PART FOUR

INFLUENTIAL THINKERS & METHODS OF THE MODERN SCIENTIFIC ERA

BY

IKEDINACHI WOGU.

I. THE ERA OF CRITICAL RATIONALIST THINKERS & METHODS OF SCIENCE

All nature, from the smallest thing to the biggest, from a grain of sand to the sun, from the protista to man, is in a constant state of coming into being and going out of being, in a constant flux, in a ceaseless state of movement and change.

FRIEDRICH ENGELS, *DIALECTICS OF NATURE.*

1. General Introduction

Science is a never-ending, always changing process through which we learn to know the material nature of the universe. Science does not deal with nonmaterial entities such as gods, for there is no way their existence can be either proved or disproved. No single, identifiable method applies to all branches of science; the only method, in fact, is whatever the scientist can use to find the solution to a problem. This includes induction, a form of logic that identifies similarities within a group of particulars, and deduction, a form of logic that identifies a particular by its resemblance to a set of accepted facts. Both forms of logic and a few more that we shall be studying in this section are some of the tools and methods that have aided scientist in advancing in the area of their research, even though these methods have in some cases not really lead to the solution of the scientist's problem.

Being a good scientist requires patience, perseverance, imagination, curiosity, and skepticism; the essence of science is to doubt without adequate proof. Science

also requires knowing how to make and interpret observations (which presupposes a broad point of view), how to ask the right questions, how to

theorize without getting lost in the details, and knowing when to do experiments and apply statistical tests. Recognition of one's work is desirable but should not be the primary goal, and publishing papers should be used primarily as a test of the scientist's ability to pursue good science.

In this section, we shall generally consider the contributions of outstanding thinkers and methods that have distinguished the enterprise of science since the modern era of knowledge. One common feature that cuts across these thinkers and methods is the application of **Reason** as the only viable denominator, this singular factor laid the foundation for the kind of thinking and reasoning that became the *modus operand* for this era, an era most scholars have preferred to identify as "the era of **critical rationalism**".

What is critical rationalism? Critical rationalism is an **epistemological philosophy** advanced by **Karl Popper**. Popper wrote about critical rationalism in his works, *The Open Society and its Enemies Volume 2*, and *Conjectures and Refutations.*

Critical rationalists hold that scientific **theories, laws, or methods** and any other claims to knowledge, can and should be rationally criticized, and (if they have empirical content) can and should be subjected to tests which may falsify them. Thus claims to knowledge may be contrastively, normatively evaluated. They are either falsifiable and thus empirical (in a very broad sense), or not falsifiable and thus non-empirical. Those claims to knowledge that are potentially falsifiable can then be admitted to the body of empirical science, and then further differentiated according to whether they are (so far) retained or indeed are actually falsified. If retained, yet further differentiation may be made on the basis of how much subjection to criticism they have received, how severe such criticism has been, and how probable the theory is, with the least [iii] probable theory that still withstands attempts to falsify it being the one to be preferred. That it is the *least* probable theory that is to be preferred is one of the contrasting differences between critical rationalism and classical views on science, such as positivism, who hold that one, should instead accept the *most* probable theory. Critical Rationalism as a discourse positioned itself against what its proponents took to be epistemologically relativist philosophies, particularly post-modernist or sociological approaches to knowledge. Critical rationalism has it that knowledge is objective (in the sense of being embodied in various substrates and in the sense of not being reducible to what humans individually "*know*"), and also that truth is objective (exists independently of social mediation or individual perception).

Since a theory has to be falsifiable in order to be scientific, all currently accepted

theories are falsifiable in the sense of being capable of being proved false or changed and improved upon later on in the same way as they falsified or improved upon their previous versions. **Being proved false does not imply that the falsified theory has no truth content in it.** The old theory that 'the earth is flat' has been falsified but it continues to contain the truth that it appears to be flat. What is held to be true today might be improved upon later on. Therefore, Popper holds that a theory that has not yet been falsified has a certain degree of truth or verisimilitude in it. This does not mean that at no stage can truth be known. What it means is that with every improved version of the truth or verisimilitude, human knowledge draws closer to truth. Thus **'human truth' will never reach the truth but it will continue to draw closer to it.** Whatever resists falsification will remain a part of human truth until it is falsified or improved upon.

However, this contrastive, critical approach to objective knowledge is quite different from more traditional views that also hold knowledge to be objective. (These include the **strong rationalism** of the Enlightenment, the **verificationism** of the **logical positivists**, or approaches to science based on **induction**, a supposed form of logical inference which critical rationalists reject, in line with **David Hume**.) For criticism is all that can be done when attempting to differentiate claims to knowledge, according to the critical rationalist. Reason is the **organon** of criticism, not of support; of tentative refutation, not of proof.

Supposed positive evidence (such as the provision of "good reasons" for a claim, or its making of successful predictions) actually does nothing to bolster, support, or prove a claim, belief, or theory. In this sense, critical rationalism turns the normal understanding of a traditional rationalist, and a realist, on its head. Especially the view that a theory is better if it is less likely to be true is in direct opposition to the traditional positivistic view that holds that one should seek for theories that have **a high probability**. [1] Popper notes that this "may illustrate Schopenhauer's remark that the solution of a problem often first looks like a paradox and later like a truism".

Critical rationalism rejects the classical position that **knowledge is justified true belief**; it instead holds the exact opposite: That, in general, knowledge is unjustified untrue unbelief. It is unjustified because of the non-existence of good reasons. It is untrue, because it usually contains errors that sometimes remain unnoticed for hundreds of years. And it is not belief either, because scientific knowledge, or the knowledge needed to build a plane, is contained in no single person's mind. It is only available as the content of books.

The contents of various books, however, do not agree with each other, Popper's 'Objective Knowledge' is not constituted by the contents of all books but by their

highest common factor, something on which they all agree. That highest common factor may be called the 'human mind' that changes from time to time and place to place but continues to draw closer to the truth. In the last few centuries, the human mind has grown exponentially but it is destined to remain short of being coterminous with reality or the final truth.

In fact, 'the contents of books' was used by Popper in his 'Objective Knowledge' as an idea in the context of a parable. In order to demonstrate that human knowledge was objective, Popper asked the reader to imagine two scenarios of an armageddon: one in which every single thing is destroyed and only a few humans are left and the other in which books survive along with the humans. In these two scenarios, while the first group may take forever to rebuild human civilization, the second group will be able to rebuild much more quickly with the help of the books proving that the knowledge contained in them was indeed objective.

a. Justificationism not Allowed

William Warren Bartley compared critical rationalism to the very general philosophical approach to knowledge which he called "justificationism". Most justificationists do not know that they are justificationists. Justificationism is what Popper called a **"subjectivist"** view of truth, in which the question of whether some statement is true, is confused with the question of whether it can be justified (established, proven, verified, warranted, made well-founded, made reliable, grounded, supported, legitimated, based on evidence) in some way.

According to Bartley, some justificationists are positive about this mistake. They are naive rationalists, and thinking that their knowledge can indeed be founded, in principle, it may be deemed certain to some degree, and rational.

Other justificationists are negative about these mistakes. They are **epistemological relativists**, and think (rightly, according to the critical rationalist) that you cannot *find* knowledge, that there is no source of epistemological absolutism. But they conclude (wrongly, according to the critical rationalist) that there is therefore no rationality, and no objective distinction to be made between the true and the false.

By dissolving justificationism itself, the critical rationalist regards knowledge and rationality, reason and science, as neither foundational nor infallible, but nevertheless does not think we must therefore all be relativists. Knowledge and truth still exist, just not in the way we thought.

b. The problems of justificationism and positivism

Are all swans white? The classical view of the philosophy of science is that it is the goal of science to "prove" such hypotheses or induce them from observational

data. This seems hardly possible, since it would require us to infer a general rule from a number of individual cases, which is logically inadmissible. However, if we find one single black swan, logic allows us to conclude that the statement that all swans are white is false. Falsificationism thus strives for questioning, for falsification, of hypotheses instead of proving them. [8]

The rejection of "positivist" approaches to knowledge occurs due to various pitfalls that positivism falls into. We shall discuss a few here.

1. The naive **empiricism** of **induction** was shown to be illogical by Hume. A thousand observations of some event A coinciding with some event B does not allow one to logically infer that all A's coincide with B's. According to the critical rationalist, if there is a sense in which humans accrue knowledge positively by experience, it is only by pivoting observations off existing conjectural theories pertinent to the observations, or of underlying cognitive schemas which unconsciously handle perceptions and use them to generate new theories. But these new theories advanced in response to perceived particulars are not *logically* "induced" from them. These new theories may be wrong. The myth that we *induce* theories from particulars is persistent because *when* we do this we are often successful, but this is due to the advanced state of our evolved tendencies. If we were really "inducting" theories from particulars, it would be inductively logical to claim that "the sun sets *because* I get up in the morning", or that "all buses must have drivers in them" (if you've never seen an empty bus).

2. **Popper** and **David Miller** showed in 1983 (*Nature* 302, April 21, "A Proof of the Impossibility of Inductive Probability") [8] that evidence supposed to partly support a hypothesis can in fact only be neutral to, or counter-supports the hypothesis.

3. Related to the point above, David Miller (in his *Critical Rationalism : A Restatement and Defence*, Chapter 3 "A Critique of Good Reasons"), [8] attacks the use of "good reasons" in general (including evidence supposed to support the excess content of a hypothesis). He argues that good reasons are neither attainable, nor even desirable. Basically, the case, which Miller calls "tediously familiar", is that valid arguments are either circular or invalid. That is, if one provides a valid deductive argument (an inference from premises to a conclusion) for a given claim, then the content of the claim must already be contained within the premises of the argument (if it is not, then the argument is **ampliative** and so is invalid). Therefore the claim is already presupposed by the premises, and is no more "supported" than are the assumptions upon which the claim rests, i.e. begging the question. [8]

II.   CARTESIAN RATIONALISM

> *If I am being deceived, then I am thinking; if I am thinking, then I exist;*
> *if I exist, then there exists a God.*

RENE DESCARTES

a.   A Priori Method

René Descartes' major work on scientific method was the *Discourse* [8] that was published in 1637 (more fully: *Discourse on the Method for Rightly Directing One's Reason and Searching for Truth in the Sciences*). He published other works that deal with problems of method, but this remains central in any understanding of the Cartesian method of science. The common picture of **Descartes** is as one who proposed that all science become demonstrative in the way Euclid made geometry demonstrative, namely as a series of valid deductions from self-evident truths, rather than as something rooted in observation and experiment. Descartes is usually portrayed as one who defends and uses an a priori method to discover infallible knowledge, a method rooted in a doctrine of innate ideas that yields an intellectual knowledge of the essences of the things with which we are acquainted in our sensible experience of the world.

Descartes argues that the laws in the basic mechanistic framework that he takes to hold for sciences like optics and physiology – these laws about laws that guide empirical research in these sciences – are not themselves empirical but are rather necessary truths that are knowable a priori. Thus far we have seen that Descartes is well aware of the logical structure of the experimental method in natural science. To that extent he is not a philosopher who asserts that the a priori method applies everywhere. But he is nonetheless correctly to be counted among the rationalists. In fact he argues that in principle at least all laws could be known a priori. It is just that the world of ordinary things is too complicated in its structure for us, with our finite minds and limited capacity to grasp the a priori structure of the world, to deduce from self-evident premises the laws of the mechanisms underlying ordinary observable things and processes. We can know a priori the law about laws that *there are* more specific laws with the generic structure of physical mechanisms, of machines. But what those specific laws are requires empirical research; they are too complex logically to be knowable a priori by us, with our finite capacities.

Descartes argues that all things, including the material world we know by sense, have an inner essence or form, and its presence explains the structure of things as they ordinarily appear. These essences or forms are known not by sense but by

reason. [7] **Reason** is precisely the capacity to grasp these essences which are the reasons for things, the reasons why there are these patterns and regularities in the sensible world rather than others. He takes for granted that when the form is known that form is literally in the mind of the knower: there is an identity of the knower and the known. To grasp the essence of a thing is to know a priori the structure and behavior of the thing of which it is the essence. Material things are all modes of a single substance, the essence of which is extension. When we grasp the axioms of geometry as necessary truths, we are grasping the logical and ontological structure of the material world. Descartes is like Aristotle in attributing essences to things, but for Aristotle knowledge of the essence is given by syllogisms and by real definitions of species in terms of genus and specific difference. For Descartes, the structure is given by the truths of geometry.

Descartes holds in the Fifth Part of the *Discourse on Method* that the basic laws of physics are those of the geometry of objects in motion. [8] These laws, he suggests, can be deduced from our knowledge of God. He creates world the essence of which is given by the laws of geometry together with the principle that in any change quantity of motion is conserved. This conservation principle is thought to follow from the unchanging nature and stability of God the creator. There is a much more detailed derivation in the *Principles of Philosophy*. It is far from adequate. Descartes' knowledge of the laws of physics and of mechanics falls far short of Newton's. Perhaps this shows the weakness of the a priori method proposed by Descartes for obtaining the basic framework laws for science, the framework that provides the starting point of the experimental method and of the "how possibly" explanations he offers for material processes. Many have thought so.

In the *Principles of Philosophy* he goes so far as to attempt a derivation of the basic laws for planetary motions, based on the mechanistic supposition that the planets are material objects moved in circular fashion by vortices in a surrounding material fluid. Newton was soon enough to present his *Mathematical Principles* (*Principia Mathematicae*) to the world. Descartes had been able to present only a set of non-mathematical principles, but Newton demonstrated that the vortex account, whatever its pretensions to being established a priori, was, given his three laws of motion, inconsistent with the facts of elliptical orbits as established by observation by Kepler. After Newton had succeeded in his attempt to "demonstrate the frame of the system of the world" (as he set out to do in Book III of his *Principia Mathematicae*), little was heard, save for a rearguard of French Cartesians, of the vortex theory. It became an historical curiosity.

Be that as it may, it could be concluded that Descartes had merely misapplied his

method a priori, not that it was incorrect. Some later thinkers such as William Whewell argued this point. The method did not disappear in the way the vortex theory disappeared.

b. Geometrical Deduction

In one sense, this method is like the method of geometry that Euclid had given to the world in that one began with self-evident truths as axioms and then deduced by equally self-evident steps a set of theorems. Descartes referred to this as the "synthetic method" of doing geometry and (he had hoped) physics. He attempted this in outline in the *Discourse on Method* and in detail in his *Principles*, taking as his axiom the existence of God as an unchanging and stable creator of the natural world. The mechanistic framework for carrying on empirical research followed.

However, there is the issue of how the premises are discovered. Euclid never showed how this was to be done. But the later Greek mathematician Pappus, to whom Descartes referred on the issue of method in the *Rules for the Improvement of the Understanding*, had suggested that the method of finding premises reversed as it were the deductions of the synthetic method. This was the "analytic method." On the synthetic method one begins with premises that are accepted as true and works deductively towards conclusions, the theorems. Having reached the theorem, one has constructed a demonstration of that proposition. This synthetic method takes as given the premises from which it starts. But often to find a demonstration one must locate the premises from which the demonstration is to be constructed. This task of discovery was the point of **the analytic method.** On this method, one takes the conclusion to be demonstrated not as something accepted as true but merely as an hypothesis. One then works deductively towards the premises which one hopes to find for constructing a demonstration. Having arrived at the appropriate self-evident premises, one reverses the steps to obtain a synthetically organized demonstration of the hypothesis from which the analytic process started. And now that one has this demonstration, the proposition is transformed from a mere hypothesis to one that can be accepted as true.

A particular version of the analytic method occurs in a *reductio ad absurdum* proof. Here one begins from an hypothesis and derives a contradiction; one then concludes that the hypothesis must be false, and that its denial is true. And as a special case of *reductio ad absurdum*, one begins with a proposition taken hypothetically and derives a conclusion that contradicts a known truth, concluding thereby that the original hypothesis is false. Descartes proposed to use this method to discover the axioms for his synthetic deductions: he is inspired by its uses in algebra, but extends it to his proof that the truths of geometry,

arithmetic and physics, while self-evident, can themselves be demonstrated to be incorrigibly true from still more fundamental premises. The synthetic method was fine enough for the presentation of demonstrations in a science where the basic axioms are already known, and Descartes was to use this method, or thought he was so using it, in those parts of the *Principles of Philosophy* where he offered demonstrations of the basic truths of physics. Needless to say, his "proofs" have for the most part come to be seen as inadequate. But the analytic method was necessary from the discovery of the required premises. This is the method he proposes in the *Discourse on Method* as basic to firmly grounding the edifice of knowledge; and it is the method he uses in his presentation of the search after fundamental and incorrigible truths in the *Meditations on First Philosophy*, though here again he has generally been taken to be less successful in his application of the method than he himself hoped to be and expected he was. But his advocacy of the methods has continued to have their influence, in mathematics and algebra, and perhaps in physics, if not in first philosophy. Nevertheless, no one now expects to construct in either physics or geometry or first philosophy the rationalist ideal of an a priori demonstrative science.

c. Deduction in the *Discourse* and *Meditations*

As for the analytic method, Descartes was to use the first of the treatises appended to the *Discourse on Method* to illustrate the power of this method. This was the treatise on *Geometry*. This work in mathematics is remarkable, and it too was to revolutionize the way people thought about both algebra and geometry.

Descartes first set out to purify algebra. This was to be done by separating its patterns of thought from the particular subject matter to which it could be applied. He first separated what is given from which is to be discovered, developing the still current notation of $a, b, c, ...$ for known quantities and $x, y, z, ...$ for unknowns. He also reformed the notation for exponents replacing verbal terms such as "square" and "cube," and so forth, by superscripts $^2, ^3, ...$, eliminating the geometrical connotations of the verbal terms. We continue to use this Cartesian notation.

Descartes then set out to apply this purified algebra in the solution of geometrical problems. The details need not concern us. For us it suffices to look at the problem he first addresses. This problem, which was posed originally by Pappus, is one of finding a curve of a point y relative to a point x, subject to certain geometrical constraints. To solve this problem he invents and uses the notion of a coordinate system. In effect he creates an arithmetical interpretation of geometry. (Descartes himself uses only an "x- axis"; the familiar extension of this idea to using two orthogonal "x" and "y" axes – what we now call "Cartesian coordinates" – were a

later development of Descartes' pioneering idea.) Descartes shows how the finding of this curve can be done algebraically by solving certain equations. The point for us is that the solving of an equation is a matter of applying Pappus' "analytic method." Given $a, b, c, ...$, standing in certain arithmetical relations to one another, the equation in x and y asserts that *there are* values satisfying these conditions, that is, that there are solutions to the equation. This is the theorem to be proved. One proceeds by taking it as an hypothesis that x and y are solutions, and works out what those solutions are. This is the analytic process. Having found the solutions, one then has the premises from which the theorem to be proved follows. Deriving the theorem from the newly discovered premises is the synthetic process.

The algebraic methods that Descartes developed enabled him to present a series of entirely novel and original moves in geometry. Descartes' work in its applications is itself significant, but what was revolutionary was the new methods for solving problems in geometry and algebra. It is easy to prove theorems, but the greatness of a mathematician is **the new methods of proof that he or she introduces**. By this standard Descartes was indeed a great mathematician. Thinking in terms of equations, one can see why Descartes valued the analytic method over the synthetic, for the latter amounted to a footnote to the former. **The analytic method was the one to be used if one was aiming to discover new truths**; once these are discovered the synthetic method can be used to present this knowledge to students. As a method for discovering truth, the synthetic procedure was largely useless, the searcher after truth will need, and will use, the analytic method. This was why Descartes argues that the analytic method is the appropriate method for discovering the a priori necessary truths that are the starting point for any genuine science, not only a science like geometry but also as providing the necessary theoretical truths required by the eliminative methods of empirical experimental science.

Now, Descartes makes clear in the *Discourse on Method* that his starting point for his science and his physics is **the existence of God**. It is from the existence of God as stable and unchanging that he claims to be able to deduce, and thereby demonstrate, the basic laws of physics, the laws of motion and the laws describing the causes of changes in motion. **That God is the starting point for his demonstrative science of physics is made even clearer in the *Meditations***. In both this and the *Discourse*, Descartes moves from his own existence to that of God, and then uses this as a premise from which his physics is deduced. It is evident that he is working with necessary truths and necessary inferences, or at least apparently necessary ones.

Descartes makes some important remarks in reply to some objections to the argument of the *Meditations*. Prior to publication of the *Meditations*, Descartes had circulated the manuscript to various other philosophers; they raised objections, and he wrote replies. He published his *Meditations* together with these *Objections and Replies*. In one of the Objections, the issue is raised why Descartes did not present his work in geometrical fashion, **proceeding from axioms to theorems,** using the synthetic method. In his Replies, Descartes explains *he could have done so, but preferred to present his thoughts in the analytic method, which gives the order of discovery, through which the mind rises from hypotheses to the premises that are then used to prove synthetically the hypotheses that were the starting point of the inferences.* He does, however, accede to the request of the Objection and does give a synthetically organized presentation of his inferences.

The Ultimate Proof of God's Existence: In this synthetic presentation the first proposition that he establishes is God's existence, which he takes to be something involved in the very idea of God as a being who, of His own nature, has all perfections. He then proceeds to the causal arguments for God's existence, and then to the proposition that God guarantees the truth of all propositions self-evidently implied by our ideas. Naturally enough this reverses the order of the *Meditations* themselves, which proceed in the order of the analytic method.

This means that the order of the *Meditations* is from propositions taken hypothetically to the proposition which is to form the first proposition to be discovered to be true and from which the hypotheses are then to be proved, that is, transformed from hypotheses to known truths.

The Methodic Doubt: Descartes reports in the First of the *Meditations* how he discovers that he can doubt almost everything about the material world that surrounds him. At the beginning of the Second *Meditation* his attention suddenly shifts from the world given in sense experience to the world given in inner awareness. He here discovers a proposition that he cannot doubt, namely the proposition that he expresses by "**I think.**" Since this thinking is a mode, it must clearly be a mode of something, a substance: "**I think, therefore I am.**" Further, his thinking is inconceivable apart from himself, unlike, for example, extended things such as his body. He draws the further inference that he is a thinking thing. That is, he apparently is a substance, not a rational animal as Aristotle said, but a being or substance that is purely rational, one the essence of which is to aim to grasp the reasons for things. He carefully points out that this distinction between mind and body, based on the **separability** in thought of thinking from extension is only tentative. It may be that the world is not such as it here self-evidently appears to

be. Thinking and extension may in the end be necessarily connected and it may be that modes can exist apart from substances, inconceivable though these things apparently seem to be. All this is to be here taken hypothetically, as a starting point in the analytic process leading to the discovery of a premise or premises that will serve to guarantee their truth and to justify the **Meditator** accepting them as truth.

It must be emphasized that Descartes does not, as so many seem to think, deduce the existence of God from the principle that "I think, therefore I am." The latter is *not* a first truth from which all other knowledge is taken to follow, including our knowledge of God, as theorems proceed from axioms. To suppose this would be to suppose that the *Meditations* are organized in the order of a synthetic process, proceeding from known truths to true theorems that are deduced from those known truths. But Descartes clearly states that the order of the *Meditations* is that of the analytic method, from propositions taken hypothetically to simpler propositions which can then be used to prove deductively the hypotheses that were the starting point of the inferences. At the start of the process, one has only a proposition taken hypothetically. So the Meditator's own existence is a mere hypothesis, not a known truth, as is the premise from which it derives that all properties or modes exist only in substances.

This is where the Meditator is at the beginning of the Third *Meditation*. He or she can conclude, however, that as he or she is an imperfect being. Being a being that aims to know the doubt with which he or she is presently seized, it is clear he or she does not exist as his or her essence naturally implies that he or she should exist but lacks something the presence of which would be his or her Good. The idea that one has of oneself is that of an imperfect being; but **to conceive an imperfect being requires one to be able to conceive a perfect being,** just as conceiving something to be a non-square requires one to have the idea of a square. **The presence of the negative idea requires the presence of the positive idea.** So, the Meditator has the idea of a being that lacks no Good, no perfection—for any way of being this entity has that way either actually or formally. (Recall here that an idea, which, as Descartes speaks, formally exists as a property of the mind, exists objectively as the form or essence of a substance; the idea is true only if that substance of which it is the essence actually exists in sense that it has actually the properties the essence determines that it ought to have; the idea is false if the substance has properties contrary to those that the essence requires it to have.)

The Meditator now infers the existence of such a perfect being from the fact that he as a finite being must be caused by such a perfect being, and from the fact that he or she could have present in his or her thoughts the idea of such a being only if it

were placed there by such a being. But the existence of a perfect being is only established hypothetically – the arguments depend upon causal principles that, while self-evident, have not yet been established as true – following hypothetically from propositions that are themselves only hypothesis, the existence of God at this point in the inferences of the *Meditations* can only be an hypothesis – a further stage as one is led on by the analytic method to the discovery of what one hopes will be a truth upon which all other truths can be made demonstratively to rest.

The Fourth *Meditation* is a sort of aside in which Descartes clears away an apparent difficulty. There appears to be an inconsistency between the idea of a perfect being causing one with the idea that one falls into error and doubt: shouldn't a perfect being create beings that do not fail to be what essentially they ought to be? Descartes replies that such error is not caused by God but by ourselves. **Located in a world that often hastens us on, we must regularly conclude before full evidence is available.** Our will moves us to judge and such judgments often outrun what reason can justify. Now, God has given us free will, and this is a greater good than is mere avoidance of error. God's will does not cause us to err, it is our own will that does that, so the idea of a perfect God creating us is compatible with our being beings that fall into error. The apparent difficulty disappears, and we can return to the process of analysis that is, one hopes, leading one to a premise which can serve to demonstrate the hypotheses through which one is being led by a series of apparently necessary connections.

The Idea of an Infinite Being: This brings us to the **Fifth *Meditation*.** Thinking of oneself as a finite being one is led to the idea of God and then to the idea of God as one's creator and as one who is created with the idea of such a perfect being within oneself. But now before one's mind is the idea of a being with creative powers that lacks nothing, lacks no perfection. It must therefore in particular cause itself to be and to be in this state of full perfection. But if it has the creative power to maintain itself as a being which lacks nothing, if, in other words, it is a being which as a creating being is infinitely powerful, then there is nothing else that could cause it not to be in any way at all. We have within us this idea and as we plumb its depths we recognize that this is an idea of a being which has the creative powers of which guarantee that it exists, it is the idea of a being that guarantees the truth of this very idea. Our other ideas are ideas of finite beings none of which can guarantee their own existence and the ideas of which might therefore be false; but this one idea, this one essence that is before the mind, is the idea of a being infinite in its creative powers and which is therefore the essence of a being that can guarantee its own existence, which in turn therefore guarantees the truth of the idea of itself.

Here, then, in the existence of God, we have reached the end point of our analytic process in a **truth which guarantees its own truth and upon which all other truths can be made to rest.** This truth can therefore form the incorrigible base upon which all our knowledge claims can be made to rest. Descartes can now hastily draw things to a close: **God as a perfect being, could not create non-being: it is a contradiction to suppose non-being could be brought into being.** But for a rational being, a thinking substance, to err is for it to not know: it is a form of non-being. So God could not create a rational being for which principles clearly and distinctly perceived to be true were after all false: that would be to create a being which systematically erred about the structure of the world. So what is clear and distinct, what is self-evident, and compels its acceptance by the Meditator and indeed by any rational being, is guaranteed to be true. In particular, the laws of geometry, of extended substance, are guaranteed to be true. And further, the incompatibility of thought and extension as essence of substances, which, in the Second *Meditation*, while clear and distinct, can now be affirmed as not merely apparently true but as actually true.

With God, we have reached at the conclusion of the analytic process the starting point of the synthetic presentation that Descartes gives in his *Replies* to the *Objections*. In that synthetic presentation, the sequence ends with the conclusion (theorem) that **what is clear and distinct must be true.**

Two points need to be mentioned. First, the move of "I think, therefore I am" (*cogito, ergo sum*) is not a direct insight into the Meditator's own being. It is, rather, an inference, based on the principle that every mode (property) exists only if it is in a substance. Since it is based on a metaphysical principle the truth of which has not yet been established, it could not provide a starting point for constructing the edifice of knowledge.

Second, the existence of God is in the end not established by argument. The so-called ontological argument of the Fifth *Meditation* is not in fact an argument. It is rather a case where we have direct insight into the essence of God – what is formally the idea of God is objectively the essence of God –, where we recognize that here we have an essence that guarantees its own existence as an infinitely powerful being and thereby guarantees the truth of the idea through which we think it. Other ideas we have are no doubt true, but none save this one alone guarantees its own truth – guarantees it in a way that requires no argument. With God we reach a point where no further premises are either available or needed.

The Cartesian method to science thus indeed yields an a priori science. It is a deductive method but one that involves both analysis and synthesis.

d. The Science in the 'Method of Doubt'

We have so far studiously avoided one feature of the Cartesian method. This is the so-called "method of doubt." Descartes takes very seriously the notion that progress in science will be hindered if we allow our minds to be clouded by the worthless standards inherited from the past and from our teachers. Thus, he begins the *Geometry* with his clarification of the notion of a power, removing the irrelevant geometrical connotations attached to expressions like "x cubed" and replacing them with the perspicuous notation of "x^n" that we continue to use to this day. Again, he believed it to be important to shed ourselves of all forms of teleological thinking – he chastised Harvey for falling away from the mechanistic reasoning he used to establish the circulation of the blood and into teleological thinking when he came to discuss the action of the heart.

He therefore recommended that one undertake a cleansing intellectual project in the attempt to move towards truth by first eliminating error and indeed all possibility of error. This could be done by rejecting as false all propositions that could in any way be doubted. This is Descartes' first rule of method in the *Discourse on Method*. This is stated as the injunction:

Never to accept anything as true if I did not have evident knowledge of its truth: that is, carefully to avoid precipitate conclusions and preconceptions, and to include nothing more in my judgments than what presented itself to my mind so clearly and so distinctly that I had no occasion to doubt it.

By eliminating all dubitable beliefs, truths would of course be excised along with the false, but then in the re-building of the edifice of knowledge that was to follow those truths would be recovered, free from the errors of the past.

This was an exercise to be undertaken by oneself, simply taking oneself to be a rational being. But if one is rational, one is also animal, even if being an animal is not part of one's essence. The animal makes demands – one must eat and drink, one must sleep, perchance to dream, one must live with others, one might even take a lover. One could not do this if all beliefs were eliminated. So Descartes also recommends that one go along with this second best, **the beliefs that one needs to survive and to have a decent and pleasant life** – interrupted only occasionally by bouts of meditating on the foundations of knowledge, or the basic laws of physics – just as one must in the end do science empirically, through observation and experiment, even though it is only uncertainly founded. **Reason demands for itself the method of doubt, but the remainder of one's being makes unavoidable demands that require one to ignore the promptings of reason to try to doubt everything.** The reasonable person will accede to those demands, just as reason must attempt a universal doubt. It is also part of Descartes' method that one does

accede to those extra-rational demands. The reasonable person could not do otherwise: there is in the end more to being human than simply being rational.

It is remarkable, however, just how far Descartes, while meditating, is prepared to take the doubt his method recommends. In the *Discourse on Method* he seems to stop with what is self-evident, what is clear and distinct: he seems to assume is true, and therefore makes this his starting point. In the *Meditations*, he takes the doubt a step further, finding a way to call into doubt even what is most evident. **His model is the traditional doctrine of transubstantiation according to which the bread and wine during the saying of the mass is miraculously transformed by God into the body and blood of Christ.** [n] The sensible appearances remain the same, but the substance changes in its essence. The heretic and unbeliever will be deceived by appearances into thinking no change has occurred. But the good Christian *knows* that whatever be the sensible appearances what is really there is the body and blood of Christ. His or her faith prevents him or her from falling into the error of the heretic and the unbeliever. Indeed, it is out of God's goodness that the heretic and the unbeliever be deceived in this way, since if they realized what was really happening, that the body and blood of Christ were being consumed, they could charge the Christian with the sin, horrid to conceive, of cannibalism.

So Descartes at least takes Thomas Aquinas' account of **transubstantiation** seriously and uses it as a model. He creates the hypothesis that there is a powerful being who has the capacity to deceive me into thinking that world is not as my clear and distinct ideas make it out to be when in fact in its essence it is something else. One hypothesizes that there is a powerful being, like God no doubt, but instead an **evil genius**, intent on deceiving one about the basic ontological structure of being. In fact, the hypothesis is sufficiently strong to make is possible that I am deceived about my own being, that contrary to what appears to me to be true, that *cogito ergo sum* holds, it really does not and I am really something essentially different from the thinking thing that I appear to me to be. (**Descartes makes clear at the beginning of the Third *Meditation* that the hypothesis of the evil genius calls even the *cogito* into question.**)

So we have the structure of the *Meditations* as follows:

[Hypothesis:] There is an evil genius who is deceiving me about the truth of clear and distinct ideas. [From this hypothesis] now infer] if I am being deceived, then I am thinking; if I am thinking, then I exist; if I (as a finite creature) exist, then there exists a God (an infinite being) who creates me; – [here the existence of God is hypothetical, but having reached the idea of God as an infinite cause of all being, including myself, I can see as I grasp this idea that it non-hypothetically requires its own truth] – God (as an infinite creator) guarantees His own being and therefore

exist – [here we have reached a certain and incorrigible categorical truth]; but [now upon this truth all other truths hinge] **an infinite being is a perfect being and therefore cannot create finite beings who are systematically deceived**; therefore our clear and distinct ideas are true; therefore there is no evil genius.

The *Meditations* thus have the form of **an analytic structure of a *reductio ad absurdum*** of the hypothesis of the evil genius who systematically deceives me: I find in God that necessary truth which contradicts and therefore eliminates the hypothesis of the evil genius. The method of doubt is solved by Descartes to his own satisfaction, but to few others. For him it was a way to purge the mind of inherited prejudice, and therefore merely a first and preliminary step on the way to truth. It was clear to him that if one stopped there then one had fallen into a skeptical morass – a skepticism close to that into which Montaigne had suggested was the inevitable fate of the human intellect, it was human hubris to think that one could really know anything. One had to settle for such mere belief and opinion that one could learn from experience of the ordinary world – which was also the position Descartes recommended for the human being to fall back into while undertaking the intellectual exercise of the method of doubt. Descartes felt he could find the natural light of reason and move out of Montaigne's skeptical morass – he felt that the illumination began with his discovery that *cogito, ergo sum*, and from there was led on by that light of reason to discover its source in God and to discover in that source a firm point on which to tie down incorrigible and indubitable knowledge of the rational structure of the world.

III. Positivist Methodology of Science

a. Introduction

Another important method of science that we need to consider here is the positivist methodology of science, often known as "Positivism." Positivism refers to a set of **epistemological** perspectives and **philosophies of science** which hold that the **scientific method** is the best approach to uncovering the processes by which both physical and human events occur. Though the positivist approach has been a recurrent theme in the history of western thought from the Ancient Greeks to the present day, the concept was developed in the early 19th century by the philosopher and founding sociologist, **Auguste Comte.**[IX]

b. Background to The Study of Positivism

Positivism asserts that the only authentic knowledge is that which is based on sense, experience and positive verification. As an approach to the philosophy of

science deriving from Enlightenment thinkers such as **Henri de Saint-Simon** and **Pierre-Simon Laplace, Auguste Comte** saw the **scientific method** as replacing metaphysics in the history of thought, observing the circular dependence of theory and observation in science. Sociological positivism was later reformulated by **Émile Durkheim** as a foundation to **social research**. At the turn of the 20th century the first wave of German sociologists, including **Max Weber** and **Georg Simmel**, rejected the doctrine, thus founding the **anti-positivist** tradition in sociology. Later anti-positivists and critical theorists have associated positivism with "scientism"; science *as ideology*.

In the early 20th century, **logical positivism**—a descendant of Comte's basic thesis but an independent movement— sprang up in **Vienna** and grew to become one of the dominant schools in Anglo-American philosophy and the analytic tradition. Logical positivists (or **'neo-positivists'**) reject metaphysical speculation and attempt to reduce statements and propositions to pure logic. Critiques of this approach by philosophers such as **Karl Popper, Willard Van Orman Quine** and **Thomas Kuhn** have been highly influential, and led to the development of post-positivism. In psychology, the positivist movement was influential in the development of behavioralism and operationalize.

c. Some Basic Principles of Positivism

Positivism in its strongest original formulation could be thought of as a set of five principles:

1. The unity of the **scientific method** – i.e., the logic of inquiry is the same across all sciences (social and natural).

2. The goal of inquiry is to explain and predict. Most positivists would also say that the ultimate goal is to develop the law of general understanding, by discovering necessary and sufficient conditions for any phenomenon (creating a perfect model of it). If the law is known, we can manipulate the conditions to produce the predicted result.

3. Scientific knowledge is testable. Research can be proved only by **empirical** means, not argumentations. Research should be mostly **deductive**, i.e. deductive logic is used to develop statements that can be tested (**theory** leads to hypothesis which in turn leads to discovery and/or study of evidence). Research should be observable with the **human senses** (arguments are not enough, sheer belief is out of the question). Positivists should prove their research using the logic of confirmation.

4. Science does not equal **common sense**. Researchers must be careful not to let common sense bias their research.

5. The relation of theory to practice – science should be as value-neutral as possible, and the ultimate goal of science is to produce knowledge, regardless of any politics, morals, or values held by those involved in the research. Science should be judged by **logic,** and ideally produce universal conditionals:

   - For all conditions of X, if X has property P and P=Q, then X has property Q.

   - Statements must be true for all times and places.

d. Logical Positivism

In the original Comtean usage, the term "positivism" roughly meant the use of scientific methods to uncover the laws according to which both physical and human events occur, while "sociology" was the overarching science that would synthesize all such knowledge for the betterment of society. "Anti-positivism" formally dates back to the start of the twentieth century, and is based around the belief that natural and human sciences are ontologically and epistemologically distinct. Neither of these terms is any longer used in this meaning.[111]

Logical positivism (later and more accurately called logical empiricism) is a school of philosophy that combines **empiricism**, the idea that observational evidence is indispensable from knowledge of the world, with a version of **rationalism,** the idea that our knowledge includes a component that is not derived from observation.

Logical positivism grew from the discussions of a group called the "First Vienna Circle" which gathered at the **Café Central** before World War I. After the war **Hans Hahn**, a member of that early group, helped bring **Moritz Schlick** to Vienna. Schlick's **Vienna Circle,** along with **Hans Reichenbach's Berlin Circle,** propagated the new doctrines more widely in the 1920s and early 1930s. It was Otto Neurath's advocacy that made the movement self-conscious and more widely known. A 1929 pamphlet written by Neurath, Hahn, and **Rudolf Carnap** summarized the doctrines of the Vienna Circle at that time. These included: the opposition to all metaphysics, especially ontology and synthetic a priori propositions; the rejection of metaphysics not as wrong but as having no meaning; a criterion of meaning based on **Ludwig Wittgenstein's** early work; the idea that all knowledge should be **codifiable** in a single standard language of science; and above all the project of

"rational reconstruction," in which ordinary-language concepts were gradually to be replaced by more precise equivalents in that standard language.

In the early 1930s, the Vienna Circle dispersed, mainly because of fascist persecution and the untimely deaths of **Hans Hahn** and **Schlick.** The most prominent proponents of logical positivism emigrated to the United Kingdom and to the United States, where they considerably influenced American philosophy. Until the 1950s, logical positivism was the leading school in the philosophy of science. After moving to the United States, Carnap proposed a replacement for the earlier doctrines in his *Logical Syntax of Language.* This change of direction and the somewhat differing views of Reichenbach and others led to a consensus that the English name for the shared doctrinal platform, in its American exile from the late 1930s, should be "logical empiricism."

e. Positivism in science today

The key features of positivism as of the 1950s, as defined in the "received view",[111] are:

1. A focus on science as a product, a linguistic or numerical set of statements;

2. A concern with **axiomatization**, that is, with demonstrating the logical structure and coherence of these statements;

3. An insistence on at least some of these statements being testable, that is amenable to being verified, confirmed, or falsified by the empirical observation of reality; statements that would, by their nature, be regarded as untestable included the **teleological**; thus positivism rejects much of classical metaphysics.

4. The belief that science is markedly cumulative;

5. The belief that science is predominantly trans-cultural;

6. The belief that science rests on specific results that are dissociated from the personality and social position of the investigator;

7. The belief that science contains theories or research traditions that are largely commensurable;

8. The belief that science sometimes incorporates new ideas that are discontinuous from old ones;

9. The belief that science involves the idea of the unity of science, that there is, underlying the various scientific disciplines, basically one science

about one real world.

Positivism is elsewhere defined as "the view that all true knowledge is scientific,"[12] and that all things are ultimately measurable. Positivism is closely related to reductionism, in that both involve the view that "entities of one kind... are reducible to entities of another,"[13] such as societies to configurations of individuals, or mental events to neural phenomena. It also involves the contention that "processes are reducible to physiological, physical or chemical events,"[12] and even that "social processes are reducible to relationships between and actions of individuals,"[12] or that "biological organisms are reducible to physical systems."[12]

While most social scientists today are not explicit about their epistemological commitments, articles in top American sociology and political science journals generally follow a positivist logic of argument. [13] It can be thus argued that "natural science and social science [research articles] can therefore be regarded with a good deal of confidence as members of the same genre". [14]

f.   Some Criticism

Historically, positivism has been criticized for its universalism, i.e. for contending that all "processes are reducible to physiological, physical or chemical events,"[12] "social processes are reducible to relationships between and actions of individuals,"[12] and that "biological organisms are reducible to physical systems."[12]

Max Horkheimer and other critical theorists criticized the classic formulation of positivism on two grounds. First, they claimed that it falsely represented human social action. The first criticism argued that positivism systematically failed to appreciate the extent to which the so-called social facts it yielded did not exist 'out there', in the objective world, but were themselves a product of socially and historically mediated human consciousness. Positivism ignored the role of the 'observer' in the constitution of social reality and thereby failed to consider the historical and social conditions affecting the representation of social ideas. Positivism falsely represented the object of study by reifying social reality as existing objectively and independently and labor actually produced those conditions. Secondly, he argued, representation of social reality produced by positivism was inherently and artificially conservative, helping to support the status quo, rather than challenging it. This character may also explain the popularity of positivism in certain political circles. Horkheimer argued, in contrast, that critical theory possessed a reflexive element lacking in the positivistic traditional theory.

Few scholars today hold the views critiqued in Horkheimer's work. Since the time

of his writing, critiques of positivism, especially from philosophy of science, have led to the development of **postpositivism**. This philosophy greatly relaxes the epistemological commitments of logical positivism and no longer asserts the separation of the knower and the known. Rather than dismissing the scientific project outright, postpositivists seek to transform and amend it, though the exact extent of their affinity for science varies vastly. For example, some postpositivists accept the critique that observation is always value-laden, but argue that the best values to adopt for sociological observation are those of science[15]: skepticism, rigor and modesty. Just as some critical theorists see their position as a moral commitment to egalitarian values, these postpositivists see their methods as driven by a moral commitment to these scientific values. Such scholars may see themselves as either positivists or **antipositivists.**

Positivism has also come under fire on religious and philosophical grounds, whose proponents assert that truth begins in sense experience, but does not end there. Positivism fails to prove that there are not abstract ideas, laws, and principles, beyond particular observable facts and relationships and necessary principles, or that we cannot know them. Nor does it prove that material and corporeal things constitute the whole order of existing beings, and that our knowledge is limited to them. According to positivism, our abstract concepts or general ideas are mere collective representations of the experimental order — for example, the idea of "man" is a kind of blended image of all the men observed in our experience. This runs contrary to a Platonic or Christian ideal, where an idea can be abstracted from any concrete determination, and may be applied identically to an indefinite number of objects of the same class. From the idea's perspective, the latter is more precise as collective images are more or less confused, become more so as the collection represented increases; an idea by definition remains always clear.

Echoes of the "positivist" and "antipositivist" debate persist today, though this conflict is hard to define. Authors writing in different epistemological perspectives do not phrase their disagreements in the same terms and rarely actually speak directly to each other.[16] To complicate the issues further, few practicing scholars explicitly state their epistemological commitments, and their epistemological position thus has to be guessed from other sources such as choice of methodology or theory. However, no perfect correspondence between these categories exists and many scholars critiqued as "positivists" actually hold post-positivist views. One scholar has described this debate in terms of the social construction of the "other", with each side defining the other by what it is *not* rather than what it *is*, and then proceeding to attribute far greater homogeneity to their opponents than actually exists.[16] Thus, it is better to understand this not as a debate but as two different arguments: the "antipositivist" articulation of a social meta-theory

which includes a philosophical critique of scientism, and "positivist" development of a scientific research methodology for sociology with accompanying critiques of the reliability and validity of work that they see as violating such standards.

VI.   Inductivist & Deductivist Methodology of Science

a.   Introduction

In an essay entitled *Is the Scientific Paper a Fraud?* [15], Peter Medewar claimed that induction, in contrast to deduction, had no place in science. His implication of fraud was not aimed, not at the paper's contents, but at how they were presented, and here he strongly implied that this presentation was an inductive process. Medewar was a great admirer of Karl Popper, a philosopher of science. In *The Logic of Scientific Discovery* [16], Popper rejected induction as a legitimate form of logic in the practice of science. To bolster his argument against induction in science, Medewar cited an unsuccessful attempt by John Stuart Mill to solve problems in sociology by induction, but neglected to mention Francis Bacon's contribution to the birth of modern science in the 17th century by the use of induction as a powerful alternative to Aristotelian and scholastic dogma.

Popper and Medewar argued vehemently for a method of scientific practice based on the so-called hypothetico-deductive system, the essence of which is the formulation of a hypothesis derived from a collection of facts, testing the hypothesis by trying to 'falsify' it, collecting more facts if 'falsification' fails, and repeating the falsification tests until either you and the hypothesis agree on a draw or one of you admits defeat. Medewar (1915–1987) shared the 1960 Nobel Prize in Medicine or Physiology with Sir Frank MacFarlane for their work on the mechanism of tolerance to acquired immunity. Karl Popper (1902–1994) was knighted by Queen Elizabeth II in 1965 and elected a Fellow of the Royal Society in 1976, so there's no question here about the kinds of minds we're dealing with.

It is perhaps not too hard to understand that a philosopher, even of science, could make judgments about any aspect and especially the methods of science, but what confuses me and I'm sure would confuse any graduate student or postdoc or, in fact, anyone with an inquiring mind is why someone like Medewar, a practicing scientist, and certainly no dummy, should get worked up enough about induction to write an essay excommunicating it from the scientific community. Is it really that wicked? Or useless? Should I, as a graduate student, watch my step to make sure I don't ever use induction in my research? Can I still become a scientist if I do? Should I be careful to use only deductive reasoning and not lift a finger to make my

next advance into knowledge without first having formulated a hypothesis? What if I just want to ask a question?

Medewar's essay and Popper's philosophy of science are a good example of an idiosyncratic viewpoint about what science is and how it should be practiced. It is not my own point of view. The purpose of this essay is to make three main points that emerge from this difference. The first is that induction is an integral part of the practice of science and Popper and Medewar, therefore, in spite of their membership in the class of intellectual giants, are not only talking nonsense about induction having no place in science, but are committing a logical heresy by doing so. The next is that scientific methods such as hypothetico-deductive [17], Koch's postulates [18], or any other system based on rules of procedure or analysis, while they may be legitimate ways to practice science, are far from the only ways to do so. The final point is that certain features of the practice of science, theorizing, for example, are essential parts of *all* branches of science and far more important than searching for a non-existent only true "scientific method." Most of what I have to say should be seen only as a perspective of my own ideas about how we practice science, arising from my familiarity with the practical and theoretical methods of science, or having read or heard about or observed being used by other scientists. Most (if not all) of this has been said before but that doesn't matter. Each viewpoint, like each human being, is different and the differences can sometimes be more interesting than the similarities. A close friend and colleague, for example, disagree with my definition of science! That's the point. There is no consensus, even among scientists and Philosophers, about exactly what science is and every viewpoint, therefore, can be at least potentially, valuable. It hardly needs saying that the views expressed in this essay are not necessarily those of the SSR or its Web site.

Before we get into the nitty-gritty of this essay, however, a small light touch may help to set the stage, especially since it serves very well as a pleasant example of what science can be all about. In a charming essay entitled *Can an Ape Tell a Joke?* [19], Vickie Hearn describes a problem-solving study in which a chimpanzee and an orangutan, housed separately, were each given a small hexagonal block of wood and an assortment of differently shaped openings into only one of which the block would fit. They knew they would be rewarded for making the right choice.

The chimp examined every detail of the floor, walls, and ceiling; the openings and every side of the hexagonal block; smelled it, tasted it and, after trying one opening after another, found one opening the block would fall into. The orangutan scratched his back with the block, and then sat with a faraway look in his eyes for what seemed to the human observer like forever. He then put the block directly

into the hexagonal opening.

Was the chimp an inductivist? Did the orangutan consider the problem, form a hypothesis, then test it? Which one was the scientist? These questions and more shall be the focus of this following section as we consider this fundamental method of science.

b. General Background Study to The Study of Induction and Deduction

A commonly held idea of the distinction between these logical paths to knowledge is that induction is the formation of a generalization derived from examination of a set of particulars, while deduction is the identification of an unknown particular, drawn from its resemblance to a set of known facts. For example, if we examine enough feral cats we can generalize that feral cats are a rich sources of fleas (induction). If, like Robinson Crusoe, we come across footprints on the beach of a desert island, we can conclude from our knowledge of the human footprint that another human is or was on the island (deduction). In fact, however, both terms can have more subtle meanings. Let's start with a look at their etymology and definitions.

Etymology: The etymology of these words does not seem to have any of the judgmental qualities attributed to them by Popper and Medewar. They come from the Latin verb *ducere*, to draw on or along, to pull or drag, to draw to oneself, to lead, and with the Latin propensity for prefixes. Suffixes, and the modification of the verb itself, *ducere* has spawned an enormous population of derivatives [m]. Even with only the prefixes *in* and *de*, meaning 'in' and 'from,' respectively, both words may have many more than one meaning. Simply put, *to induce* could mean 'to lead or draw into, to infer, to persuade,' and *induction*, 'to lead to the conclusion that etc....' *To deduce* could mean 'to lead from, to draw from' and *deduction*, 'to draw a conclusion from etc....' The official lexicographic and practical definitions are not always much more distinctive.

c. Definitions of Terms

Induction: From *The Oxford English Dictionary* (*OED*); *to induce* (in relation to science and logic) means "to derive by reasoning, to lead to something as a conclusion, or inference, to suggest or imply," and induction "as the process of inferring a general law or principle from observation of particular instances." Another version is the "adducing (pulling together) of a number of separate facts, particulars, etc. especially for the purpose of proving a general statement."

The 1967 edition of the *Encyclopedia Britannica* (*E. Brit.*) gives two versions by John Stuart Mill: "the operation of discovering and proving general propositions" or "that operation of the mind by which we infer that what we know to be true in a

particular case or cases will be true in all cases that resemble the former in certain assignable respects."

A paraphrase of Francis Bacon's view (also from the *E. Brit.*) is "a selective process of elimination among a number of alternative possibilities." The *E. Brit.* in a separate entry defines *primary induction* as "the deliberate attempt to find more laws about the behavior of the thing that we can observe and so to draw the boundaries of natural possibility more narrowly" (that is, to look for a generalization about what we can observe), and *secondary induction* as "the attempt to incorporate the results of primary induction in an explanatory theory covering a large field of enquiry" (that is, to try to fit the generalization made by primary induction into a more comprehensive theory).

E. Mayr in his *Growth of Biologic Thought* [nn] offers this definition: "Inductivism claims that (we) can arrive at objective unbiased conclusions only by...recording, measuring, and describing what we encounter without any root hypothesis...."

Deduction: Sherlock Holmes' "Elementary, my dear Watson!" has made deduction common knowledge a more familiar feature than induction in problem solving. The *OED* definition of *to deduce* is "to show or hold a thing to be derived from etc...." or "to draw as a conclusion from something known or assumed, to infer"; *deduction* thus is "inference by reasoning from generals to particulars," or "the process of deducing from something known or assumed...."

Both terms define systems of logic the purpose of which is to solve problems, in the one case by looking for a general characteristic (generalization, conclusion, conjecture, supposition, inference, etc.) in a set or group of observations, in the other to identify a particular instance through its resemblance to a set or group of known instances or observations. Popper's ridicule of induction was based on the premise that induction requires the observation of *every* instance of a given phenomenon for the generalization to be true—an obvious impossibility; the fact that all known crows are black, for example, doesn't prove that no white crows exist. Of course it is ridiculous when looked at in this way, but what *really* matters is that most if not all crows *are* black, and even if a white one should show up and prove to be a crow and not another kind of bird, most crows would still be black. His argument can also be used to make deduction useless for it, too, is based on an incomplete set of known facts. Even if the identified fact resembles the members of the set, how can we be sure that *every* possible feature of either the unknown or the members of the set itself has been considered? As we will see in what follows, in many of the examples of the way science is practiced, induction is as much a part of this practice as is deduction or any system of logic that serves the purpose of advancing knowledge. Induction and deduction are two, usually

different but never contradictory, approaches to problem solving. The problem must be solved by testing the validity of the conclusion or inference, etc. reached from either direction. Induction and deduction are thus valuable, often complementary, tools that facilitate problem solving.

d. Induction as a Method of Science: Matters Arising

In spite of what I have said so far, is there a particular method we can call THE scientific method? To answer this question it is essential that we first ask another question: even though we have talked about this before, there is need to be really abreast with the meaning / definitions of science again in this context.

What do we mean by science? The word comes from Latin *scire*, "to know," and *scire* comes from an earlier Latin root meaning "**to cut through,**" i.e. to take apart, to analyze. But science is more than just knowing by analysis. As noted before, Science is a process of learning to know the nature of everything in the material world, from atoms to the most complex of living organisms and inanimate objects. Nonmaterial things, like *gods*, whose existence can be neither confirmed nor disproved, are excluded, for science deals only with those **elements** of the universe that can be shown, at least potentially, to exist. **Science, therefore, is never-ending** and always changing. **Although its goal is knowledge, it is more than and different from knowledge itself,** for knowledge is its product not its essence. Its essence is to **doubt without adequate proof.** Science is the offspring of philosophy, and differs from it mainly in the methods used in learning to know.

As with almost all systems of classification, we can't draw a sharp distinction between science, as defined here, and other forms of scholarship as sources of knowledge such as the *OED*, *Grove's Dictionary of Music and Musicians*, the *Dickson Baseball Dictionary*, etc. or even history, for example. In many respects, history is a science but it is poorly endowed with or even lacks the ability to predict, one of the important things that separates science from other forms of learning.

In all respects science is logically incompatible with the belief in a nonmaterial intelligent entity that controls the universe and is called God [13], [14], yet many scientists, especially among the chemists and physicists but even among some biologists have such a religious belief. I can think of only three resolutions of this paradox. The scientist's God either is not an intelligent entity or has no control over the universe. The second is to accept the concept of science as defined here with a part of one's mind and that of God with another, with an impermeable barrier between the two parts. The third is either not to be a scientist or not to believe in God, i.e. to be **an atheist**, or euphemistically, a nonbeliever since among

many people 'atheist' is a dirty word. The funny thing about these solutions is that they all work! The troublemakers are the **zealots**, i.e. the proponents of Intelligent Design on the one hand, and the Russian communists' idiotic attempt to prohibit religion on the other.

A firm distinction between the so-called *hard* and *soft* sciences, e.g. physics and sociology, can also not be made simply because it is easier to test reality in some more than in other sciences. Science itself, therefore, answers our question with a simple but firm No. There cannot be one method that every kind of scientific study—in the field, the library, or the laboratory—must follow; the things scientists are curious about differ too much from one another for all of them to be studied according to the same or any set of rules or algorithms.

Medewar's caricature of the scientific paper boils down to a matter of **beating a dead horse.** He labels it inductivist because the authors often present their results without comment and reserve interpretation of them for the Discussion. In the first place, this isn't induction. Even Bacon, its chief proponent, saw induction mainly as a way to separate particulars from one another into groups of similarities. This is exactly what the taxonomist does. But even if it were induction (the meaning of which seems to depend on who defines it), what's unscientific about saying, "Here's what we found. How would you interpret them? Then we'll tell you what we think"? Shouldn't a scientific paper be at least as much fun to read as a good detective story? There are plenty of things wrong with the way many scientific papers are written (freight-train adjectives, misplaced clauses, redundancies, mistakes in grammar and/or syntax, teleologisms, etc.), but presenting the results without comment is not one of them. I have a hunch that Medewar was not a lover of who-done-its!

The only true scientific method is to **use whatever tools we can to make observations, ask and answer questions, solve problems, test a theory, etc.,** and it doesn't matter whether we use induction, deduction, or any other kind of reasoning to do so; it would be a heresy to deny the validity of any method that helps us learn to know. Induction, in fact, resembles what prose was to Moliere's bourgeois gentleman [25]. We use some form of induction in almost every kind of scientific endeavor: no matter how it is defined, induction amounts to making and collating observations. This was Francis Bacon's great contribution to science, i.e. induction as a path to knowledge through *direct* observation of nature [26].

Let's come back now to the chimp and the orangutan. Were both scientists? Yes. Was the orangutan more so than the chimp? No. He was only different. Who can say which was better? Are **Mayr's** contributions to evolution through ornithology [27] less valuable than **Dobzhansky's** through genetics [28]? Was **Vesalius** less a

scientist than **Mendel** because he described human anatomy while Mendel did experiments? Both made observations, one by dissection and the other by making hybrids. Both increased our knowledge of the natural world. Yes, some are better than others; its how the game is played. We can't all play the violin like Heifetz, and the likes of a **Copernicus**, a **Newton**, a **Darwin**, and an **Einstein** don't make the headlines every day. But we can all be scientists. I shall be talking more about this attack on the method of induction latter when I discuss Paul Feyerabend ideas of science and philosophy.

e. Ancient and Early Modern Origins

At this point I think it is important that we consider the some of the Ancient and early modern origins of the problems of induction.

Pyrrhonian skeptic **Sextus Empiricus** first questioned the validity of inductive reasoning, positing that a universal rule could not be established from an incomplete set of particular instances. He wrote [26]

> When they propose to establish the universal from the particulars by means of induction, they will effect 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.

The focus upon the gap between the premises and conclusion present in the above passage appears different from Hume's focus upon the **circular reasoning** of induction. However, **Weintraub** claims in The Philosophical Quarterly [30] that although Sextus' approach to the problem appears different, **Hume's** approach was actually an application of another argument raised by Sextus[31]:

Those who claim for themselves to judge the truth are bound to possess a criterion of truth. This criterion, then, either is without a judge's approval or has been approved. But if it is without approval, whence comes it that it is truthworthy? For no matter of dispute is to be trusted without judging. And, if it has been approved, that which approves it, in turn, either has been approved or has not been approved, and so on *ad infinitum*.

Although the **criterion argument** applies to both deduction and induction, Weintraub believes that Sextus' argument "is precisely the strategy Hume invokes against induction: it cannot be justified, because the purported justification, being inductive, is circular." She concludes that "Hume's most important legacy is the supposition that the justification of induction is not analogous to that of deduction." She ends with a discussion of Hume's implicit sanction of the validity

of deduction, which Hume describes as intuitive in a manner analogous to modern foundationalism.

Medieval writers such as **al-Ghazali** and **William of Ockham** connected the problem 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. [31] **Duns Scotus** however 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.'" [32][33] Some 17th century Jesuits argued that although God could create 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. [34]

f. Inductive Reasoning

Before talking in details about the problems of induction, there is need to consider the various issues associated with inductive reasoning as a method of thought or thinking in the field of science.

Inductive reasoning, also known as **induction** or **inductive logic**, is a kind of reasoning that constructs or evaluates inductive arguments. It is commonly construed as a form of reasoning that makes generalizations based on individual instances. In this sense it is often contrasted with **deductive reasoning**. However, philosophically the definition is much more nuanced than simple progression from particular / individual instances to wider generalizations. Rather, the premises of an inductive **logical argument** indicate some degree of support (inductive probability) for the conclusion but do not **entail** it; that is, they suggest truth but do not ensure it. In this manner, there is the possibility of moving from generalizations to individual instances.

1. **90% of humans are right-handed.**

2. **Joe is a human**

   Therefore, Joe is right-handed.

Induction is employed, for example, in the following argument:

> **Every life form we know of depends on liquid water to exist. All life depends on liquid water to exist.**

Inductive reasoning allows for the possibility that the conclusion is false, even where all of the premises are true. [36] For example:

> **All of the swans we have seen are white. All swans are white.**

Note that this definition of *inductive* reasoning excludes **mathematical induction,** which is considered to be a form of ***deductive*** reasoning.

Though many dictionaries define inductive reasoning as reasoning that derives general principles from specific observations, this usage is outdated.

1. Strong and weak induction

The words 'strong' and 'weak' are sometimes used to praise or demean the goodness of an inductive argument. The idea is that you say "this is an example of strong induction" when you would decide to believe the conclusion if presented with the premises. Alternatively, you say "that is weak induction" when your particular world view does not allow you to see that the conclusions are likely given in the premises.

Strong induction

> The equation, "the gravitational force between two objects equals the gravitational constant times the product of the masses divided by the distance between them squared," has allowed us to describe the rate of fall of all objects we have observed.
> Therefore:
> The gravitational force between two objects equals the gravitational constant times the product of the masses divided by the distance between them squared.

The conclusion of this argument is not absolutely certain, even given the premise. At speeds we normally experience, Newtonian mechanics holds quite well. But at speeds approaching that of light, the Newtonian system is not accurate and the conclusion in that case would be false. However, since, in most cases that we experience, the premise as stated would usually lead to the conclusion given, we are logical in calling this argument an instance of strong induction.

Weak induction

Consider this example:

> I always hang pictures on nails.
> Therefore:
> All pictures hang from nails.

Here, the link between the premise and the conclusion is very weak. Not only is it possible for the conclusion to be false given the premise, it is even fairly likely that the conclusion is false. Not all pictures are hung from nails; moreover, not all pictures are hung. Thus we say that this argument is an instance of weak

induction. The question that results fro this situation is "**Is induction reliable**" ?

2. Is Induction Reliable?

Inductive reasoning has been attacked for millennia by thinkers as diverse as **Sextus Empiricus** and **Karl Popper.**

The classic philosophical treatment of the problem of induction was given by the Scottish philosopher **David Hume**. Hume highlighted the fact that our everyday functioning depends on drawing uncertain conclusions from our relatively limited experiences rather than on deductively valid arguments. For example, we believe that bread will nourish us because it has done so in the past, despite no guarantee that it will do so. However, Hume argued that it is impossible to justify inductive reasoning. Inductive reasoning certainly cannot be justified ductively, and so our only option is to justify it inductively. However, to justify induction inductively is circular. Therefore, it is impossible to justify induction.

However, Hume immediately argued that even if induction were proved unreliable, we would have to rely on it. So he took a middle road. Rather than approach everything with **severe skepticism**, Hume advocated a p ctical **skepticism** based on **common sense**, where the inevitability of indu tion is accepted.[ ] Resolutions that are made from inductive reasoning are often thought to be redden with a lot of '**Bias**'

Bias: Inductive reasoning is also known as hypothesis construction because any conclusions made are based on educated predictions. There are three biases that could distort the proper application of induction, thereby preventing the reasoner from forming the best, most logical conclusion based on the clues. These biases include the *availability bias*, the *confirmation bias*, and the *predictable-world bias*.

The availability bias causes the 'reasoner' to depend primarily upon information that is readily available to him. People have a tendency to rely on information that is easily accessible in the world around them. For example, in surveys, when people are asked to estimate the percentage of people who died from various causes, most respondents would choose the causes that have been most prevalent in the media such as terrorism, and murders, and airplane accidents rather than causes such as disease and traffic accidents, which have been technically "less accessible" to the individual since they are not emphasized as heavily in the world around him/her.

The confirmation bias is based on the natural tendency to confirm rather than to deny a current hypothesis. Research has demonstrated that people are inclined to seek solutions to problems that are more consistent with known hypotheses

rather than attempt to refute those hypotheses. Often, in experiments, subjects will ask questions that seek answers that fit established hypotheses, thus confirming these hypotheses. For example, if it is hypothesized that Sally is a sociable individual, subjects will naturally seek to confirm the premise by asking questions that would produce answers confirming that Sally is in fact a sociable individual.

The **predictable-world bias** revolves around the inclination to perceive order where it has not been proved to exist. A major aspect of this bias is superstition, which is derived from the inability to acknowledge that coincidences are merely coincidences. Gambling, for example, is one of the most obvious forms of predictable-world bias. Gamblers often begin to think that they see patterns in the outcomes and, therefore, believe that they are able to predict outcomes based upon what they have witnessed. In reality, however, the outcomes of these games are always entirely random. There is no order. Since people constantly seek some type of order to explain human experiences, it is difficult for people to acknowledge that order may be nonexistent. [20]

3. Types of Inductive Reasoning

Thinkers and researchers have come up with a various types of Inductive reasoning. For the purpose of the focus of this text, we shall be considering four of the outstanding type of inductive reasoning discussed so far, they include: **Generalization; Statistical Syllogism, Simple Induction and .**

1, Generalization: A generalization (more accurately, an *inductive generalization*) proceeds from a premise about a sample to a conclusion about the population.

> The proportion Q of the sample has attribute A.
> Therefore:
> The proportion Q of the population has attribute A.

Example

There are 20 balls--either black or white--in a bucket. To estimate their respective numbers, you draw a sample of four balls and find that three are black and one is white. A good inductive generalization would be that there are 15 black, and five white, balls in the bucket.

How much the premises support the conclusion depends upon (a) the number in the sample group compared to the number in the population and (b) the degree to which the sample represents the population (which may be achieved by taking a random sample). The **hasty generalization** and the **biased sample** are generalization fallacies.

2, Statistical syllogism: A statistical syllogism proceeds from a generalization to a conclusion about an individual.

> **A proportion Q of population P has attribute A.**
> **An individual X is a member of P.**
> **Therefore:**
> **There is a probability which corresponds to Q that X has A.**

The proportion in the first premise would be something like "3/5ths of", "all", "few", etc. Two *dicto simpliciter* fallacies can occur in statistical syllogisms: "**accident**" and "**converse accident**".

3, Simple induction: Simple induction proceeds from a premise about a sample group to a conclusion about another individual.

> **Proportion Q of the known instances of population P has attribute A.**
> **Individual I is another member of P.**
> **Therefore:**
> **There is a probability corresponding to Q that I has A.**

This is a combination of a generalization and a statistical syllogism, where the conclusion of the generalization is also the first premise of the statistical syllogism.

Under this kind of reasoning, we can have '**Arguments from Analogy**'. Some philosopher believe that an argument from analogy is a kind of inductive reasoning. An argument from analogy has the following form:

> I has attributes A, B, and C
> J has attributes A and B
> So, J has attribute C

An analogy relies on the inference that the attributes known to be shared (the similarities) imply that C is also a shared property. The support which the premises provide for the conclusion is dependent upon the relevance and number of the similarities between I and J. The fallacy related to this process is false analogy. As with other forms of inductive argument, even the best reasoning in an argument from analogy can only make the conclusion probable given the truth of the premises, not certain.

Analogical reasoning is very frequent in common sense, science, philosophy and the humanities, but sometimes it is accepted only as an auxiliary method. A refined approach is case-based reasoning.

4, Causal inference: A causal inference draws a conclusion about a causal connection based on the conditions of the occurrence of an effect. Premises about the correlation of two things can indicate a causal relationship between them, but

additional factors must be confirmed to establish the exact form of the causal relationship. Under this kind of reasoning we have **'Predictions'**

Prediction: A prediction draws a conclusion about a future individual from a past sample.

> Proportion Q of observed members of group G have had attribute A.
> Therefore:
> There is a probability corresponding to Q that other members of group G will have attribute A when next observed.

For the purpose of balance, we will at this juncture, discuss briefly some of the main themes of Deductive reasoning.

4. Distinguishing features of inductive methods of Reasoning

- They claim that the inductive methods of scientific inquiry are far more superior to the deductive method of science because it is integrally connected to the discovery of scientific laws and theories.

- The inductive methods allows us to make a leap from the finite data of observation to a law covering all that are known in the present and all that could be known in the future. While on the contrary, the deductive methods of reasoning can never advance to knowledge of the hitherto unobserved

- No inductive argument can be inductively valid

- The premise of an inductive argument can never provide conclusive grounds for the truth of the conclusion.

- There is no inductive argument which is such that the conclusion follows from the premise necessarily.

- The premise of an inductive argument can only provide more or less probable grounds for the truth of the conclusion.

- Inductive arguments can only be weekend or strengthened by additional evidence.

g. Deductive Reasoning

Deductive reasoning, also called **deductive logic**, as earlier discussed, is the kind reasoning which constructs or evaluates deductive arguments. Deductive arguments are attempts to show that a conclusion **necessarily follows** from a set of premises or hypotheses. A deductive argument is **valid** if the conclusion does follow necessarily from the premises, i.e., if the conclusion must be true provided that the premises are true. A deductive argument is **sound** if it is **valid** and its premises are **true.** Deductive arguments are valid or invalid, sound or unsound, but are never false nor true. Deductive reasoning is a method of gaining knowledge. An example of a deductive argument:

1. All men are mortal
2. Socrates is a man
3. Therefore, Socrates is mortal

The first premise states that all objects classified as "men" have the attribute "mortal". The second premise states that "Socrates" is classified as a man – a member of the set "men". The conclusion states that "Socrates" must be mortal because he inherits this attribute from his classification as a man.

Deductive reasoning has some basic mode of practice that have been captured in three different laws. These laws include: the law of detachment, The law of Syllogism and the Law Deductive Logic.

1. Law of detachment

The law of detachment is the first form of deductive reasoning. A single **conditional statement** is made, and then a hypothesis (P) is stated. The conclusion (Q) is deduced from the hypothesis and the statement. The most basic form is listed below:

1. $P \perp Q$
2. P (Hypothesis stated)
3. Q (Conclusion given)

We can conclude Q from P by using the law of detachment from deductive reasoning. However, if the conclusion (Q) is given instead of the hypothesis (P) then there is no valid conclusion.

The following is an example of an argument using the law of detachment in the

form of an If-then statement:

1. If $m\angle A>90°$, then A is an obtuse angle.

2. $m\angle A=120°$.

$\square$

3. A is an obtuse angle.

Since the measurement of angle A is greater than 90° degrees, we can deduce by that statement alone that A is an obtuse angle.

2. Law of syllogism

The law of **syllogism** takes two conditional statements and forms a conclusion by combining the hypothesis of one statement with the conclusion of another. The following is an example:

1. If Larry is sick, then he will be absent from school.

2. If Larry is absent, then he will miss his class work.

3. If Larry is sick, then he will miss his class work.

We deduced the solution by combining the hypothesis of the first problem with the conclusion of the second statement.

3. The law of deductive logic

Deductive reasoning / arguments from this perspective are generally evaluated in terms of their *validity* and *soundness*. This basically is a logical law that determines the side to which the scale pan will tilt to.

An argument is *valid* if it is impossible for its premises to be true while its conclusion is false. In other words, the conclusion must be true if the premises, whatever they may be, are true. An argument can be valid even though the premises are false.

An argument is *sound* if it is valid and the premises are true.

The following is an example of an argument that is valid, but not sound; this is because the premise is false:

1. Everyone who eats steak is a quarterback.

2. John eats steak.

3. Therefore, John is a quarterback.

The example's first premise is false (there are people who eat steak that are not

quarterbacks), but the conclusion must be true, so long as the premises are true (i.e. it is impossible for the premises to be true and the conclusion false). Therefore the argument is *valid*, but not *sound*. [38]

The theory of deductive reasoning known as categorical or term logic was developed by **Aristotle**, but was superseded by **propositional (sentential) logic** and **predicate logic**.

Deductive reasoning can be contrasted with **inductive reasoning**. In cases of inductive reasoning, even though the premises are true and the argument is "valid", it is possible for the conclusion to be false (determined to be false with a counterexample or other means). For more information on this see **Wogu, I. A. (2010).**

4. Hume's skepticism

Philosopher **David Hume** presented grounds to doubt deduction by questioning induction. Hume's problem of induction starts by suggesting that the use of even the simplest forms of *induction* simply cannot be **justified** by inductive reasoning itself. Moreover, induction cannot be justified by deduction either. Therefore, induction cannot be justified rationally. Consequentially, if induction is not yet justified, then deduction seems to be left to rationally justify itself – an objectionable conclusion to Hume.

Hume did not provide a strictly rational solution per se. He simply explained that we cannot help but induce, but that it is lucky that we do so. Certainly we must appeal to **first principles** of some kind, including **laws of thought**.

5. The Major Claims of the Deductive Methods of Reasoning

- In deductive reasoning or arguments, the author claims that the conclusion of the argument necessarily follows from the premise.

- Proofs in geometry and in other related area of mathematics will be one kind of deductive reasoning or argument as the case may be.

- When a deductive argument lives up to the authors expectations, that the conclusion follows necessarily from the premise, such argument is said to be valid. In other words, a valid argument is one where it is impossible for the premise to be true and the conclusion false.

- Where the authors claims fails to meet with the stated condition, we say the argument is *invalid*

  - But where the valid argument has true premises, then we say such an argument is *sound*

- On the contrary, the inductive argument that lives up the author's claims, i.e., where the premise makes the conclusion highly probable, we say that the "*argument is strong*".

- A *strong argument* that actually dose have true premise is called a *cogent argument.* Let us note that cogent arguments dose not absolutely guarantee the conclusion, as those of the sound argument) but it does give us strong reasons for believing the conclusion.

h. The Problem Of Induction

Formulation of the problem: In **inductive reasoning,** one makes a series of observations and **infers** a new claim based on them. For instance, from a series of observations that a woman walks her dog by the market at 8am on Monday, it seems valid to infer that next Monday she will do the same, or that, in general, the woman walks her dog by the market every Monday. That next Monday the woman walks by the market merely adds to the series of observations, it does not prove she will walk by the market every Monday. First of all, it is not certain, regardless of the number of observations that the woman always walks by the market at 8am on Monday. In fact, Hume would even argue that we cannot claim it is "more probable", since this still requires the assumption that the past predicts the future. Second, the observations themselves do not establish the validity of inductive reasoning, except inductively.

1. David Hume Description of The Problem of Induction

David Hume described the problem in *An Enquiry concerning Human Understanding,* §4, based on his **epistemological** framework. Here, "reason" refers to **deductive reasoning** and "induction" refers to inductive reasoning.

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,"[iii] 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 it 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 fact are based on causal relations, and all causal relations are found by induction, then induction must be shown to be valid somehow. He uses the fact that induction assumes a valid connection between the proposition "I have found that such an object has always been attended with such an effect" and the proposition "I foresee that other objects which are in appearance similar will be attended with similar effects."[iii] One connects these two propositions not by reason but by induction. This claim is supported by the same reasoning as that for causal relations above, and by the observation that even rationally inexperienced or inferior people can infer, for example, that touching fire causes pain. Hume challenges other philosophers to come up with a (deductive) reason for the connection. If the justification of induction cannot be deductive, then it would **beg the question;** for induction to be based on an inductive assumption about a connection. Induction, itself, cannot 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.**

2. Nelson Goodman's New Problem of Induction

Nelson Goodman presented a different description of the problem of induction in the third chapter of "**Fact, Fiction, and Forecast**" entitled "The New Riddle of Induction" (1954). Goodman proposed a new predicate, "**grue**". Something is grue if and only if it has been observed to be green before a certain time or blue after that time. The "new" problem of induction is, since all emeralds we have ever seen are both green and grue, why do we suppose that after time T we will find green but not grue emeralds? The standard scientific response is to invoke **Occam's razor**.

Goodman, however, points out that the predicate "grue" only appears more complex than the predicate "green" because we have defined grue in terms of blue and green. If we had always been brought up to think in terms of "grue" and "bleen" (where bleen is blue before time T, or green thereafter), we would intuitively consider "green" to be a crazy and complicated predicate. Goodman believed that which scientific hypotheses we favour depend on which predicates

are "entrenched" in our language.

3. Interpretations and Explanations of The Problems of Induction

A, **David Hume on the Problem of Induction:** Although induction is not made by reason, Hume observes that we nonetheless perform it and improve from it. He proposes a descriptive explanation for the nature of induction in §5 of the *Enquiry*, titled "Skeptical solution of these doubts". It is by custom or habit that one draws the inductive connection described above, and "without the influence of custom we would be entirely ignorant of every matter of fact beyond what is immediately present to the memory and senses."[xi] The result of custom is belief, which is instinctual and much stronger than imagination alone.[xii]

B, **Karl Popper:** a philosopher of science, sought to solve the problem of induction.[xiii] He argued that science does not use induction, and induction is in fact a myth.[xiv] Instead, knowledge is created by conjecture[xv] and criticism. The main role of observations and experiments in science, he argued, is in attempts to criticize and refute existing theories.[xvi]

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 an authoritarian answer". Instead, Popper said, what should be done is to look to find and correct errors.[xvii] Popper regarded theories that have survived criticism 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. Popper therefore 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 the one hand (which is the same as saying that they are highly falsifiable and so there are lots of ways that they could turn out to be wrong), but still all actual attempts to falsify them have failed so far (that they are highly corroborated).

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 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.[xviii]

David Miller has criticized this kind of criticism of Salmon and others, because it makes inductivist assumptions.[xix] Popper does not say that corroboration is an indicator of predictive power. The predictive power is in the theory itself, not in its corroboration. The rational motivation for choosing a well-corroborated theory is that it is simply easier to falsify: Well-corroborated means that at least one kind of experiment (already conducted at least once) could (but did not) falsify the one theory, while the same kind of experiment, regardless of its outcome, would not falsify the other. So it is rational to choose the well-corroborated theory; it may not be more likely to be true, but at least it is easier to get rid of it if not.

Other proofs: There are some deductive and mathematical ways to justify some of the logic behind induction. Besides those responses mentioned above, of further relevance to deductively proving aspects of the practice of inference are: **law of large numbers, Neyman–Pearson lemma, de Finetti's theorem,** and **Hans Reichenbach's** theories.

Philosopher **John Vickers** summarizes the ways these mathematical and deductive proofs respond to Hume's Problem of Induction. For one, Hume's algebraic foundations allowed for only rather weak logic, unlike those more complex theorems just mentioned. Moreover, modern mathematical reasoning has incorporated probability in a way that had not been done in Hume's time. At very least these provide good reason to trust inductive methods over simply **The Wisdom of Crowds** or single **testimony.** That is, the method of *induction* makes good *deductive* and probabilistic sense, but it is still up to people to determine which starting premises to hold true.

Vickers concludes that we should use induction, not because it yields **certainties,** like deduction, but because it is a method that actually seems to correct itself - and is thus more likely to bring us closer to truth than other methods.

i. A summary of all the Issues raised so far

1, THE QUESTION?

- As good as the so claimed "hall mark" may seem, there seem to be a problem when we try to ask whether induction can be justified.
- The method of induction even seem fallible to common sense.
- Critics have had to wondered whether the position and method of a gambler is not the same as those of the inductivist.

- So under such a situation, thinkers would ask what is the certainty that an event that took place in the past will reoccur as proposed by the inductivist?

- Matters arising from these issues have made thinkers to wonder why a method so ridden with "logical fallacies and inconsistencies" is still held in such high esteem, especially when we know that such claims are not justifiable

- It is the problem of justifying inductive leap that we call the problem of induction. R.H. Harre & E.H Madden in their book causal powers, defined the problem of induction as "the problem of the legitimacy of generalizing any result obtained in any particular empirical investigation.

2, THE SOLUTION

In an attempt to offer solutions to these matters arising from the problem of induction, three approaches were opened to the inductivist, (1) the logical defense, (2) the empirical defense, (3) the probability defense.

- **Logical Defense**

A valid argument we have stated earlier, is one with all its premise held to be true. While the deductive argument has this characteristic, the inductive argument does not. Inductive arguments cannot be appraised as valid, though most inductive arguments have a false conclusion and a true premise without being involved in a contradiction.

Examples of such inductive arguments will certainly show that there is a legitimate influence in reaching the conclusion, but there is no logical guarantee that the next proposed outcome will follow from the premise before it.

Conclusion: We can thus conclude on the account of arguments made on logical grounds that "while there will be no logical contradiction in claiming that a position is the case. There are no logical grounds that can justify the sweeping claims that are being made.

Consider a chicken that makes a sweeping claim about the time it was always fed, 9.00 am, everyday haven observed this for a while. But on this occasion, Christmas -eve to be precise, the chicken was shocked to know that this claim could not hold, for the chicken lost his head that very day to the caretakers Pot of **stew.**

- **Experiential Defense**

Where often the inductivist fail to explain or justify himself with logical defense, he fall back to experience. This they do by often recounting the successful predictions of a phenomenon from where inferences have been successful in the past, are made. Based on these, they propose another outcome. Consider the "eclipse of the moon as an example

The truth is that this way of justifying induction is untenable. This is because it employs the very kind of inductive argument whose validity is in need of justification

- **Example**
- **The principle of induction worked successfully on occasion X1**
- **The principle of induction worked successfully on occasion X2**
- **Therefore the principle of induction always works.**

Now because of the problem inherent in this kind of reasoning, any attempt to use this argument to justify induction is bound to be unsuccessful. This in turn will mean justifying induction with induction, which is circular. • Probability defense

Seeing that both the logical and the experiential methods have failed the inductivist resort to the method of "Probability" where most proponents of the inductive mode of reasoning have argued that the problem of induction could readily be solved.

They insist that rather than inferring the conclusion, "All A's are B", from the premise "All examined A's are B", the conclusion should read "it is more probable than not that "All A's are B".

Conclusion: From all indications, this reformulated version of induction faces the same problems that the previous attempted to justify. By this we do not see how this probabilistic defense successfully overcomes the problem of induction.

Max black captures this fact when he said;..."those who insist that the conclusion of inductive arguments should be probability statements are faced with the same dilemma that bedevils all previous attempts to justify induction"....

3, HUME AND THE PROBLEM OF INDUCTION

- Hume was the first philosopher to give serious thought to the problem of induction, though Hume was never known to have used the word "induction", in any of his works, his analysis of causation arises from his view that all reasoning concerning

matters of fact are grounded in the connection between cause and effect.

- He argued for instance: if I observe that event "A" is accompanied by event "B" on one occasion, it does not follow that "A" will be accompanied by event "B" on subsequent occasions. Where it happens often enough, I may come to expect that when next "A" occurs "B" follows.

- In Hume's own opinion, this mode of thought is a fact of sychology and not logic.

- He believes that no matter how numerous the numbers of observed instances may be, they do not logically entail that general statement (laws or theories) are inferred from them

- Hume nevertheless recognizes that the whole of science assumes that the future will always resemble the past in those aspects in which the laws of nature are said to operate. He was however quick to note that this assumptions by the inductivist are unjustifiable.

Hume's Summation

- Observation he strongly believed cannot establish this claims since the future that is being talked about is unobservable.

- He also argued that logic cannot resolve the issues at hand. ie. The fact that all past futures resembled past ones does not entail that the future will resemble the future past.

- In all, Hume comes to the understanding that although there is no way of validating the inductive procedure, our psychological constitution makes us think in terms of them.

I.   Critical Rationalism Karl Popper

> *I approached the problem of induction through Hume.*
> *Hume, I felt, was perfectly right in pointing out that*
> *induction cannot be logically justified.*

KARL POPPER

a.   Introduction

Critical Rationalism" is the name Karl Popper (1902-1994) gave to a modest and self-critical rationalism. He contrasted this view with "uncritical or comprehensive rationalism," the received **Justificationist** view that only what can be proved by reason and/or experience should be accepted. Popper argued that comprehensive rationalism cannot explain how proof is possible and that it leads to inconsistencies. Critical rationalism today is the project of extending Popper's approach to all areas of thought and action 'n each field the central task of critical rationalism is to replace allegedly justificatory methods with critical ones.

Karl Popper is generally regarded as one of the greatest philosophers of science of the 20th century. He was also a social and political philosopher of considerable stature, self-professed 'critical-rationalist', a dedicated opponent of a forms of skepticism, conventionalism, and relativism in science and in human affairs generally, a committed advocate and staunch defender of the 'Open Society', and an implacable critic of totalitarianism in all of its forms. One of the many remarkable features of Popper's thought is the scope of his intellectual influence. In the modern technological and highly-specialized world scientists are rarely aware of the work of philosophers; it is virtually unprecedented to find them queuing up, as they have done in Popper's case, to testify to the enormously practical beneficial impact which that philosophical work has had upon their own.

In this section of our study we shall pay close attention to his life, the background to his philosophy, his ideas about the growth of human knowledge, his thoughts on the probability of knowledge and verisimilitude, his contributions to the problem of induction, his works on knowledge, History and Prediction. We will in concluding this part, consider some of the various criticisms that have been levied against his methods and ideas of the philosophy of science.

b.   The Life of Karl Popper

Karl Raimund Popper was born on 28 July 1902 in Vienna, which at that time could make some claim to be the cultural epicentre of the western world. His parents, who were of Jewish origin, brought him up in an atmosphere which he was later to describe as 'decidedly bookish'. His father was a lawyer by profession, but he also

took a keen interest in the classics and in philosophy, and communicated to his son an interest in social and political issues which he was to never lose. His father was also a doctor of law at the Vienna University and a **bibliophile** who had 12,000–14,000 volumes in his personal library.[ᵇᵉ] Popper inherited both the library and the disposition from him.[ᵇᶦ]

His mother inculcated in him such a passion for music that for a time he seriously contemplated taking it up as a career, and indeed he initially chose the history of music as a second subject for his Ph.D examination. Subsequently, his love for music became one of the inspirational forces in the development of his thought, and manifested itself in his highly original interpretation of the relationship between dogmatic and critical thinking, in his account of the distinction between objectivity and subjectivity, and, most importantly, in the growth of his hostility towards all forms of historicism, including historicist ideas about the nature of the 'progressive' in music. The young Karl attended the local *Realgymnasium*, where he was unhappy with the standards of the teaching, and, after an illness which kept him at home for a number of months, he left to attend the University of **Vienna** in 1918. However, he did not formally enroll at the University by taking the matriculation examination for another four years.

1919 was in many respects the most important formative year of his intellectual life. In that year he became heavily involved in left-wing politics, joined the **Association of Socialist School Students,** and became for a time a **Marxist.** [ᵇᶦ] However, he was quickly disillusioned with the doctrinaire character of the latter, and soon abandoned it entirely. He also discovered the psychoanalytic theories of **Freud** and **Adler** (under whose aegis he engaged briefly in social work with deprived children), and listened entranced to a lecture which **Einstein** gave in Vienna on **relativity theory**. The dominance of the critical spirit in Einstein, and its total absence in Marx, Freud and Adler, struck Popper as being of fundamental importance: the latter, he came to think, couched their theories in terms which made them amenable only to confirmation, while Einstein's theory, crucially, had testable implications which, if false, would have falsified the theory itself.

His Academics: Popper obtained a primary school teaching diploma in 1925, took a Ph.D. in philosophy in 1928, and qualified to teach mathematics and physics in secondary school in 1929. The dominant philosophical group in Vienna at the time was the *Wiener Kreis*, the circle of 'scientifically-minded' intellectuals focused around **Moritz Schlick**, who had been appointed Professor of the philosophy of the inductive sciences at Vienna University in 1922. This included **Rudolf Carnap**, Otto Neurath, Viktor Kraft, Hans Hahn and Herbert Feigl. The principal objective of the members of the Circle was to unify the sciences, which carried with it, in their

view, the need to eliminate metaphysics once and for all by showing that metaphysical propositions are meaningless—a project which Schlick in particular saw as deriving from the account of the proposition given in Wittgenstein's *Tractatus*. Although he was friendly with some of the Circle's members and shared their esteem for science, Popper's hostility towards Wittgenstein alienated Schlick, and he was never invited to become a member of the group. For his part, Popper became increasingly critical of the main tenets of logical positivism, especially of what he considered to be its misplaced focus on the theory of meaning in philosophy and upon verification in scientific methodology, and reveled in the title 'the official opposition' which was bestowed upon him by Neurath. He articulated his own view of science, and his criticisms of the positivists, in his first work, published under the title *Logik der Forschung* in 1934. The book—which he was later to claim rang the death knell for positivism—attracted more attention than Popper had anticipated, and he was invited to lecture in England in 1935. He spent the next few years working productively on science and philosophy, but storm clouds were gathering—the growth of Nazism in Germany and Austria compelled him, like many other intellectuals who shared his Jewish origins, to leave his native country.

In 1937 Popper took up a position teaching philosophy at the University of **Canterbury** in **New Zealand**, where he was to remain for the duration of the Second World War. The annexation of Austria in 1938 became the catalyst which prompted him to refocus his writings on social and political philosophy. It was during this period that he wrote *"The Open Society and its Enemies"*. In 1946 he moved to England to teach at the London School of Economics, and became professor of logic and scientific method at the University of London in 1949. From this point on Popper's reputation and stature as a philosopher of science and social thinker grew enormously, and he continued to write prolifically—a number of his works, particularly *The Logic of Scientific Discovery* (1959), are now universally recognized as classics in the field. He was knighted in 1965, and retired from the University of London in 1969, though he remained active as a writer, broadcaster and lecturer until his death in 1994

c.   A background to his thoughts

A number of biographical features may be identified as having a particular influence upon Popper's thought. In the first place, his teenage flirtation with Marxism left him thoroughly familiar with the Marxist view of economics, class-war, and history. Secondly, he was appalled by the failure of the democratic parties to stem the rising tide of fascism in his native Austria in the 1920s and 1930s, and the effective welcome extended to it by the Marxists. The latter acted on the

ideological grounds that it constituted what they believed to be a necessary dialectical step towards the implosion of capitalism and the ultimate revolutionary victory of communism. This was one factor which led to the much feared *Anschluss*, the annexation of Austria by the German Reich, the anticipation of which forced Popper into permanent exile from his native country. *The Poverty of Historicism* (1944) and *The Open Society and Its Enemies* (1945), his most impassioned and brilliant social works, are as a consequence a powerful defence of democratic liberalism as a social and political philosophy, and a devastating critique of the principal philosophical presuppositions underpinning all forms of totalitarianism. Thirdly, as we have seen, Popper was profoundly impressed by the differences between the allegedly 'scientific' theories of Freud and Adler and the revolution effected by Einstein's theory of relativity in physics in the first two decades of this century. The main difference between them, as Popper saw it, was that while Einstein's theory was highly 'risky', in the sense that it was possible to deduce consequences from it which were, in the light of the then dominant Newtonian physics, highly improbable (e.g., that light is deflected towards solid bodies—confirmed by Eddington's experiments in 1919), and which would, if they turned out to be false, falsify the whole theory, nothing could, even *in principle*, falsify psychoanalytic theories.

The Marxist account of history too, Popper held, is not scientific, although it differs in certain crucial respects from psychoanalysis. For Marxism, Popper believed, had been initially scientific, in that Marx had postulated a theory which was genuinely predictive. However, when these predictions were not in fact borne out, the theory was saved from falsification by the addition of *ad hoc* hypotheses which made it compatible with the facts. By this means, Popper asserted, a theory which was initially genuinely scientific degenerated into pseudo-scientific dogma. These factors combined to make Popper take *falsifiability* as his criterion for demarcating science from non-science: if a theory is incompatible with possible empirical observations it is scientific; conversely, a theory which is compatible with all such observations, either because, as in the case of Marxism, it has been modified solely to accommodate such observations, or because, as in the case of psychoanalytic theories, it is consistent with all possible observations, is unscientific. For Popper, however, to assert that a theory is unscientific, is not necessarily to hold that it is unenlightening, still less that it is meaningless, for it sometimes happens that a theory which is unscientific (because it is **unfalsifiable**) at a given time may become falsifiable, and thus scientific, with the development of technology, or with the further articulation and refinement of the theory.

d. Popper's Philosophy

at a given time may become falsifiable, and thus scientific, with the development of technology, or with the further articulation and refinement of the theory.

d. Popper's Philosophy

Popper coined the term *critical rationalism* to describe his philosophy. The term indicates his rejection of classical **empiricism**, and of *the classical observationalist-inductivist account of science* that had grown out of it. Popper argued strongly against the latter, holding that **scientific theories** are abstract in nature, and can be tested only indirectly, by reference to their implications. He also held that scientific theory, and human knowledge generally, is irreducibly conjectural or hypothetical, and is generated by the creative imagination in order to solve problems that have arisen in specific historio-cultural settings. Logically, no number of positive outcomes at the level of experimental testing can confirm a scientific theory, but a single counterexample is logically decisive: it shows the theory, from which the implication is derived, to be false. The term "falsifiable" does not mean something is made false, but rather that, if it is false, it can be shown by observation or experiment.

Popper's account of the logical asymmetry between **verification** and **falsifiability** lies at the heart of his philosophy of science. It also inspired him to take falsifiability as his criterion of **demarcation** between what is and is not genuinely scientific: a theory should be considered scientific if and only if it is falsifiable. This led him to attack the claims of both **psychoanalysis** and contemporary **Marxism** to scientific status, on the basis that their theories are not falsifiable. Popper also wrote extensively against the famous **Copenhagen interpretation** of **quantum mechanics**. He strongly disagreed with **Niels Bohr's instrumentalism** and supported **Albert Einstein's realist** approach to scientific theories about the universe. Popper's falsifiability resembles **Charles Peirce's** nineteenth century **fallibilism**. In *Of Clocks and Clouds* (1966), Popper remarked that he wished he had known of Peirce's work earlier.

The Goal of Popper's Philosophy: In *All Life is Problem Solving*, Popper sought to explain the apparent progress of scientific knowledge—how it is that our understanding of the universe seems to improve over time. This problem arises from his position that the truth content of our theories, even the best of them, cannot be verified by scientific testing, but can only be falsified. Again, in this context the word 'falsified' does not refer to something being 'fake'; rather, that something can be (i.e., is *capable* of being) shown to be false by observation or experiment. Some things simply do not lend themselves to being shown to be false, and therefore are not falsifiable. If so, then how is it that the growth of

science appears to result in a growth in knowledge? In Popper's view, the advance of scientific knowledge is an *evolutionary* process characterized by his formula:

$$PS_1 \rightarrow TT_1 \rightarrow EE_1 \rightarrow PS_2.$$

In response to a given problem situation (PS_1), a number of competing conjectures, or tentative theories (TT), are systematically subjected to the most rigorous attempts at falsification possible. This process, error elimination (EE), performs a similar function for science that natural selection performs for biological evolution. The theories that better survive the process of refutation are not more true, but rather, more "fit"—in other words, more applicable to the problem situation at hand (PS_1). Consequently, just as a species' biological fitness does not ensure continued survival, neither does rigorous testing protect a scientific theory from refutation in the future. Yet, as it appears that the engine of biological evolution has produced, over time, adaptive traits equipped to deal with more and more complex problems of survival, likewise, the evolution of theories through the scientific method may, in Popper's view, reflect a certain type of progress: toward more and more *interesting problems* (PS_2). For Popper, it is in the interplay between the tentative theories (conjectures) and error elimination (refutation) that scientific knowledge advances toward greater and greater problems; in a process very much akin to the interplay between genetic variation and natural selection.

Where does "truth" fit into all this? As early as 1934 Popper wrote of the search for truth as "*one of the strongest motives for scientific discovery.*" Still, he describes in *Objective Knowledge* (1972) early concerns about the much-criticized notion of truth as correspondence. Then came the **semantic theory of truth** formulated by the logician **Alfred Tarski** and published in 1933. Popper writes of learning in 1935 of the consequences of Tarski's theory, to his intense joy. The theory met critical objections to truth as correspondence and thereby rehabilitated it. The theory also seemed, in Popper's eyes, to support metaphysical realism and the *regulative* idea of a search for truth.

According to this theory, the conditions for the truth of a sentence as well as the sentences themselves are part of a **metalanguage**. So, for example, the sentence "Snow is white" is true if and only if snow is white. Although many philosophers have interpreted, and continue to interpret, Tarski's theory as a **deflationary theory**, Popper refers to it as a theory in which "is true" is replaced with "**corresponds to the facts**". He bases this interpretation on the fact that examples such as the one described above refer to two things: assertions and *the facts* to

which they refer. He identifies Tarski's formulation of the truth conditions of sentences as the introduction of a "metalinguistic predicate" and distinguishes the following cases:

1. **"John called" is true.**

2. **"It is true that John called."**

The first case belongs to the metalanguage whereas the second is more likely to belong to the object language. Hence, "it is true that" possesses the logical status of a redundancy. "Is true", on the other hand, is a predicate necessary for making general observations such as "John was telling the truth about Phillip."

Upon this basis, along with that of the logical content of assertions (where logical content is inversely proportional to probability), Popper went on to develop his important notion of **verisimilitude** or "truthlikeness".

The intuitive idea behind verisimilitude is that the assertions or hypotheses of scientific theories can be objectively measured with respect to the amount of truth and falsity that they imply. And, in this way, one theory can be evaluated as more or less true than another on a quantitative basis which, Popper emphasizes forcefully, has nothing to do with "subjective probabilities" or other merely "epistemic" considerations.

The simplest mathematical formulation that Popper gives of this concept can be found in the tenth chapter of *Conjectures and Refutations*. Here he defines it as:

$$Vs(a) = CT_v(a) - CT_f(a)$$

where $Vs(a)$ is the verisimilitude of a, $CT_v(a)$ is a measure of the content of truth of a, and $CT_f(a)$ is a measure of the content of the falsity of a.

e. The Problem of Demarcation

As Popper represents it, the central problem in the philosophy of science is that of demarcation, i.e., of distinguishing between science and what he terms 'non-science', under which heading he ranks, amongst others, logic, metaphysics, psychoanalysis, and Adler's individual psychology. Popper is unusual amongst contemporary philosophers in that he *accepts* the validity of the Humean critique of induction, and indeed, goes beyond it in arguing that induction is never actually used by the scientist. However, he does not concede that this entails the scepticism which is associated with Hume, and argues that the Baconian/Newtonian insistence on the primacy of 'pure' observation, as the initial step in the formation of theories, is completely misguided: all observation is

selective and theory-laden—there are no pure or theory-free observations. In this way he destabilises the traditional view that science can be distinguished from non-science on the basis of its inductive methodology; in contradistinction to this, Popper holds that there is no unique methodology specific to science. Science, like virtually every other human, and indeed organic, activity, Popper believes, consists largely of problem-solving.

Popper, then, repudiates *induction*, and rejects the view that it is the characteristic method of scientific investigation and inference, and substitute's *falsifiability* in its place. It is easy, he argues, to obtain evidence in favour of virtually any theory, and he consequently holds that such 'corroboration', as he terms it, should count scientifically only if it is the positive result of a genuinely 'risky' prediction, which might conceivably have been false. For Popper, **a theory is scientific only if it is refutable by a conceivable event.** Every genuine test of a scientific theory, then, is logically an attempt to refute or to falsify it, and one genuine counter-instance falsifies the whole theory. In a critical sense, Popper's theory of demarcation is based upon his perception of the logical asymmetry which holds between **verification** and **falsification**: it is logically impossible to conclusively verify a universal proposition by reference to experience (as Hume saw clearly), but a single counter-instance conclusively falsifies the corresponding universal law. In a word, an exception, far from 'proving' a rule, conclusively refutes it.

Every genuine scientific theory then, in Popper's view, is *prohibitive*, in the sense that it forbids, by implication, particular events or occurrences. As such it can be tested and falsified, but never logically verified. Thus Popper stresses that it should not be inferred from the fact that a theory has withstood the most rigorous testing, for however long a period of time, that it has been verified; rather we should recognise that such a theory has received a high measure of corroboration and may be provisionally retained as the best available theory until it is finally falsified (if indeed it is ever falsified), and/or is superseded by a better theory.

Popper has always drawn a clear distinction between the *logic* of falsifiability and its *applied methodology*. The logic of his theory is utterly simple: if a single ferrous metal is unaffected by a magnetic field it cannot be the case that all ferrous metals are affected by magnetic fields. Logically speaking, a scientific law is conclusively falsifiable although it is not conclusively verifiable. Methodologically, however, the situation is much more complex: no observation is free from the possibility of error—consequently we may question whether our experimental result was what it appeared to be.

Popper stresses in particular that **there is no unique way, no single method such**

as induction, which functions as the route to scientific theory, a view which Einstein personally endorsed with his affirmation that 'There is no logical path leading to [the highly universal laws of science]. They can only be reached by intuition, based upon something like an intellectual love of the objects of experience'. Science, in Popper's view, starts with problems rather than with observations—it is, indeed, precisely in the context of grappling with a problem that the scientist makes observations in the first instance: his observations are selectively designed to test the extent to which a given theory functions as a satisfactory solution to a given problem.

where a 'basic statement' is to be understood as a particular observation-report, then we may say that a theory is scientific if and only if it divides the class of basic statements into the following two non-empty sub-classes: (a) the class of all those basic statements with which it is inconsistent, or which it prohibits—this is the class of its *potential falsifiers* (i.e., those statements which, if true, falsify the whole theory), and (b) the class of those basic statements with which it is consistent, or which it permits (i.e., those statements which, if true, corroborate it, or bear it out).

I.   The Growth of Human Knowledge

For Popper accordingly, the growth of human knowledge **proceeds from our problems and from our attempts to solve them.** These attempts involve the formulation of theories which, if they are to explain anomalies which exist with respect to earlier theories, must go beyond existing knowledge and therefore require a leap of the imagination. For this reason, Popper places special emphasis on the role played by the independent creative imagination in the formulation of theory. The centrality and priority of *problems* in Popper's account of science is paramount, and it is this which leads him to characterize scientists as 'problem-solvers'. Further, since the scientist begins with problems rather than with observations or 'bare facts', Popper argues that the only logical technique which is an integral part of scientific method is that of the **deductive testing** of theories which are not themselves the product of any logical operation. In this deductive procedure conclusions are inferred from a tentative hypothesis. These conclusions are then compared with one another and with other relevant statements to determine whether they falsify or corroborate the hypothesis. Such conclusions are not directly compared with the facts, Popper stresses, simply because there are no 'pure' facts available; all observation-statements are theory-laden, and are as much a function of purely subjective factors (interests, expectations, wishes, etc.) as they are a function of what is objectively real.

How then does the deductive procedure work? Popper specifies four steps: