful. By classifying the phenomena or objects with which a science deals, the way is open for a closer study to enable the discovery of hidden connections. Classification paves the way for explanation. We may say briefly that:—

(*a*) A good classification facilitates the work of explanation. The arrangement of available material in a proper form suggests Hypotheses (provisional explanations, see Chapter X) and aids inference from Analogy (Chapter VII). Classification is, thus, 'condensed and implicit explanation.'

(*b*) Explanation, however, deals with *processes*, but classification is content with the sorting of existing *things*. 'The former deals with the dynamic (the moving), the latter with the static (the stable and fixed) aspect of Nature.' But what looks static to the layman and in the beginning, turns out to be dynamic through and through on later and more thorough investigation. This is shown very clearly by the developments of Physical Science during the last half-century. Classification is, thus, only a *stage* which a positive science has to pass through. Sciences like Botany, Zoology, Geology, etc., are still at this stage and hope to pass onwards when causal laws are discovered in their respective departments.

(c) Classification is also a very efficient aid to memory. What is docketed and pigeonholed properly is easily available when required. System is always better than 'no-system.'

VIII. Limits of Classification.—Every available object in nature cannot be classified. How, for instance, should one classify a sponge? Is it an animal or a plant? It seems to possess the characteristics of both. Where there is ignorance of definite and *peculiar* characters, classification is not possible. Again, there are composite objects in nature whose constituents combine in different ways and in various proportions. There are objects whose composition is not known; etc. A good classification is not possible in such cases. We also see here *the provisional character of all classification*: there is no finality about it. "Real things are cross-related to each other in far too complicated a manner for any single and simple scheme of classification to embrace them as they stand. We must consider aspects of them, and attempt to ascertain what various forms some particular property may assume, and under what conditions.... The things themselves which we have to classify, if we take them in their completeness, cannot be caged in a neat logical arrangement."*

IX. Nomenclature and Terminology.—As a science develops it requires technical terms to express its thoughts and the results of its investigations. These

*Joseph, *Logic* p. 135.

technical terms have their significance rigidly and arbitrarily fixed. This fixity of meaning enables different scientists to use the same term in the same sense. Confusion of thought is thus avoided and the purpose of logical definition is served.

Such technical terms are of the most vital importance for those sciences especially which are yet at the classificatory and descriptive stage. In this chapter, we have considered the part played by systematic classfication in a positive science. [Such a science arranges objects in an hierarchy of groups.] [Each of these groups has some characteristics or peculiarities which mark it off from all other groups in that scheme of classification.] These characteristics are so many attributes possessed in common by the individuals of that group. Hence we require technical terms to designate the groups as well as the attributes or peculiarities of the individuals of each group. [Now "*a Nomenclature is a system of names for the groups* of which a classification consists.] And a *Terminology* is a collection of terms which will enable us *to describe individuals or objects*" (*i.e.*, their attributes and peculiarities).]

[A good classification and a good nomenclature go together. Each is indispensable for the other.] The sciences of Botany, Zoology and Chemistry provide excellent examples of exhaustive nomenclature. "Without Nomenclature, the system is not permanently incorporated into the general body of knowledge, and made an instrument of future progress. Without system, the name cannot express general truths, and contain no reason why they should be employed in preference to any other names."* To fix the groups in our memory, we require distinct names for them. But natural groups in the plant and animal kingdoms are so many that it would be impossible to remember them all if every group had a distinct and independent name. Hence a nomenclature should be so devised that :

(1) " the names of the lower groups are formed by combining names of higher and lower generally ; and

(2) " the names indicate relations of things by modifications of their form."†

The first of these methods is adopted by Botany, for instance ; and the second has been thoroughly developed in Chemistry. In Botany " the higher groups have distinct names, *Dicotyledon*, *Rosa*, *Geranium*, etc The species is marked off by adding a distinctive attribute to the name of the genus, as *viola*, *odorata*, *orchis meculata*, etc. These distinctive attributes are not the logical differentia of the species ; hence, the specific names are not definitions. They are, on the contrary, formed from all kinds of more or less important considerations. Sometimes the name is given in honour of an individual, as *Rosa Wilsoni* ; sometimes from a country in which the plant was first observed, as *Anemone Japonica* ; sometimes from some peculiarity of the plant, as *Geranium Sanguineum*."‡

The second method of devising a nomenclature is employed by Chemistry. Relations are expressed by

*Whewell, *N. O. R.*, *p.* 288.

†Welton, *Manual of Logic, Vol. I.*, *p.* 148.

‡ *ibid*, *p.* 148.

modifications of the forms of the names. Here the significance of the word is changed by means of different suffixes and affixes attached to it (*e.g.*, *ide*, *ic*, *ous*, *ate*, *ite*, etc.,), (*mono*, *di*, *tri*, *sesgui*, etc). From sulphur are derived such terms as sulphu*ric* and sulphu*rous* acids; sulpha*tes* and sulph*ites* of bases; sulphur*ets* of metals; etc.

Such terms as proposition, syllogism, hypothetical syllogism, disjunctive syllogism, dilemma etc., are nomenclature in Deductive Logic; while terms like sensation, feeling, perception, emotion, sentiment, etc., are nomenclature in Psychology.

Terminology.—A science's terminology consists of terms which enable one to describe individual objects by mentioning their characteristics, peculiarities or attributes. For scientific accuracy it is necessary that description should leave nothing to fancy. Each term should have a fixed connotation attached to it and the reader should be able to picture in his mind the same object which the speaker or writer tries to describe. Terminology is part of scientific language and herein lies its importance. The words which form it are general names, but by their combination we can describe each individual.

The science of Botany is the most perfect in its terminology and it owes its richness and precision in this respect to the famous botanist, Linnaeus. "Every part of a plant has been named; the form of every part, even the most minute, has had a large assemblage of descriptive terms appropriated to it, by means of which the botanist can convey and receive knowledge of form and structure, as exactly as if each minute part were presented to him vastly magnified......Thus the flower was successively distinguished into the *calyx*, the *corolla*, the *stemens* and the *pistils* ; the sections of the corolla were termed *petals* by Columna ; those of the Calyx were called *sepals* by Necher.. ...Thus leaves may be called *pinnatifid*, *pinnatipartite*, *pinnatisect*, *pinnatilobate*, *palmatipid*, *palmatripartite*, etc., and each of these words designates different combinations of the modes and extent of the divisions of the leaf with the divisions of its outline.*

Such terms as distribution, attribute, connotation, denotation, etc., in Deductive logic ; and hedonic tone, brightness, chroma, elementary mental process, psycho-neural dispositions, etc., in Psychology are terminology.

It is to be noted that the meaning of technical terms is fixed by convention to begin with. Even when words of common speech are elevated into technical terms, their meaning has to be fixed and rigidly adhered to. For instance, the word ' distribution ' which in common speech means a sort of ' dividing,' means in Logic ' using a term in its entire extension '.

To sum up : Classification and Nomenclature go together. Each is helpless without the other. But there must be a classification before we can have a nomenclature. Terminology is needed when description comes in. All these processes are essential and invaluable in positive sciences, and when a science is yet at its pre-causal, descriptive and classificatory stage, these processes *form* the science.

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*Whewell, *N. O. R.*, *pp.* 316-17.

Exercises.

1. What is meant by Classification? Explain by means of an example.

2. What is the importance of Classification in inductive science?

3. Distinguish between *mental* and *concrete* (or *actual*) Classification. Give examples.

4. What type of Classification would it be when you have to deal with the following objects : books in a library, animals, human beings, fossils.

5. Distinguish between *scientific* and *artificial* Classification. Give examples.

6. (*a*) What is the principle of Classification?

(*b*) Why is Classification regarded as an important preliminary process in inductive science? At what stage is it particularly useful?

7. What is Classification by Series? Explain by means of an example.

8. What light does the Theory of Evolution throw on the problem of Classification?

9. Should Classification be by Definition or by Type? Discuss both views. Which view do you consider to be the better of the two? Why?

10. What are the rules of Classification? Discuss.

11. Distinguish between Classification and Division.

12. What are the uses of Classification?

13. What are the limits of Classification?

14. What is meant by Nomenclature and Terminology? Give examples of each.

15. What connection is there between Classification and Nomenclature and Terminology?

16. In what different ways can a good Nomenclature be devised?

17. In which sciences are Nomenclature and Terminology best developed?

18. Explain the importance of Classification in science and discuss its right to a place in the study of Inductive Logic. What are the marks of a good Classification? (P. U. 33).

19. Define Natural Classification, explaining what is meant by essential or important properties as bases of Classification. What is the value of Natural Classification for Induction? (P. U. 30).

20. Distinguish natural from artificial classification. What makes the former more useful in science than the latter? (P. U. 28).

21. Explain what is meant by scientific classification and distinguish it from logical division. What are the conditions of a good classification? What do you understand by essential qualities in classification? (P. U. 25).

22. Discuss the nature, method and value of Classification. (P. U. 18).

23. Is Classification an Inductive or a Deductive process? (P. U. 16).

CHAPTER VII.

IMPERFECT INDUCTIONS. Counter

(A) INDUCTION BY SIMPLE ENUMERATION.

I. Its Nature.—It is the simplest form of inductive reasoning. We observe that a certain phenomenon, *x*, is followed or is accompanied by another, *y*. This observation is repeated several times afterwards; whenever we notice *x* occurring, we also notice *y* following or accompanying it. We do not come across contradictory cases; *i.e.*, we do not observe any *x* that is not followed or accompanied by *y*. But we do not know *why* *x* should have been followed or accompanied by *y*. We have merely observed this sequence or co-existence. We then *generalise* that *x* is *always* followed or accompanied by *y*. This generalisation is the result of an *induction by simple enumeration*.

For example, I observe a basket full of mangoes. Some mangoes are of a peculiar greenish-yellowish hue. I taste several mangoes of different hues and find that whereas some are sweet while others are sour, the mangoes of the peculiar greenish-yellowish hue that I have tasted have invariably been sweet. I infer that *all* mangoes of this hue are sweet. This is an induction by simple enumeration. I do *not* know *why* mangoes of this peculiar hue should be sweet. I simply say that since all the mangoes of this hue that I have tasted have turned out to be sweet, the remaining mangoes must also be sweet. We say that all crows are black. Why? Because all the crows so observed have turned out to be black. Had any non-black crow existed, somebody would undoubtedly have observed it and recorded the fact. But *why* are all crows black? We do not know. Similarly, botanists have noticed the fact that 'scarlet flowers have no scent'. This, again, is a generalisation based on simple enumeration. But why have scarlet flowers no scent? We do not know.

II. Its Characteristics.—Induction by Simple Enumeration has the following characteristics:—

(*a*) Its value and strength depend on the *number* of *positive* instances observed. The larger the number, the greater the probability of the resulting generalisation being true.

(*b*) The field of experience should be wide enough to get good results. In other words, we should try our best to discover if there are *any negative* or contrary *instances*. We should not be content with our own limited experience. We should explore all possible avenues in search of exceptions to our generalisation. The strength of our generalisation would be 'in proportion to our assurance that if an exception ever did occur we should know of it'. This assurance should not be merely *subjective*; *i.e.*, a matter of mere faith or private belief. It should be *objective*, *i.e.*, we should have exhaustively explored all those fields where a negative instance, if any, would most likely have been present.

III. Its Weakness.—In our discussion of the relative importance of Theory and Fact we have said that however nice or well-constructed a theory might be, a single important fact to the contrary is enough to wreck it. This statement is true of every induction by simple enumeration. Even if we have observed millions of crows, a single non-black crow would suffice to negative our generalisation that 'all crows are black'. Similarly, a single sour mango of that peculiar greenish-yellowish hue would smash my induction about the sweetness of all such mangoes; and a single scarlet flower which has scent would falsify that generalisation about this class of flowers.

Every induction has some element of *risk* in it, because we have to proceed from the known to the unknown; or from the observed-*some* to the unobserved remainder of the *all.* This risk is reduced to a very narrow margin in the case of scientific induction by means of the *analysis of the given* and the *elimination of the irrelevant.* But in the case of 'simple enumeration' these factors are *absent.* We have to depend *only* on the number of positive instances observed and the area of uncontradicted experience. Hence Francis Bacon calls this kind of induction "childish; its conclusions are precarious, and exposed to peril from a contradictory instance; and it generally decides on too small a number of facts, and on those only which are at hand. But the induction which is to be available for the discovery and demonstration of sciences and arts must analyse nature by proper rejections and exclusions; and then, after a sufficient number of negatives, come to a conclusion on the affirmative instances." So also J. S. Mill says: "To Europeans not many years ago, the proposition, All swans are white, appeared an...unequivocal instance of uniformity in the course of nature." But with the discovery of black swans in Australia this time-honoured induction fell to the ground.

IV. Simple Enumeration and Scientific Induction. Suppose that biological research reveals some years hence that there is something in the nervous make-up of a crow which gives it a black coat; or something in the make-up or metabolism of the scarlet flower which gives it its beautiful colouring but denies it scent; or again there is something in its metabolism which gives a mango a peculiar greenish-yellowish hue and also its flavour,—suppose, in other words, that the *why* (cause) of blackness, of odourlessness, and of sweetness is discovered. What then? Well, in that case, the generalisations 'all crows are black,' 'no scarlet flowers have scent,' and 'all mangoes of this peculiar greenish-yellowish hue are sweet'—would become *scientific* generalisations, the results of scientific induction; the reason being that these generalisations would not now depend on the mere *number* of instances but on their *quality* and *causal character*.

V. Its Value.—However risky an induction by simple enumeration might be, it is not without real value. (1) It can suggest hypotheses (*i.e.*, provisional explanations) for further enquiry. (2) It can serve in cases where scientific induction is not possible. It can record the results of unanalysed experience for use later on by means of scientific methods. (3) It can furnish very useful material for the collection of statistics and the calculation of probabilities.

(B) ANALOGY.

I. **What is it?** - Let *X* and *Y* resemble each other in certain important respects, say qualities *p, q, r, s,* and differ in certain other respects, say qualities *l, m,*; then if, later on, *X* is found to possess another quality, *w*, the question is, what probability is there that *Y* would also possess this quality, *w*? The argument from analogy would be that if the points of resemblance between *X* and *Y* are greater in number and importance than the points of difference, then the new property *w* which is found in *X* may also be expected to be present in *Y*.

(*a*) For example, a comparative study of the bodily and nervous make-up of man and lower animals shows that (1) there are many features in common between the two; (2) that there are certain features which are present in a rudimentary form in animals but are present in a highly developed state in man; (3) that there are certain points in which men and animals differ; and (4) that man possess a quality called 'consciousness.' What probability is there that animals also possess this quality in some degree or form? In other words:— "Certain animals are characterised by a given......structure of their nervous organs and nervous systems, together with an ability to learn rapidly from experience; Human beings are characterised by a similar structure of sense-organs and nervous system, and also by their speed in learning from experience; Therefore these animals are probably (beyond a reasonable doubt) characterised by another property known to belong to human beings, *viz.*, mentality (consciousness.) As the degree or number of resemblances in animal and human structure becomes less, that is, as the differences increase, and the speed of animal learning drops far below that of man, the analogy is weakened, though it still has some force."*

(*b*) How do I know that my neighbour has a mind? By analogy! I have a certain bodily make-up. My neighbour resembles me in that make-up. Suppose that I go out for a walk. A strange dog runs towards me. I feel *afraid* that it would attack me. I run away or beat it off with my stick. Suppose now that I perceive my neighbour pass through the same experience, *i.e.*, I perceive that he is attacked by the mad dog, and that he acts in the way I did. I infer that he, too, was afraid, *i.e.*, he like me has a mind.

II. The Principle of Analogy.—The basis of analogy is the principle: "Upon the evidence that certain particulars have a number of properties in common, it is probable that they have other properties in common and perhaps that they share all properties of some class or type."†

Bain says that "Analogy (as different from induction, and as a distinct form of inference) supposes that two things found resembling in a number of points, may resemble in some other points, which other point is not known to be connected with the agreeing points by a law of causation or of co-existence".

*Eaton: *General Logic*, p. 552.

†*Ibid.*

The strength of such an argument, says J. S. Mill, would depend "on the extent of ascertained resemblance, compared first with the amount of ascertained difference, and next with the extent of the unexplored region of unascertained properties". This means that (1) if the number of resemblances known to exist is great (compared with the number of points of difference) the truth-probability of the analogical argument is strengthened. (2) If, however, the number and importance of the points of difference is great, then the analogy is weak and misleading. (3) The greater the number of unknown properties in the subject of our argument, the less the value of any inference from those properties that we do know. (4) "The probability that analogous particulars (*e.g.*, objects *X* and *Y*) have a great many more properties in common, beyond those observed would of course be less than the prabability that they share only a *few* more". (Eaton). In other words, there is greater probability of truth in the assertion that the new property, *w*, which is found in *X* would also be present in *Y*, than in the statement that *several new* properties, say *w*, *l*, *m*, which have been discovered in *X* would also be present in *Y*.

Rules of Analogy.—(1) The points of resemblance should be greater in number and importance than the points of difference.

(2) If some points of resemblance (or of difference) are mutually related in a *causal* way, they should count as one.

(3) Our knowledge of the subject should be fairly

extensive. For instance, an analogy between the Earth and the planet Mars cannot justify the conclusion 'that Mars is inhabited like the Earth', because we know so very little about the surface conditions of that planet.

(4) The ultimate value of analogy and its numerical measure is 'the ratio of the points of resemblance to the points of difference *plus* the unknown points.'

(5) None of the points of resemblance and difference should be known to be related to the (new or) inferred property in a causal way. When knowledge of the causal relation is available, the argument from analogy ceases to work.

III. Analogy and Induction.—Both Induction and Analogy, like Deduction, assume that things which are alike in certain respects are also alike in others. In this sense, they are applications of the Principle of Uniformity of Nature. Unlike Deduction, however, both Analogy and Induction are forms of *probable* reasoning. Some logicians go further and hold that Induction is really analogical in nature. There is some truth in this assertion because very often what an inductive method (with positive and negative instances) does is to change an imperfect analogy into a perfect one.

But there are also vital differences between these two forms of inference. In Induction we have *some* cases or instances which agree in some property, and from the examination of these instances we infer about *all* cases or instances agreeing in that property. There is inference from some to all. In Analogy, on the other hand, we have *only two* cases or instances. We compare and contrast their properties and infer something (on the basis of this contrast and comparison) about the *probable* presence of some new character in the second instance on the strength of the *actual* presence of that character in the first instance which resembles it in certain respects. "Induction by simple enumeration proceeds from statements about *some particulars* of a given class to a generalisation about *all particulars* of that class; Analogy proceeds from statements about *some properties* of given particulars, to statements about *other properties* of those particulars, and possibly to a statement about *all properties* of a given 'sort belonging to those particulars."*

I go into a College class-room and discover that all students are matriculates. I infer that probably *all* the students of the College are matriculates. This is an induction by simple enumeration. I see two boys in a class room. They are brothers and resemble each other in features, habits, quality of work, etc. I conclude by analogy that these two boys must also resemble in their tastes, desires and intelligence.

J. S. Mill describes true reasoning as one from particulars to particulars. In this sense, pure analogy would be a better form of reasoning than pure induction which *does* generalise. It is not meant here that it is correct to say that true reasoning is 'from particulars to particulars.' What is true is that *pure analogy cannot give us a general conclusion.*

With a little modification, however, of the principle

*Eaton, *General Logic*, p. 555.

of analogy mentioned in II, pure analogy can be raised to the status of a *generalised analogy*. Thus Eaton says:— "If *a* has certain properties, *any X* that has some of these properties will probably have others of them; more exactly, if *a* has *m* properties, *any X* that has *n* of these properties will probably have the remaining ones, and this probability will be greater as this remainder is smaller." In other words, the exhaustive and discriminative study of *one* case may lead to a generalisation of high probability. Induction, on the other hand, must depend on *numbers* too, in addition to the *analysis* of given instances.

IV. Uses of Analogy.—It is not always possible to discover an analogy that may satisfy all the requirements stated in the previous sections. But even the faintest analogy may be of the utmost use in suggesting new observations and experiments which may, in their turn, lead to the discovery of more positive truths. *The principle of analogy—things alike in certain respects are alike in others, perhaps even in all—*guides us not only in daily life but also in scientific investigation. One of the great charms of Poetry consists in its fertile analogies. Scientific research, more often than not, has started with an analogy in the mind of the scientist. Jenner, struck by the resemblance between cowpox and smallpox, was led to the discovery of vaccination as a potent preventive measure against the latter disease. The inventors of aeroplanes and gliders were impressed by the flight of insects, birds and kites. The recognition of general similarities leads to the discovery of fundamental relations. In this sense, analogy is one of the most potent incentives to scientific and artistic research. Perhaps it is the privilege *of genius* to be struck by analogies where mortals of ordinary clay see no resemblance at all.

But Analogy has its dangers too. False analogies are all too common and result in a great deal of loose thinking and mischief. Hence the force of Heine's ironical prayer: 'Lord God, save us from the Evil One and from metaphors'!

Ordinary analogical arguments are uncritical in two ways. Either the importance of the points of difference is overlooked; or one's ignorance of the subject is under-estimated. If these two sources of fallacy are guarded against, the analogical argument can reach a high degree of truth-probability.

V. Aristotle's definition of Analogy.—It may be noted in passing that the term analogy has not been used in the preceding sections in the sense in which Aristotle used it. He defined it as *an equality of relations*. We would (in this sense) be said to argue from analogy, when having laid down that—since A : B : : C : D., therefore, if A is, say, double of B, C must also be double of D; etc. Or, as a child is to the parent, so is the colony to the mother country. Hence, since the child should be obedient to the mother, the colony should also be obedient towards the mother-country.

Analogy in this sense, if carelessly used, as in the 'child and colony' analogy, can be a very fertile source of fallacies. In modern Logic, however, the term analogy is not generally used in this ancient sense of 'equality of relations.'

Exercises

1. What is meant by Induction by Simple Enumeration? Define and explain by means of examples.

2. In what way does 'induction by simple enumeration' differ from 'scientific induction'?

3. What are the characteristics of induction by simple enumeration?

4. What is the value of such induction?

5. Can an induction by simple enumeration change into scientific induction? Show how.

6. Give four examples of induction by simple enumeration.

7. Wherein lies the weakness of this form of induction? Can the margin of error be reduced to a minimum by multiplying the number of positive instances?

8. Define and discuss the basis of induction by simple enumeration. State the chief limitations of this method. How does it contrast with 'induction by complete enumeration' (*i.e.*, perfect induction)?

9. What is Induction by Analogy? Define and exemplify.

10. Give two concrete examples of analogical inference.

11. Distinguish between Analogy and Simple Enumeration. Use examples.

12. Discuss critically the Principle of Analogy. What rules follow from it?

13. What is the relationship between Analogy and Scientific Induction?

14. What are the uses of analogical inference? Do we use this form of reasoning in daily life?

15. In what sense was Analogy used by Aristotle? Give examples.

16. Indicate with examples the various kinds of fallacy that are liable to occur in reasoning by Analogy. (*See Chapter on Fallacies*). Do you consider that reasoning by Analogy is of any value in the study of science? (P. U. 33).

17. What is the nature of argument from Analogy? Can it ever be regarded as conclusive? What are the conditions on which the strength of such arguments depends? (P. U. 27).

18. Explain carefully the nature of Analogical Reasoning. What is the weak point in an argument from Analogy? Illustrate your answer by an example. (P. U. 25).

19. Explain the nature of an argument from Analogy. Give an illustration. The use of Analogy is peculiarly liable to lead to fallacious inference. Why so? (P. U. 23).

20. Explain the nature of Inference from Analogy. Give a concrete example. On what conditions does the value of analogical inference depend?

21. Can you prove by Analogy that if prohibition of the sale of liquor has increased crime in another country, it will necessarily do the same in India? (P. U. 33).

22. Distinguish between Perfect Induction and Simple Enumeration. Discuss the value of a conclusion reached by Simple Enumeration. Show how this method of reasoning depends on the Uniformity of Nature. (P. U. 34).

CHAPTER VIII.

SCIENTIFIC INDUCTION—(I).

MILL'S INDUCTIVE OR EXPERIMENTAL METHODS.

I. **Introductory.**—It has been pointed out in Chapters IV and V that the ***Law of Uniformity of Causation*** (which is the principle of Uniformity applied to Causation) serves, more or less, the same function in Induction that the *Dictum* of Aristotle does in the classical doctrine of the Syllogism. The Law asserts roughly that ***under similar circumstances similar antecedents lead to similar consequents.*** This, however, is quite a general and perhaps a vague formula. We should know how to apply it to actual and concrete cases. Given a complicated phenomenon, how are we to find out what are its causes and to what effects does it lead? It is to apply the Law of Uniformity of Causation to actual and concrete cases that J. S. Mill devised his *Methods.* They are so many devices for the discovery of causal relations between different phenomena by a successful *elimination* or rejection of irrevelant attendant circumstances.

Functions of the Methods.– Mill points out only *two* functions of his methods. They are (1) *methods of discovery of the causal relationships* between different phenomena. They try to suggest and formulate hypotheses which may enable investigators to explain the facts under observation. (2) They are also *methods of proof* in the sense that they enable us to prove the validity or truth of these hypotheses.

For the logician, however, their function as methods of proof is the more important of the two. The logician will leave it to the expert scientist to discover his laws and causal relations as best as he might. But *given* such a discovery, he will try to rationalise the process of discovery by pointing out the distinct steps or stages in the evidence which, through their cumulative strength, have led to the discovery.

The task of discovery and proof is made easy by the gradual and complete rejection (*elimination*) *of all irrelevant circumstances*. This can be done, as Bacon had suggested, by varying the circumstances from instance to instance. "Elimination means the successive exclusion of the various circumstances which are found to accompany a phenomenon in a given instance, in order to ascertain what are those among them which can be absent consistently with the existence of the phenomenon". This ensures the separation of the casual and the accidental from the causal and the essential. Our observations and experiments should be conducted in such a way, *i.e.*, the instances should be so gradually varied, that we should be able to note what happens when certain antecedents or consequents are absent. If we discover that the presence or absence of a certain antecedent is always followed by the presence or absence of a certain consequent, we are justified in inferring some causal relationship between them.

The examination of instances by a successive variation of circumstances should be exhaustive. This can only be done if both the positive and negative instances are carefully noted. We should study the cases of the occurrence as well as the cases of the non-occurrence of the phenomenon under consideration. The study of negative instances is particularly important. In order to find out whether a particular sequence is both invariable and unconditional we should note both the positive and the negative sets of instances.

Principles of Elimination.—Just as the *Dictum de omne et nullo* is analysed into three canons of the syllogism, so is the Law of the Uniformity of Causation resolvable into *three Principles of Elimination.* These are:—

(1) *What can be eliminated without prejudice to the effect is not the cause.* Or, whatever antecedent can be left out without injuring or destroying the effect, is not the cause. In other words, that is not the cause which, when absent, the effect is still present, (and which, when present, the effect is still absent). x is not the cause of y, if when x is absent, y is still present, (and when x is present y is absent). A variable antecedent cannot be the cause of a phenomenon. If in the case of a certain person the eating of a melon on one occasion was followed by cholera but on another occasion it was not, then the eating of of a melon by itself cannot be regarded as the real cause of cholera.

(2). When an antecedent cannot be left out, without the consequent also disappearing, such antecedent must be the cause or a part of the cause. Or, *whatever cannot be eliminated without prejudice to the* *effect, is the cause.* x is the cause of y, if the absence of x is always followed by the absence of y. If there is malaria in a certain locality whenever there are mosquitoes and no malaria whenever there are no mosquitoes, then the mosquitoes are the cause or a part of the cause of malaria in that locality.

(1) and (2) jointly give us these conditions of elimination: x is not the cause of y, if when x is present, y is absent; or when x is absent, y is present. To be the cause (or a part of the cause), the presence of x must always entail the presence of y, and the absence of x must always entail the absence of y.

(3) *When an increase or decrease of a certain antecedent is followed by a corresponding and proportionate change in a certain consequent, then that antecedent is causally connected with that consequent.* The doctrine of Conservation of Energy supposes the cause and effect to be quantitatively equal, and this third principle follows from this supposition. We believe that heat expands bodies because we notice that any increase in the former is followed by a corresponding increase in the volume of the latter.

On these three principles *Mill* bases his *five methods*. These are the Methods of Agreement, of Difference, of Joint Agreement and Difference, of Concomitant Variations, and of Residues. Let us now turn to them.

II. Method of Agreement.—*Canon*:—"If two or more instances of the occurrence of the phenomenon under consideration have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or indispensable condition) or effect of the given phenomenon." (Mill).

Symbolic Illustration :—

Antecedents.	*Consequents.*
(1) *A B C*	*l m n*
(2) *A D C*	*l o n*
(3) *A D E*	*l o p*
(4) *A E K*	*l o q*

etc.

∴ *A* is the cause of *l*.

Suppose that we have to find the cause of *l*, or the effect of *A*, by means of this method. Our reasoning would be :—In case (1), *l* may be effect of *A* or *B* or *C* or *AB* or *AC* or *BC* or *ABC*. But in case (2), *l* occurs although *B* is missing. Hence *B* is neither the cause nor any part of the cause of *l*, because what can be eliminated without prejudice to the effect is not the cause. Again in case (1), *D* was absent and yet *l* was present. Hence *D* cannot be the cause either. In a similar way we find that *E* and *K* are not the causes of *l*. *A* alone is present in *all* cases as an antecedent. Hence *A* alone is the cause of *l*. We have a *syllogism* :—

Whatever can be eliminated is irrelevant (*i.e.*, is not the cause). Now *B*, *C*, *D*, etc., can be eliminated. ∴ *B*, *C*, *D*, etc., are irrelevant (are not the cause). But *l* must have a cause. Therefore, the only remaining antecedent, *A*, is the cause. In other words, the sole invariable antecedent, *A*, is probably the cause; or, the sole invariable consequent, *l*, is (probably) the effect.

Concrete Examples.—(1) Suppose that some people in a village suddenly fall sick of cholera. We find that their occupations were different, their habits were different, their ages were different, their diet was different, etc. But they all got their water supply from the same well. We infer that the water of the well is responsible for the outbreak of cholera.

(2) Suppose that there is an outbreak of small-pox in a certain town. Many people suffer. We observe that none of the victims had been vaccinated. We, therefore, infer that the absence of vaccination is the cause or part of the cause of all that suffering.

(3) We have several friends. Some of them are healthy while others are not. We want to determine the cause of the good health of those who are blessed with it. We notice that all of them without exception take regular physical exercise. We infer, therefore, that regular physical exercise is the cause or part of the cause of good health.

General Remarks and Criticism. – (1) This method is one of observation only, and is, therefore, subject to all the defects of observation. It can give us more or less probable conclusions, but never certainty. Of course, if the number of instances examined is very large, the degree of truth-probability becomes very high.

(2) To get the best results, *all* irrelevant circumstances should be eliminated. This, however, is not so easy to do. In nature, relevant and irrelevant circumstances are mixed together and observation alone cannot help us ; *i.e.*, elimination remains incomplete.

(3) Sometimes events *co-exist* in nature; sometimes they are reciprocal. For instance, education and national prosperity, and crime and drink, are somehow causally connected. But we do not know which of them is the cause and which the effect. Each influences the other. Such cases of *the mutuality of cause and effect* are outside the scope of the method of Agreement.

(4) This method is equally useless in cases where two or more events are *joint-effects of one and the same unknown cause.* If, *e.g.*, sleeplessness at night is accompanied by headache, we are inclined to regard the one as the cause of the other. But both may be due to worry or over-work or a bad digestion.

(5) Again, the results obtained by this method may be invalidated on account of an Intermixture of Effects.

(6) The objections mentioned above, however, should not lead us to suppose that this method is valueless. It is of great use in those cases where experimentation is not possible. If its conditions are satisfied, it can give us a very high degree of truth-probability. Given a hypothesis, this method can test it and pave the way for future experimentation.

(7) It can be used both for the discovery of the cause of a given effect and of the effect of a given cause.

(8) We should distinguish this method from induction by simple enumeration. The latter is unscientific since it relies for its conclusions merely on the number of instances. This method, on the other hand, relies on both the *quality* (character) *and* the *number* of the instances examined. It is a method of elimination.

III. Method of Difference.—*Canon.* "If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one, that one occurring only in the former; then the circumstance in which alone the two instances differ, is the effect, or the cause, or an indispensable part of the cause of the phenomenon." (Mill).

In the method of Agreement we select a *number* of instances and observe in what respect they all *agree*, but in this method we take *only two instances* and observe in what respect they *differ* from each other.

Symbolic Illustration :—

Antecedents.	*Consequents.*
A B C D....................	......*p q r s.*
B C D..........................	..........*q r s.*
∴ *A*............	..*p*

What is the cause of *p*, or better what is the effect of *A*?

An examination of cases (1) and (2) shows that the factors *B C D*......*q r s* are the same in the two cases. In (2), however, *A* is absent and also *p* is absent. We infer, therefore, that they are causally connected. Our syllogism is :—

What cannot be eliminated without prejudice to the effect, is the cause. *A* cannot be eliminated without prejudice to the effect. Therefore, *A* is the cause (of *p*).

Concrete Examples. (1) We know that air transmits sound because we hear the tick of the watch when it is placed inside a jar; but not when the same jar is emptied of all air contained in it. All circumstances *except one* being the same, we regard *that one* circumstance (the emptying of all air) as the cause of the phenomenon (absence of sound).

(2) Of two children living in the same house and belonging to the same family, one suffers from small-pox while the other escapes. If, now, we know that the sick one had not been vaccinated while the other had been, we can infer that vaccination prevents small-pox.

(3) The college bell strikes in the compound and the students leave their classes for home. Hence the bell is the cause or a part of the cause of the phenomenon (the dispersing of students).

(4) I feel thirsty and drink a glass of water. The feeling of thirst disappears. What is the cause? Of course, the water which I drank.

(5) Prof. Erskine wanted to test the potency of a serum that he had prepared to prevent bubonic plague. He took twenty healthy rats from a ship which had just come into port, after a long voyage, from another port which was free from plague. During the voyage there had been no case of a rat dying of plague. The rats, therefore, were strong and healthy. He inoculated ten of these rats with his serum; the others were left as they were. He next took a rat suffering from plague and introduced it among those twenty. After a day or two it was observed that the ten *un-inoculated* rats were suffering from plague but the inoculated ten had escaped. This proved conclusively that the serum was a good preventive.

General Remarks and Criticism.—(1) The validity of the results obtained by means of this method depends on the essential condition that *only one circumstance shall be varied at a time*. Nature, however, rarely presents to us cases in which a single circumstance has varied (*i.e.*, by addition or by substraction). Hence this method is useless in cases of *pure* observation. To use it we must devise our own instances: *we must experiment*.

(2) The method of Difference is thus *experimental* in nature, just as the method of Agreement is observational.

(4) Agreement is based on the law that what can be eliminated is not the cause. Difference is based on the law that what *cannot* be eliminated *is* the cause.

(4) The suggestion or hypothesis arrived at as the result of the application of Agreement can be tested and verified by Difference. Every experiment is an instance of this method.

(5) Difference is better than Agreement in that it can give us *certain* results if its conditions are satisfied; *viz.*, if only *one* circumstance is varied at a time.

IV. Joint Method of Agreement and Difference

Canon: "If two or more instances in which the phenomenon under investigation occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of that circumstance; then the circumstance in which alone the two sets of instances differ, is the cause or the effect, or an indispensable part of the cause of the phenomenon." (Mill).

Symbolic Illustration:—

	Antecedents.	*Consequents.*
Positive	A B C	l m n
	A C D	l n o
	A B E	l m p
	etc.	
Negative	B D F	m o q
	E Q H	p r s
	G R C	t u n
	etc.	

$\therefore$ A l

Here we have two *sets* of instances. The *positive set*, which resembles the method of Agreement, shows cases in which the circumstance, *A*, common to all the instances, is followed by *l* whose cause we desire to discover. Agreement tells us that *A* is the cause of *l* since *A* is the invariable and indispensable antecedent of *l*, whereas *B*, *C*, *D*, *E*, are not. This conclusion is confirmed by the *negative set* of instances which shows that even though *B*, *C*, *D*, etc., are present, yet the consequent *l* is absent in every case. Hence they cannot be causes of *l*.

The positive set tells us that what can be eliminated (*B*, *C*, *D*, *E*) without prejudice to the effect *l*, is not the cause. The negative set tells us that what cannot be so eliminated (*i.e.*, *A*) is the cause (of *l*).

Concrete Examples.—(1) If it is found that those districts are free from small-pox where people had been vaccinated in large numbers, while those districts suffer most from it (though similar to the former in most respects) where vaccination had not been introduced, then we can correctly infer that vaccination prevents small-pox.

(2) Similarly, if malaria rages in districts where the drainage is bad and cess-pools and marshy areas are common, while those districts are relatively free from malaria in which these defects are absent, then we can correctly conclude that malaria and bad drainage are in some way causally connected.

(3) If the teacher finds that those of his pupils score the best marks in the examination who were most regular in the performance of their home tasks, while those fare worst who, though equally intelligent, had been consistently neglecting their home exercises, then he would be justified in concluding that the success of the former is due in great measure to their industry outside the class-room.

(4) Dr. Wells inferred that the formation of dew depended on the coldness of the surface of bodies below the temperature of the surrounding air. The reason was that all those substances (stones, plants, etc.) on which much dew is formed, agree in that they radiate heat from their surface very rapidly, while on the contrary, those substances on which little or no dew is formed agree in having very little radiation.

General Remarks and Criticism. -- (1) This method can be called one of Double Agreement because it consists in a double application of the m. of Agreement; *viz,* first to those instances which *agree in the presence* of the circumstance and the phenomenon under investigation, and, secondly, to those instances which *agree in the absence* of the circumstance and the phenomenon under consideration, other factors remaining more or less the same.

(2) It may also be regarded as an *extension* of the m. of Difference because whereas Difference requires only *one* positive instance and *one* negative instance (which in other respects remains the same), this method requires *one set* of positive instances and *one set* of negative instances (in other respects more or less similar).

(3) The m. of Difference can only be applied when all concomitant (or accompanying) circumstances remain *constant.* But such instances are not easy to find. Again, there are cases where experimentation is out of the question. In such cases, the Joint Method can give to our results the nearest approach to certainty. As Deighton says: "In trying to reach generalizations regarding the behaviour of human individuals or human societies—in looking for moral or social or economic laws—it is, of course, impossible to employ Experiment. Mere observation of the Agreement type would, however, lead to faulty results. Hence, we have recourse to this method which can give the best possible results under the circumstances."

(4) The two sets of instances should have many factors in common, because otherwise there can be no comparison between them. For this reason Deighton modifies Mill's canon into:—"If when two sets of instances—one in which the phenomenon under investigation occurs and one in which it does not occur—are drawn from the same field of inquiry—it is found that there is one circumstance which is invariably present when the phenomenon occurs and invariably absent when it does not occur, while each of the other circumstances

in both is sometimes absent when the phenomenon is present, and sometimes present when the phènomenon is absent, then the first circumstance is causally connected with that phenomenon."

V. Method of Concomitant Variations.—*Canon*: "Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it by some tie of causation." (Mill).

Symbolic Illustration:—

Antecedents.	*Consequents.*
A_1 B C	x_1 l m
A_2 B D	x_2 l n
A_3 D C	x_3 n m
etc.	
∴ A	x

We find that an increase or decrease in the amount of A is followed by a corresponding increase or decrease in the amount of x. Other circumstances, B, C, D, may or may not change from instance to instance. We infer, then, that B, C, D, etc., are unconnected with the production of x, and that the only cause of x is A. When the circumstances B, C, D, etc., also change from instance to instance, it should be regarded as a variation of the m. of Agreement. If, however, these antecedents *do not* change from instance to instance, then it would be a modification of the m. of Difference. The distinction here between these two methods would be that whereas in Difference A and x are present in *one* instance and entirely absent in the second, in Concomitant Variations, on the other hand, A and x are present in *all* instances in varying degrees while other circumstances remain the same.

Concrete Examples : (1) Friction is the cause of heat because an increase in the former is always followed by an increase in the quantity of the latter.

(2) Heat expands bodies because we always find that the volume of a material substance increases (through the mutual repulsion of its molecules) when its temperature also increases. There is *regular and proportionate correspondence* between the two.

(3) Suppose that a rat is placed inside the receiver of an air-pump. The air is gradually extracted, but not exhausted. The rat's suffocation agonies increase. Now we gradually pump the air in. We observe that the rat gradually regains its first healthy condition. We infer that air is necessary for life.

(4) A survey of the animal kingdom tells us that the animals whose brain-centres are comparatively more complicated in structure and greater in volume are the animals which possess a keener intelligence. We infer that brain and intelligence are causally related in some way.

(5) The tides are regarded as "due to the attraction of the moon and sun, because the periods of high and low spring and neap tides, succeed each other at intervals corresponding to the *apparent* revolutions of these bodies round the earth" (Jevons). All cases of

periodic changes in natural phenomena are cases for the application of this method.

General Remarks.—(1) Such natural agents as gravitation, temperature of bodies, friction, etc., cannot be entirely eliminated in the performance of experiments. Hence, we require a method to determine the effect of these causes when we cannot entirely get rid of them but can have *more or less* of them. This is done by the m. of Concomitant Variations.

(2) Science requires *exact quantitative determination* of causes and effects. Mere observation may tell us that quinine cures malaria, but if this discovery is to be of real use we should also know how much of quinine would be necessary for patients of different ages and conditions.

(3) In employing this method, it is, however, risky to infer the existence of a correlation between certain antecedents and consequents without examining in some *detail* the nature of the concomitant variation. In general, 'the more definitely the relationship can be shown in a considerable number of cases, the more ground there is for the conclusion that the conjunction is not accidental' (Deighton). For example, psychologists have found that certain definite correlations exist between a child's chronological age and his mental age (*i.e.*, his mental equipment at any particular period). But though this 'measurement of intelligence' is quite exact within certain limits, it fails entirely in the cases of freaks like prodigies, geniuses, idiots, etc. Similarly, it is known that cold contracts bodies; but at a certain

degree of temperature, the contraction again changes into expansion. In such cases the formulation of the correlation should *not* go beyond the range of cases observed.

(4) This method helps us in *classification by series*. It has been pointed out by Bain that if the individuals of a class possessing a common property are arranged in the order of the degree in which they possess that property, then, it is possible to detect some corresponding property which varies concomitantly with it.

(5) Exact measurements are possible only where the cases admit of *quantitative changes. Changes of quality cannot be measured in mathematical terms.* Hence in no such case should this method be used.

VI. Method of Residues. – *Canon:* "Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents." (Mill).

Symbolic Illustration:—

	Antecedents.	*Consequents.*
	A, *B*, *C*...... ...	......*m*, *x*, *y*.
(*Known by previous inductions*)	*B*.................	.*x*.
	C,.................	.*y*.
	∴ *A*...........	.*m*.

We observe that the antecedents *A*, *B*, *C*, produce the consequents *m*, *x*, *y*. But we also know from past experience that *B* produces *x*, and *C* produces *y*. We, therefore, infer that the remaining antecedent, *A*, is the cause of the residual (remaining) phenomenon, *m*.

Concrete Examples: (1) Raleigh observed that the density of nitrogen obtained from the atmosphere was greater than that of the nitrogen prepared in the laboratory. What was the explanation of the difference? Careful investigation by him and Ramsay led to the discovery that the greater density of atmospheric nitrogen was due to the presence of an hitherto unknown gas in the atmosphere. This gas was isolated and named Argon. After the isolation of this gas the nitrogen of the atmosphere was found to possess the same density as that of the laborotary.

(2) Suppose that the cost of a building, including furniture is Rs. 5,000. We know that Rs. 1,200 were paid as wages, and Rs. 3,200 for building material. We infer, then, that the remaining sum, Rs. 600, was spent on furniture.

(3) The occupants of a third class railway compartment find, when leaving the train at the terminus, a Rs. 100 note lying on the floor. Not one of them is rich enough to have possessed (and dropped) such a valuable note They remember that a rather pot-bellied *sowcar* was with them for a short time. Therefore he must have dropped the note.

(4) 'Almost all the greatest discoveries of Astronomy have resulted from the consideration of residual phenomena of a quantitative or numerical kind;" *e.g.*, the discovery of the planet Neptune in the last century is an oft-quoted illustration.

General Remarks.—This method may be regarded as a modification of Difference. But whereas in Difference the negative instance is arrived at as the result of direct observation and experiment, in Residues it is obtained from *previous inductions*

(2) Difference is mainly experimental in nature, but Residues is mainly mathematical in nature. It implies previous knowledge of the laws of separate causes which are deductively calculated and then subducted from the positive instance.

(3) It is, however, most profitably used only when the science employing it has already made some advance. Given this, it is one of the most fertile sources of discovery.

(4) Deighton has analysed the implications of this method into *two* parts :—

(*a*) " In the case of a complex phenomenon which is the result of several causes, this method enables us to find out what part each of these causes plays in the determination of the whole fact under consideration."

(*b*) The method also recommends that "when any part of a complex phenomenon is still un-explained by the causes which have been assigned, a further cause for this remainder must be sought."

VII. Mill's Methods: General Criticism and Remarks.—The methods of Mill are really *formal* in nature. They are so many applications of deductive inference to the facts of experience. Carveth Read describes them as follows:—" Inductive Logic may be considered as having a purely formal character. It consists, first, in a statement of the Law of Causation; secondly, in certain immediate inferences from this law, expanded tno tfie Canons; thirdly, in the syllo gistic application of the canons to special propositions of causation by means of minor premisses showing that certain instances satisfy the Canons."

The Canons or Laws of Elimination are really immediate inferences from the Law of Uniformity of Causation. They serve as the major premisses of the inductive syllogisms of which the minor premisses consist of data supplied by experience, *i.e.*, by observation and experiment. The five methods can be reduced to two ultimate forms. The Joint Method and the Method of Concomitant Variations are modifications of the Method of Agreement:—the method of Observation. The Method of Residues (and the Method of Concomitant Variations, too) are modifications of the Method of Difference:—the Method of Experiment. Let us now see whether these two basic methods can be reduced to syllogistic form.

Agreement is based on the first canon of Elimination. The syllogism reads:—

Whatever antecedent can be eliminated without prejudice to the effect *is not* the cause; *B, C, D, E*, etc., *are* antecedents which can be eliminated without prejudice to the effect; ∴ *B, C, D, E*, etc., *are not* the cause. (*Celarent.*) But according to the law of Causation, every event must have a cause. Hence since *B, C, D, E*, etc., are not the cause, the only remaining antecedent, *A*, must be the cause of the phenomenon under consideration.

Difference is based on the second canon of Elimination. The syllogism reads:—

Whatever antecedent cannot be eliminated without prejudice to the effect *is* the cause; A *is* the antecedent which cannot be eliminated without prejudice to the effect; ∴ A *is* the cause. (*Barbara*).

We see, then, that the methods of Agreement and Difference are easily reducible to the moods *Celarent* and *Barbara*, respectively. This formal nature of the inductive methods s sometimes expressed by the statement:—*The Law of Uniformity of Causation is the ultimate major premiss of all inductive reasoning.*

Whewell's objections against Mill's Methods.— The logician Whewell regarded Mill's methods as useless, because (1) they presuppose the very thing which is most difficult to discover, *viz.*, the reduction of phenomena to so many 'cut and dried' and calculable instances. It is all very well, on paper, to say that *A*, *B*, *C*, produce *a*, *b*, *c*, but Nature is too complex for these formulas and clear-cut combinations. (2) Again, no discoveries in science have been made by means of these methods The discovery is made somehow by a scientist who is unaware even of the existence of these methods. What the methods can do is to reduce the discovery, after it is made, to symbolic form.

Mill's answer.— (1) It *is* very difficult to come across clear-cut instances of phenomena in Nature. Gold in its natural state is always mixed with dross. But we still know what genuine gold is. The irrelevant complexities (attendant circumstances) can be got rid of, like dross, by the help of these methods. (2) They serve as models to which we can reduce all inductive reasoning. They are methods of *proof* and *not* of discovery. (3) These methods perform the same function in inductive logic that the syllogism performs is deduction. Reason is not limited to the syllogism, but still the syllogism serves as an indispensable criterion of validity in many cases. Whewell's objection, if true, would make the syllogism equally valueless.

To sum up:—Mill's methods are *useful* because (1) they suggest hypotheses; and (2) because they furnish the means by which iuductive generalizations and hypotheses can be tested. (3) In very complicated cases, however, these methods fail to give us results whose truth-probability may be equal to certainty. (4) In cases of Intermixture of Effects, for instance, these methods are entirely unavailing: we cannot even apply them.

Exercises.

1. Ennnciate the canons of all the five Methods of Mill. Illustrate each of them *symbolically*.

2. Give two concrete examples of each method and state clearly in what respects each method differs from the others.

3. Distinguish the method of Agreement from Induction by Simple Enumeration. Use concrete examples.

4. Distingnish between the following methods:—(*a*) Agreement and Difference; (*b*) Agreement and the Joint Method; (*c*) Agreement and Concomitant Variations; (*d*) Difference and the Joint Method; (*e*) Difference and Concomitant Variations: (*f*) Difference and Residues.

5. What is meant by saying that the m. of Residues is not experimental but deductive in nature?

6. Mention and illustrate the advantages of each method.

7. Mention and illustrate the defects of each method.

8. Is it true to say that each method performs a function which the others cannot perform ?

9. On what occasions is the m. of Concomitant Variations particularly useful?

10. Is it true to say that the Methods of Mill are really formal or deductive in nature ?

11. What is meant by saying that the Law of Uniformity of Causation is the ultimate major premiss of all inductive inference?

12. Reduce the Methods of Mill to syllogistic form.

13. What is the importance of the Method of Residues?

Or

What is the m. of Residues, and indicate its special value? (P. U. 28).

14. What objections has Whewell urged against Mill's Methods? How does Mill meet them? What do you suppose to be the right view?

15. When is the m. of Concomitant Variations to be preferred to the m. of Difference? Illustrate your answer by examples of both methods. How does the m. of Residues differ for the m. of Difference? (P. U. 33).

16. What is the m. of Difference? Give an example of its use from experimental science and show the practical difficulties in using it. (P. U. 33).

17. What is the Joint m. of Agreement and Difference? What advantages does it possess over the Methods of Agreement and Difference separately? Illustrate your answer by a concrete example. (P. U. 32).

18. Explain and illustrate the m. of Concomitant Variations. What are the circumstances under which it is specially applicable? (P. U. 31).

19. Explain the canon of the Double Method of Agreement (*i.e.,* Joint Method) and illustrate your answer by a concrete example. When is it necessary to employ this Method? (P. U. 30).

20. How does the m. of Agreement differ from that of Simple Enumeration? In what way is the former superior to the latter as an instrument of discovery and proof. (P. U. 29).

21. Explain the nature and use of the m. of Difference. Prove by this method that heat expands bodies. (P. U. 27).

22. Explain precisely the principle of the m of Difference contrasting it with that of the m. of Agreement. What defects are there in the former and how can they be overcome? (P. U. 23).

23. Explain the use and application of Concomitant Variations. Prove by this method that air is an essential condition of the phenomenon of sound.

24. Attempt two of the following problems explaining in detail the inductive methods used:—

(*a*) Describe an experiment showing that a plant turns its flower to the sun.

(*b*) Investigate the causes of a sudden fall in the number of students attending a certain College.

(c) Demonstrate the connection between the amount of rainfall and the rate of food prices in India. (P. U. 33).

25. Construct an inductive argument to prove that 'Tea causes sleeplessness' and analyse your reasoning showing the method or methods you have employed. (P. U. 32).

26. The more the number of pools of stagnant water in a district is reduced, the rarer does the occurrence of malarial fever become. What conclusion can be drawn from this statement? Analyse the reasoning involved, naming the method employed and estimate the logical value of the inference. (P. U. 30).

27. With the help of one or more of the inductive methods either prove or disprove that the present unemployment in India is due to the spread of education. (P. U. 29).

28. What inference would you draw from the following facts? Timber entirely submerged in water lasts a very long time, and if sunk in mud or clay below water, longer still. Again, painted or varnished timber does not decay as quickly as

unpainted or unvarnished timber. With reference to the requirement of the Inductive Method or Methods employed, estimate the value of your inference. (P. U. 29)

29. Prove the following propositions by the Method of Difference. (*a*) (*i*) Oxygen supports combustion. (*ii*) Heat is the cause of the melting of ice. (*b*) A teacher having noticed signs of disorder in a corner of his class-room on several successive occasions suspected one of the students and expelled him from the class. Subsequently there was perfect order in the class for weeks. (P. U. 26).

30. How are the direct methods (*i.e.*, Mill's Methods) of inductive inquiry correctly described as Methods of Elimination? (P. U. 25).

31. Discuss the view that the methods of inductive inquiry are Methods of Proof and not of Discovery. (P. U. 22).

CHAPTER IX.

SCIENTIFIC INDUCTION—(II).

THE DEDUCTIVE METHOD OF INVESTIGATION.

I. **Introductory.**—We have seen that the Methods of Mill fail to give satisfaction in complicated cases, especially in cases of intermixture of effects. When several causes are operative at the same time, it is difficult to determine which part or aspect of the joint-effect is due to which one (or more) of these causes. For example, the health of an individual depends on so many factors: proper diet, hygienic habits, good climate, physical exercise, congenial occupation, absence of worries, inherited constitution, etc. Each of these factors has its own peculiar effects which can be observed under properly managed conditions. But when all these factors operate *together*, the joint-effect is something different in nature, both qualitatively and quantitatively from those separate effects. It is unique. How, then, are we to determine the causal relation in these cases? The Methods of Mill do not help us here. We require a new method which should not only be free from the limitations of Mill's methods but should also combine the advantages of both the inductive and the deductive forms of reasoning. This final and comprehensive method is known variously as the Deductive Method of Investigation (Mill), the Combined or Complete Logical Method (Jevons), or the Method of Rational Induction (Dubbs). The problem of this method is to "*find the law of an effect from the laws of the different tendencies of which it is the joint result.*" We should calculate the joint effect of the separate agencies which seem to be operative in producing the phenomenon under consideration. This calculated result is then compared with the actual result. If the two agree, our analysis of the causal relation is correct. If there is disagreement, we should begin again.

II. Analysis of the Deductive Method.—There are three stages in the process :—

(1) Inductive Stage. —The law of each separate cause which seems to have a share in producing the joint-effect is ascertained by *observation* and *experiment.* On the basis of this examination an *hypothesis* is formed to explain the phenomenon under investigation. Whenever possible, the *Methods of Mill* are used to examine the hypothesis and the laws of the various causes. In short, all the inductive processes which can be of help in guiding us towards the right analysis of the phenomenon, are made use of.

(2) Deductive or Ratiocinative Stage.—The inductive stage gives us either the laws of the various operative factors, or an hypothesis (or both). In the former case, we calculate the joint-effect of these laws; in the latter case, we deduce and elaborate the consequences of our hypothesis. Or we may have to do both.

(3) Verification.—The computed result is now compared with the actual result, *i.e.*, with the phenomenon itself. If the two agree, our analysis of the causal relation and our hypothesis are verified. If they disagree, then either our inductive investigation was wrong, or our calculations and deductions were incorrect, or both were wrong. In other words, our work shall have to be done over again.

Carveth Read sums up the method as follows :—"Given any complex mechanical phenomenon, the inquirer considers—(1) what laws already ascertained by induction seem likely to apply to it (in default of known laws, hypotheses are substituted) ; he then (2) computes the effect that will follow from these laws in circumstances similar to the case before him, and (3) he verifies his conclusion by comparing it with the actual phenomenon."

III. Importance of the Method.—Induction and Deduction by themselves, *i.e.*, independently of each other, cannot give us real scientific knowledge. They must co-operate. The Deductive Method combines both these modes of reasoning and enables us to tackle not only the great and complicated problems of the inorganic world, but also those of Life, Mind and Society, *i.e.*, the Organic world. It is the logical method of investigation *par excellence*, and to it, as Mill says, "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." It may be noted here that this method is not only an *ideal* method of investigation, but is also the method which every great scientist has *actually* used in the discovery of nature's laws.

Example :—A man suffers from fever. A physician is called in. He observes the symptoms of the patient, inquires into his habits, his general health, his diet before the illness, the hygienic conditions of his neighbourhood, etc. A consideration of all these factors leads him to the hypothesis that the fever is malarial. This is the inductive stage. From this hypothesis, he draws consequences, *viz.*, that the administration of quinine with some other drugs should soon lead to a cure. This is deduction. He prescribes the medicine. After a day or two of treatment it is found that the patient has shaken off his fever. This is verification. Suppose, however, that the patient is not cured. In that case, the physician shall have to revise his previous view and suggest another line of treatment in the light of a more intensive examination of the symptoms.

IV. The Inverse Deductive Method.—The form of the method discussed so far is not the only one in which it can work. It is (1) *the Direct Form* in which a deduction is verified by comparing it with experience. But we can also (2) *compare our experience with the result of a deduction.* This is called the *Inverse Method.* The Direct Method is best applied in dealing with the inorganic world: hence, it is also called the *Physical* Method. The Inverse Method is called the *Historical* Method, and we can apply it in the investigation of the phenomena of 'life, mind and society.' In such cases the forces at work are so subtle and complicated that the Direct Method is of little use. We should begin by observing the result. As there are numerous subtle agencies at work, we should make tentative (provisional) hypotheses to account for the phenomenon under investigation. We should, then, deduce consequences from these hypotheses and see to what extent they conform with the actual course of events. This is how, for example, a Sherlock Holmes sets out to solve the riddle of a mysterious crime. The historian, the moralist, the sociologist, in fact every investigator who studies the phenomena of 'life, mind and society' and tries to account for them, must follow this Inverse Method.

Exercises.

1. From what limitations do the Methods of Mill suffer? How can you overcome these defects?

2. What is the Deductive Method of Scientific Investigation? What are its two forms?

3. Mention the three stages of the Deductive Method. Explain the significance of each stage.

4. Give two examples each of the *Direct* and *Inverse* forms of the Deductive Method.

5. Why is the Deductive Method called the Complete Logical Method?

6. What part do Hypothesis and Ratiocination play in the Deductive Method?

7. Is it correct to say that to the Deductive Method we owe the most conspicuous triumphs of science? Mention some famous discoveries to support this view.

8. How would you distinguish between the m. of Residues

and the Deductive Method. In what respects is the latter superior to the former.

9. Read the following passage carefully, and show how it illustrates the *three* stages of the Deductive Method :—

" The ancients found that the sun travelled in a path they called elliptic, and that the sun and major planets all appear in a belt known as the zodiac. For them, these were merely observed uniformities or empirical generalizations"......*Kepler* was the first to discover the first rational law. He worked upon observations of the positions of Mars. He "tried a number of hypotheses and finally found that by taking the hypothesis that Mars moves in an orbit which is an ellipse, he could deduce all the observed positions of the planet." This was before the invention of the telescope. His results were approximate; nor did he consider possible alternative hypotheses. His law 'gave an approximate statement of the behaviour of the planet, which because it was stated in quantitative terms, permitted a comparatively secure result... Kepler fortunately realised neither the intricacy of determining the planetary motions nor the limitations of his own hypothesis, and so was saved the trouble of propounding supplementary hypotheses to account for the failure of his laws.

" Newton propounded and proved a broader generalization, which not only made Kepler's laws a deduction from his general law of gravitation, but also enabled the deduction of deviations from Kepler's laws from the same hypothesis that Kepler's laws were deduced from. In addition there is deducible from Newton's hypothesis a wide range of phenomena *e.g.*, (1) the succession of day and night; (2) the succession of the seasons; (3) eclipses of the sun and moon; (4) the phases of the moon: (5) the motions of the planets with respect to the fixed stars: (6) the precession of the equinoxes; (7) the motion of comets; (8) tides and trade winds; (9) the observed experience or facts that a weight dropped from a great height falls a little to the east of the vertical; (10) the fact that a pendulum set swinging in a north-and-south direction (in the northern temperate zone) appears to change its plane of vibration, and that a gyroscope appears to change its axis of rotation; (11) the fact that the equitorial diameter of the earth is greater than its polar diameter; (12) the fact that in the case of certain constellations, certain stars appear farther apart at certain dates than six months earlier or later The first five of these facts of experience could be equally well explained by (*i.e.*, be deducible from) the Ptolemaic hypothesis; but the others could not be so explained. The circumstance that the Newtonian hypothesis explains facts, not simply in the astronomical field, but also in other fields—the tides, many of the phenomena of meteorology, certain geographic characteristics of the earth, certain peculiar constituents of the bodies from a height. certain phenomena of pendulums and gyroscopes, etc.,—shows that it is more than an empirical generalization; it is a rational hypothesis. The phenomena it explains are so diverse that it is the *only* hypothesis which could fit those facts. Nevertheless, it is possible that Newton's law is only a limited universal, and the Newtonian physics may be a special case of the more universal Einsteinian physics. This possibility. that every rational law may later be shown to be a limited universal, does not detract from the certainty of that rational law; Newton's laws have remained as true as ever, but their application may be shown to be limited in range.

We may thus conclude that a hypothesis may be considered verified when it enables the drawing of a sufficiently wide range of verified deductions."—Dubbs, *Rational Induction*, *pp*. 234—237.

CHAPTER X.

HYPOTHESIS.

1. **What it is.**—J. S. Mill defines an hypothesis as "any supposition which we make (either without actual evidence, or on evidence avowedly insufficient) in order to endeavour to deduce from it conclusions in accordance with facts which are known to be real; under the idea that if the conclusions to which the hypothesis leads are known truths, the hypothesis itself must be, or at least is likely, to be true". In this sense, an hypothesis is a sort of *provisional explanation* of the facts at our disposal. For instance, we wish to explain phenomena of a certain class. The evidence at our disposal is not sufficient to warrant an entirely reliable conclusion. But some provisional explanation is needed to start the enquiry. We proceed on the basis of that provisional explanation. Should it *work*, *i.e.*, it is fruitful of results and is verified by facts discovered by later enquiry, it may cease to be merely a *provisional* explanation and may gain the status of a *scientific* hypothesis.

An hypothesis may have another significance too. Not only may it be an explanation, provisional or real, of the phenomena under investigation (*i.e.*, of facts already known): it may also serve as a *light*, however dim at first, by the help of which we can *discover facts* to form the basis of an enquiry. The facts at our disposal may be so few to begin with that no enquiry worth the name can start. In such a case, an hypothesis would be a lantern in our hands to help us *collect* facts in the gloom of our surroundings.

II. Conditions of a Valid or Legitimate Hypothesis. Every guess or conjecture, however, cannot be called an hypothesis. It should not be a figment of the imagination. And it must fulfil its *double function*: it must serve as a workable and *provisional explanation* of facts already in our possession, and it must give a definite trend or *orientation* to our enquiry. To fulfil these two functions, it should satisfy certain conditions. As C. Read says, it should be "verifiable and therefore definite; and to establish itself as a true theory, it must present some symptom of reality, and be adequate and unconditional and in harmony with the system of experience." More fully, it should be judged in the light of the following criteria:—

(*a*) *Verifiability and definiteness.* These two conditions are designed to eliminate vagueness and unreality from every hypothesis. Verifiability consists in comparing theory with fact. We draw consequences from our hypothesis, and compare them with facts as found in nature. If the two agree, our hypothesis is valid. This would be verification by means of *observation* only. But we may also devise *experiments, i.e.,* put the provisional explanation to a test whose conditions are controlled by us. If, however, direct observation and experiment are not possible, we should compare the derived consequences of our hypothesis with well-known facts or with established laws of nature or with the uncontradicted experience of mankind. Should any or all of these conditions be unfulfilled or violated, we must reject our hypothesis or so modify it that it stands the test.

Similarly, definiteness should be insisted upon in every hypothesis. Mere poetic imagination cannot do. The provisional explanation should be dragged down from the limitless space of fantasy to solid earth. It should be so *concrete* that we can handle it, so to speak. So long as it remains vague and indefinite, we cannot know what we are about. Like the ghost in a haunted house it would for ever elude our grasp, and be useless for the purpose for which it was framed. It was horror for such vagueness and unverifiability which led Newton to exclaim 'I do not make hypotheses'! Now he did make hypotheses throughout his life, but they were not vague and unverifiable 'airy nothings', but definite and verifiable theories, *i.e.*, scientific hypotheses. To explain rainfall by saying that 'it is the work of angels', would be such an airy nothing, because we cannot verify (by observation or experiment or any other empirical means) the existence of angels; nor are we told anything definite about the way in which they cause rain to fall. Similarly, at the present day, many seekers after truth are perplexed at the vehemence with which the phenomena of 'spiritism' or 'spiritualism' are being discussed by those who devoutly believe in them and those who as dogmatically disbelieve in them. Such phenomena are those concerning haunted places, the intercourse of mind with mind across vast streches of space and without the use of any known physical means, table-tapping, conversations with the alleged spirits of dead people, etc. Now so long as these phenomena remain outside the limits of controlled observation, *i.e.*, experimentation, the scientific mind will continue to fight shy of a belief in them. And rightly; because once the conditions of *verifiability* and *definiteness* are relaxed, the genuine gold of truth in any or all of these phenomena would be overwhelmed by a huge mass of superstition, fraud and belief born of misguided faith.

(*b*) *Verae Causae.*—The necessity of *concreteness*—*i.e.*, verifiability and definiteness—in every hypothesis is expressed by Newton in his famous maxim that only *verae causae* (*i.e.*, real or actually existing causes) should be regarded as valid explanation of the phenomena under investigation. A *vera causa* should be a real agent in nature; it should be known to exist independently of the phenomena which are to be explained by its help. It is a "thing or occurrence in a thing, whose reality we are thoroughly convinced of from the necessity of reconciling observed *data*, and there is no reason in the nature of things why a single science or a single range of reality should not suffice to produce such conviction".* *A vera causa* is not necessarily one which was known prior to the phenomena which are explained by its help; for otherwise *new* knowledge of causes would be impossible. We would have to explain everything in terms of the previously known causes. What *is* meant is that the *vera causa* should not be invented or presupposed *merely* for the phenomena under consideration. It may be invented for them, but it must *also* be shown to be a *vera causa*

*Bosanquet, *Logic II. p.* 159.

for other phenomena for which it was not invented. In other words, a *vera causa* should not be a question-begging epithet. The *ether* of space, the *quanta* of energy, etc., are *verae causae* in Physics; nervous impulses, psycho-physical dispositions, etc., are such in Psychology. Similarly, other empirical sciences employ *verae causae.*

Newton's maxim about the *verae causae* should not be taken to mean that *imagination* has no room in scientific investigation. Constructive Imagination and Reason are very closely allied mental processes. Without imagination we could do or know nothing new. What Newton stops us from in scientific investigation (and explanation) is fantasy or uncontrolled imagination, *i.e.,* imagination which has lost all touch with reality, or imagination which does not rest on the bed-rock of fact. The man rich in constructive imagination is the man rich in his hypotheses. Darwin, for instance, devised scores of hypotheses to explain the origin of animal and vegetable species before he could hit upon one that satisfied him. The others were ruthlessly criticised and rejected. This is the distinguishing mark of the great scientist: he allows free scope to his imagination to develop and devise hypotheses in accordance with the requirements of fact; but he is also his own most uncompromising critic. Where fact conflicts with theory or hypothesis, it is the latter which is discarded or modified.

One important function which *controlled imagination* performs in scientific investigation is the elaboration of *Representative Fictions.* For instance, the heat of a body is said to consist in the motion of its particles; or, light is said to consist in the vibrations, at tremendous frequencies, of an hypothetical ether; etc. Now we cannot perceive the motion of the particles of the heated body, nor the vibrations of the ether produced by light-stimuli. But these concepts are regarded as *representative fictions* in that they enable us to understand the phenomena and are also consistent with the known laws of heat and light.

The second condition of a valid hypothesis, then, is that it should be in terms of *verae causae* (real causes or agents); but that *verae causae* do not exclude the valuable constructions of controlled imagination.

(c) *Consonance with known laws and absence of self-contradiction.*—The hypothesis should not conflict with laws of nature already known to be true, nor should it be self-contradictory. Scientific knowledge forms a continuity. What has been proved to be true by past experience by observation and experiment—forms the basis of all *new* knowledge. If, therefore, an hypothesis conflicts with or contradicts the *established* laws of nature, it is by that very fact condemned straightaway. Very rarely, however, it does happen that some of the so-called established laws of nature are themselves false and the new hypothesis is true. But in such cases either the new hypothesis is based on facts not hitherto known or cared for, or the so-called laws previously established fail to account for these facts in any satisfactory way, or the new hypothesis is more comprehensive and has a firmer foundation of facts than those other laws of nature. For instance, the geocentric theory of the solar system (that the sun revolves round the earth as centre), known as Ptolmey's System, was regarded as true before Copernicus (1473 – 1543) acquainted Europe with his heliocentric theory (that the Sun forms the centre round which the system of planets, including the earth and the comets, revolves). This new theory or hypothesis conflicted with previously established 'laws' or notions in regard to the cosmology of the Solar System. But as it could explain in a more satisfactory way *all* that the Ptolemic hypothesis did, and had in addition a firmer and wider foundation of facts, it succeeded in displacing the older hypothesis.

In all such cases, where the old is displaced by the new, one rule should never be lost sight of. To use the language of lawyers, *the onus of proof must always lie with the new-comer*. The hypothesis which contradicts or conflicts with laws previously known to be true can be accepted as true *only* when the evidence in *its* favour and against *them* is so overwhelmingly strong that no other alternative is possible.

That the hypothesis should not be self-contradictory means that there should be, as far as possible, complete *formal* consistency in its parts.

(*d*) *Adequacy to account for facts.*—The hypothesis should be adequate to account for the phenomenon under consideration and for *all* other phenomena of that type. There was, for instance, an old Greeco-Roman belief that earthquakes were caused by some commotion in the smithy of the god Vulcan who worked under Mount Vesuvius (or perhaps Etna). The craters of these volcanoes were his chimneys

Now apart from the other defects of this hypothesis (*e.g.*, its unverifiability), it was inadequate to account for those earthquakes which took place in other parts of the earth. Similarly, if people were to believe that an epidemic in a certain locality is due to a curse pronounced on it by an insulted saint, we would have to reject the hypothesis because it does not explain why the same epidemic is raging in another place where no such curse was pronounced. This condition of adequacy is of great importance because the greater the number of facts or phenomena that an hypothesis can explain, the nearer truth is it bound to be.

(*e*) *Parsimony in the number of presuppositions.*—Of two equally good hypotheses the one which involves the lesser number of presuppositions (*i.e.*, real or supposed agencies, or representative fictions) should be regarded as the better. We should not assume more than what we *cannot* do without. The greater the number of our presuppositions, the greater the risk of any one or some of them being false. (This is the principle known as *Occam's Razor*—*viz.*, *that unnecessary and gratuitous principles of explanation should be cut out*). Similarly, Newton mentions 'Two Rules of Philosophising' (in his *Principia*):—"Rule I—No more causes of natural things are to be admitted than such as are both true and sufficient to explain the phenomena of those things. Rule II—Natural effects of the same kind are to be referred as far as possible to the same causes." The first of these rules is before us now. If we can account for a phenomenon by assuming one real agent, why should we assume two?

(*f*) *Prediction.*—The good hypothesis should not only account for what is before us now or what has occurred in the past; it should *also* say something definite about what we may expect to happen in the future if it (the hypothesis) is true. The scientist of to-day must have this much of the prophets of old in him. He must prophesy about the future and his predictions should not be rough and ready: they should be exact in a quantitative way. It has been said above (*d*) that the hypothesis should be adequate to account for *all* the facts. 'All' includes not only the past and the present, but also the future. When the prediction made on the basis of a certain hypothesis is verified, our faith in its adequacy is intensified. It has a very high probability of being true.

III. Crucial Experiments and Instances.--We have dealt above with those conditions which every hypothesis must fulfil if it is to be regarded as valid or legitimate. But it may happen at times that more than one hypothesis can satisfy these conditions. For example, even to-day there are rival theories of light, and scientists are not agreed as to which is conclusively the better of the two. In all cases of a plurality of valid hypotheses we require some criterion to decide in favour of one which may possess the good points of the others *plus* some other advantage which they lack. Suppose, for instance, that a certain person, Mr. X, has been found dead by his neighbours under suspicious circumstances. A noise as of a pistol shot was heard. People rushed into the house where X lived alone. X was found lying dead on the floor of his room. There was a bullet wound in his breast, and blood on his clothes and the floor.

The warmth of the dead body showed that the deed was recent. A pistol was lying near the dead body. Two people, *Y* and *Z*, were in the room with the dead man. The neighbours knew not only that both *Y* and *Z* were avowed enemies of *X*; but that they were also at daggers drawn with each other. Each of them accuses the other of being the murderer and explains his own presence in the room by the assertion that he had got wind of the other's murderous designs and that though he was himself was no friend of *X*'s, he certainly had never wished him that tragic end. Each disclaims the ownership of the pistol. Suppose now that the local Sherlock Holmes is called in by the neighbours He has three hypotheses before him;—that *X* committed suicide; that *Y* is the murderer; and that *Z* is the murderer. He examines the pistol. It shows that it had very recently been fired. There are fingerprints too on it. Whose? *Y's*! Then *Y* is very probably the murderer. The finger prints would form the *crucial instance* because they point the way towards the correct hypothesis. Suppose, however, that the finger prints are too dim to be made out. Then the enquiry proceeds. Whose pistol? *X* never had one. The various firms dealing in fire arms are referred to. It is found that the pistol belongs to a Mr. *P* who had lent it a few days back to his friend *M*. *Y* is *M's* nephew. This discovery would be crucial in favour of the hypothesis that '*Y* is the murderer'. Further, the examination of the wound shows that *X* could not have succeeded in firing the shot at that angle. The hypothesis is now still further strengthened.

We now quote two examples of crucial instances and experiments in Physics : –

(*a*) 'Copernicus asserted, in opposition to the ancient Ptolemaic theory, that the earth moved round the Sun, and he *predicted* that if ever the sense of sight could be rendered sufficiently acute and powerful, we should see phases in Mercury and Venus. Galileo with his telescope was able in 1610 to *verify* the prediction as regards Venus and subsequent observations of Mercury led to a like conclusion. The discovery of the aberration of light added a new proof, still further strengthened by the more recent determination of the parallax of fixed stars. Hooke proposed to prove the existence of the earth's diurnal motion by observing the deviation of a falling body, an experiment successfully performed by Benzenberg; and Foucault's pendulum has since furnished an additional indication of the same motion, which is indeed also apparant in the trade winds. All these are crucial facts in favour of the Copernican theory".*

(*b*) "If the undulatory theory of light, be true, light must move more slowly in a dense refracting medium than in a rarer one; but the Newtonian theory assumed that the attraction of the dense medium caused the particles of light to move more rapidly than in the rare medium. On this point, then, there was complete discrepency between the theories, and observation was required to show which theory was to be preferred.

*Jevons, *Principles of Science, p.* 522.

Now by simply cutting a uniform plate of glass into two pieces, and slightly inclining one piece so as to increase the length of the path of a ray passing through it, experimenters were able to show that light does move more slowly in glass than in air. More recently Fizeau and Foucalt independently measured the velocity of light in air and in water, and found that the velocity is greater in air." Thus these crucial experiments support the undulatory theory of light and not Newton's Corpuscular Theory."*

In short, as Jevons says "a crucial experiment must not simply confirm one theory, but must negative another; it must decide a mind which is in equilibrium, as Bacon says, between two equally plausible hypotheses."†

IV. Hypothesis and Induction.—The importance of hypothesis in induction depends on what view we adopt in regard to the aim of induction. According to J. S. Mill, induction deals with *proof*. If so, then hypothesis is a very poor form of induction because it is a mere presupposition based 'either on no actual evidence or on an evidence avowedly insufficient'. Hence for Mill it is only useful in that it starts an enquiry, or suggests a line of investigation which may lead, later on, to the discovery of inductive truths. It is, in other words, a preliminary to induction, but not itself an induction. What it suggests is to be tested later on by means of the so-called 'Experimental Methods', which themselves are methods of proof.

*Jevons, *ibid*, p. 521.
†*Ibid*, p. 519.

For Whewell, on the other hand, induction deals with discovery. The scientist should frame one hypothesis after another until he hits upon the one that most successfully accounts for the facts. From this point of view the framing of hypotheses becomes one of the most important functions of inductive science.

It is not possible or desirable to reject any one of these two views of induction as false. For Mill (and those who agree with him) Induction, as the science and art of proof, has to deal with definite rules. The Methods of Mill are such instruments of elimination and proof. They help us to separate the relevant from the irrelevant. But this procedure leads also to the *discovery* of inductive generalisations. 'Proof and Discovery' are, therefore, to some extent allied processes.

Those for whom *discovery* is the main concern of Induction, would suggest the following procedure :—

(*a*) Examination of a large number of instances. Such examination would enable the mind to *abstract* (draw out) the common features of the cases under observation; and these common features would then serve as basis for an hypothesis.

(*b*) Critical study of a few *selected* instances. Out of the group of instances before us, a few should be taken up for a very close examination. This is done to enable the mind to grasp the hidden peculiarities and resemblances which 'rough and ready' observation cannot reveal.

(*c*) Critical study of some *simble* (uncomplicated) instances. Such study has great advantages. The essential nature of a phenomenon is most evident in cases where there are no complications to cloud one's observation.

(*d*) The instances under examination should next be *classified* in a methodical way. Good classification (as has been discussed in a previous chapter) is a necessary and fertile source of inductive generalisations.

(*e*) Classification prepares the ground for the application of the Experimental Methods (especially of the Method of *Concomitant Variations*). When cases are so arranged that they form a *graduated* series, slight variations in the antecedents and consequents are at once noted and good hypotheses about the causation of the phenomena under investigation can be framed.

(*f*) *Analogy* can also be of very great value in the formulation of hypotheses. For example, the study of the flight of insects, birds, kites and eagles can throw a flood of light on the various problems of aviation.

(*g*) Given previously established laws and generalisations, much new and valuable knowledge can be derived in a purely deductive way. Francis Bacon, who advocated direct intercourse with Nature in the search after truth, overlooked the fact that both induction and deduction are necessary for perfection in the art of Discovery. The astronomer who works out his enormous equations in the quiet of his study is as important, and in some cases discovers greater truths, than his brother who traverses the heavens with his telescope in the solitude of the night. The discovery of the planet Neptune is just one of several famous instances illustrative of this truth.

We have mentioned above some of the important *stages* on the road to Discovery, but when all is said and done, it must be remembered that *discoverers are born, not made.* Just as we can take a horse to the waterside but cannot force it to drink (if it is not that way inclined), similarly a man may have all sorts of facts and formulas and rules of guidance before him and yet find nothing new. This 'aptitude' for discovery is a gift of nature. It may show itself variously as 'knack' or 'talent' or 'genius', but in every case it is an expression of *sagacity, i.e.*, of that element of reason which is pure *native intelligence* and quite distinct from learning or acquired knowledge. *Given* this element of sagacity, a scientist is helped in his endless search after the secrets of nature if he follows the above-mentioned procedure.

V. Kinds of Hypothesis. - There are two chief kinds of hypothesis. Sometimes the cause of a phenomenon is known but we do not know how it *works, i.e.*, how it produces the effect of the phenomenon under consideration. At other times, we do *not* know the cause but we do know according to what laws it works. In the former case our hypothesis shall have to assume a law, while in the latter case it must assume a cause.

(*a*) *Hypotheses which assume a law.*—For example, bacteriologists and epidemiologists know that influenza spreads on account of certain minute living organisms. There is experimental evidence to show that these organisms (germs or bacilli) exist. But it is not yet known how these bacilli act on the nervous centres to produce their dread effects. When dealing with such cases, various 'modes of operation'—hypotheses—are assumed and tested, and whenever there is conclusive evidence in favour of any one of several tentative hypotheses, it is accepted as the *law* of that class of cases. Hypotheses of this type are called *descriptive* because they indicate how things happen.

(*b*) *Hypotheses which assume a cause.*—Certain effects are produced by causes whose nature is not yet known. Their mode of operation—their law—is, however, accurately known and calculated. For example, 'the Law of Inverse Squares' is a very accurate summing up of the effects of gravity, but the force of gravity (whatever that may mean) itself remains entirely hypothetical. Similarly, the undulatory theory of light assumes the existence of an hypothetical entity—ether—whose vibrations at tremendous frequencies, are supposed to produce the phenomena of light. Such hypotheses are *explanatory* because they tell us something about the *causation* of phenomena, *i.e.*, what real or supposed agents are responsible for those phenomena.

VI. Hypothesis, Science and Abstraction.—(A) *Hypothesis and Science.*—Enough has been said above to show the importance of hypothesis in scientific investigation. Most of what is now regarded as true in science originated as hypothesis. And the field of choice is limitless. As Jevons says:—"Provided it is consistent with the laws of thought there is nothing that we may not accept as a probable hypothesis, however difficult it may be to conceive or understand it.* Hypothesis is almost co-extensive with scientific investigation. At the beginning of the inquiry it suggests to us a road to follow, and gives us a lamp to light our way. As we go along, it continues to play this double role and, in addition, renews itself every now and then like the phoenix in the fable. At the end of the inquiry it is still with us as the perfected fruit of our labours. But it has now ceased to be a mere hypothesis: it is a *theory* or a *law*.

The fundamental defect of Mill's system of Inductive Logic is that he has greatly underestimated the importance of hypothesis.

It has been said that science rests on the belief in the Uniformity of Nature. But this belief is only an assumption based on uncontradicted experience. Hence, all science is hypothetical in nature...This is not a desirable way of using the term hypothesis. Our confidence in the Uniformity of Nature is based on such strong foundations that its truth-probability is almost 100 per cent. A hypothesis, on the other hand, can never reach this limit of conviction, because it is, after all, based on the assumption of Uniformity in Nature.

(B) *Hypothesis and Abstraction.*—Some logicians (*e.g.*, Dugald Stewart) use the term hypothesis in sense entirely different from what it has been taken to mean in this chapter. They mean by it an *abstraction* or an 'ideal' as opposed to what actually exists. In this sense, they

**Elementary Lessons in Logic*, p. 271.

maintain that Geometry and pure Mathematics are hypothetical in character. 'Theorems' in Geometry are such assumptions. A line is defined as 'having length but no breadth'; a point 'as that which has position but no magnitude', etc. As thus defined, 'points' and 'lines' are not actual existents. They are only 'ideals' towards which approximations may be attempted but which no actual point or line, however fine and infinitisimal it may be, can ever hope to reach. Their existence is purely *conceptual*: they are the products of our own thought and are meant to serve as 'norms' or standards of perfection in a certain department of knowledge. We assume these abstractions to be true and then base a huge superstructure of reasoning on this foundation.

Like this *Method of Abstraction* Mathematics also employ the *Method of Limits*. The following quotation from Whewell* illustrates this form of reasoning:—"A curve is not made up of straight lines, and therefore, we cannot by any of the doctrines of elementary Geometry measure the length of any curve, but we may make up a figure nearly resembling any curve by putting together many short lines, just as a polygonal building of very many sides may nearly resemble a circular room. And in order to approach nearer and nearer to a curve we may make the sides more and more small, more and more numerous. We may then possibly find some mode of measurement, some relation of these small lines to other lines, which is not disturbed by the multiplication of the sides, however far it be carried. And thus we may do

History of Scientific Ideas, Bk. 11, p. 12.

what is equivalent to measuring the curve itself; for by multiplying the sides we may approach more and more closely to the curve till no appreciable difference remains. The curve line is the *limit* of the polygon; and in this process we may proceed on the *Axiom* that 'what is true up to the limit is true at the Limit'".

Hypothesis as Abstraction and hypothesis as used in Induction have this much in common that both are *representative* in character. Further, in both we try to explain the actual (and concrete) by that which is *not-yet*; but whereas in Mathematics this *not-yet* is really a *never-can-be* (an ideal), in induction it is a *should-be* (as a theory or law) at the end of the inquiry. In Abstraction we look at the thing in one aspect only and exclude all other aspects. This use of Abstraction is not peculiar to Mathematics. All such concepts as virtue, vice, whiteness, rationality, etc., are abstractions. In hypothesis (Induction), on the other hand, we draw *consequences* and see that they agree with facts. If they do not, we reject or modify the hypothesis. As against the ideal result of an Abstraction which is a 'Platonic Idea' resident in the unattainably high heaven of the Intellect, the hypothesis of Induction is always in touch with concrete reality, *i.e.*, tied to facts which it must explain and by which it must finally and all along be judged.

Exercises.

1. What is meant by Hypothesis? In what different senses may this term be used?

2. Mention and illustrate the various *Kinds* of Hypothesis.

3. What are the conditions of a valid or legitimate hypothesis? Explain critically and give examples.

4. Write short notes on the following:—(*a*) Verifiability and definiteness of hypotheses, (*b*) Vera Causa, (*c*) Representative Fictions, (*d*) Occam's Razor.

5. Is it necessary that a good hypothesis should also predict the course of events (in the department of knowledge with which it deals)?

6. Why should a good hypothesis be consonant with known laws? Can this condition be satisfied always? If not, why not?

7. What is meant by saying that a good hypothesis should be adequate to explain all the facts with which it deals?

8. 'An hypothesis should not have more than a necessary minimum of presuppositions.' Why not?

9. What is meant by a crucial instance or a crucial experiment? Give examples.

10. If two hypotheses seem to be equally good, how would you decide which is the better of the two?

11. What is the relationship between Hypothesis and Induction? In what way do Mill and Whewell differ in this connection? With which view do you agree?

12. If Induction is the science and art of Discovery, what stages of investigation and deduction must be traversed?

13. What is meant by saying that 'dicoverers are born, not made'?

14. What is the place of Hypothesis in Science?

15. What functions does Hypothesis perform in scientific investigation?

16. If Induction is the science of proof, what place, if any, can be allowed to hypothesis?

17. What is the relationship between Hypothesis and straction?

18. Write short notes on:—(1) Method of Abstraction, (2) Method of Limits.

Do these methods belong to Inductive Logic? If not, why not?

19. Point out the function of Hypothesis in the process of Scientific discovery and trace the stages through which a hypothesis must pass before it becomes established as Law. (P. U. 22).

20. Explain clearly what is meant by Hypothesis in Science. What are the conditions of a Valid Hypothesis? It is said that all Induction depends upon Hypothesis. How far is this true? (P. U. 26).

21. What is Hypothesis? Distinguish between a working hypothesis and an established hypothesis so as to bring out the conditions on which the latter depends. (P. U. 28).

22. Define Hypothesis and indicate its value for scientific investigation. Distinguish the different kinds of Hypothesis, giving one example of each. (P. U. 29).

23. What is meant by Hypothesis? Explain its importance in deductive investigation. What are the conditions of a good Hypothesis? (P. U. 32).

24. Define Hypothesis and explain its essential conditions. (P. U. 31).

25. How would you decide between two Hypotheses explaining the cause of Malaria: (1) that it is due to vapours in the air, and (2) That it is due to mosquito bites? (P. U. 33).

26. Construct two hypotheses which might explain some scientific phenomenon in which you are interested (such as the monsoon, earthquakes, wireless telegraphy or dreams). Describe how you might verify the two hypotheses, indicating the inductive methods you are using, and attempt to obtain a crucial instance which would decide between the two hypotheses. (P. U. 33).

CHAPTER XI.

GENERALISATION.

I. **What is it ?**—Let us take our stock example of the mangoes. I taste some out of a heap, and find them sweet. I infer that the remaining mangoes are also sweet. This is a generalisation. We study some cases and on the basis of this examination we infer something about the whole class. But is not this an induction ? It is. Only, the concept 'induction' covers this process as well as others closely connected with it. Generalisation means the process of deducing laws from the consideration of the facts of experience. In this sense, it is the most essential process of induction. The law so deduced covers, *i.e.*, explains, the facts of experience on which it is based as well as *other* facts of the same class.

Now a science is nothing if it has discovered no laws, *i.e.*, no generalisations. The larger the number of generalisations in a science the higher is its status. Generalisation, we may say, is one of the most important functions of a science.

II. **Basis of Generalisation.**—What right have we to generalise ? How can we infer something about a whole class when we have examined only a few individuals of that class ? What guarantee is there that what is found true of 'some' will also be found true of 'all'? The answer to these questions has already been given in the discussion of 'Uniformity of Nature'. Briefly, we may say that the universe is a 'cosmos' and not a 'chaos'. It is a system of inter-related parts. Everything in it is directly or indirectly connected with everything else. There is nothing in it which is out of all possible relationship with other things. The various sciences are revealing new connections and interdependences between phenomena every day. There is a uniformity in the occurrence of natural phenomena.

Since, now, the universe is an ordered 'whole' of interconnected parts, it is not surprising that by examining some parts we can, to a great extent, understand the nature of the 'whole'. We find that when our generalisations are based on facts, they are always verified by later experience. Of course, we have false and hasty generalisations, too. But their falsity does not follow from the nature of generalisation: it is rather due to the insufficient evidence on which they are based.

The unity and uniformity of nature is, then, the basis of generalisation. This is the *objective basis*; *i.e.*, nature's permission to us to generalise. But there is another basis, too – the *subjective basis*: *we cannot help generalising*. We are so made that when we have a knowledge of 'some' we at once jump to an inference about the 'all' or the 'whole'. In fact, one important difference between the ordinary man and the *scientist* is that the latter *waits before he generalises*. The former rushes into it at once. The ordinary man has not the patience of the scientist. That is why his generalisations are very often false. A man goes to a certain town. He is cheated by the tonga-wallah, the porter, the hotel-manager, etc. He rushes to the conclusion—the generalisation—that *all* the people of that town are rascals. Later experience proves that he was wrong in his hasty generalisation.

[Most of our proverbs are half-truths and hasty generalisations, in a similar way.] Imp.

[To sum up: we generalise because (1) nature is a system, a cosmos; and (2) because we cannot help generalising.]

III. How to Generalise? – When we generalise, the individuals examined (*i.e.*, the particulars) are regarded as exemplifying the whole (the universal) which can be *read out* of them by a process of thought. But before we extend the knowledge gained from those particulars to others of that class, we must be sure of our ground. I examine certain mangoes and find that those whose colour is, say, yellow (x) are sweet (y). In other words, *if* x, *then* y. This is true of the cases examined. How can I infer that it would also be true of others? Two conditions must be satisfied to enable me to do so:—(1) Our facts should be relevant; our conjectures should be properly reasoned out; and our inference should be methodical. (2) [We require relevant facts properly arranged and reasoned out.] (2) Our evidence should be uncontradicted. [We must be *sure*, and not merely suppose, that there are *no exceptions*.] (3) The relationship should be present in all the cases examined. Thus we can 'infer [from its uncontradicted frequency to its universal prevalence.']

IV. Kinds of Generalisation. - There are two kinds: *Empirical* and *Scientific*. based upon scientific gr

(1) An *Empirical Generalisation* is based merely on unanalysed experience. We observe that certain qualities or

phenomena are always found together, *e.g.*, that crows are always black But we do not know *why* these phenomena are so connected. We do not know the *causal connection* between blackness and crowness. Such generalisations are not always reliable. A single negative case—a single white crow—would be enough to break a generalisation of centuries. Darwin mentions several such generalisations. Scarlet flowers have no scent; white tom-cats with blue eyes are dumb. Why? We do not know. Hence scientists always try to go beyond such generalisations. They try to discover the underlying causal relationship.

(2) A *Scientific Generalisation* is one based on the discovery of the causal connection responsible for the observed relationship. *E.g.*, should it be discovered that the blackness of the crow is due to the presence of a particular gland or secretion in its body, then the generalisation 'all crows are black' would be scientific. We observe, for instance, that those vertebrate animals are most intelligent (like foxes, apes, men) which possess relatively large and complex brains, while those animals are less intelligent (like rabbits, goats, etc.) whose brains are small and simple. Hence, the generalisation:—'the larger and more complex the brain the greater the intelligence' is scientific because some form of causal connection is found to exist between the two.

A scientific generalisation is sometimes termed a *Law*, and then it must be considered to be an achievement. A generalisation is also, very often, a *Theory* in the sense that it covers and explains the facts on which it is based. When a theory has been established as a law, it is a scientific generalisation.

A scientific generalisation is not merely based on a repitition of instances. It consists rather in the *identity of essential conditions.* By analysis, we distinguish the essential from the inessential. Again, the number of instances at the basis of a scientific generalisation should be fairly large. And, lastly, we should have *adequate insight into the science* whose facts are under consideration. For this reason, the discovery of scientific generalisations 'is not a part of logical theory but of experimental practice.'

Exercises.

1. What is meant by Generalisation?

2. What is meant by saying that the status of a science is determined by the number and quality of its generalisations?

3. What is the *basis* of Generalisation? Distinguish between the *objective basis* and the *subjective basis.*

4. In what way does the scientist differ from the ordinary man in the street from the point of view of their generalisations?

5. Analyse some proverbs and show that they are hasty generalisations.

6. How should we generalise scientifically?

7. What are the different kinds of generalisation? Give examples of each kind.

8. (*a*) What is an *empirical* generalisation?

(*b*) What is a *scientific* generalisation?

(*c*) How can an empirical generalisation change into a scientific generalisation?

CHAPTER XII.

LAWS OF NATURE.

1. What are Laws of Nature? – After Generalisation, Laws! We have seen what Generalisation is. It is the inevitable propensity of the human mind to go beyond its limited experience. Our expectations about the future are to a great extent based on our memories of the past. Having had a series of experiences of a particular kind, all uniformly recurring under more or less similar conditions, we expect that the same sort of thing will happen in the future. These expectations are very often justified and verified by experience. But at the pre-scientific stage, these generalisations are very rough and ready. We are only too prone to generalise. Many of our generalisations are hasty and easily contradicted afterwards. At the scientific stage such rough and ready generalisations will not do. Hence, only such generalisations are selected as are based on wide and uncontradicted experience of instances of the class under consideration. Such generalisations change into Laws of Nature.

Law – The word *law* is ambiguous. It really belongs to jurisprudence and politics. There it signifies a command imposed on the public by the legislative and executive arms of the state. These political laws (*must-laws*) are upheld by the authority of the State. They can be violated and changed. Their violation entails punishment. Then, there are the laws of normative sciences (*ought*-laws); *e.g.*, those of Logic, Ethics, etc. These laws can be violated but cannot be changed.

Now the Laws of Nature (with which Inductive Sciences deal) belong to neither of these classes. They can never be violated, and many of them cannot be and do not change. They are *uniformities of occurrence*: *i.e.*, so many general statements of fact. Individual phenomena are found to conform to such general statements. These uniformities of occurrence are, of course, uniformities of nature. Two kinds are important: uniformities (1) of succession; and (2) of co-existence. (We overlook the uniformities (3) of persistence at this stage). *E.g.*, *A* is always followed by *B*: a lighted matchstick applied to dry gun-powder is always followed by an explosion. This is a uniformity of succession. *A* is always accompanied by *B*: 'clovenfootedness in animals' is always accompanied by the quality 'chewing the cud.' This is a uniformity of co-existence.

These 'uniformities' may be of a wider or narrower range of application. The term *law* is sometimes reserved for the highest, the widest, the most exact and the most ultimate uniformities of nature, *e.g.*, the Law of Gravitation, the Law of Chemical Combination, etc.

II. Kinds of Natural Law.—The ambition of all inductive science is the discovery and formulation of such laws. The wider its generalisations the higher the status of a science. The best laws are those which cover the entire universe from their particular point of view. For example, the Law of Gravitation in Physics, the General Law of Relativity in Astronomy and Physics, the Law of Chemical Composition of Bodies in Chemistry, the Laws of Thought in Logic, etc., are the widest known generalisations in these sciences. Such laws are *Fundamental* or *Primary*. All other laws (dealing with the same classes of phenomena) can be deduced from them; but they themselves cannot be deduced from other laws Those other laws which can be deduced from them are called *Derivative* or *Secondary*.

Fundamental Laws, however, were not the first to be discovered by scientists. They are the result of centuries of labour and research. The earliest type of laws was most commonly arrived at as the result of an induction by simple enumeration. Such an elementary law is known as an empirical generalisation or *Empirical Law*. *E.g.*, all crows are black; scarlet flowers have no scent; white tom-cats with blue eyes are dumb; etc. These are statements of certain uniformities which have been observed in certain classes of phenomena. But just *why* crows are black, or *why* scarlet flowers have no scent, or *what* connection is there between the cat's eyes and its dumbness,--are points *not* known. The empirical law merely says *that* such and such phenomena occur together or follow each other, but *why* they do so or *what causal connection* is there between them, is not known.

An empirical law is based merely on uncontradicted experience. It is a purely descriptive statement which is dumb causally. A single contrary instance can shatter it. A single white crow will break the generalisation 'all crows are black', Before the discovery of

Australia it was believed that 'all swans are white'. But the discovery of black swans in that continent shattered a generalisation of centuries.

All such empirical laws, based as they are on induction by simple enumeration, share this defect. Hence every effort should be directed towards changing them into causal laws. Empirical laws are so many stepping stones to higher laws.

Causal Laws are either *Fundamental* (*primary*) or *Derivative* (*secondary*). Fundamental laws, are, as has been stated above, the widest and highest generalisations in science. Derivative or secondary laws are either direct deductions from fundamental laws or can be deduced from some newly formulated fundamental law, though they themselves were discovered before it. Kepler's Seven Laws of Planetary Motion were formulated before Newton discovered his Law of Universal Gravitation. Kepler's laws were the widest generalisations (fundamental) in Solar Astronomy before Newton. But after the formulation of the Law of Gravitation they became derivative, because they could be deduced from or subsumed under that law. Thus the fundamental law of to-day may be the derivative law of to-morrow.

The criterion of a *fundamental law* is that it cannot be explained by or be regarded as a corrolory of any law higher than itself. Again, a *derivative law* "can only be applicable in circumstances similar to those in which the law is known to be true." Its conditions are only imperfectly known. An *empirical law*, on the other hand, is true only within the narrow limits of its observed range. Its conditions are not known at all. There is no certainty about it simply because there is no analysis of the causal relation.

Exercises.

1. In what different senses is the word *law* used? In what sense is it to be used in inductive logic?

2. What are the Laws of Nature?

3. What are *uniformities of occurrence*? Mention and exemplify the various kinds of such uniformity.

4. How do generalisations change into Laws of Nature?

5. Enumerate and give examples of the various kinds of Laws of Nature.

6. Explain:—(1) Primary Laws; (2) Secondary Laws; (3) Fundamental Laws; (4) Derived Laws; (5) Scientific Laws and (6) Empirical Laws. Give examples of and mention the connections between these different kinds.

7. How can an empirical law change into a scientific law?

8. What is the criterion of a fundamental law?

9. Explain with examples:—Law, Theory, Hypothesis. Indicate the difference between them. (P. U. 33).

10. What is the difference between the Laws of Nature and the Laws of a Land? Give examples of the Laws of Nature and explain how they are discovered. (P. U. 18).

11. Distinguish between and with the aid of examples display the characteristic of the following:—Municipal Laws, Laws of Nature, Empirical Laws, Fundamental Laws. (P. U. 22).

12. What is a Law of Nature? Distinguish between Empirical Laws and Laws of Nature. (P. U. 26).

13. Explain clearly what is meant by the terms:—Fact, Hypothesis, Theory, Law, as used in science, giving illustration whenever possible. (P. U. 27).

CHAPTER XIII.

EXPLANATION.

I. What is Explanation ? – The earliest questions that the growing child asks its parents are 'why'? 'what'? and 'how'? These questions are prompted by the experience of new objects and phenomena every day. The child's curiosity, his inborn desire for knowledge, has to be satisfied, and he riddles his parents and elders with a never-ending series of 'whys'. The answers to these questions are so many *explanations* of those objects or phenomena. Of course, the child's questions are easier asked than answered, but whatever the answer may be, right or wrong, it is an explanation or an attempt at one.

The questions do not cease with childhood. On the contrary, they become more methodical and intricate. Every day of our life is full of unsolved puzzles, of unforeseen difficulties, of strange experiences, of new inventions and discoveries, etc. In all such cases we require explanations. As such, explanation is the means by which a man's understanding is satisfied. Something was obscure before explanation made it clearer and easier to understand.

This is *explanation in the popular sense; the unfamiliar phenomena are explained in terms of familiar phenomena.* The rain falls. The child asks:—how does it fall ? The father answers: 'Let us take a pot with water in it. We cover it with a lid. A fire is lighted underneath. After some time the water begins to boil. We remove the lid. Its lower surface is covered with drops of water. Steam or vapour is rising from the pot'. The child sees all these phenomena. They are familiar to him. But he again asks : 'how does the rain fall'? Now we *can* answer. The ocean is a huge pot full of water. A great fire, the fire of the Sun, is burning on it, not below it. Steam or vapour is produced. It rises high in the atmosphere. Up there the air is very cold. This is the lid. When the hot steam strikes the lid, it is changed into drops of water. The water is heavier than the air. Hence it begins to fall. This is rain. Thus we explain the obscure phenomenon by resolving it into familiar facts.

But as man's knowledge grows, *i.e.*, as science develops, he begins to find that *what is familiar is as difficult to explain as the unfamiliar. Now* science has to devise newer modes of explanation. These are extremely unfamiliar to us. For instance, I pour a pint of hot milk into a glass tumbler. It cracks! Why? Because it was a badly-made tumbler. This explanation satisfies the child and the ordinary uneducated man. 'Badly made things break' is a very familiar formula. But for a scientist this explanation will not do. He is more elaborate. The tumbler cracked because heat expands bodies. The hot milk served to drive apart very suddenly the molecules which composed the glass tumbler. The temperature outside the tumbler was very different from that obtaining inside it when the hot milk was poured in. As there was no proper adjustment of the two temperatures, the glass cracked. This is *explanation in the scientific sense.*

Thus there is a difference of meaning when we use the term 'explanation' in the popular sense and when we use it in the scientific sense. The former proceeds *from the unfamiliar to the familiar*; the latter *from the familiar to the unfamiliar, or from the unfamiliar to the still more unfamiliar.* In brief "scientific explanation consists in discovering, deducing and assimilating the laws of phenomena".

Generally speaking, both forms of explanation have this much in common: *both aim at the discovery and statement of causal connections between phenomena.*

II. Why do we explain?—It may be asked: what compels us to explain phenomena? What is the 'urge', the push, which does not let us rest as long as our explanation is incomplete or not forthcoming at all? There are, at least, two very clear reasons why we try to explain our experiences:—

(1) *We are all naturally curious.*—This inborn curiosity is not something peculiar to man. It is to be found in a greater or lesser degree in almost all animals. Look at the dog nosing about the rooms, the grounds, everywhere. In fact, the more intelligent the animal, the greater its inborn curiosity. The curiosity of the fox or the monkey is insatiable. Man, also, is curious. We have an innate urge, an overmastering desire to discover new facts and explain the different phenomena that confront us every day. The savage's explanation

may be bad, the scientist's may be good. But *both* try to explain.

(2) Again, *it pays us to explain.*—The discovery of the cause of a phenomenon enables us to control it, to deal with it successfully in practical daily life. All the great discoveries and inventions for which science is so justly famous are instances of this truth. The steam engine was made because the power of steam to raise the lid of a pot of boiling water was observed and explained. The invention of airships is based on the observation and successful explanation of the nature of smoke and gases lighter than the air. The flight of birds and insects explains, and is itself partly explained by, the flight of airplanes and gliders. Everywhere we find the truth illustrated: that to master nature we must first discover her secrets. By explaining the growth of plants, the scientist has succeeded in perfecting new species, improving existing ones, quickening their rate of growth, etc. The whole structure of civilization is one great testimony to, and reward of, successful explanation.

III. Explanation and Generalisation.—Generalisation is the ultimate aim of all explanation. Now, induction means the inference of some truth or law about a whole class on the basis of the observation of some members thereof. The law to be inferred should successfully *explain* the class by generalising the attributes observed in particular cases. Causal laws are merely forms of such generalisation. Such explanatory generalisation can assume *three forms*:

(1) It may *harmonise fact with fact*; *e.g.*, why has

this brick fallen from the roof? Because, the roof is broken or the brick was loosely cemented with others. Here, one fact is explained by another. (2) We may *harmonise fact with law.* Why has the apple fallen on the ground? (Fact). Because, all unsupported bodies fall on the ground. (Law). (3) We may *harmonise law with law.* Why do all unsupported bodies fall on the ground? Because of the Law of Universal Gravitation. Why do all planets move round the Sun? Because of the Law of Gravitation; etc.

IV. Kinds of Explanation.—There are three kinds of explanation :-

(1) *Subsumption of the lower or of the less general under the higher (or the more general).*—When we explain a fact by showing it to be a particular case of the working of a law, or explain a law by showing it to be an aspect of a higher law, we are subsuming the lower, *viz.*, the fact or the less wide law, under the higher. Subsumption consists in "gathering up several laws into one more general law" which should embrace them all. For example, Kepler's Seven Laws of Planetary Motion, the Laws of Tides, the Law of Terrestrial Gravitation, etc., are all subsumed under and follow from Newton's Law of Universal Gravitation.

(2) *Analysis of the Complex into the Simple.*—In the world of science, as also in the world of politics, the law of conquest is to 'divide and rule'. The complex phenomenon is too difficult to grasp. Hence, we break it up into its simplest constituents. We study the separate laws of these constituents and the laws of

their mutual relationship. In this way, what would otherwise have proved too difficult a problem for our understanding, is easily mastered. *E.g.*, why do the planets move round the Sun? Because their movement is the joint result of (1) the gravitational pull of the Sun and (2) the tendency of the planets to move in a straight line. In a similar way we explained above the causation of rain.

(3) *Concatenation, i.e., interposition of intermediate links.*—Events follow one another. All stages of the process, however, are not of equal importance or interest for us. Hence, we only observe some important links and overlook the rest. I observe (in this disjoined fashion) that *K* has produced *N*. How? I explain the relation by discovering the intermediate links: *K*...*L*...*M*...*N*. *L* and *M* were the hidden links or stages of the process. *E.g.* there is a fire in the street. Why? Because somebody carelessly threw a cigarette end. How can a cigarette end burn a house? Because the still burning cigarette end fell on a carpet, the carpet caught fire, also the varnished furniture on it, then the wall-paper, the ceiling, and so on. We supply the missing links and the phenomenon is understood. There is a well-known Urdu verse:—

magas ko bagh men ja-ne nah de-na
keh na-haq khun parvane ka hoga.

(Don't allow the honey-bee to go into the garden, or else the poor moth will lose its life). How? The honey-bee will collect nectar from the flowers. To store the honey it will prepare a comb. The comb is made of wax. Somebody is sure to turn up for the honey. He will remove the comb. The honey will serve for food and the wax will be changed into candles. The candle will be lighted and the poor moth will perish in the flame.

Exercises.

1. What is meant by Explanation in Science?

2. Give examples of popular and scientific explanation to bring out the difference between the two.

3. Why do we explain phenomena? What compels us to explain?

4. What is the connection between Explanation and Generalisation?

5. How many forms may explanatory generalisation assume? Illustrate these forms.

6. Enumerate and discuss the various kinds of explanation. Give examples.

7. Write short notes on :– Explanation by subsumption; explanation by analysis; and explanation by concatenation:

8. What is meant by 'fact' in Science? How is a fact explained? How will you explain the following facts:—

(a) The rise of mercury in a thermometer.

(b) The student in an examination. (P. U. 26).

9. What is meant by explanation? Is there any difference between scientific and popular explanation Describe and illustrate the part played by analysis and generalisation in scientific explanation.

10. What constitutes scientific explanation? "Explanation describes the unknown and unfamiliar as being made up of the known and the familiar." Discuss.

11. Is it true to say that to explain the familiar is as difficult as to explain the unfamiliar? Give examples to support your answer.

CHAPTER XIV.

FALLACIES OF INDUCTION.

I. **Introductory.**—The road to Truth is not a prefect road: it is full of pitfalls and snares. Some people fall into them accidentally and unconsciously. Others deliberately dig such pitfalls for unwary passers-by. These snares and pitfalls are technically called *fallacies.*

Inductive science being mainly an observational science, most of its fallacies are due to the shortcomings of the observational and allied processes. We may roughly classify inductive fallacies under the following heads :—

Fallacies (1) of Simple Inspection ; (2) of Observation ; (3) of Generalisation ; (4) of False Analogy; and (5) of False Causation.

II. (1) **Fallacies of Simple Inspection.**—They are also called ***a priori fallacies.*** They consist in the fallacious tendencies of the human mind. We are naturally prejudiced and biassed. We are born in a social atmosphere which is not of our making, but is the joint product of centuries of the moral, social, religious, economic and political experiences of our race. Truths and untruths are present ready-made for us to accept or reject, as the case may be. Our own observational powers are thus so completely enmeshed by these ready-made 'judgments' that it is almost impossible to 'judge' for ourselves. Obviously, under such circumstances, the genuine gold of Truth is mixed up with tons of dross--

falsities, superstitions, half-truths, etc. The scientist's first duty is to purify his mind of this dross. Only then can he be a fit and successful seeker after Truth. Francis Bacon was the first thinker in modern times in Europe to emphasise the necessity of such a purge of the human mind. These several fallacious tendencies of the mind are (he says) so many 'Idols', false gods, who have secured wrongful possession of the temple of Truth—the human mind. The false gods must be ejected before Truth can be installed in its proper place.

Bacon mentions four such 'idols'. (1) *Idols of the Cave.*—These are the fallacious tendencies of *each particular mind.* They may vary from one individual to another. For example, some of us look at the bright of things (optimists); others look only at the dark side (pessimists). Some are prone to exaggeration, while others are cautious in their statements, etc. Everyone looks at the world through the spectacles of his own prejudices. (2) *Idols of the Tribe.*—These are fallacious tendencies common to large groups of people, tribes, races, etc. For example, it is a very common tendency with most people to observe only the positive instances (those which confirm a theory or a 'point of view) and neglect the negative ones (those which go against the theory). All of us are inclined to give less weight to, and even neglect altogether, that which does not agree with our own views and theories. (3) *Idols of the Market-Place.*—These are fallacies which get currency in the public through social intercourse.

Everybody has noted how rumours spread, growing in volume like snowballs. One victim of an untruth succeeds in infecting hundreds of others with it. (4) *Idols of the Theatre.*—These are made up of the exploded doctrines of yesterday. The theatre is the lecture hall in which various thinkers and scientists expound their doctrines. But it often happens that the 'truths' of yesterday are proved false by the research of to-day. The public, however, goes on believing in them, and takes time to realise their untruth. For instance, the astronomical system of Ptolmey is still believed in by many uneducated people.

III. Fallacies of Observation.—When observing we overlook many vital factors and cases. Hence, our conclusions turn out to be false. There are two kinds of observational fallacies :—(*a*) Non-Observation, and (*b*) Mal-Observation.

(*a*) ***Non-Observation.***—It consists in neglecting to observe certain *instances* or *particular cases* or *facts* or *aspects* of an instance which ought to have been observed. This fallacy is committed in either of two ways :—(1) Either we overlook *entire instances*, *e.g.*, the fortune teller will only tell us of the cases in which his predictions turned out to be true, but not a word will he utter about his failures. Similarly, we accept those cases as true which agree with our pet theories or beliefs, but overlook contradictory instances. A vendor of quack medicine will publish certificates of cures but will be discreetly silent about the hundreds of victims whom his drugs have worsened.

(2) The second form of this fallacy appears when in a complex instance we neglect to observe *certain vital circumstances or aspects.* For example, if a friend was ill and was cured by a certain physician, we may falsely ascribe the cure only to the medicines used. We may overlook the truth that such concomitant circumstances as rest, proper exercise, change of air, proper diet, freedom from worries, etc., were, at least, as much responsible for the cure as the drugs used. Incantations, says Voltaire, can kill a flock of sheep if, at the same time, a little arsenic is mixed in sheep-food and water. The incantations, being weird and strange formulas, catch the attention of the ordinary man, but the arsenic, being so very small in quantity, is overlooked.

(*b*) ***Mal-Observation.***— This is the second kind of the observational fallacy. In this case *what is observed is observed wrongly.* All *illusions* are instances of this fallacy. Getting up from his bed in the twilight hours of the early morning, somebody notices a dark and silent figure in a corner of the room, and jumps up with cries of 'thief ! robber !!' etc. On closer inspection, however, he notices that it was only his own coat hanging from a clothes' peg with his turban on top of it. This, mixed with his own dazed state of mind, conjured up the vision of a thief. In Mal-Observation we *confuse* our *inferences with observed facts.* Our ordinary perceptions in daily life are mixtures of given fact and past knowledge, and mistakes are inevitable. Such mistakes are called 'illusions'. A hungry child comes into a room, sees something ovalish, bright and yellow at a table at the other end; infers that it is a "mango and grabs at it only to find that it was—a clay mango. Here his past knowledge of mangoes led him to an illusion. From the mere *look* of the object he inferred that it was a mango, without waiting for the evidence of the other sense-organs.

IV. Fallacies of Generalisation.—We cannot help generalising. There is an 'urge' within us to infer the unobserved from the observed, to try to grasp the nature of the whole class by observing only some members thereof. This urge is the basis of all inductive science. But like most such 'urges' it has to be controlled and guided. We are only too hasty in our generalisations. These *hasty generalisations* are so many fallacies.

The following are the chief sources of error:—(1) We rashly try to extend our inferences to remote parts of the universe which are beyond the limits of observation and verification. (2) We rashly try to formulate a simple and single explanatory principle for all the diversity of natural phenomena. Thinkers are always seeking a 'One' to explain the 'Many'. (3) We are only too ready to rely on the results of induction by simple enumeration. They are always risky generalisations, and should not be given the status of causal laws of nature.

In short, hasty generalisations are caused by our own impatience. We do not wait for further evidence. *E.g.*, somebody goes to a school and comes across a few naughty boys. If he decides straightaway that the discipline of the school is bad, it would be a false and hasty generalisation. But this *is* how the ordinary mind works. We do judge people and things in this hasty way. Most of our proverbs are such hasty generalisations. *E.g.*, 'haste makes waste'. Does it always do so? Sometimes, haste alone can save the situation.

V. Fallacies of False Analogy. – The great German satirist and poet, Heinrich Heine, once prayed: 'Lord God, save us from the Evil One and from metaphors'! Now to put a metaphor on par with His Satanic Majesty is really staggerring. But there is a measure of truth in the comparison. Metaphors have a way of leading the mind to irrelevant, and sometimes dangerous, associations. Superficial similarities should not be allowed to pass muster for real analogies. 'A king is to his subjects what a father is to his children.' This is a false analogy because the father is connected with his children by ties of blood; their interests are common; the father lives for and sacrifices his own happiness, even his own life, for his children; and, above all, he is in age and experience wiser than them. This is *not* the relationship between the king and his subjects. How very dangerous, therefore, would it be if some ultra-royalists of today were to claim absolute and despotic rights for a king on the basis of this false analogy! Hence the force of Heine's prayer. Similarly, this analogy is false: What the mother is to her children, *that* the mother-country is to its colonies.

Analogy is, at best, an imperfect induction, and effort should always be made to advance from it either to scientific induction or to *Homology, i.e.*, to the consideration of *vital and structural resemblances.* Homology is of the greatest use in Botany and Zoology.

VI. Fallacies of False Causation. – These fallacies arise when we take mistaken views of the causal relationship between phenomena. They can assume various forms, of which some of the most common are noted below : –

(1) ***Mistaking Co-existence for Causation.***—We observe that animals which chew the cud have divided hoofs. If, then, we infer that 'chewing the cud' is the cause of 'divided hoofs' (or *vice versa*), we should be committing a fallacy. Both are co-effects of an hitherto unknown cause. Sometimes, a mere chance accompaniment of a phenomenon is mistakenly regarded as the cause. The accidental entry of a 'saint' in a village coincides with long prayed-for rain. Hence, the 'saint' is the cause of the rainfall !

(2) ***Underestimating or Overestimating the Cause.*** In the former case we overlook essential conditions which led to the effect. The fall of Napolian, for instance, may be said to be due to his defeat at Waterloo. Here we overlook the other factors which contributed towards his downfall. Similarly, it would be false to say that the Mughal Empire declined merely because Aurangzeb started levying *jazia*.

We overestimate the cause when we assign more conditions than are really necessary to produce the effect. Why does Mr. *X* suffer from cholera ? Because he ate a dishful of cocumbar on an over-loaded stomach, drank three pints of butter-milk on top of it, and not content with that, injured a perfectly innocent man who had not voted for him at the last Election. This last factor has nothing to do with the causation of cholera.

(3) ***Single and Simple Causes for Complex Effects.***—Sometimes the supposed cause does not explain the effect in all its complexity. Political and social phenomena, for instance, have too many ramifications to be explained by any one cause or set of conditions. Many important details in the effect remain unexplained, however hard one may try. *To specify one cause in* such *complex cases* would be a *fallacy.*

(4) ***Metaphysical Causes for Physical Phenomena.***—The essence of inductive science is to explain phenomena by phenomena, *i.e.*, facts of experience by means of other facts of possible or actual experience. We should not go beyond phenomena in our search for causes. To explain an earthquake by the 'Will of Providence' is a consolation in a religious sense, but does not satisfy science.

(5) ***Mutuality of Cause and Effect.***—The nature of this mutuality has been explained in the discussion of causation (Chapter V, section X). Fallacy arises when we overlook the mutuality and falsely consider one event of the series as cause and another as effect.

(6) ***Non causa pro causa.***—This fallacy consists in assuming something which is not a cause to be the cause. In general, many cases of false causation can be grouped under this name, *viz.*, (*a*) mistaking a sign or inessential condition for the cause, *e.g.*, the belief that incantatious can produce death; or (*b*) reversing the causal relation, *i.e.*, mistaking the effect for the cause and the cause for the effect, *e.g.*,

the belief that a country is wealthy because it has money, whereas the reverse is the case; etc.

A very common form of this fallacy is called ***post hoc, ergo, propter hoc*** (after this, therefore, on account of this). In this case, mere sequence is mistaken for causation. Only that sequence is causation which is invariable and unconditional. Anything less than that would lead to a fallacy. Any and every antecedent of an event is not its cause. If in a certain case, y occurs after x, we cannot merely on this ground infer that y is the effect of (*i.e.*, is on account of) x. If a king has died after the appearance of a comet, or a misfortune has occurred after the accidental spilling of salt by a guest, or a traveller has been robbed because he met a Brahmin directly he left home, then we cannot validly infer that the appearance of the comet, the spilling of salt by the guest and the sight of the Brahmin are respectively causes of the various misfortunes which followed them. A man sneezes vigorously and comes to grief shortly afterwards. Hence, the sneeze caused his misfortune! Most superstitions are instances of this fallacy. Comets and morning stars, witches and saints, blessings and curses, charms and amulets, etc., have from the earliest times been regarded as causes of various bad and good effects. What happens usually in such cases is a mere accidental sequence of two phenomena with no causal connection between them. is taken to be the cause.

Exercises.

1. What is meant by a *fallacy*? Enumerate the various inductive fallacies.

2. Discuss and exemplify the following inductive fallacies?

Fallacies of (*a*) Simple Inspection, (*b*) of Observation, (*c*) of Generalisation, (*d*) of False Analogy, and (*e*) of False Causation.

3. What are *a priori* fallacies?

4. Discuss the fallacies known as Bacon's Idols. Give examples.

5. What are the two chief forms of observational fallacies? Give examples from your own experience and distinguish carefully between the two forms.

6. What are the two sub-classes of the fallacy of Non-Observation?

7. Give examples of Mal-Observation from your own experience.

8. What are the chief sources of the observational fallacy?

9. What are the chief sources of the Fallacy of Generalisation?

10. Discuss the nature of and give examples of Hasty Generalisation.

11. What is the nature of the Fallacy of False Analogy? Mention and analyse some examples of False Analogy.

12. Enumerate and exemplify the various forms of the fallacy of False Causation.

13. Discuss and give examples of the following fallacies:—

(*a*) Mistaking co-existence for causation.

(*b*) Underestimating or overestimating the cause.

(*c*) Too simple causal explanation of a complex phenomenon.

(*d*) Metaphysical Causes for Physical Phenomena.

(*e*) *Non causa pro causa.*

(*f*) Mistaking the nature of a mutuality of causes and effects.

(*g*) Post hoc, ergo, propter hoc.

The following exercises are culled from the P. U. Examination question-papers:—

14. Analyse (any two of) the following arguments and discuss their validity, pointing out the fallacy, if any:—

(*a*) So far all men with whom I have come in contact are selfish. Why should I not infer, therefore, that man is selfish?

(b) What better explanation can we give of the fact that we see through glass than that it is transparent?

(c) He must be an excellent man for I have been favourably impressed with his manner of talking.

15. Test the following arguments:—

(a) A woman never can be a priest, for women never have been priests.

(b) Astrologers can tell the future, because an astrologer told me that I was to be successful and I have been successful.

(c) Yesterday my brother called. To-day I am ill. His visit must have caused my illness.

(d) He must pass this examination, because his brother who studied in the same school as he does, passed it last year.

16. Analyse (any two of) the following arguments and discuss their validity, pointing out the fallacies, if any:—

(a) A democratic government has been a success in England therefore, we should have a democratic form of Government in India.

(b) My father, grandfather and great grand-father were successful businessmen, therefore, I shall be successful in business.

(c) Night invariably precedes day, therefore, night is the cause of day.

17. Criticise (any two of) the following arguments:—

(a) Two students sitting near each other in an examination room offer identical incorrect answers to two problems in the paper; therefore, one has been copying from the other.

(b) In recent years there has been a remarkable increase in the number of medical practitioners in most of the large towns of India. Therefore, sickness in the country is increasing.

(c) Babies sleep a good part of the 24 hours and school boys 10 hours or more. Whilst adult men sleep for six to nine hours, old men find themselves unable to sleep for more than four hours at night. It, therefore, appears that the number of hours necessary for sleep is determined by the actual amount of work done by body and mind.

18. Examine (any two of) the following arguments, setting forth the evidence separately from the inference in each case. naming the method or methods employed and pointing out the fallacies, if any:—

(*a*) This must be a really good medicine since according to the testimonials printed by the makers. it has proved efficacious in thousands of cases.

b) A planet without life is as great an absurdity as a house without tenants or a city without inhabitants.

(*c*) The weight of a one year old child is greater than that of a baby of six months, and a young man of 20 is, of course, heavier than a boy of 12. Therefore, the weight of the body is dependant on the age of the individual.

19. Analyse (any two of) the following:—

(*a*) People are not blamed for speculating in cotton or corn; why should then betting on horse races be condemned ?

(*b*) The percentage of passes in Matricluation is higher than in the Intermediate. Therefore, the teaching given in schools in superior to that given in colleges.

(*c*) Great rivers generally flow past big cities. Therefore. the greatness of rivers must be due to the prosperity of the towns situated on their banks.

20. Examine the following:—

(*a*) England has a democratic franchise. Therefore, India should have a democratic franchise too.

(*b*) This college passed the least number of students in the last University examination. Therefore, it is the worst college in the University.

(*c*) Oak does not grow in the plains, for I have never come across any.

(*d*) All the great empires that have ever existed have lost their position of eminence: hence no great empire in the future will maintain supremacy.

(e) I have only one servant in the house: therefore, the money that I lost must have been stolen by him. false Cause

(f) The fruits of the tropical countries are far sweeter than those of temperate regions. Heat is therefore the cause of sweetness. false Causation

(g) The mouse in a fable, describing the cat to its mother said, 'I believe it would be very friendly towards us, for its ears are of the same shape as yours'. false analogy

(h) The metropolis of a country is like the heart of the animal body; therefore, the increased size of the metropolis is a disease. false analogy

(i) It will certainly rain for the sky looks very black. Hasty genera

(j) What fallacy if the farmers explain a poor crop by a recent change in the government? false-mal obser

(k) Opium cannot be injurious for I have just read in the paper of the death of a confirmed opium eater at the ripe age of 98 years. Hasty generation

(l) You brought a curse upon my house for no sooner did you leave it than the lightening struck. non-Cause

(m) 'I travelled to London and then to Paris by air, and on my way I met a Frenchman. Now I have known that all Frenchmen are liars ever since a Frenchman told me my fortune five years ago (That fortune-teller told me that all Indians were lucky and that many lucky people became rich, so that I should certainly become rich). The Frenchman I met in the aeroplane could not have been a very intelligent man because he was reading a very stupid book. I asked him why he liked reading such stupid books, and he replied, 'Because I enjoy the reading of foolish literature'. He went on to, ask, 'And what about that silly book you are reading yourself?' 'It is a wise book,' I answered, 'because it contains many wise sayings. Its author too was a dear friend of my father's.' The Frenchman replied' 'When, will you give up using fallacious arguments?' I had no answer to this, so I kicked him out of the aeroplane'. (Discover and name the fallacies).

CHAPTER XV.

DEDUCTION AND INDUCTION.

Deduction consists in the application of general rules or laws to particular cases. These particular cases are subsumed under those rules or laws. This is most evident in *Barbara*, the typical deductive mood. Induction, on the other hand, goes beyond the immediate data before us. Its conclusions are always wider than its premisses. The two disciplines differ in their methods and points of view. C. S. Pierce, the famous American thinker, illustrates their mutual relationship as follows:—

Let us take our stock example of the mangoes in the basket. We draw out *at random* a dozen or so. On tasting each of these mangoes we find that it is sweet. Our inductive argument can be expressed as follows:—

These dozen mangoes were in this basket,
These mangoes are sweet, (Induction).
∴ All the mangoes of this basket are sweet.

Let us now partially invert the order of these premisses. We find that it forms a deductive syllogism:—

All the mangoes of this basket are sweet,—*Rule*
These mangoes are in this basket,—*Case*
∴ These mangoes are sweet.—*Application of rule to case.*

This is an argument in the typical mood, *Barbara*.

Comparing the two arguments, we find that the *inductive argument consisted in the inference of the rule from the case and the result.*

It has already been pointed out that induction involves the occasional use of Hypothesis and Analogy. What is the nature of 'hypothesis'?

Suppose that I have before me a score or so of mangoes *lying near* a basket. On tasting each I find that about a dozen are sweet and of a particular type or hue: but the remaining mangoes are not sweet and also look different from those which are. I am told *for certain* that all the mangoes *in* the basket itself are sweet, and of a hue which resembles that of the sweet mangoes tasted by me. I conclude that these sweet mangoes were from that basket. This is an Hypothesis. The argument is :—

Rule—All the mangoes in this basket are sweet,

Result—These dozen mangoes are sweet,

∴ *Case*—These dozen mangoes must have belonged to this basket.

Hypothesis, then, *is the inference of a case from a rule and a result.*

To sum up:—In *induction* we observe certain cases of a given class and find a certain statement true of them all or of a certain definite proportion of them. We infer that that statement is also true, either of all the remaining cases of that class or of a definite proportion of them. We go beyond the data before us, and on the basis of a certain degree of probability, we infer that what is true of a part will also be true of the whole class of unobserved cases.

We have an *hypothesis* when we find a certain phenomenon which can be explained by the supposition that it is only a special case of a certain general rule.

We adopt that supposition, and if it is verified by actual facts afterwards, our hypothesis is confirmed; otherwise, we think of some other supposition to explain the phenomenon in question.

Lastly, we have an *Analogy* when we find that two objects or two phenomena resemble each other in certain important respects. We infer that they must resemble each other in certain other respects, too, which we find are present in one and expect (on this ground) to be present in the other.

It may be noted that if from certain true premisses a certain true conclusion *necessarily* follows, then from the falsity of the conclusion the falsity of the premisses would also follow. (*Modus tollens* of the mixed hypothetical syllogism.)

For example, we have in *Barbara*

Rule......M a P
Case......S a M
Result...S a P

A person who denies '*S a P*' (*i.e.*, asserts *S o P*) may still admit *the rule*. But in that case, he shall have to deny *the case*. His argument would be—

Rule...M a P
Denial of Result...S o P
Denial of Case...S o M

Again, the person who denies the result and still admits the case must, perforce, deny the rule. His argument would be—

Denial of Result ..S o P
Case..................S a M
Denial of Rule......M o P

The moods *Baroko* and *Bokardo* are, we know, the two indirect moods and the typical moods of the Second and Third figures, respectively.

Take a concrete example:—

Rule—All mangoes of this basket are sweet,

Case—These dozen mangoes are from this basket,

∴ *Result*—These dozen mangoes are sweet.

If somebody denies the result (*i.e.*, asserts that 'some of these dozen mangoes are not sweet') but admits the rule that 'all the mangoes of this basket are sweet', then he must *deny* that 'these dozen mangoes are from this basket'. Similarly, if somebody denies the result (*i.e.*, asserts that 'some of these dozen mangoes are not sweet') but admits that 'these dozen mangoes are from this basket', then he must perforce *deny* that 'all mangoes from this basket are sweet'.

In general, inductions are not of this necessary nature. The sphere of inductive reasoning does not include the two extreme degrees of probability, *viz.*, zero % probability (impossibility) and 100 % probability (certainty). Induction and hypothesis deal with the more or less probable. Substituting elements of probability, then, in the above examples, we have real cases of induction and hypothesis. Let us take a probable deduction in *Barbara* :—

Rule—*Most* of the mangoes of this basket are sweet,

Case—These dozen mangoes are from this basket,

Result—*Probably*, most of these dozen mangoes are sweet.

Suppose that we deny this result, but accept the rule. We shall, then, have to deny the case :—

Denial of result—Most of these dozen mangoes are *not* sweet,

Rule—Most mangoes of this basket are sweet,

Denial of C.—Therefore, *probably* these dozen mangoes were not from this basket; *i.e,* probably, they were taken from another basket.

This would be an *hypothesis.*

Let us now deny the result but accept the case. We shall, then, have to deny the rule :—

D. of Result—Most of these dozen mangoes are not sweet,
Case—These dozen mangoes are from this basket,
D. of rule.—Therefore, *probably* most mangoes of this basket are not sweet.

This would be an *induction.*

The above method of conceiving the relationship of induction and deduction is not entirely satisfactory, though certainly very interesting. Two points are to be noted. (1) It is true that in this way we can succeed in emphasizing only the negative aspect of induction and hypothesis, whereas they have certainly a positive aspect, too. (2) Again, if the truth of a certain premiss would render the truth of a certain conclusion probable, it does not follow that the falsity of this conclusion would make the falsity of that premiss also probable.

THE END.

Printed by M. M. Malik, at the Punjab Educational Press, 33, Nabha Road, Lahore, and Published by A. H. I. Book Depot, Brandreth Road, Lahore.