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**CHAPTER ONE**

**PHILOSOPHY OF SCIENCE: HISTORY AND DEVELOPMENT**

Philosophy of science is an old discipline. Both Plato and Aristotle wrote on the subject, and, arguably, some of the pre-Socratics did same. In the Middle Ages, both in its Arabic and high Latin periods, made many commentaries and disputations touching on topics in philosophy of science. This ancient beginning of the discipline does not dispute the fact that the new science of the seventeenth century brought along widespread ruminations and manifold treatises on the nature of science, scientific knowledge and method.

The Enlightenment pushed this project further trying to make science and its hallmark method definitive of the rational life. With the industrial revolution, the term ‘science’ became a synonym for progress. In many places in the Western world, science was venerated as being the peculiarly modern way of thinking. The nineteenth century saw another resurgence of interest when ideas of evolution melded with those of industrial progress and physics achieved a maturity that led some to believe that science was complete. By the end of the century, mathematics had found alternatives to Euclidean geometry and logic had become a newly re-admired discipline.

Just before the turn to the twentieth century, and in those decades that followed, it was physics that led the intellectual way. Freud was there too, he and Breuer having published *Studies in Hysteria* in 1895, but it was physics that garnered the attention of the philosophers. Mechanics became more and more unified in form with the work of Maxwell, Hertz and discussions by Poincare. Plank derived the black body law in 1899, and in 1902 Lorenz proved Maxwell’s equations were invariant under transformation, and in 1905 Einstein published his paper on special relativity and the basis of the quantum. Concomitantly, Hilbert in 1899 published his foundations of geometry, and Bertrand Russell in 1903 gave forth his principles of mathematics. The development of unified classical mechanics and alternative geometries, now augmented and challenged by the new relativity and quantum theories made for period of unprecedented excitement in science.

What follows provides a brief historical overview of the problems and concepts that have characterized philosophy of science from the turn of the twentieth century until the present day. This is presented in the form of conceptual and problem oriented history because I believe that the real interest in philosophy of science and the lessons to be learned from its history are found in the topics it addressed and the methods it used to address them. It must be noted that the historical facts considered here are almost exclusively restricted to certain aspects of one Austro-Germanic-Anglo-American tradition. This is not because there was not interesting and important work in philosophy of science going on in France and elsewhere; but because this tradition is the one that is formative for and dominant in contemporary philosophy.

To provide some structure for the exposition, I shall break this text into three mportant periods:

• 1918–50s: Logical Positivism to Logical Empiricism

• 1950s through 1970s: New Paradigms and Scientific Change

• Contemporary Foci: What’s “hot” today

**Logical Positivism to Logical Empiricism: 1918–55**

As was noted above, the forming spirit of twentieth century philosophy of science was the grand syntheses and breakthroughs (or revolutions) in physics. Relativity and, later, quantum theory caused scientists and philosophers alike to reflect on the nature of the physical world, and especially on the nature of human knowledge of the physical world. In many ways, the project of this new philosophy of science was an epistemological one. *If* one took physics as the paradigmatic science, and *if* science was the paradigmatic method by which one came to obtain reliable knowledge of the world, then the project for philosophy of science was to describe the structure of science such that its epistemological underpinnings were clear. The two antecedents, that physics was the paradigmatic science and that science was the best method for knowing the world, were taken to be obvious. Once the structure of science was made precise, one could then see how far these lessons from scientific epistemology could be applied to other areas of human endeavor.

Another important background tradition needs to be described. Propositional and predicate logic became the model for clear reasoning and explicit statement. First in the work of Frege (in the 1880s–90s), and later with Russell and Whitehead (in the 20th century), logic came to be regarded as the way to understand and clarify the foundations of mathematics. It became the ideal language for modeling any cognitive enterprise. Simultaneously, Hilbert re-introduced to the world the ideal of axiomatization. Again this was a clarifying move to ensure that there were no hidden assumptions, and everything in a system was made explicit. This logico-mathematical language became the preferred form, because of its precision, into which philosophy of science had to be cast.

The epistemological project of the positivists was to explicate how science was grounded in our observations and experiments. Simultaneously, the goal was to provide an alternative to the neo-Kantianism that was the contemporaneously concurrent form of philosophy. Taking from the tradition of British empiricism, empirical grounding, or being based on the facts, was seen as the major difference between science and the other theoretical and philosophical pretenders to knowledge. This insight led the positivists to attempt to formulate and solve the problem of the nature of meaning, or more specifically, empirical meaning. What was it, they asked, that made statements about the world meaningful? This attempt to explicate the theory of meaning had two important parts. First, claims about the world would have to be made clear, avoiding ambiguity and the other confusions inherent in natural language. To this end, the positivists tried to restrict themselves to talking about the language of science as expressed in the sentences of scientific theories, and attempted to reformulate these sentences into the clear and unequivocal language of first-order predicate logic. Second, they tried to develop a criterion that would show how these sentences in a scientific theory related to the world, i.e. in their linguistic mode this became the problem of how theoretical sentences related to observation sentences. For this, one needed to develop a procedure for determining which sentences were true. This method came to be codified in the verification principle, which held that the meaning of an empirical sentence was given by the procedures that one would use to show whether the sentence was true or false. If there were no such procedures then the sentence was said to be empirically meaningless.

The class of empirically meaningless sentences were said to be non-cognitive, and they included the sentences comprising systems of metaphysics, ethical claims and, most importantly, those sentences that made up theories of the pseudo-sciences. This latter problem, distinguishing scientific sentences from those only purporting to be scientific, came to be known (following Karl Popper’s work) as the problem of demarcation. The verification principle was thought to be a way of making precise the empirical observational or experimental component of science. Obviously, the positivists, following in the empiricist tradition, thought, the basis of science lay in observation and in experiment. These were the tests that made science reliable, the foundation that differentiated science from other types of knowledge claims.So, formally, what was needed was a set of sentences that bridged the gap from scientific theory to scientific experiment and observation. These sentences that tied theory to the world were called bridge sentences or reduction sentences. The set of sentences that described the world to which theoretical sentences were reduced or related was called the observation language. Sentences in the observation language were taken to be easily verifiable or decidable as to their truth or falsity.

So that these bridge sentences might be made very explicit, theories were themselves idealized as sets of sentences that could be put into an axiomatic structure, in which all their logical relations and deductions from them could be made explicit. The most important sentences in a scientific theory were the laws of science. Laws came in two types: universal and statistical. Universal Laws were sentences of the theory that had unrestricted application in space and time (sometimes they were explicitly said to be causal, and, later, they were held to be able to support counterfactual claims.) Idealized universal laws had the logical form: (*x*)(*Fx* …*Gx*) Since such a form could be used to clearly establish their logical implications. Obviously, this was an idealized form, since most of the laws of interest were from physics and had a much more complex mathematical form. Statistical laws only made their conclusions more or less probable.

Scientific explanation was conceived as deducing a particular sentence (usually an observation or basic sentence) from a universal law (given some particular initial conditions about the state of the world at a time). The particular fact, expressed by the sentence, was said to be explained if it could be so deduced. This was called the deductive-nomological model of explanation. “Nomos” is the Greek word for law. If, a particular sentence was deduced before the fact was observed, it was a prediction, and then later if it was verified, the theory from which it was deduced was said to be confirmed. This was the hypothetico-deductive model because the law was considered a hypothesis to be tested by its deductive consequences.

The names of some of the major players in this period of philosophy of science were Moritz Schlick, Rudolf Carnap, Otto Neurath, Hans Reichenbach, and Carl Hempel. There were two main groups, one centered in Vienna (Schlick, Carnap and Neurath), called the Vienna Circle that was established late in the 1920s, and the other, coming a bit later, in Berlin (Reichenbach and Hempel). There was an important third group in Warsaw, doing mostly logic and consisting of Alfred Tarski, Stanislau Lesnewski and Tadeusz Kotarbinski.

This view of science, as an idealized logically precise language which could have all its major facets codified, never worked. Throughout the history of logical positivism there were debates and re-formulations among its practitioners about the idealized language of science, the relations of explanation and confirmation, the adequate formulation of the verification principle, the independent nature of observations, and the adequacy of the semantic truth predicate. The static, universalist nature of science that was idealized by positivism proved to be wrong. The attempt to fix procedures and claims in a logically simplified language proved to be impossible. The neat, clear attempts at explicating explanation, confirmation, theory and testability, all proved to have both internal difficulties with their logical structures and external problems in that they did not seem to fit science as it was actually practiced.

The positivists themselves were the first to see the problems with their program, and, as they attempted to work out the philosophical difficulties, the positions changed and shifted into what became logical empiricism. This happened in the mid-to late 1930s, the same time that many of the group left Germany and Austria because of World War II and the rise of Adolph Hitler. Reichenbach left Germany immediately after Hitler took power in 1933 and went first to Istanbul, Turkey, Richard von Mises went also. Reichenbach then in 1938 went to UCLA in the USA. Neurath and Popper both ended up in England. Carnap, from Prague, and Hempel, from Berlin, came to the USA.

Here is some slice of sociology of how philosophy of science developed. The first modern program in history and philosophy of science (HPS) was set up at University College, London. A. Wolf first offered a history of science course in collaboration with Sir William Bragg and others in 1919–20. Then a “Board of Studies in Principles, Methods and History of Science” was established in 1922, and an M.Sc. was first offered in 1924. Wolf was the first holder of the chair in “History and Method of Science.” In 1946, the Chair became full time with the appointment of Herbert Dingle. The London School of Economics’ Department evolved after the appointment of Karl Popper to the Readership in Logic and Scientific Method in 1945. The same Wolf who was associated with U.C., London also held the Chair in Logic and taught courses at LSE, prior to Popper. The University of Melbourne in 1946 began teaching courses in HPS.

*Erkenntnis*, the journal of the Vienna Circle, or rather the Max Plank Society, was first published in 1930. This followed on the first congress on the Epistemology of the Exact Sciences held in Prague in September of 1929. In 1934 the journal, *Philosophy of Science*, published its first issue. William M. Malisoff, a Russian biochemist, was its first editor. Malisoff died unexpectedly in 1947, and C. West Churchman became editor. The Philosophy of Science Association (PSA) was in existence in 1934. In 1948, the PSA had 153 members, and Philipp Frank was its President. In the discipline of history of science, the American History of Science Society was founded in 1924. The History of Science Society journal *Isis*, had been started earlier in 1912 by George Sarton when he was still in Belgium.

Logical empiricism never had the coherence as a school that logical positivism had. Various influences began to make themselves felt after the late 1930s. One most important conceptual addition came from American born pragmatism. Its specific influences can be seen clearly in the post-1940 work of Hempel, and even Carnap; also in the work of American born, Ernest Nagel and W. V. O Quine. But, until the late 1950s, despite significant changes in the programs and allowable methods, philosophers of science were still trying to work out and change things to fit into the goals and aspirations left by the positivists. Moreover, it ought to be noted clearly that virtually all the major moves that were to come later and so change the character of philosophy of science were first initiated by the original positivists themselves. This continuity was not noted by those who became famous during the next decades; they saw themselves as revolutionary and stridently anti-positivistic. By the late 1950s, philosophy of science included ever-increasing complex models, much looser claims, many new philosophical methods and increasingly vague philosophical goals.

**New Paradigms and Scientific Change: Late 1950s through the 1970s**

While the logical positivists, and later the logical empiricists, were attempting to explicate and clarify the structure of science, another group of scholars had begun to transform an old activity into the modern academic discipline of history of science. The goal of much history of science was to examine historically significant intellectual episodes in science and to articulate these analytically in a way that exhibited the character of science at that particular historical moment and also showed that moment fit into the development and progress of science. Questions for which answers were sought were, e.g. about the nature of Galileo’s physics, and what made it both continuous with and yet different from his medieval predecessors. Was Galileo the last of the Medievals or the first of the moderns? What was the nature of Galileo’s methodology, and how did he frame explanations? Was Galileo’s use of mathematics in physics really revolutionary? Did Galileo really use experiments in some modern sense? Of course, it was not just Galileo who was of interest; historians of science studied all the heroes of modern science, and reached backwards into the Greek, Roman and Medieval periods. The attempt was to describe the actual practice of science of these thinkers and to discern what was peculiar to these historical periods. While history of science courses had been taught in a number of places, by the mid-1960s history of science was an established enterprise with programs and departments in universities that trained graduate students in the discipline. Actually, the University of Wisconsin started its department in 1942, but World War II kept it from being staffed until 1947. Harvard offered degrees in History of Science, but their department was started only in 1966.

In the late 1950s, philosophers too began to pay more attention to actual episodes in science, and began to use actual historical and contemporary case studies as data for their philosophizing. Often, they used these cases to point to flaws in the idealized positivistic models. These models, they said, did not capture the real nature of science, in its ever-changing complexity. The observation language, they argued, could not be meaningfully independent of the theoretical language since the terms of the observation language were taken from the scientific theory they were used to test. All observation was theory-laden. Yet, again, trying to model all scientific theories as axiomatic systems was not a worthwhile goal. Obviously, scientific theories, even in physics, did their job of explaining long before these axiomatizations existed. In fact, classical mechanics was not axiomatized until 1949, but surely it was a viable theory for centuries before that. Further, it was not clear that explanation relied on deduction, or even on statistical inductive inferences. The various attempts to formulate the deductive-nomological model in terms of necessary and sufficient conditions failed not only because counter-examples were found, but also because explanation seemed to be more complex phenomena when one looked at examples from actual sciences. Even the principle of verification itself failed to find a precise, or even minimally adequate formulation.

All the major theses of positivism came under critical attack. But the story was always the same – science was much more complex than the sketches drawn by the positivists, and so the concepts of science – explanation, confirmation, discovery – were equally complex and needed to be rethought in ways that did justice to real science, both historical and contemporary. Philosophers of science began to borrow much from, or to practice themselves, the history of science in order to gain an understanding of science and to try to show the different forms of explanation that occurred in different time periods and in different disciplines.

Debates began to spring up about the theory ladeness of observation, about the continuity of scientific change, about shifts in meaning of key scientific concepts, and about the changing nature of scientific method. These were both fed by and fed into philosophically new areas of interest, areas that had existed before but which had been little attended to by philosophers. The social sciences, especially sociology, became of considerable interest, as did evolutionary biology. These fields provided not only new sciences to study and to be contrasted with physics, but also new models and methods which were then borrowed to study science itself.

By the early 1960s, as the result of the work of Thomas Kuhn – and concurrently Norwood Russell Hanson and Paul Feyerabend – the big philosophical question had become: Were there revolutions in science? The problem of scientific change, as it was called, dealt with issues of continuity and change. Kuhn had argued that science in one period is characterized by a set of ideas and practices that constitute a paradigm, and when problems or anomalies begin to accumulate in a given paradigm, there often was introduced a new paradigm which, in fact and in logic, repudiated the old and supplanted it. (This model was not unlike Gaston Bachelard’s view about crises in science leading to *rupture*.) This concept of a revolutionary paradigm shift implied that scientific change was discontinuous, and that the very meaning of the same terms, e.g. ‘mass’, changed from their use in one paradigm (Newtonian) to their use in the new paradigm (Einsteinian). This was called meaning variance. One methodological implication for philosophers of science, clearly, was that to study science, one had to confine oneself to a historically dominant paradigm and one could not look for more general, trans-paradigmatic models that covered all science, except maybe for the process of paradigm change itself.

Many philosophers made a job of criticizing Kuhn’s paradigms and his program. They began to search for alternative, general models of scientific change that were more accurate in describing episodes in science, more sensitive in analyzing the parts of science that actually underwent change, and that avoided the ambiguities and unclarities of Kuhn. So, talk of paradigms gave way to research programmes (Lakatos) and then to research traditions (Laudan). Another group of philosophers began to look at explanations in different periods and disciplines to find out if there could be general principles that could be said to apply to all explanations, and thus undercut the meaning variance thesis. Yet, other thinkers, including some philosophers, began to take Kuhn’s claims about practices seriously, argued, as had some historians of science earlier, that science could not be explained solely in terms of its concepts and internal structure. One needed, it was held, to understand the social and political settings in which such concepts were developed to understand how they became acceptable and why they were thought to be explanatory.

It should be noted also that many of the more purely philosophical moves (including those of Hanson, Kuhn and Feyerabend) had been influenced by the new dominance of the more central philosophical practices of ordinary language philosophy, inspired to a large extent by the work of the later Wittgenstein. This was still philosophy which dealt with analyzing language, but the language was no longer just the formal language of logic, but the various language games that comprised the various disciplines of human endeavor. New directions in linguistics, spurred on by Chomsky and his followers, had also changed the way people, including philosophers, looked the problem of syntax, semantics, and meaning. Even basic epistemology itself began to be questioned. W. V. O. Quine (1969) announced to the world that philosophy of science was philosophy enough, and epistemology had to be naturalized and was part of natural science.

By the mid 1960s, logical positivism and logical empiricism was quite out of fashion in Anglo-American philosophy. At this time, philosophical analysis was the key mode of operation, and the logic that had provided the guiding model for the earlier philosophical work, was superseded by the study of real scientific language and by the complexities uncovered in studying the history of science. During this period, Indiana University founded its Department of History and Philosophy of Science (1960), which was followed a decade later by the institution of HPS at the University of Pittsburgh (1971). Adolph Grunbaum was president of the Philosophy of Science Association in 1968. (The preceding President was Ernest Nagel.) The PSA seems to have waned somewhat during the post war years, but Grunbaum began the tradition of biennial meetings that continues to this day.

The result for philosophy of science was invigorating, exciting, and devastating. General characterizations of scientific change proved to be just as intractable as earlier general models of scientific explanation. The laudable tendency to explore the nature of sciences other than physics and to examine in detail cases from the history of many sciences left philosophers without a ‘paradigm’. There was little consensus about the nature of explanation, confirmation, theory testing or, even scientific change. Yet science itself, more than ever, was recognized by the populace at large, as a (if not the) major force in human life, and philosophy of science had become a discipline to stand alongside ethics, epistemology and metaphysics. But there was intellectual disarray over its nature in the philosophical community at large. In fact, some philosophers, following Paul Feyerabend took the intellectual confusion as evidence that science had no identifiable structure, and proffered the view that in science, as in art, ‘anything goes’. All evidence and proof is just rhetorical, and those with the best rhetoric, or the most power (Foucault), become the winners, i.e. their theories became the ones accepted. Luckily, this epistemological relativism was not followed by many philosophers, though, as we shall see below in some contemporary communities this idea still flourishes.

A consensus did emerge among philosophers of science. It was not a consensus that dealt with the concepts of science, but rather a consensus about the ‘new’ way in which philosophy of science must be done. Philosophers of science could no longer get along without knowing science and/or its history in considerable depth. They, hereafter, would have to work within science as actually practiced, and be able to discourse with practicing scientists about what was going on. This was a major shift in the nature of philosophy. It is true that most of the early positivists were trained in science, usually physics. But this scientific training had led them to try to make philosophy scientific after the image of their own philosophical–logical model of science. In contrast, from the 1950s on, more and more philosophers had been trained by the Oxbridge inspired analytic philosophers, who adhered to Wittgenstein’s dictum that philosophy was a *sui generis* enterprise and so had nothing to do with, and nothing to learn from, science. It is no wonder that students of philosophy so trained found it hard to figure out what philosophers of science should be doing, and as a result turned either to science itself or to various forms of sociology of science, which was taken to be legitimate because it was a sub-discipline of an actual science (sociology). Ironically, despite this confusion about goals, there were more philosophers of science than ever before.

**Contemporary Foci and Future Directions**

The turn to science itself meant that philosophers not only had to learn science at a fairly high level, but actually had to be capable of thinking about (at least some) science in all its intricate detail. In some cases, philosophers actually practiced science, usually theoretical or mathematical. This emphasis on the details of science led various practitioners into doing the philosophy of the special sciences. Currently, there are philosophers of space-time, who variously specialize in special or general relativity theory, and philosophers of quantum theory and quantum electro-dynamics. There do not seem to be any philosophers of plasma physics. Fairly recently, philosophy of chemistry has become somewhat of a ‘hot’ research area. Philosophers of biology continue to work on problems in evolutionary theory, and finally some study molecular biology, which is the area in which almost all biologists work. Work on genetics has been around for some time, but usually connected to evolutionary biology. Work on biological development is just starting and is seen to be increasingly important.

With the explosion of health care, philosophy of medicine also became a newly emergent and important field of research. Philosophy of the social sciences still continues to be worked upon, but sociology as the paradigmatic social science has been replaced by anthropology, except for those people who work in science studies which still treats sociology with some respect. Philosophy of economics, especially game theoretic modeling, is a somewhat popular field today. This is interesting since the game theory model had been started in the 1940s (von Neumann and Morgenstern), and then mostly dropped in 1960s, only to be revived by biologists using game theory to model evolution and by experimental economists trying to find an empirical model for studying economic behavior; these then influenced philosophers of economics who revived game theory as tool for economic analysis.

One of the most innovative and biggest changes has come in the area that used to be known as philosophy of psychology. Philosophy of psychology used to be tied to philosophical psychology, to philosophy of mind, and to behaviorism and cognitive psychology, especially to questions about the nature of the mental. In a way it still is, but the ‘cognitive revolution’ hit philosophy quite hard. Cognitive studies now include many of those working in experimental psychology, neuroscience, linguistics, artificial intelligence, and philosophers. There are many aspects to this re-defined field, including work on problems of representation, explanatory reduction (usually to neuroscience), and even confirmation. Confirmation theory has used techniques from artificial intelligence to re-establish a modern form of older confirmation functions as developed originally by Carl Hempel. Cognitive problem solving has even been used by some to model the nature of science itself. A new direction to be explored is the relations of neuroscience to traditional philosophical problems, such as representation and knowledge.

Historically, it is of note that cognitive science began to emerge in the mid-1950s, close to the time that the shift away from logical positivism began. Many of the intellectual forces that caused the philosophical change were also the causes of the emerging new cognitive paradigm, but, even more importantly, one needs to note the impact of the computer and its related ways of acting and thinking. The computer was not only a tool for calculation, reasoning and processing, but also became a model for thinking about human beings, and, even, for thinking about science.

One interesting implication of this work in the specialized sciences is that many philosophers have clearly rejected any form of a science/philosophy dichotomy, and find it quite congenial to conceive of themselves as, at least in part of their work, ‘theoretical’ scientists. Their goal is to actually make clarifying and, sometimes, substantive changes in the theories and practices of the sciences they study.

A very different current trend is exhibited by those philosophers of science who have become part of the science studies movement, which is dominated by historians and sociologists. This movement focuses on the social dimensions of science (as opposed to the ‘outmoded’ intellectual aspects.) In one sense the social study of science grew out of the dispute between internalist and externalist historians of science, which was resolved in favor of the externalists when the discipline of history itself shifted to quantitative social history and away from intellectual history. From another direction the work of the epistemological relativists, whom I referred to earlier, fits nicely with the relativism thought to characterize historical periods and with cultural (and ethical) relativism that is rampant in much of cultural anthropology. Essentially the view here is that science is a human social activity not unlike any other and so is subject to historical and cultural contingencies. In order to study such activities we must look at the socio-cultural milieu in which scientists are raised, trained, and in which their work occurs. So, for example, we should study the laboratories in which scientists work and describe how these function to self-validate knowledge claims issued from the laboratory. Moreover, we should study the conventions of discourse that comprise the ‘rules’ by which scientists’ influence and exert power over one another. For example, in the seventeenth century there were codes of conduct that English gentleman had to adhere to, and these provided (somehow) the structure of the debates and experimental practices for the members of the Royal Society. A concomitant belief held by most of the science studies group, though it is not necessarily implied by their position, is the relativism of different or competing claims. That is, it is a historical, cultural and/or epistemic peculiarity that a given group of scientists holds the views that they do. From this, it is presumed to follow that no one views is any better than any other. You are what your time and culture has made you, and that’s an end to it.

Such claims for relativism often lead people to worry about values and their status, for cultural relativism is closely tied with ethical relativism. But questions about the relations between values and science also arose from even more pressing sources. Perhaps the most important and influential questions about values arose from medicine. The practical problems of medical ethics began to make themselves felt due to changes in the practice of medicine and in medical technology. All of a sudden, there were urgent questions concerning life and death, physician-patient relations, and informed consent that had to be answered in pragmatically expeditious ways. This coincided with, and was in part responsible for, a shift in philosophical ethics away from the theoretical, from meta-ethics, towards the practical. Philosophers of ethics and of science, became involved in consulting about the day to day decisions in hospitals and about the re-writing of health care policies. Philosophers of science are especially useful here because they actually know some of the science that is involved in making informed decisions, and they have often studied various aspects of decision making and the use of evidence.

This practical side of ethics in the sciences has other dimensions too. Codes of ethics for the various professions, e.g. engineers, have become ‘hot’ topics for philosophical research. One of the more interesting and important new fields that philosophers of science dealing with values are involved in have to do with issues concerning how science is used to base regulatory decisions, e.g. concerning lead or dioxins or global warming. Also, there is work being done of the values that are implicitly or explicitly involved in the actual doing of scientific research. For example, what values are assumed in choosing a certain type of experimental paradigm, or, more generally, what values are assumed in giving more money to AIDS research rather than malaria (which is back with us in a big way.) The feminist movement of the late 1960s, also brought many value questions to the fore, and some excellent work has been done on how gender assumptions have influenced scientific practice.

This practical side of the ‘new’ philosophy of science, I believe, derives from the same need for relevance that pushed other thinkers into dealing with the special sciences. There is an often unacknowledged awareness that philosophy must become important in ways that go beyond the hallowed halls of academe. The logical positivists, though some of them had studied physics, had little influence on the practice of physics, though their criteria for an ideal science and their models for explanations did have substantial influence on the social sciences as they tried to model themselves on physics, i.e. on ‘hard’ science. The analytic philosophers of the mid-1950s onwards had little influence outside of the universities in which they taught. They were content to defend their professional turf as being a thing unto itself and in some ways were quite proud to be ‘irrelevant’ to the concerns of ordinary life, despite the ironic emphasis on ordinary language. By the 1980s, this intellectual isolationism had begun to break down, philosophers, and especially philosophers of science, had to get involved in the real world, the world of science.

I end this little essay by noting that the old questions and topics that had been raised by the logical positivists, and even in previous 2000 years, have not disappeared. Philosophers of science still puzzle over what makes a good explanation, what kind of evidence provides what kind of confirmation for theory, and what is the difference between science and pseudo-science. These are the perennial questions of philosophy of science. Today, we still try to answer them in specific ways that will have effects on science and the larger world. Philosophers of science have been instrumental in showing the non-scientific status of creationism and some versions of sociobiology and, now, evolutionary psychology. They have discussed fruitfully the role of scientific evidence in making decisions about nuclear energy plants or about levels of toxicity in our environment. They have asked hard questions about how to discover mechanisms such that finding them allows us to understand how systems of molecular biology or neuroscience work. And they have continued to elucidate and elaborate the misconceptions and confusions in the special sciences.

Of course, there is much left to do. There are always more puzzles than people, more problems than solutions. The twentieth century saw many changes in what are taken to be the important puzzles and problems, but even more importantly, these same years have seen changes in how people need to be trained to approach problems and in what solutions to problems must look like. Maybe this past century has only taught us that there are no simple answers to truly complex questions. Yet, with this realization comes the awareness that there must be pragmatic answers provided in a timely and efficacious manner. Decisions must be made, and, hopefully, philosophy of science can help us to see how they may be made in better ways.

***Note: The bulk of the facts on the historical development of philosophy of science were gathered (of course with slight changes) from the article “A Brief Historical Introduction to the Philosophy of Science” written by Peter Machamer and published in “The Blackwell Guide to the Philosophy of Science”.***

**CHAPTER TWO**

**Nature of Philosophy of Science**

Philosophy of science is a sub-field of philosophy. It is concerned with all the assumptions, foundations, methods and implications of science and the rise and merit of science. The central questions of this study concern what qualifies as science, the reliability of scientific theories and the ultimate purpose of science.

Theories in Philosophy of science sometimes overlay or share similar scopes with metaphysics, ontology and epistemology for example when it explores the relationship between science and truth. Science is a project whose goal is to obtain knowledge of the natural world but philosophy of science is a discipline that deals with the system of science itself. It examines science’s structure, components, techniques, assumptions, limitations and so forth.

There is no consensus among philosophers about many of the central problems concerned with the philosophy of science, including whether science can reveal the truth about unobservable things and whether scientific reasoning can be justified at all.

In addition to these general questions about science as a whole, philosophers of science consider problems that apply to particular sciences such as biology and physics. Some philosophers of science also use contemporary results in science to reach conclusions about philosophy itself.

Although philosophical thoughts related to science began as early as the time of Aristotle, philosophy of science emerged as a separate discipline only in the mid-20th century with the rise of the logical positivism movement which aimed to formulate criteria for ensuring the meaningfulness of all philosophical statements and the means of objectively assessing them.

**The Basic Structure of Science**

To properly understand the contemporary philosophy of science, it is necessary to examine some basic components of science. The components of science are – data, theories and what is often called shaping principles.

DATA refer to the body of collected pieces of information about physical processes. Sometimes, collecting and finding data to support theories can be rather laborious. This is because the specific details of data that come into play can make science such a tricky business that some scientists, when talking to laymen, sometimes leave them out. Also, it is easy to fit a theory in with the data if the data are vague and over-generalized. It usually becomes more difficult to fit the theory with specific data especially since the details make it more likely for the theory to become less plausible. Even so, data are important parts of theories and of science.

THEORIES come in roughly two forms. Contrary to what some might think, a theory in the scientific sense does not have anything to do with whether or not it is supported by the evidence, contradicted by the evidence, well liked by scientists and so forth. It only has to do with its structure and the way it functions. That is, just because a theory is a scientific theory does not mean that the scientific community currently accepts it. There are many theories that though technically scientific, have been rejected because the scientific evidence is strongly against it. Phenomenological theories are empirical generalizations of data. They merely describe the recurring processes of nature and do not refer to their causes or mechanisms. Phenomenological theories are also called scientific laws, physical laws and natural laws. Newton’s third law is one example. It says that every action has an equal and opposite reaction. Explanatory theories attempt to explain the observations rather than generalize them. Whereas laws are descriptions of empirical regularities, explanatory theories are conceptual constructions to explain why the data exist. For instance, atomic theory explains why we see certain observation. The same could be said with DNA. Explanatory theories are particularly helpful in such cases where the entities (like atoms, DNA and so forth) cannot be directly observed.

SHAPING PRINCIPLES are non empirical factors presuppositions that form the basis of science and go into selecting a ‘good’ theory. Why are they necessary? Can’t theories be selected solely on the basis of empirical data? Surprisingly, the answer is no. Why not? Describing some mistaken views of science come in handy for explaining the answer.

**Scope of Philosophy of Science**

Despite its straightforward name, the field is complex and remains an area of current enquiry. Philosophers of science actively study such questions as:

1. What is a law of nature? Are there any in non-physical sciences and accidental regularities?
2. What kind of data can be used to distinguish between real causes and accidental regularities?
3. How much evidence and what kinds of evidence do we need before we accept a hypothesis?
4. Why do scientists continue to rely on models and theories which they know are at least partially inaccurate like Newton’s physics?

Though, they might seem elementary, these questions are actually quite difficult to answer satisfactorily. Opinions on such issues vary widely within the field and occasionally part ways with the views of scientists themselves who mainly spend time doing science, not analyzing it abstractly. Despite this diversity of opinion, philosophers of science can largely agree on one thing; there is no single simple way to define science. Though the field is highly specialized, a few touchstone ideas have made their way into mainstream. What follows is a quick explanation of just a few concepts associated with the philosophy of science which you may (or may not) have encountered.

1. **Epistemology**: The branch of philosophy that deals with what knowledge is; how we come to accept some things as true and how we justify that acceptance.
2. **Empiricism**: Set of philosophical approaches to building knowledge that emphasizes the importance of observable evidence from the natural world.
3. **Induction**: A method of reasoning in which a generalization is argued to be true based on individual examples that seem to fit with that generalization. For example, after observing that trees, bacteria, sea anemones, fruits, flies and humans have cells, one might inductively infer that all living organisms have cells.
4. **Deduction**: Method of reasoning in which a conclusion is logically reached from premises. For instance, if we know the current relative position of the moon, sun and earth, as well as exactly how these move with respect to one another, we can deduce the date and location of the next solar eclipse.
5. **Parsimony/Ockham’s Razor**: The principle from philosophy which suggests that suppose there are two explanations for an occurrence, the simpler one is usually preferred. Another way of explaining this is that the more assumptions you have to make, the more unlikely an explanation is said to be correct. The term Razor refers to distinguishing between two hypotheses either by “shoving away” unnecessary assumptions or cutting apart two similar conclusions. The principle suggests that all other things being equal, we should prefer a simpler explanation over more complex ones.
6. **Demarcation Principle**: The problem of reliably distinguishing science from non-science. Modern philosophers of science largely agree that there is no single simple criterion that can be used to demarcate the boundaries of science.
7. **Falsification**: The view that evidence can only be used to rule out ideas, not to support them. Popper proposed that scientific ideas can only be tested through falsification, never through a search for supporting evidence.
8. **Paradigm shifts and Scientific Revolutions**: A view of science associated with philosopher Thomas Khun which suggests that the history of science can be divided up into times of normal science (when scientists add to, elaborate on and work with a central accepted scientific theory) and times of revolutionary science.

**Some Central Figures in the Development of Philosophy of Science**

**Aristotle (384 – 322 BC)**

He is arguably the founder of both science and philosophy of science. He wrote extensively about the topics we now call physics, astronomy, psychology, biology and chemistry, as well as logic, mathematics and epistemology.

**Francis Bacon (1561 – 1626)**

He promoted a scientific method in which scientists gather many facts from observations and experiments and then make inductive inferences about patterns in nature.

**Rene Descartes (1596 – 1650)**

He was a mathematician, scientist and philosopher who promoted a scientific method that emphasized deduction from first principle. These ideas as well as his mathematics influenced Newton and other figures of the scientific revolution.

**Piere Duhem (1861 – 1916)**

He was a physicist and philosopher who defended an extreme form of empiricism. He argued that we cannot draw conclusions about the existence of unobservable entities conjectured by our theories such as atoms and molecules.

**Carl Gustav Hempel (1905 – 1997)**

He developed influential theories of scientific explanation and theory confirmation. He argued that a phenomenon is explained when we can see that it is the logical consequence of a law of nature. He championed a hypothetical deductive account of confirmation similar to the way we characterize ‘making a scientific argument.’

**Karl Popper (1924 – 1994)**

He argued that falsifiability is both the hallmark of scientific theories and the proper methodology to be adopted by scientists. He believed that scientists should always regard their theories with a sceptical eye, seeking every opportunity to try to falsify them.

**Thomas Kuhn (1922 – 1996)**

He was a historian and Philosopher who argued that the picture of science developed by logical empiricists such as Popper did not resemble the history of science. Kuhn formally distinguished between normal science where scientists solve puzzles within a particular framework or paradigm and revolutionary science, when the paradigm gets overturned.

**Paul Feyeraband (1924 – 1994)**

He was a rebel within the philosophy of science. He argued that there is no scientific method or in his words, ‘anything goes.’ Without regard to rational guidelines, scientists do whatever they need to in order to come up with new ideas and persuade others to accept them.

**SCIENTIFIC PROCEDURES**

**Hypothesis, Theories and Laws**

The principles and theories of science have been established through repeated experimentation and observation and have been subjected to constant review before general acceptance by the scientific community. Acceptance does not imply rigidity or constraint, or denote dogma. Instead, as new data become available, previous scientific explanations are revised and improved or rejected and replaced. Science is a way of making sense of the world, with internally-consistent methods and principles that are well described. There is a progression from a hypothesis to a theory using testable, scientific laws. Only a few scientific facts are natural laws and many hypotheses are tested to generate a theory.

**Hypothesis**

A hypothesis is an idea or proposition about the natural world that can be tested by observation or experiments. A scientific hypothesis is a proposed explanation for a natural phenomenon. In order to be considered scientific, hypotheses are subject to scientific evaluation and must be falsifiable, which means that they are worded in such a way that they can be proven to be incorrect. Put differently, for a hypothesis to be a scientific hypothesis, the scientific method requires that one can test it. Even though the words ‘hypothesis’ and ‘theory’ are often used synonymously, a scientific hypothesis is not the same as a scientific theory.

In common usage, in the 21st century, a hypothesis refers to a provisional idea whose merit requires evaluation. For proper evaluation, the framer of a hypothesis needs to define specifics in operational terms. A hypothesis requires more work by the researcher in order to either confirm or disprove it. In due course, a confirmed hypothesis may become part of a theory or occasionally, may grow to become a theory itself. Normally, scientific hypotheses have the form of a mathematical model, sometimes, but, not always. One can formulate them as existential statements, stating that some particular instance of the phenomenon under examination has some characteristic and causal explanations, which have the general form of universal statements, stating that every instance of the phenomenon has a particular characteristic.

People sometimes describe scientific hypothesis as an “educated guess” because it provides a suggested solution based on the evidence. However, some scientists reject the term “educated guess” as incorrect. Experimenters may test and reject several hypotheses before solving the problem. According to Schick and Vaughn, researchers weighting up alternative hypotheses may take into consideration the following:

1. **Testability** (falsifiability)
2. **Parsimony** (as in the application of Ockham’s razor discouraging the postulation of excessive number of entities).
3. **Scope** – the apparent application of the hypotheses to multiple cases of phenomena.
4. **Fruitfulness** – the prospect that a hypothesis may explain further phenomena in the future
5. **Conservatism** – the degree of ‘fit’ with existing recognized knowledge systems.

A **working hypothesis** is a hypothesis that is provisionally accepted as a basis for further research in the hope that a tenable theory will be produced even if the hypothesis ultimately fails. Like all hypothesis, a working hypothesis is constructed as a statement of expectations, which can be linked to the exploratory research purpose in empirical investigation. Working hypotheses are often used as a conceptual framework in qualitative research. The provisional nature of working hypotheses make them useful as an organizing device in applied research. Here, they act like a useful guide to address problems that are still in a formative phase. In recent years, philosophers of science have tried to integrate the various approaches to evaluate hypotheses, and the scientific method in general to form a more complete system that integrates the individual concerns of each approach. Notably Imre Lakatos and Paul Feyerabend, Karl Popper’s colleague and student respectively have produced novel attempts at such a synthesis.

**Theory**

A theory to the scientist is a coherent explanation for a large number of facts and observations about the natural world. It refers to a well substantiated exploration of some aspects of the natural world based on a body of facts that have been repeatedly confirmed through observation and experiment. The strength of a scientific theory is related to the diversity of phenomena it can explain which is measured by its ability to make falsifiable predictions with respect to those phenomena.

A theory is:

1. Internally consistent and compatible with evidence
2. Firmly grounded in and based upon evidence
3. Tested against a wide range of phenomena
4. Demonstrably effective in problem-solving.

In popular usage, a theory is often assumed to imply mere speculation, but in science, nothing is called a theory until it has been confirmed through many independent experiments. *Theories are more certain than hypotheses but less specific than laws.* Theories are comprehensive explanation of some aspects of nature that are supported by a vast body of evidence. Many scientific theories are so well established that no new evidence will demonstrate that the earth does not orbit around the sun (heliocentric theory) or that living things are not made of cells (cell theory), that matter is not composed of atoms or that the surface of the earth is not divided into solid plates that have moved over geological timescales (theory of plate tectonics). One of the most useful properties of scientific theories is that they can be used to make predictions about natural events or phenomena that have not yet been observed.

**Laws**

A scientific law is a description of a natural phenomenon or principle that invariably holds true under specific conditions and will occur under certain circumstances. Scientific laws always apply under the relationship involving its elements. Scientific laws are statements based on repeated experimental observations that describe some aspects of the universe. A central problem in the philosophy of science going back to David Hume is that of distinguishing causal relationship (such as those implied by laws) from principles that arise due to constant conjunction.

*Laws differ from scientific theories in that they do not posit a mechanism of explanation of phenomena; they are merely distillations of the results of repeated observation.* As such, a law is limited in applicability to circumstances resembling those already observed and may be found false when extrapolated. For example, Ohm’s law of universal gravitation only applies to linear networks and Newton’s law of universal gravitation only applies in weak gravitational fields. Like theories and hypotheses, laws make predictions and can be falsified if they are found in contradistinction with new data.

*However, in strict sense, a law predicts what happens while a theory proposes why*. A theory must not necessarily grow into a law, though, the development of one often trigger progress on the other. Scientific laws and theories have different jobs to do. A scientific law predicts the results of certain initial conditions. It might predict the possible hair colour of an unborn child. In contrast, a theory tries to provide the most logical explanation about why things happen as they do. For instance, a theory might invoke dominant and recessive genes to explain how brown-haired parents ended up with red-haired child, or use gravity to shed light on the parabolic trajectory, of a baseball. Laws usually resist change since they wouldn’t have been adopted if they didn’t fit the data; though laws are occasionally revised in the face of unexpected information. A theory’s acceptance is however often gladiatorial. Multiple theories may compete to supply the best explanation of a new scientific discovery. Upon further research, scientists tend to favour the theory that can explain most of the data, though there may still be gaps in our understanding. A good scientific law is a firmly-tuned machine accomplishing its task brilliantly but ignorant of why it works as well as it does. This is because scientific laws are like mathematical propositions. But a good scientific theory is a bruised but unbowed fighter who risks defeat if unable to overpower or adapt to the next challenger. Therefore laws and theories are different. Science however, needs both to understand the whole picture.

**Falsification and Verification of Hypothesis**

Scientists design experiments and try to obtain results by verifying or disproving hypothesis, but philosophers are the driving force in determining what factors determine the validity of scientific results. Science and philosophy have always worked together to try to uncover truths about the world and the universe around us. Both are a necessary element for the advancement of knowledge and the development of human society. Scientists design experiments and try to obtain results; verifying or disproving a hypothesis, but philosophers are the driving force in determining what factors determine the validity of scientific results. Often, they even determine the nature of science itself and influence the direction of viable research. As one theory is falsified, another evolves to replace it and explain the new observations.

**Meaning of Falsification of Hypothesis**

The idea of falsifiability or falsification of hypothesis or theory gained recognition through Karl Popper’s scientific epistemology where he postulated the principle of falsificationism. Popper stresses the problem of demarcation - distinguishing the scientific from the unscientific and makes falsifiability the demarcation criterion such that what is falsifiable is classified as science and what is not falsifiable is classified as unscientific.

In its basic form, falsifiability is the belief that for any hypothesis to have credence, it must be inherently disprovable before it can become accepted as a scientific hypothesis or theory. For example, the interrogative, “Does God exists?” can never be science because it is a theory that cannot be disproved. The idea is that no theory is completely correct, but, if it is not falsified, it can be accepted as truth. For example, Newton’s Theory of Gravity was accepted as truth for centuries because objects do not randomly float away from the earth. It appeared to fit the figures obtained by experimentation and research, but was always subject to testing.

Put differently, statements, hypothesis or theories have falsifiability or refutability if there is the inherent possibility that they can be proven false. They are falsifiable if it is possible to conceive of an observation or an argument which could negate them. In this sense, falsify is synonymous with nullify, meaning to invalidate or “show to be false”. For example, the universal generalization that all swans are white is falsifiable since it is logically possible to falsify it by observing a single black swan. Thus, the term falsifiability is sometimes synonymous to testability. Popper saw falsifiability as a black and white definition such that if a theory is falsifiable, it is scientific and if not, then, it is unscientific. While pure sciences do adhere to this strict definition, pseudo-sciences may fall somewhere between the two extremes.

**Popper’s Submission on Pseudo-Science**

According to Popper, many branches of applied science, especially social sciences are not scientific because they have no potential for falsification. Anthropology and Sociology for example, often use case studies to observe people in their natural environment without testing any specific hypotheses or theories. While such studies and ideas are not falsifiable, most would agree that they are scientific because they significantly advance human knowledge. Even pure or true science must make compromises and assumptions on occasions. The testing of any theory must take into account the equipment and resources available. Falsifiability is not a simple black and white matter because a theory which is difficult to falsify at the time, may be falsified in the future.

For many of the pure sciences, the idea of falsifiability is a useful tool for generating theories that are testable and realistic. If a falsifiable theory is tested and the results are significant, then, it can become accepted as a scientific truth. The advantage of Popper’s idea is that such truths can be falsified when more knowledge and resources are available. Even long accepted theories such as Gravity, Relativity and Evolution are increasingly challenged and adapted. The major disadvantage of falsifiability is that it is very strict in its definitions and does not take into account that many sciences are observational and descriptive.

**Meaning of Verifiability of Hypothesis**

In the philosophy of science, verificationism (also known as the verifiability theory of meaning) holds that a statement must in principle, be empirically verifiable in order that it be both meaningful and scientific. This was an essential feature of the logical positivism of the so-called Vienna circle that included such philosophers as Moritz, Schlick, Ruldolf Carnap, Otto Neurath, Hans Reichenbach and the logical empiricism of A. J. Ayer. Popper noticed that the philosophers of the Vienna Circle had mixed two different problems, that of meaning and that of demarcation and had proposed in verificationism, a single solution to both. In opposition to this view, Popper emphasized that there are meaningful theories that are not scientific and that, accordingly, a criterion of meaningfulness does not coincide with a criterion of demarcation. Thus, Popper urged that verifiability be replaced with falsifiability as the criterion of demarcation.

Put simply, verification is the belief that any scientific statement must be verifiable for it to have any relevance. Concisely, this means that it should make sense and also be worth researching. In its broadest sense, verification refutes ethics, metaphysics and theology as non-provable and scientifically non-testable. Verificationism is rooted in Aristotelian philosophy where the basic tenet is that “only what is known can be tested.” The idea fell out of use superseded by falsifiability and later theories.

Science is in serious danger of devaluation in the public perception, due to the media saturation with sensationalist results. Verificationism acts as a barrier against junk science and useless research. If a theory is non-testable, or has no conceivable use, then, it is not worth testing. A lack of verification leads to bias, where a scientist fits the evidence around a theory, rather than using the scientific method. Let us take a practical example:

Erich Von Daniken postulated a theory that the Nazca lines were landing guides for alien spacecraft. This idea was built around a flimsy premise: they can only be seen fully from the air; therefore, they must have been constructed for the benefit of aliens. Verification error occurred because he started with the assumption that his theory was right and looked for evidence, however it tends to fit. Verification spots out the fallacies in this thesis statement but, undaunted, he went on to find evidence to fit his theory. Proudly, he proclaimed that he had proven beyond doubt that aliens landed in the Nazca desert. If, he had followed the scientific method, he should have said, “The Nazca lines are visible from the air. There must be a reason. What is the most likely reason?” He could then use reasoning and Ockham’s Razor, to generate simpler hypothesis and avoid verification errors.

**Verification and Falsification: Similarity and Difference**

The process of science is undertaken through two similar but distinct paths: verification and falsification. The two, though different, have more similarities than they have differences. Verification and falsification are based on two strands of knowing something; these are empirical data and rationality; Empirical knowledge is basically that knowledge which is presented to our senses. Direct empirical knowledge is generally considered reliable and so, it is a solid and trusted route to knowledge. Rational knowledge tends to depend on things that are logically true and which could be no other way. One plus one equals two (1 + 1 = 2) is a logical truth. The law of excluded middle, “All objects of a certain type have attribute x or all objects of a certain type do not have attribute x”, is a logical truth. Example “all pigs have legs” is either true or not true. If we find a pig that does not have four legs, then, the statement is false. But, we can be sure that all pigs either have four legs or do not have four legs, because if they do, then, they do, and if they do not, then, they don’t. Either way, they do have four legs or they do not have four legs. There is no middle ground.

Verification and falsification are each based on empirical data and rational argument though each places a different emphasis on one side of this equation over the other. Verification demands that any scientific hypothesis be confirmable through the senses. So, important is the idea of verification that any statement which cannot be examined via the senses is dismissed as nonsensical. Falsification requires that an idea be put into a theoretical postulate which is assumed to be a candidate for truth. The postulate has to be capable of being falsified. The process then necessitates the scientist designing an experiment which is capable of disproving the hypothesis. If the hypothesis stands up against the experiment, it is not considered to be true, merely a candidate for truth. The more the experiments the hypothesis defeats, the more that hypothesis is considered a candidate for truth. With falsification, nothing advances past the idea of being a theory, though something could be highly rated as a good theory.

Simply put, in verification, the observation comes first and the theory develops out of the observation. In falsification, the theory comes first and our observations are manufactured in an attempt to disprove our theory. Science can provide examples from history where both verification and falsification have proven to be successful routes to scientific truths. Often, the route taken was a matter of luck or circumstance rather than something that was considered beforehand. If someone has a good theoretical idea, then, he will design an experiment to test that theory. This would make him a practitioner of the falsification principle. But, through experiment, the scientist spots an anomaly in his theory and adjusts that theory because of what he observes. He is now verifying his observation. This is an application of the verification principle.

**Models in Science**

Models are of central importance in many scientific contexts. They are one of the principle instruments of modern science. Philosophers are increasingly acknowledging the importance of models and are probing the assorted roles models play in scientific practice. Thus, today, we talk about different model-types in the realm of philosophical literature; examples include probing models, phenomenological models, computational models, developmental models, explanatory models, idealized models, scale models, didactic models etc.

It is however a concern trying to actually tell or understand the real nature of models. What is the representational nature of models (ontology)? What kind of things are models (epistemology)? How do we learn with models? How do models relate with theory? What are the implications of a model based approach to science for the debates over scientific realism, reductionism, explanation and laws of nature?

**Models as Representational Categories**

Models perform basically two fundamentally different representational functions (1) A model can be a representation of a selected part of the world (the target system) depending on the nature of the phenomena or models of data. (2) A model can also represent a theory in the sense that it interprets the laws and axioms of that theory. These two notions of functions of models are not mutually exclusive as scientific models are representations in both senses and are the same.

**Models as Representations of Phenomena**

Many scientific models represent a phenomenon, where ‘phenomenon is used as an umbrella term covering all relatively stable and general features of the world that are interesting from a scientific point of view. Empiricists like Van Fraasen (1980) limits the phenomena represented by models to only observables while realists like Bogen and Woodward (1988) do not impose such restrictions.*[Realism is the belief that matter, objects etc have real existence beyond our perception of them]*. The billiard ball model of a gas, the Bohr model of an atom, the double helix model of DNA, the scale model of a bridge etc are well known examples for models of this kind. A problem however arises when we consider the virtue, way or manner in which a model is a representation of something else. Not that it is now common to interpret or construe models as non-linguistic entities rather than as descriptions, this has a wide range of consequences. If we for instance, understand models as descriptions, the problem arises – how well can language relate to reality because language is the required tool through which any phenomena can be described. This has been a concern in the field of philosophy of language – relating language to actual experience which language describes. Also, if we understand models as non-linguistic entities, we face the new question of what it is for an object (that is not a word or sentence) to scientifically represent a phenomenon. Surprisingly, though, until recently, this question has not attracted much attention in the 20th century philosophy of science, despite the fact that the corresponding problems in the philosophy of mind and in aesthetics have been discussed extensively.

**Another problem arises when we reflect on the representational style of models.**

It is common place that one can represent the same subject matter in different ways. This pluralism does not seem to be a prerogative of the fine arts alone as the representations used in sciences are not all of one kind either. Weizacker’s liquid model represents the nucleus of an atom in a manner very different from the shell model; a scale model of the wing of an airplane represents the wing in a way that is different from how a mathematical model of its shape does. What representational styles are there in sciences? Because of the proliferation and variety in the use of models in representing specific phenomena, scholars have postulated ideas on what relationship should exist between a model and the targeted phenomenon it represents.

Scholars like Fraasen suggests that a model and its target have to be isomorphic or partially isomorphic to each other. Another set of scholars such as Mundy and Swoyer de-emphasize formal requirements in favour of similarity between the model and the phenomenon it represents. This approach enjoys some advantage over the isomorphism view because it is less restrictive and also can account for cases of inexact and simplifying models. However, this account remains empty as long as no relevant respects and degrees of similarity are specified. The specification of such respects and degrees depends on the problem at hand and cannot be made on the basis of purely philosophical considerations.

**INDUCTION**

**Conceptual Analysis**

Induction is a specific form of reasoning in which the premises of an argument supports a conclusion, but does not ensure it. The topic of induction is important in analytic philosophy for several reasons and is discussed in several philosophical subfields including logic, epistemology and philosophy of science. However, the most important philosophical interest in induction lies in the problem concerning the justifiability of induction. This problem is often called “the problem of induction” and was discovered by the Scottish Philosopher – David Hume (1711 – 1776).

Inductive reasoning (induction) is the procedure of reasoning in which we take a particular fact towards common conclusion, but it does give guarantee that the grounds of intellectual argument hold the truth or correction of a conclusion. Through inductive conclusion, a single statement can be converted into large amounts of general theories or statements which mean that inductive reasoning is the process which leads specific statements into more general form. Induction is based on individual occurrences and on these bases, those occurrences or things are generalized in higher range. To simplify this, we can make our example supposing we know and have seen seminarians studying at Bigard Memorial Seminary; we can conclude that all seminarians study at Bigard Memorial Seminary. But, this position cannot be justified because there are many other seminaries both within Nigeria and beyond where seminarians study.

Inductive reasoning is criticized by many philosophers such as David Miller, Karl Popper and David Hume. These philosophers have controversial debate on induction and some of them even reject its state of being entirely.

**Types of Inductive Reasoning**

1. **Enumerative Induction:** This is induction in the real sense of the word. It is the kind of induction that philosophers are interested in. Enumerative induction comes in two forms – strong induction and weak induction. Here, induction is classified according to the strength of its output. Strong induction has the following form;

A1 is a B1

A2 is a B2

A3 is a B3

Therefore all As are Bs

An example of strong induction is that all ravens are black because each raven that has been observed has been black. In other words, since each observed raven is black, all ravens are black. Notice that in strong induction, the morality or nature of the assumptions can make us sure or clear that the conclusions will be based on truth, but still there is no guarantee that it will be 100% correct. Consider the earlier example that seminarians are observed to study at Bigard. But, this position is doubtful or unclear – uncertain because, once we find a single seminarian that studies outside Bigard, the foundation of that argument crumbles.

However, notice that one needs not make such a strong inference with induction because of the tendency of such to fail at the first test. This is what the other type of induction known as weak induction brings to us. Weak induction has the following form:

A1 is a B1

A2 is a B2

An is a Bn

Therefore, the next A will be a B.

An example of a weak induction is that because every raven that has ever been observed has been black, the next observed raven will be black. Notice that the tendency to over generalize conclusions drawn from particular instances is minimized.

**Mathematical Induction**

Enumerative induction should not be confused with mathematical induction. When enumerative induction concerns matters of empirical facts, mathematical induction concerns matters of mathematical facts. Specifically, mathematical induction is what mathematicians use to make claims about an *infinite set* of mathematical objects.

Mathematical induction is different from enumerative induction because it guarantees the truth of its conclusions since it rests on what is called an “inductive definition” (sometimes called a “recursive definition”). Inductive definitions define sets (usually infinite sets) of mathematical objects. They consist of a ***base clause*** specifying the basic element of the set, one or more ***inductive clauses*** specifying the additional elements as generated from existing elements and the ***final clause*** stipulating that all of the elements in the set are either basic or in the set because of one or more applications of the inductive clause or clauses. For example: A is the set of 2, 4, 6. 8, 10, 12, 14, 16. This written mathematically appears thus:

A = {2, 4, 6, 8, 10, 12, 14, 16}

The above immediately indicates to one that A is a set which contains even numbers and the members of the set are infinite even though only eight numbers are listed in the set. Thus, every even number ad infinitum falls within the set ‘A’. This is why we say that mathematical set unlike enumerative set guarantees the truth of its conclusion. In the above sample, set A, the base clause is 2, the inductive clause(s) are the other members of the set generated from 2 such as 4, 6, 8, etc; while the final clause is 16 but, notice that from 16, we can also infer the subsequent members of the set. Notice, that mathematical induction are both infallible and infinite because it rests on the inductive definition unlike enumerative induction which does not. *Inductive definition defines the nature of the set, its membership and the way subsequent members of the set must be derived.*

**Non-inductive Reasoning**

Induction contrasts with two other important forms of reasoning- deduction and abduction.

**Deduction**

Deduction is a form of reasoning whereby the premises of the argument guarantee the conclusion. Or more precisely, in a deductive argument, if the premises are true, then the conclusion is true. There are several forms of deductive reasoning (deduction) but the most basic one is *modus ponens*. Modus ponens takes the following format:

If A, then B

A,

Therefore B

Deductions are unique because they guarantee the truth of their conclusions if the premises are true. In this sense, deduction shares some affiliation with mathematical induction. Consider the following example of deductive argument:

Either Chucks runs track or he plays tennis

Chucks does not play tennis

Therefore, chucks runs track.

Notice from the conclusion of this argument that there is no way the conclusion can be false because the premises are true. Thus, the veracity of the conclusion of an ideal deductive argument is already and always contained in the premise(s) that help(s) to draw the conclusion. This is not the case however with inductive reasoning. Take the following example:

Every raven that has ever been observed has been black

Therefore, all ravens are black.

The above example is a typical inductive mode of reasoning. This manner of reasoning (induction) is deductively invalid because its premises can be true while its conclusion is false. For instance, some ravens could be brown although no one has seen them yet. Thus a feature of induction is that they are deductively invalid.

**Differences Between Induction and Deduction**

In Logic, induction and deduction are prominent methods of reasoning. Sometimes, people use induction as a substitute for deduction and erroneously make false and inaccurate statements.

Deduction uses more general information to arrive at a specific conclusion. It can be viewed as a pattern of reasoning wherein the conclusion is considered as the logical following of the premise or argument. The validity of the conclusion is based on the validity of the premise or argument. The conclusion strongly depends on the premises or the arguments in a deductive reasoning. Consider the following examples of deductive reasoning:

1. The solar system has 8 planets.

Earth is one of the planets in the solar system.

Therefore, Earth is one of the eight planets.

1. Party ‘A’ won the election

Mr X was the candidate for party ‘A’

Therefore, Mr X will get the office.

Induction is a process where individual arguments and premises are used to develop a generalization or a conclusion that can be attributed to much more than the initial subjects. In this method, the conclusion may be validated or disproved by the preceding premises. Consider the following examples:

*All the rivers I crossed flow toward the ocean*

*Therefore, all the rivers are flowing toward the ocean.*

The above induction is true for all rivers because every river naturally flows into the ocean. But notice the movement from particulars to general. Consider this example also:

*Month of August has experienced drought for the last 10 years.*

*Therefore, there will be drought conditions here for every August in Future.*

This conclusion is not certain; it is probabilistic; it may hold true or may not. Most traditionally inductive reasoning follow this standard and hence suffer from the same lack.

Summarily, the following points demarcate deduction from induction:

1. Deduction is a form of logic that achieves a specific conclusion from the general, drawing necessary conclusions from the premise. Induction is a form of logic that achieves general results from specific cases, drawing probable conclusions from the premises.
2. In deduction, the conclusion is accepted as the logical result of the premises, while in induction, the conclusion is formed from individual premises which may support it but does not make it true.
3. In deduction, the premises both support and confirm the truthfulness of the conclusion but in induction, the premises may support the conclusion but it rarely confirms it.
4. Deduction concludes with necessity while induction concludes with probability.

**ABDUCTION**

Abduction is a form of reasoning whereby an antecedent is inferred from its consequent; a cause is inferred from its effect. The form of abduction is below:

If A, then B

B,

Therefore, A

Notice immediately that abduction is a form of reasoning that is totally different from both induction and deduction. Abductive reasoning usually starts with an incomplete set of observations and proceeds to the likeliest possible explanation for the group of observation. It is based on making and testing hypothesis using the best information available. *It often entails making an educated guess after observing a phenomenon. For which there is no clear explanation.* For example, a person walks into their living room and finds torn up papers all over the floor. The person’s dog has been alone in the room all day. The person concludes that the dog tore up the papers because it is the most likely scenario. Note, a rat may have been the culprit or some other factor; but the ‘dog theory’ is the most likely conclusion.

Notice that abductive reasoning is deductively invalid just like inductive reasoning because the truth of the premises in an abductive argument does not guarantee the truth of their conclusions. For example, *though all dogs have legs, seeing legs does not imply that they belong to a dog.* Abduction is different from induction, even though, both are used amply in everyday affairs as well as in scientific reasoning.

Note: *While both forms of reasoning do not guarantee the truth of their conclusions, scientists since Isaac Newton (1643 – 1727) have believed that induction is a stronger form of reasoning than abduction.*

Abductive reasoning is useful for forming hypotheses to be tested. Abductive reasoning is often used by doctors who make a diagnosis based on test results and by jurors who make decisions based on the evidence presented to them.

**The Problem of Induction**

The problem of induction calls into question all empirical claims made in everyday life or through the scientific method and, for that reason, the philosopher C. D. Broad asserts that “induction is the glory of science and the scandal of philosophy.” Although the problem arguably dates back to the Pyrrhorism of ancient philosophy, as well as the Carvaka school of Indian Philosophy, David Hume introduced it in the mid 18th century.

The original problem of induction can be simply stated thus: *it concerns the support or justification of inductive method;* method that predict or infer, in Hume’s words, that “instances of which we have had no experience resemble those of which we have had experience. Such methods are clearly essential in scientific reasoning as well as in the conduct of our everyday affairs. The problem of induction borders on the philosophical question of whether inductive reasoning leads to knowledge understood in the classic sense since it focuses on the alleged lack of justification for either.

1. Generalizing about the properties of a class of objects based on some number of observations of particular instances of that class (e.g. the inference that “all swans we have seen are white and therefore, all swans are white,” before the discovery of black swans) or
2. Presupposing that a sequence of events in the future will occur as it always has in the past (e.g., that the laws of physics will hold as they have always been observed to hold.)

Hume calls this the principle of Uniformity of Nature. The problem is how to support or justify the above claims made by induction and it leads to a dilemma: *the principle cannot be proved deductively, for it is contingent and only necessary truths can be proved deductively*. *Nor can it be validly supported inductively – by arguing that it has always or usually been reliable in the past – for that would beg the question by assuming just what is to be proven.* A century after Hume emphasised the problem and argued that it is insoluble; J. S. Mill gave a more specific formulation of an important class of inductive problem. Mill notes, “Why is a single instance in some cases sufficient for a complete induction, while in others myriads of concerning instance, without a single exception known or presumed, go such a little way toward establishing a universal proposition?”

For example, compare the following two assertions:

1. Everyone seated in the bus is going northward
2. Everyone seated in the bus was born on a prime numbered day of the month.

It is very easy to accept the first assertion inductively as true because the bus itself is heading northward, but it is illogical to say the same of the second. These inconsistencies are also part of what constitute what is now known as the problem of induction.

**Origin of the Problem Prior to Hume**

Although David Hume is usually considered as the one that first raised doubts on the validity and justifiability of inductive reasoning, evidence indicates that as early as the ancient period of the development of human reasoning, scholars like Sextus Empiricus had already made such an observation. Pyrrhonian skeptic Sextus Empiricus first questioned the validity of induction, positing that a universal rule could not be established from an incomplete set of particular instances. He notes; “when they propose to establish the universal from the particulars by means of induction, they will affect this by a review of either all or some of the particulars. But, if they review some, the induction will be insecure, since some of the particulars omitted in the induction may contravene the universal; while if they are to review all, they will be toiling at the impossible since the particulars are infinite and indefinite. (see, Sextus Empiricus, *Outlines of Pyrrhonism,* p. 283).

Although, the criterion argument applies to both deduction and induction, scholars believe that Sextus Empiritus’ argument “is precisely the strategy Hume invokes against induction: it cannot be justified, because the purported justification, being inductive is circular. Weintraub, commenting on the problem of induction notes that Hume’s most important legacy is the supposition that the justification of induction is not analogous to that of deduction.

The Carvaca, a materialist and skeptic school of Indian Philosophy, used the problem of induction to point out the flaws in suing inference as a means of gaining valid knowledge. They held that since inference needed an invariable connection between the middle term and the predicate and further, that since there was no way to establish this invariable connection, that the efficacy of inference as a means of valid knowledge could never be stated (see, S. Radhakrishnam, *Indian Philosophy*, Vol. III, Pg. 533). The 9th century Indian skeptic, Jayarasi Bhalta, also made an attack on inference along with all means of knowledge, and showed by a type of reductive argument that there was no way to conclude universal relations from observation of particular instances (see Franco Eli, *Perception, Knowledge and Disbelief: A Study of Jayarasi Scepticism*, 1927).

Medieval writers such as Ghazali and William of Ockham connected the problem of induction with God’s absolute power, asking how we can be certain that the world will continue behaving as expected when God could at any moment miraculously cause the opposite.

Duns Scotus argued that inductive inference from a finite number of particulars to a universal generalization was justified by “a proposition reposing in the soul, whatever occurs in a great many instances by a cause that is not free, is the natural effect of that cause” (Duns Scotus, *Philosophical Writings*, 1962). Some 17th century Jesuits contend that although God could make the end of the world at any moment, it was necessarily a rare event and hence, our confidence that it would not happen very soon was largely justified.

**Hume on Induction**

The source of the problem of induction as it is known today is Hume’s brief argument in Book 1, part 3, section 6 of the *Treatise on Human Nature.* The great historical importance of this argument, not to speak of its intrinsic power, recommends that reflection on the problem begin with a rehearsal of it.

It should be noted that the term induction does not appear in Hume’s argument or anywhere in the *Treatise* or the *First* *Inquiry*, for that matter. Hume’s concern is with inferences concerning causal connections which on his account are the only connections which can lead us beyond the immediate impression of our memory and senses (see, *Treatise on Human Nature*, 89). However, the difference between such inferences and what we know today as induction, allowing for the increased complexity of the contemporary notion is largely a matter of terminology. Hume divides all reasoning into demonstrative (by which he means deductive) and probabilistic (by which he means the generalization of causal reasoning). The deductive system that Hume had at hand was just the weak and complex theory of ideas in force at the time augmented by syllogistic logic (*Treatise*, Book 1, Part 3, Section 1). His demonstrations are not same with the usual idea of deductive reasoning but they are founded on the principle which holds that conceivable connections are possible; inconceivable connections are impossible; and necessary connections are those the denial of which are impossible or inconceivable. It should also be noted that Hume’s argument against induction applies only to what is known today as enumerative induction.

First, Hume ponders the discovery of causal relations, which form the basis for what he refers to as ‘matters of fact.’ He argues that causal relations are found not by reason, but by induction. This is because, for any cause, multiple effects are conceivable, and the actual effect cannot be determined by reasoning about the cause; instead, one must observe occurrences of the causal relation to discover that it holds. For example, when one thinks of a billiard ball moving in a straight line toward another, one can conceive that the first ball bounces back with the second ball remaining at rest, the first ball stops and the second ball moves, or the first ball jumps over the second etc. there is no reason to conclude any of these possibilities over the others. Only through previous observation can it be predicted, inductively, what will actually happen with the balls. In general, it is not necessary that causal relation in the future resemble causal relations in the past, as if is always conceivable otherwise. For Hume, this is because the negation of the claim does not lead to a contradiction.

Next, Hume ponders the justification of induction. If all matters of facts are based on causal relations, and all causal relations are found by induction, then induction must be shown to be valid somehow. Hume posits that there is no logical connection between the propositions put together to arrive at an inductive conclusion. He suggests that one connects two or more propositions not by reason but by induction. If a deductive justification for induction cannot be provided, then, it appears that induction is based on an inductive assumption about the connection which could be begging the question. Induction itself cannot validly explain the connection. In this way, the problem of induction is not only concerned with the uncertainty of conclusions derived by induction, but, doubts the very principle through which those uncertain conclusions are derived.

In summary, David Hume questions the strength and justification of inductive reasoning. He argues that induction is an unjustifiable mode of reasoning for the following reasons. One believes inductions are good because nature is uniform in some deep respects. For instance, one induces that all ravens are black from a small sample of black ravens because he believes that there is a regularity of blackness among ravens, which is a particular uniformity in nature. However, why suppose that there is a regularity of backness among ravens? What justifies this assumption? Hume claims that one knows that nature is uniform either deductively or inductively. However, one cannot deduce this assumption and an attempt to induce the assumption only make a justification of induction circular. Thus, induction is an unjustifiable form of reasoning. This is Hume’s problem of induction.

Instead of becoming a sceptic about induction, Hume sought to explain how people make inductions, and considered this explanation as a good way of justification of induction that could be made. Hume claimed that one can make induction because of habits. In other words, habit explains why one induces that all ravens are black from seeing nothing but black ravens beforehand.

**Nelson Goodman – The New Riddle of Induction**

Nelson Goodman (1955) questioned Hume’s solution or rather position, with regard to the problem of induction in his classic text, *Fact****,*** *Fiction**and**Forecast****.*** Although Goodman thought that Hume was an extraordinary thinker, he believed that Hume made one crucial mistake in identifying habit as what explains induction. The mistake is that people readily develop habits to make some inductions but not others even though they are exposed to both observations. Goodman develops the following example to demonstrate his point: “suppose that all observed emeralds have been green. Then we would readily induce that the next observed emerald would be green. But why green? Suppose ‘grue’ is a term that applies to all observed green or unobserved blue things, then, all observed emeralds have been ‘grue’ as well. Yet none of us would induce that the next observed emerald would be blue even though there would be equivalent evidence for this induction.”

Thus, the New Riddle of Induction is not about what justifies induction, but, rather, it is about why people make the inductions they do given that they have equal evidence to make several incompatible inductions. Goodman’s solution to the new riddle of induction is that people make inductions that involve familiar terms like “green” instead of ones that involve unfamiliar terms like “grue” because familiar terms are more entrenched than unfamiliar terms, which simply means that familiar terms have been used in more inductions in the past. Thus, statements that incorporate entrenched terms are “projectible” and appropriate for use in inductive arguments.

Notice that Goodman’s solution is somewhat unsatisfying. While he is correct that some terms are more entrenched than others, he provides no explanation for why unbalanced entrenchment exists. More so, he ended up only explaining why induction as a kind of reasoning is always invoked by people in spite of its shortcomings; he did not deal precisely with the questions posed by Hume against induction – that is, how to justify inductive reasoning which Hume considers as flawed.

**Willard Van Orman Quine on the Problem of Induction - The Raven Paradox**

In order to complete the Goodman’s project, Quine, (1956 – 2000) theorizes that entrenched terms correspond to “natural kinds.” In 1969, Quine demonstrates his position with the help of a familiar puzzle he borrowed from Carl Hempels (1905 - 1997), known as ‘the Raven Paradox.’

It reads: “*suppose that observing several black ravens is evidence for the induction that all ravens are black, then, since the contra-positive of “all ravens are black” is “all non-black things such as green leafs, brown basketballs and white baseballs is also evidence for the induction that all ravens are black. But how can this be*?” Quine argues that observing non-black things is not evidence for the induction that all ravens are black because non-black things do not form a natural kind and projectible terms only refer to natural kinds (eg. “ravens” refer to ravens); thus, they are projectible and become entrenched because they refer to natural kinds.

Even though this extended solution proffered by Quine to the New Riddle of Induction sounds plausible, it is not without any flaw. Several of the terms we use in natural language do not correspond to natural kinds, yet, we still use them in induction. A typical example from the philosophy of language is the term ‘game’ first used by Ludwig Wittgenstein (1889 – 1951) to demonstrate what he called “family resemblance”. Look at how competent English speakers use the term “game”. Examples of games are monopoly, card games, the Olympic games, war games, tic-tac-toe, and so forth. Now, what do all of these games have in common? Wittgenstein would say “nothing”, or if there is something they all have in common, that feature is not what makes them games. So, games resemble each other although they do not form a kind. Of course, even though games are not natural kinds, people make inductions with the term, “game”.

**Karl Popper on the problem of Induction**

Popper posits that science does not use induction and induction is in fact a myth (see, *Conjectures and Refutations*, p. 53). Instead, knowledge is created by conjecture and criticism. The main role of observations and experiments in science, he argued, is in attempts to criticize and refute existing theories. According to Popper, the problem of induction as usually conceived is asking the wrong question: it is asking how to justify theories given they cannot be justified by induction. Popper argued that justification is not needed at all and seeking justification “begs for authoritarian answer.” Instead, Popper said, what should be done is to look to find and correct errors. Popper regarded theories that have survived criticisms as better corroborated in proportion to the amount and stringency of the criticism, but in sharp contrast to the inductivist theories of knowledge, emphatically, as less likely to be true (see, *Logic of Scientific Discovery*, p. 43). Popper held that seeking for theories with a high probability of being true was a false goal that is in conflict with the search for knowledge. Science should seek for theories that are most probably false on one hand (which is the same as saying that they are highly falsifiable and so there are lots of ways they could turn out to be wrong), but still all actual attempts to falsify them have failed so far (that they are highly corroborated).

Popper gave two formulations of the problem of induction. The first is the establishment of the truth of a theory by empirical evidence; the second, slightly, weaker is the justification of a preference for one theory over another as better supported empirically. He declared both of these as insoluble on the grounds that scientific theories have infinite scope and no finite evidence can ever adjudicate among them. He did however hold that theories can be falsified and that falsifiability or the liability of a theory to counter example was a virtue. Falsifiability corresponds roughly to the proportion of models in which a (consistent) theory is false. Highly falsifiable theories thus make stronger assertions and are in general more informative. Though, theories cannot be corroborated; a better corroborated theory is one that has been subjected to more and more rigorous tests without having been falsified. Falsifiable and corroborated theories are thus to be preferred, though, as the impossibility of the second problem of induction makes evident, these are not to be confused with support by evidence.

Wesley C. Salmon criticizes Popper on the grounds that predictions need to be made both for practical purposes and in order to test theories. That means that Popperians need to make a selection from the number of unfalsified theories available to them, which is generally more than one. Popperians would wish to choose well-corroborated theories, in their sense of corroboration but face a dilemma; either they are making the essentially inductive claim that a theory’s having survived criticism in the past means it will be a reliable predictor in the future; or Popperian corroboration is no indicator of predictive power at all, so there is no rational motivation for their preferred selection principle.

**Confirmation Theory**

In contemporary philosophy, confirmation theory can be basically described as the area where efforts have been made to take up the challenge of defining plausible models of non-deductive reasoning. Its central technical term- confirmation, has often been used more or less interchangeably with “evidential support,” “inductive strength” and the like. Confirmation theory has proven a rather difficult Endeavour. In principle, it aims at providing understanding and guidance for tasks such as diagnosis, precaution and learning in virtually any area of enquiry. Yet, popular accounts of confirmation have often been taken to run into troubles even when faced with toy philosophical examples. Be that as it may, there is at least one real-world kind of activity which has remained a prevalent target and a bench-mark, ie, scientific reasoning and especially key episodes from the history of modern and contemporary natural sciences. The motivation for this is easily figured out. Mature sciences seem to have been uniquely effective in relying on observed evidence to establish extremely general, powerful and sophisticated theories. Indeed, being capable of receiving genuine support from empirical evidence is itself a very distinctive trait of scientific hypothesis as compared to other kinds of statements. A philosophical characterization of what science is would then seem to require an understanding of the logic of confirmation. And so, traditionally, confirmation theory has come to be a central concern of philosophers of science.

**The Goal of Confirmation Theory**

The ultimate purpose of confirmation theory is to solve the problem of induction. This problem or its solution has two parts: First, to codify induction, that is, to state rules of inductive inference comparable to the rules of deductive logic. Secondly; to justify inductive inference or explain why this sort of reasoning is rational. The motivation of the first part of the problem seems straightforward enough. The reason why it constitutes a philosophical ‘problem’ is due to the great difficulty that arises in carrying the project out. The source of the second part of the problem is not immediately obvious. Just as we do not waster our time attempting to justify deduction per se, it is not at first clear why we should feel required to ‘justify’ induction. But, the requirement derives from an argument of David Hume’s that appears to show that inductive conclusions are never justified. If there is such an argument, then in the light of it, one would consider how inductive knowledge is possible.

To refresh our memory briefly on Hume’s argument against induction; Hume’s refutation of induction essentially goes as follows;

1. There are only three possible kinds of knowledge (a) ‘Relations of ideas’ which are things that are true by definition (b) Direct observations and (c) Knowledge based on inductive reasoning, where an inductive inference is a generalization from experience.
2. Any generalization from experience presupposes the ‘uniformity principle,’ or that the future will resemble the past.
3. So, inductive knowledge can only be justified if this presupposition is justified.
4. The uniformity principle is not true by definition
5. Nor is its truth directly perceived
6. And since all the inductive inference presupposes the uniformity principle, any inductive argument for it would be circular.
7. So, the uniformity principle cannot be justified
8. Hence, no inductive conclusion is justified.

**Background to Hempel’s Confirmation Theory**

In a written essay on induction (1924), Jean Nicod made a very important remark; ‘consider the formular or the law: *F entails G.* How can a particular proposition, or more briefly, a fact affect its probability? If this fact consists of the presence G in a case of F, it is favourable to the law………, on the contrary, if it consists of the absence of G in a case of F, it is unfavourable to this law.

Nicod’s work was influential to the development of Carl Gustav Hempel’s early studies in the logic of confirmation. In Hempel’s view, the key valid massage of Nicod’s statement is that the observation report that an object ‘a’ displays properties ‘f’ and ‘g’ (eg. That ‘g’ is a swan and is white) confirms the universal hypothesis that all f-objects are G-objects (namely, that all swans are white). Apparently, it is by means of this kind of confirmation by instances that one can obtain supporting evidence for statements such as “sodium salts burn yellow”, “wolves live in a pack,” or “planets move in elliptical orbits.”

**Carl Gustav Hempel’s Theory of Confirmation**

Before he gives his account of confirmation, Carl Hempel enunciates these three conditions on the confirmation relation that he thinks any theory of confirmation aim to satisfy.

1. **Entailment Condition**: If E entails H, then, E confirms H.
2. **Consequence Condition**: If E confirms each of a set of sentences K, then, E confirms every logical consequence of K.
3. **Consistency Condition**: E is consistent with the class of all hypotheses that E confirms.

Hempel’s theory of confirmation which is supposed to satisfy the above conditions says that for any observational evidence, E, and any hypothesis, H, E confirms H, if and only if E entails the ‘development’ of H with respect to the objects mentioned in E. The ‘development’ of a hypothesis with respect to a set of objects is to be understood as what the hypothesis would assert if those were the only objects in existence; or what the hypothesis does assert about those objects. For instance, the development of “everything is pink” with respect to the Empire State Building and Peter would be: “The Empire State Building and Peter are Pink.” The development of “There is a perfect being” with respect to Chucks Peter would be “Chucks Peter is a perfect being.” To put it another way: the development of H with respect to O plus the proposition that nothing but O exists entails H; and H plus the assumption that nothing but O exists entails the development of H with respect to O; and the development of H is an observational sentence.

To sum up, we have four illustrations of how Hempel’s theory articulates Nicod’s basic ideas. They are as follows:

1. (The direct report of) a white swan (directly)Hempel confirms that all Swans are white;
2. (The observational report of) a white swan also hempel confirms that a further swan will be white
3. (The observational report of) a non-white swan (directly) Hempel disconfirms that all swans are white
4. (The observational report of) a non-white swan also Hempel disconfirms that a further swan will be white.

**Some Objections to Carl Hempel’s Theory of Confirmation**

In spite of the outstanding logic indicated in Hempel’s theory of confirmation, scholars have shot several criticisms at his position.

Consider the observation that this pen I am using to write occupies this region of space (a certain pen-shaped volume). This observation under Hempel’s theory, must confirm both “every region of space it occupied” and “everything that occupies this region of space.” But the two hypothesis thus confirmed are contradictory. About the other regions of space besides the one this pen occupies, one hypothesis says they are all filled, while the other says they are all empty. The first impact of this is that Hempel violates his own adequacy condition – the consistency condition.

To speak more generally, Hempel’s account is quite prodigal in doling out confirmation. His theory permits us to infer from the observation of something having a certain property, anything we please about the objects that don’t have the property. One application of this Hempelian logical liberality is the “Raven’s Paradox” – we can confirm that all ravens are black by observation of say, white shoes. Hempel is apparently willing to live with this consequence but we cannot but continue to find it counter-inductive. A parallel result is that the observation of several green emeralds before the year 2000 would confirm that all emeralds are ‘grue’, which is counter-intuitive. Hempel considers this counter-example in his ‘postscript’ and appears to give in. He does not seem, though, to regard himself as abandoning his theory of confirmation when he concedes that in actuality, contra the implications of his initial account, observations of ‘grue’ emeralds do not confirm “all emeralds are ‘grue’.” He thinks the solution is that unprojectible predicates like “grue” must be omitted from the language of science. But he has failed to see that the emeralds case is no different in principle from the raven’s case.

Both paradoxes result from Hempel allowing the observation of an X to confirm anything you please about non-Xs. He is willing to accept this for non-ravens; why is he unwilling to say the same thing about “things observed before the year 2000? That is, since Hempel accepts that observations of non-ravens confirm anything and everything about ravens, why doesn’t he accept that observations before 2000 confirm anything and everything about things after the year 2000.

Normally, the observation of some type of object is taken to confirm that there are other objects similar to it. For example, the discovery of a black hole would confirm that there are other black holes. But, in Hempel’s criterion, the observation of a black hole would disconfirm that there are other black holes, because it confirms that this object (this black hole) is the only thing in existence: “observing any object (x)x=a because (presumably) one observes that a=a, which is the development of the hypothesis.”

Similarly, we can see that Hempel’s criterion makes the observation of any sort of thing disconfirm, and never confirm, the existence of anything even ever so slightly different from it. For instance, the observation of a six foot tall man would disconfirm that there are any people as tall as 6’1” (because it entails the development of “every man is less than 6’1” tall – with respect to the man observed), and the observation of a five-foot and a six-foot man would disconfirm that there is anybody between five and six feet tall.; whereas intuitively, the evidence ought to confirm the hypotheses in these cases.

Finally, Hempel makes no attempt to actually justify induction. There is no explanation of why it would be rational to believe in things that have been confirmed under his criterion of confirmation. Furthermore, in the absence of any such justification, it is difficult to feel attached to his account as an accurate description of how we reason.