OBSERVABILITY

AND SCIENTIFIC REALISM

A Thesis Submitted to the College of

Graduate Studies and Research

in Partial Fulfillment of the Requirements

for the Degree of Master of Arts

in the Department of Philosophy

University of Saskatchewan

Saskatoon

By

Md. Nuruzzaman

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ABSTRACT

The goal of this thesis is to explore the debate between Bas van Fraassen's constructive empiricism and scientific realism. For this purpose I discuss the existence of observable and unobservable entities, the observation/theoretical dichotomy, inference to the best explanation, the no miracles argument, pessimistic induction, and epistemic risk. I strive to show that, contrary to the view of constructive empiricism, there is no clear demarcation line between observable and unobservable entities, and that not only naked eye observation but also the instrument-based observation plays an important role in acquiring knowledge. I agree with scientific realists that there is no highest point to the human power of observation; it is open-ended for further development. Moreover, naked eye observations are not themselves beyond doubt, as sometimes even naked eye observations deceive us. In that context, theoretical explanations help us to understand the real situation. As such, there is no reason to give more credit to naked eye observations than to instrument-mediated, theory-informed observations.

Scientific realists are confident in their knowledge of unobservables, and reject the epistemic significance of the observable/unobservable distinction. To justify their knowledge of unobservables, they use inferences to the best explanation. Such inferences play an important role in choosing the best theory amongst a group of theories. For their part, constructive empiricists use what is called the 'bad lot' argument to refute these inferences. I try to show that such 'bad lot' arguments fail to succeed at undermining inferences to the best explanation. Following scientific realists, I assert that nothing is miraculous in the domain of science, and that we can be assured of the approximate truth

of successful scientific theories. It is true that many contemporary scientific theories contradict previously successful scientific theories, but that does not compel us to be pessimistic about such contemporary theories. Instead of pessimism, we can have an optimistic attitude about the progress of science. Considering the different arguments of constructive empiricism and scientific realism, this thesis gives more credit to scientific realism than to constructive empiricism.

ACKNOWLEDGEMENTS

Many people contributed to complete this thesis and I am expressing my heartiest gratitude to every one of them. At the very beginning, I would like to express my heartiest gratitude to my supervisor, Professor Robert G. Hudson who gave me his valuable time, advice, suggestions and ideas for the last two years to complete this thesis successfully. I also express my gratitude to the committee members of this thesis, Professor Karl Pfeifer and Professor Sarah Hoffman for their suggestions. I would like to thank the external examiner of this thesis, Professor Susan Kaminskyj, for her important suggestions. I would also like to thank all the professors and graduate students of the Philosophy Department of the University of Saskatchewan for their cooperation at different stages for the last two years, and particularly Professor Eric Dayton who chaired my defense. My debt extends as well to the authority of the University of Dhaka, Bangladesh, for financial support and for granting me a study leave to complete this program. Many thanks, in addition, to my family members and my friends for their support. Especially, I am remembering my friend and wife Ruma for her sacrifices, emotional support and encouragement for the last two years. Finally, I would like to recall our only son Manan who has passed a hard, long time without his father's affection.

DEDICATION

To my parents.

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Introduction

My goal this thesis is the examine one of the key debates in the philosophy of science, the realism/anti-realism debate. Here I understand realism as 'scientific' realism, that is, the thesis that the claims of a scientific theory concerning the reality of unobservables are true, or at least can be counted on to be true in an advanced state of scientific advance. Different philosophers enrich this debate, and in my thesis I will draw a special attention to the anti-realist position called 'constructive empiricism' as developed by the pre-eminent philosopher of science, Bas van Fraassen.

Constructive empiricists, according to van Fraassen, believe in a clear demarcation line between observable entities and unobservable entities. As such, they express doubt about the reliability of aided observation in scientific research; for them, the epistemic value of aided/instrument-mediated observation is questionable. But a realist's position is different in this regard. In an advanced stage of technological development, they believe that we can rely on instruments to provide us with detailed knowledge of unobservable, physical objects. That is, not only can we can acquire reliable knowledge about the world through unaided observations but also by aided observations. In the first chapter, my main task will be to try and show that the constructive empiricists' demarcation line between observable and unobservable entities is not acceptable. Human beings, I argue, can extend their power of observation by using different instruments and, as a result, their power of observation is not constant -- it develops with technological advance. This progress in technology, I submit, changes the demarcation line between observable and unobservable entities. Moreover, I argue that the constructive empiricists' notion of naked eye observation is not itself without doubt; sometimes naked eye observations deceive us. Such deceptive observations need theoretical explanations to become meaningful, explanations that make reference to unobservables. In this way the reality of unobservables, and our knowledge of them, is justified.

In my second chapter, I discuss various arguments one can use in support of scientific realism. The main such argument utilizes what are called 'inferences to the best explanation' (henceforth IBE). To illustrate IBE, consider a situation in which we have a number of theories about a subject-matter. In this situation IBE helps us choose the best theory by presenting several criteria to determine what to call 'the best'. I discuss these criteria and show how they work to help researchers arrive at the best hypothesis. I submit that the truthfulness of this best hypothesis is assured by meeting these criteria. Why is this so? The way this works is by means of the 'no miracles' argument (henceforth NMA). According the NMA, we suppose that a scientific theory is successful according to the criteria alluded to above (criteria such as the ability to account for and predict phenomena). For me, this success proves that this scientific theory has accurately depicted the physical structure of the world. This is because, otherwise, the success of this theory would be miraculous, and I take it to be false that the world contains miraculous (i.e., unexplainable) events.

Conversely, constructive empiricists assert that scientific theories are only empirically adequate. That is, scientific theories can only be claimed to accommodate or predict empirical phenomena, and these features of a theory are in no way connected to the truth of a theory (as regards unobservables). To this end, constructive empiricists offer what is called the ‘bad lot’ argument that speaks against the reliability of IBE and the truthfulness of scientific theories . What constructive empiricists are suggesting by means of the bad lot argument is this: in following IBE, a scientist could be choosing the best theory from a bad (i.e., deceptive) group (lot) of theories. Thus, when the evidence points to a particular theory, this may only be because the competitors to this theories were so poor that they posed no challenge to this theory. But, in response, I will try to show that constructive empiricists cannot use the bad lot argument against IBE, since realists can raise a similar problem for empirically adequacy. For what can a constructive empiricist say in a case where a scientist chooses an empirically adequate theory from bad lot empirically adequate theories? Doesn’t the same problem arise for her?

Larry Laudan, another anti-realist, presents a pessimistic view on contemporary scientific theories. He cites a long list of scientific theories that were successful in the past but that are now proved to be false. From this experience he contends that our present theories will turn out to be false in the future, and that therefore a realist view of science is mistaken. In denying the pessimistic induction, scientific realists try to justify their optimistic attitude about scientific theories. In my thesis I will stand in favor of the realists’ optimistic arguments, and in support of my view I cite an approach taken by Philip Kitcher, John Worrall and Stathis Psillos, an approach that sees progression in science but only with respect to those parts of science that remain constant over time. Accordingly I will show that the history of science does not indicate pessimism only; there is scope to be optimistic about successful scientific theories.

By analyzing various arguments for and against scientific realism, I finally give more credit to scientific realism than to constructive empiricism. In my thesis my method will be analytical and critical and will involve an evaluative study of constructive empiricism and scientific realism.

Chapter 1

Observable vs. Unobservable Entities

‘Observation’ and ‘power of observation’ are the key terms in both constructive empiricism and scientific realism. No one has doubt about the importance of observation in the process of scientific knowledge -- it is an important means of acquiring objective knowledge. In fact, all forms of experimentation and measurement depend on observation for the purpose of acquiring knowledge and their success also depends on the accuracy of observations. What is the nature of observation? How do researchers observe? What is observable? Is everything observable? Can we observe the world where we are living? Do we believe in only unaided observation? What is the epistemic position of aided observation? Those are the basic questions of the philosophy of science. Constructive empiricists and scientific realists both try to answer these questions in their own way. But they contradict each other on all of these points. This debate has been around for almost half a century and it seems to everyone that it will continue for a long time. In the first phase of the first chapter of my thesis I will begin by explaining van Fraassen’s concepts of observation and power of observation. Following this I will examine different responses to his views and finally I will express my own views.

In this phase of my discussion I would like to draw a common picture of observation and the power of observation. In our daily life, we are very much familiar with the ideas of perception and observation -- we see with our eyes, we hear with our ears and smell with our noses. Those are very much common and innate phenomena in human life. But not only in our common everyday life but also in our academic activities observation plays an important role. We are familiar with some words -- ‘see’, ‘look’ and ‘watch’ which are very similar to ‘observation’. Although all of them are synonyms, they have some different connotations. Observation requires attention. It means to look or to watch something attentively. Observation demands an observer’s attention. As Roberto Torretti explains,

> I believe, therefore, that instead of trying to cope with perception in all its rich variety, the philosopher of science will do well to concentrate on the one form of it that is directly relevant to his subject, namely, the attentive, deliberate, explicitly cognitive mode of perception that goes under the name of observation. (1986, 1)

In the history of the philosophy of science, several philosophers discuss this term ‘observation’ and study observation in their research. One of the earliest modern philosophers to emphasize the importance of observation for the growth of knowledge was Francis Bacon. He strove to reveal the obscurities of nature and in this regard he developed three Tables:

1. Table of presence
2. Table of absence
3. Table of comparison. (Bacon 1620, 110-120)

These Tables intrinsically involve observations and Francis Bacon proposed a scientific methodology based on them that describes the process by which one determines the causes of an observable phenomenon. For Bacon, observation means naked eye observation. As such one can observe the simple objects and events of nature and life. Of course, the success of empirical research depends on good observations. The term ‘observation’ gained momentum in the philosophy of science through the logical positivist movement. To differentiate between meaningful and meaningless statements, logical positivists use the verifiability principle according to which observations determine the meaning of a sentence. According to A. J. Ayer, "a sentence is factually significant to any given person, if, and only if, he knows how to verify the proposition which it purports to express -- that is, if he knows what observations would lead him, under certain conditions, to accept the proposition as being true, or reject it as being false." (1952, 35) At the very beginning logical positivists explained verification and observation concepts in a strict literal sense and as a result this movement was widely criticized by different philosophers. At last the positivists accepted a weak sense of verifiability according to which "[a proposition] is verifiable, in the weak sense, if it is possible for experience to render it probable." (Ayer, 1952, 37) We see that logical positivism emphasized observation in the search for meaningful sentences. Even though this movement is dead, contemporary philosophy still feels its influence.

Both realists and anti-realists admit the importance of observation. Constructive empiricists and scientific realists both believe in observation, its potential and its consequences. But realism and anti-realism oppose one another with respect to the limitations of observation. Is the power of observation unlimited or is there a demarcation line between observable and unobservable entities? Constructive empiricists support only the epistemic value of naked eye observation in the case of scientific research whereas scientific realists extend their notion of the power of observation through the use of different instruments. Such instrument-based observation brings a new dimension into the context of observation. Here we find another question -- does the power of observation vary from person to person or does everyone have same capacity for observation? From common sense we can say that it varies from person to person. In fact, there is room to increase one’s ability to observe using different practices and instruments. A researcher who uses a microscope regularly is a better observer than a new user of microscope. In Ian Hacking’s words, “observation is a skill. Some people are better at it than others. You can often improve this skill by training and practise.” (1983, 168) In our practical life we see that trained, aided eyes are more capable of observation than unaided eyes.

We observe a lot of things like chairs, tables or trees in everyday life. They occupy some space, they have weight. No one questions their existence. Everyone can see them when they open their eyes. Realists and anti-realists both agree on the question of their existence. We can achieve certain knowledge of them. But realists and anti-realists do not agree on where to draw the demarcation line between observable and unobservable entities. Unobservable entities are often the subject matter of academic inquiry and we are not able to observe them directly in our daily experience. As a result they are unreal entities according to anti-realists. Realists, on the other hand, try to prove the existence of theoretical entities on the basis of observation. Whereas the anti-realist notes that we do not get any certain knowledge of theoretical entities, realists are optimistic about our knowledge of unobservable entities.

On my view, there is no clear demarcation line between observable and unobservable entities. Different aids like microscopes and telescopes allow us to extend our ability to observe. By using instrument-based observation, we can acquire reliable knowledge about the world. For example, instrument-based observation can achieve a reliable position in the domain of sub-atomic research. I will explain these comments below.

Still, I would like to indicate that there is room for false observations. Illusions, hallucinations, and misperceptions generally are not impossible. But there is room to rectify these errors. A wise researcher does not accept the results of observation as true at first sight. She collects several data, and if she observes the same things in the same situation repeatedly she at last considers these things as a source of true knowledge.

Debates about observable and unobservable entities are enriched by different philosophers and a lot of elements are involved in this debate. In my discussion in the first chapter of my thesis I am going to show that not only naked eye observations but also instrument-based observations are reliable for the purpose of acquiring scientific knowledge. Van Fraassen emphasizes only naked eye observations and expresses doubt about instrument-based observations in scientific research. I would like to show that there is no scope to give more credit the naked eye observation than to instrument-based observations. Following scientific realists I will try to show that there is no clear demarcation line between observable and unobservable entities. The power to observe is an open-ended idea; we can extend this ability using different instruments. I would like to show in my discussion how both observable and unobservable entities exist and one helps the other to prove their existence. Moreover, I would like to support the claim that sometimes we find more reliable knowledge about unobservable entities than about observable entities.

1.1 The Power of Observation, according to van Fraassen

The concept of the ability to observe receives a new dimension in van Fraassen's 'constructive empiricism', as set forth in his book *The Scientific Image*. Concerning the power of observation, he distinguishes entities as either observable or unobservable. He also discusses our epistemic access to different entities. On van Fraassen's view, reliable knowledge is only possible with respect to observable entities. He claims that we are not certain of our knowledge about the unobservable world. He believes that we get an epistemic advantage in the case of naked eye observation but no such advantage with instrument-based observation. That is, he does not believe in instrument-based observation; he is skeptical about instrument-based observation. Observation for him is only valuable with respect to our bare sensory abilities. Here van Fraassen expresses doubt about the observability of some entities such as electrons and protons. He only believes in naked eye observations as a way to achieve certainty and objectivity in knowledge. Van Fraassen describes the nature of observable entities in *The Scientific Image*: things like chairs, tables, and different animals are observable for him since we have immediate experiences of them. Comparatively, according to van Fraassen, we do not observe micro-organisms such as viruses or bacteria since we do not have any direct experience of them, that is, we cannot observe them by the naked eye. Therefore they are for him unobservable entities and he withdraws all belief in their existence. As he says,

> to be an empiricist is to withhold belief in anything that goes beyond the actual, observable phenomena, and to recognize no objective modality in nature. To develop an empiricist account of science is to depict it as involving a search for truth only about the empirical world, about what is actual and observable. (1980, 202-203)

No one has doubt that observation is the main means to acquire scientific knowledge, and many procedures of scientific research are dependent on observation. As a result observation and the capacity to observe receive important attention in the philosophy of science. They also receive a special importance in van Fraassen's philosophy. In his discussion, we see that he accepts human-based observation as a reliable means of knowledge. The existence of things which are observed by the naked eye, according to van Fraassen, is not generally doubted by anyone. He notes other kinds of things which are observable though no one observes them. As he comments, “a flying horse is observable -- that is why we are so sure that there aren’t any.” (1980, 15) And there are things which are not observable at all, such as electrons and protons.

For the purpose of observing something, van Fraassen relies only on unaided observation. As a result, according to him, we cannot observe microparticles. By ‘unaided’ observation he means ‘human-based’, unaided observation, and for him only human-based observation is reliable in the process of acquiring scientific knowledge. Nevertheless, he recognizes that ‘power of observation’ is a vague notion; that is, ‘observable’ is a vague predicate. To explain what a vague term is, we can cite the classic example -- baldness. How do we define this term? What is the demarcation line between being bald and not bald? In fact we do not get any certain criteria that can make difference between a bald man and a man who’s not bald. We do not know the number of hairs that we can use as a demarcation line between being bald and not bald. I would like to cite another example of vague term, i.e., capital. We know that money can turn into capital, but no one can say that how much money it takes to turn into capital. There is no certain criterion that determines when money becomes capital; thus, ‘capital’ is a vague term. Now I would like to explain the vagueness of the term ‘observable’. For the purpose of observation we use several means. We can observe things by the naked eye or we can develop our observation power by using spectacles, magnifying glasses, telescopes, microscopes and many other sophisticated instruments. Some things are observable by the naked eye and some things are observable by instruments. Also, some things are not observable at all. Overall, we cannot draw a strict demarcation line between observable and unobservable entities. As a result 'observable' becomes a vague predicate. Nevertheless, van Fraassen comments, "a vague predicate is usable provided it has clear cases and clear counter-cases. Seeing with the unaided eye is a clear case of observation." (1980, 16) Thus, van Fraassen is confident in the reliability and coherence of naked eye observation. On this basis, scientific theories can said to be empirically adequate, that is, "what [they say] about the observable things and events in the world [are] true (van Fraassen 1980, 12). Such empirical adequacy is possible only where we have observable entities. In fact, van Fraassen notes, "when [a] hypothesis is solely about what is observable, the two procedures [(i.e., the decision to accept and the decision to accept as empirically adequate)] amount to the same thing. For, in that case, empirical adequacy coincides with truth." (1980, 72)

With van Fraassen's view on the power of observation, we gain an epistemic distinction between observable and unobservable entities. Instruments can play a role in observation, but they result only in conditional observations. We cannot accept them directly. Van Fraassen uses the example of the moons of Jupiter that researchers can see through a telescope as well as by the naked eye if they could come close to them (1980, 16). An astronaut can see the moons of Jupiter by telescope and it is possible for him to see these by the naked eye. In the same way we can guess the existence of a plane in the sky by seeing a vapor trail and we can see it by naked eye when it is grounded. But in this way we cannot see any microscopic element. There is no way to see electrons with the naked eye. We cannot see them as we can see planes or moons. As a result, there is an epistemic distinction between unaided observation and aided observation.

We can see lots of things like chairs and tables if we open our eyes. No one has doubt about that. But if we closely evaluate our observation then we realize that observation depends on certain circumstances. Our experience of a thing may differ with time. We see a rose under sun light as red but in a different circumstance we see it to have a different color. In a dark place a rose is seen as black. Van Fraassen offers the principle that "X is observable if there are circumstances which are such that, if X is present to us under those circumstances, then we observe it." (1980, 16) Thus, according to him, unobservable entities are such that they cannot be observed by the naked eye under any circumstances. He denies the concept of circumstance-dependency in the case of unobservable entities. No sort of technological development can bring them into the area of observation. Rather the existence of unobservable entities is inferred on the basis of observations of the behaviors and activities of observables since unobservable entities are not themselves observable. Moreover, anyone can raise questions about the authenticity of such kind of inferences.

Although van Fraassen accepts only unaided observation for the purpose of acquiring scientific knowledge, we know that the power of observation has no single dimension. It has several dimensions; its development is related to technological advancement and its acceptance has different degrees. Also, some technological developments involving observation are more reliable than others. But following van Fraassen, we need to distinguish between observation and a different notion, i.e., detection. As Hanson and Levy note,

> although van Fraassen does not consistently use the following terminology, we believe that his position can be properly represented by distinguishing between an observation of, say, an entity, and its detection. An observation is an unaided human act of perception; a detection is an aided act of perception. (1982, 291)

We can say that van Fraassen does not reject the role of instruments in detection but simply does not approve of aided observation. According to him, "perhaps some things can only be detected with the aid of an optical microscope, at least; perhaps some require an electron microscope, and so on." (1980, 16) Scientists can detect sub-atomic particles in cloud chambers, but they cannot observe them. One could say that this is a weak sense of observation in van Fraassen's philosophy. Researchers do not see objects through different instruments; they only observe the images of objects and they can detect objects by means of such images. In a sense, detection is an aided perception of an entity whereas observation is a naked eye perception of an entity. In this respect, we specify the role of instruments in experimental research. For example, researchers observe a cloud chamber and they detect sub-atomic particles in this cloud chamber. But this detection is fully different from our unaided observation. We cannot say that we observe sub-atomic particles in a cloud chamber. According to van Fraassen "while the particle is detected by means of the cloud chamber, and the detection is based on observation, it is clearly not a case of the particle's being observed."(1980, 17)

According to constructive empiricism, instrument-based observation is less reliable than the unaided observation. We can easily justify our unaided observations. The existence of the objects of unaided observations is easily provable. But those detected through aided observation require more justification. As Angus Menuge explains, with aided observations

> other instruments are used in addition to our sensory apparatus, and the resulting system (sense plus instrument) is more complex and reliant on theory, and hence more likely to fail us, than are our senses alone. So we may legitimately require some justification for accepting the deliverances of an instrument which we do not require in the case of unaided sensing. (1995, 66)

Realists believe that instruments help us to widen our capacity to observe. Adding such instruments to our eyes or other sense organs helps us observe objects or events. We thus see that there are clear differences between the processes of observation for constructive empiricists and scientific realists, and these different processes generate different results for realists and constructive empiricists.

Observation and the power to observe play an important role in van Fraassen's philosophy. To explain these concepts, Van Fraassen rejects the contributions of instruments for the purpose of observation and this has had an important influence on contemporary philosophers. To draw a difference between observable and unobservable things, he establishes a criterion (naked eye observation[1]) and whatever does not correspond to this criterion is regarded by him as unobservable. Moreover, for him, we cannot have knowledge of unobservable entities. Perhaps we can say that he is agnostic about their reality, whereas by comparison we can achieve knowledge of the reality of observable entities. Along the way he offers a new idea about scientific theories. According to him, contemporary successful scientific theories are not literally true; they are merely empirically adequate. On his view "the belief involved in accepting a scientific theory is only that it 'saves the phenomena', that is, correctly describes what is observable." (1980, 4)

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[1] For the sake of simplicity, I limit my discussion to visual observation, though observation clearly can involve other sense modalities.

The power of observation has different dimensions. But van Fraassen's view on it is very clear. By the power of observation, he clearly means a human capacity (anthropocentric observation). In the logical positivism movement, in contrast, we see that they accepted the logical possibility of observation in their weak sense of verification. But van Fraassen rejects the idea of the mere logical possibility of observation as setting the demarcation line of what is observable. Someone can imagine a very powerful devil that can carry a hundred story building but this does not indicate that this building is portable. According to van Fraassen, "I have a mortar and pestle made of copper and weighing about a kilo. Should I call it breakable because a giant could break it? Should I call the Empire State Building portable" (1980, 17) He draws a clear distinction between the empirical possibility of observation and the logical possibility of observation and he does not accept that the logical possibility of observing something determines whether it is observable or not.

Van Fraassen depends on human observation for reliable scientific knowledge. According to van Fraassen,

> the human organism is, from the point of view of physics, a certain kind of measuring apparatus. As such it has certain inherent limitations -- which will be described in detail in the final physics and biology. It is these limitations to which the 'able' in 'observable' refers -- our limitations qua human beings. (1980, 17)

His epistemology develops on the basis of a human's observation power. The human ability to observe determines the area of scientific research and he is also aware of human limitations in this regard. Scientists should not go beyond this ability in the case of their research. The aims of science are to reveal the truth about observable entities and to explain the nature of observable entities. All of our knowledge is evolving on the basis of our observational abilities and scientists can only achieve reliable knowledge about observable entities. Theories about observable entities can be empirically adequate and we can accept empirically adequate theories. But when exactly is a theory empirically adequate? In response to this question, van Fraassen says, “a theory is empirically adequate exactly if what it says about the observable things and events in the world, is true -- exactly if it saves the phenomena.” (1980, 12)

In this phase of my thesis I would like to explain the role of the inductive method in van Fraassen’s philosophy. Science gives us knowledge of the world. This is the purpose of a scientist’s work with both observable and unobservable entities. Now someone like van Fraassen depends only on the naked eye for observation. On the other hand, someone who is a scientific realist widens his observation power by using different instruments. Van Fraassen, however, has strong reservations about widening the concept of the power of observation. In his research, a scientist observes a phenomenon and depending on this observation he establishes a theory. Naked eye observation is a reliable means of acquiring information. From here a scientist follows the inductive method in which by observing some instances he draws a general conclusion. Drawing such a conclusion involves a leap, and where this leap moves from observable to observable van Fraassen expresses no doubt about the appropriateness of such kinds of leap in constructive empiricism. But in scientific research, we find that scientists sometimes try to reveal the hidden structure of the life and nature. This hidden structure (perhaps composed of sub-atomic particles) is not observable by the naked eye and in this respect scientists depend on an inference to affirm the reality of such hidden things. They are able to draw inferences about the existence of such hidden structure by observing the effects, causalities and behaviors of this structure. But they do not observe this structure directly. Thus there is an inductive leap here, this time from the observable to the unobservable, and van Fraassen does not approve of such kinds of inferences. An inductive leap, from observable to observable is acceptable for him but inductive leaps from observable to unobservable are not acceptable -- there is an important difference between these two. The inductive leap is a historical problem in the domain of methodology. In this context the inference from observable to unobservable adds a new problematic dimension, beyond an induction from observable to observable.

1.2 Responses to van Fraassen's Notion of the Power of Observation

In the above discussion, we see van Fraassen providing new ideas on observation and the power of observation in his constructive empiricism. His contribution has an important place in the anti-realist literature. But it is very hard to swim against realist currents. His philosophy is attacked by many different realists. In their philosophy, we see that they try to establish that not only unaided observations but also aided observations are reliable for the purpose of knowing life and nature. Following scientific realists, I would like to say that in our practical life instrument-based observations are reliable, and I would like to cite some examples in this context. Scientists use different types of microscopes to observe several kinds of microparticles and they acquire reliable information about microparticles through such kinds of aided observations. Also, in astronomical research, scientists use different kinds of telescopes for the purpose of astrophysical observation. Depending on such kinds of aided observations they make predictions, and some of these predictions turn to be true. In our practical life, we note that some people suffer from myopia. In this case, if anyone uses a concave lenses in her spectacles, she could see more clearly. So we often believe our aided observations. Van Fraassen does not accept instrument-based observation as a reliable source of knowledge about unobservables. With his observable/unobservable distinction, he cites some examples of observable and unobservable entities but his demarcation line between observable and unobservable entities is not acceptable. As James Ladyman notes,

> the first and most fundamental realist objection to constructive empiricism is that no meaningful line can be drawn between the observable and the unobservable, and the second is that even if such a demarcation is possible, there is no ground for thinking that it has any ontological or epistemological significance. (2002, 187)

Moreover, it seems that van Fraassen tries to make use of such a demarcation line in our cognitive ability by denying our knowledge of unobservable entities. According to his constructive empiricism, our cognitive power does not permit us to acquire reliable knowledge about unobservable entities. But in the history of science we know that it is not possible to determine any highest point of human beings' cognitive capacity. My goal is to show that we can rely on our aided observations, that we can believe our aided observations just as much as our unaided observations and that it is not possible to determine the highest point of human capacity.

'Grass is green' -- we can observe the color green by our naked eye. The color green is an observable property of (macroscopic) objects. No one has doubt about it. On the other hand micro-organisms like viruses or bacteria are unobservable/theoretical entities. We cannot see viruses directly. Constructive empiricists do not expand their notion of the power of observation to include the property of being a virus. But scientific realists consider the term 'power of observation' on a larger scale than that of constructive empiricists. According to scientific realists, not only the naked eye but also different instruments are a reliable means of observation. In this respect, the domain of scientific realism is broader than constructive empiricism. Scientific inquires are not only limited to the observable entities; scientists also try to reveal the nature of unobservable entities. They use different instruments to acquire knowledge about unobservable elements. Scientific realists are very much confident about aided observations. According to them, we can justify our aided observations just as well as unaided observations.

Although van Fraassen is not able to draw a clear demarcation line between observable and unobservable entities, he cites some examples of observable and unobservable entities in *The Scientific Image*. He says that the moons of Jupiter are observable entities. Astronauts can observe them by telescope and they can go there to justify their observation. But a DNA strand is not an observable entity because it is not observable by the naked eye. Still, according to van Fraassen, scientists can observe the image of a DNA strand using a powerful microscope, though this does not for him express any reliable knowledge (of the existence of DNA strands). In response to this view, I would like to say that we cannot see a lot of things directly but we can get reliable knowledge of them. In this regard I would like to cite an example from sociology, i.e., the university. Suppose a visitor comes to Saskatoon to visit its educational institutions. He wants to see the University of Saskatchewan. The guide shows him different parts of the university, such as the Arts Tower, Science Building, Commerce Building, Library and the Administrative Building. After observing these buildings, the visitor says that he observed different buildings, but never saw the university itself. What would the guide say in response? The guide would say that the university itself is unobservable, but that nevertheless no one has any doubt about its existence. Thus, van Fraassen's contention that we lack knowledge of unobservables is mistaken.

Several philosophers reject the distinction between observable and unobservable entities, and here various arguments are presented. Grover Maxwell's 'the argument from the continuum' is one of them. This argument has had a great influence on the realism/anti-realism debate. As van Fraassen describes Maxwell's work (see van Fraassen 1980, 14), we are faced with two important questions in his renowned article "The Ontological Status of Theoretical Entities". The first question is, Is language divided into theoretical and non-theoretical parts? Secondly, Can we get any demarcation line between observable and unobservable entities? Maxwell's answers are negative in response to both these questions. According to him, our language is theory-laden and we can not draw any clear demarcation line between observable and unobservable entities. Rather, we have to consider the circumstances of the observation. An object may be unobservable due to its present position. But if we can change the circumstances we will be able to observe the thing. Better instruments can make a better situation of observation; unobservable entities may turn out to be observable. According to Maxwell,

> the line between the observable and the unobservable is diffuse, it shifts from one scientific problem to another, and it is constantly being pushed toward the 'unobservable' ends of the spectrum as we develop better means of observation -- better instruments. (1962, 13)

At the beginning of his article Maxwell tells a science fiction story to explain the power of observation. We imagine a time when no one had the idea of a microscope. At that time people had no idea about microbes (crobes). It was beyond the human capacity to observe them. But after the invention of the microscope, Jones was able to prove the existence of crobes. But his proofs were not without doubt. Some philosophers did not admit the existence of crobes. On the other hand, some philosophers concurred with Jones. As Maxwell describes the situation

> one group maintained that Jones' crobes actually never had been unobservable in principle, for, they said, the theory did not imply the impossibility of finding a means (e. g., the microscope) of observing them. A more radical contention was that the crobes were not observed at all; it was argued that what was seen by means of the microscope was just a shadow or an image rather than a corporeal organism. (1962, 6)

We get two currents in this regard -- everything is in principle observable, or some things are not observable at all, and we see only the images of them. It is true that at present we cannot observe some things for the lack of appropriate technological support, but perhaps we can observe them in future by the invention of appropriate technology. The history of the technological development tells us that it will be possible to remove the obscurity of entities. But anti-realists are not optimistic about the evolution of the power of observation; they limit this ability to only naked eye observation. The power of observation is not related to technological development.

Van Fraassen is one of the philosophers who believes that we do not see objects under a microscope; we can see only the images of objects. In this context, we get an important criticism against van Fraassen -- i.e., he admits the distinction between observable and unobservable entities, but he does not make any clear demarcation line between them. According to Maxwell, there is a continuum between naked eye observation and instrument-based observation and he provides a strong argument against the theory/observation distinction. We can either observe a thing by the naked eye, or use different instruments such as glasses, binoculars, microscopes to help us for the purpose of observation. Maxwell sees a continuum among all these means of observation. To show "a continuous transition from observable to unobservable" (1962, 7), Maxwell cites contemporary valency theory. According to this theory, there are several kinds of molecules and their sizes are different from each other. Some of them are observable with the naked eye and some of them are observable by instrument. Particularly, there is a continuous transition from microscopic to very large molecules. (Maxwell, 1962, 9) An example of a small molecule is hydrogen; fatty acids and proteins are examples of medium-sized molecules; and, as Maxwell asserts (on his understanding of the relevant science), "crystals of the salts, diamonds and lumps of polymeric plastic" (1962, 9) are examples of very large molecules. Whereas such large molecules are observable by the naked eye, small and medium sized molecules are not. Citing this example, Maxwell rejects the division of observational and theoretical vocabularies, where terms in the observational vocabulary refer only to observables and terms in the theoretical vocabulary refer to unobservables. Since the term 'molecule' refers to both observables and unobservables, it is not possible to definitively decide whether the term 'molecule' is observational or theoretical. Hilary Putnam makes a similar point as regards observational and theoretical terms. He defines observational and theoretical terms as follows: "observation terms apply to what may be called publicly observable things and signify observable qualities of these things" and "theoretical terms correspond to the remaining unobservable qualities and things." (Putnam 1975, 215) Here he cites some examples -- 'red', 'touches' and 'stick' are observational terms whereas 'electron', 'dream' and 'gene' are theoretical terms. Similar to Maxwell, Putnam rejects the existence of a strict demarcation line between observable and unobservable entities for we do not find any term that indicates only observable entities. According to Putnam, "if an 'observational term' is one that cannot apply to an unobservable, then there are no observational terms.” (1975, 217) In this regard Putnam cites the example of Newton’s red corpuscles. Newton, Putnam notes, “postulated that red light consists of red corpuscles” (Putnam 1975, 218). But if ‘red’ is an observation term, then according to Putnam’s definition, it can only apply to observables. Obviously, the redness of a (Newtonian) corpuscle is not observable. Thus, on Putnam’s view, ‘red’ is no longer an observational term. And so we have, again, a blurring of the observation/theoretical dichotomy.

We see in Maxwell’s paper that the term ‘power of observation’ is not tied up with any hard and fast rule. He does not reject the idea of the development of the ability to observe. In this respect, we find similarities between the nature of science and the power of observation. Nothing is final or absolute in science. We know that scientific theories are open-ended for further development and the same goes for the power of observation. Human beings can widen their capacity of observation by using different instruments; there is no highest point of the ability of observation. At this moment, it is true that we cannot see ‘WIMPs’ (weakly interacting massive particles) but it may be possible to see them in the future. Five hundred years ago, our predecessors had no idea of cryogenic heat and ionization detectors located in deep mines. But now we are using these instruments for the purpose of observation. The same idea goes in the case of the future development of instruments. We cannot guess what success future generations will have in the context of observations. According to Richard Creath, “only a fool would try to predict what sort of instruments might be developed.” (1985, 323) This technology is advancing day by day. We should express positive attitude to its development and activities.

Van Fraassen limits the area of observation to only naked eye observations. But from the exercise of contemporary science we know that observation and the power to observe have a broader sense than that of van Fraassen. Jeff Foss tries to break van Fraassen's restriction. According to Foss, "from a scientific point of view, observing is no more or less than the connecting causally of the exterior processes of one's nervous system with the object to be observed in such a way that one is informed by it (i.e., gets some information about it)." (1984, 90) That is, in the observing process, there is a causal relation between the observer and the observed thing. For example, in van Fraassen's example concerning the mouse, he infers the existence of a mouse by observing various signs. He does not observe the mouse directly; rather, these signs are an indirect observation of a mouse and they are a reliable source of knowledge. No one can reasonably deny the importance of such kinds of observations in the domain of knowledge. In the same way, by observing the behaviour of sub-atomic particles, researchers can acquire knowledge about them. There is no room to distinguish between the epistemic status of observable entities and unobservable entities. Paul Churchland suggests that anti-realists such as van Fraassen are 'gullible' about observation, "since they suppose that the epistemic situation of our beliefs about observables is in some way superior to that of our beliefs about unobservables. But in fact their epistemic situation is not superior." (1985, 41)

Another realist, Alan Musgrave, also criticizes van Fraassen's constructive empiricism. According to van Fraassen, we can rely on telescopic observation. Using a telescope, a researcher can see the moons of Jupiter, moons which are observable. The moons are observable because it is possible to observe these moons by the naked eye.

Although a researcher cannot observe them at the present moment, they would be observable if she were close enough. But, according to van Fraassen, we can not apply this idea to the case of microscopic observation. We can detect micro-organisms using a microscope but we can not observe them -- they are not observable. Thus we cannot rely on such kinds of observations. In his philosophy, van Fraassen relies on indirect observations, where by ‘indirect observation’ I mean observing the effects of entities. Depending on these kinds of observations, researchers infer the existence of entities. For example, van Fraassen infers the existence of a mouse by seeing some signs. But this indirect observation is not applicable to the case of electrons, protons or other micro-particles. Realists, like Alan Musgrave, do not see the difference between indirect observations of observable as opposed to unobservable entities. There is no reason to demarcate between the evidence for the existence of the mouse and the evidence for the existence of sub-atomic particles. Moreover, van Fraassen does not give us any criterion to differentiate between these kinds of evidence. According to Musgrave , “it is a curious sort of empiricism which sets aside the weight of available evidence on the ground that a casual observer might one day see his mouse or yeti, while the scientist can never see (but can only detect) his electrons.” (Churchland, 1985, 206) Van Fraassen’s empiricism is curious because he accepts the available evidence in the context of observable entities but he does not give weight to the available evidence in the context of unobservable entities.

To demarcate between observable and unobservable entities, we need to consider both sides of this line. At first we have to admit the existence of both observable and unobservable entities; then we proceed to demarcate between the two. But in van Fraassen’s philosophy we see that he only believes in observable entities; he does not believe in the existence of unobservable entities. As a result, in his demarcation process we see an inconsistency. Following Alan Musgrave (1985, 207- 208), we can prove that there is an inconsistency in the demarcation process in the following way. Suppose a theory T distinguishes observable entities from unobservable entities. This theory has two parts -- one explains the existence of observable entities (A) and another explains the existence of unobservable entities (B). According to van Fraassen we can acquire knowledge about the observable part of this theory but we cannot know the unobservable part of this theory. Van Fraassen accepts the knowledge of the observable part of this theory but according to his constructive empiricism the knowledge of unobservable part is unacceptable. Thus, we can say that van Fraassen does not believe the whole of theory (T) -- he only accepts the observable part of this theory. As a result, we see van Fraassen cannot forward any coherent theory to demarcate between observable and unobservable entities. The demarcation process itself is inconsistent. According to Musgrave,

> the constructive empiricist can accept as true, on the basis of observation, statements of the form 'A is observable by humans'. But the consistent constructive empiricist cannot accept as true, on the basis of observation or anything else, a statement of the form 'B is not observable by humans'. Constructive empiricism requires a dichotomy which it cannot consistently draw. (1985, 207-208)

Denying van Fraassen's anthropocentric conception of the power of observation in the case of scientific research, scientific realists use instruments as an aid to widen the range of their observational abilities. Contemporary sophisticated instruments of observation have broken the rigid wall between observable and unobservable entities and the success of their instruments in different contexts supports the idea that everything is in principle observable. Instruments play a positive role in increasing the power of observation. Paul Churchland, a critic of the observable/unobservable distinction, rejects the human ability to observe as the ultimate criterion of reality. He develops the idea of a humanoid who has electron microscopic eyes and who can easily observe microparticles with his eyes. We find a similar imaginative scenario in Maxwell's philosophy; he comments, "suppose a human mutant is born who is able to observe ultraviolet radiation, or even X-rays, in the same way we observe visible light." (1962, 11) In the light of these imaginative scenarios, we have to change the idea of 'in principle unobservable'. In the history of science, we find that the power of observation is a progressive capacity, and according to scientific realists we should not tie up this ability to a limited area, such as to the human capacity to observe, as van Fraassen has it.

Does naked eye observation provide any epistemic advantage for the purpose of acquiring knowledge? Van Fraassen believes that naked eye observations generate direct knowledge for observers. So they can accept these observations without further justification. But one cannot accept instrument-based observations about unobservable entities without further justification. Scientists have to prove the reliability of their instruments. Do they get same result under similar circumstances? How does the instrument work? Scientific realists like Stathis Psillos (1999, 199) do not give an extra advantage to naked eye observations. If instrument-based observation needs extra justification, then naked eye observation needs such justification too, since the human eye itself is a complex instrument of observation. As Menuge puts this point, "it is not a true principle that reliance on . . . instruments requires more justification than does reliance on our senses alone. But if there is no such principle, then, since you apparently insist that justification is required when I use a microscope, you should require it in the case of unaided vision as well." (1995, 67)

1.3 Some Observations about Observable Entities, Unobservable Entities and the Power of Observation

In the above discussion, I have tried to show that there is no clear demarcation line between observable and unobservable entities. This casts doubt on the use of this distinction to support anti-realism. Moreover, there is no highest point of a human's power observation. If we want to draw a demarcation line between observable and unobservable entities, we have to define both of them; we have to find some criteria to separate them. In the history of science, the concepts of observable and unobservable are changeable. We use instruments to observe the micro-organism like viruses or bacteria. Now we can observe them with a microscope which was not possible in the time of our predecessors. Instrument-based observation brings a new dimension into scientific research. But van Fraassen depends only on human-based observation in his constructive empiricism. I would like to prove that in scientific research, observable and theoretical entities both play an important role. There is no room to deny the importance of instrument-based observation as well as sense-experience in knowing nature and life.

In the discussion of constructive empiricism, van Fraassen depends on naked eye observation for the purpose of getting reliable knowledge. Now this raises the question -- is naked eye observation beyond doubt? Does everyone observe the same thing in the same way? Do they get same experience from the same observation? In this context, I would like to discuss Necker's cube. Suppose some observers are looking at the Figure 1. Do they have the same experience? If we ask them what their experiences are we get different answers. Someone will say it is a cube, others say it is a box. According to N. R. Hanson "some will see an ice cube viewed from below. Others will see it from above.

Still others will view the figure as a polygonally-cut gem. Some see only crisscrossed lines in a plane. Others will see it as an aquarium, a wire frame for a kite or any of a

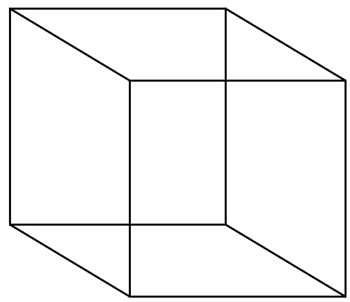

Figure 1. Necker's Cube

number of other things." (Hanson 1967, 91-92) This example shows us that observations are sometimes ambiguous. We see the same thing in different ways. Sometimes we do not accept naked eye observations directly. As a result, we can say that such observations need further interpretation or explanation to become meaningful.

We observe a thing with our eyes; we hear things using our ears. Sense experience is a reliable means for acquiring knowledge. But sometimes sense experience deceives us. In that context, I would like to cite a very popular example. By this example I would like to show that objects have both observable and unobservable properties. Moreover, I want to show how both the observable and unobservable properties help make one another meaningful. The example is this: if we submerge part of a straight stick in water then we see a bent stick (see Figure 2)

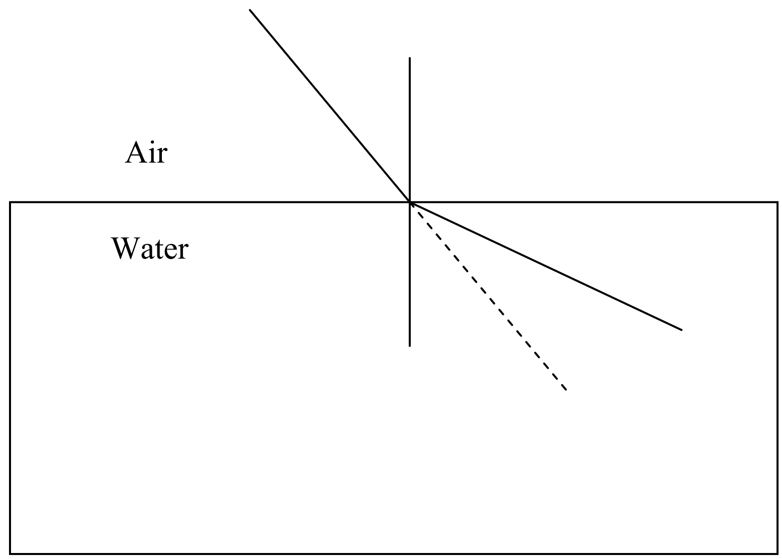

Figure 2. Refraction of light with different media

That is, the stick does not appear straight any more, but appears bent. From this observation, we conclude that our sense experiences can deceive us. Thus we can not be certain that our sense experiences are not deceiving us in other cases and van Fraassen's human-based observation will lead to uncertainty. In reflecting on this example I can show that it requires that objects have both observable and unobservable properties. In fact, the stick is not bent, it is an illusion; and if we explain the circumstances we can find out the real cause of the stick's apparent bentness. We know that light goes through a medium. When it changes media it changes its course because of the different specific gravities of the media. In our example we see the light go through two media -- air and water. The refractive index of water is different from that of air. As a result, we see that the stick is bent. But in fact the stick is straight -- it is an illusory experience. In this context we see that 'refractive index' refers to an unobservable property of media; we cannot see the refractive indices of water or air and they are not observable. Still, this unobservable property of media helps us to explain stick's observed position. As a result, we can say that both the observable and the unobservable properties exist and help one another to prove their existence.

I would like to support the independent existence of different entities whether we observe them or not. Being unobservable is not a deficiency with entities; it is a limitation on observers and the existing situation. This situation is not rigid; it is a flexible matter. If an observer changes his situation, he can get a different result. There was a time when different micro-organisms, such as viruses and bacteria, were unobservable to human beings. Researchers could only speculate about them, as they were hypothetical entities. But their inability to be observed was only a limitation on the observers; they simply could not make instruments or create situations to observe these small entities. Now researchers are able to observe such kinds of micro-organisms through different sophisticated microscopes and in this way they are acquiring reliable knowledge. The discovery of different micro-organisms is a great achievement in medical science. This knowledge helps medical scientists to understand different diseases. Moreover, this knowledge assists us in inventing different vaccines. These sorts of cases are very common in our practical life and are related to the existence of human beings. In this regard, a researcher's success proves the existence of different micro-organisms and also proves that their knowledge about micro-organisms is reliable. So we draw the conclusion that there is no doubt about the existence of viruses, bacteria and other such kinds of theoretical entities.

Now I would like to explain another kind of observation that supports the existence of unobservable entities. We are not able to observe some entities by means of the naked eye. Rather, we confirm their existence by inspecting their activities, behaviours and characteristics. It is our current scientific knowledge that oxygen is necessary for the existence of animal life, but no one can observe oxygen with the naked eye. Nevertheless, it is an important part of air. We can guess the existence of air by the naked eye in a special moment, for example, in a storm, but we can not see oxygen in this way. Still, scientists are certain that the air contains oxygen and other unobservable gases, such as nitrogen and carbon dioxide, through the use of the scientific method. Thus, although we can say that, although oxygen itself is unobservable, its activities, behaviours and characteristics as revealed through experimental inquiry prove its existence, its necessity. The unobservability of oxygen does not prove its non-existence.

In this phase of my discussion I would like to prove that there is no real reason to allot extra reliable status to our knowledge of observable entities comparatively to that of unobservable entities. Here let me compare two cases:

1. Five thousand years ago people lived in a place that is now called Saskatoon.
2. Some kinds of bacteria (Helicobacter pylori) are the causes of peptic ulcers.

In case 1, we note that people are observable entities but we cannot observe the people at that time. To confirm their existence we need to use indirect observations, i.e., inferences. Depending on the inferences used, archaeologists make a decision on whether there were people then or not. In the latter case, we see that our subject matter is the existence of bacteria which are unobservable entities. But we are able to get immediate results about their existence. Depending on the result of laboratory tests, a doctor can draw a conclusion about the existence of these microscopic entities and can suggest some medicine. At last, the patient can get rid of the disease. Certainly, this evidence proves the authenticity of our knowledge of van Fraassen's unobservable entities.

In the above discussion we see that there are different approaches to observation and the power of observation. We get a complex relation among them; we can not draw any definite conclusions about this relation. But one thing is clear: anti-realists can not make any concrete demarcation line between observable and unobservable entities. There is no clear criterion that can separate observable entities from unobservable entities. We have to consider them according to the circumstances. Observation and the power of observation depend on the circumstances and these circumstances are changeable. In this context, I would like to recall the role of modern technology such as telescopes, microscopes, and hearing aids which is playing an important role in enhancing human observation power. The power of observation depends on technological development, and realists are optimistic about the role of instruments for the purpose of observation. Van Fraassen cannot deny the importance of instruments in the case of observation. But he does not admit the importance of instruments in observations directly; he uses the word 'detection' instead of 'observation' in the context of instrument-based observation. But this brings another problem for him. We do not get any clear demarcation line between observation and detection. At last, we see that realists want to know both observable and unobservable entities, and their subject-matter of research is broader than that of constructive empiricists; naked eye observations about observable entities do not provide any epistemic advantage beyond the instrument-based epistemic achievements of scientific realists, and the progressive attitude of scientific realists about the power of observation is helpful for the development of science. Considering all of this we can support the realist's progressive attitude towards observation power.

In my discussion I tried to show that not only naked eye observations but also instrument-based observations are reliable means of acquiring knowledge about nature and life. Constructive empiricists deny that we have knowledge about unobservables, and on this basis claim that there is a distinction between observables and unobservables. On the other hand, realists are confident that we have knowledge of both observables and unobservables. According to them, there is no good reason to give more credit to naked eye observations than to aided, instrument-mediated observations. In the next chapter, I will show that scientific realists are correct in their assessment that we do have knowledge of unobservables. As a result, there is no reason to distinguish between observables and unobservables on epistemic grounds.

Chapter 2

Inference to the Best Explanation

In my discussion in the first chapter, I mentioned that the debate between realism and anti-realism has been continuing for a long time. The participants in this debate discover different arguments in favor of their views. One of the strongest arguments in favor of scientific realism uses the notion of an ‘inference to the best explanation’ (‘IBE’). Using this argument, scientific realists try to prove the existence of unobservable entities as well as decide on what is the best theory. The idea of IBE was presented early on in C. S Pierce’s conception of abduction, and following Pierce, Gilbert Harman, Peter Lipton and Stathis Psillos have enriched the literature on IBE. For his part, van Fraassen considers the IBE argument to be a bad argument on behalf of scientific realism. According to him, scientific realists in choosing the theory that best explains the data may be simply choosing the best theory from a bad lot of theories. It is to reject the IBE argument that van Fraassen puts forward this bad lot argument. In what follows, I will examine a variety of arguments both for and against scientific realism, along with the IBE and bad lot arguments. Overall, I will try to show that although scientists could never discover the whole truth about any subject matter, some truth may lie within current theories and that we should reject a negative attitude towards the contemporary theories. That is, we need to express a positive attitude towards them and be optimistic about the progress of scientific theories.

To understand IBE, we first have to discuss what is meant by IBE. To this end, I would like to delineate the meaning of ‘explanation’. Generally we believe that ‘explanation’ is an important means to reveal the obscurities of nature and life. At the very beginning of our civilization, everything was very much surprising to our ancestors, and science and other branches of knowledge helped to answer their wonders. But science has particularly been playing a pioneer role among the different branches of knowledge in illuminating all kinds of obscurities. As Alex Rosenberg notes,

> science seeks explanations to satisfy the wonder. But so do other human enterprises. The difference between science and other enterprises that seek explanations of why things are the way they are can be found in the sorts of standards that science sets itself for what will count as an explanation, a good explanation, and a better explanation. (2000, 21)

We can accept or reject a theory depending on its explanatory power. When we ask a solution for a problem or want to know the causes of a certain event, we find that people often express different views on the issue. Sometimes not even experts express the same view on the same issue. To justify their views, they explain their views and try to prove that their views are better than the views of others. At last, the best explanation is accepted by the scientific community. Here IBE plays a vital role. Van Fraassen explains the process of IBE in this way: “let us suppose that we have evidence E, and are considering several hypotheses, say H and H′. [IBE] then says that we should infer H rather than H′ exactly if H is a better explanation of E than H′ is.” (1980, 19) Similarly, Paul Thagard defines IBE as follows: “to put it briefly, inference to the best explanation consists in accepting a hypothesis on the ground that it provides a better explanation of the evidence than is provided by alternative hypotheses. We argue for a hypothesis or theory by arguing that it is the best explanation of the evidence.” (1978, 77)

Explanation plays an important role in different branches of knowledge -- social science, philosophy and the natural science. Suppose someone asks, what is the cause of poverty in Third World countries? In this regard a lot of hypotheses are introduced, such as poverty is caused by colonial exploitation lasting for a long time, by a political or military bureaucracy, by political corruption, an absence of democracy, illiteracy, shortage of expert manpower, discrimination in wealth distribution, poor natural resources and so on. The supporters of these views argue in favour of their views and try to establish that one's view is better than the others. It is usually the case that not all of these hypotheses are equally important. Some of them can explain the problem more accurately and elaborately than others. In this context the view that can explain the problem comprehensively is accepted by social scientists. As a result, explanation plays a pivotal role in making a hypothesis acceptable.

We get a new dimension on explanation when we use IBE. Sometimes we get a single explanation of an incident and we accept this explanation. But with IBE we often get several explanations of the same incident. These different explanations bring different insights to understanding a phenomenon. In the context of IBE, we have the option to choose the best explanation from a lot of explanations. We compare different explanations and choose the best one.

Clearly, then, it is a major obstacle for the supporters of IBE to determine the best hypothesis from a number of hypotheses about a certain problem and different philosophers try to resolve this problem in different ways. Although explanatory power is an important means to realize an IBE, there are several other criteria on what counts as a 'best explanation' in the literature that we need to consider. For example, to judge a best hypothesis Harman says, "presumably such a judgment will be based on considerations such as which hypothesis is simpler, which is more plausible, which explains more, which is less *ad hoc*, and so forth." (1965, 89) Paul Thagard, for his part, notes that there are three major criteria to determine the best explanatory hypothesis (1978, 79). These criteria are used to evaluate the best hypothesis among a spectrum of hypotheses. These three criteria are consilience, simplicity and analogy. Let's briefly discuss these criteria.

We know that we can find many hypotheses about a certain subject-matter. But all of them are not equally important. Some have more explanatory power than others. But how do we choose the best hypothesis? In this regard consilience is an important means to judge that one hypothesis is better than other hypotheses. A hypothesis is said to be consilient when it can explain more evidence, more facts than other hypotheses. That is, consilience indicates the unification of different hypotheses on a certain subject-matter and the ability to explain the maximum number of events and facts using a minimum of assumptions. As Paul Thagard explains,

> a theory is said to be consilient if it explains at least two classes of facts. Then one theory is more consilient than another if it explains more classes of facts than the other does. Intuitively, we show one theory to be more consilient than another by pointing to a class or classes of facts which it explains but which the other theory does not. (1978, 79)

Simplicity is another important indicator in choosing a good hypothesis. We know that explanations reveal the obscurities of nature and life and every researcher looks to the simplicity of explanatory hypotheses; a group of supporters of a scientific paradigm try to make their paradigm simpler. This raises the question -- what is meant by 'simplicity'? Is it subjective or objective? Some philosophers say that simplicity is a very subjective notion, a concept that challenges the idea of the objectivity of scientific knowledge. But, as Alexander Bird responds, "people may have differing views as to what is simple, but that does not show that simplicity is subjective (any more than the fact that the people disagree about what is true shows that truth is subjective).” (1998, 158) What Bird is suggesting is that simplicity is context dependent just as truth is context dependent but that does not mean that simplicity is relative, just as it does not mean this in the case of truth.

Finally, I would like to discuss the criterion of analogy. By analogy, we mean seeking the similarities between two or more things and drawing further inferences about these things based on these similarities. In this respect, researchers make predictions based on the observed similarities of two things in their past and present circumstances. If they find some similarities in the present context they can predict further similarities with these two things in the future or in different circumstances. In the history of science, analogy has played an important role in scientific discovery. For example, following Thagard, I would like to cite the importance of analogy in Darwin’s development of the theory of evolution. Selection works as a filter to accept the fit variations and reject the unfit variations in a species’ characteristics. Darwin compared artificial and natural selection and, according to him, analogy played an important role in justifying his theory. Specifically, Darwin noted some similarities between artificial selection and natural selection. Artificial selection is a human activity -- it may happen consciously or unconsciously. On the other hand, people have no role in the context of natural selection, where natural selection is defined by Darwin as the “preservation of favourable variations and the rejection of injurious variations” (1859, 81). But both kinds of selections are similar in that they are effective only given the prolific spontaneous production of novel traits by offspring and the inheritability of these traits in future generations. But people select the useful variations in the context of artificial selection, whereas nature selects the useful variations in the context of natural selection. Following C. Kenneth Waters (1986, 507) we can compare artificial selection and natural selection in this way:

	Artificial Selection		Natural Selection
1.	Variations produced (through an unknown mechanism)	**1.**	Variations produced (through an unknown mechanism)
2.	Man selects variations (by conscious efforts but by sometimes unconscious means)	**2.**	Nature selects variations (by providing conditions that give organisms with certain variations a better chance to live and reproduce)
3.	Variations inherited (through an unknown mechanism)	**3.**	Variations inherited (through an unknown mechanism)
4.	Production of domestic races.	**4.**	Production of natural races

(Of course, the description of the science here is insufficient, but my interest here is solely to illustrate a methodological point.) It was (Waters claims) Darwin's contribution to infer, on the basis of this analogical comparison, that natural selection plays an essential role in the process of evolution. Some variations, that is, the genetic change of plants and animals, are favourable allowing species to adapt to their environment, and other variations are not so favourable. Researchers then observe that favourable variations survive generation after generation, whereas comparatively unfavourable variations become extinct. In the process of the modification of organisms through variations, nature selects the favourable variations and in this way natural selection plays role in the evolution of plants and animals.

This is similar to what occurs with artificial selection. In this context I would like to cite the artificial selections of rice farmers. Rice is the staple food in some Asian countries. Its production quantity used to be so poor that it was not able to cope with the needs of people. Presently, the IRRI (International Rice Research Institute) is working to discover high quality rice seeds that can increase production and for this purpose they are successful. Now farmers are using IRRI's seeds to increase rice production on less land. As a result, conventional kinds of rice are losing their importance day by day. A breeder will select his favourable breeds. In this context, a farmer selects breeds that suit his purpose and these breeds survive, reproduce and proliferate. Though conventional rice seeds will never disappear, they may not be used as much as before, which is unfortunate since although newer varieties can produce higher yields they only do so with artifical inputs.

As for criteria for good theory choice, W. H. Newton-Smith (1981, 226-230) offers a long list. I will discuss these criteria very briefly.

1. Observational nesting.

Observational success is an important indicator of a good theory. A good theory has a good observational capacities and it maintains a good relation with its predecessor's observational success. According to Alexander Bird, "if one theory explains all the observations [that] another explains, and more besides, then, other things being equal, it is a better explanation." (1998, 264) Moreover, a good theory increases its observational success by making different predictions.

2. Fertility.

A good theory is always open-ended for the further development; it does not close the room for progress. A fertile theory provides us with enough opportunities for producing more observations to help the researchers provide better explanations with a theory.

3. Track record.

There are several facts or events covered by a theory. A good theory explains all of these facts or events successfully. A good theory should have good success record. According to Newton-Smith, “the longer the theory is in the field, the more important its past track record becomes. Continuing observational success not only counts in itself for the theory, it also an indicator of future fertility.” (1981, 227)

4. Inter-theory support.

A theory is interrelated with others theories. This integration among different theories works in favor of their reliability. According to Bird, “mutual integration among theories is a sign of their truth.” (1998, 265)

5. Smoothness.

Success and failure are common phenomena in scientific research. Success of a theory indicates that it is a systematic development. If a theory is systematic, that means it works in certain conditions, follows some rules or methods. As Alexander Bird notes, a smooth explanation does not assure us that it is right in every aspect, only that its exceptions or failures are also systematic. (1998, 265) In the context of smooth theory, there is hope to discover the conditions under which it does not work. Alexander Bird cites as an example of a smooth theory the ideal gas law. An ideal gas law works in a certain context and fails in some conditions; specifically, the ideal gas law works successfully in a certain ranges of temperatures, pressures and volumes but systematically does not work in low temperatures and high pressures. (1998, 265)

6. Internal consistency.

Consistency is an important property of a successful theory. Generally we believe that successful scientific theories are true or approximately true. But if there is any kind of contradiction in a theory then we cannot accept it as a true, since p and –p can not be simultaneously true.

7. Compatibility with well-grounded metaphysical beliefs.

This is a kind of external consistency. When researchers try to construct a theory, they are inspired by certain established rules or beliefs. According to Newton-Smith, "theory construction and theory choice are guided by certain very general metaphysical beliefs." (1981, 229)

Using these criteria for theory choice, we can say that the best explanation for a set of data is one that satisfies the majority of these criteria. IBE thus helps researchers choose the best hypothesis from a lot of hypotheses. Using these criteria, scientists find the best hypothesis and reject alternative hypotheses, where the best hypothesis is the one that explains the evidence in the best possible way. As Gilbert H. Harman summarizes the process,

> in general, there will be several hypotheses which might explain the evidence, so one must be able to reject all such alternative hypotheses before one is warranted in making the inference. Thus one infers, from the premises that a given hypothesis would provide a 'better' explanation for the evidence than would any other hypothesis, to the conclusion that the given hypothesis is true. (1965, 89)

Inferences, such as an inference to the best explanation, can be either inductive or deductive. Here it is important to mention that the true premises of an inductive inference do not assure us that conclusion will be true. In this regard, explaining the data can play an important role in making an inference meaningful. According to Peter Lipton,

> our inferential practices are governed by explanatory considerations. Given our data and our background beliefs, we infer what would, if true, provide the best of the competing explanations we can generate of those data (so long as the best is good enough for us to make any inference at all). (1991, 58)

He is claming that explanatory considerations guide what inferences we should make.

IBE plays an important role in different phases of our personal and academic activities. Suppose one of our friends is invited to a party, but is absent from the party. How do we explain it? In this context, we can provide several hypotheses.

a. He is sick
b. He had a road accident.
c. He forgot about the party.
d. He does not enjoy parties.
e. He is busy with urgent business.

All of these hypotheses may be true. From our experience and our knowledge of his nature we might infer that the last explanation is the best and accordingly infer that it is true. Indeed it is a very common phenomenon in everyday activities for people to give a preference to the urgent business over attending parties. (See a similar argument in Ladyman 2002, 209)

I would now like to discuss the role of IBE in our academic activities. In the first chapter I discussed both how constructive empiricists and scientific realists use inferences to prove the existence of observable entities Van Fraassen notes how IBE can be used to explain the sound of scratching in the wall or a missing piece of cheese. To explain these, he infers the existence of mouse and this inference is often quite reliable given our knowledge of mice and their habits. According to van Fraassen, “I hear scratching in the wall, the patter of little feet at midnight, my cheese disappears -- and I infer that a mouse has come to live with me. (1980, 19-20) Although he does not see the mouse, he infers its existence. He also infers the existence of a plane in the sky by observing a trail of vapour. Both of these inferences to the existence of a mouse and of a plane (whose cogency depends on experiential background knowledge) are for van Fraassen warranted. They are warranted because the inferred entity is observable. But van Fraassen expresses doubt about the role of IBE in inferring the existence of unobservable entities. For van Fraassen, as Stathis Psillos (1996) notes, “IBE is not a means of forming warranted beliefs about the realm of unobservable things or process. In other words, van Fraassen claims that IBE does not warrant belief when the potential explanation of the evidence stretches to the unobservable world.” (32) Rather, constructive empiricists such as van Fraassen only use IBE to prove the existence of observable entities.

Scientific realists on the other hand, use IBE to prove the existence of both observable and unobservable entities. According to Psillos “scientific realists have always suggested that IBE is the mode of reasoning that scientists follow in order to form their theoretical beliefs, and have argued that it can reliably produce and sustain (approximately) true beliefs about the world.” (1996, 31) For example, we cannot observe dinosaurs at this stage. But we can prove their existence in the past using IBE. We find some evidence such as big fossils and footprints of a big animal. Explaining these specimens, we infer the existence of a huge animal. Moreover, we can get some reliable explanations of the causes of their extinction. That is, for realists, we gain information about unobservable entities and forces.

2.1 The 'No Miracles' Argument

There are some influential arguments in favour of scientific realism. The 'NMA' is one of them, introduced by Hilary Putnam. According to Putnam, "realism is the only philosophy that does not make the success of science a miracle." (1975, 73) By 'miraculous' we mean something that is unexplainable or unexpected. A lot of things were miraculous to our predecessors. They could not explain the causes of a flood-tide or an ebb-tide and they did not know the causes of rain or drought. To them, all of these things were miraculous. Comparatively, we can these days explain such phenomena successfully and our scientific explanations are true or approximately true. We can explain the causes of the rotation of the Earth and the Sun, medical scientists know the causes of several diseases, and the weather office can predict the weather of the next day or the next week. If we do not accept their theories as true or approximately true then their successes will be miraculous. But there is no room to consider these successes as miraculous events for us. In this regard I would like to advance the following argument. Suppose an event occurs that seems to be miraculous. But there is no scope to believe that this event is miraculous. Thus, when we find a comprehensive and elaborate explanation of this event, we can infer that this explanation is true.

In the history of science, many scientific theories have been very successful, and by the NMA these theories are true or approximately true. Some theories of unobservable entities have been successful at explaining observed phenomena by postulating the existence of microscopic entities such as viruses and bacteria and I believe there is no miracle in the success of such theories. To define the aim of NMA Stathis Psillos writes,

> NMA aims to defend the realist claim that successful scientific theories should be accepted as true (or better, near true) descriptions of this world, in both its

> observable and its unobservable aspects. In particular, the realist claim is that accepting that successful scientific theories describe truly (or near truly) the unobservable world best explains why these theories are empirically successful." (1999, 71)

To illustrate the NMA, let me cite some examples from medical science. According to medical science, several viruses and bacteria which occasionally attack human beings and other animals are responsible for several diseases. We cannot see these entities by the naked eye, but we can observe their effects. Moreover, these effects prove the existence of these microscopic entities; if these entities did not exist, the diseases and their symptoms would seem miraculous to us. In addition, medical science has discovered some medicines to treat these diseases and is successful in this purpose, where such medicines are designed with the nature of these microscopic organisms in mind. In this way, we prove the existence of microscopic organisms. There is no miracle, everything is explainable.

In this context, I would like to discuss some activities of one sort of virus. We know that dengue is a viral fever and that the dengue virus is the cause of this fever. Aedes mosquitoes are the carrier of this virus. The symptoms of this disease are a high fever, rash, headache, bone pain, pain behind the eye and muscular pain, symptoms that may continue for five to seven days. At the beginning of the history of this fever, some symptoms were unfamiliar to common people and even medical scientists were in the dark about such a kind of fever. Some symptoms of this fever are different from all other fevers and initially medical scientists did not have any idea about its cause. At last they discovered the cause of dengue, and they also found the means to prevent it. Here medical science has made great strides in understanding this disease, and their success proves that nothing is miraculous in the context of the dengue fever and that their knowledge about this virus and fever is accurate.

At this stage I would like to explain how successful predictions work in favour of NMA. To began, I would like to clarify the idea of prediction. Prediction is an important criterion of a successful theory that works in favour of the reliability of scientific theories. Depending on some present information, we say something about present events or about future events -- this is called prediction. According to Stephen G. Brush, "in ordinary language 'predict' means foretell or 'prophesy,' implying a statement about future events. [Comparatively] physicists (and many other scientists) currently use the word to mean 'deduce from a theory' whether before or after the fact is known or has occurred." (1994, 135) The accuracy of a prediction of any theory exhibits the success of that theory. In the history of science, we find many predictions that have been proved to be true, and those theories that successfully predict are accepted by scientists as true or approximately true. To illustrate a successful prediction, I would like to discuss Mendeleyev's Periodic Table. Dimitri Ivanovich Mendeleyev (1834–1907) was a renowned chemist. His great contribution to chemistry is the Periodic Table of chemical elements. Mendeleyev's predictions using the Table show how prediction increases the reliability of a scientific theory. A good number of chemists during Mendeleyev's time had worked to discover the basic chemical elements and they wanted to determine the various properties (such as atomic weight, density and specific heat) of these elements. Mendeleyev, for his part (along with Julius Meyer), sought to find periodic relations between the elements and to arrange them according to their properties. Here Mendeleyev noticed, as Maher (1988) points out, "that if the elements were arranged by their atomic weights, then valences and other properties tended to recur periodically" (274). In his research, Mendeleyev emphasized the properties of chemical elements and he made some predictions about the properties of chemical elements. Eventually, he presented his Table before the scientific community of Russia.

Eventually, he noticed a gap in his Table and he predicted in 1871 the existence of some new chemical elements. He named three undiscovered chemical elements by describing their different properties (see Maher 1988, 274):

1. eka-aluminum
2. eka-boron
3. eka-silicon

This prediction is an important strength for the Mendeleyev's Periodic Table. It exhibits the reliability of his knowledge of the chemical elements. It also illustrates the success of the scientific realists' argument for the authenticity of scientific knowledge, since Mendeleyev's predictions about the undiscovered elements were later proved true by chemists. In this regard, I would like to mention the contribution of Lecoq de Boisbaudran. In his research in 1875, he found an element that is very much similar to the properties of Mendeleyev's eka-aluminum, an element he called gallium (Ihde 1964, 248). This was an important event in the history of science. As Maher notes, "it was the first time in history that a person had correctly foreseen the existence and properties of an undiscovered element" (1988, 274). Nilson and Winkler added more support for about Mendeleyev's predictions. In 1879, Nilson discovered a new chemical element that is similar to Mendeleyev's eka-boron and Nilson named it scandium. And Mendeleyev's third asserted element also turned to be true. In 1886 Clemens Winkler found an element whose properties are similar to eka-silicon, an element called germanium. From this observation of the history of chemical elements, we can draw the conclusion that prediction plays an important role in science. Correct predictions help scientific theories to become meaningful. Mendeleyev's accurate predictability made it sensible to accept his Periodic Table and illustrates the reliability of this Table.

2.2 The Aim of Science is Truth or Approximate Truth.

The aim of science is an important issue in scientific research. In *The Scientific Image* van Fraassen describes a new view on the aim of science. From my perspective, we know that science works to reveal the obscurities of nature and life; we have scientific knowledge of nature and life and we believe that scientific knowledge is true or approximately true. But van Fraassen says that the aim of science is not truth; rather, the aim of science is empirical adequacy. When a theory is empirically adequate, we accept it, where empirical adequacy only depends on observable consequences. In this respect, scientific realists have a very clear vision. According to scientific realism, the aim of science is to discover the truth or the approximate truth of a theory. Of course, in the history of science we find that a good number of scientific theories have been proved to be false. Still we can accept contemporary successful scientific theories as true or approximately true. Here scientific realists are being more optimistic than constructive empiricists. According to the realist Stathis Psillos,

> the best explanation of the instrumental reliability of scientific methodology is that background theories are relevantly approximately true. These background scientific theories have themselves been typically arrived at by abductive reasoning. Hence, it is reasonable to believe that abductive reasoning is reliable: it tends to generate approximately true theories. (1999, 80)

Scientific progress is a continuous process and its aim is to acquire certain knowledge of the world.

In his philosophy, van Fraassen discusses the success of science, on his view, the success of science is not miraculous, but he opposes the application of 'true' in the case of successful scientific theories involving reference to unobservables. Very much interestingly, he takes shelter in Darwin's evolutionary theory to explain the success of scientific theories. He finds some similarities between successful scientific theories and the evolutionary theory of Darwin. According to evolutionary theory, a lot of species have been struggling for their survival in the world. The popular slogan in this context is 'Survival of the Fittest'. Everyone has to fight at every moment in their environment to survive, a task that is endless. Those species that are successful in this fight survive. So, in this regard, when asking "why the mouse runs from its enemy", van Fraassen suggests that we not make reference to the true beliefs in the mouse's head, but rather simply say that "species which did not cope with their natural enemies no longer exist". (1980, 39) And, for van Fraassen, the same idea works in the case of scientific theories. In the history of the science, we see a lot of theories that have been struggling (like species) for their survival in the scientific world. Some of them can survive and some of them go extinct. Here, van Fraassen submits, there is no need to explain the success of a scientific theory by pointing to its truth. Rather, he comments, "born into a life of fierce competition, a jungle red in tooth and claw, [only] the successful theories survive -- the ones which in fact latched on to actual [observed] regularities in nature." (1980, 40)

In response to the Darwinian explanation of the success of scientific theories I would like to say that there is no doubt that there are some similarities between Darwin's evolutionary theory and the process of scientific theory change. Some scientific theories have existed in the scientific world for a long time just as some species have existed for a long time in nature. Some species can adapt themselves keeping pace with the changing environment and an analogous phenomenon occurs in the case of scientific theories in that supporters of a paradigm try to enhance a theory's ability to adapt to new situations. Still, although these characteristics show how species and theories are similar, we do not get any explanation of the predictability of scientific theories from this analogy. Here I would like to follow James Robert Brown in his explanation of the demerits of anti-realist views on the success of scientific theories. Brown sets forth three criteria for successful scientific theories (1994, 4)

1. The organising and unifying ability of theories.
2. The ability to systematize empirical data and
3. The predictability of scientific theories.

Following the Darwinian view, van Fraassen can explain the first and second criteria of a successful scientific theory, but not the third criterion. Darwinian evolutionary theory can explain the changes of plants and animals, but we do not get any particular prediction about them through this theory. To show the limitation of van Fraassen's analogy James Brown notes, "the Darwinian analogy breaks down since most species could not survive a radical change of environment," (1994, 7)

In the history of the philosophy of science there has been long debate on the aims of science. Realists and anti-realists are clearly divided in this aspect. According to constructive empiricism the aim of science is empirical adequacy. On the other hand, the goal of science according to scientific realists is to acquire truth or approximate truth. In this regard, I would like to support scientific realism in a moderate sense. Scientists discover theories about observable and unobservable entities. We can consider a theory as true if its explanations and predictions are correct. If most of the predictions of a theory are correct then we can consider that theory as approximately truth. Now anti-realists can say that the concept of approximate truth is vague. To clarify this concept I would like to cite an example -- we know that Everest is the tallest mountain of the earth and its height is 8,850 meters. If someone says that the height of Everest is 8,825 meters then we can accept it as approximate truth. In short approximate truth means its difference from truth is not too much. Now I would like to explain the concept of truth in science. According to scientific realism, we have good reason to accept a successful scientific theory as a true. At the very beginning of his research work, a scientist tries to construct a hypothesis. Then he deduces a single instance from this hypothesis and tests this instance. In this process he tests a large number of instances and at last he reaches a decision and establishes a theory. As long as we do not find any counter example, we accept this discovery as a true theory. In this context I would like to cite Avogadro's hypothesis. According to this hypothesis, the volume of a gas is directly proportional to the number of molecules of the gas. Therefore, two equal volumes of gas with the same pressure contain the same number of molecules. Subsequent researchers have tested this hypothesis and confirmed Avogadro's result, even in cases when different kinds of gas are examined. As a result, it is established as a theory. As long as we do not get any negative instances, we can accept this theory as a true theory of science.

2.3 Van Fraassen's Response to IBE

In van Fraassen's constructive empiricism, he only accepts theories that explain observable entities and he is happy to draw inferences in the case of observable entities. In this respect we can cite his inference about the existence of a mouse. He observes some signs of the mouse, and depending on these signs, he draws an inference that there is a mouse. If we consider the existence of a mouse as a hypothesis then we see that this hypothesis is able to explain the available evidence (e.g., the distinctive 'mouse sounds', the disappearance of cheese, and so on). But van Fraassen expresses strong reservations about using IBE in the context of unobservable entities. Here again we find the basic problem of the observable/unobservable distinction. According to van Fraassen, IBE is acceptable in the case of observable entities but not in the case of unobservable entities. His contradictory position here is criticized by various philosophers. Stathis Psillos, for example, draws a distinction between horizontal and vertical IBE, where vertical IBE indicates abductive reasoning that involves hypotheses about unobservables and horizontal IBE means abductive reasoning that involves only hypotheses about unobserved but observable entities. Van Fraassen does not doubt the legitimacy of horizontal IBE, but rejects vertical IBE. Thus, following Psillos, we can ask the question, "what really is [van Fraassen's] objection to vertical IBE and the formation of warranted beliefs about the unobservable world?" (1996, 32) That is, what is the difference between vertical and horizontal IBE that makes one acceptable and the other not?

According to scientific realism, explanatory power is an important criterion in accepting scientific theories. We can explain an incident of nature or life in several ways and scientists choose the best of the possible explanations. For example, suppose we have to explain an event. To this end we collect information about it. Different scientists then arrive at different theories depending on available information. As a result, we get several theories of this event. For example, given event ‘e’, a group of researchers may be involved in bringing to light the causes of this event and presenting their explanations separately in front of scientific community. Let’s suppose we have three theories A, B, and C concerned with the event ‘e’, and that

A explains the event ‘e’

B explains the event ‘e’, and

C explains the event ‘e’.

Each of these theories may have different views on this event and the theories may differ both quantitatively and qualitatively. According to scientific realists, we accept the best explanation of the lot and realists suggest that this explanation describes a real state of affairs. But then the constructive empiricist asks -- which explanation is correct? All of them may be wrong, that is, scientists may be choosing the best amongst a bad lot of theories. This is the ‘bad lot’ argument advanced by constructive empiricists against scientific realists. We can show two kinds of attitudes to our contemporary successful scientific theories -- positive and negative attitude. If we show a positive attitude towards contemporary successful theories then we can believe that the truth lies within these theories. On the other hand, with a negative attitude, we say that the truth lies outside the current theories. Scientific realists show a positive attitude towards contemporary successful scientific theories, whereas anti-realists exhibit a negative attitude.

I would like to support scientific realism in this context and I will express my view by citing an example. Suppose some people in an area are suffering from diarrhea and suppose we can find several explanations of the cause of this disease. Someone can argue that a bad sanitation system is the cause of this disease; someone can say that their drinking water was not pure and some people can argue that their food was not healthy. According to constructive empiricism all of these explanations may be wrong. This disease may have another cause which is not discovered by scientists; it may be possible that the real cause of this disease is still uncovered. Following van Fraassen, one can say that we could get a more accurate explanation of this disease in the future. But I would like to say that the different explanations of the cause of this disease can play a positive role in getting to the real cause of it and that we should not necessarily consider this set of theories as a bad lot. A researcher who is working on this disease will find some information by analyzing the present hypotheses. He can use the trial and error method to locate authentic knowledge. In any event, those researchers who do not have a minimum of background knowledge about this problem are similar to someone looking for a black cat in a dark room; for to be successful in research, certain conditions need to be in place, just as no one can find a black cat without enough light. In the context of scientific research, background knowledge helps researchers to reach their destination. As Psillos notes, "theory-choice operates within and is guided by a network of background knowledge." (1996, 38)

According to scientific realists, there is scope for further development of current successful scientific theories. I would like to say that present hypotheses and explanations of various problems do not close the door for further development. A phenomenon may have several explanations, but we do not accept all of them as true or approximate truth. Only when we can adequately justify an explanation must we accept it. Nothing is accepted without sufficient evidence. Occasionally contemporary explanations do not show the whole truth, but still they can express a partial truth and lead researchers to the whole truth. To say, as van Fraassen seems to, that current theories of a subject-matter are bad lot, expresses an overly negative attitude towards scientific research and closes the way for the further development of science. In this respect, the bad lot argument represents a negative outlook about scientific knowledge. Rather, on my view, the successes of contemporary scientific theories show that there is no good reason to have such a negative attitude about science.

In addition, van Fraassen's position is contradictory in the context of explanation. According to him, the best explanation works in the case of observable entities (e.g., a mouse in the wainscoting) but it does not work in the case of unobservable entities. But, as Psillos notes, (1996, 41) if the realists' best explanation concept is unwarranted then we can say that Fraassen's empiricist best explanation concept is also unwarranted. For someone can say that constructive empiricists may be choosing an empirically adequate theory from a bad lot of empirically adequate theories. We may have a number of theories about an event and all of these theories may be empirically adequate to some degree. Yet following van Fraassen's bad lot argument, perhaps the 'truly' empirical adequate theory is still unborn. According to Psillos, "it is more likely that the truth lies in the space of hitherto unborn hypotheses." (1999, 217) As a result, constructive empiricists could be accepting an empirically adequate theory from a bad lot. Depending on these analyses, we can draw the conclusion that van Fraassen's bad lot argument in fact goes against constructive empiricism.

Finally, I would like to say that van Fraassen's view leads to skepticism. Scientists try to discover the truth of nature and life. For this purpose they follow different methods, collect a large amount of information, make hypotheses and test these hypotheses. Generally, researchers express a positive attitude towards their hypotheses and they try to discover the truth in these hypotheses. It is true that the available theories or hypothesis do not guarantee that scientists will reach their destination. But there is no room to eliminate the possibility of truth among the present hypotheses. Van Fraassen rejects the possibility of truth in advancing his bad lot argument, and this rejection makes the path of skepticism in van Fraassen's philosophy.

2.4 Pessimistic Induction and Responses to It.

Constructive empiricists claim that some previously successful scientific theories are not true in the present context. Thus, they conclude that we should not be certain about the future of our presently successful scientific theories. In this regard I would like to discuss Larry Laudan's pessimistic induction which is an influential argument against scientific realism. Laudan depends on the history of science to make this argument. According to scientific realists, most of our current successful theories are true or approximately true. But a pessimistic induction vehemently opposes this view. In this respect, Larry Laudan presents historical evidence to refute scientific realism. In the history of science paradigm shifting has been a common phenomenon where old paradigms are replaced by new paradigms. Some theories which were considered as true are replaced by new theories, and now we consider the old theories as false. In this context, Laudan presents a long list of theories that were successful in their field in the past, but at present are considered to be false. His list is:

- the crystalline spheres of ancient and medieval astronomy;
- the humoral theory of medicine;
- the effluvial theory of the static electricity;
- 'catastrophist' geology, with its commitment to a universal (Noachain) deluge;
- the phlogiston theory of chemistry;
- the caloric theory of heat;
- the vibratory theory of heat;
- the vital force theories of physiology;
- the electromagnetic aether;
- the optical aether;
- the theory of circular inertia;
- theories of spontaneous generation. (Laudan 1981, 33)

Citing this long list of past scientific theories, Laudan wants to show that the concept of truth does not make any sense in the context of successful scientific theories. Truth or approximate truth is not a necessary condition for the success of scientific theories. Some theories were successful in their respective areas but they were not true. Very much interestingly, Laudan claims that if present successful theories are true or approximately true then previous successful theories are false. This is true because there are significant differences between present and past theories. Moreover, he claims that our present successful theories may not be true in the future.

Moreover, according to Laudan, "for every highly successful theory in the past of science which we now believe to be a genuinely referring theory, one could find half a dozen once successful theories which we now regard as substantially non-referring" (1981, 35). That is, the unobservable entities that were referred by some previous theories are probably not real and do not have existence. From this historical evidence, Laudan tries to prove that the unobservable entities that are referred to by contemporary successful theories are not real. From here, Laudan suggests drawing the conclusion that presently successful theories are also likely false. So, following Laudan (1981) we can draw the logical form of pessimistic induction in this way:

If contemporary successful scientific theories are true, then previously successful scientific theories are false.

But all contemporary successful scientific theories become in time previously successful theories.

Therefore, contemporary successful theories are false.

Here, I would like to counter Laudan by suggesting that he only offers a partial picture of the history of science. In his long list of scientific theories, he only cites those theories that have had serious problems. He deliberately avoids the truly successful theories of science. To evaluate the contribution of science, we have to discuss both the successes and failures of science. If we examine the history of human civilization then we can easily discern the differences in living standards between our ancestors and us. We use computer technology, lead a comfortable life, and have even sent people to the moon. What does this prove? Certainly these are the indicators of the success of science. But it would be mistaken to consider the success of contemporary science as a miraculous achievement, and unless our scientific picture of the world were correct, we would be forced to say that such success *is* miraculous. The optimist is swayed by these considerations, and thinks that contemporary successful theories are true or approximately true. On the other hand, a pessimist tries to pick up the negative instances from the history of science.

I do not say that scientific theories are always true or the absolute truth. If we discuss the history of science then we see that the claims of anti-realists are partially true.

But this does not make us pessimistic about our present scientific theories or the success of science. If we analyze the nature of science, we can realize that science is a progressive subject. From the history of science we see that sciences are developing day by day. A theory dominates a certain area of science and sometimes it makes a path for a new theory. This is a positive aspect of science; in this way science is enriched. Scientists do not demand that their theories are the final or absolute truth; if they did, science would not have any scope for further development. Moreover, they try to develop their invented theories. In this process they sometimes change their theories. But this does not indicate that previous theories are completely false.

It is true that the pessimistic induction is the basis for a strong argument against scientific realism. But pessimism is not the final result about scientific theories. The different positive contributions of scientific theories to the different aspects of life and nature make us optimistic about science. In this regard, several philosophers such as Philip Kitcher, John Worrall and Stathis Psillos reject Laudan's pessimistic attitude about scientific theories. All of them explain science as a continuous developing process, one that does not stand still. In this continuous process, scientists accept new theories and reject old theories. This rejection does not exhibit pessimism in science. A scientific theory has several parts. In its evolving process, scientists emphasize the useful parts and reject the useless portion. So, to reject pessimism in science, realists should pick up the important, useful and perhaps true parts of a theory. As Psillos notes, "the best way to defend realism is to use the generation of stable and invariant elements in our evolving scientific image to support the view that these elements represent our best bet for what theoretical mechanism and laws there are." (1999, 109)

In the process of rejecting and accepting the different parts of a scientific theory, realists should find out the essential part of a theory. The essential part of a theory may prove that this theory is true or approximately true. For example, Kitcher (1993, 149) notes that there are two kinds of posits in scientific practice -- 'working posits' and 'presuppositional posits.' He defines working posits as, 'the putative referents of terms that occur in problem-solving schemata' and defines the presuppositional posits as 'those entities that apparently have to exist if the instances of the schemata are to be true.' Kitcher considers the ether, the mechanical medium that early theorists claimed was necessary for the propogation of light waves, as a presuppositional posit. It does not play any role in the context of explanation and prediction in the current theory of electromagnetism, despite the fact that James Clerk Maxwell in first developing this theory assumed its existence. Comparatively, the true working posits of ether theory remain (i.e., Maxwell's equations) even if the ether is shown not to exist.

John Worrall's views on pessimistic induction are also relevant in this regard. Worrall tries to refute Laudan's pessimistic induction. In explaining the history of successful scientific theories, he supports an optimistic induction instead of a pessimistic induction. He comments, "structural realism encourages an optimistic induction from the history of theory-change in science, but an optimistic induction concerning the discovery of mathematical structure rather than individual ontology." (1994, 336) Like Kitcher and Psillos he also divides a successful scientific theory into different components -- the essential component and idle component. Thus, he suggests, "no realist should advocate a 'realist attitude' towards all theoretical claims -- even theoretical claims within successful theories." (1994, 336) For among the theoretical entities in different successful theories, some do not play any significant role.

To refute the pessimistic induction Psillos offers various arguments, of which the *divide et impera* move is one. According to this argument, a successful scientific theory may have different parts. The parts do not have equal importance and not every part contributes to the success of the theory; some parts do not play any useful role and are eliminable parts of a successful theory. So realists should not accept every part of a successful theory; they should be selective about accepting parts of a successful theory. This process will help them reject the false part of a theory, where the false part of a theory does not play any active role in the success of a scientific theory. To define the *divide et impera* move Psillos remarks,

> it is based on the claim that when a theory is abandoned, its theoretical constituents, i.e., the theoretical mechanisms and laws it posited, should not be rejected *en bloc*. Some of those theoretical constituents are in consistent with what we now accept, and therefore they have to be rejected. But not all are. Some of them have been retained as essential constituents of subsequent theories. (1999, 108)

In explaining the *divide et impera move,* Psillos cites caloric theory and ether theory. Both these theories were once successful, despite the fact that they postulate entities -- caloric and the luminiferous ether -- that are not real. According to Psillos, the references to such entities are the idle parts of these theories. As a result, they are abandoned in the next development of theories. Still, these theories have some true or approximately true parts that help them to be successful. Scientific realists should pick up the true or approximate true part of a successful theory and should determine the idle part of a successful theory. In this way, they can disprove the pessimistic induction in the context of successful scientific theories.

To conclude this chapter, I would like to say that explanation is an important characteristic of a successful scientific theory and I have argued in favour of this virtue of a scientific theory. In this context I mentioned some criteria that make a hypothesis reliable. At the same time they also work as indicator of a successful scientific theory. I have argued in favour of IBE and tried to show how IBE works in the context of both observable and unobservable entities. Van Fraassen himself uses IBE in proving the existence of mouse. To refute the IBE, Van Fraassen uses the bad lot argument. But we have seen that van Fraassen has failed to refute IBE. Moreover, we have found that a bad lot argument goes against van Fraassen's constructive empiricism and that this argument leads to an unwarranted situation in which the truth is claimed to lie outside the range of presently successful theories. As a result, we can reject the bad lot argument in the context of IBE.

From the above discussion we can realise that scientists discover the truth about nature and life (even though sometimes, or even lots of times, they fail at this). To succeed at discovering the truth, scientists have to go through a process. In this process, we get several activities, such as data collection, hypothesis making and hypothesis testing. Scientists get several kinds of results with their theories -- some of them are false, some are approximately truth and some are true. I differ from the widely accepted view that scientific discoveries are either true or false. Here I would like to suggest that there is room for partial or approximate truth. I would like to say that, although absolute truth is not possible in science, scientists can achieve approximate truth and our present successful theories are closer to the truth than previous theories. This is the progressive character of science. Moreover, the idea of absolute truth is a dogmatic attitude that closes the path of progress in science and contradicts the central character of science. Instead of the concept of absolute truth, the concept of approximate truth makes scientific realism flexible as well as realistic. We can accept this concept of realism.

In the history of science, we see some past successful theories that are not active in the present context. This might lead us to be pessimistic about scientific theories. But this is not the only true lesson about past science -- its opposite side is also true. Some previously successful theories are still working in their areas successfully. This experience helps us to be optimistic about science. There is no scope to deny the importance of the contributions of our previous scientists. Sometimes we see successors receiving help from their predecessors' contributions. In paradigm-based research, we see a group of scientists working for the development of their paradigm. The old paradigm is fully or partially replaced by the new paradigm. But this new paradigm is not new forever. This new paradigm may itself be replaced by another new paradigm. In this way science moves ahead and the history of science is enriched by several contributors. Still, the contributors of the new paradigm receive some information from the previous paradigm. In this changing process of the history of science, we see that some of the claims of successful scientific theories have survived for a long time, that some theoretical entities referred by previously successful theories are real, and that some of the claims of previous scientific theories still serve as a source of information. All of these points should make us optimistic about science.

We have advanced a moderate sense of scientific realism in the context of the *divide et impera move* argument. To refute the pessimistic induction, Psillos presents this argument to show that the idle parts of a successful theory do not play important role in the success of a theory and these can be removed. Thus in being realist about a theory we need not affirm the truth of these idle parts. This moderate sense of scientific realism makes it more acceptable than a hard-core realism that asserts the truth of all parts of a successful theory.

Conclusion

I would now like to analyze the previous chapters and evaluate the arguments of constructive empiricists and scientific realists. In the first chapter I discussed ‘observation’ and ‘the power of observation’. Observation plays an important role for the purpose of acquiring knowledge. In the history of the philosophy of science, we see that various philosophers have contributed to the discussion on observation and the capacity to observe. Once people observed only through the naked eye, but now they use different sophisticated instruments for the purpose of observations -- this is a huge development in the context of observations. To keep pace with this technological development of observations, we see that the literature on the power of observation is enriched by the valuable contributions of different philosophers. In contemporary philosophy, both constructive empiricists and scientific realists contribute to this debate. In my discussion I have tried to show the major arguments of constructive empiricists and scientific realists. In the first chapter of my thesis, I have discussed how van Fraassen rejects instrument-based observations and why he only believes in naked eye observations. He only believes in naked eye observations for the purpose of acquiring reliable knowledge. According to him, we cannot observe a thing through an instrument; we can only observe the images of things through instruments that cannot provide us with reliable knowledge. Constructive empiricists give more credit to naked eye observation than to instrument-based observation.

On the other hand, scientific realists accept both naked eye and instrument-based observation as sources of reliable knowledge. Contemporary scientists do not limit their observation to only naked eye observations. They use different instruments to extend their ability to observe. Scientific realists support instrument-based observation as an important means of acquiring knowledge about nature and life. They try to show that observation is a circumstance-dependent activity -- if we are able to change the circumstances, then we can turn unobservables into observables. For example, we do not see a thing in a dark place. However, we can see it if we bring it under light. A similar idea works in the case of micro-organisms. Once researchers could not observe micro-organisms, nor could they even detect them. But now they are able to observe them using sophisticated instruments. Again, I cannot observe a distant thing clearly by the naked eye but my spectacles help me to see things clearly. All of these instances are working in favour of scientific realism to prove that observation is a circumstance dependent activity.

Depending on only naked eye observations for the purpose of acquiring knowledge, constructive empiricists show a conservative attitude to the domain of knowledge. They confine their research to a certain area and reject knowledge of sub-atomic particles and micro-organisms. But following the history of science, we can say that the domain of knowledge is open-ended and progressive. Constructive empiricists cannot make a limit or boundary of this domain. In this context, we see that the scientific realists' position is very reasonable. They extend their power of observation through different instruments. I have shown in the previous chapters that instrument-based observations are reliable, and that scientists are using different instruments to observe such things as micro-organisms. Moreover, in this context they are successful. As a result, we can say that the scientific realists' view on the power of observation is more acceptable than that of the constructive empiricists.

Finding a demarcation line between observable and unobservable entities is an important mission of constructive empiricists. But we have seen that they cannot make any clear demarcation line between observable and unobservable entities. In this regard, they have chosen anthropocentric observation as the criterion to distinguish between observable and unobservable entities. But we have seen in the above discussion how naked eye observations deceive us and that what is observable with the naked eye needs theoretical explanation to be meaningful. As a result, sometimes we cannot accept naked eye observation as a reliable means of observation without further justification. In the history of science we find that the power of observation changes with technological development, and as a result van Fraassen's demarcation line between observable and unobservable entities is also changeable.

Constructive empiricists express doubt about the knowledge of theoretical entities. In the above discussion I have argued in favour of the mind-independent existence of unobservable entities. The ability to observe and the failure to observe depend on observers and their circumstances. For example, I argued in favour of the existence of a theoretical construct (i.e., refractive index) to explain the phenomenon of refraction. Overall, we see that both observable and theoretical entities exist and that one helps the other to prove their existence. This fact is borne out by the revolutionary change in contemporary medical science. Medical scientists are able to determine the causes of several diseases. Some microorganisms like viruses or bacteria are responsible for certain diseases (such as influenza and dengue) and medical scientists not only discover the causes of these diseases but have discovered the means to prevent them. These activities and their observed successes prove the authenticity of medical knowledge about micro-organisms and prove as well the existence of different micro-organisms.

In my thesis I have discussed IBE and have shown how IBE works in scientific research as well as in our every day activities. Bas van Fraassen, a notable critic of scientific realism, follows IBE in his argument to prove the existence of observable entities (such as the mouse in his wainscoting) but does not use it in the context of unobservable entities. I have discussed in the second chapter of my thesis the NMA and have shown how it works in favour of scientific realism. In contemporary medical science, scientists have discovered several microorganisms and some of them are harmful to human beings and other animals. Medical scientists are working to get rid of these problems and in some respects they are successful. Some of the epidemics that were once considered as the curse of God or some supernatural power have been successfully explained by scientists. Even today, some people consider a tsunami to be a miraculous event or a curse of God. But a tsunami is not a miraculous things or a curse for we can explain the cause of it. There is no scope to consider these occurrences as miraculous in this advanced stage of civilization. If we say that our knowledge of microorganisms, things like viruses or bacteria, is not reliable, then we have to deny the various successes of medical science, such as immunization and vaccination programs. The success of science in different aspects of nature and life would be miraculous if we did not consider our contemporary successful scientific theories as true or approximately true.

To refute IBE, van Fraassen uses his 'bad lot argument'. It is an important suggestion made by van Fraassen to be careful about accepting any theory. No one has doubt the importance of carefully accepting any scientific theory. It is only after a long process of justification that a scientist should accept a theory. Still I would like to say that van Fraassen's suggestion does not subvert the reliability of the knowledge contained in successful scientific theories. That is, we need not follow van Fraassen in rejecting the possibility of reliable knowledge in successful scientific theories and becoming skeptical. In denying van Fraassen's view, that truth lies beyond contemporary successful theories, scientific realists express an optimistic attitude that could easily play a very important role in encouraging researchers to solve different problems and make new discoveries in science.

In my thesis I have discussed several criteria for successful scientific theories and I have explained a realist philosophical view on successful scientific theories. In this regard we have seen some similarities between constructive empiricists and scientific realists. But we have seen that van Fraassen ignores the predictability of successful scientific theories that is an important criterion of successful scientific theories. He defines the success of science from an empirical standpoint. But his analogy between successful scientific theory and Darwin's evolutionary theory does not provide any explanation of the predictability of successful scientific theories. In our discussion on Periodic Table, we saw how Mendeleyev predicted the existence of undiscovered chemical elements and his success in this regard certainly works in favour of scientific realism. It adds credit to scientific realism.

In my thesis I have discussed the aim of science. In this context, van Fraassen says that the aim of science is not truth but rather empirical adequacy. On the other hand, according to scientific realists, the aim of science is truth. In this debate, my position is in favour of a moderate sense of realism that supports that the aim of science as approximate truth. I can explain my position in this way. To begin with, what does van Fraassen mean by truth? Does he indicate absolute or eternal truth in the context of scientific theories? It is clear that scientists do not pursue such kind of truth. Snow is cold and all bachelors are unmarried -- those are absolute truths. No one expresses doubt about them. But scientific theories are not such kinds of truths. It is a fact that scientific knowledge is changeable; science rejects rigidity as regards aims and methods. The idea of absolute truth is a rigid idea and it is not applicable to any changing subject-matter like science. Thus, we have to consider truth in a moderate sense in the context of science. In the history of science, we see that a paradigm works in a particular area for a certain period of time. No paradigm is eternal in the scientific world; previous paradigms are replaced by new paradigms. As long as a paradigm exists, it exists as a source of truth, and we accept a scientific theory as true so long as it corresponds to its subject matter in an appropriate manner. This liberal approach towards scientific theories shows that scientists are not dogmatic about their discoveries. If anyone claims than science provides us with absolute truth, then I would like to say that this is not the aim of science for it is beyond the scope of scientific activities. It is out of human capacity to achieve eternal truth or absolute certainty. In this context, I would like to quote from Bertrand Russell -- according to him, "final truth belongs to heaven, not to this world." (1927, 3)

We have seen that van Fraassen differs with scientific realists about the aims and research areas of science. He restricts the research field to naked eye observations for the aim of acquiring reliable knowledge. He believes that scientists aim only for empirical adequacy. Theories, at best, are said to be empirically adequate and if scientists try to go further than empirical adequacy they take an unnecessary risk for truth. As Ladyman *et* *al*., (1997) note, "certainly the realist takes an extra epistemic risk by believing the background theories to be (approximately) true rather than only empirically adequate" (308). Believing in truth instead of empirical adequacy, scientists cannot show any extra empirical gain (Ladyman 2002, 224). As a result van Fraassen suggests that we not take this extra risk. In this context, van Fraassen says, "there is no argument there for belief in the truth of accepted theories, since it is not an epistemological principle that one might as well hang for a sheep as for a lamb." (1980, 72) This is the main difference between truth and empirical adequacy -- truth requires more information than empirical adequacy.

The possibility of epistemic risk is an interesting objection against scientific realism in scientific research. In claiming that aided-observation leads to knowledge, the scientific realist is taking more of a risk than the constructive empiricist. Comparatively, constructive empiricists are more careful than scientific realists in approaching scientific investigation -- certainly their epistemic caution presents an interesting contrast to scientific realists. Van Fraassen is suggesting that we limit scientists' beliefs to empirical adequacy; scientists should limit their research to observable entities. If anyone extends her beliefs to more than empirical adequacy and she wants to know more than the observable entities, i.e., through instrument-based observations, then there is a possibility of mistake. In this context, scientific realists believe that scientific knowledge about unobservable entities is reliable and that scientific theories are true or approximately true. According to constructive empiricism, such a belief poses an unnecessary risk for scientific realists; it is unnecessary and unproductive to pursue the truth instead of empirical adequacy. But in the above discussion we see that sometimes we get more reliable knowledge about unobservable entities than about observable entities. We have also seen that there is no reason to give more credit to naked eye observations than to instrument-based observations. Moreover, we have seen that naked eye observations may deceive us. So, naked eye observations are epistemically risky as well.

Constructive empiricists also express strong reservations regarding the inference from observable actions to unobservable entities. Here they are engaging the classical inductive debate. Depending on some present available instances, scientists draw a conclusion about unknown instances. They take a leap to the unknown. For example, suppose we observe some black crows and from these observations draw the conclusion that all crows are black. This is an inductive leap to a much stronger claim. Similarly, depending on some observable actions of unobservable entities, we might infer the existence of some unobservable entities. This is also a leap and such a leap is part and parcel of scientific research. Someone might describe this as a limitation of research or scientific knowledge. Someone might say that there are white crows in the deep forest and, to be sure, no one can prove or disprove it. It is not possible for a human being to see all the crows in the world. Still, observing some black crows we draw the conclusion that crows are black and as long as we do not see any white crows we can accept this statement as true. Here we take a leap. But if anyone considers this leap as too risky in the context of acquiring reliable knowledge then I would like to say that this risk is essential to the progress of science. Scientific realists want to know the truth in scientific theories, so they take such kinds of risk. According to Psillos,

> in taking this extra risk, the realist wants to know more about scientific theories than the constructive empiricist. So the latter is unjustified in suggesting that this risk is not worth taking on safety grounds for two reasons: first, this is also to take an inductive risk which goes beyond current evidence; and second if risk is the price for pushing back the frontiers of ignorance, then, as the motto of this paper suggests, it is a price well worth paying. (1996, 42)

At last I would like to say that science is a progressive concept. Its discoveries make our lives easier; science makes it easy to acquire knowledge. In the history of science, we find some scientific discoveries that have been proved false but we cannot deny the success of science. Science is a human activity and so it has some limitations. So under the umbrella of science, no one can say that it is the final or absolute truth. To say that science currently has the absolute truth is a dogmatic attitude and there is no scope for dogmatism in science. Science is open-ended for further development and scientists are open-minded to accept new theories. This is the way of progress in science and scientific progress may continue indefinitely. The debates between constructive empiricists and scientific realists are progressing and in this process we are getting interesting arguments, concepts and theories. In my thesis, I have tried to show the existence of observable and unobservable entities in our world. If we want to know our world comprehensively then we have to explore both of them. But constructive empiricists rely only on the observable entities. In fact, not only the naked eye but also instruments help us for the purpose of observations. Scientific realists accept instrument-based observation as a reliable source of knowledge. As a result, they are getting more opportunities than constructive empiricists to know life and nature. We saw that Laudan's pessimistic induction is skeptical about scientific knowledge. On the other hand, a realist's optimistic attitude about scientific theories can play a positive role in their development. The realists' 'NMA' plays an important role for successful scientific theories in achieving a firm position in the domain of knowledge. The success of medical science is also a strong argument in favour of scientific realism. Considering all these aspects of scientific realism, we can give more credit to scientific realism than to constructive empiricism.

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