CONSTRUCTIVE EMPIRICISM: A CRITICAL INQUIRY

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Signed Arun Datta Date 25/02/2008

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This thesis has been submitted for examination with our approval as university supervisors.

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ABSTRACT

This study is an endeavour to understand, explain and critique constructive empiricism, which is an empirical alternative to both logical positivism and scientific realism. Bas C. van Frassen is nearly solely responsible for this position in philosophy of science and presented it in his seminal work *The Scientific Image (1980).*

Against logical positivism, the author insists on a literal interpretation of the language of science. Against scientific realism he argues that the central aim of science is empirical adequacy and the belief involved in the acceptance of a scientific theory is belief that the theory fits the observable phenomenon.

Constructive empiricism is, therefore, a normative, semantic and epistemological thesis. The normative component is that science aims to be empirically adequate and the semantic component is that scientific theories are semantically literal. The epistemological component is that the belief involved in acceptance of a theory is that it saves the observable phenomena.

This study looks at historical development of science and philosophy of science. An attempt is made to see if science has some exclusive methodology and set of rules that make it successful. Constructive empiricism is defined as a philosophical position and its main features are explained and compared to other philosophies of science. It is found that there is a problem with the way 'observables' are defined for empirical adequacy in constructive empiricism.

Reasons for van Frassen`s refusal to accept observation through instruments are brought forward and made clear, using diagrams. Observation of something, confirms its existence, but unobservability does not negate it. It is shown how induction plays an important part in scientific practice. Status of explanation in science is elaborated, by first showing what exactly is scientific explanation and where does it fit in constructive empiricism.

It is amply shown that there is a problem with the definition of 'observable' in constructive empiricism. A suggestion is made in this study to redefine observable by introducing the Kantian idea of faculty of understanding.

Consequences of redefined 'observable' are shown by platonic analogy of cave and a new term - ' layers of reality '. Scope and need for further study on the lines of layers of reality are brought out in chapter five.

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CHAPTER ONE

Introduction

1.1 Philosophy of science

Constructive empiricism is the dominant form of anti-realism in the philosophy of science today. It urges us to restrict our belief to observable things only. According to constructive empiricism, science aims at giving us theories which save the observable phenomena as observed by unaided eyes. But in actual practice, scientists postulate theories which save even the phenomena, which are unobservable to unaided human eyes.

Science can be defined as an attempt to understand, explain and predict the world we live in. There are particular methods that scientists use to investigate the world, use of experiments marks a turning point in the development of modern science. Scientists attempt to explain the results of experiments in terms of scientific theories.

Philosophy of science tries to understand how techniques such as experimentation, observations and theory construction enable science to be successful. Scientific investigations were pursued in ancient and medieval times too and the dominant world-view was Aristotlelianism. The origins of modern science lie in period of rapid scientific development that occurred in Europe between years 1500 and 1750.

In 1542, Nicolas Copernicus created a modern scientific world-view by attacking geo-centric model of universe. His proposal of helio-centric model led to the works of Johannes Kepler (1610) and Galileo Galilei (1620). Kepler`s laws provided a better planetary theory and solved many outstanding problems. Galileo made new observations with his telescope and further showed the empirical accuracy of Copernicus` theory. He emphasized on the importance of testing hypotheses experimentally.

During the middle of 16th century, Rene Descartes (1641), developed a 'mechanical philosophy', according to which the physical world consists simply of corpuscles, which keep colliding and interacting with each other. Descartes believed that this philosophy could explain all observable phenomena in terms of the motion of those inert corpuscles. Isaac Newton (1680) agreed with the mechanical philosophers and sought to improve on Descartes laws of motion and rules of collision. The result was his three laws of motion and the principle of gravitation. During the eighteenth and nineteenth centuries Newton's theories were believed to have revealed the true workings of nature and to be capable of explaining everything.

In the early 20th century two developments took place in Physics. Relativity theory, developed by Einstein (1920) showed that Newtonian mechanics does not give the right results when applied to very massive objects or those moving at very high speeds. Quantum mechanics, conversely, showed that Newtonian theory does not work on very small scale, to subatomic particles.

In biology, an important event was publication of *"The Origin of Species"* by Charles Darwin in 1859. Darwin argued that contemporary species evolved from ancestral ones through a process known as natural selection. He showed evidence to support his theory and today the biological world view is based on Darwin's theory.

The principal task of philosophy of science is to analyze the methods of enquiry used in various sciences and to question the assumptions that scientists take for granted.

Karl Popper (1963), a 20th century philosopher of science thought that the fundamental feature of a scientific theory is that it should be falsifiable. A theory must make some definite predictions.that are capable of being tested against experience. If these predictions turn out to be wrong, then the theory is disproved. According to Popper's view, Freud's psychoanalytic theory and Marx's theory of history are not falsifiable and therefore not scientific.

But there is evidence that "respectable" scientists also explain away the data that conflicts with their theories, instead of rejecting the theories. As an example, the observed orbit of Uranus differed from what Newton's theory predicted. Two scientists, Adams in England and Leverrier in France suggested that there was a planet, yet undiscovered, causing the aberration. Shortly afterwards the planet Neptune was discovered.

The behaviour of the scientists Adams and Leverrier was "unscientific" by Popper's standards, they should have rejected Newton's theory instead of explaining the observation! Their suggestion led to the discovery of a new planet.

The important question is that, is it possible to find some common feature shared by all the things we call 'science' and not shared by anything else? Science is a hetrogeneous activity encompassing a wide range of different disciplines and theories. May be they share some features, may be not. The philosopher, Ludwig Wittgenstein (1922) argued that there is no fixed set of features for a 'game', rather a loose cluster of features, most of which are possessed by most games. Any particular game may lack any of the features and still be a game. The same may be true of science.

1.2 Constructive Empiricism as a philosophy of science

Bas C. van Fraassen `s philosophy of science is an empirical alternative to both logical positivism and scientific realism. He opts for a more limited notion of empirical adequacy. His view, as expressed in *The Scientific Image* (Fraassen 1980: 12) is that empiricism is correct but not in the linguist form of the logical positivists. He pursues the question- "What is it to accept a scientific theory?" this question has two dimensions. Firstly the epistemic one, how much belief is involved in accepting a scientific theory? Secondly the pragmatic one, what else is involved besides the belief?

According to the philosophical view he develops, the belief involved in accepting a scientific theory is only that it correctly describes what is observable and to accept one theory rather than another one, involves also a commitment to a research programme, of framework of one conceptual scheme rather than another.

Explanatory power, simplicity etc are virtues which a theory may have. Even if two theories are empirically equivalent, and acceptance of a theory involves belief only that it is empirically adequate, it may still make a great difference, which one is accepted. The difference is pragmatic and pragmatic virtues do not give us any reason over and above the evidence of the empirical data, for thinking that a theory is true.

Constructive Empiricism, as formally defined by Bas C. van Fraassen is the claim that " *Science aims, to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate*" (Fraassen 1980: 12) . (Italic in the original)

A theory is empirically adequate exactly if what is says about the observable things and events in the world are true. This refers to all the phenomena; these are not exhausted by those actually observed, nor even by those observed at some time whether past, present of future. If a scientist accepts a theory, he thereby involves himself in a research programme. Thus acceptance involves not only belief but a certain commitment, to confront any future phenomena by means of concepts of the theory.

Empirical adequacy is about the empirical evidence, the observables, which classify entities which may or may not exist. For example a flying horse is observable that is why we know that it does not exist and numbers are unobservable entities. That something is observable does not mean that conditions are right for observing it now.

Van Fraassen gives the principle for observables as, *"x is observable if there are circumstances which are such that if x is present to us under those circumstances, then we observe it"*. (Fraassen 1980: 16). (Italics in the original).

'Observable', is for 'us', the epistemic community, the humans. It is the humans who accept a theory as empirically adequate, therefore observable to humans is relevant. Even if observability has nothing to do with existence, it still has much to do with the proper epistemic attitude to science.

A summary of core ideas of constructive empiricism is-

1. We have knowledge only of the observable i.e. observable by naked eye.
2. Unobservable entities and processes may exist but we can never know.
3. Theories may be true but we can never know.
4. Theories may nevertheless be accepted as empirically adequate.
5. Empirical adequacy, not truth, is the aim of science.

Constructive empiricism is an alternative to logical positivism and realism. Logical positivists` problem was epistemological. They wanted to do away with Aristotelian realist's world of powers, properties and disposition. But the observation of phenomena did not point unambiguously to the supposed causal connection behind them. A scientist's belief in unobservable, theoretical entities could not be reconciled with her antipathy to metaphysics. Constructive empiricism resolves this problem by limiting the aim of science to empirical adequacy.

For the realist, science aims at truth and success of science is no miracle because science has latched on to some truth. Constructive empiricist, on the other hand explains the success of science using Darwinian theory of survival of the fittest. Theories that can not survive the environment of experimental results face extinction. Only theories that are empirically adequate survive, the ones which in fact are latched on to actual regularities in nature.(Fraassen 1980: 40)

Van Fraassen views scientific activity as that of construction of theories and models that must be adequate to the phenomena. The activity is not of discovery of some truths regarding the unobservable. Scientists use existing empirically adequate theories as background in their experiments and come up with newer theories and thus science progresses.

1.3 Statement of the Problem

Constructive empiricism is an anti-realist philosophy of science, according to which science aims to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate. A theory is empirically adequate, exactly if what it says about the observable things and events in this world, is true or exactly if it saves the phenomena.

The 'observables', as suggested by van Fraassen, limit the scope of science and scientific theories to human physiology. The limits to what humans can observe are continuously being pushed by ever advancing scientific theories and their application in scientific instruments. In actual practice of science, belief in a scientific theory is not limited to what is observable by unaided eyes. The belief is also not complete, as to consider scientific theories to be true.

This study agrees with van Fraassen`s assertion that science aims at giving us theories which are empirically adequate. The problem is with the principle for observables, which limits empirical adequacy to observations made with unaided eyes. With the current principle for observables, constructive empiricism does not represent the actual happenings in science.

1.4 Objective

This study endeavors to understand, explain and critique constructive empiricism as proposed by van Fraassen in *The scientific Image* (1980). An attempt is made to redefine 'observable', so that empirical adequacy and belief in a scientific theory truly represent the actual practice of science.

Philosophy of science tries to understand how scientific methods, including those of observation and theorization enable it to be successful. Constructive empiricism attempts an answer that science aims at giving us theories which save the observable phenomena. But the 'observable' phenomena are restricted to unaided observation. In actual practice, scientists explore the phenomena that transcend human visibility range.

1.5 Justification and significance of the study.

Since the publication of "*The Scientific Image* (1980), there have been various reactions, for and against van Fraassen`s account of empirical adequacy indicating that the controversy exists. This study is an attempt to understand the controversy and to make a proposal towards resolving it.

1.6 Literature review

Van Fraassen considers constructive empiricism as a stance, as opposed to a factual thesis. From his point of view, it is the recurrent rebellion against metaphysics and the admiration for science that characterizes the empiricist's stance and strengthens their philosophical arguments. Van Fraassen gave public lecture at the university of Munster on 30th May 2005 titled "*Weyl`s paradox: The distance between structure and perspective*", where he reiterated that science is representation of the observable phenomena, by means of mathematical models. The whole phenomena are infinitesimal and infinite, and can not be displayed. The concrete representations, in the model form, are developed in mathematics. Consequently science represents structure only and that science is essentially perspectival; we can not understand what it does except in relation to us, the doers.

Otavio Bueno of School of philosophy at the University of Leeds echoes similar approach in his paper *"Empiricism, conservativeness and Quasi-Truth"*, (2006). He says that instead of taking conservativeness as the norm of mathematics, the empiricist accepts the weaker notion of quasi-truth. Instead of quantifying over space-time regions, the empiricist only admits quantification over "occupied" regions, since this is enough for her needs. In other words the aim of science is not truth but something weaker, empirical adequacy and that it is possible to provide an account of science without the commitment to unobservable entities and other metaphysical notions.

Van Fraassen is skeptical about the laws of nature and does not accept justification on the basis of inference to the best explanation. He does not grant reality to the hypothetical items like electrons, quarks, muons that play a crucial role in the development of scientific theories. These objects in question, cannot be observed, yet, are none the less treated as necessary, if the theory is to explain.

However, the sceptism creates problems for philosophers of science who consider explanation as an aim of science. Christophers Norris, July 1997 *("Ontology according to van Fraassen: some problems with constructive empiricism")*, says that it becomes almost impossible to explain, how knowledge has so often advanced, if we do not accept the demonstrative proofs given by advanced scientific instruments. Van Frassen`s refusal to accept such proofs, is due to his sceptism about the theories on which the instruments are based.

In his paper *"On an inconsistency in constructive empiricism"*, Prasanta S. Bandheyopadyhyay 1997, finds an inconsistency with van Fraassen`s view. According to van Fraassen, if a scientific theory is only about observables, empirical adequacy coincides with truth (Fraassen, 1980: 72). That means for purely empirical theories, reasons for accepting a theory and believing it are always one and the same.

Van Fraassen (1989, 1991) has also argued that reasons for accepting a theory are not always reasons for believing it to be true; because there is an inverse relation between informational content and the probability of a theory. The second statement is for all theories, therefore applies to the first set of theories which are only about observables and that is where the inconsistency is.

Constructive empiricism tells us to believe as true only those propositions of an accepted scientific theory that are about actual observables only. F.A. Muller 2004, in his paper *"Can a constructive empiricist adopt the concept of observability?"* says that it is impossible to distinguish between observables and unobservables, as defined by van Frassen. He finds the distinction anthropomorphic and vague; but essential for constructive empiricism. Muller`s (ibid) suggestion to the problem of distinction is that judgments about observability of every object must be based on some accepted scientific theory.

Van Fraassen has already accepted such an approach. He says that although "what is observable" in principle, is a theory independent question. A scientific theory is proposed to save what is observed, and not to ascertain what is observable. But in practice we must rely on our current best theories to answer that question. (Monton & Fraassen 200: 414). Van Fraassen does not make it clear, as to which are "current best theories" and how and when to apply them. He seems to accept that there is a problem with his principle of observables.

1.7 Hypothesis

Constructive empiricism, as postulated by Bas van Fraassen is not consonant with the actual practice of science.

1.8 Methodology

This is a library based study focusing on Bas C. van Fraassen`s "*The Scientific Image*" (Oxford 1980); where constructive empiricism, as a philosophy of science is proposed as an alternative to scientific realism, many critiques of constructive empiricism, in various journals of philosophy of science, and printed and electronic material on scientific realism, anti realism and related philosophies.

The research utilizes philosophical method of conceptual analysis, explanation and critical assessment of arguments, concepts and related issues.

CHAPTER TWO

Scientific Realism and Anti-Realism

2.1 Introduction

There is an ancient debate in philosophy between two opposing schools of though called realism and idealism. Realism holds that the physical world exists independently of human thought and perception; whereas idealism claims that physical world is in some way dependent on the conscious activity of humans.

This chapter is devoted to defining, and understanding the modern debate, that is specifically about science. Different views of scientific realism and scientific anti-realism are discussed in brief. Arguments and examples, for different positions are put forward.

Constructive empiricism, as one position in philosophy of science, can be best critiqued, in light of the arguments for other competing positions.

2.2 Realism

Realism holds that the physical world exists independently of human thought and perception. Scientific realism is the view that aim of science is to provide a true description of the world.

There are regularities in nature. Reasons of these regularities are not obvious from the observations of the phenomena or substances involved. Scientists attempt to explain such regularities, by scientific theories. A scientific theory accounts for the observed phenomena by postulating other processes which are not directly accessible to observation. To give an account of phenomenon as heat, or chemical reactions, scientists postulated an atomic theory. Atoms and molecules are the theoretical entities, which are attributed certain properties.

For example the phenomenon of rusting of iron can be explained by the reaction between atoms of iron with the molecules of water present in the air. What we can see is the iron before rusting and the rusted iron later. The process of rusting; the actual reaction is not accessible to human sight. Scientists can interpret the unobservable as an equation.

Fe	$+$	H_20	$=$	$Fe0$	$+$	H_2
Iron		Water		Rusted iron		

Traditionally, scientific realism asserts that objects of scientific knowledge exist independently and that scientific theories are true. On one side it is a metaphysical doctrine, claiming the independent existence of certain entities. On the other hand it is an epistemological doctrine, asserting that we can know what individuals exist and that we can find out the truth of the theories that govern them. Constructive empiricism differs on the metaphysical aspect and on the aim of science.

Typically, the realist restricts her realist attitude to mature theories, that is, those theories which:

1. have been around for a while and are not speculative,
2. are generally accepted by the scientific community and have a general consensus,
3. are seriously tested and have survived falsification,
4. are supported by significant body of evidence i.e. have been verified.

Philosophers like Hilary Putnam (1976) argued that unless the theoretical entities proposed by scientific theories actually existed and the theories, at least approximately true, the success of science would be a miracle (Fraassen 1980:40).

Science is considered massively successful; it has changed our world through technological implication and it has changed our fundamental picture of the world, by giving us evolution, curved space time and quantum mechanics. But this argument for realism is basically the same as the argument for the truth of scientific theories.

- Scientists argue that theory T is best explanation of phenomenon
  Therefore T is true.

- Realists argue that realism is the best explanation of the success of science
  Therefore realism is true.

In the beginning of twentyfirst century, we can say that science is on the right track or is empirically successful. There is no certainty of the truth of reality and the miracles argument seems inconclusive. Constructive empiricism, therefore takes the aim of science as empirical adequacy only and not truth.

Realism offers the best explanation for success of science but the success of science is only at instrumental or observational level. There is no certainty that our scientific theories are literally true. Moreover the principle, to regard as true, that which explains the best is itself refutable. Chapter 3.3 has been devoted to scientific explanation and related issues. There have been many theories that explained very well but latter found to be untrue. Van Fraassen considers explanatory power of a theory a virtue and different from truth. Scientific realists suggest that the best of the current scientific theories should be taken as true, but van Fraassen says that the best could be from a bad lot. His argument is that better theories could be proposed in future.

History of science shows that there were many scientific theories, once considered to be true, but which were later found to be false and replaced.
This pessimistic metainduction argument, questions the current scientific theories and also the nature and existence of theoretical entities, which had to be altered dramatically. This is an inductive argument, which uses examples form history rather than science itself. The well known examples are those of phlogiston, vital force in physiology, the electromagnetic ether, the optical ether, spontaneous generation etc. Therefore our current successful theories are likely to turn out false, and hence we have no grounds for adopting a realist attitude towards them.

Underdetermination suggests that evidence is more or less impotent to guide choice between rival theories, making it difficult to choose the best among the existing theories and thus claim truth. For example extinction of dinosaurs can be explained by a massive meteor strike and also by a massive volcanic eruption. Evidence available to us supports both the theories equally well. Realists counter this argument by still other factors like that of simplicity to choose one theory rather than the other. Simplicity can be the use of lesser unobservable entities in a theory. Just as for explanation, simplicity also has nothing to do with truth. Why should a simple theory be closer to truth? Einstein did say that the universe just is simple, but that was his personal faith and not an argument. After all, Einstein also expressed his opinion and said "*There is not a slightest indication that energy will ever be obtainable from the atom*" (Youngstown, scientific blunders 1998: 340). Van Fraassen considers simplicity and explanatory power as virtues, which a scientific theory may have and can be factors in determining which theory is accepted; but the accepted theory still remain only empirically adequate and not true.

2.3 Entity realism

Many philosophers of science feel that source of pessimistic metainduction problem, is the apparent abandonment of certain unobservable entities throughout history and that underdetermination is caused, due to our search for true theories. Entity realism offers a way out, by suggesting that our focus should be on the unobservable entities, that we are confident exist. Our confidence in the entities is not because they are presupposed in some theories, but because we use them and can manipulate them. It is a rather pragmatic approach.

Entity realism suggests belief in independent existence of theoretical entities, without committing to the belief in their scientific theories. An experiment is discussed in detail in this paper where scientists bombard theoretical entities electron and positrons and study the new particles produced, thus proving entity realism. In the experiment, theoretical entities are the 'input', the 'cause' and therefore must be real. But to commit to existence of theoretical entities and not to theories employing them is not very convincing. Also the above example shows a particular case and the findings can not be generalized to all the theoretical entities. Constructive empiricism is the philosophy that such entities may exist, but we can never know.

Attempts have been made to dilute realism by employing it to only those entities that survive the scientific revolutions; for example electrons and genes. Our belief that these entities exist has nothing to do with the truth of theories but with their practical manipulation in the creation of phenomena. But how can we say what an electron or gene is, if our theories about it change or if we have incompatible theories about it? As an example, our description of an electron has shifted in the past hundred years from being matter, to wave-particle, to quantum entity, to superstring……………this proves van Fraassen`s assertion that we can not know about the theoretical entities.

2.4 Structural realism

Structural realism can best be understood through an example. Newton (1680) postulated that light is made up of tiny particles, and that explained the phenomenon of refraction. It was latter proposed that light is in fact a wave and Fresnel (1815) developed a set of equations describing its behaviour. Maxwell (1870) explained the behaviour of light through his theory of electromagnetism, according to which, light is an oscillating electromagnetic wave. Einstein (1920) argued that light should be seen as particle, which has a quantum wave- particle duality.

According to pessimistic meta-induction argument, particle theory of light was found to be wrong and also the wave theory of light. Therefore our current and future theories would also be found to be wrong and rejected. We cannot be realists. On careful inspection, it is found that throughout the above theoretical shifts, something is retained. And that is the structure, as depicted by Fresnel`s and Maxwell's equations. Structural realism is the view, that we can be realists about the structure of theories. Even if there is a radical change at the level of theoretical entities, their interrelations depicted by the equations; the structure, remains the same. A structural realist does not take the entire theory to be true, just those structural aspects that are retained through theory change. Van Fraassen says that science represents structure only and the book of science is written in the language of mathematics (Fraassen, B. *"The fortunes of empiricism"* 2006)

The problem of undertermination still remains, if more than one theories are empirically adequate but have no common structure. Adherents of structural realism believe that all we can know about the world, is the structure and not the nature of entities.

2.5 Logical positivism

During the early years of 20th century, many scientific advances took place. These advances impressed philosophers, who wanted to learn the methods of science which made it so successful and saw in it a path to reach the truth. Most striking thing about science was its objectivity. Scientific information did not depend upon an individual scientist's opinion. It was found to be logical; any one could conduct an experiment and compare theory with the facts. Merits of a theory could be found out objectively.

The logical positivists noticed that the method of science consisted in hypothesizing a theory and then testing its validity. The first part, the context of discovery, was thought to be a subjective, psychological process and was not dependent on any rules. It was not very important, how a theory is conjectured. It is second part of justification, which is objective and logical.

The positivists were confident that science is rational and objective, therefore an objective method of choosing one theory from another is possible. And the method was of finding neutral observational facts which could be found in nature or through controlled experiments. They aimed at creating a revolutionary scientific philosophy, without controversies of traditional metaphysics. According to logical positivism, propositions are meaningful if they can be accessed either by an appeal directly to some foundational form of sense experience or by an appeal to meaning of the words and the grammatical structure that constitute them.

They paid insufficient attention to history of science and were wrong in their assertion that scientific theories are floated at random and that observational facts are available, that can discriminate between different theories. Van Fraassen on the other hand insists on the literal interpretation of the language of science and that observational facts may not necessarily be available now.

2.6 Instrumentalism, constructivism and phenomenalism

One of the problems, faced by scientific realism, rises from unobservable entities which are accepted as objects put forward by the theories as 'out there' in the world. One way to avoid that problem, is to insist that the worth of theories lies not in whether they are true or false, but simply in how useful they are, when it comes to explaining and predicting phenomena. Rather than telling us how the world is, theories should be regarded as nothing but instruments themselves, which we use for predicting observable phenomena. Importance is given to reliability and not to the truth of theories.

K.R. Popper (1963) criticized instrumentalism as non-scientific, because an 'instrumental theory' can not be falsified. In real practice of science, theories function as more than mere instruments for prediction in scientific experiments, theories not only make a part of the instruments, they are also the background. Some amount of belief is required in scientific theories for science to be a rational activity. According to constructive empiricism, belief in a scientific theory is that it is empirically adequate.

Problem of unobservables is tackled by constructive empiricism, by claiming that theories tell us how the world is, in its observable aspect and how the world could be, in its unobservable aspect (French, S. *Science, Key Concepts In Philosophy*, 2007).

Constructivism takes scientific knowledge as socially constructed and therefore not objective. On the other hand, constructive empiricism considers scientific knowledge as objective and firmly based on human observation. Phenomenalism claims that to say that a physical object exists, is to say that one would have a sequence of sensations. Primary motivation being to avoid sceptism with respect to the real world.

Empiricism, as a doctrine in epistemology holds that all knowledge is based on experience. Yes, there can be different levels, where the lower level originates in experience. Constructive empiricism is the philosophy that science is an activity of construction and not discovery and that belief in the scientific theories is that they save the observable phenomena.

CHAPTER THREE

The question of empirical adequacy

3.1 Introduction

Constructive empiricism, as a philosophy of science, hinges belief in a scientific theory to empirical adequacy and empirical adequacy is limited to what is observable. That shows the importance of defining what is observable. A common sense view of science is that it explains the phenomena, but van Fraassen considers explanation as a pragmatic virtue only. In this chapter we try to understand what is a scientific explanation and its importance in constructive empiricism.

Van Frassen says that main aim of science is empirical adequacy and explanatory power of scientific theories is invoked only to choose one theory among many empirically adequate ones, i.e. to solve the problem of underdetermination

Scientific experiments are performed to verify empirical adequacy of theories and to fill the gaps in information available. The fact that experiments also save unobservable phenomena, poses a question to van Frassen`s definition of 'observables'.

This chapter discusses various issues concerning empirical adequacy as applied to constructive empiricism and explores ways by which it can represent the actual practice of science.

3.2 Observable, unobservable dichotomy

Philosphers have pondered over unreliability of human observation. Post positivists subjected the positivists dogmas to a devastating critique and have shown the theoryladenness of observation in bringing out an appropriate aspect of a figure or an object into focus. Picture on the next page is taken from an essay *"Seeing and seeing as"* (Balshow, V. and Rosenberg) and shows that observations are not theory-independent. It attacks the empiricist's belief that knowledge based on experience (observation with unaided eyes) is neutral and objective. Van Fraassen`s assertion that science aims at giving us theories that save the observed phenomena becomes that science aims at giving us theories that save other theories on which observation is made. But that is not consonant with the actual practice of science, as the hypothesis of this study states.

According to van Fraassen, for something or some event to be 'observable', it must be observable to members of the epistemic community. That is the community for which knowledge, as we understand it, applies and is sought. That community is the human beings, as they are today, but can undergo changes with time. Their sense-prowesses can become more acute or dull.

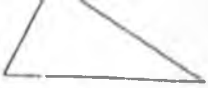


Figure 8

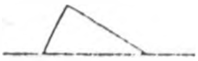
which he considers "... can be seen as a triangular hole, as a solid, as a geometrical drawing, as standing on its apex; as a mountain, as a wedge, as an arrow or a pointer, as an overturned object which is meant to stand on the shorter side of the right triangle, as a half parallelogram, and as various other things . . . You can think now of *this*, now of *this* as you look at it, can regard it now as this, now as this, *and then you will see it now this way, now this . .* "*

Of course the context here is given in Wittgenstein's designations. For example:

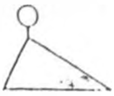
"... triangular hole . . ." does this to *Figure 8*

"... solid . . ." does this

"... geometrical drawing . . ." this



"... standing on its base . . ."



"... hanging from its apex . . ."

"... a mountain . . ."

"... a wedge . . ."

and so forth.

Also there are variations among human beings regarding sense -- capabilities. As an anti-realist, van Fraassen is of the opinion that beliefs about the world change with the changes in the epistemic community. "If the epistemic community changes in fashion Y, then my beliefs about the world will change in manner Z". (Fraassen 1980: 18).

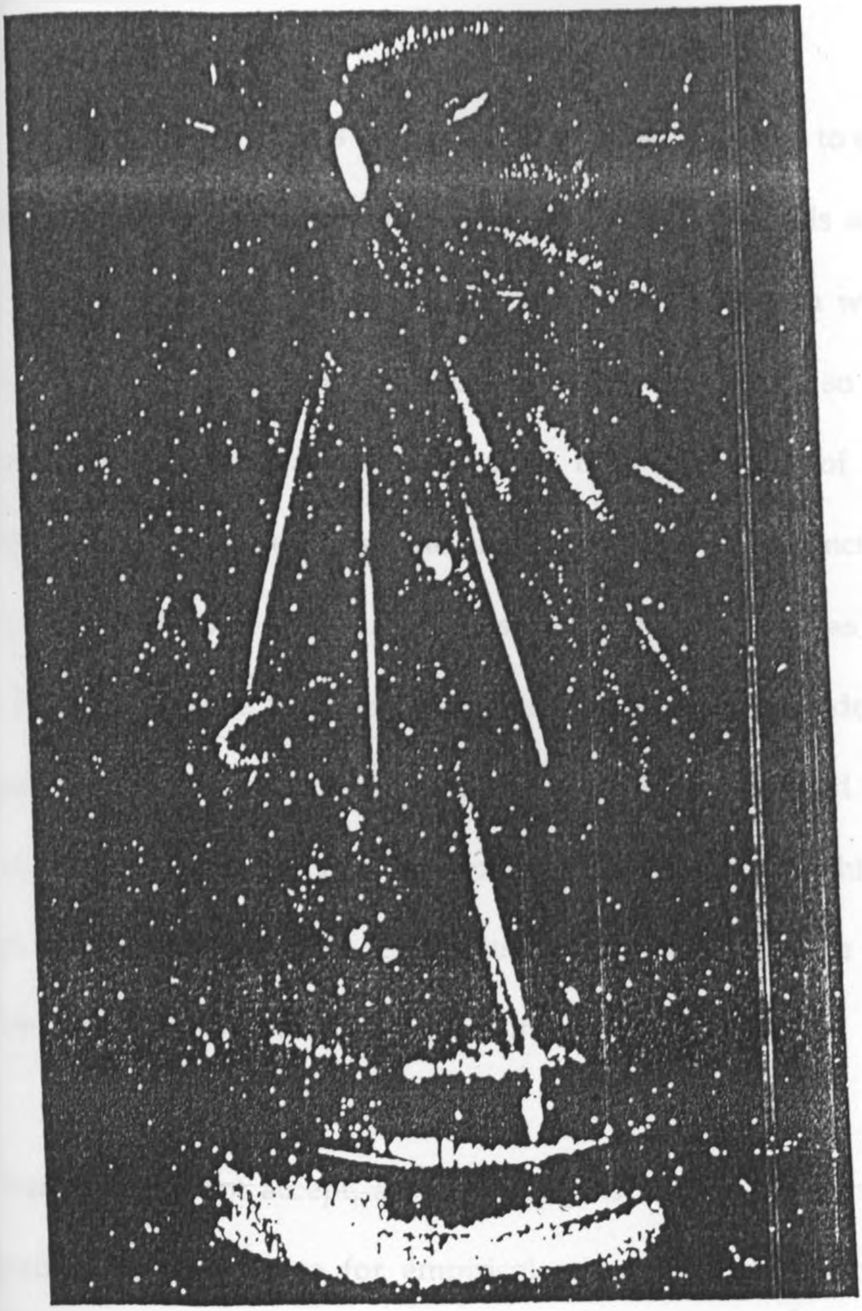
Van Fraassen has given a principle for observables. According to that principle, the circumstances for observation can be of the past or even of future (Ibid, 72). For example, dinosaurs are considered as observable because in those circumstances, any human would have observed them.

Regarding the future, science aims at giving us theories which are empirically adequate, i.e. save the observable phenomena, even if the observation will be available in future. That gives predictive power to scientific theories and expects them to hold good for future. What about a scientific theory which entails observables, circumstances of whose observations will be available in future? The theory will carry belief that it will save the phenomenon, until the observation is actually made, when it will be found to be correct or falsified. A constructive empiricist therefore sticks her neck out and allocates belief in a theory, which may be shown to be false.

Moons of Jupiter can be observed through a telescope, which is an instrument based on certain scientific theories. These theories are only empirically adequate, but may not be true. Therefore, according to van Fraassen, observing the moons through telescope is not 'observation'. The same moons can be observed by any one who travels by a space-ship, close enough to them and observes them with unaided eyes. And that makes the moons 'observable'.

Molecules can be observed through electron microscopes of high resolutions but are considered unobservable, as the unaided eye can not observe them. There are certain molecules of some crystals, which become big enough to be visible by naked eye and therefore are considered 'observable'.

Astronauts report seeing flashes of light sometimes, which turn out to be high energy electrons and therefore 'observable', according to van Fraassen . But he does not accept their observability in a cloud chamber, where they are seen as a silvergrey line produced by an electron, but not electron itself. A photograph of subatomic particles, in a cloud chamber is shown on the next page. (Okasha, S. *Philosophy of Science*, Oxford, 2002).



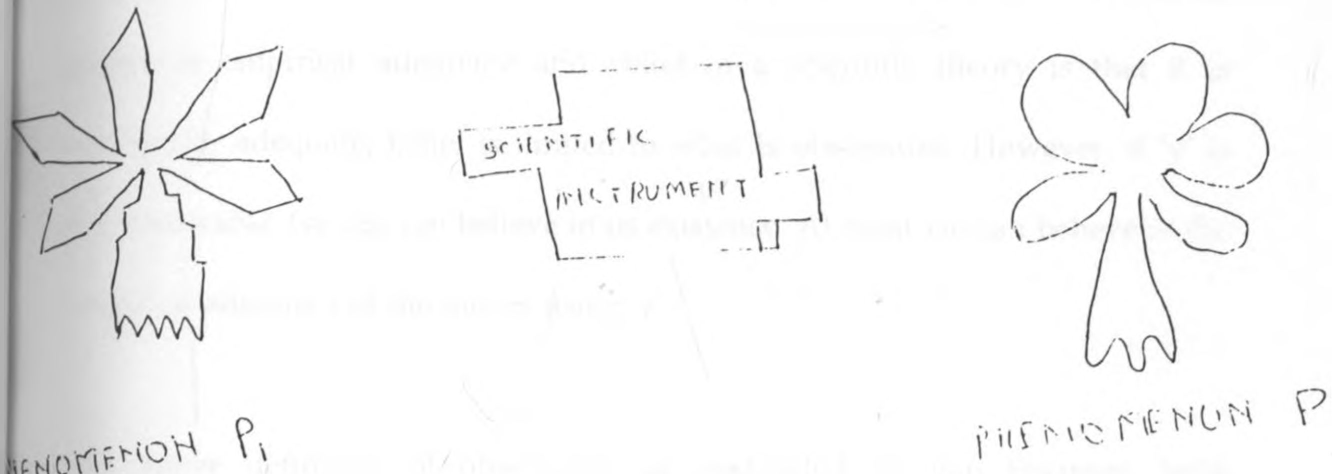
9. One of the first photographs to show the tracks of subatomic particles in a cloud chamber. The picture was taken by the cloud chamber's inventor, English physicist C. T. R. Wilson, at the Cavendish Laboratory in Cambridge in 1911. The tracks are due to alpha particles emitted by a small amount of radium on the top of a metal tongue inserted into the cloud chamber. As an electrically charged particle moves through the water vapour in a cloud chamber, it ionizes the gas, and water drops condense on the ions, thus producing a track of droplets where the particle has passed.

Grover Maxwell (1870) argues that there is no principled way to classify entities as either observable or unobservable. As an example, there is a continuum of events from looking at something with naked eye, through a window, pair of glasses, binoculars, microscope, and electron microscope and so on. Where can we draw a line? van Fraassen`s reply is, that vagueness of distinction for borderline cases does not eliminate the significance of distinction. There are clear-cut cases of observable and unobservable entities. Just as 'baldness' is a vague concept because hairloss is a continuous process, that does not make it unimportant. It is difficult to say for some men, if they are bald or not, but that does not mean that there is no distinction between bald and hirsute men. The concept is perfectly usable, despite its vagueness. Therefore the distinction between observable and unobservable is indeed real.

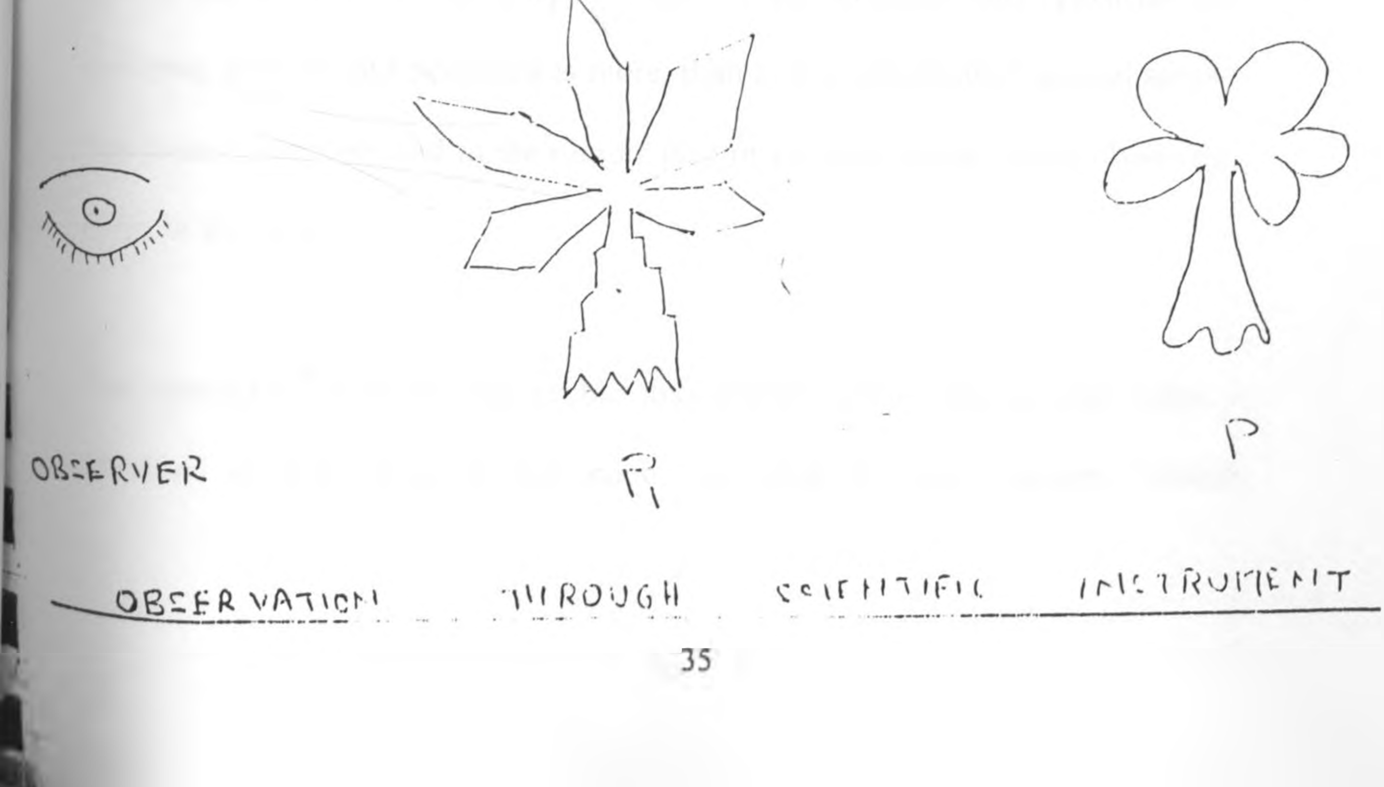
Van Frassen does not accept, seeing through scientific instruments as making observation of phenomena for empirical adequacy. Instruments like electron microscopes, particle accelerators, spectroscopes etc work on certain theories and those theories may not be true. What is seen through such instruments is another phenomenon, which needs to be saved and not the phenomenon which is purportedly observed. *"Such instruments can be understood as not revealing what exists behind the observable phenomena, but as creating new observable phenomena to be saved and once observable phenomena are, so created, the further question is, is it an* *image of something real?* (Fraassen 2001: 154). The hand drawn picture on next page, illustrates seeing through a scientific instrument.

From the above examples and discussions, we notice that according to van Fraassen, to ascertain what is observable, even if unobserved, our sensory endowment is irrelevant. What is relevant is changing our spatio-temporal location. That means we have to put ourselves, with our present sensory and mental endowments at the location and time-frame of the observable.

PHENOMENON P AS OBSERVED BY UNAIDED EYE



EW OBSERVABLE PHENOMENON P_1 CREATED BY INSTRUMENT



OBSERVATION THROUGH SCIENTIFIC INSTRUMENT

As an example, if we, as we mentally and physically are today, were present 5000 years ago, at the geographic location of earth, where dinosaurs roamed, then we would have observed them! Therefore dinosaurs are observable.

In constructive empiricism, empirical adequacy and belief depend on observation. 'Observable' and 'exist' do not imply each other. But, as the aim of science is empirical adequacy and belief in a scientific theory is that it is empirically adequate; belief is limited to what is observable. However, if 'y' is not observable, we can not believe in its existence. At most we can believe in the empirical adequacy of the theory using 'y'.

The above definition of observable, as postulated by van Fraassen, lacks epistemological significance. There can be situations where evidence for an "unobservable" is more, than the evidence for an 'observable'. For example among the scientific community, belief in the 'unobservable' particles like electrons, protons and positrons is more, than in the 'observable' animal species that existed and perished in the remote past or for that matter, some observable event of the future.

The distinction between observable and unobservable entities and what is involved in observation is not made very clear by van Fraassen. Though constructive empiricism relies mostly on this distinction. One reason for it could be, that it is for science to explain, why some objects are observable, to humans and not others. Another reason can be that 'aim' of science is to match the belief with observable while remaining epistemologically modest, i.e. unobservables may exist but we can not know.

3.3 Scientific explanation

Constructive empiricism claims that scientific theories should be empirically adequate and that aim of science is not explanation. Science only introduces theoretical entities, if there is an empirical benefit and not merely for the sake of explanation.

It is a general belief that science explains the phenomena. Carl Hempel (1965) suggested that scientific explanations have a logical structure. It consists of a set of premises followed by a conclusion. Schematically, Hempel`s model of explanation can be written as follows

General laws

Particular facts

$\Longrightarrow$

Phenomenon to be explained

For example, using Newton's laws of gravitation and some additional facts, movements of planets can be explained.

Hempel`s model faces a number of counter examples also. These counter examples fall into two classes. Firstly, there are a number of genuine scientific explanations that do not fit the model, suggesting that the model is very strict. Secondly there are cases that do fit the model but do not count as scientific explanation, suggesting that the model is too liberal.

Another idea behind an explanation of a phenomenon is simply to say, what caused it. For example, the orbits and movements of planets are caused by the gravitational attraction between planets and the sun. David Hume (1748) considered causality a fiction. For empiricists the idea of analyzing the concept of causality is not acceptable.

From the above discussion, a question that begs to be answered is: can science explain everything? Many philosophers think that the obvious answer is no. Because in order to explain something, we need to invoke something else. It could be some general law or cause. But what explains this second thing? Again, we take the example of Newton's laws. A large range of phenomena can be explained using Newton's laws and the law of gravity. But, what is the explanation for gravity? Newton himself had no answer to this question. Since nothing can explain itself, it follows that some laws will remain un-explained, though these laws will explain many other phenomena.

If we take the aim of science as finding explanations, then by Hempel`s criterion, we have to start with a true premises. Aim of science, then, becomes finding those true theories. But van Fraassen takes the aim of science as giving us empirically adequate, and not true theories! Therefore explanation is not taken as aim of science. Science only introduces theoretical entities, if there is an empirical benefit and not merely for the sake of explanation.

Wesley Salmon (1975: 118) introduced the theory that an explanation is not an argument, but an assembly of statistically relevant factors (Fraassen 1980: 119). A fact A is statistically relevant to a phenomenon E, exactly if the probability of E , 'given A' is different from the probability of E simpliciter:

$$P\ (E/A)\ \neq\ P\ (E)$$

Nancy Cartwright (1979) has provided many examples to show that Salmon`s criterion does not provide conditions for explanation. For example, phenomenon of dying of a plant, when sprayed with a poison which is 90% effective. Death of a plant can be explained "because it was sprayed with poison"; but the fact that 10% plants that survived, can not be explained by saying "because they were sprayed with poison".

The above example shows that Salmon's criterion of statistical relevance does not provide necessary or sufficient conditions for explanation. Salmon also says that an explanation provides a causal process and refers to the theory of common cause. An event C, belonging to two processes is the common cause of events A and B, in those separate processes, occurring after C, if the following conditions are met:

$$P(A \& B / C) > P(A/C) \cdot P(B/C)$$

$$P(A \& B / \hat{C}) = P(A/\hat{C}) \cdot P(B/\hat{C})$$

$$P(A/C) > P(A/\hat{C})$$

$$P(B/C) > P(B/\hat{C})$$

Relevant parts of the causal net, leading to the events to be explained, are exhibited. The above probability relations handle some standard problems. For example, barometer falling and storm coming are not causal relations since their relevance to each other is screened off by common cause of atmospheric conditions.

Van Fraassen says that Salmon has characterized certain explanations, which are of importance to science, but, explanation is not the main aim. There are many examples in the history of science, where theories that explained the phenomenon, were not necessarily true. Charles Darwin *(Origin of species*, 6th edition, Collier 1962) writes *"It can hardly be supposed that a false theory would explain in so satisfactory a manner as does the theory of natural selection, the several large classes of facts"*. As another example, around the beginning of twentieth century, assertion was that Newton's theory explains all the planetary movements. Still it was also agreed that advances in prehelion of Mercury is inconsistent with the theory.

Giving good grounds for belief does not always amount to explanation. For example if we accept the hypothesis that barometer reading falls when a storm is coming, it is indeed a good prediction but does not explain the fact that a storm is coming. Similarly length of shadow does not explain the height of a flag pole. A good explanation does not necessarily mean that good grounds for belief have been given. For example, syphilis if untreated can lead to the dreaded disease paresis. i.e. untreated syphilis is an explanation for getting paresis but is not a reason for an individual with syphilis to get paresis, because a small percentage of people with syphilis get paresis.

According to constructive empiricism, theories should save the phenomenon, but explanation of the phenomenon is a virtue which they may or may not have. For example, Boyle`s law describes and saves the phenomenon of a gas in a container, by postulating that for Pressure (P), Volume (V), and Temperature (T)

$$\frac{P.V}{T} = \text{constant}$$

But Boyle`s Law does not explain the phenomenon. Explanation is given by Kinetic theory of gases.

When more than one theory is empirically adequate, scientists choose the one that explains best. But that does not mean the theory is taken as true; it is still only empirically adequate.

Explanation is only for what is observed till now, whereas empirical adequacy means accepting it to be adequate even for future observations.

The real importance of theory, to a working scientist, is that it is a factor in experimental design and the experiments further fill the blanks in a developing theory. Development of theory and experimentation, are thus intimately intertwined by the assertion that a theory is or is not empirically adequate.

3.4 Scientific method

One role that experiments and controlled observations play, is for theory testing. For example, Halley`s prediction of the comet's return and its observation, the famous watch at the eclipse that bore out Einstein`s theory, implying the deflection of light rays in the gravitational field. This sort of experimental activity is designed to test claims of empirical adequacy.

Another role that scientific experiments play is that of 'filling the blanks'. This scientific activity is, what Thomas Kuhn calls puzzle solving (Kuhn. T. *The Structure of Scientific Revolutions*, 1996:35). There are cases where a theory says that there must be some entity or value, satisfying certain conditions and scientists attempt to discover that. In Mendeleyev`s periodic table, the key properties of the different elements are systematically arranged in the order of their atomic weights. Over ninety, naturally occurring elements are clearly shown on the table (Crump, T. *A Brief history of science*. 2002: 178). There are some "blank spaces" showing the properties of elements which are yet to be found in nature. From the symmetry of properties of elements, in nature, scientists "know" something about the elements, not yet 'observed".

According to constructive empiricism, science progresses by carrying out experiments that show how the blanks are filled, if the theory is to be empirically adequate. Once a blank is filled the theory construction moves forward and new consequences are encountered to be tested and new blanks to be filled. This is how experimentation guides the process of theory construction. A theory which has already been constructed, guides the design of the experiments.

In 1911, Robert Millikan (Fraassen 1980:75) designed an experiment to measure charge of an electron. The apparatus consisted of a brass and ebony cylinder with windows for observation and droplets of oil falling from top of cylinder downwards. An electric charge was applied between the upper and lower plates of cylinder. Now, the droplets of oil had two forces acting on them, gravity downwards and electric field upwards. Some droplets actually hovered between the two plates. For a drop with mass 'm', velocity of fall 'v' under gravity was noted. Again its velocity 'w' under a charge of 'F' was noted. The following equation was, thus formed, where 'g' is gravity.

$$\frac{v}{w} = \frac{mg}{Fe - mg}$$

All the variables except the charge on electron 'e' are known. From the equation, 'e' is thus calculated.

The experiment filled the value of a quantity which was not known, using the known theories. Constructive empiricism sees the aim of science as an activity of constructing an image of the world and not of discovering or inventing the laws that govern nature. Central activity is the construction of theories that describe this structure. Experiments are then designed to test these theories. Previously constructed theories guide the experimental inquiry.

3.5 Underdetermination.

One of the arguments in favour of scientific realism is, that the success of science can be explained by taking the best theories to be at least approximately true. van Fraassen`s counter argument is, that the best could be best among the bad lot, meaning thereby that there is no sure way of finding out, if still better theories, explaining the success of science, are yet to be postulated.

Stathis Psillos *(How Not to Defend Constructive Empiricism)*. Finds a similar fault with constructive empiricism, where belief in a scientific theory is, that it is empirically adequate. Once again; there is no sure method of choosing between more than one empirically adequate theories. As before, there could be many empirically adequate theories which have still to be postulated. There are infinite ways in which each of the empirically adequate theories can be refuted.

Therefore, the realists' claim that one of their theories is true, does not appeal to a stronger privilege than the empiricists`. But this argument does not hold, for two reasons. Firstly that taking a theory as true, is believing in much more than just empirical adequacy. Secondly, van Fraassen acknowledges that more than one theories can be empirically adequate and that accepting of one theory rather than the other is dictated by the research programme, within which the scientist is working and the pragmatic virtues of the theories in question.

The above argument can best be understood, in light of the aims. A realist aims at describing and explaining both observable and unobservable aspects of the world, which exist independently of us. A constructive empiricist aims at construction of theories that are adequate to what is observable, and not to discovery of truth concerning the unobservable.

3.6 Ontology

Constructive empiricism entails ontological commitment to whatever shows up through trained observation. It does not grant reality to various hypothetical entities like electrons, positrons, gluons and muons etc that are crucial for the development of scientific theories. These are some of the entities, which are unobservable but are treated in science, as necessary to explain the phenomenon. Without these entities, it is difficult to account for or describe what is happening.

Van Fraasen's refusal to accept the ontological status of unobsrevables stems from (a) his sceptism about 'laws of nature' and (b) not accepting justification on the basis of an inference to the best explanation. However, this creates large problems and makes it hard to explain how knowledge has advanced from the stage of theoretical conjecture regarding unobservable entities to the stage of demonstrative proof.

Even the ancient thinkers, the atomists, hypothesized about the unobservable entities through guesswork and metaphysical premises. Today we have the scientific instruments like electron microscopes with higher power of resolutions which provide 'evidence' for the existence of such entities. If we do not accept that evidence, we have no warrant for the claim that our present-day knowledge of such entities has progressed.

Van Fraassen, does not deny that in cases of successful theories, these unobservable entities are accepted by most as physical reality. (or as a layer of reality). But he does not accept it as an argument for realism with regard to such entities. Because *"scientific models may, without detriment to their function, contain much structure which corresponds to no elements of reality at all* (Fraassen 1989: 213).

In his paper *"ontology according to van Fraassen: some problems with constructive empiricism"*. Christopher Norris says that success of science can best be explained by its quest for causal-explanatory grounds beyond the mere enumeration of observed regularities in nature. This leads to vicious circularity, as the justification of inductive procedures, involves constancy of natural processes and law-governed causal relations, involves constancy of natural processes and law-governed causal relations.

Peter Lipton suggests that circularity is relative to audience; since "*the inductive justification of induction is circular for an audience of sceptics, yet not among those who already accept that induction is better than guessing*" (Lipton 1993:67). It is the existence of deep further facts like molecular, subatomic structure of physical reality that enables scientists to proceed reliably on inferences to the best explanation and not Humean 'constant- conjunction'.

Norris says that the charge of circularity may be turned back against the sceptic by asking what better justification is possible than given by induction; why induction has succeeded in advancing so far beyond the level of mere observed regularities to the construction of scientific theories with ever increasing scope, depth and causal-explanatory power. This is Lipton`s "truth argument" that "*we ought to infer first that successful theories are true or approximately true, since this is the best explanation of their success, and then that inference to the best explanation is truth-tropic, since this is the method of inference that guided us to these theories*" (Ibid)

But the above argument creates an equation between 'truth' and 'success'; one causing the other. Success of science, can be claimed only in a few fields yet, and particularly the areas where the epistemic community finds its application and usefulness. By that reasoning, 'truth' becomes merely pragmatic or instrumental.

To support his argument for induction, Lipton quotes J.S Mill as "*in almost every act of our perceiving faculties, observation and inference are intimately blended. What we are said to observe is usually a compound result, of which one-tenth may be observable and the remaining nine-tenth inference*", (Cited in Lipton 1993, 181).

The quotation sounds similar to the Kantian view that observation is made up of our faculties of sensibility and understanding, because inference is a mental process. I have deliberated further on this argument in chapter four of this project. An observation is never made in vacuum. The observer has pre-conceived ideas, intuitions and logic which work on the observation. This is theory ladenness of observation. The diagrams on page 29 emphasize the point. Wittgenstein calls it "organization" of what one sees.

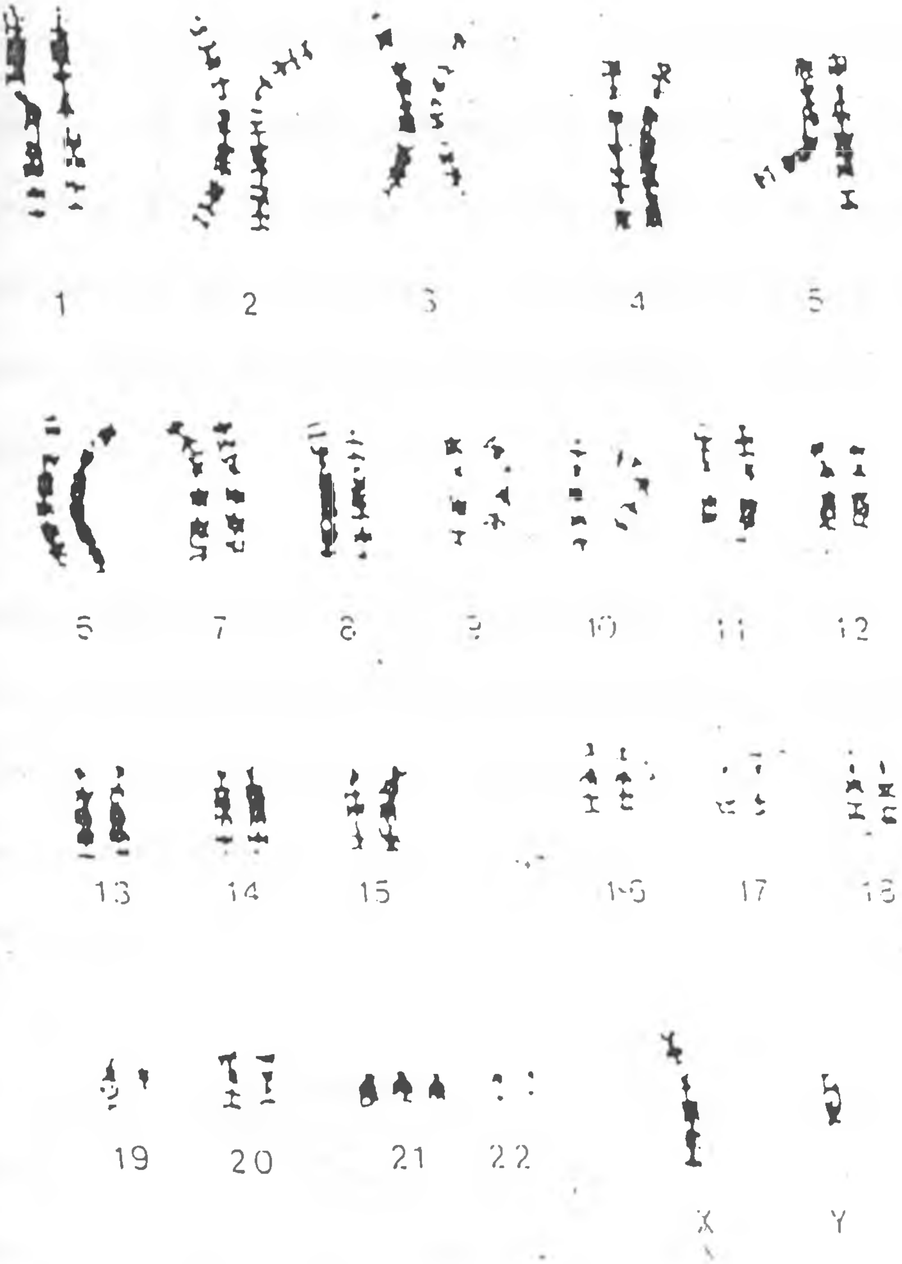
An example of scientists using inductive reasoning is diagnosis of genetic disease known as Down`s syndrome. Geneticists tell us that Down`s syndrome sufferers have an additional chromosome ___ they have 47 instead of the normal 46. See the figure attached (Okasha, S. *Philosophy of Science*, Oxford, 2002). How do they know this? They examined a large number of Down`s syndrome sufferers and found that each had an additional chromosome. They then reasoned inductively to the conclusion that all sufferers, including ones they hadn't examined, have an additional chromosome.

The fact that the Down`s syndrome sufferers in the sample studied, had 47 chromosomes, doesn't prove that all such suffers do. It is possible though unlikely, that the sample was an unrepresentative one.

Scientists use inductive reasoning whenever they move from limited data to a more general conclusion, which they do all the time. For van Fraassen ,it is the empirical adequacy of a theory which is important and not the method of reaching a theory. He does not deny the assumption, that nature could be constant, but denies belief in this assumption.

3.7 Saving unobservable phenomena

Philosophers of science, have a tendency to regard phenomena as images of reality. Phenomena are considered the threshold of what is real. The tendency stems from the Platonic myth of *"The Republic"*.



A representation of the complete set of chromosomes - or karyotype - of a person with Down's syndrome. There are three copies of chromosome 21, as opposed to the two copies most people have, giving 47 chromosomes in total.

The chained prisoners are observing the shadows on the wall of the cave. Realists believe that the prisoners can free themselves and look at the real objects that cast the shadows. Empiricists on the other hand believe that the prisoners are bound in such a way, that they can never have access to the real objects and have to make do with the images. Observable phenomena are the only source of all knowledge about the natural world for empiricists. Beyond the observable phenomena, is the elusive realm of unobservable entities. It is the observable phenomena that are saved by scientific theories, according to constructive empiricism.

A closer look at the wide variety of experiments conducted by scientists, to learn about natural world, show that phenomena are not necessarily observable. Contrary to what constructive empiricism says about the aim of science, as saving only observable phenomena, science does save even the unobservable phenomena.

In the experiments, observation is not made in the sense defined by van Fraassen, as made by humans, with unaided eyes. Instead phenomena are detected through the use of data. For example the phenomenon of decay of proton is detected by the data of patterns of discharge in electronic particle detector (Bogen and Woodward 1988: 306). Data are unusual or unexpected behaviour, which are picked up in particular experiments and typically can not occur outside of those experimental contexts. The phenomena, by contrast are not unusual to specific experiments. Under same conditions, whether in the lab or in nature, same phenomena take place. It is only the data that is available in the lab-situation of the experiment. This is similar to what van Fraassen means when he says that something is observable, does not automatically imply that the conditions are right for observing it now (Fraassen 1980: 16). In an experiment, scientists create those conditions for 'observation'. We expect phenomena to have stable, repeatable characteristics which can be detected by means of a variety of different procedures, yielding different data.

For the purpose of 'observation' of a phenomenon, data must occur in the form of records that are accessible to our senses, whereas phenomena, as they occur in scientific experiments, are not always accessible to our perception.

In the paper "Saving Unobservable Phenomena" Michela Massimi says that phenomena are not necessarily ready made in nature or as images of real objects, but as objects we have epistemic access to. In scientific practice, data provide evidence for phenomena which may not be visually accessible but can be saved by appropriate scientific theories.

A simple example can be of chemical engineers, studying the process of pure copper reacting with an acid. This phenomenon of chemical reaction can take place in nature, but actually does not, because pure copper is never found in nature. Copper being a reactive metal, is always found as a compound. Therefore to study its behaviour, copper is purified and then subjected to reaction in an experimental situation. Similarly electrons and positrons do not frequently bombard each other, at different energy levels, in nature. One of the scientific theories, of origin of universe is the Big bang theory, which postulates that energy released by the Bang, transformed into subtaomic particles, as per the famous Einsteinian equation E= mc^2. These particles bombarded each other with varying energies and formed other subatomic particles, thus forming basic electrons, protons neutrons which became atoms and molecules as we know them today (Hawking, S. *The Big Bang, Black Holes and the Evolution of the Universe* in A Briefer History of Time, 2005: 68). Now, obviously the phenomenon of Big Bang is unobservable! Scientists create similar conditions on much smaller scale, in an experimental situation, where they can control the imput and study the output.

The Experiment

In February 1973, scientists conducted an experiment, in Stanford, where they collided subatomic particles, electrons and positrons with total energy ranging from 2.4 to 9 Gev (Massimi, Saving Unobservable Phenomena). In the region of the collider, a magnetic detector was installed which consisted of four cylindrical and coaxial spark chambers. A series of scintillation counters surrounded the spark chambers and they were in turn surrounded by a 3-meter wide electromagnet, outside which there were more scintillation counters. The structure was wrapped in thick steal shields. On the outer shield, a final series of spark chambers was located. This multy-- layered structure of magnetic detector made it possible to record all types of particles produced in electron-positron collisions. The data were fed into a computer that could calculate the velocity and mass of each particle produced. Mostly muons and hadrons were produced along with some electrons.

Ratio R, of cross section of hadrons and muons was calculated. It was found that the value of R rose from 1 to 6 by increasing the energy of collision, from 2 to 5 Gev. It was further found in the experiment, that for energy value 3.1 Gev, value of R increased dramatically. According to the theory, energy released by the collision, transforms entirely into the masses of new particles, which are also unobservable. The graphs on next pages show the increased value of R at 3.1 Gev, as found in Stanford and Long Island, New York.

The unobservable phenomenon that made itself known via this increased value of R was saved by a theoretical entity: a particle named ψ. The same phenomenon had been spotted by another team of scientists at Long Island, New York, by colliding protons against beryllium.

Despite different experimental set ups, data and procedures, the two models spotted the same phenomenon. The new phenomenon was unobservable, its existence was not justified by facts concerning human perception, but rather by a feature from different kinds of data received through different experiments.

The unobservable phenomenon was saved by a hitherto unknown theoretical entity ψ, thereby increasing the scientific knowledge about subatomic particles. Science therefore gives us theories which are not only empirically adequate to the observable phenomena but also to unobservable phenomena.

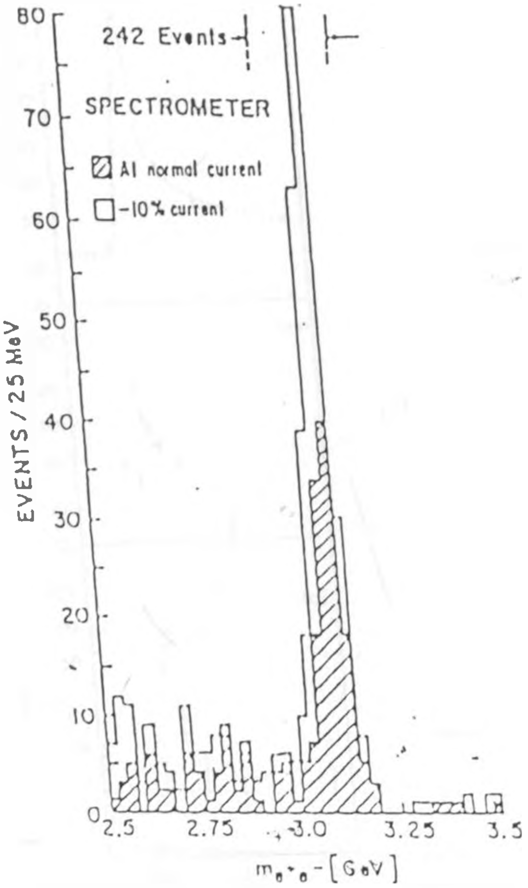


FIG. 2. Mass spectrum showing the existence of J. Results from two spectrometer settings are plotted showing that the peak is independent of spectrometer currents. The run at reduced current was taken two months later than the normal run.

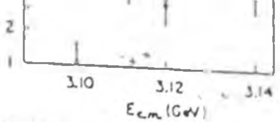
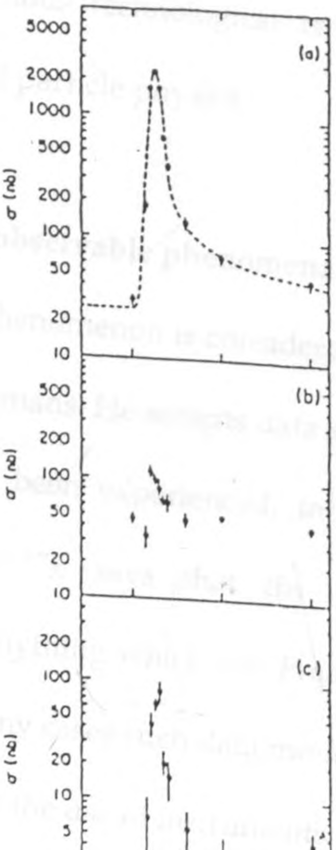


FIG. 1. Cross section versus energy for (a) multihadron final states, (b) e^+e^- final states, and (c) $\mu^+\mu^-$, $\pi^+\pi^-$, and K^+K^- final states. The curve in (a) is the expected shape of a δ-function resonance folded with the Gaussian energy spread of the beams and including radiative processes. The cross sections shown in (b) and (c) are integrated over the detector acceptance. The total hadron cross section, (a), has been corrected for detection efficiency.



5000
2000
1000
500
200
100
50
20
10
σ (nb)
(a)
500
200
100
50
20
10
σ (nb)
(b)
200
100
50
20
10
5
σ (nb)
(c)

The unobservable phenomenon, described above is a result of a laborious construction, involving a network of international scientific institutions and the coordination of various technological resources, all driven by the scientific interest in the area of particle physics.

Data models and unobservable phenomena

For van Fraassen, a phenomenon is considered observable only if it is observable by unaided eyes of humans. He accepts data as representing phenomenon only if the phenomenon has been experienced, in that sense. Paul Teller *("Whither Constructive Empiricism?")*, says that the data from experiments do not themselves represent anything which van Fraassen would count as phenomena. It is also true that in many cases such data models do count as phenomena which can be observed without the use of instruments.

Van Fraassen does not consider an observation made through scientific instruments as observation of phenomenon. *"Scientific instruments such as electron microscopes, spectroscopes, particle accelerators can be understood as not revealing what exists behind the observable phenomena, but as creating new observable phenomena to be saved"* (Fraassen 2001:154). According to van Fraassen, accepting the observation made through an instrument is believing in the scientific theory on which the instrument is based. For example the photograph attached, of the tracks of subatomic particles in a cloud chamber is an observable phenomenon which can be saved (explained) by the theory that electrically charged particles move through water vapour in a cloud chamber, they ionize the gas, and water drops condense on the ions, thus producing a track of droplets, where the particles have passed.

As an empiricist, van Fraassen is right, because a scientific instrument is based on some scientific theory which itself is at the most empirically adequate and not true. Believing in the observation made through a scientific instrument, therefore is believing through two layers. First layer, being the belief in theory on which the instrument is based and second layer being the actual observation through the instrument.

In the hand drawn pictures on page 35, (1) is the observation of phenomenon as accepted by van Fraassen. (2) Is what the scientific instruments do, creating a new phenomena to be saved and (3) observation through a scientific instrument.

In the science laboratories, new phenomena are created which can not be observed or experienced by humans without the use of scientific instruments and computers. When the experimental procedure is changed or data of the experimental output is collected by a different method, the phenomenon remains the same. The same phenomenon is observed by different scientists using different procedures in different laboratories. We are therefore justified in believing in such phenomena. For example, the phenomenon of creation of ψ is observed and recorded by two different procedures and groups of scientists and recorded differently as shown on pages 58 and 58.

Second part of van Fraassen`s constructive empiricism states that acceptance of a theory involves as belief only that it is empirically adequate (to what is observed by unaided eyes). But in actual scientific practice, scientists` belief transcends human observation. In actual practice, scientists put forward theories that save phenomena which are created and observed using putative scientific theories. Therefore scientists show their belief in the putative scientific theories which may not be empirically adequate to human observation as asserted by van Fraassen. From the above discussion, we notice that there is need to redefine 'observable' so that constructive empiricism represents the aim of science as practiced
The theoretical entity ψ is postulated in the experiment discussed above, to save an unobservable phenomenon, which in turn is created using unobservable theoretical entities electrons and positrons. Electrons were discovered by J.J Thompson in 1987 using specially designed cathode rays tubes (Thomas crump, *A Brief History of Science* 2002: 204). In the decades that followed, scientists conducted different experiments, corroborated their results and developed a belief in its existence. Scientific progress occurs in stages and this is what van Fraassen views as scientific activity ____ that of construction (Fraassen 1980:.5).

A scientific theory saves the phenomena, but the phenomena are not always available for observation, in nature. The phenomena to be saved are created in experimental situations, using other scientific theories. The observation of such phenomena is not possible by unaided eyes; it is done using scientific instruments which are based on some accepted scientific theories. Scientists have belief in those putative scientific theories, which are used in creating and observing phenomena. Van Fraassen`s assertion that science aims at giving us theories that save the phenomena as observed by humans, can not hold in light of the above discussion.

CHAPTER FOUR

Observability (Redefined)

4.1 Introduction

According to constructive empiricism, science aims at giving us theories that save the observable phenomena. Van Fraassen defines the 'observable' as that phenomenon which is observable to human beings without the aid of any instruments. In chapter three we have seen that in actual practice, scientists do save the phenomena which are not observable to unaided human eyes. Therefore, there is need to redefine 'observable', so that constructive empiricism represents the actual practice of science. An attempt to do the same is made in this chapter.

4.2 Observable redefined

Constructive Empiricism, as a philosophical position holds that science constructs models that must be adequate to the phenomena, i.e. these models or theories need not be true except in what they say about what is actual and empirically attestable. Acceptance of a scientific theory involves as belief, only, that it is empirically adequate and a theory is empirically adequate exactly if what it says about the observable things and events in this world is true.

Van Fraassen, makes it clear that observing is not the same as seeing (Fraassen 1980:15). He gives an example of a stone age person shown a car crash. The person obviously sees the crash but does not observe that, for lack of concepts and learning. A high speed car crash will be seen by all observers; but a passerby who has never driven a car; an experienced and seasoned driver; a trained traffic police officer and a trained detective such as employed by insurance companies, would all have different observations of the same crash. The latter ones have clearer concepts and better learning.

We can say that for observing, sensible observation is necessary but not sufficient. Michella Massim (Massimi, Saving Unobservable Phenomena) says that Kant strikes a middle ground, that observations are product of both the faculty of sensibility and the faculty of understanding. Faculty of understanding, can be understood as the product of one's learning, concepts, experiences and systematic study of existing 'knowledge'. For scientists, existing 'knowledge' consists of putative scientific theories, in the field of their research. Scientific instruments are based on certain theories. Belief in the observation made through an instrument, depends on the belief, a scientist has in the theory. The experiment discussed in chapter three shows that scientists do have belief in the observations made through their instruments and the theories employed therein.

Van Fraassen has given the principle for observable, as *"x is observable if there are circumstances which are such that if x is present to us under those circumstances, then we observe it"* (Fraassen, 1980:16). This principle can be reworded as: something is observable if, with the appropriate conditions, any member of the epistemic community can observe it with naked eye. Therefore, according to constructive empiricism, aim of science becomes, "to give us theories which save the phenomena, as observed in appropriate conditions by any human being, with unaided eyes".

In the real practice of science, what is observable by unaided eyes is in the form of graphs data, and apparently incomprehensible photographs, and science aims to give us theories which save phenomena so observed. For some one to observe the phenomena, one has to have understanding of the instruments and theories that produce the data.

Let us revisit the hand-drawn pictures on page 35 . The top picture shows the original phenomenon P as observed by the unaided human eye. The second picture depicts, what the scientific instruments do, they convert the original phenomenon P into another phenomenon P1 of graphs and data. The third picture shows that the observer "seeing" phenomenon P1, can "observe" the original phenomenon P.

If, the original phenomenon P is unobservable to unaided human eye; scientists "observe" it through P1. But they can "observe", only if they have belief in the scientific instruments which produced P1 from P.

Van Fraassen`s principle for observable, can be redefined to become "x is observable if there are circumstances which are such that if x is present to some one with understanding, under those circumstances, then one observes it".

With the redefined observable, many anomalies and problems discussed in chapter one are resolved. Belief in the existence of dinosaurs was based on their observerbility by humans if present at that time, which obviously is impossibility. A trained anthropologist acquainted with the process of excavation, understanding of fossil formation and other tell-tale signs has a more reasonable belief in dinosaurs' existence. It is this process of 'observation' that brought the concept of a dinosaur in the first place!

Because the putative scientific theories form a part of a practicing scientist's understanding, her observations and the theories she postulates to save the phenomena, use those putative theories.

In the experiment discussed in chapter three, the observable (with new definition) phenomenon is the controlled collision of entities, electrons and positrons. Behaviour of resultant particles was represented by the data recorded on the graphs. Those electrons and positrons were made to collide with different energies or intensities and resulting behaviour of entities formed were graphed.

The input of the experiment is observable, because the scientists have belief in the theories governing the entities there. They do not have the same belief in the theories regarding the output .Yes; there are conjectures for the possible outputs, as shown on the table 1. (Massimi, Saving Unobservable Phenomena).

Table 1 From Richter, B. (1977) 'From the psi to charm: the experiments of 1975 and 1976', *Reviews of Modern Physics* 49, 251–266. Originally printed in J. R. Smith (ed.) (1974) 'Proceedings of the XVII International Conference on High Energy Physics', London, July 1974, (Science Research Council, Chilton, Didcot). Reprinted with permission by J. Ellis and the CCLRC Library, Daresbury Laboratory, Warrington, Cheshire

TABLE I. Tables of values of *R* from the talk by J. Ellis at the 1974 London Conference (Ellis, 1974). The references in table are from Ellis's talk

Value	Model	References
0.36	Bethe—Salpeter bound quarks	Bohm *et al.*, Ref. 42
$\frac{2}{3}$	Gell-Mann—Zweig quarks	
0.69	Generalized vector meson dominance	Renard, Ref. 49
~ 1	Composite quarks	Raitio, Ref. 43
$\frac{10}{9}$	Gell-Mann—Zweig with charm	Glashow *et al.*, Ref. 31
2	Colored quarks	
2.5 to 3	Generalized vector meson dominance	Greco, Ref. 30
2 to 5	Generalized vector meson dominance	Sakurai, Gounaris, Ref. 47
$3\frac{1}{3}$	Colored charmed quarks	Glashow *et al.*, Ref. 31
4	Han-Nambu quarks	Han and Nambu, Ref. 32
5.7 ± 0.9	Trace anomaly and ρ dominance	Terazawa, Ref. 27
5.8	Trace anomaly and ϵ dominance	Orito *et al.*, Ref. 25
6	Han—Nambu with charm	Han and Nambu, Ref. 32
6.69 to 7.77	Broken scale invariance	Choudhury, Ref. 18

The experimental output matches with one of the conjectures i.e. that particular conjecture therefore is accepted. A similar experiment is conducted by a different group of scientists in New York and same results are obtained and latter corroborated. With no refutations reported, the theory becomes putative and may be used to enhance new observations. The experiment is a good example of how science progresses.

Let us consider the effect of redefined 'observable' on future observations. Looking back at the history of science, it is reasonable to expect the same trend of scientific progress to continue. Better instruments with enhanced capabilities of observation will be available to scientists. New age computers would be better equipped to analyze and interpret data. This development will increase the overall 'understanding' capabilities of scientists.

As 'observable' is defined as made up of sensible observation and faculty of understanding, more phenomena will become observable. To be empirically adequate, a scientific theory will have more phenomena to save and therefore be nearer to truth. If a scientific theory is only about observables, then, there is no difference between constructive empiricism and realism. Because when the hypothesis is solely about what is observable, empirical adequacy coincides with truth (Fraassen 1980: 72)

The above discussion portrays the picture of science, as a progressive and successful enterprise, which it is.

4.3 The Platonic Myth

According to the Platonic myth of *"The Republic"*, phenomenon marks the threshold of what is real, like the shadows on the wall of the cave. It is worth quoting Michela, (Saving Unobservable Phenomena), here

"Empiricists typically diverge as to whether the prisoners, who according to the platonic myth are sitting in chains and observing the shadows on the wall, can free themselves and look at the real objects that cast the shadows (as realists contend) or they are instead bound to never have access to real objects and hence contend themselves with their shadows (as constructive empiricists claim instead).

The idea conveyed, is that there are only two mutually exclusive options. Either the prisoners can free themselves and look at the real objects or they remain bound, never to have access to real objects.

Let us extend the scene in the Platonic cave, prisoners are sitting chained and facing the wall, they are watching the images of a line of dancers, passing behind their backs and there is an orchestra, in the dark, playing some tune on which the dancers are performing.

The chained prisoners are watching the images on the wall in front, but have somehow maneuvered their heads to glimpse at the real dancers. This glimpse makes the prisoners aware that what they are observing on the wall is caused by something else, and which is the first layer of reality. They can now ponder over tunes on which the dance is being performed and if these tunes are fixed, repetitive or there is a conductor, who alters them, at random.

Scientific instruments, provide an opportunity to glimpse at a 'layer of reality', which the naked eyes can not see. Constructive empiricists do not accept the observation made through an instrument, whereas scientists do. With the redefined observable, constructive empiricism represents the actual practice of science. Use of words 'a layer of reality' shows that the scientists do not believe that they have known the truth and the 'prisoners can free themselves and look at the real objects', instead, it means that science is moving towards truth, albeit in layers.

4.4. Layers of Reality

Van Fraassen says that acceptance of a theory involves more than belief, it means involvement in a research programme, (van Fraassen 1980: 12). When all the scientists, working in a field of study, say particle physics, share a set of beliefs, can we say that they accept a certain level of reality? In the experiment described above, different scientists have floated theories about the effect of collisions between primary particles (electrons and positrons) as shown in table 1 page 68 . They all have consensus on the properties and ontological status of these particles. By the same reasoning they have agreement that their instruments reveal what exists behind observable phenomena.

Some philosophers of science have suggested that realism could continue itself to being a doctrine about the independent existence of theoretical entities that is "entity realism", without commitment to the truth of the theories employing them as defined in chapter 2.3. If you can deploy entities experimentally to discover new features of nature then the entities must be real. Nancy Cartwright (*Routledge encyclopedia* 2006:952) has suggested that the explanation be confined to inference to the causes of phenomena, since causes are unquestionably real.

It follows from the above discussion, that for science to progress, scientists accept a certain level of reality. The level consists of certain theories that scientists, working in a field, believe in. These are some of theories, on which their instruments are based.

Van Fraassen takes a functional view. He says that atomic physics progressed while leaving some blank spaces in its theory. Those blank spaces are filled by conducting some experiments to keep the theory empirically adequate (Fraassen

1980: 75). But the argument does not hold, because in the experiment discussed in chapter three, scientists believe in the theories regarding the cause of the phenomenon and also in their instruments. But they don't agree on the effect, the outcome of the experiments. They have their different hypotheses and they agree on the one, which is found to save the phenomenon. The experiment was not conducted to keep one theory empirically adequate; rather to choose one empirically adequate theory.

The putative theories form a layer of reality and new theories are floated and then verified to be empirically adequate to the observations made using putative theories; the process explains the construction of theories and also the success of science.

In the experiment discussed in chapter three, electrons and positrons are deployed to study the effect of their collision; they make the cause of a phenomenon and therefore, by the aforementioned arguments; must be real.

Before the experiment was conducted, many scientists had floated different theories about the effect of collision between primary particles as shown in table 1 page 68. They all have consensus on the properties and ontological status of these particles, showing that they are involved in the same research programme. They share a set of beliefs which forms a level of reality. Once a level of reality is accepted, in a field of scientific research, theories are postulated for the next layer and the process continues.

CHAPTER FIVE

Conclusion

Philosophy deals with the questions that sciences can not answer now or perhaps may never be able to. It also deals with the question about why sciences can not answer those questions. Philosophy of science attempts to understand the methods that enable sciences to answer the questions that they answer.

A famous scientist of the nineteenth century, Von Hoffamann, is credited with saying. *"I will listen to any suggested hypothesis, but on one condition- that you show me a method by which it can be tested"* (Steven French; *science-key concepts in philosophy* 2007:45). It is an example of principle of verifiability as the main distinguishing feature between scientific theories and metaphysics, poetry and arts. The statement means that science aims at theories, which are verifiable.

Positivists took it to mean that science can give us theories that can be verified by observation, van Fraassen considers aim of science, as giving us theories that can be verified by unaided observation. He defines observable, as any phenomenon, of past, present or future which can be observed with unaided human eye. For example, he considers the moons of Jupiter observable, because a human being can go near them, in a space ship and see them with naked eyes and not because they can be observed through a telescope. He considers dinosaurs observable by humans, even if humans did not exist at the time of dinosaurs, because 'if' humans existed at that time, then they would have observed them

Scientists use observation, but it is not in the restricted sense of observation through unaided human eyes. All observations are not available to human, unaided eyes due to physiological limits and that is why, there is need to redefine observable so that the aim of science truly represents actual practice of science. Observations are for phenomena and scientific theories are also about the phenomena. Let us see what a phenomenon is. Oxford English Dictionary defines a phenomenon as ___

A thing that appears or is perceived, esp. thing the cause of which is in question; (philos) that of which a sense or the mind directly takes note, immediate object of perception;

Traditional view of scientific phenomena is that they are observable and are discovered in nature. Examples include rainbows, lightning, bending of star light etc and scientific view of phenomena is that these are public, regular and obey certain laws. To study phenomena, scientists create them, pure and isolated, in experimental situation, using available technology.

Accepted scientific theories are part of experiments for verifying new theories. The putative theories make the background for experiments, for example theories about nature of electrons and positrons are used in the experiment discussed in chapter 3.7 to bombard them against each other. The theories are also part of technology; the tools that scientists use for making observation of the phenomena.

In other words, scientific theories make their debut in experiments, as background and also for observation. Whatever scientists "find" from their experiments can not be taken as "true", at the most empirically adequate to what is "observed". Any verified theory can not claim more belief than the theories that are used to verify it. The whole structure of science is not sitting on "true" or firm basis, as conveyed by K.R Popper in the following quotation:

"Science does not rest upon a bed-rock. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or 'given' base; and if we stop driving the piles deeper, it is not because we have reached firm ground. We simply stop, when we are satisfied that the piles are firm enough to carry the structure, at least for the time being". (K.R. Popper, 1959: 31).

Scientific theories save the observable phenomena by postulating other processes which are not accessible to observation and therefore do not provide firm foundations. So far as the theories account for the available evidence, structure of science can be considered stable.

Constructive empiricists` claim that science only aims at empirically adequate theories is correct, but the "observation" for empirical adequacy is not with unaided eyes. This study has redefined observable as made up of the faculties of perception and understanding. With the redefined observable, constructive empiricism represents the actual happenings in science. Scientific theories save the phenomena as observed through scientific instruments, which provide evidence for belief.

Scientific theories and experimentation have a symbiotic relationship. Belief in existing theories makes the basis for newer theories which are verified by experimentation and observations. The process is like that of fluid rising in a capillary tube. Fluid rises along the walls of the tube, due to adhesion, the whole surface then rises due to the surface tension. The process repeats itself making the fluid to rise.

The study has shown that there are certain scientific theories which make the background of experiments and form the basis of scientific instruments used for observation. Scientists have belief in such theories and therefore the theories make-up a layer of reality. There is need to study and look for a criterion which qualifies a theory to become a part of such putative group.

With the redefined 'observable', constructive empiricism looses its claim to being an empirical stance. It does not even become a realist philosophy. There is need for further study to show that the modern practices in science are not confined to any predefined philosophies of science.

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