

## **Module 1: Science as Culture**

### **Methods of Science: Issues and Perspectives**

#### **Lecture 1**

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The question, ‘What is the method of science?’, is as old as science itself. Aristotle worked out a detailed answer to this question and his theory of scientific method, like his scientific theories, exercised tremendous influence till around 16<sup>th</sup> century. However, with the emergence of modern science and modern philosophy in 17<sup>th</sup> century, the question, ‘What is the method of science?’, was raised afresh. The very attempt to provide a new answer to the question amounted to a decisive break with the past, as it implies a dissatisfaction with the Aristotelean theory of scientific method. We, thus, have in the seventeenth century, the birth of “modern philosophy of science”.

#### **Inductivism and Hypothesisism**

In the whole period of three centuries – from the seventeenth to nineteenth – two views stand out prominently as answers to the question, ‘What is the method of science?’. The first view is called inductivism according to which the method of science is the method of induction. The second view is called hypothesisism according to which the method of science is called the method of hypothesis. Inductivism is pioneered by Francis Bacon and hypothesisism by Rene Descartes. The two views sought to provide two models of scientific method. Hence, one can speak of the Baconian model and the Cartesian model of scientific method. Inductivism is rooted in empiricism according to which only those ideas which are traceable to sense experience are legitimate. Hypothesisism is grounded in rationalism according to which a significant portion of human knowledge cannot be traced to, and therefore is independent of sense experience.

Inductivism looked upon certainty and breadth as the hallmarks of scientific knowledge. That means science must aim at knowledge which is definite, on the one hand, and on the other, broad in the sense that it must encompass more and more of the world we seek to know. The search for certain or definite knowledge led inductivists to legislate that science must confine itself to observations since it is only our observations that we can be certain. In other words, science, according to inductivists, must not make any reference to anything unobservable. The means of realizing knowledge that is broad Bacon found in the principle of induction which allows us to go from particular observations to generalizations. Thus, according to inductivists, science must aim at arriving at, with the help of the principle of induction, generalizations which cryptically contain knowledge of indefinite number of as yet unmade observations. We first collect observational data without recourse to any theory. We then put forward a tentative generalization which we verify. Once verified, the tentative generalization becomes a law enabling us to go from a limited number of already made observations. The aim of science is to arrive at laws, i.e. established inductive generalizations which are only cryptic statements regarding as yet unmade observations. By accumulating such established inductive generalizations,

inductivists claimed, we will have at our disposal an enormous amount of observations the totality of which constitutes reality. Science, according to the inductivist theory, thus begins with observations, remains at the level of observations and ends with observations.

If according to inductivism, the hallmarks of scientific knowledge are certainty and breadth, according to hypothesisism, they are novelty and depth. That is to say, science must aim at knowledge which is new in the sense of being trans-observational and deep in the sense of referring to entities underlying the phenomena given to us in observations. In other words, whereas inductivists insist that science must remain from beginning to end at the level of observations, hypothesisists maintain that science begins only when it goes beyond observations. According to hypothesisism, genuine science must not remain content with generalizations based on observations but must seek to explain observations in terms of the unobservable or deeper entities and processes. The term, “hypothesis” in seventeenth century meant a statement regarding unobservable entities and processes though today by hypothesis we only mean a tentative solution to a problem or hunch. Whereas there is no place for hypotheses in the inductive scheme, the hypothesisists maintain that the aim of science is to generate hypotheses to explain what we observe. The term, “theory” means a statement of a set of statements involving at least one theoretical term. A theoretical term (for example, “electron”, “proton”, etc.), unlike an observational term, does not designate observable or measurable. Inductivists are empiricists, and empiricists maintain that anything which exists must be observable. Hence, inductivists do not admit that theoretical term designates real entities. They contend that theoretical entities are fictitious entities conjured up by us for the purposes of either economic description of observations or prediction. Hence, according to inductivists, theories are not descriptions of a real world of unobservables. As against this, the hypothesisists maintain that the theoretical terms designate real entities not given to us in observations and theories, are descriptions of a real world of unobservable entities. Therefore, while hypothesisists are called realists, inductivists are called anti-realists.

Inductivism and hypothesisism were thus rival methodologies advocating antagonistic views regarding the method of science. The two methodologies competed with each other for acceptance. Both had strong followers among scientists and philosophers. Hypothesisism had an upper hand in the beginning. It had among its champions not only Descartes, but also Boyle, Hooke, Huygens and other eminent scientists. But, inductivism emerged as the dominant theory of scientific method in the early eighteenth century. The setback suffered by hypothesisism and the consequent domination of the scene by inductivism are to be traced to the fact that the method of induction had had its adherent Issac Newton whose eminence as a scientist lent inductivism a remarkable scientific respectability. Indeed, the classic statement of the inductivist position came from Newton himself. Epitomizing this position in the General Scholium of his Principia, Newton says, ‘What is not deduced from phenomena (observations) is to be called a hypothesis; and hypothesis, whether metaphysical or physical, whether on occult qualities or mechanical, have no place in experimental philosophy. In this philosophy, particular propositions are inferred from phenomena and afterwards rendered general by induction’<sup>1</sup>. Of course, Newton’s own scientific practice was at variance with his inductivist convictions. He entertained many metaphysical ideas which played an active role in his theorizing. However, the followers of Newton went by what Newton said than what he did. In order to continue

the success story of Newton, they believed that it was necessary to practice literally Newton's inductivist message. Since inductivism was cult of observations, the followers of Newton like Hales, Boerhaave and Cotes attempted to construct purely observational physics, observational chemistry and observational biology to further the cause of the master.

However, inductivism very soon began to face serious challenges. As early as 1740s and 1750s, there began to dawn the realization that many areas of scientific inquiry could not be forced into the inductivist framework. Franklin's Fluid Theory of Electricity, the Vibratory Theory of Heat, the Buffonian Theory of Organic Molecules and Phlogiston Chemistry, etc. that developed in the middle of the nineteenth century went against the spirit of the inductivist cult of observations as they involved reference to entities and processes. The scientific grounds against the inductivist position were cleared with the appearance of chemical and gravitational theories of George Le Sage, the Neurophysiological theories of David Hartley and the General Matter Theory of Roger Boscovich. These scientists accurately realized that their theories would face stiff opposition not so much on scientific considerations but due to the methodological implications considered absolutely undesirable by the prevailing methodological orthodoxy, namely, inductivism. Hence, they felt the need for methodological legitimization in terms of an alternative model. It is this need which motivated them to resurrect the method of hypothesis. In their attempt to develop the method of hypothesis, these thinkers produced works of immense significance. Their works were followed by those of Jean Senebier, best known for his work on Photosynthesis, Pierre Provost, the founder of the theory of heat exchange and many others. These scientists challenged the canons of scientific method as envisaged by inductivism and in doing so they had their professional interests at stake.

Apart from the above mentioned challenge from the protagonists of the method of hypothesis, the method of induction faced an internal crisis. David Hume, an eminent eighteenth century inductivist, undermined it from within. He showed that the very principle of induction which allowed us to proceed from observed to as yet unobserved phenomena itself stood unjustified. Any attempt to justify the principle of induction, Hume conclusively shows, results in circularity or infinite regress. Hume was himself an inductivist. He did not accept the method of hypothesis because of his commitment to empiricism. He concludes that since we have no alternative to the principle of induction, our belief is irrational; we have to boldly accept that the whole of our knowledge including science, the paragon of knowledge, rests on an irrational belief, an animal faith.

After Hume, every inductivist attempted to show that Hume was wrong in his contention that the principle of induction could not be justified. The most significant attempt in this connection was made by John Stuart Mill who realized that the main plant of the attack on induction was its inability to lend the claims based on it the degree of certainty comparable to deductive inferences. For example, in a deductive inference such as 'All men are mortal, X is a man' with certainty. That is to say, given the truth of the premises, the truth of the conclusion necessarily follows. But, in an inductive inference where the premises are about particular observations and the conclusion is a generalization, the generalization does not necessarily follow. That is to say, given the truth of the statements about certain particular observations, the truth of the generalization is not guaranteed. The generalization is at best a probable one.

That is why logicians like Aristotle could develop a system of rules for deductive inferences. By knowing those rules, we could find which of our conclusions necessarily follow and which do not. Mill took the cudgels in favour of the method of induction which he attempted to demonstrate to be on equal footing with the rules of deduction whose capacity to lend certainty to the claims based on them was unproblematic. In other words, he set out to construct an inductive logic which was supposed to be almost on par with deductive logic. ‘The business of inductive logic’, Mill writes, ‘is to provide rules and models (such as the syllogism and its rules are for ratiocination) to which if inductive arguments conform, those arguments are conclusive’<sup>2</sup>. Five such rules were conceived and articulated: method of agreement, method of difference, joint method of agreement and difference, method of residues and method of concomitant variation. Mill claims for these “methods”, the dual role of aiding discoveries and proving/disproving our claims with certainty. That is, their role is both instrumental and demonstrative. For Mill, the latter is more promising, for he says, ‘even if they are not methods of discovery, it would not be less true that they are the sole methods of proof’<sup>3</sup>. Mill’s methods fail to perform either of the two functions for the simple reason that in either case the successful performance involves factors that go beyond the methods or rules that Mill has proposed<sup>4</sup>. Let us elaborate this point.

It is obvious that these methods cannot solve the purpose of discovery, i.e. cannot be sufficient as instruments for theory formation. For, if that were so, by now all the problems of science could have been solved by proposing answers mastering the use of these rules which are only mechanical. The formation of a theory involves factors which go beyond these methods. But what is more important is that even after a theory is proposed, verified and established, it cannot be demonstrated or proved in a manner comparable to deductive proof. The use of any Mill’s methods presupposes an antecedent, assumption about which circumstances are relevant for the explanation of the phenomena under investigation. Once these circumstances are chosen as possible causes, the method(s) help to correlate some of them with the phenomena under consideration. But this choice of possible causes might be erroneous. If it is so, the conclusion inferred by Mill’s methods first cannot remain unaffected by the original mistake. Secondly, even if a correlation is established, there is no proof that correlation is not fortuitous but necessary (or lawful). Though it is true that greater the number of observed instances of correlation, higher the chances of the correlation being lawful and not fortuitous; we can never assert with certainty, no matter how many the observed instances, that the correlation is not fortuitous. Thus, the logical cleavage between induction and deduction which Mill tried to get rid of remained intact. The cruel fact that induction is induction, and deduction is deduction and the twin shall never meet remained unaltered to the discomfort of the inductivists.

The intention of all these historical details is to set the stage for the discussion on twentieth century deliberations on the method(s) of science. For, the various views that have been developed in twentieth century are to be understood not only as reactions to each other but also as reactions to a whole historical tradition. We shall now come to a detailed discussion on the various theories that have been put forward in the twentieth century regarding the method(s) of science.

## Twentieth Century Views: Positivism

The twentieth century begins with the emergence of a school of thought called positivism. Positivism is an extremely well-known and till recently very influential theory of science and its method. The acknowledged founder of positivism or ‘the positive philosophy’ was the French philosopher and social scientist Auguste Comte (1798-1857). Comte also invented the term ‘sociology’ to describe his proposed positive science of society.

Positivism is, above all, a philosophy of science. As such, it stands squarely within the empiricist tradition. Metaphysical speculation is rejected in favour of ‘positive’ knowledge based on systematic observation and experiment. The methods of science can give us knowledge of the laws of coexistence and succession of phenomena, but can never penetrate to the inner ‘essences’ or ‘natures’ of things. It is a closely knit set of tenets formulated with an admirable amount of clarity and consistency. Some of these tenets are:

- (i) Science is distinct from other areas of human creativity because it possesses a method which is unique to it (methodological).
- (ii) There is only one method common to all sciences irrespective of their subject matter (methodological monism).
- (iii) The method of science is the method of induction (inductivism).
- (iv) The hallmark of science consists in the fact that its statements are systematically verifiable.
- (v) Scientific observations are or can be shown to be “pure” in the sense that they are theory-independent.
- (vi) Theories are winnowed from facts or observations such that a theory is nothing more than a condensed version of and therefore reducible to a set of statements describing observations.
- (vii) The relation between theory and observation is unilateral in the sense that theories are dependent on observations whereas observations are theory-independent.
- (viii) To a given set of observation-statements, there corresponds uniquely a theory such that we can deduce the latter from the former.
- (ix) Our factual judgments are value-neutral and our value judgments have no factual content (fact-value) dichotomy). Science, being the paradigmatic instance of actual inquiry, does not have any value commitments.
- (x) All scientific explanation must have the following pattern.

$$\begin{array}{c} L_1 \dots L_n \\ I_1 \dots I_n \\ \text{Therefore } E \end{array}$$

Where  $L_1 \dots L_n$  is a set of laws,  $I_1 \dots I_n$  is a set of statements describing initial conditions, and  $E$  is a statement describing the phenomenon to be explained. In other words, to explain a phenomenon is to deduce its description from a set of premises constituted by laws and statements describing initial conditions. In sum, all explanation involves deduction. An explanation which does not have or cannot be recast into the pattern given above is not a legitimate scientific explanation (deductive nomologism).

- (xi) The progress of science consists in the increasing accumulation of observations and the cumulative growth of our theories.
- (xii) The objectivity of science is guaranteed by the fact that our scientific theories based upon indubitable observations. Our observations can be indubitable because they are or can be shown to be theory-independent.
- (xiii) The aim of philosophy of science is to discover and systematize those universal and changeless norms which science follows and by following which science has become the most rational enterprise. Philosophers of science seek to understand science in terms of these norms which determine scientific practices. In doing so, they provide an account of science which is normative. Since these norms constitute the very logic of scientific practices, philosophers of science provide what may be called a logic of science.

Keeping these tenets in mind, positivists set for themselves a programme by adopting which they thought they could defend the principle of induction in the face of the formidable attack made by Hume. As inductivists, they were obliged to ward off the ghost of Hume by showing that the principle of induction can be rationally justified. Positivists asserted that scientific observations are in principle theory-free and therefore are indubitable. Observations or facts are prior. Theories which are their interpretations are posterior. These observations constitute the bedrock on which the theoretical edifices of science rest. The edifices constituted by theories are arrived at by using the principle of induction. Now, positivists thought that if they could show that the inductively arrived at scientific theories are related in certain specifiable ways to the bedrock constituted by indubitable observations, they would succeed in establishing the rationality of our belief in the principle of induction. Critique of positivists' programme collapsed like a house of cards. Not only did they fail to identify the specific way in which observational substructure and theoretical superstructure of science were related but they also dismally failed to show that our observations are or can be shown to be theory-free and therefore indubitable. The opponents of positivism convincingly showed that the idea of "pure" or theory-independent observation was a myth. Telling arguments were advanced to show that all observations are theory-dependent. It may be noted that positivism dominated the scene during the bulk of the first half of the twentieth century. But, every tenet of positivism has been successfully called into question by subsequent developments. The first tenet of positivism to fall was the one concerning the idea of "pure" observation. It is interesting to see in this connection how the critics of positivism exploded the myth of "pure" observation by showing how our observations presuppose theory. We may mention a couple of arguments in this connection.

### **Observations Presuppose Theory**

First, observations presuppose some principle of selection. We cannot go on observing anything we come across. We need "relevant" observations. In science it is the problem that decides what is relevant and thus provides the principle of selection. Hence, there cannot be observations without a prior problem. To quote Karl Popper, 'Before we can collect data, our interest in data of a certain kind must be aroused; the problem always comes first'<sup>5</sup>. It may be objected that the problem itself is due to the observations we make, and hence, observations come first. But, this objection does not hold. Two persons might make similar observations though only one might come

out with a problem. This shows that mere observations will not generate a problem. How, then, are scientific problems generated? It is usually when there is a clash between what we observe and what we expect. Of the two persons making similar observations one may come out with a problem whereas the other may not because the former has expectations which conflict with the observations s/he makes, whereas the latter does not have any expectations. The expectations are generated due to our belief in a theory. Thus, problem generation presupposes a prior theoretical commitment. In other words, a prior belief in a theory is necessary for a problem to be generated and a prior awareness of the problem is necessary for making relevant observations.

Secondly, in science, observations are taken into account only if they are desirable in a language that is currently used in a particular science. An observation, which howsoever genuine, cannot be expressed in the recognized idiom for all scientific purposes is no observation at all. It is the theory which provides the language or the idiom to be used in describing observations. It is tempting to quote in this connection words of the physicist and philosopher Pierre Duhem:

Enter a laboratory: approach the table crowded with an assortment of apparatus, an electric cell, silk-covered copper wire, small cups of Mercury, spools, a mirror mounted on an iron bar; the experimenter is inserting into small openings, the metal ends of ebony-headed pins; the iron bar oscillates, and the mirror attached to it throws a luminous band upon a celluloid scale; the forward-backward motion of this spot enables the physicist to observe the minute oscillations of the iron bar. But ask him what he is doing. Will he answer ‘I am studying the oscillations of an iron bar which carries a mirror?’ No, he will say that he is measuring the electrical resistance of the spools. If you are astonished, if you ask him what his words mean, what relation they have with the phenomenon he has been observing and which you have noted at the same time as he will answer that your question requires a long explanation and that you should take a course in electricity<sup>6</sup>.

Thirdly, most of the observations in science made with the help of instruments are constructed or designed in accordance with the specifications provided by some theories. These theories, one may say, constitute the software of these instruments. Belief in the reliability of these instruments implies the acceptance of these theories which have gone into the making of these instruments. Thus, observations presuppose prior theoretical commitments.

Fourthly, observations in science need to be legitimized or ratified by a theory. We all know that Galileo used some telescopic observations to support his theory. His opponents did not consider telescopic observations accurate. It is not that they did not believe in the reliability of telescope. They had no problem in using telescope for terrestrial (of the earth) purposes. They opposed its extension to celestial (of heavenly) sphere where things like background, neighbourhood, possibility of verification which are usually found in normal instances of perception are absent. They rightly demanded from Galileo a theory of optics which would justify the extension of the use of telescope from terrestrial to celestial sphere. Galileo had no such theory. But he rightly believed that in future such a theory could be formulated.

Thus, Galileo believed that it was possible to justify the type of observations on which he was dependent. This instance brings out how observations need ratification or justification in terms of either an actual or possible theory. In this sense too, our observations are theory-laden.

All this does not imply that observations are theory-dependent whereas theories are observation-independent. Theories and observations depend on each other. All this only implies that positivists were wrong in claiming that observations are theory-independent.

Thus, no observation is presuppositionless as positivists thought. An observation is not a passive reception constituting the beginning of knowledge, but involves the active participation of our cognitive faculties characterized by purposiveness, prior knowledge and expectations. After all, observations are not “given” but are “made”.

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## Notes and References

<sup>1</sup> Edited by Floreian Cojorie, University of California Press, Berkeley, 1934, p. 274

<sup>2</sup> *A System of Logic*, Book III, Chapter 9, Sec. 6

<sup>3</sup> *Ibid.*

<sup>4</sup> For a detailed description and criticism of Mill’s methods, see Copi, Irving M. *Introduction to Logic*, Macmillan Pub. Co., 1982 edition, pp. 409-441

<sup>5</sup> Karl Popper, *The Poverty of Historicism*, Routledge and Kegan Paul, London, 1957, p. 121

<sup>6</sup> Quoted in N.R. Hanson: *Observation and Explanation: A Guide to Philosophy of Science*, George Allen and Unwin, London, 1972, p. 4

## Questions

1. What is inductivism?
2. What is hypothesisism?
3. Who is the founder of inductivism?
4. Who is the founder of hypothesisism?
5. What is the basis of inductivism?
6. What is the basis of hypothesisism?
7. What are the hallmarks of scientific knowledge in the inductivist schema?
8. What are the hallmarks of scientific knowledge according to hypothesisism?
9. How did Hume challenge the principle of induction?
10. Discuss Mill’s rules or methods of inductive logic.
11. Critically examine the central tenets of positivism.
12. What is fact-value dichotomy?
13. What is methodological monism?
14. What is deductive nomologism?
15. ‘Observations presuppose theory’, according to positivism. Comment.