The Critical Rationalist Alternative

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The problem of truth and knowledge has been a continuing focus of philosophical debates. The issues that have been raised include: What are the sources of knowledge? How does knowledge grow? What role does reason play in the advancement of knowledge? The various positions that have been adopted on these issues have left their mark on contemporary interpretations of the philosophy of science. In this paper, I shall discuss the more salient points of the critical rationalist or hypothetico-deductive theory of knowledge as seen from some of the writings of Karl Popper, Morris Cohen and Peter Brian Medawar.

Sources of Knowledge

A much discussed epistemological problem is: How do we know? This has been an issue between the British and Continental Schools of Philosophy. For the British School, which included Bacon, Locke, Berkeley, Hume and Mill, observation was the ultimate source of knowledge. This position is better known as classical empiricism. The Continental School, which had Descartes, Spinoza and Leibniz among its followers, held that reason or the intellectual intuition of distinct ideas was the ultimate source of knowledge.[1] This is popularly known as classical rationalism or intellectualism.

Despite these differences, both theories contributed to the rise of an optimistic epistemology: an optimistic view of man's ability to perceive the truth and to gain knowledge. This view may be linked with historical movements of liberalism from the Renaissance to the reformation and religious revolutionary wars. It also inspired the birth of modern science and technology.

The essence of this optimistic epistemology can be seen in the doctrine that "truth is manifest." As Popper interprets it:

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. . . Truth may perhaps be veiled. But it may reveal itself. And if it does not reveal itself, it may be revealed by us. Removing the veil may not be easy. But once the naked truth stands revealed before our eyes, we have the power to see it, to distinguish it from falsehood, and to know that it is the truth.[2]

This doctrine is evident in Descartes's theory of *veracitas dei* (the truthfulness of God), i.e., what we clearly and distinctly see to be true must indeed be true, for otherwise God would be deceiving us. It is similarly expressed in Bacon's doctrine of *veracitas naturae* (the truthfulness of nature), i.e. "Nature is an open book; he who reads it with a pure mind cannot misread it."[3]

Popper points out that the theory of *veracitas dei* can be traced back to the Greeks who often referred to their sources of knowledge as divine, e.g., the Muses. Similarly, Plato's theory of *anamnesis* grants to each man the divine sources of knowledge, i.e., knowledge of the essence or nature of a thing.[4]

Belief in the doctrine that truth is manifest led to the optimistic view that man need not appeal to authority in matters of truth since he carried in himself the sources of knowledge. These were his power of sense-perception which could be used for careful observation or his power of intellectual intuition which he could use to distinguish truth from falsehood. Man can know and thus he can be free. Corollary to the doctrine that truth is manifest is the conspiracy theory of ignorance. It attempts to explain why men still fall into error. Error is viewed as due to man's refusal to see the manifest truth or to his ignorance which comes from prejudices inculcated by education, tradition and the work of powers that conspire to keep men in ignorance by poisoning their minds with falsehoods.[5] Popper points out that this conspiracy theory of ignorance has been one of the elements in Marxist theory but also inspired liberalism and protestantism.

In contrast to epistemological optimism is the distrust of man's power of reason and his ability to discern the truth. This is historically linked with the doctrine of human depravity. Popper shows that in Plato's story of the prisoners in the cave we can see the beginnings of this epistemological pessimism.[6] In this story, Plato demonstrates that the world that we experience is only a shadow, a reflection of the real world. The difficulties of understanding the real world are nearly insuperable that only very few, if anybody at all, will, according to Plato, be able to attain a divine state of understanding of the real world or true state of knowledge, or *episteme*.

Such epistemological pessimism tended to lead to the demand for the establishment of powerful traditions and a powerful authority in order to save man from the chaos caused by his folly and wickedness. It can be seen that the optimistic and pessimistic epistemologies each lead to two opposing philosophies of the state and society. On the one hand, there is the anti-traditional, anti-authoritarian, revolutionary and utopian rationalism of the Cartesian kind, and on the other hand, there is authoritarian traditionalism.

Popper regards these contrasting epistemologies as erroneous. The doctrine that truth is manifest and the conspiracy theory of ignorance are viewed as myths. For Popper, the main source of our ignorance is the fact that our knowledge can only be finite while our ignorance is necessarily infinite.[7] He points out that the optimistic epistemology of Bacon and Descartes failed to free man from authority in the search for truth and knowledge. Both merely succeeded in replacing it with new authority: authority of the senses and authority of the intellect. In the final analysis, it appears that both optimistic and pessimistic epistemologies tended to subject men to authority.

There are no ultimate sources of knowledge according to Popper. However, knowledge cannot also start from nothing—from a *tabula rasa* nor yet from observation.[8] The advance of knowledge consists mainly in the modification of earlier knowledge. While he regards the theory of inborn ideas as absurd, he asserts that in one sense we can speak of "inborn knowledge." Every organism has inborn reactions or responses, e.g., responses adapted to impending events or expectations. Because of the close relation between knowledge and expectation, we can thus speak of inborn knowledge in a reasonable sense. This knowledge is not, however, valid *a priori.*[9]

Apart from inborn knowledge, Popper considers tradition as the most important—qualitatively and quantitatively—source of our knowledge. This fact, he argues, condemns anti-traditionalism as futile but does not also support a traditionalist attitude. This is because every bit of our knowledge is open to critical examination and may be overthrown. What differentiates science from older myths or first-order tradition is this critical attitude. Science is accompanied by a second-order tradition—the critical or argumentative tradition.[10] In this second-order tradition, observation, intuition, imagination and reason are not to be regarded as authorities but important means to help us in the critical examination of existing knowledge. They are useful instruments to detect and eliminate error. This is the essence of Popper's Critical Rationalism. It is a more realistic theory or pessimism. In this view

> . . . all knowledge is human; . . . it is mixed with our errors, our prejudices, our dreams, our hopes; — all we can do is to grope for truth even though it be beyond our reach. We may admit that our groping is often inspired, but we must be on guard against the belief, however deeply felt, that our inspiration carries any authority, divine or otherwise. If we thus admit that there is no authority beyond the reach of criticism to be found within the whole province of our knowledge, however far it may have penetrated into the unknown, then we can retain, without danger, the idea that truth is beyond human authority. And we must retain it. For without this idea, there can be no objective standards of inquiry, no criticism of our conjectures; no groping for the unknown: no quest for knowledge.[11]

For Popper then, the proper epistemological question is not concerning the sources of our knowledge but whether the assertions we make are true.

Growth of Scientific Knowledge

There are two approaches to the epistemological problem of understanding the growth of knowledge: common-sense knowledge versus scientific knowledge. Some philosophers consider scientific knowledge to be a mere extension of common-sense knowledge. They, therefore, concentrate on the analysis of ordinary language in which common-sense knowledge is formulated. Popper points out that most problems of the growth of knowledge transcend the confines of common-sense knowledge since "the most important way in which common-sense knowledge grows is precisely by turning into scientific knowledge."[12] Analysis of scientific knowledge, he asserts, requires more than the method of linguistic analysis employed by some philosophers.

The issues that often crop up in the analysis of the logic of scientific knowledge include such questions as: Is there a logical path to the discovery of scientific laws? When should a theory be ranked as scientific? Is there a scientific method that would contribute most to the advancement of knowledge?

Scientific Knowledge as Conjectures and Refutations

Popper attributes the success of science to luck, ingenuity and the purely deductive rules of critical argument. It does not depend upon the rules of induction. Induction, i.e., the inference of universal statements from many singular statements about observation or experience, is regarded by Popper as a myth.[13] Any conclusion drawn in this way may always turn out to be false. Thus he argues, "No matter how many instances of white swans we may have observed, this does not justify the conclusion that all swans are white." Moreover, he demonstrates that the attempt to justify the practice of induction by appealing to experience merely leads to infinite regress or apriorism.

It follows from this argument that theories can never be inferred from observation statements or rationally justified by them. The belief in induction is traced by Popper to a confusion between psychological problems and epistemological ones.[15] The psychology of knowledge deals with empirical facts while the logic of knowledge is concerned with logical relations. Popper asserts that there is neither a psychological nor logical induction. He explains that our propensity to expect regularities in what we observe is not the result of repetition. Rather, we observe repetition as the result of our propensity to expect regularities and to search for them. Thus

> Scientific theories are not the digest of observations, but they were inventions — conjectures boldly put forward for trial, to be eliminated if they clashed with observations; with observations which were rarely accidental but as a rule undertaken with the definite intention of testing a theory by obtaining, if possible, a decisive refutation.[16]

Popper calls this a theory of trial and error — of conjectures and refutations. It is a theory of knowledge which includes "an irrational element" or "a creative intuition" in explaining the logic of scientific discovery.[17] From this perspective, there is no such thing as a logical method of having new ideas in science or a logical reconstruction of this process. Moreover, all laws or theories remain essentially tentative, or conjectural or hypothetical. In this sense, science is not a system of certain or well-established statements nor one which steadily advances towards a state of finality or knowledge (*episteme*). While science can never claim to have attained truth or even a substitute for it such as probability, the search for truth and knowledge remains the strongest motive of scientific discovery.

The problem of induction is related to the philosophical problem of demarcation, i.e., of distinguishing between empirical sciences, on the one hand, and mathematics and logic as well as metaphysical systems, on the other hand. It also relates to validation or the question of when a theory should be considered scientific.[18] Popper points out that the criterion of demarcation inherent in inductive logic (the positivistic dogma of meaning) requires that all statements of empirical science must be capable of being finally decided with respect to their truth and falsity. They must be "conclusively decidable." Thus, they should be stated in such a form that would make it logically possible to verify them and to falsify them with reference to experience or reality. Popper emphasizes, however, that there is no such thing as induction, and therefore, inference to theories from singular statements which are verified by experience is logically inadmissible. Theories are never empirically verifiable, "*. . . only the falsity of the theory can be inferred from empirical evidence, and this inference is a purely deductive one.*"[19]

Popper proposes the falsifiability of an empirical system as the criterion of demarcation. Thus, the empirical or scientific status of a theory is its falsifiability or refutability or testability. This criterion is based upon an asymmetry between verifiability and falsifiability which results from the logical form of strictly universal statements. Strictly universal statements can be put in the form: "of all points in space and time (or in all regions of space and time) it is true that . . . ." Statements which only relate to finite regions of space and time are called specific or singular statements.[20] Universal statements, Popper explains, are nonverifiable. They are never derivable from singular statements but can be contradicted by singular statements. It is possible by means of purely deductive inferences to argue from the truth of singular statements to the falsity of universal statements. This, in Popper's view, is the only strictly deductive type of inference that proceeds in the inductive direction, from singular to universal statements.[21]

Based on this criterion of demarcation, strictly existential ("there is" or "there exists") statements are not falsifiable and are hence nonempirical or metaphysical.[22] By the same logic, philosophical or metaphysical theories such as determinism, idealism, irrationalism, voluntaries and nihilism, will be irrefutable by definition.[23]

Popper's theory of knowledge emphasizes that the rationalist tradition of critical discussion is the only practicable method of expanding our knowledge. It is a tradition which was developed in Ancient Greece and is incorporated in modern science.[24] This implies that the growth of scientific knowledge lies not in the accumulation of observations but in the repeated replacement of unsatisfactory theories by better ones. Our knowledge of what a good scientific theory should be like or meta-scientific knowledge, makes it possible for us to speak of progress in science and of a rational choice between theories.[25]

According to this theory of knowledge, there are only two ways in which theories may be superior to others; they may explain more and they may be better tested. Popper speaks of a criterion of relative potential satisfactoriness or progressiveness which can be applied to a theory even before subjecting it to empirical tests. A theory which is preferable is one which tells us more, i.e., has a greater amount of empirical information or content; is logically stronger; has greater explanatory power and can be more severely tested by comparing predicted facts with observations. In short, an interesting, daring and highly informative theory is preferable to a trivial one.[26]

There are three requirements that must be fulfilled, according to Popper, in order for science to get nearer to the truth and for knowledge to grow.[27] First, a new theory should proceed from some simple, new and powerful and unifying idea about some connection or relation between hitherto unconnected things or facts or new theoretical entities. Popper admits that this requirement of simplicity is rather vague but is an important ingredient for the logical analysis and testability of the new theory.

The second requirement is that the new theory should be independently testable. Apart from explaining all the *explicanda* which it was designed to explain, it must have new and testable consequences. It must lead to the prediction of phenomena which have not yet been observed. This requirement, Popper explains, is needed to eliminate trivial or *ad hoc* theories since it is always possible to produce a theory to fit any given set of explicanda by introducing some auxilliary assumption.[28] This requirement also ensures that the new theory will be fruitful as an instrument of exploration—it will suggest new experiments. Even if these experiments lead to a refutation of the theory, the results will add to our factual knowledge and suggest new problems to be solved by new theories.

The first and second requirements are the formal, rational requirements of scientific knowledge. These can be met largely by logical analysis and comparison of old and new theories. They are needed, according to Popper, to restrict the range of our choice among the possible solutions to the problem at hand.

The third requirement is that the new theory should pass some new and severe tests. This is a material or empirical requirement which, Popper points out, depends on luck for its success. Scientific theories are tested by the deductive approach, i.e., by way of empirical applications of the conclusions which can be derived from them. If these conclusions are falsified, then the theory from which they were logically derived is also falsified. If these are, however, corroborated by experimental evidence, the theory has for the time being passed its test. Theories that withstand detailed and severe tests and which are not superseded by other theories in the course of scientific progress are considered to have proved their mettle. Together with the reports of their tests, such theories can be regarded as the "science" of that time.[30] Refutation of a theory, in Popper's view, should not be considered a failure for the theory or the scientist. He argues that this is an inductivist error. Rather, every refutation should be regarded as great success both for the scientist who refuted the theory and the scientist who created the theory since the latter indirectly suggested, in the first place, the refuting experiment.

An important issue in the testing of scientific theories is the question of their objectivity or empirical basis. Popper emphasizes the need to distinguish between our "*subjective experience* or our *feelings of conviction,* which can never justify any statement and . . . the *objective logical relations* subsisting among the various systems of scientific statements, and within each of them."[31] The objectivity of scientific statements lies in the fact that they can be *inter-subjectively-tested.* Inter-subjective testability implies that from statements which are to be tested other testable statements can be deduced. These basic statements in turn are to be inter-subjectively testable, and so on. It thus becomes evident that with this criterion of objectivity "*there can* be no ultimate statements in science . . . no statements . . . which cannot be tested, and therefore none which cannot in principle be refuted by falsifying some of the conclusions which can be deduced from them."[32] In this deductive method of testing. Popper points out, there is no danger of infinite regress.

An important epistemological problem which Popper also discusses concerns truth. Science, he asserts, constantly aims at true theories even though we can never be sure that any particular theory is true. The idea of objective truth is, for Popper, the standard, ideal or regulative principle against which we can measure the success of scientific theories. He defines this, according to Tarski's objective or metalogical theory of truth, as correspondence with the facts.[33] In some cases, Popper realizes that we have to work with theories which are at best approximations of truth, as in the social sciences. In such instances, he argues that we can compare theories in terms of degrees of *verisimilitude,* i.e., better or worse approximations of truth. We can choose a theory which contains a greater number of true statements compared with another.[34]

Popper's theory of scientific progress may be summarized as moving from problems to problems. In this perspective,

> . . . the most lasting contribution to the growth of scientific knowledge that a theory can make are the new problems which it raises so that we are led back to the view of the science of the growth of knowledge as always starting from and always ending with problems—problems of an ever increasing depth and an ever increasing fertility in suggesting new problems.[35]

Cohen's View: Reason and the Scientific Method

Like Popper, Cohen criticizes empiricism for creating a false impression that modern science distrusts reason and relies on observation and experiment for its progress. He asserts that

> . . . wisdom does not come to those who gape at nature with an empty head. Fruitful observation depends not as Bacon thought upon the absence or bias of anticipatory ideas but rather on a logical multiplication of them so that having many possibilities in mind we are better prepared to direct our attention to what others have never thought of as within the field of possibility.[36]

Cohen points out that reason functions in science in two ways. First, it provides us with expectations of what we observe, and second, it is necessary for the proper interpretation of the results of our experiment and observation. He asserts that the scientific method cannot begin with a *tabula rasa* and pure sense impressions on it as a new born babe is supposed to have (p. 78). Sensations are, in his view, elements in a logical analysis of what we know and not starting points in scientific investigations. Science, he argues, begins with wonder or active curiosity and an effort to answer questions or problems arising out of intellectual difficulties

Cohen rejects as erroneous the popular view that the facts that we observe suggest the appropriate scientific hypotheses. He argues that the same facts do not suggest the same hypothesis to everyone. The history of science indicates that fruitful hypotheses have generally come to "certain gifted minds as musical themes or great poetic expressions have come to others" (p. 80). Cohen stresses that it requires a plenitude of previous knowledge to enable one gifted with fortunate insights or guesses to develop them into sucessful scientific hypotheses. Reason thus plays a more active part in the scientific method than the positivists and anti-rationalists would admit.

No amount of reason, however, can eliminate contingency in the world. Thus, Cohen argues, observation and experiment perform the necessary function in the science of testing hypotheses. They provide the means for choosing which of several logically possible hypotheses show greater agreement with reality. Like Popper, Cohen emphasizes that no number of single experiments or observations can ever prove a hypothesis to be true (p. 82).

Cohen distinguishes science from ordinary common-sense knowledge by its rigorous preoccupation with the pursuit of the ideal of certainty, exactness, universality and system. Science aims at knowledge that is certain by its efforts to eliminate baseless opinions and to establish propositions by evidence or proof. Certainty as used by Cohen is not to be confused with what Popper calls *episteme* or absolute knowledge or truth. Cohen points out that the use of the word certain is often misunderstood because of the confusion between its logical and psychological senses. Psychologically, it denotes a state of feeling or conviction as when we say that we are certain that none but those baptized by our church will go to heaven (p. 83). Cohen stresses that certainty in this sense is no guarantee of truth nor is the feeling of certainty that embodies itself in a consensus of opinion through the ages. Often this psychologic certainty becomes a barrier to the search for truth because it reflects people's inability to conceive the opposite of what they happen to believe.

The certainty which science aims to bring about is the logical ground on which its claims to truth can be founded. According to Cohen, science does this by the method of ". . . questioning all things that can be questioned and in this way it seems to destroy psychologic certainty" (p. 84). At the same time, he argues that the method of science "seeks to conquer doubt by cultivating it and encouraging it to grow until it finds its natural limits and can go no further" (p. 85). Thus, progress in science is possible because no single proposition in it is so certain that it can block the search for a proposition which is better founded. In thinking about the progress of science, Cohen stresses that we must be on guard against the popular notion that scientific theories succeed each other "by killing their predecessors and kindred." Citing the Copernican and Ptolemaic systems as examples, he demonstrates that a new theory does not eliminate an old one. Rather it explains what the old theory did and also goes beyond it.

Science aims at greater exactness than which characterizes ordinary common sense, by its emphasis on accuracy and measurement. Two devices for attaining definiteness which is discussed by Cohen are enumeration, often elaborated in the form of statistics, and measurement by which relations are numerically expressed. He noted some caveats in the use of statistics, e.g., the practice of inferring causality from correlations (pp. 90-92).

The third ideal of science discussed by Cohen is abstract universality and necessity. He asserts that the more developed a science is, the more are its laws formulated in terms of abstract or ideal elements. He disputes the positivistic dogma that the laws of nature are mere descriptions of the routines of our perception or of the habitual sequence of our sensations. He argues that

> whatever may be the historic or psychological origin of scientific laws, . . . they certainly do not describe the order of our perceptions or the sequence of our sensations. Nor do these laws assert any temporal sequence. They assert rather a mutual implication between the parts of an equation; though the elements of the equation refer to what is in time (p. 101).

Science is thus not a mere catalogue of what has happened but seeks to explain why things happen in the particular way they do and not in some other way. It inquires not only to what extent propositions about uniform sequences of events are true but also why they are true. In this manner, science provides us "our assurance of a real connection not merely on the fact that such sequences have been observed, but on an analysis which shows elements of identity between antecedent and consequent" (p. 103).

Cohen notes that this interest of science in formulating abstract universal laws explains why, as a science develops, it drops the popular notion of causality and "seeks for a mathematical formulation of invariant relations from which the numerical results of measurement can be deduced."[37] In the search for abstract or universal laws, science resorts to description in terms of ideal entities. Cohen explains that this conceptual order in science is necessary in order to help us discriminate relevant from irrelevant facts and conditions in the search for real connections and invariant relations. Abstract or universal laws assert what would happen if only certain conditions prevailed and everything else remained indifferent. Prediction is thus made possible "to the extent that nature does offer us instances where the action of bodies can be accounted for by a limited number of factors, and the efforts of all other influences either balance each other or are so small as to be negligible or unnoticeable" (p. 105).

While abstract laws are always necessary for the understanding of phenomena, their sufficiency varies in different fields. Thus, Cohen stresses that

> in verifying a law not only must we (1) deduce or explain all relevant phenomena, but (2) our explanation must have some advantage over rival explanation either involving fewer hypothetical elements or in being characterized by . . . 'greater appropriateness'. The most effective verification of a law is the prediction of a new phenomenon that ought not to take place on the assumption of any other known law (p. 106).

The above quotation might be misunderstood as Cohen's endorsement of the verificationist's or empiricist's view of validation. His use of the term "verification," however, seems to be closer in meaning to Popper's idea of corroboration. He stresses that the ideal of science is not only to find laws but to make sure that these laws are genuine universals. Science leads us to challenge all generalizations or abstractions and offers us a protection against hasty generalizations and established superstition.

Science pursues the ideal system in order to overcome the defects of pre-scientific or common-sense knowledge, knowledge that is often disconnected, fragmentary, chaotic or illogical, Cohen asserts that this is the one essential trait of developed science and all the other traits—e.g., certainty, evidence and proof, accuracy and measurement, or abstract universality and necessity—are incidental to it (p. 106). The first trait of a system is the connectedness of its parts. According to Cohen, we approximate this trait when we ask for the significance of a given fact or law. A scientific system views facts as connected in essence rather than isolated or separate events (p. 107).

Completeness is another aspect of a scientific system. This means that a group of propositions is internally connected and that all possible propositions can be derived from these axioms without the aid of further assumptions. Thus, a scientific system is not attained by merely adding facts. It must have some guiding principle to explore and take account of all possibilities and introduce order into the seemingly unconnected facts (p. 108).

A scientific system is also characterized by logical order. Cohen stresses that this is needed to help eliminate inconsistency and contradictions between scientific propositions. It forces us to make our assumptions about these propositions explicit and thus aids in revealing logical consequences and alternative possibilities. Thus, logical order in a scientific system is essential for the attainment of truth (pp. 109-14).

Cohen's view of the role of induction in scientific discovery and proof is somewhat different from that of Popper. He does not dismiss induction as a myth but considers it as a special form of deduction. He points out that much of the thinking about induction has been influenced by three traditional confusions. The first confusion is the traditional contrast between deduction as reasoning from universals to particulars, and induction as the exact reverse. Cohen argues that this is not a true account of the matter. We cannot, in deduction or any strictly demonstrable reasoning, always draw a particular conclusion from universals alone for universals may be pure hypotheses (p. 115). To warrant a particular conclusion, Cohen asserts that one of the premises must be particular. He points out that one problem is that our minor premises are often unexpressed. He contends that if we thus get used to the idea that the logical premises of an agrument need not always be expressed, it will not be hard to realize that, in inductive arguments also, our conclusion must be just as particular or universal as the combination of premises. To be considered valid, an inductive influence must conform to the condition of all valid inference. If the latter is called deduction, Cohen maintains, induction is not its antithesis but a special form for it (p. 116..

The second confusion in contrasting induction with deduction is the tendency to mix up the concept of reason as a logical and as a psychologic term. In the logical sense, reason is concerned with the weight of evidence or proof rather than with the manner in which ideas or propositions actually succeed each other in our consciousness. Thus Cohen argues,

> If then we distinguish between the premises which logically justify a conclusion and the psychologic starting points from which we jump to arrive at them, it becomes extremely doubtful whether there is any well defined psychologic difference between the actual processes of reasoning in inductive science like experimental medicine and deductive sciences like geometry or dynamics. (p. 117)

In the realm of purely formal logic then, induction and deduction are not antithetic terms. The difference between them is a matter of degree and material evidence, i.e., "the degree of conclusiveness of the initial evidence in favor of the homogeneity of the class concerning which we wish to establish a law" (p. 119). Thus, Cohen argues that, since all natural sciences involve unproved assumptions of homogeneity, they can all be said to be inductive. Similarly some sciences may be recognized as more deductive or less inductive than others. We may also analyze the historical progress of any science from a relatively inductive stage to one which is deductive.

The third conclusion which Cohen discusses concerns the view that induction is a method for discovering general truths while deduction is merely a method of exposition. Cohen argues that there is no definite method of discovering new truths "any more than there is a definite method for creating new forms of beauty or for inventing things that solve our practical difficulties" (p. 123). Old knowledge and native genius are important factors in making discoveries. But in most cases, Cohen admits that systematic deduction from previous knowledge or rigorous deductive reasoning has been a most fruitful source of discovery in the physical sciences.

In discussing the growth of knowledge, Cohen points out that the vision into Absolute Truth or certainty is needed to characterize our knowledge as incomplete and fragmentary. It thus serves as a motivation or inspiration in the search for knowledge. Thus

> the wells of rational knowledge offer no magic potion to those who thirst for the absolute certainty which will solve all ultimate questions. But they do offer us the living waters which strengthen us in our arduous journey (p. 146).

Medawar: A Scientist's View of Scientific Knowledge

It may be noted that the above accounts of science and the growth of scientific knowledge have been presented by philosophers and not scientists. These may be compared with the view of Peter Brian Medawar, who won the Nobel Prize for Medicine in 1960 for his researches on growth, aging, immunity and cellular transformations.[38]

Medawar notes that there are two popular conceptions of science and scientific activity. On the one hand, science is viewed as an imaginative and exploratory activity. In this sense the scientist is a discoverer, innovator and adventurer into the realm of what is still unknown or not yet understood. Intuition, imagination or having ideas, therefore, plays a very important role in the advancement of knowledge. It may even be said that the history of science is the history of men of genius. On the other hand, science is conceived as a critical and analytical activity. A scientist is pictured as a critical man, a skeptic, a questioner of received beliefs. In this view, imagination must be controlled by a skeptical habit of thought.[39]

In the first view of science, truth is shaped in the mind of the observer. It is the imaginative speculation of what might be true that motivates the scientist to search for the truth. In the second view, truth is to be found in nature and can be apprehended by the use of the senses. It is the scientist's task to discern and comprehend the truth with the aid chiefly of the scientific method.

Medawar points out that these views which are usually thought of as "two alternative and competing accounts of *one* process of thought are actually accounts of *two* successive and complementary episodes of thought that occur in every advance of scientific understanding."[40] He attributes these popular misconceptions about science and scientific reasoning to the writings of certain philosophers. None of those who are recognized as great methodologists of science was a practicing scientist himself. Francis Bacon was a lawyer, a sociologist of science. John Stuart Mill was more of a political theorist whose deeper scientific knowledge was acquired second-hand from William Whewell's *History of the Inductive Sciences* (1837). William Whewell was not a practicing scientist as are most contemporary methodologists of science, e.g., Karl Pearson (mathematician). Stanley Jevons and John Maynard Keynes (economists), C. S. Pierce and Karl Popper (philosophers).[41] Medawar blames John Stuart Mill's methodology of science for the mistaken belief that the process of induction could fulfill the same two functions of science, i.e., discovery and rational criticism. According to Medawar, it is not the origin but only the acceptance of a hypothesis that depends upon the authority of logic. Experimentation in the modern sense, i.e., contrived experience intended to enlarge our knowledge of what actually went on in nature, is also different from Bacon's idea of experiment which was intended to answer the question 'I wonder what would happen if . . . ."[42]

While the formal distinction between the creative and critical components of scientific thinking can be shown by logical dissection, Medawar asserts that this is not so obvious in the actual practice of science. This is because these two processes "work in a rapid reciprocation of guesswork and checkwork, proposal and disposal, *Conjecture and Refutation.*"[43] In his view the hypothetico-deductive approach is the general conception of science which is able to reconcile or join together these two views of the scientific process.

In discussing the problem of scientific methodology, Medawar argues that most scientists do not receive any instruction in scientific method in the sense of a system of inquiry or a code of practice for behavior. Those who are taught such a method do not perform any better than those who have not been instructed. He explains that the scientist is not conscious of acting out a method. Moreover, success in the scientific enterprise is often attributed to luck or learning or perceptiveness or flair of the scientist and never to to the use or misuse of a formal methodology.[44]

Medawar's views on the scientist and scientific knowledge is expressed in the following:[45]

(1) *There is no such thing as a scientific mind.* Most people who are in fact scientists could easily have been something else instead.

(2) *There is no such thing as the Scientific Method.* Although there is indeed a Scientific Method, scientists observe its rules unconsciously and do not understand it in the sense of being able to put it clearly into words.

(3) *The idea of naive or innocent observation is a philosopher's make-believe.* In all sensation we pick and choose, interpret, seek and impose order, and devise and test hypotheses about what we witness. Sense data are taken, not merely given: we learn to perceive.

(4) *Induction is a myth.* Scientists do not profess to be trying to discover laws and use the word itself only in conventional contexts (Hooke's Law, Boyle's Law). . . . It is indeed a myth to suppose that scientists actually carry out induction or that a logical autopsy upon a completed episode of scientific research reveals in it anything that could be called an inductive structure of scientific thought.

(5) *The formulation of a natural law begins as an imaginative exploit and imagination is a faculty essential to the scientists' task.* In a modern professional vocabulary, a hypothesis is an imaginative preconception of *what might be true* in the form of a declaration with verifiable deductive consequences.

The hypothetico-deductive scheme of thought approximates what Medawar considers to be a good methodology for science. In many ways, it is similar to Popper's conception of science as advancing by means of bold guesses or conjectures and refutations. Medawar mentions several characteristics of the hypothetico-deductive approach.[46] First, it makes a clear distinction between scientific discovery and proof as two separate and dissociable episodes of thought. Second, the initiative for scientific action is held to come from an imaginative conception of what might be true rather than the apprehension of facts. This usually takes the form of a hypothesis which starts scientific inquiry and also gives it direction. Third, the hypothetico-deductive scheme provides a theory of special incentive. Observations no longer range over the universe of observables but are confined to those that have relevance on the hypothesis under investigation. Fourth, the scheme permits the continual rectification or running adjustment of hypothesis by the process of "negative feedback." If a hypothesis is true, it need not be altered, but correction is obligatory if it is false. Fifth, error is explained as part of human fallibility. The scheme also incorporates the element of luck in scientific discovery which was unintelligible in inductive reasoning. Finally, the scheme gives due weight to the critical purposes of experimentation. Experiments are carried out more often to discriminate between probabilities rather than to enlarge the stockpile of scientific (factual) information.

Medawar is nevertheless aware of the shortcomings of the hypothetico deductive approach. First, he points out that the scheme sets no upper limit to the number of hypotheses we might propound to account for our observations. Second, although falsifiability or disproof is a logically conclusive process, we may yet be fallible in our imputation of falsifiability. If our inferences are false, the axioms from which we deduce them must be false also. However, we could be mistaken in thinking that our observations falsified a hypotheses when these observations may themselves have been faulty or were made against a background of misconceptions, or our experiments may have been ill-designed.[47] A third and major defect of the scheme from Medawar's point of view is

its disavowal of any competence to speak about the generative act in scientific inquiry, "having an idea", for this represents the imaginative or logically unscripted episode in scientific thinking, the part that lies outside logic. The objection is all the more grave because an imaginative or inspirational process enters into all scientific reasoning at every level; it is not confined to "great discoveries" as the more simple-minded inductivists have supposed.[48]

To illustrate this point, Medawar discusses the role of intuition in scientific inquiry. Intuition takes many forms in science but these share common characteristics: the suddenness of their origin, the wholeness of the conception they embody, and the absence of premeditation.[49] Intuition may take the form of perceiving logical implications instantly or seeing at once what follows from holding certain views. It can be seen in the thinking up of a hypothesis or the invention of a fragment of a possible world which often leads to scientific discovery. It may also take the form of thinking up an experiment which provides a really searching test of a hypothesis. For Medawar these are important aspects of the scientific process which should be taken into account in discussing scientific methodology.

Concluding Remarks

The critical rationalist or hypothetico-deductive approach raises important issues for the development of the social sciences, particularly political science. Popper, Cohen and Medawar all emphasize that scientific discovery does not follow any logical process and that scientific theories or hypotheses are not the product of observations or experience but are bold guesses or imaginative conceptions of what might be true. This runs counter to the prevailing view, especially in political behavior, that we can build a science of politics from the bottom up, i.e., by the piecemeal accumulation of data from observations that would hopefully yield generalizations and theories. It would seem from the account given in this paper that this conception of science is still heavily influenced by Bacon's and Mill's classical empiricism.

Induction is considered a myth by both Popper and Medawar. In Cohen's essay, there seems to be an ambiguity in his view of the role of inductive reasoning in science. Although his explanation of the induction-deduction debate is similar to Popper's (i.e., that the problem of induction is due to a confusion between the logical and psychological aspects of reasoning), he does not dismiss induction in the same manner. Cohen views induction and deduction as not antithetic terms but as a continuum in the reasoning process proceeding from a more inductive, less deductive stage to a more deductive, less inductive stage.

For Popper, the only valid logical reasoning that follows the inductive process is one involving the falsification or disproof of a strictly universal statement by a singular statement. Medawar concurs that this is a logically conclusive process but gives a caveat that we may yet be wrong in imputing falsifiability to a given theory when our observations may have faulty or our experiments well ill-designed. It would seem, therefore, that the road to falsification is not as smooth as Popper has pictured it.

Medawar compares the hypothetico-deductive conception of science with the general strategy of controlling performance by the consequences of the act performed, i.e., the process of feedback. Thus a false hypothesis can be continually rectified or adjusted by the process of "negative feedback." This follows from his assertion that "Scientific research is not a clamor of affirmation and denial. Theories and hypothesis are modified more often than they are discredited."[50] This view would meet Popper's objective as resorting to a "conventionalist twist" of rescuing a hypothesis from refutation by introducing modifications. In Popper's view a falsified hypothesis points to new problems of inquiry and thereby becomes a source of alternative hypothesis rather than being modified. It appears that Medawar is here describing the actual practice of science while Popper prescribing an ideal course for scientific practice.

Popper's discussion of his third requirement of the growth of knowledge, i.e., that a new theory should pass new and severe tests, is criticized by some as a residue of verificationist or empiricist thought. Popper admits this criticism but justifies his insistence on this requirement to avoid the charge of instrumentalism which considers theories to be mere instruments of exploration.[51]

The problem of objectivity in science is discussed by Popper along the same lines as Cohen's notion of certainty in science. Both argue that there is a need to distinguish between subjective experiences or feelings of conviction which can never justify any statement and the objective logical relations within and between scientific statements. Objectivity refers to inter-subjective testability of statements. This view has obvious implications for the goal of creating a value-free social science.

On the whole, the critical rationalist or hypothetico-deductive approach offers a more realistic conception of science than the positivist or empiricist views. It places the hope for building a science of politics or the social sciences not so much in the preoccupation with developing a strict methodology—such as that used by the physical sciences—but in the critical use of reason in advancing theories about society and subjecting these to rigorous tests. As Medawar sympathetically puts it, the "backwardness" of contemporary sociology or political science for that matter (as in 19th century biology) has little now to do with a failure to use authenticated methods of scientific research in trying to solve its manifold problems. I very much doubt whether a methodology based on the intellectual practices of physicists and biologists (supposing that method to be sound would be of any great use to sociolgists. [52]

NOTES

[1]Karl R. Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge,* (London: Routledge and Kegan Paul, 1963), p. 4.

[2]*Ibid.,* p. 5.

[3]*Ibid.,* p. 7.

[4]According to Plato's *Meno,* "there is nothing which our immortal soul does not know prior to our birth . . . . In being born we forget; but we may recover our memory and our knowledge, though only partially: only if we see the truth again shall we recognize it. All knowledge is therefore recognition — recalling or remembering the essence or true nature we once knew." *Ibid.,* pp. 9-10.

[5]*Ibid.,* pp. 5-7.

[6]*Ibid.,* pp. 10-11.

[7]*Ibid.,* p. 28.

[8]*Ibid.*

[9]*Ibid.,* p. 47.

[10]*Ibid.,* Ch. 4.

[11]*Ibid.,* pp. 29-30.

[12]Karl R. Popper, *The Logic of Scientific Discovery,* (London: Hutchinson, 1959), pp. 18-19.

[13]*Ibid.,* pp. 27-29.

[14]*Ibid.,* p. 29.

[15]*Ibid.,* p. 30; *Popper, Conjectures and Refutations,* pp. 53-55.

[16]*Popper, Conjectures and Refutations,* p. 46.

[17]Popper, *The Logic of Scientific Discovery,* p. 32. Popper quotes Einstein's view of scientific discovery as ". . . the search for those highly universal laws . . . from which a picture of the world can be obtained by deduction. There is no logical path to these . . . laws. They can only be reached by intuition based upon something like an intellectual love "Einfuhlung') of the objects of experience."

[18]*Ibid.,* pp. 34-36.

[19]Popper, *Conjectures and Refutations,* p. 55. See also Ch. 11. (Underscoring supplied by author.)

[20]Popper, *The Logic of Scientific Discovery,* pp. 62-63.

[21]*Ibid.,* pp. 40-42. Popper calls his group "falsificationists or fallibilists or negativists" in contrast to the "verificationists or justificationists or positivists." *Conjectures and Refutations,* pp. 228-30.

[22]Popper, *The Logic of Scientific Discovery,* pp. 68-69.

[23]Popper, *Conjectures and Refutations,* pp. 194-97.

[24]*Ibid.,* pp. 151-53.

[25]*Ibid.,* pp. 217-17.

[26]*Ibid.*

[27]*Ibid.,* pp. 241-44.

[28]*Ibid.*, p. 37. Such a procedure according to Popper involves a conventionalist twist and rescues a theory from refutation but at the price of lowering its scientific status.

[29]Popper, *The Logic of Scientific Discovery,* pp. 32-33.

[30]Popper, *Conjectures and Refutations,* p. vii.

[31]Popper, *The Logic of Scientific Discovery,* p. 43.

[32]*Ibid.*, p. 47:

[33]Other theories of truth, e.g., the coherence theory which mistakes consistency for truth, the evidence theory which mistakes 'known to be true' for "true" and the pragmatic or instrumentalist theory which mistakes usefulness for truth, are all subjective (epistemic) theories of truth according to Popper in *Conjectures and Refutations,* pp. 224-28.

[34]*Ibid.*, pp. 233-35.

[35]*Ibid.*, p. 222.

[35]*Ibid.*, p. 222.

[36]Morris R. Cohen, *Reason and Nature: An Essay on the Meaning of Scientific Method,* (New York: Harcourt, Brace and Company, 1931), pp. 16-17.

[37]Thus in place "of a causal law to the effect that differences of potential produce differences of current, or differences of current produce differences of potential, physics formulates â non temporal law of proportionality from which both statements can be deduced . . . ." *Ibid.*, p. 104.

[38]P. B. Medawar, *Induction and Intuition in Scientific Thought,* (Independence Square, Philadelphia: American Philosophical Society, 1969), p. 4.

[39]P. B. Medawar, *The Art of the Soluble,* (London: Methuen and Co., Ltd., 1967), pp. 117-18.

[40]*Ibid.*, p. 118.

[41]Medawar, *Induction and Intuition in Scientific Thought,* pp. 9-10. Medawar declares that about the only scientist who has written about his methodology is Claude Barnard, a Frenchman. His opinions seem to have made little impact on the English-speaking world.

[42]Medawar, *The Art of the Soluble,* p. 119.

[43]*Ibid.*, p. 120.

[44]Medawar, *Induction and Intuition in Scientific Thought,* p. 9.

[45]Medawar, *The Art of the Soluble,* pp. 132-39. (Underscoring supplied by the author.)

[46]Medawar, *Induction and Intuition in Scientific Thougtht,* pp. 51-53.

[47]*Ibid.*, p. 53.

[48]*Ibid.*, p. 55.

[49]*Ibid.*, p. 56.

[50]*Ibid.*, p. 41.

[51]Popper, *Conjectures and Refutations,* p. 248.

[52]Medawar, *Induction and Intuition in Scientific Thought,* p. 13.