The Fallibilistic Foundation of Karl Popper's Philosophy of Science

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Even a cursory survey of the history of western philosophical thought will clearly suggest how knowledge has traditionally been equated with epistemic certainty. According to this epistemology, a putative claim for knowledge is justifiably a part of the corpus of human knowledge if it is beyond epistemic doubt, if it is an indubitable claim that can not be subject to skeptical scrutiny. Thus, because the world we as we know it is governed by the ceaseless flow of change, rendering the very notion of incorrigible empirical knowledge problematic, philosophers who sense an affinity with Platonic thought seek knowledge in an immutable world that transcends the empirical. The epistemic model we are considering also plays a crucial role in Cartesian metaphysics. Emulating the logical rigor of mathematics, where elaborate theorems of logical certainty can be deduced logically from a set of self-evident axioms by applying inference rules that are truth preserving, this grandiose system attempts to rationally construct a logically incorrigible worldview by applying the canons of logic to a self-evident premise. The Cartesian program is predicated on the belief that a viable metaphysics must expunge philosophical skepticism by manifesting the certainty which we find in mathematics. Kant's adherence to the epistemic model that equates knowledge with certainty is latent in his philosophy of knowledge. Kant's renowned criticism of the metaphysical enterprise follows from his philosophical investigations into the conditions of human experience as such. Because metaphysics purports to give answers to questions that are beyond the reach of human experience, a philosophically sound metaphysics is impossible. We cannot but experience the world as causally interconnected within the dimension of space and time. The epistemic conditioning of human experience presupposes the certainty of Newtonian physics, for the mind's cognitive machinery is necessarily a Newtonian framework that gets imposed on the datum of experience.

Popper's rebuttal of the model we have been considering is clear. Empirical knowledge is forever bound to be fallible. The best-corroborated theories we have remain conjectural. Understanding knowledge in terms of certainty is simply, for Popper, a blatant contradiction, an egregious error that has a detrimental effect on the way we should philosophically understand the true nature of human knowledge. The following two passages will make explicit Popper's overarching fallibilism : "Even our best-tested and best-corroborated scientific theories are mere conjectures, successful hypotheses, and they are forever condemned to remain conjectures or hypotheses." (2000, pg.38) Elsewhere Popper writes : "What we have best is conjectural knowledge : that is all we can have. Our best knowledge, by far our best, is scientific knowledge. Yet scientific knowledge too is only conjectural knowledge." (2005, pg.55)

Popper's fallibilism, being the cornerstone of his philosophical account of scientific knowledge, underlies his exposition of the standard philosophical themes that appear in the philosophy of science. It is, therefore, not an epistemic doctrine that can be expunged from Popper's philosophy as otiose without attenuating both the originality and force of the arguments he presents. But what exact role does fallibilism have within Popper's philosophy of science? To what extent is Popper's theory of science founded upon his fallibilism? The purpose of this paper is to examine and answer the aforementioned questions.

I

For many, scientific knowledge is objective, rational, and reliable, in contradistinction to the alleged claims for knowledge propounded by those belonging to academic disciplines outside the sciences. Further, the objectivity of scientific knowledge is commonly thought to result from the application of the method of scientific inquiry. It is this method employed by scientists which helps demarcate science from pseudoscience. Even without recourse to the philosophical analysis of the methodology of science, we undoubtedly have a somewhat vague notion as to how scientists proceed with their work. The very word 'science' implies even for the neophyte, experiments, the framing of hypotheses, data collection, mathematical analysis, statistics, and much more. One of the central themes we find in the philosophy of science is to articulate with clarity and precision this very method that is responsible for yielding the wealth of scientific knowledge.

One highly influential philosophical theory, commonly referred to as inductivism, gives us the following account of the method of science: First, scientists, because interested in framing objective hypotheses that objectively reflect the true nature of the empirical world they are investigating, passively record the ways in which sense-experience impinges upon their sensory faculties. If theories are to faithfully reflect the way in which the world is objectively structured, scientists should allow the world to determine the nature and content of the hypotheses they formulate. The hypotheses should conform to the world, and not the other way around. Scientists shouldn't prematurely decide upon the truth of the theories they uphold by distorting the facts so as to make them conform to what their theories maintain. But in order to derive the laws of nature from the spectrum of facts that is somehow given in experience, scientific inquiry must require scientists to record what they experience without recourse to prejudices, tradition, or any other conceivable factor that can inhibit the objective recording and description of the facts. Scientists are to approach the world empty of preconceptions. Secondly, the passive observation of the world will reveal various types of regularities, some of which will be accidental or coincidental. But amongst the empirical events scientists witness, some will be regularly conjoined, implying an empirical conjunction of events that is far from being arbitrary. Such events might be empirically significant, for they may suggest the course nature actually takes, revealing scientific truths that are true independent of human understanding. The third stage of the inductive process involves the framing of hypotheses. From observing the finite yet regular series of conjoined empirical events, scientists will formulate a universal proposition of the linguistic form "All Xs are Ys" that will collate the facts in question. That is, a scientific hypothesis is nothing other than an inductive generalization derived from the passive observation of a finite number of empirical facts. When the hypothesis is thus framed, the scientists will then be required to amass the relevant facts that lend support to it. The truth of the hypothesis can be proven, or at least the probability of the theory being true will be increased, by accumulating the facts that verify it.

Popper is highly critical of inductivism as a viable method of science. His scathing criticisms against this method in science were partly responsible for toppling it from the throne of orthodoxy. His thoughts on this topic therefore merit serious reflection. However, instead of giving an exhaustive account of every argument he raises against inductivism, criticisms that directly or indirectly reveal his philosophical views concerning the nature of science will be considered below.

First of all, inductivism presupposes the viability of observing the world without relying on or making any reference to theoretical preconceptions. Yet "observation is always selective. It needs a chosen object, a definite task, an interest, a point of view, a problem." (1989, pg.46) The sensory apparatus functions as a cognitive filter that selects and organizes the sensory input we receive. The selection process helps us carve up the world into manageable units, allowing us to make informed judgments about the world we live in. Otherwise we will literally be bombarded by an array of chaotic and disconnected sensations. The apparatus selects the sensory inputs that are deemed significant in light of the theoretical preconceptions we have, while neglecting or deleting those that have marginal theoretical significance. The human mind is not a blank slate awaiting what sense-experience can imprint. Thus, unlike what inductivism maintains, we can not jettison our preconceptions without seriously depriving the precondition for making informed and meaningful observations.

Secondly, because inductivists conceive scientific hypotheses to be derivative of sense-experience, they commonly expound the ways in which experience can function as a source or origin for the theories that get posited by scientists. Yet for Popper, the analysis of the epistemic context from which theories somehow arise is not philosophically important. "The question how it happens that a new [scientific] idea occurs...may be of great interest to empirical psychology ; but it is irrelevant to the logical analysis of scientific knowledge." (1995, pg.31) The source of knowledge (whether it be experience, rational intuition, divine inspiration, etc) is not (or should not be) a relevant concern for philosophy. What is philosophically important is whether or not the theory in question is true. Knowing the circumstances under which the theory originated in the mind of a given scientist isn't conducive for ascertaining its truth.

Finally, Popper's overtly critical arguments against induction as a logical procedure for conducting scientific research should be examined. In deductive logic, if the premises are true, then provided that valid logical inference rules are applied to the premises, the conclusion that follows must be true. It is logically contradictory to affirm the truth of the premises and deny the truth of the conclusion. Inductive reasoning is deductively invalid. The truth of the premises doesn't logically imply the truth of the conclusion, "for any conclusion drawn [inductively] may always turn out to be false." (1995, pg.27) The philosophical implication of the deductive invalidity of induction for inductivism is this : Scientific theories that are established inductively can not be proven true. This is because standard scientific theories, though couched in the form of universal propositions, are established by only appealing to a finite sequence of evidence. Scientific theories transcend the evidence adduced in favor of what they maintain. Evidence amassed in favor of a given theory in the past can not foretell whether the required evidence will be forthcoming in the future. However, those who uphold inductivism may wish to salvage inductive reasoning from the criticism just alluded to by weakening their claim as to what this reasoning process can actually accomplish. That is, they may argue that though induction can not prove the truth of scientific theories, it can, by amassing more and more evidence, increase their probable truth. But this standard response will not do for Popper. In fact, the probability of any given scientific hypothesis being true will always remain zero because it "makes assertions about an infinite number of cases, while the number of observed cases can only be finite." (1996, pg.219) Though every universal proposition of the form "All Xs are Ys" is based on a finite number of observations, it extends to an infinite number of possible observations. The probability of its truth will therefore always remain zero.

Accepting the deductive invalidity of induction, some opt for a more pragmatic justification of induction. Though the inductive method may be riddled with problems in light of philosophical analysis, making it suspect as a viable candidate for demarcating scientific from pseudoscientific theories, no one can seriously deny the fact that induction has succeeded in generating a myriad of scientific theories that has withstood the test of time. And because the method has worked in the past, we may have the epistemic warrant to rely on this method as a reliable form of inquiry to be employed in the future. The problem with this response, as Popper convincingly argues, is that it presupposes the viability of induction. By deducing "induction will work in the future" from "induction has worked in the past", the argument presupposes that inductive generalizations from the past are legitimate. But the legitimacy of induction is the very issue at stake. It seems that a pragmatic justification of induction would "have to employ inductive inferences ; and to justify these we should have to assume an inductive principle of a higher order." (1995, pg.28)

For the reasons we have examined, Popper thinks that an alternate way of demarcating scientific from pseudoscientific theories should be sought. What then is the philosophical proposal he offers? This will be the subject of the next section.

II

What differentiates scientific from pseudoscientific theories is not that the former can be inductively confirmed by experience whereas the latter can't, but that only theories of scientific status can be falsified by experience. "The criterion of the scientific status of a theory is its falsifiability, or refutability, or testability." (1989, pg.37) Elsewhere Popper reinforces the same point : "A theory is part of empirical science if and only if it conflicts with possible experiences and is therefore in principle falsifiable by experience." (2005, pg.16) As these two passages attest, scientific theories must satisfy the logical condition of being incompatible with experience. It is not because theories can be confirmed or made probable by experience that bestows them their scientific status, but because they can be shown to be wrong, that they can be subject to experimental testing that can unambiguously stipulate their mistakes and weaknesses.

More specifically, the theory, in order to be scientific, must be a universal proposition of the form "All Xs are Ys", and further, there must exist basic statements that will refute what the universal proposition maintains. Now, basic statements "have the form of singular existential statements" (1995, pg.102) that assert an observable event occurring in a certain individual region of space and time. Whereas the finite accumulation of evidence will never prove the truth of a theory, the joint acceptance of a single basic statement by the scientific community that is incongruent with what a theory maintains will prove the theory to be false. "If we are successful in deriving, logically, unacceptable conclusions from an assertion, then the assertion may be taken to be refuted." (2000, pg.75) There is thus an asymmetrical relationship between falsification and verification. Though the universal proposition "All ravens are black" can not be proven true by observing a finite number of ravens that is black, the observation of a single raven that is not black will refute the universal proposition. Thus, observation plays a significantly different role in Popper's theory of science. It is not used for confirmation but for falsification. "The function of observation...is the more modest one of helping us to test our theories and to eliminate those which do not stand up to tests." (1994b, pg.98) Yet to state the whole logical schema that grounds Popper's criterion of demarcation differently, a given theory is scientific provided that it is capable of logically excluding the existence of certain publicly observable, empirical state of affairs. That is, it can not be empirically compatible with every empirical state of affair that we find in the physical world. If empirical consequences that don't correspond to the world of experience are deducible from a given theory, then it can be deemed scientific.

Yet a theory is not rendered scientific by only satisfying the logical criterion of falsifiability. A theory can be perfectly falsifiable in the sense of logically implying the existence of putative basic statements that can possibly refute what it empirically maintains without being scientific. The other requirement Popper proposes has to do with the attitude people should take toward theories in general.

What then is the attitude Popper has in mind? The mentality he envisions is the critical attitude of forever subjecting theories to the severest tests that will reveal the theoretical faults they contain. It is the attempt of proving theories wrong, and learning from the errors they exhibit. This requires the active pursuit of countervailing evidence that will find fault with the theoretical pictures theories present. Critical tests that don't falsify a theory are so many abortive attempts at learning something about the physical world through ascertaining the errors it is impregnated with. Thus, "all theories are trials ; they are tentative hypotheses, tried out to see whether they work ; and all experimental corroboration is simply the result of tests undertaken in a critical spirit, in an attempt to find out where our theories err." (1994b, pg.97)

Given this Popperian contention that "the spirit of science is criticism" (1971a, pg.185), the very idea of confirming or justifying the truth of theories is anathema to science. This is because this procedure often dogmatically presupposes the possession of truth, which is contrary to the hypothetical or conjectural understanding of scientific knowledge. It simply sees the purpose of science as being the strengthening of the theoretical viability or truth of any given theory by amassing more and more evidence. Yet the scientific enterprise is founded upon the "spirit of the search for truth, as opposed to the belief in its possession." (1971 a, pg.131) Moreover, the uncritical and dogmatic nature of this approach in science may be responsible for scientists turning a blind eye to countervailing evidence, not to mention the deliberate distortion of facts that are not consonant with what the theory in question predicts. "If we are uncritical we shall always find what we want : we shall look for, and find, confirmations, and we shall look away from, and not see, whatever might be dangerous to our pet theories." (1994b, p.134)

In fact, Popper denies the scientific status of Marxism and Freud's theory of psychoanalysis, not because they both fail to satisfy the logical criterion of excluding putative empirical events from happening, but because Marxists and Freudians alike fail to manifest the critical method of inquiry that looks out for the theoretical errors their theories entail. Confronting evidence that doesn't accord with their predictions, they are inclined to make complex theoretical maneuvers that they think will exempt their theories from falsification. Though these maneuvers may make the theories compatible with any conceivable empirical event we find within their range of prediction, they become unfalsifiable. There is only confirmation and nothing that can count against their truth. But if the Popperian motto that in science "nothing gets justified, everything gets criticized" (Bartley, pg.112) is used as a litmus test for separating theories that are scientific from those that aren't, then it becomes highly questionable, provided Popper's characterization of Marxism and Freudian psychoanalysis is accurate, whether they can be granted the status of being scientific.

In any case, Popper's caveat against dogmatism and his endorsement of criticism as the exemplar of human rationality are rather bland and lacking in theoretical content unless given a more precise philosophical formulation. That is, the commendation of critical inquiry in science, and his philosophical injunction against dogmatism, will lack substance unless Popper specifies exactly how criticism is to be conducted in science, or outlines methodological rules that should be employed when practicing scientific inquiry. This Popper sets out to do by prescribing a number of methodological rules that should guide scientific research. The significance Popper ascribes to all the rules is not on a par. One rule is singled out as being most important, and the rest are derived from it. The most important methodological rule is this : "It is the rule which says that the other rules of scientific procedure must be designed in such a way that they do not protect any statement in science against falsification." (1995, pg.54) It is beyond the scope of this paper to examine every rule derived from the rule just quoted in detail. Yet two which serve a very important role in Popper's theory of science will be examined.

The first rule is a rule against certain types of ad hoc maneuvers that are not uncommon in science. Ad hoc hypotheses in science are hypotheses proposed for the sole purpose of protecting theories from falsifying evidence. They are theoretical adjustments made within the theory in light of evidence that contradicts the empirical predictions made by the theory. Such changes are permitted provided that they don't "diminish the degree of falsifiability or testability of the system in question, but, on the contrary, increases it." (1995, pg.83) For example, in light of falsifying evidence found during the summer, the hypothesis "All metals expand when heated" can not be modified into, say, "All metals expand when heated during the winter" because the adjustment doesn't increase its testability. The latter hypothesis is lacking in new testable consequences. Another related ad hoc maneuver which Popper doesn't admit is to turn scientific hypotheses into definitions so that they become irrefutable. Referring back to our example "All metals expand when heated", this empirical hypothesis can be made irrefutable by making expansion under heat a defining feature of all metals, precluding the possible discovery of metallic substances that don't expand when heated. Given this ad hoc maneuver, anything that doesn't expand when heated can not possibly be metallic.

The second methodological rule Popper prescribes asserts that "the game of science is, in principle, without end. He who decides one day that scientific statements do not call for any further test, and that they be regarded as finally verified, retires from the game." (1995, pg.53) The implication here is that nothing in science is exempt from criticism. They are no irrefutable scientific statements. Any item of scientific knowledge, no matter how well corroborated by passing the severest tests imaginable, remains conjectural. This contention has received considerable criticism from those who advocate foundationalism in epistemology. Foundationalists argue that in order to secure scientific knowledge from skeptical scrutiny, the scientific edifice must be built upon statements that are incorrigible. The truth of most scientific statements is in need of epistemic warrant. Their truth claims are justified in reference to other statements, by demonstrating how they are founded upon other statements. But if these statements that confer epistemic warrant are also in need of epistemic justification, we seem to be trapped in an infinite regress unless there are statements that are self-justifying, statements that are not justified in terms of other statements. Foundationalists claim that science is built upon such self-justifying statements that are impervious to doubt. Popper, however, denies that there are such incorrigible statements in science that can function as a foundation for scientific knowledge. The foundationalist program of "starting from what appears to be the most certain or basic knowledge available..., in order to erect on those foundations an edifice of secure knowledge, does not stand up to criticism." (2000, pg.183) The foundation of science is itself fallible. "The empirical basis of objective science has thus nothing "absolute" about it. Science does not rest upon solid bedrock. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles." (1995, pg.111)

Before proceeding to the next section, the fallibilistic elements that have appeared in Popper's philosophy of science presented thus far will be examined. First of all, Popper's criterion of demarcation, understood in terms of falsifiability, presupposes that scientific knowledge is never immune from refutation. It is fallibility that characterizes the salient feature of scientific knowledge, and it is this epistemic feature that separates it from pseudoscientific theories that only purport to be scientific. Epistemic certainty is the defining feature of pseudoscience which can quite easily vindicate its claim by making it compatible with both actual and possible sense-experience. Secondly, the spirit of criticism which scientists convey when conducting research is another feature that characterizes the scientific enterprise. The scientific endeavor at its best is not guided by the epistemic goal of acquiring more and more evidence that will somehow ensure the certitude of what theories claim. Rather, it is guided by the goal of finding the errors necessarily inherent in every scientific theory so that it can be proved false once such errors are found. The critical mentality Popper champions is parasitic upon epistemic fallibilism. The active search for theoretical errors presupposes that theories are bound to be fallible, that such errors can be found given enough intellectual ingenuity and painstaking scrutiny. The critical approach in science, therefore, can not presuppose the epistemic certainty of scientific theories. Thirdly, because everything, from the most theoretically primitive basic statements to the most abstract theories postulated in science remains conjectural, the foundationalist approach in epistemology is doomed from the very beginning. There are no indubitable statements in science upon which the entire scientific edifice can be built. The foundation of science forever remains fallible. Thus, in science, we should simply dispel "the quest for justification, in the sense of the justification of the claim that a theory is true. All theories are hypotheses ; all may be overthrown." (1981, pg.29)

III

Any academic discipline, whether it belongs to the humanities or the sciences, has undergone historical change, and this change can mean one of many things. It can signify the difference in the theoretical problems that have engaged the interests of those belonging to a particular discipline. It can mean the difference in the methods employed to solve problems that have remained constant and invariable. Or the evolutionary path undertaken may be more about theories once popular and dominant being overthrown and replaced by others found to be more plausible or convincing. Or it could even mean the shift in the socio-political environment that supposedly gives birth to and defines the nature of the theoretical presuppositions people living in any social setting have.

The historiography of an academic discipline purports to understand the true significance and direction of its history. It does so by adopting and analyzing its historical change in terms of a framework of interpretation which will hopefully shed more meaningful light to what may at first seem to be a meaningless flux of random events. The framework rightly understands the historical change by selecting and focusing upon one or possibly two of the changes (the shift in problems, theories, socio-political environment, etc) it reveals.

One of the central themes in the philosophy of science is whether or not the history of natural science displays a rational pattern that can be discerned and analyzed by a given framework of interpretation. Though the very possibility of rationally reconstructing the history of science is much contested in contemporary philosophy, many assume that such patterns can be discovered depending on the framework that gets adopted. The question then becomes which approach in historiography will best reconstruct the evolutionary course of science.

Popper does side with those who think that a philosophical account of the history of scientific thought can be given. The purpose of this section is to first examine Popper's understanding of the evolution of science, and then to articulate the epistemic fallibilism that emerges from his historiography.

Popper (1981, pg.287) makes use of the following tetradic schema which he believes gives an accurate account of how science evolves : $P_1 \rightarrow TT_1 \rightarrow EE_1 \rightarrow P_2$

The first point that should be noted about this schema is that it claims that scientific inquiry starts with problems (P_1) that demand solutions. It is customary, however, to think that science proceeds by way of formulating hypotheses that account for observations made prior to theory construction. In other words, paying heed to the inductivist approach, it seems customary to regard observation as the legitimate point from which scientific inquiry proceeds. The problem with this contention is that it assumes that observation can by itself stipulate problems which require theoretical solutions. Popper maintains otherwise. What we observe is considered problematic only in light of the theoretical commitments, however rudimentary and primitive, we have ; if observation clashes with the theoretical expectations we have about the world we live in. "Problems crop up especially when we are disappointed in our expectations, or when our theories involve us in difficulties, in contradictions." (1989, pg.222) Thus, scientific inquiry proceeds by way of solving the problems that result from the acceptance of a theoretical framework.

Further, it should be noted that Popper underscores the relevance and indispensability of tradition in scientific inquiry. The rather crude yet pervasive and compelling account of the nature of science we often find in the literature on this very subject proffers a characterization that ascribes a somewhat marginal significance to tradition in scientific inquiry. Science, being the paradigm example of human rationality, is not indebted to tradition which is often seen to be replete with the prejudice and parochialism of a bygone age. This view from the Enlightenment depicts a science liberated from the shackles of the authoritative value of tradition, whereupon it increasingly yields reliable and objective factual truths about the world by dispassionately applying the objective canons of scientific research. The whole notion of being bound by tradition is equated with dogmatism, coupled with the intellectual insularity and myopia that result from the blind acceptance of what tradition pontificates. For Popper, the lacuna with the Enlightenment view of science is that it is not founded upon how scientific research is actually conducted. If, as Popper suggests, science is predominantly a problem solving activity, and if problems stem from the background assumptions or theories that are taken for granted, then science as we know it can not proceed without at least tentatively accepting traditional lore bequeathed to those engaged in research. Science can not simply start from scratch by jettisoning every item of knowledge acquired, preserved, and transmitted by the tradition we find in science.

This is not to say that tradition in science is not susceptible to criticism. After all, the great theoretical breakthroughs in science, though partly founded upon tradition, have been brought by the refutation or at least the serious questioning of traditional presuppositions. It is that tradition can not be consecrated into an irrefutable dogma impervious to criticism. Yet the Enlightenment view of science becomes overtly unrealistic by accentuating the dispensability of tradition in science. Popper writes : "Traditional knowledge...is open to critical examination and may be overthrown if need be. Nevertheless, without tradition, knowledge would be impossible." (2000, pg.49)

Referring back, however, to the schema proposed by Popper, we now enter the second stage as it were in the evolution of scientific thought whereby a theory (TT_1) that purports to solve the problem in question is proposed. The theoretical conjecture is usually highly improbable in the sense of having great informative content. In probability calculus, tautological statements like "Either it is or isn't raining" will receive the maximum probability of one since the informative content is zero. Tautological statements are compatible with any imaginable empirical state of affair, for reference to the empirical world is not made in the first place. Their truth, if it is true, is not dependent upon the world of experience. Compared to tautologies, a statement like "It will rain tomorrow in Japan" will have higher informative content not only because reference is made to the empirical world but it also excludes the possibility of certain empirical state of affairs (ie : sunshine, snow, etc) from occurring. It is not compatible with every empirical state of affair. Yet this means that on the probability scale, the probable truth of "It will rain tomorrow in Japan" will be lower due to the higher informative content this statement has. Resorting back to our example, we can imagine a statement with even more informative content. That is, a putative empirical statement such as "It will rain tomorrow in Fukuoka at 2pm" will be less probable by possessing higher informative content. And because it is more exact in what it asserts, the empirical testability of the last statement we considered will be higher in comparison to the other two. It will be easier, that is, to refute what it claims by being more incompatible with what might empirically happen in the world. Thus, "the informative content, which is in inverse proportion to probability, is in direct proportion to testability." (Magee, pg.34) Popper argues that a theoretical conjecture usually has "a high degree of explanatory power, in a sense which implies that it is logically improbable truth" (1989, pg.229) and that "a theory which is more precise and more easily refutable than another will also be the more interesting one. Since it is the more daring one, it will be the one which is less probable." (1989, pg.256) We are being presented here with a philosophical construal of the nature of the advancement in science, where in response to challenging anomalies, bold and daring conjectures with high informative content are proposed.

After a theory is proposed, it is then subjected to severe tests and criticisms that attempt to show that it fails to give a viable solution to the anomaly in question. In other words, the rationale behind these tests is to either demonstrate the falsity of the theory, to critically ascertain its inherent weakness, or both. Hence, EE_1 represents the critical process of error elimination whereby erroneous theories are discarded by subjecting them to criticism. The critical procedure is important for two reasons. First, it is only through the abortive attempts at solving problems that we gain a more thorough and clearer understanding of problems in general. Popper elaborates upon this point by saying that "to understand a problem means to understand why it is not easily soluble-why the more obvious solutions do not work." (1994a, pg.98) And, for Popper, the theoretical precondition for a viable solution to any given problem is to gain a precise understanding of the nature of the problem by failing to solve it. Secondly, the process of learning in science is such that we only learn from the mistakes we make. We gain a richer and fuller understanding of the world by realizing how our scientific conjectures fail to give us an accurate account of its reality. Science can give an approximate account of what the reality of the world is not like. "We learn only through trial and error. Our trials, however, are always our hypotheses. They stem from us, not from the external world. All we learn from the external world is that some of our efforts are mistaken." (2005, pg.47)

For Popper, the process of error elimination (EE_1) is what marks science as a critical form of inquiry, differentiating it from dogmatism. Dogmatism is a feature that can invade any intellectual discipline, including science itself. It is characterized by the unwillingness to question dogma by turning it into an unassailable truth that can be buttressed by arguments but can never be modified or refuted. Even the slightest whiff of dogmatism is apparent in science if the scientific community fails to question and criticize the prevalent scientific understanding of the day. Science, if it doesn't want to abdicate its search for knowledge, must not blindly accept and reiterate the scientific dogma of the past. It must retain and extend the tradition of critical inquiry which alone can cast some light upon the immensity of our ignorance. "What may be described as scientific objectivity is based solely upon that critical tradition which, despite all kinds of resistance, so often makes it possible to criticize a dominant dogma." (2000, pg.72)

Another point of importance about the EE_1 phase which must be noted is that though dogmatism as adumbrated above can always become a theoretical menace that hinders the quest for knowledge, there still is, for Popper, room and space in science for defending the truth of theories facing searching criticism. "It is of great importance that the theories criticized should be tenaciously defended." (1994a, pg.94) This seems contrary to what Popper thinks underpins and defines scientific inquiry which is none other than the method of criticism. For criticism as understood by Popper is the search for faults in theories. Yet defending a theory is important, "for only in this way can we learn [the theory's] real power. And only if criticism meets resistance can we learn the full force of a critical argument." (1994a, pg.94) What Popper is implying here is that in light of criticism the viability of the theory being defended can be strengthened in any number of possible ways : clarifying the theoretical ambiguities that may result in misunderstanding, making it more consistent by removing possible inconsistencies, rebutting counter-examples by showing how they result from a jaundiced understanding of the theory, etc. The tenacious defense of a theory, therefore, is permitted in science as long as it promotes critical discussion.

During the EE_1 phase, most theories, failing to pass the tests that are put to them, will be discarded. Yet usually a theory of groundbreaking originality with great explanatory power and scope that withstands such tests is proposed. This theory will in a matter of time be the accepted theoretical framework for conducting research. Science will probe into the inner mechanics of the world by depending upon and gaining illumination from this framework with great success. But further testing will sooner or later reveal problems with the theory, thus creating a new problem situation P_2 that will require a different conjecture for its solution. Every scientific theory, no matter how well corroborated, is impregnated with theoretical anomalies. But a theory shown to be erroneous is not for that reason alone rejected. As Popper rightly observes, in actual science "once a hypothesis has been proposed and tested, and has proved its mettle, it may not be allowed to drop out without 'good reason'". (1995, pg.53-54) What then constitutes a good reason for abandoning a theory? The answer is if there is another theory available. If an alternate theory is not available, science can and does continue its research, implementing and making great use of the theory which it knows to be erroneous. This is permitted in science for two reasons. The first reason, which is the more obvious one, is that science can not get off the ground without having recourse to a theoretical framework. Assuming otherwise would imply an inductivist picture of science where science can, without recourse to any theoretical guidance, construct theories that are inductively derived from the collection of data. The second reason is that false theories can still give us veracious and reliable predictions and explanations of phenomena. Every scientific paradigm is a complex web of theoretical beliefs, where beliefs complexly crisscross and intertwine at different points and levels. When aberrant data falsify a theory, it doesn't thereby ascertain the falsity of every single theoretical belief it entails. There must still be some truth to the theory, though every claim made by the theory can not be right. Newtonian physics, for example, is an erroneous theory because it fails to give an accurate account of events approaching the speed of light. But this failure doesn't imply that every item of theoretical belief entrenched in the paradigm is wrong. Or consider the heliocentric model that was proposed by Copernicus. Notwithstanding its predictive success in determining the course of planetary orbits we find in our solar system, it was still erroneous in assuming planets to orbit in circular motions around the sun, in contrast to the elliptical orbits the planets exhibited in Kepler's astronomy.

Yet what if an alternate theory to the one deemed erroneous is available? Any alternate theory will not do. The new theory will be adopted provided that it "solves those problems which its predecessor solved and those which it failed to solve" (1981, pg.15), and addresses and attempts to solve issues that were not referred to by the theory that was superseded. Popper thinks that this criterion for the replacement of theories in the history of science can "justify our preference for one theory over another." (1992, pg.118) There is, therefore, a theoretical continuity that runs through the various scientific paradigms we find in the history of science. In this history, subsequent theories we find emerging from their predecessors entail their theoretical successes and solve problems that demonstrated their falsity, while the progressive march to provisional truth is guaranteed by the continual resurgence of new theories entertaining new solutions to new problems. Yet Popper ends his historiography with a dim yet salutary reminder. He writes : "With almost every new scientific achievement, with every hypothetical solution of a scientific problem, both the number of the unsolved problems and the degree of their difficulty increase." (2000, pg.198)

As a way of recapitulating this section, Popper's epistemic fallibilism that underlies his historiography of science will be examined. First, the actual point of departure for scientific inquiry is the solution of problems that appear problematic only in light of theories. As Popper voices this view, "Each new development in science can be understood only in this way, that its starting point is a problem or a problem situation." (2005, pg.6) The theoretical conjectures must be highly falsifiable by having great informative content. The purpose behind designing highly falsifiable theories is that they have the potential, if proven wrong, of teaching us a lot about what we don't know. From the very outset, theories that are easily susceptible to confirmation are not designed. But this presupposes that science is not after epistemic certitude. If certitude is the aim of science, then bold and risky theories will not be posited in the first place. Science is about the systematic search for mistakes it knows will be inherent in any theoretical conjecture. Secondly, theories are subjected to criticism that will demonstrate their falsity. The point of criticism is not that of justifying or confirming the theoretical claims theories make by amassing evidence. Again the critical procedure is rooted in epistemic fallibilism. It is guided by the conviction that the inherent errors in theories can be identified, and the identification of such errors will give us a greater understanding of the reality of the world. Thirdly, we saw how Popper reproached the Enlightenment view of science by stressing the importance tradition has on scientific inquiry. Although tradition does form a basis from which inquiry proceeds, it can not and does not function as an infallible guide to truth. Tradition, in science, is a fallible yet indispensable source for scientific research. Fourthly, the overall picture of the history of science Popper presents has a strong overtone of fallibilism. For every theory we find, however well corroborated, will inevitably yield problems that require a different scientific paradigm for their solution. Every theory then is impregnated with problems which will sooner or later become eminent. The idea that there are theories devoid of problems is a myth. For Popper, the moral to be drawn from the history of science is this : "In the development and improvement of... science itself, we learn only by trial and error, and we need the criticism of others in order to find out our mistakes." (1994b, pg.57)

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The very notion of truth has not figured very prominently in what we have been examining so far. This section is on Popper's philosophical account of truth. It will be argued in what follows that not unlike the other philosophical themes that figure in his systematic treatment of science, his stance on truth has a strong dose of fallibilism that questions the whole notion of the finality of scientific knowledge.

Popper is a metaphysical realist. Metaphysical realism claims that there is an objective reality that exists independent of human conception. The ontological reality of the world is therefore not dependent on the ways it is differently conceived by us. Moreover, the reality of this world is not constructed but discovered by the cognitive apparatus we are equipped with. The laws that govern the workings of the world and the inherent properties it has are not the product of our conception, but are inherent in the way the world is objectively structured, awaiting to be discovered and analyzed by scientific conjectures. Though Popper concedes that the realist thesis is "neither demonstrable nor refutable" (1981, pg.38), he does think that it has more philosophical plausibility when contrasted to an idealistic metaphysics that is predicated on the philosophical premise that asserts the ontological dependence of the world upon human conception.

For Popper, the primary goal of science is to gain an accurate and reliable understanding of this mind independent reality. More specifically, "science is the search for truth and also its aim is the approximation to the truth." (2000, pg.227) This immediately disposes the viability of any form of philosophical instrumentalism that denies that truth is or should be the aim of science. Instrumentalism in the philosophy of science regards "scientific theories as devices for helping us deal with experience." (Godfrey-Smith, pg.183-184) Theories have nothing other than the instrumental value of collating data in an economical fashion so that reliable predictions can be drawn from them. The predictive accuracy of theories does not imply truth. Theories are merely tools we use for predictive purposes, and the philosophical question of truth need not deter us from appreciating the instrumental value theories have.

Popper doesn't deny the instrumental value behind theories. However elusive the notion of truth may be, the staggering predictive success of the theoretical sciences, for Popper, can not be explained without making some recourse to truth. But what does Popper mean by truth? Is there any room for truth in science given Popper's espousal of fallibilism? Truth, undoubtedly, has been the subject of much heated discussion in philosophy ever since the dawn of intellectual curiosity. To grossly oversimplify a rather complex issue, in the Western philosophical tradition, three theories of truth have withstood the test of time by having advocates even to this day. The coherence theory likens any theory to a web of interrelated beliefs, where the systematic coherence of the web is equated with its truth. The pragmatic theory equates truth with utility. Theories are true if they pragmatically carry out what they are designed to do ; if they produce results that work. The correspondence theory, which is the theory

Popper accepts, claims quite simply that "truth is correspondence with the facts (or with reality) ; more precisely, a theory is true if and only if it corresponds to the facts." (1981, pg.44) Thus, scientific theories are true if what they claim correspond to an objective reality that is independent of human conception. Yet how does Popper reconcile the correspondence theory with his view that all scientific theories are fallible? That is to say, if truth is understood in terms of correspondence, are we ever entitled to say of any given theory that it corresponds to reality, that it is true, given that all scientific theories are subject to future refutation? It seems that we can not but surmise from Popper's philosophy of science that theories, because fallible, can never be true since their claims can never correspond to objective reality. Popper tries to meet this objection. Though we never have any epistemic warrant for claiming the truth of scientific theories, we are justified in thinking that theories are forever getting closer to the truth, that though the scientific quest for truth will never be complete, science does make theoretical progress towards this unattainable aim. "We can...know that we are making progress ; and it is this knowledge that to most of us atones for the loss of the illusion of finality and certainty." (1971b, pg.12) Before examining this point in more detail, Popper is convinced that his thesis will seriously undermine the philosophical plausibility of the following two endemic yet mistaken views regarding the nature of scientific knowledge.

(1) It is possible for the scientific community to someday generate a theory that gives us a literal description of reality, a theory that faithfully reflects and pictures the ultimate nature of how the world is scientifically structured and organized. (2) Because we lack in science or philosophy a neutral and objective Archimedean point in terms of which the relative truth of scientific theories can be compared and contrasted, all scientific theories are on a theoretical par in the sense that they are all true irrespective of the differences in the theoretical claims they make.

It is not hard to see why Popper can not accept (1). It smacks of absolutism in science which is at variance with Popper's core teaching that undercuts any alleged claim to finality or certainty in scientific knowledge. If, as Popper argues, every scientific theory is impregnated with problems that require a solution in terms of another scientific paradigm, any claim to finality is an attractive yet dangerous illusion. Attractive because it does imply the possibility for science to unravel and solve every imaginable scientific problem we are beset with by resorting to an infallible theory. Yet ultimately dangerous because the very notion of finality will stultify the growth of scientific knowledge by depriving the function of critical inquiry which, for Popper, is nothing other than the systematic search for the errors inherent in scientific theories.

The relativistic implication that can be drawn from (2) is obvious. If there lacks an overarching, Archimedean point of reference that can help adjudicate the relative merits of scientific theories, we lack an important possible resource for determining the truth or falsity of theories. All we get is a continuum of theories that is equally credible. But this would mean that scientific theories "do not improve on one another, and that therefore science does not cumulate in the direction of successive approximation to the truth." (Rosenberg, pg.153) This seems counter-intuitive. We rightly believe in the progressive nature of science. Notwithstanding the occasional backwardness and stagnation the history of science bears witness to, we sense that it manifests a triumphant march to truth where scientific inquiry is responsible for furthering and extending our understanding of the world. Contrary to relativism, we think that scientific theories having the same explanatory domain can be compared, and that contemporary science, though still inchoate and requiring minor if not major theoretical modifications in the future, bestows a more reliable and accurate picture of the world in comparison to the science of the past. And this is exactly what Popper wants to underscore when he argues in favor of the progressive nature of science, where subsequent theories replacing theories preceding them in the history of science, though fallible, are approaching and getting closer to the truth.

Indeed, Popper's progressive view of science can be understood as being a philosophical response to both absolutism and relativism in the philosophy of science. More specifically, the whole notion of scientific theories approximating to truth, Popper thinks, can eschew absolutism without acquiescing to relativism. But the picture of the progressive growth of science Popper presents is lacking in philosophical sophistication unless he can propose a criterion in terms of which we can justifiably ascertain whether a particular theory is closer to the truth in comparison to another. This is what Popper sets out to do.

Popper (1981, pg.201) has introduced the following criterion: Given two comparable theories T_1 and T_2, the latter is closer to the truth (or has more verisimilitude) if the truth-content (the class of all true statements that T_2 entails) is greater than T_1 while the falsity-content of T_2 (the class of all false statements that T_2 entails) is less than T_1. Given the fact that both T_2 and T_1 are comparable, T_2 has more verisimilitude if T_2 entails all the true statements T_1 entails plus additional true statements, and if T_2 doesn't entail all the false statements entailed by T_1.

Another way of ascertaining the verisimilitude of theories is to relate it to the function assigned to tests in Popper's philosophy of science. Tests, as we have already seen, are simply not conducted in order to increase the probability or certitude of the truth claims made by theories. Rather, tests are employed so as to prove them wrong. Tests are, however, said to "confirm the theory only if they are the results of unsuccessful attempts to overthrow its prediction, and therefore a telling testimony in its favor." (1971b, pg.260) The verisimilitude of a theory is said to increase if it passes tests that purport to falsify it. The passing of tests (corroboration) is no sure indication of the absolute truth of the theory. The corroboration of theories doesn't imply its ability to withstand future tests. In fact, this is impossible bearing in mind the fact that for Popper, every scientific theory is impregnated with problems. Corroboration only lends support to a theory's provisional truth.

Popper conceives science as a never-ending quest towards a more plausible and accurate mapping of a mind independent reality, the existence of which is presupposed by metaphysical realists. But the nature of this reality independent of scientific theorizing is beyond our ken. It was and will always remain elusive. But metaphysical realism has an important heuristic function. The understanding of this reality is the ultimate goal that prompts the scientific endeavor. Popper's metaphysical realism for science is a "realism of aspiration rather than a realism of achievement." (Artigas, pg.201) The scientific endeavor can never rest content with its theoretical achievements because the reality it aims to understand has an unfathomable richness that far extends beyond what science can manage to cognitively grasp. It has to continuously revise and even overthrow the paradigms that inevitably fail to unerringly mirror what this reality is like. Science is faced with this constant challenge. Even with the advancement of science, "there will be deeper problems, and there will be more of them. The further we progress in knowledge, the more clearly we can discern the vastness of our ignorance." (1994a, pg.4) The provisional success of scientific theories will open new vistas that will pose new problems demanding new scientific exploration.

This final section, once again, will be concluded by stipulating the epistemic fallibilism that surfaced in our discussion of Popper's thesis of verisimilitude. Metaphysical realism affirms the existence of a reality that is not ontologically dependent on human conception. Scientific conjectures are true in so far as their assertions correspond to the way in which this reality is objectively structured. Popper dismisses out of hand the possibility for science to propose theories that unerringly reflect this reality, nor does he concur with a relativistic understanding of theories that equates truth with what any given theory theoretically asserts.

Though an unfailing correspondence between theoretical conjectures and reality is not possible, science does manifest progress. The progressive nature of science amounts to the generation of theories that has more verisimilitude. Subsequent theories in the history of science encompass the theoretical insights and truths of their predecessors. Thus, "in a sense, no field of thought is more conservative than science. Each change necessarily encompasses previous knowledge. Science grows like a tree, ring by ring." (Holton, pg.48) But theories with high verisimilitude will be refuted by future testing. This is the predicament facing every scientific theory. Theories can gain verisimilitude by passing stringent tests, but this is what they only gain. They remain fallible. "Science is a phenomenon to be understood as perpetually growing ; it is essentially dynamic, never something finished ; there is no point at which it reaches its goal once for all." (2005, pg.15)

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