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STRUCTURAL REALISM VERSUS ENTITY REALISM: A CRITICAL EVALUATION

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To my wife, Brij

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ABSTRACT

The two partial scientific realist positions, called structural realism and entity realism make conflicting claims about our knowledge of the unobservable world. They appear to be mutually exclusive and create a tension in the scientific realist camp. In this dissertation I have attempted to reconcile the two as follows.

In the first chapter, I state the problem and set the objectives of the study. The second chapter gives an overview of the scientific realism debate, focusing on the epistemological dimension. I bring out the challenges facing scientific realism. The third chapter surveys the development of structural realism and explains the stance put forward by John Worrall in defense of scientific realism. I examine his arguments and show that they are valid only where the structural part of a theory can be expressed mathematically in classical physics. Worrall has appealed to history of science to argue that we cannot know the unobservable theoretical entities. I utilize the same case-study from optics to argue that the unobservable entity ether was never an accepted and empirically adequate theoretical entity.

The fourth chapter presents the arguments put forward by two entity realists - Nancy Cartwright and Ian Hacking. They have argued that the theoretical entities, which cause a phenomenon, exist; and by establishing the causal link, we can know them. Further, the entities, which can be interfered-with and manipulated, can be known and this knowledge is independent of the theories. I have argued that knowledge of

unobservable causes is parasitic on theories putating them. Entity realists` arguments are valid only where causal links can be theorized and then established experimentally. Interference and manipulation reveal certain aspects of the nature of the entities and are not possible for all types of unobservable entities.

The fifth chapter brings out the tension created by structural realism and entity realism. After analyzing their arguments, I show that they do not apply to the whole enterprise of science. In some areas of the enterprise, beliefs about unobservables are justified by mathematization whereas in some other areas by manipulation and by showing causal connection. Thus the two schools of thought do not contradict each other and can coexist. The tension created by the two partial realist positions, is thus shown to be a pseudo- problem and dissolved.

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OPERATIONAL DEFINITIONS

1. Scientific Theory

A Scientific Theory refers to an unproven hunch or a conceptual device for systematically characterizing the state-transition behaviour of systems.

2. Theoretical Entity

A theoretical entity is a concept devised to account for the observed phenomena.

3. Scientific Observation

Scientific observation is more than a physical act of sensation, it must be an epistemic act as well, with sufficient meaning and credibility to contribute to knowledge.

4. Scientific Realism

Scientific Realism asserts that the objects of scientific knowledge exist independently of the minds or acts of scientists and that the scientific theories are true of that objective world.

5. Scientific Anti-realism

Scientific anti-realism asserts that science does not tell us anything about the unobservable part of the world.

6. No Miracle Argument (NMA)

Science is a successful enterprise. It would be a miracle if the scientific theories, on which science is based, were false.

7. Pessimistic Meta-induction Argument (PMI)

Many empirically successful and accepted theories of the past have been found to be false. Our current accepted theories are empirically successful and by inductive reasoning, may be found out to be false too.

8. Under determination of Theory by Evidence (UDTE)

The empirical evidence available, can be accounted for by more than one, mutually incompatible theories.

9. Structural Realism

Structural realism is a view that science can tell us about the structural part of the unobservable world.

10. Entity Realism

Entity realism is a view that the unobservable theoretical entities exist and that we can know them by scientific method.

CHAPTER ONE

INTRODUCTION

1.0 Background to the Study

The aim of science is to increase our knowledge and understanding of the world we live in. Science is distinguished from other fields of knowledge by its empirical method which proceeds from observation, experiment and theory. A scientific theory is put forward to account for observed phenomena and in general, is made up of two parts. One part consists of unobservable, theoretical entities for example, molecules, electromagnetic waves, atoms and ether, the second part is the structural part which tells how the entities are configurated and behave.

There is an ongoing debate between scientific realists and anti-realists over the knowledge that science can provide (as detailed on page 26 of this dissertation). Scientific realists are of the opinion that science, through its theories, tells us a true story about both, the observable and the unobservable parts of the world and that our successful theories are, at least, approximately true. The scientific realists invoke the success of science in favor of their position. They claim that the success of science would be a miracle if the scientific theories were not true. On the other hand, the anti-realists hold the view that science can tell us about the observable part of the world only and that our belief in scientific theories should be limited to what they tell us about the observables. Some anti-realists take the scientific theories as mere instruments for systematization and prediction of observable phenomena, without attributing reality to the invisible entities they posit.

The debate between scientific realists and anti-realists is far from settled. It seems unlikely that they have any final, knockdown arguments against each other. Two partial realist positions have been proposed to defend scientific realism. These are entity realism and structural realism. Some philosophers of science consider these two as among the most promising formulations of scientific realism. Entity realists claim that the unobservable theoretical entities that cause a phenomenon and can be manipulated do actually exist and can be known. It is important to note that the entity realists do not commit themselves to judgments concerning the truth of scientific theories. Structural realists on the other hand, commit themselves only to the structural contents of scientific theories and not to the truth of the entities.

The two views defend scientific realism by claiming that some unobservable component of a scientific theory can be known. The two scientific partial realist positions are incompatible with each other and could hardly disagree more as one commits to the theoretical entities while remaining agnostic about the structure and the other position is committed to the structure only, while remaining agnostic about the entities. Niiniluoto (1999,139) says that they are "diametrically opposite".

Structural realism is the philosophical view developed to defend scientific realism against pessimistic meta-induction argument and also to account for success of science. The former is the argument that many successful theories of the past have been falsified, so our current accepted theories may also be false. Structural realism blames theoretical entities for the falsification of theories and credits our knowledge of the unobservable structure for the success of science. John Worrall, pioneer of the program quotes an episode from the history of science where the structural part survived the radical theory-change but the entity was found not to exist. But there are examples from history of science where the theoretical entities survived the theory-change whereas the structure underwent many changes. For example, the structure theorized about atom has undergone many changes since Rutherford-Bohr Model (Crump, [2001]229) whereas the theoretical entity they all refer to, is the same. Structural realism emphasizes that the structural part of a scientific theory, which is expressible mathematically survives radical theory-change. But the structural parts of all the scientific theories are not mathematical.

Entity realism was inspired by the actual scientific practice of experimentation and observation under controlled conditions using technology. It appeals to manipulation as evidence for the existence of theoretical entities but manipulation affirms only the manipulated aspect and not all the attributes of an entity. For example, the entity carrying light has been manipulated by refraction, diffraction and polarization and believed to be an electromagnetic wave. But, there are circumstances when it behaves like particles (Gribbin, [2002] 430). That means manipulation has confirmed that there is an entity, but knowledge of the entity has not been revealed. Evidence for the ontological existence of theoretical entities is necessary but not sufficient for realism. Moreover manipulation of an entity or by an entity can be established in those areas of science where appropriate experiments can be conducted.

1.1 Literature Review

Twentieth century gave birth and rebirth to different types of realisms and anti-realisms. Beginning of the century saw a very general form of realism by Roy Wood Sellars (in Hooker 1987), formed as a reaction to idealism of nineteenth century. In the second quarter of the century quantum and relativistic revolutions took place in physics giving rise to logical positivists' version of anti-realism. Realism was revised by arguments put forward by philosophers like Karl Popper, Grover Maxwell and J. J. C .Smart.

Almost during the same period, the historically motivated works of Thomas Kuhn and Paul Feyerabend put forward new versions of anti-realism. In the seventies the main realist voices were of Hilary Putnam and Richard Boyd. In the eighties Bas van Fraassen and Larry Laudan refined the anti-realist arguments and presented new challenges for the scientific realists.

One of the major challenges to scientific realism is the pessimistic meta-induction argument according to which, so many of the past scientific theories have failed, so our current theories may also fail.

Larry Laudan (1981:158) gives a very influential argument with the following structure:

1. There have been many empirically successful theories in the history of sciences which have subsequently been rejected and whose theoretical terms do not refer according to our best current theories.
2. Our best current theories are no different in kind from those discarded theories and so we have no reason to think they will not ultimately be replaced as well.

So, by induction we have positive reason to expect that our best current theories will be replaced by new theories according to which some of the central theoretical terms of our best current theories do not refer and hence we should not believe in the approximate truth or the successful reference of the theoretical terms of our best current theories.

Jules Henri Poincare (1854-1912), a French mathematician and philosopher of science noted that failure of scientific theories does not mean the failure of scientific enterprise and that scientific theories are fallible. He argued that acceptance of a scientific theory means only, that it is empirically adequate and explains the phenomena. When this theory is falsified and replaced by a new theory, this shows that the new theory also saves and explains phenomena. Poincare says "Fresnel's theory enables us to predict optical phenomena as well as it did before Maxwell's time" (1902:173). He suggests that the scientific theories are not merely useful tools, instead, the successful ones can tell something about the unobservable world. Combined with Kantian views about the nature of arithmetic and group theory we can put Poincare's ideas as follows:

A. The falsified theory, once accepted, was empirically adequate and successful. It told us something about the unobservable (metaphysical) world over and above being empirically adequate.

B. According to Immanuel Kant (1724-1804), mathematical knowledge is a-priori and transcendental.

The structural part of many scientific theories can be expressed in mathematical language and that can be the part, which:

(a) Tells something about the unobservable (metaphysical) world and

(b) Transcends theory-change.

Poincare's idea, paved the way for structural realism.

John Worrall introduced structural realism in 1989. It is the view that we should not accept scientific realism, which asserts that our best theories describe the unobservable entities correctly. Rather we can commit ourselves only to the mathematical or structural content of our theories, because there is retention of structure across theory-change. And this can be regarded as the manifesto of scientific structural realism in its current form.

Worrall gives the example of theory-change in optics from Fresnel's ether to Maxwell's electromagnetic field and says:

> There was an important element of continuity in the shift from Fresnel to Maxwell - and this was much more than a simple question of carrying over the successful empirical content into the new theory. At the same time it was rather less than a carrying over a full theoretical content or full theoretical mechanism (even in "approximate" form).... There was continuity or accumulation in the shift, but the continuity is one of form or structure, not of content (1989:117)

Maxwell's theory of electromagnetic field replaced Fresnel's theory for the nature and propagation of light, while retaining its structure, but the theoretical entity ether was completely replaced by the theoretical entity ....wave.

Structural realism is considered as the best of both worlds because of two reasons. Firstly, it enjoys the no-miracle argument for scientific realism in its favor. Success of science is not a miracle because, according to structural realism, science, through its methods can tell us a true story about the structure of the unobservable world, the reality. Secondly, it counters the pessimistic meta-induction argument against radical theory-change by claiming that the structural part of a theory transcends the theory-change and is retained in the new theory. Falsification of an accepted theory is attributed to the unobservable entities.

But Ladyman (1998) has raised the question of whether Worrall's structural realism is intended as a metaphysical or epistemological modification of scientific realism i.e. whether the theoretical entities posited in scientific theories are eliminated or just unknowable. Worrall (1989) has not answered the question directly but he has cited Poincare, who in turn says "The true relations between these real objects are the only reality we can attain" (Poincare [1905] 1952, 161). That means structural realism accepts the existence of 'real objects', the unobservable entities. Worrall points to the constant revision of the intrinsic nature of these elements of reality. According to Worrall, it is our 'false' knowledge of these entities that explains the falsification of past accepted theories.

We can reach the above conclusion about the entities, even without referring to Poincare. Both scientific realism and anti-realism are the philosophic positions within philosophy of science and are against idealism. Both believe that there is a mind-independent world and that we, the epistemic community can know the observable part of this world. The difference in belief is epistemological and is about the unobservable part of the world. If Worrall's structural realism is metaphysical, that is, the unobservable entities do not exist then he is an idealist, which is not the case. Yes, at the theoretical level Worrall suggests that the theoretical entity posited in a scientific theory does not exist, that is, does not refer to the "true" real entity of the world. For example, flogiston, ether and caloric, as theorized, do not exist. It is the knowledge of the true, unobservable entity that Worrall doubts. Therefore Worrall's structural realism is epistemic. Psillos (2006) calls it 'restrictive structural realism'. Russell (1927) and Carnap (1928) took the extreme view that we cannot know the individuals and their properties but we can know the structure of their relational properties. They argued that science tells us only about purely logical features of the world.

As mentioned earlier, Poincarean structuralism incorporated Kantian ideas. He thought that the putative theoretical entities were Kant's noumena or *things in themselves*. Ponicare revised Kant's view by suggesting that the noumena can be known indirectly through the relations into which they enter. Zahar's (2001) structural realism is of a Kantian form according to which science can never tell us more than the structure of the noumenal world and the nature of the entities are epistemically inaccessible to us. Jackson (1998) similarly argues that science only reveals the causal/relational properties of physical objects and that "we know next to nothing about the intrinsic nature of the world. We know only its causal cum relational nature" *(ibid* 24).

Redhead (2001a) cites examples where the structural continuity between old and new is difficult to maintain. Regardless of the discontinuity Redhead notes an apparent affinity between old and new structures:

> Qualitatively new structures emerge, but there is a definite sense in which the new structures grow naturally, although discontinuously, out of the old structures. To the mathematician introducing a metric in geometry, or non-commutativity in algebra are very natural moves. So looked at from the right perspective, the new structures do

> seem to arise in a natural, if not inescapable way out of the old structures (*ibid* 19).

In other words, if, like the mathematician, we see how natural the leap is from old to new structures, then we realize that the discontinuity is not debilitating.

A form of ontic structural realism has been proposed by Howard Stein (1989: 57). According to Stein, if epistemic structural realism is the claim that all we know is the structure of the relations between things and not the things themselves, then the ontic structural realism is the claim that there are no 'things' and that structure is all there is. Bas van Fraassen (2007) calls it 'radical structuralism'. The view that there are no individuals but there are relational structures is called eliminative structural realism by Psillos (2001). It is criticized on the grounds that there cannot be relations without relata. Chakravartty says "one cannot intelligibly subscribe to the reality of relations unless one is also committed to the fact that something are related" (2007: 39).

We can understand the issue of ontological structural realism by an example from modern physics. Molecules were considered as unobservable individual entities and were later found out to be structures of individual entities, atoms. Atoms were found out to be structures of individual electrons, protons and neutrons. Electrons are now known to be waves around the nucleus of atoms; protons and neutrons are taken as combinations of further sub-atomic entities like hadrons and bosons which may, in future be found out to be just structures or waves, i.e. disturbances and not entities. The subject is of current heated debate for philosophers and scientists alike.

Structural realism faces many objections. For structural realism to hold, a pre-requisite condition is that there should be a distinction between our ability to know the structure and our ability to know the nature of the world. Psillos (1995: 31) says "the nature and the structure of a physical entity form a continuum". Hence structural realism is either false or collapses into traditional realism.

Psillos' objection can be understood in terms of scientific concepts. Scientific theories propose unobservable theoretical entities and their structures to explain the observed phenomena. These entities and structures are concepts and there is no distinction between our epistemic abilities of conceptualizing between the two. That means, the nature and structure of the entities can be distinctly theorized. Scientists then design experiments to confirm if the posits refer.

Psillos' objection can also be countered by claiming that first order properties of an unobservable entity describe its material or intrinsic nature and second order properties describe its structure. And further that the two sets of properties do not overlap.

Another objection to structural realism is that the mathematical structure is often lost in theory change too. Post (1971: 229) says that the empirical content of a theory is retained in the successor theory, whereas the structure may undergo changes. In fact, the structural parts of all the scientific theories are not expressible mathematically.

So, the structural realist's claim that it is the mathematical part of scientific theories that transcends theory-change does not hold.

Bas van Fraassen (1997) has vehemently attacked both the epistemic and ontic forms of structural realism, arguing instead for an empiricist version of structuralism, which he aptly calls 'empiricist structuralism'. He agrees with Worrall that there is a preservation of structure through theory-change, but argues that the type of structure involved, is the structure of the (observable) phenomena, not the structure of the unobservables (1997: 30). In van Fraassen's eyes there are two realms of scientific investigation: (1) the phenomenon (2) the mathematical structures. We represent the structure of the phenomenon with the help of mathematical structures.

Van Fraassen claims that the empiricist can explain how and why the earlier theories were successful. Instead of the realist explanation that requires old theories to have latched on to the structure of the unboservables, his explanation requires that the new theories imply "approximately the same predictions for the circumstances in which the older theories were confirmed and found adequately applicable" (*ibid*). This, according to van Fraasen, doubles up as a criterion for theory acceptance. That is, a new theory must at least be able to make approximately the same confirmed predictions as the old one. It also satisfies the no miracles intuition, continues van Fraassen, without making the success of science a miracle, "because in any theoretical change both the past empirical success retained and new empirical successes *were needed as credentials* for acceptance" (*ibid* 25) [original emphasis].

The mathematical structure of the phenomena is not accounted for by Van Fraassen's empiricist explanation. Worrall attributes the mathematical structure to unobservable reality, which explains the structure of all similar phenomena. Worrall's assertion is strengthened by the argument of unification of theories. The empiricist is satisfied with empirical adequacy of the theory whereas the realist attempts to know the underlying causes which explain more than the phenomenon at hand.

Another view that attempts to defend scientific realism is entity realism. Entity realism is a moderate form of scientific realism. Its adherents hold that one can believe in some of the unobservable entities postulated by our best scientific theories, while not believing in everything that the theories say. Nancy Cartwright (1983) argues that we can be compelled to believe in those entities that figure essentially in causal explanations of the observable phenomena, but not in the theoretical explanations that accompany them. For example the statement: "a change in pressure is caused by molecules impinging on the surface of a container with greater force after heat energy introduced into the container increases the mean kinetic energy of the molecules " makes no sense unless we really believe in the existence of molecules. According to the position of entity realism, you have offered no explanation at all if you say "for all we know molecules might not really exist, and the world simply behaves as if they exist."(Cartwright1983:35).

Theoretical explanations, on the other hand, which merely derive the laws governing the behavior of those entities from more fundamental laws, are not necessarily to be believed. Cartwright argues that scientists use different and incompatible theoretical models in experimental situations and they cannot be committed to the truth of all those models. However, scientists do not admit incompatible causal explanations for the same phenomenon; that is because, a causal explanation cannot explain at all unless the entities that play the causal roles in the explanation exist.

The thesis about explanation is that explanations can either cite causes or can be derivations from fundamental laws and the inference rule states that one cannot endorse a causal explanation without believing in the entities that play a role in causing the phenomenon. Cartwright rejects the rule of inference to the best explanation but accepts a rule of inference to the most probable cause.

The argument for entity realism, as proposed by Cartwright depends on the justification of inference to the most likely cause, that is, on the fact that it is reasonable to accept the most likely cause as actually existing. It is here that the main problem for entity realism emerges. To argue for the existence of a cause, we have to designate that cause by means of the causal explanation. But how do we decide whether we have reasonable grounds to accept the causal explanation which designates that cause as a theoretical entity? Bas van Fraassen (1980) rejects the notion that a causal explanation cannot be acceptable unless the entities it postulates exist. A constructive empiricist can reject Cartwright's arguments since he holds a different view of what scientific explanation consist in.

Ian Hacking (1983) takes a different route in arguing for an entity realist position. He argues that the mistakes that Cartwright and van Fraassen both make are in concentrating on scientific theory rather than experimental practice. His approach is "Don't just peer, interfere", and "If you can manipulate them, they must be real" (Hacking 1983: 167).

Hacking (1985) argues that what convinces experimentalists that they are seeing microscopic particles has nothing to do with the theory of those particles or how a microscope behaves but that they can manipulate those particles in very direct and tangible ways. His arguments can be put as follows:

a) The ability to see through a microscope is acquired through manipulation. That means manipulation causes cognitive changes that give us new perceptual abilities.
b) We believe what we see because by manipulation we have learnt the process of converting "unobservable" to observable.
c) Our belief in the instrument is enhanced because we can invent new and better ways of seeing. The fact that different instruments give the same visual results gives us additional reasons to believe that what we are seeing is real. This is an argument from coincidence. i.e. wouldn't it be a miracle if all these independent viewing techniques shared stable features and those features were not really present?

The argument is that we don't see *through* a microscope, we see *with* a microscope (italic as in original). That is something that must be learnt by interacting with the microscopic world, just as ordinary vision is acquired by interacting with the macroscopic world around us. For example, if we notice something like a snake, by the roadside, how do we confirm if it is a reptile or a rope or a branch of a tree looking like a snake? By interacting; i.e. by throwing a stone at it or prodding with a stick and waiting for a reaction.

A high resolution microscope does not just enlarge an entity to be observed directly. It uses some hypothesis to convert the unobservable entity to some observable phenomenon. The new observable phenomenon is supposed to be causally linked to the unobservable entity.

Entity realism suggests that it is rational to accept a causal explanation as true whenever we have good reasons to assume that we use the causal properties of hypothetical causes to interfere with other hypothetical parts of nature. But the question whether we actually have good reasons to believe that we use the causal properties of hypothetical entities to interfere with other hypothetical parts of nature is still not settled.

Morrison (1990) points out that entity realism addresses only the metaphysical question and not the epistemological question. The thesis that we can know about what exists in the world through the theoretical entities, without knowing how those entities are structured or behave is not convincing. For example, knowing that all chemicals are made up of molecules and not how the molecules interact does not tell much about the chemicals.

Another argument against entity realism is that the theoretical entities for whose existence Cartwright and Hacking are arguing are unobservable. Different scientists could be referring to different entities. Herman (2005) brings out this tension between epistemological and ontological claims of theoretical entities. He suggests that the entities can be referred by their empirical derivatives. But Herman's suggestion for referring cannot hold because it is a hypothesis that suggests an entity and its empirical derivatives. If we use the empirical derivatives to refer the entity, we are arguing in circles. Moreover, a hypothetical entity can have more than one empirical deductions and that brings us back to the original problem of referring.

Andre Kukla (1998) says that manipulability of an unobservable entity can be understood from an instrumentalist view. Hacking's (1983) argument that "if you can spray them, they are real", has the weakness of the other traditional realist arguments. Nibodium ball sprayed with electrons behaves "as if" it is sprayed. Kukla asserts that Cartwright (1983) weakens the realist claim from truth of a scientific theory to the truth of its entities, but the weakness of evidence remains. He says "the desired conclusions are dished out as naked posits" (*ibid* 90).

Structural realism faces an argument based on the human capability to imagine and that argument can be extended to entity realism and throws a new light on scientific realism. Ernam McMullin says "imaginability must not be made the test for ontology" (1990:14). In other words, if we cannot imagine something, it does not mean that it does not exist. But that cannot be avoided. A scientific theory is proposed to account for the observed phenomena. The unobservables in the theory are "imaginations". The imagined unobservable entity, that is used causally in an experiment or considered as cause of a phenomenon is argued as 'existing' ontologically by entity realists. The unobservable entities that cannot be imagined (yet) or have not been imagined, have not been argued for. It does not mean that such entities do not exist or cannot exist. McMullin's argument therefore is that the entities that were imagined may not be existing, but that does not mean that we cannot imagine the true entities, which may be found to be existing.

Structural realists' claim that we cannot "know" the theoretical entities is the claim that we cannot have "justified true belief" in such entities. Let us analyze this statement further. Belief is provided by imagination of such entities (and even structures). Existence of such unobservables is necessitated by the explanation they provide for the observed phenomena. Scientific realists take inference to the best explanation argument for the existence of unobservables. Scientists justify the belief in the imagined unobservables by experimentally testing the observable derivatives of the hypotheses. For example, the electrons from an electron gun behave as suggested by the theory about electrons. For another example, the theory about ether suggested that the speed of light should be different in different directions; experiments showed the negative result and the entity ether was dropped.

Conventional scientific realism is the philosophical position that the epistemic community can imagine the true, unobservables, and further that scientific method can justify such beliefs. Structural realists claim that humans can justifiably imagine only the structure of the world and they argue for their position by showing examples from history of science where the imagined entities were actually non-existing. Entity realists argue for their position by stressing the experimental method which confirms the causal powers of the imagined theoretical entities, and hence justifies the belief in their existence.

Another interesting development has seen the reconciliation of structural realism with entity realism. For example, Anjan Chakravartty (1998) has sought to bring the two together under the banner of a new position, which he calls 'semi-realism'. He argues that the properties we detect in experiments should be central to both accounts. Commitment to the existential claims of entity realism, says Chakravartty, can be achieved only through relying on relations between detectable properties. Conversely, these relations, which are the focus of structural realists, contain substantive information about entities. Thus, he concludes, properly understood entity and structural realism "entail one another, they are, in fact, one and the same position: semirealism" (Chakravartty 1998: 407).

But Chakravartty does not address the conflicting assertions of structural realism and entity realism. He does not attempt to reconcile the two. Instead he dilutes the entity realists' claim of knowledge to that of detection. Detection, he claims, uses the structural properties of the entities. Therefore it is the structure of the unobservable world which is revealed by the entity realists' arguments. Structure between the detected entities is claimed as the true structure. The semi-realist position does not address the anti-realist and structural realist arguments against our knowledge of the entities. It does not attempt to alleviate the entity realists' worries about the truth of scientific theories.

Both the partial realist positions have defended scientific realism by arguing that something in the unobservable world can be known. Philosophers of science have critiqued the validity of their arguments independently. However the conflicting assertions made by the two positions, have not been addressed. No attempt has been made to confirm or deny if the two can co-exist. There is need to evaluate their arguments in light of those of their adversaries.

As the foregoing literature review clearly demonstrates, structural realism and entity realism have generated debate. Views on the two positions vary from Niiniluoto's (1999) suggestion that these are diametrically opposite and have nothing in common to Anjan Charkravartty's (1998) opinion that the two actually entail each other. The debate is far from settled and is taking new dimensions.

Tension exists between the structural realists and entity realists. Indeed the arguments put forward for the two positions are not decisive and seem to be rather selective. There is need to evaluate the arguments and counter-arguments put forward for the two positions further and to make them address each other. This dissertation is a modest contribution to the debate.

1.2 Statement of the Problem

In its current form, structural realism is claimed as the best of both worlds. It explains the success of science by arguing that we can know the structure of the world. It endorses the pessimistic meta-induction argument and attributes the falsification of past accepted theories to the theoretical entities. Entity realists argue against the explanatory and predictive powers of scientific theories as justification for their truth. Instead they argue that if an unobservable entity causes a phenomenon or can be manipulated, then it exists and can be known.

The structural realists believe that we can have epistemic access to the structural part of the world and further that we cannot know the unobservable entities. Entity realists on the other hand believe that we can know the unobservable entities with certainty and that the scientific theories may be false.

The two partial realist positions defend scientific realism by claiming that we can know something about the unobservable world, but they are mutually exclusive and create a tension within the scientific realist camp. The two appear to be diametrically opposite. The question that this thesis seeks to answer is: Can the two positions be reconciled?

1.3 Research Objectives

This study is an attempt to dissolve the tension created by the two views within scientific realism. More specifically, the objectives of the study are:

1. To bring out the challenges facing scientific realism and to trace the history of the two partial realist positions.
2. To analyze and evaluate the arguments proposed by structural realists and entity realists to defend scientific realism.
3. To exhaustively explain the tension created by the arguments proposed for the two partial realist positions.
4. To dissolve the tension within the scientific realist camp.

1.4 Scope of the Study

This study focuses on the conflicting epistemic claims made by the two partial realist positions of structural realism and entity realism. The claims of the two positions lie between scientific realism and anti-realism. John Worrall, Nancy Cartwright and Ian Hacking are the philosophers of science, who have initiated the two positions in the current form. This research will present and analyze their arguments within the realist-antirealist debate.

1.5 Research Hypothesis

Although structural realism and entity realism make conflicting claims, the two can be reconciled. The tension can be dissolved by critically analyzing and assessing their arguments and showing that the former appeals to the history of science and mathematics whereas the latter appeals to causality and manipulability. The two take selected view of the scientific enterprise.

1.6 Methodology

This is a library based study and is carried out through the consultation of written sources. It involves a critical survey of both, the primary works written by the proponents of structural realism and entity realism, namely, John Worrall, Nancy Cartwright and Ian Hacking, and the various criticisms of their views. Errors have been avoided by evaluating the arguments of the proposer and the counter-arguments by their critics.

The philosophical material of the two views is analyzed and examined for two purposes:

(a) To rationally reconstruct the ideas and thoughts of the thinkers by identifying the arguments adduced.

(b) To logically demonstrate the strengths and weaknesses of the thinkers' reasoning. This is achieved on the basis of reconstructed ideas, their limitations and scope.

The criticism is purely qualitative. It enables us to determine the strengths and limitations or consistencies and inconsistencies in the arguments, with regard to the concepts under investigation.

The synthetic method of isolating and deciphering in a systematic way is applied to appraise the views of structural realism in light of the arguments for entity realism and vice versa.

The two positions of structural realism and entity realism have been proposed with the backdrop of scientific realism. Therefore the demands of realism are taken into consideration while evaluating the arguments put forward by the two positions.

CHAPTER TWO

REALISM VERSUS ANTI-REALISM

2.0 Introduction

A key question in the philosophy of science is epistemological: what kind of knowledge of the physical world does science provide? Answers to the question divide philosophers of science into two: realists and anti-realists. Scientific theories posit a number of unobservable entities and their structures. The realists believe that we can know those theoretical posits and that our successful theories are at least approximately true. The anti-realists, broadly speaking, do not commit to the existence and knowledge about the unobservables.

Structural realism and entity realism are partial, scientific realist positions. The former, is the position that we can know the structural part of the unobservable world and not the entities. The latter, however is the position that our epistemic access to the world, so far as the unobservable part is concerned is restricted to the entities and that the theories that posit these entities, may not be true.

This chapter is devoted to understanding the current debate between scientific realists and anti-realists. The main arguments for the two positions are brought out and explained, thus setting the stage for the two partial realist positions.

2.1 The origins of the debate

There is a very old debate in philosophy between two schools of thought: idealism and realism. Idealism is the philosophy that the world consists of ideas in the human mind. Realism, on the other hand is the view that the physical world exists independently of human thought and perception. The enterprise of science requires us to believe in the independent existence of the physical world and therefore realism and not idealism is the mainstream philosophy of science. Scientific anti-realists are realists only about what is observable in the world.

Roy Woodsellars (Trelo, 1966) proposed critical realism as a reaction to the idealism of nineteenth century. Beginning of the twentieth century saw many accepted theories getting falsified. Quantum theory and the theory of relativity revolutionized physics. Scientific theories were understood as mere instruments. Philosophers' belief in the metaphysical positions declined and logical positivism flourished. But logical positivism could not account for all the new developments in science. For example, there was increasing evidence of existence, nature and structure of theoretical entity, atom. It was after the middle of the century that philosophers like Karl Popper, J. J. C Smart and Grover Maxwell attempted to resurrect scientific realism.

Karl Popper showed that belief in scientific theories is not derived from induction; rather it is derived from falsification. By the process of elimination of errors, the theories come closer to the truth. Around the same time, scientific realism was attacked with arguments from the history of science by Thomas Kuhn. Kuhn attempted to show that the progress of science is only a shift in paradigms. Hilary Putnam and Richard Boyd kept the debate between scientific realism and anti-realism alive by arguing for realism. In the early eighties Bas C. van Fraassen proposed a version of empiricism called constructive empiricism, as the anti-realist challenge to the realism. Van Fraassen considered scientific activity as that of constructing a scientific image of the world and not that of discovering the truth.

2.2 The debate

The debate, as it is carried out today, and parts of which will be evaluated in this dissertation, is derived from the developments in the last three decades. The current debate is very varied and philosophers of science differ on many aspects. In this dissertation, scientific realism will be taken to mean the following:

1. The mind-independent world exists.
2. We, the epistemic community, can know the world.

Number two above implies that scientific statements have truth values. That the words used in the scientific theories have literal meaning and the truth or falsity of the scientific statements can be determined by scientific methods.

In the present context, the debate between scientific realism and anti-realism is broadly based on the following theses.

R1. We can have knowledge of the observable aspects of the world.

R2. We can have knowledge of the unobservable aspects of the world.

Grover Maxwell's (1962) is the main realist voice for observable-unobservable aspects of the world. Most realists concur that there is a continuum from the observables to the unobservables. It is not possible to draw a clear line of demarcation between observable and unobservable. For example, there is a continuous series: looking through a vacuum, looking through a windowpane, looking through a lens, looking through a low powered microscope, looking through a high powered microscope etc. The current anti-realist reply to this continuity is by van Fraassen (1980:15), who says that the observable-unobservable distinction, though vague is still usable and retorts that hair-loss is a continuous process, still we do distinguish between bald and hairsuit people. Van Fraassen defines observable as:

> x is observable if there are circumstances which are such that, if x is present to us under those circumstances then we observe it (*ibid*, 16).

Anjan Chakravartty (2007) proposes to shift the debate from observable-unobservable for knowledge, to detectability. He says that detection with the help of scientific instruments warrants belief in the theoretical entities and processes. His position will be explained and discussed later in this dissertation.

Scientific realism and anti-realism are discussed in detail in the following sections. From the arguments for and against the two, the main challenges to scientific realism are brought out.

2.3 Scientific Realism

Observablity and knowledge

Broadly speaking scientific realism is a thesis, which is conjunction of R_1 and R_2 (as defined on the previous page). That means, according to scientific realists, we can have knowledge of both the observable and unobservable aspects of the world. Observability is itself controversial. What we observe depends upon two factors. One is our physiology, (e.g. the makeup of our eye) and second is theory-dependence, which has been addressed by Pierre Duhem ([1914] 1991), T. S. Kuhn ([1962] 1996), N. R. Hanson (1958) and others and is not yet settled. Philosophers of science from both sides of the debate i.e. realists and anti-realists, use these factors to argue for their positions. The general meaning of theory-dependence or theory-ladenness, as accepted by most philosophers of science is that because the observation statements are made in context of some accepted theory, they are biased.

It has been mentioned above that scientific realism is the thesis that we, the epistemic community can know the world. The concept of 'to know' is again not settled fully and has exercised the great philosophers of all times. Plato demonstrated in *Theaetetus* that there is more to knowledge than true belief. According to him, we can have knowledge of mathematics and morals but only opinion about the facts of nature. Rene Descartes (1596-1650) started with extreme skepticism but consequently reinstated the human capacity for knowledge. John Locke (1632-1704) was among the first of the empiricist opponents of Descartes who replaced the neoplatonic innatism with a modest naturalistic conception of our cognitive capacities. He made careful observation and description, the primary source of knowledge of nature. Ludwig Wittgenstein (1953) addressed the problem of knowledge of other minds. Austin (1962) argued that justification of our beliefs about the existence of material objects is just an issue and not a problem. A.J. Ayer (1964) echoed Lockean views on knowledge of the natural world.

A definition of knowledge can be: to have a justified, true belief. But Gettier (1963) showed by his famous examples that the conditions of justification, truth and belief are not sufficient to have knowledge. Goldman (1978) argued that the condition of justification can be dropped and that true belief counts as knowledge only if it is caused by the state of affairs which make it true. Another proposal was that a true belief is knowledge only if it has been arrived at by a reliable method. These proposals introduce the idea that the 'knower' fulfills some conditions for knowledge without being aware of it. It can be accepted that according to scientific realism, we can have at least justified, true belief in the statements about the world. In other words, scientific realism is the position that the scientific claims about the observable and unobservable world can be justified and true.

Most of the scientific realists believe that we can know the truth about the world, but that does not mean that they believe that our accepted theories are true. There can be different reasons for it, one of which is that even our best theories do not produce exact predictions. The idea of not-true but close-to-truth came from Karl Popper (1963). Popper used the terms 'verisimilitude' to convey the sense of 'very-similar' to truth. A scientific theory is made up of sentences or statements about the world. In Popperian sense, a theory is more similar to truth than its rival if its 'truth' content is more and if its 'false' content is less. A theory H1 is more truth-like than the theory H2, if its conjunction with the set of all true statements T is more and its conjunction with set of all false statements is lesser than that of its rivals.

None of the theories, available in science, is purely true. Popper's definition was meant to compare one false theory with another false theory.

The concept of verisimilitude gives the idea that there is a destination of truth and all the theories are approaching it. A theory is more similar to the truth if its distance from truth is lesser. The assumption is that all theories are epistemically improving; removing the false content and increasing the truth-content. Science does not seem to be progressing in that neat and orderly fashion; even if it is, we do not yet have a way of finding it out.

The claim that science is moving towards truth is contentious. It can only be claimed that the successful scientific theories are approximately true. It brings us to the two issues of aim and belief.

2.3.1 Tenets of scientific realism

The (ultimate) aim of science and how much belief should be apportioned to the current scientific theories, is expressed in Van Fraassen's definition of scientific realism:

> Science aims to give us, in its theories, a literally true story of what the world is like: and acceptance of a scientific theory involves the belief that it is true. (1980: 8)

I think that this definition does not represent reality. Acceptance of a scientific theory, does not necessarily carry the belief of truth in it. The definition alludes that the "aim" of science has been achieved. A theory is accepted, as the best (available) explanation, by the realists. In the light of the discussion above, this definition can be reworded as:

Science aims to give us, in its theories, a true story of what the world is like and has given us theories which are approximately true, to both the observable and unobservable world. The belief in those accepted theories is that they are approximately true.

Larry Laudan (1981) has come up with the main tenets which reflect the ambitions of scientific realism. The tenets convey that the enterprise of science is moving towards its aim of providing a theory that truthfully depicts reality.

1. Scientific theories in mature sciences are typically approximately true.
2. More recent theories are closer to the truth than earlier ones.
3. All the terms i.e. observational and theoretical of theories in mature science genuinely refer.
4. Successive theories in mature science 'preserve' the theoretical relations and references of earlier theories.
5. New theories (do and should) explain the success of their predecessors.
6. The claims 1 to 5 constitute the best, if not the only, explanation for the success of science and this success provides empirical confirmation for realism (p 90).

It is in mature sciences like physics, where most of these claims apply. Number (3) means that the theoretical entities and their structures as described in the scientific theories do exits and behave as described. Number (4) is a feature of structural realism, as will be discussed soon in this chapter. The conjunction of all the above claims is what Laudan calls 'convergent epistemological realism'.

Most realists do not subscribe to all these claims and most varieties of realism disagree over some of these. Some of the philosophers of science who subscribe to the total realism are Richard Boyd, Philip Kitcher, W. H. Newton-Smith, Stathes Psillos and Ilkka Niniluoto

Structural realism and entity realism are the two partial realist positions. They "partially" agree with all the five tenets. It is in the third and fourth tenets that their differences come out clearly. According to structural realism, the theoretical terms, in the scientific theories, may be referring but cannot be known. Entity realism, on the other hand is the position that the theoretical terms can be known. On the subject of 'theoretical relations', the structural realists stress, that these are preserved in successive theories and explain the success of the falsified predecessors. The entity realists on the contrary believe that the theoretical relations may be epistemically inaccessible.

2.4 Argument in support of realism

2.4.1 Success of science and realism

The twentieth century has seen enormous success of science through practical applications of atomic theory, the electromagnetic theory and others. Science has become the synonym of systematic method and reasoning. In spite of the success of scientific theories, it has not been possible to confirm, beyond doubt, the existence of the entities and structures that scientific theories propose. Scientific realists offer arguments to defend the realist attitude towards the successful scientific theories and offer counter arguments against the anti-realists' stance that the scientific theories cannot be accepted as approximate truth. The endeavour is of epistemic optimism associated with scientific realism.

One of the strongest arguments in favor of scientific realism is the "no miracle argument" (NMA) which aims to show that our best scientific theories should be reasonably taken as approximately true. It was independently proposed by J. J. C Smart (1963) and Hilary Putnam (1975). According to NMA, scientific realism is the only view that does not make the success of science a miracle. Hilary Putnam has aptly put forward, the NMA argument as:

> The positive argument for realism is that it is the only philosophy that does not make the success of science a miracle. That, terms in mature scientific theories typically refer (this formulation is due to Richard Boyd), that the theories accepted in a mature science are typically approximately true, that the same terms can refer to the same even when they occur in different theories – these statements are viewed not as necessary truths but as part of the only scientific explanation of the success of science, and hence part of any adequate description of science and its relations to its objects (1975: 73).

NMA aims to defend the scientific realists' claim that the successful scientific theories must be taken as describing truth, in both the observable and unobservable aspects. The reasoning is that the successful scientific theories must have latched on to the truth in postulating the unobservable entities and structures that the observable phenomena are almost as suggested by the theory. For example an electric motor is a simple scientific, technical implement that has contributed to our modern world as a result of success of science. The electric motor works on the electro-magnetic theory, that there are unobservable electromagnetic waves. When electro-magnetic waves, caused by the current, interact with the magnetic field of the magnet, a mechanical force is produced (Hesse 1970). For another example, radio, televisions, mobile phones and other wireless communication systems work on the theory about electro-magnetic waves. The technical innovations are the know-how derived from the successful scientific theories which in turn depend upon the existence of unobservable entities like the electro-magnetic waves. NMA is, that it would be a miracle if all the scientific innovation based on the electromagnetic theory work and behave as dictated by the theory but the electromagnetic waves do not exist and the theory is false!

In other words, many theories that posit unobservable entities are empirically successful, i.e. they make true predictions about the observable phenomena and have technical use. As another example, the laser technology is based on the atomic theory that when electrons from an inner orbit move to an outer orbit around the nucleus or from higher to lower energy state, they release energy as lasers. Lasers are used in medical science and warfare in guiding missiles and other applications. The atomic theory is empirically successful. It would be an extraordinary coincidence if the theory is empirically successful, makes true predictions about the observables, unless its unobservable entities actually exist. Without the existence of electrons and atoms, how can the success of the theory be explained?

According to the No Miracles Argument, considering the unobservable entities as just 'convenient fiction', as maintained by anti realists, would be equivalent to believing in miracles. It would be a miracle if imaginary, fictitious entities produce correct predictions, and concrete practical results. Therefore, to avoid being a believer in miracles one must be a scientific realist. It can be argued that NMA poses an unfair dilemma: either accept scientific realism in its general form or accept that success of science is a miracle. In other words, one is given two choices: either believe in the truth of scientific theories or believe in miracles.

NMA is a case of inference to the best explanation (IBE), which was introduced in its present form by Gilbert Harman (1965). The realists' claim is that taking the successful scientific theories as truly describing the unobservable phenomena, best explains the empirical success of such theories. The explanation, here, is the overall empirical success of scientific theories. The best explanation of this fact, according to NMA is that the theories are at least approximately true and the entities posited in the theories do actually exist and also behave as the theories claim. Wilfred Sellars (1962) says "As I see it, to have good reason for holding a theory is *ipso facto* to have good reason for holding that the entities postulated by the theory exist" (p 97).

Anti-realists claim that the inference to the best explanation for no-miracle argument for scientific realism is circular. Fine (1991: 82) says that inference to best explanation is not a forceful argument in favor of realism since it employs "the very type of argument whose cogency is the question under discussion". The anti-realist argument against the no miracle argument is that empirical success of science is explained by its empirical success! This argument can be understood in the following four steps:

1. Science is successful at empirical level;
2. Therefore, scientific theories must be true.
3. And scientific theories are true;
4. Because of their (predictive) empirical success.

The rule of inference invoked in NMA is credited to C.S Pierce (1966: 76). The explanation and the use of this rule has been clarified by Gilbert Harman (1965: 88). According to Harman, if E is the evidence and H and H' are the hypotheses, then, we should infer H rather than H' only if H is a better explanation of E than H'.

In the case of NMA, E, H and H' can be defined as follows,

E Success of science.

H Scientific theories are approximately true.

H' Scientific theories are empirically adequate.

That means, according to the scientific realists, taking the scientific theories as approximately true, explains the success of science better than taking them as only empirically adequate.

Van Fraassen (1980: 21) argues that in the case of success of science, the rule of inference cannot apply. He argues that in ordinary cases, we may be following this rule of inference. For example, if whenever one hears the noise of little feet at night and cheese disappears, one can infer that there is a mouse, and one would predict the other signs of the presence of a mouse. Even if unobserved, the mouse is an observable entity in this case. Our hypothesis 'presence of mouse' can be confirmed or is confirmable or is empirically adequate. Unfortunately in science, the theoretical entities are unobservable. Indeed, given the human physiology, there will never be circumstances when such entities will be observed unaided. We cannot use the same pattern of inference for our belief for such entities. For a premise to lead us to true inference there should be some rules to follow. Each logical rule is a rule of permission. We can infer B from A i.e. if A then B. But the rule does not forbid one to infer B or C instead. In this sense any conclusion may be inferred from any premise. That means if one is following a rule one must be willing to believe all conclusions that the rule allows and not believe conclusions at variance with those allowed or else, change one's willingness to believe the premises in question.

Van Fraassen's argument can be put in the following tabular form:

Evidence	Rule	Inference
1 a) patter of little feet b) Cheese disappearing	IBE	Presence of mouse
2. Increase of pressure with decrease of volume at constant temperature	IBE	Molecular theory
3. Success of science	IBE	H. Scientific theories are true H' Scientific theory are empirically adequate

In (1), the inference is an observable one and all the evidence are equivalent. With our knowledge about mice, sound of the little feet implies disappearing of cheese and vice versa. The inference, 'presence of mouse', is empirically adequate and is correct.

(2) Is an example of what scientists actually do.

(3) Shows how van Fraassen is using the argument. Both inference H and H' can be drawn from the premises of IBE, and one should be willing to accept both. IBE does not help us to decide between H and H'; therefore it is not useful. In simple words, both H and H' explain the success of science equally well, then why choose one instead of the other? He argues against IBE to show that NMA is not a good enough argument in support of realism against his constructive empiricism.

Putnam has since drawn a distinction between the two doctrines of metaphysical realism and internal realism. He denies the former, and identifies his preceding realism with the latter.

Van Fraassen offers the following explanation for the success of science:

> I claim that the success of current scientific theories is no miracle. It is not even surprising to the scientific (Darwinist) mind. For any scientific theory is born into a life of fierce competition, a jungle red in tooth and a claw. Only the successful theories survive – the ones which *in fact* latched on to actual regularities in nature. (1980: 40).

He is attributing the success of science to competition between theories and that the current theories are empirically successful because these are the ones that have not been falsified by the available evidence. Had they been falsified, they would have been replaced by better and empirically adequate theories! Therefore the "current" pool of accepted theories will always be the ones that are empirically adequate, to what has been observed and can explain the success of science.

Arthur Fine argues that success of science is at instrumental level. When realists appeal to approximate truth of a scientific theory, they must "allow some intermediate connection between the truth of the theory and success in its practice. The intermediary here is precisely the pragmatist's reliability" (Fine, 1986a: 159). That means, the job of explanation is done by instrumental–reliability and there is no need to assume the approximate truth of the theories. Fine, therefore adds that "if the phenomena to be explained are not realist-laden, then to every good realist explanation there corresponds a better instrumentalist one" (*idib*)

Stathis Psillos (1999) argues that instrumentalists account for the empirical success of scientific theories by appealing to a *capacity* or disposition that the theories have. But the question still remains: what explains that capacity or disposition? Therefore Psillos concludes "The realist account is the best overall explanation of the empirical success of science" (*ibid* 93)

Psillos (*ibid*, 96) further argues that if all our current accepted theories are empirically successful, then success of science is not explainable by these theories. He gives an example, if the membership of a group is only for red heads, then an individual member's being red-head is not explained by her membership to the group. Any one or all the current empirically successful theories need an explanation for their success, beyond their empirical adequacy so far. The realists' explanation is deeper; it tells a story about the unobservable common traits because of which the theories are not falsified. The overall realists' stance is that it is not only the set of evidences that need explanation rather it is the overall success of scientific enterprise that needs explanation. Here, the hypothesis is: science is successful because scientific theories are at least approximately true.

If a scientific theory is proposed to save a phenomenon, then the theory will obviously explain that phenomenon. Scientific realists emphasize the importance of novel prediction to avoid that circularity and to strengthen NMA. A prediction is novel if the phenomenon predicted was not known before the theory predicted it. For example Einstein's theory of relativity predicted that the light ray coming from a star will be bent when traveling close to the sun.

Elie Zahar (1973) has proposed an improved version of the notion of novel prediction, called the heuristic novelty. Even if a phenomenon is known before the inception of a theory, if this phenomenon is not used in the construction of the theory, then the prediction of this phenomenon is novel.

That means, so far as an empirical evidence is not used for the construction of a theory, it can be counted as heuristically novel. For example, precession of equinoxes was known before Newton's time, but his theory of gravitation was not constructed using it. Therefore the prediction of this phenomenon, using Newton's theory is counted as heuristically novel. The same can be said about Einstein's theory of relativity which was able to explain the anomalous precession of the planet Mercury.

I think that the "novel" and "heuristically novel" are the cases of confirmation of the theory. Realists go beyond the empirical adequacy of a hypothesis and therefore need predictive power as confirmation of their belief. Constructive empiricists, on the other hand include the predictive power in empirical adequacy.

Using inference to the best explanation argument, to choose one theory against its rivals, does not assure the theory's truthness. If a theory explains better than other available theories, it does not mean that the theory is giving the true explanation. It is also possible that all the available theories are false. We can never be certain if the true theory is among the theories available. Success of science begs to be explained. But taking all the current accepted scientific theories approximately true, as an explanation for that success is arguable.

Philosophers of science often use the term "mature" for the theories which have been around for a long time and not yet falsified. It would be reasonable to assume that such theories have contributed more to success of science than their "younger cousins". Realists argue for the truth or at least approximate truth for mature theories. It seems reasonable, then, to imagine a proportional relationship between truth-content of a theory and its contribution to the success of science. Newer theories are usually built on the existing accepted ones and have more metaphysical content. By the same reasoning the latter ones depend for belief on the former. Levels of belief give rise to idea of levels or layers of reality. The notion of levels of belief can be thorny for empiricists because they consider justified and true for observed and empirically adequate for unobservable. This area of realist-antirealist debate, calls for further research.

Psillos' argument that instrumentalists appeal to the theories' *capacity* without explaining or accounting for that capacity is valid. That capacity is defined and explained by Nancy Cartwright as a causal one. The unobservable entities (or processes), cause the observable phenomena, which in turn are the evidence. The empirical success of science is explained by our knowledge of those unobservable entities which cause the phenomena (the expression of success!). In simple words an entity-realist is saying that the science is successful because we have known the cause of whatever is observable. Similarly, the structural realists claim that success of science is no miracle because we have known the true structure underlying the phenomena.

Both entity realists and structural realists are telling a story about the unobservables. How they argue for their stories, is the topic of chapters three and four of this thesis.

2.5 Scientific Anti-Realism

As the name suggests, a common feature of all different forms of anti-realisms is distrust or skeptism towards the realist claims. The anti-realists agree with the realists that the mind-independent world exists, but they part ways when the realists claim that we can know even the unobservable parts of the world. The anti-realists do not find enough justification in the beliefs of the realists.

The current anti-realist voice in the realism versus anti-realism debate is that of constructive empiricism. This is the position that responds to the tenets for scientific realism as proposed by Larry Laudan (1981) and mentioned earlier in this chapter.

2.5.1 Constructive Empiricism (C.E)

Van Fraassen put forward this empiricist position in his book *The Scientific Image* in 1980. As noted earlier, empiricism requires theories to give a true account of only what is observable. Constructive Empiricism deviates from traditional empiricist positions by suggesting that the theoretical terms should be taken literally. Van Fraassen says "The language of science, being a proper part of natural language, is clearly part of the subject of general philosophy of logic and language" (1980: 4). Using a literal meaning does not mean any amount of belief in the theoretical terms. It only means a convenience of having to use the same language for science and philosophy and even for day-to-day use. The problem of existence, or our having knowledge, of an unobservable term used, is not resolved; it is only set aside.

Constructive empiricism, as proposed by van Fraassen is different from the empiricism of the positivists and argues against the scientific realist position. Whereas the realists consider the scientific activity as that of discovering of truths concerning the unobservable part of the world, constructive empiricists consider the same activity as that of construction of theories that are adequate to what is observable. The first part of the formulation of constructive empiricism is: *Science aims to give us theories which are empirically adequate* (1980: 12), (Italics as in original). Scientific realists, not only aim at truth, but also believe that the successful theories are at least approximately true. Empirical adequacy means that what the theory says about the observable part of the world is true, or that the theory saves the phenomena.

The reason for taking the aim of science as empirical adequacy is the empiricists' distrust for metaphysical and unprovables. It seems that van Fraassen softens that stance from unacceptance of the unobservables to tolerance. By taking the unobservable posits of scientific theories literally and still remaining agnostic about them, he attempts to remain an empiricist or anti-realist but at the same time bringing his position closer to actual happenings in science (Datta 2007:37). An example can make this point very clear. Ian Hacking quotes an experiment, as a case study to argue for his case for entity realism. This experiment, named PEGGY, is discussed in detail in chapter four of this dissertation. PEGGY involves the use of unobservable theoretical entity electron, as an input to know about some other theoretical entities. The empiricism of the positivists' type could not accommodate the discussion of such an event. The philosopher and the scientist would differ over the meaning of the 'input' itself, with hardly any room for discussion about the 'output' or the findings. It is because in the experiment, both, the input and the output are unobservable theoretical entities. Constructive Empiricism avoids such confrontations by taking the unobservable theoretical entities literally, while remaining agnostic about them. Both, the scientist and the constructive empiricist, refer to the same entities but with different epistemic construal.

I strongly feel that the agnostic attitude towards all the unobservable theoretical entities, gives rise to some problems for constructive empiricism. If one such entity can be manipulated experimentally, to intervene in the unobservable world, to justify theoretical claims about another unobservable entity, then the two entities cannot be treated as epistemically equal. In the experiment PEGGY electrons are manipulated to verify the theory about bosons. The former demands epistemic advantage. And granting any epistemic advantage is preceded by some episteme of the unobservable realm, which goes against the very core of empiricism. I had alluded to this anomaly in my M.A. thesis (Datta, 2007: 21). This argument against constructive empiricism will be discussed in detail in the fifth chapter of this thesis. In his latest writings, van Fraassen has acknowledged the mistake of taking experience as our only source of information (Monton, 2007: 366).

With the aim of science limited to empirical adequacy, the scientific activity becomes that of constructing a scientific image of the world (and hence the title of van Fraassen's book: *The Scientific Image*) i.e. how we, the epistemic community understand the physical world. And further, predict and maneuver it. Against the realists claim that science is converging towards truth, and successive theories are improvements over their predecessors and also explain their success, constructive empiricism considers scientific activity as that of improving our world view.

The second part of the formulation of constructive empiricism is epistemological. It says: *acceptance of a theory involves as belief only that it is empirically adequate* (*ibid* 12) [Italics as in original]. It answers the question: how much belief is involved in theory acceptance? The constructive empiricists has no qualms about unobservable posits in the theory. There is no difference of opinion about the meaning of posits either. When more than one theories are empirically adequate, then the other pragmatic virtues of the theories in question, are considered (*ibid* 4, 12). Such virtues include the explanatory power, brevity, beauty, unifying power etc. Considering these pragmatic virtues, to choose one theory from another, does not give us any reason over and above the empirical evidence, for taking the theory as true. The accepted theory is still only empirically adequate, but the acceptance of one theory rather than the other, involves a commitment to a research program.

We have seen above, that according to constructive empiricists, the scientific activity is that of constructing an image of the world. Van Fraassen advises us to select 'that' theory, among empirically equivalent ones, which has the virtues, which are valued by realists, like explanatory and unifying powers. He gives the reason for considering pragmatic virtues as choice for a theory, as commitment to a research programme (*ibid* 4). Now, what is a research program for? According to a constructive empiricist, it is for constructing a scientific image of the world. Indirectly, van Fraassen is accepting that the explanatory power and unifying power of a theory are the correct virtues to construct the correct (true) scientific image of the world. Further, according to scientific realism, the explanatory power and unifying power of a theory are derived from the truth-ness of the unobservable theoretical posits. For example if the molecules and their structure is true picture of unobservable reality, then the theory with those posits, the molecular theory, explains the gas laws. Also if the same molecular theory explains a different phenomenon like the Brownian motion, then it has the unifying power.

Van Fraassen maintains that the fact that a theory has a great explanatory power does not mean that it is true. He suggests "...the theory which best explains the evidence, is empirically adequate" (*ibid* 20). The question that begs an answer is: what is it, in the explanatory power of a theory that van Fraassen is invoking when using it to choose between two empirically adequate theories?

In the words of van Fraassen :

Theory acceptance has a pragmatic dimension. While the only belief involved in acceptance as I see it, is the belief that the theory is empirically adequate, *more than belief is involved* (*ibid* 88) [Italics as in original].

Choice of a theory means commitment to a research program. It means confronting new phenomena within the framework of the accepted theory. A commitment does not mean "acceptance as true", it can be confirmed or falsified in future. The unobservable posits and their structure, make a part of the framework of a theory. Thus the constructive empiricists remain agnostic about the theoretical constructs but accept only that theory, which has 'accepted' (pragmatic, working, useful) theoretical posits!

According to van Fraassen, a theory is empirically adequate if "what the theory says *about what is observable* (by us) is true (*ibid* 18) [Italics as in original]. 'Observable' does not imply that the conditions are right for observing it now. The principle of observability is:

> x is observable if there are circumstances which are such that, if x is present to us under those circumstances, then we observe it (*ibid* 16).

The epistemic part of constructive empiricism is that acceptance of a theory, involves as belief that what the theory users will be observing in future or what the epistemic community has observed in the past, is according to the theory.

The notion of empirical adequacy attracts many objections. John Worrall (1984) and Alan Musgrave (1985) have independently argued that if a theory is to be empirically adequate in van Fraassen's sense then it must save all the phenomena, not just those actually observed so far. Since we can never have access to all the phenomena, we will never be warranted in accepting a theory as empirically adequate.

Van Fraassen draws a distinction between observables and unobservables on the basis of what can be observed by unaided human eyes. Paul Churchland (1982) and Gary Gutting (1983) argue that selective skepticism that van Fraassen advocates, cannot in reality be upheld since it is based on the arbitrarily drawn lines.

Nancy Cartwright in an essay entitled "Why be Hanged for Even a Lamb" (Monton (ed.) 2007), argues that there is nothing so special about what is observable, epistemically, that it warrants belief. She questions the use of our physical constitution, in deciding observability. Moreover, she argues that van Fraassen is taking observability as certainty. Van Fraassen responds to her arguments. He says ".... The only belief that is *ipso facto* involved in acceptance is that the active criterion of success is met – and that the criterion of success is empirical adequacy" (*ibid* 342). Further, van Fraassen clarifies "...let us not equate reasons why a belief is adopted with anything like justification for holding the belief" (*ibid* 345).

I think van Fraassen's stance is quite strong. He proposes an empiricist position which is parsimonious about scientific knowledge. Why go beyond the justification provided by the evidence? His answer to his critics is that the belief in acceptance of a theory is that even the observables which have not yet been observed will be, as suggested by the accepted theory (and that is the predictive power of the theory). The constructive empiricist is sticking her neck out in accepting that theory. But the risk is lesser than the one taken by a realist, who takes the theory as true. The justification for the empiricists' belief is obtained, when the actual observations are made.

In support of this definition for 'observable' van Fraassen quotes Harry Frankfurt "…what is special about the observable is not the *epistemic* virtue at all ….rather, it depends on the fact that we are creatures bound in a world of sensation" (*ibid* 344), [stress as in original]. The thinking behind the definition of observable, "as observable to us" is that the knowledge and beliefs are meant for us, the epistemic community.

This parsimony of limiting belief to what is observable to us (unaided) is not good enough for the practice of science. Scientists, in quantum physics or some other fields of science, do conduct experiments and provide reasons for belief and their justification, which can never be observed in van Fraassenian sense (Datta 2007).

It can be observed, from the above discussion, that the modern accepted anti-realist position extends the belief in the accepted theories to all the observations, whether actually made or not. The justification for the belief will come, when the actual observations will be made. The unobservable theoretical terms will always remain as accepted (and not justified) beliefs. I will now discuss some arguments in support of the anti-realist, and against the realist position.

2.6 Arguments in support of anti-realism

There are two main arguments that support the anti-realist position. These are (1) the underdetermination of theory by evidence and (2) the pessimistic meta-induction argument.

2.6.1 The underdetermination of theory by evidence (UTE)

A scientific theory is postulated to account for some empirical data. It can happen in science that more than one incompatible theories account for the same data equally well. Anti-realists stress that the data to which scientific theories are responsible for, are ultimately always observational in character. For example, the kinetic theory of gases postulates the unobservable entity molecules, which are continuously in motion. As the molecules themselves cannot be observed, the validity of kinetic theory can be ascertained by deducing some observable effect of the theory. One observable deduction of the theory is that the volume of a gas should increase on heating if the pressure is kept constant. This can be observed by heating a gas in a lab situation. But if the same observation can, be deduced from another theory which does not posit molecules, then the theories remain underdetermined.

Constructive empiricism is one of the main anti-realist stances. Van Fraassen (1980: 87) uses underdetermination to show that theories should be taken at most empirically adequate and more than one theories, can be empirically adequate. Selection of one rather than other theories is not based on epistemic grounds, but on pragmatic virtues. When scientists are confronted with making a choice between more than one empirically adequate theories they choose the one which is mathematically elegant, simple, of great scope, complete in certain respects, of wonderful use in unifying our account of hitherto disparate phenomena and most of all explanatory. These pragmatic virtues do not make a theory better than the other; they still remain only empirically adequate. *Once a scientist selects a theory, he makes a commitment to the further confrontation of new phenomena within the framework of that theory, a commitment to a research programme, and a wager that all relevant phenomena can be accounted for without giving up that theory.* (*ibid* 88).

Stathis Psillos (1999: 163) analyzes the structure of underdetermination argument and finds that it capitalizes on two aspects of theory construction. When a theory is constructed from a finite set of observational data, the assumption is that all the others unobserved data of the phenomena will be found to be similar. It is the problem of induction. The limited data cannot fix or uniquely entail a hypothesis. The same data can be accounted for or saved by different hypotheses also. Howson and Urbach (1989) show that on standard accounts of confirmation, the inductive inference from a limited data does not confirm a scientific hypothesis but that does not mean that the same data does not support one hypothesis more than the others. Also that, even if the same data can be saved by more than one hypotheses, does not imply that the data supports all the hypotheses equally, and that no future data can favor only one of the hypotheses.

Underdetermination argument does not just doubt the inductive aspect of scientific method of generalization from a limited data; it doubts the very fabric of scientific realism. It questions the possibility of gaining knowledge about the world around, the observable and unobservable, from a limited observed data. The argument actually is, that the scientific theories which are accepted are as good or as bad as the ones rejected because all the theories *equally* account for the observed phenomena.

The UTE argument can be divided into two parts. One is that for every theory put forward to account for an observed phenomenon, another different theory can be put forward in such a way that both the theories are empirically equivalent to the observation. The second part is that the observational data is the only constraint for theory choice.

The first part is attacked by Laudan. Laudan (1996: 61) says that there is 'no algorithm for generating genuine theoretical competitors to a given theory'. History of science does not have many examples of different theories competing for given evidence. Against Laudan, Duhem ([1914]1991) and Quine (1975), have argued that it is always possible that a theory and some auxiliary hypotheses can accommodate any recurring evidence. That means any evidence can be accounted for by a theory by making some *ad hoc* adjustments. If we go by the Duhem-Quine thesis, then for a given theory and evidence, there can always be another suitably adjusted theory, such that the two theories are empirically equivalent. Duhem (*ibid*) maintained that crucial and decisive experiments are impossible in the physical sciences because they require a complete enumeration of all possible theories to explain a phenomenon – something that cannot be achieved.

The thesis put forward by Duhem and Quine goes against the falsificationist account of theory testing by Popper. Popper (2004) says that scientists propose hypotheses and then attempt to refute them by examining potential falsifiers. If attempted refutations are the sole test of theories (*ibid* 37), then two incompatible theories, which are not refuted by the evidence, end up being equally well tested by it (Jardine 1986: 85).

Psillos says that "the fact that any theory can be suitably adjusted so that it resists refutation does not show that all theories are equally well confirmed by the evidence" (*ibid* 165); meaning thereby, that the theory that does not need adjustment for empirical adequacy, or to save the phenomenon, is better than the one that does.

Larry Laudan has suggested another argument against use of auxiliaries to create competing theories which avoid refutation. Suppose that there are two theories which are empirically equivalent and have similar predictions of observable phenomena at a time 't'; the theories may need auxiliary assumptions to account for the observation made. These auxiliaries will propose different empirical consequences which can break the underdetermination (1996: 57).

We have an example of two competing theories of light, the wave theory and the particle-theory. In spite of the theories having their auxiliaries, they remain underdetermined. This example does not prove Laudan's argument, but does not support Duhem-Quine (D-Q) thesis either, because certain evidence or observation like polarization can be explained by wave theory and not by particle theory and some other observations like the ones given in "two-slit experiment" can be explained by particle-foton theory and not the wave theory. A particle and a wave are different entities. To explain both observations, the wave theory needs particle theory as an auxiliary and vice versa. This is done by the 'wavicle' theory, according to which, at different times light behaves as wave or particle. This is an example of two competing, under-determined theories, complementing each other showing that D-Q argument does not hold.

So far we have discussed the first part of underdetermination of theories by evidence (UTE) argument, which stated that for every theory, it is possible to propose another theory which is empirically equivalent to the first. The second part of UTE argument is that the selection of a theory from among empirically equivalent theories is done only on the basis of observational evidence.

Newton-Smith (1978) has offered a response to the argument from the realist metaphysical stance. He calls it the 'ignorance response', according to which, one of the underdetermined, competing theories is actually true but we may never be able to know. That means there are areas of scientific enquiry, where it is not possible to find evidence that can distinguish between competing theories. When using this line of argument, realists have to show that in such cases there are other rational methods of theory selection. Instead of accepting the UTE argument that evidence cannot decide between rival theories, 'ignorance response' shifts the onus of selection to other epistemic reasons. Psillos calls it entailment thesis (1999: 169). Scientific realists propose other theoretical virtues besides empirical adequacy. These include coherence with other established theories, completeness or comprehensiveness, unifying power and a capacity to generate novel predictions. Such virtues enhance the power of a scientific theory to explain. Explanation is one of the main aims of science and also has the potential of confirming a theory.

Underdetermination of theories by evidence is a serious challenge to scientific realism. But in spite of Duhem's assertion that no decisive experiments are possible in physical sciences, scientists frequently regard certain experiments as crucial. Peter Achinstein (2005) says that such experimental results help make one theory among a set of competitors very probable and the others very improbable, given what is currently known.

The realists' response to UTE is the attempt to show that there are justifiable virtues like simplicity and explanatory power through which we can choose between empirically equivalent theories.

2.6.2 Pessimistic Meta-Induction argument (PMI)

Pessimistic meta-induction is employed by Larry Laudan in his anti-realist manifesto *A confutation of convergent realism* (1981). Laudan appeals to a historical record of successful yet false theories to argue against the connection that realists draw between successfulness of a theory and its approximate truth – the connection that a successful theory is deemed probably approximately true.

Laudan (*ibid*) gives a list of theories which were once empirically successful and had explanatory power, yet were not true and the entities they proposed do not exist.

- The crystalline spheres of ancient and medieval astronomy.
- The effluvial theory of static electricity.
- The phlogiston theory of chemistry.
- The caloric theory of heat.
- The vibratory theory of heat.
- The theory of circular inertia.
- The optical either.
- The electromagnetic ether.

The PMI argument attempts to show that the history of science does not support the realist belief that current successful theories are approximately true. Because the current successful theories are also empirically adequate and have explanatory power, just like the falsified theories of the past.

Laudan's PMI argument can be reconstructed as follows (Lewis 2001: 373; Psillos 1996).

1. Assume that success of a theory is a reliable test of its truth.
2. So most current successful scientific theories are true.
3. Then most past scientific theories are false, since they differ from current successful theories in significant ways.
4. Many of those past theories were also successful.
5. So successfulness of a theory is not a reliable test for its truth (since this leads to contradiction in (3) and (4)).

Step (3) above, is a candidate for rebuttal. According to structural realism, which we will discuss in detail in the next chapter, it can be shown that some theoretical elements were solely responsible for the success of past theories. These elements render those theories continuous with otherwise incompatible current theories, and hence candidates for approximate truth.

But Laudan says:

> Because they (most past theories) have been based on what we now believe to be fundamentally mistaken theoretical models and structures, the realist cannot possibly hope to explain the empirical success such theories enjoyed in terms of the truth-likeness of their constituent theoretical terms (1984a: 91-92).

Laudan's argument cannot be ignored. A scientific theory can have explanatory power and be empirically adequate and still its theoretical furniture may not refer. A possible way out for realists is to dilute the claim from truth to approximate truth for such theories. Because, an approximately true theory can be false. So, the falsified, empirically adequate theories from the history of science were approximately true and our current accepted theories are at least approximately true.

The philosophy behind scientific realism is that from empirical success of a scientific theory, we can infer that the theoretical claims of the theory are real; that the theoretical, unobservable entities posited by the theory actually exist and have the structure as proposed by the theory. This is what the no miracle argument is all about. If there were a way to check the existence of entities and structures of scientific posits, realism could be shown to be correct philosophy for science. But the only way to infer about the theoretical entities and their behavior is through the theories that propose them. It is the empirical derivatives of a theory that show its truthfulness.
It is the falsification of some of the accepted theories that puts to doubt the realist claim about the theoretical infrastructure. Laudan asserts that there have been many incompatible theories making incompatible claims about the theoretical entities, which cannot all be true. Therefore, the claims made by the current theories should not be taken as true.

Psillos (1999) suggests that realists can counter the PMI argument by showing that (1) the theoretical discontinuities in theory-change were not drastic and also not very frequent, (2) there have been clear network of theoretical activities and structures which is our best account of the world around and (3) theoretical terms have been retained during theory change (p 109).

The PMI argument stresses the susceptibility of scientific method to errors. Science is an enterprise of trial and error. As this enterprise progresses, the pool of empirical data and beliefs, keeps getting bigger and refined. The new observations modify the beliefs and improved theories so formed provide better inputs for observations. Even when errors occur in forming beliefs, they are detected with new empirical information and in the process scientists learn how to better- test their theories and avoid pitfalls. With experience, the evidence obtained is evaluated and errors in reaching false conclusions and beliefs avoided. The reasoning inherent in the process of trial and error or learning from experience does not guarantee that science is moving from false to true theories. The PMI argument creates an impression that most of the theoretical entities and processes posited in the current theories are very different from their predecessors. Most of the theories in the mature sciences on the contrary, have retained the theoretical entities, structures and mechanisms of the past theories with some adjustments. The common examples can be atoms (which have been around since pre-modern science), energy, electromagnetic fields, and genes (which have even been confirmed by observation now, as against when they were proposed!). It shows that Laudan has exaggerated the PMI problem.

PMI and Two Fallacies

Pessimistic Meta Induction argument can be attacked from two fronts. One is by showing that the turnover of accepted and falsified theories was more in the past than in the present. So, the inductive strength of the argument is diffused.

Juha Saatsi (2001) presents a *turnover fallacy* argument against PMI. Central to the argument is the difference between the two statements (*ibid* 285).

(i) That most of the theories that have ever been accepted were false and

(ii) That at most of the past moments, most of the theories then accepted were false.

(ii) Is closer to truth, but Laudan's argument only refers to *number* of past false theories as an inductive basis and yet draws a conclusion about our present scientific theories.

I propose the following example:

(i) The electric bulbs manufactured before 1960 had a short average life span of only 500 hours.

(ii) The modern electric bulbs last much longer.

From these two statements one can draw two conclusions:-

a) History shows that the electric bulbs are unreliable and have a very short life.

b) Over the years, quality of bulbs manufactured, has improved and modern bulbs are quite dependable.

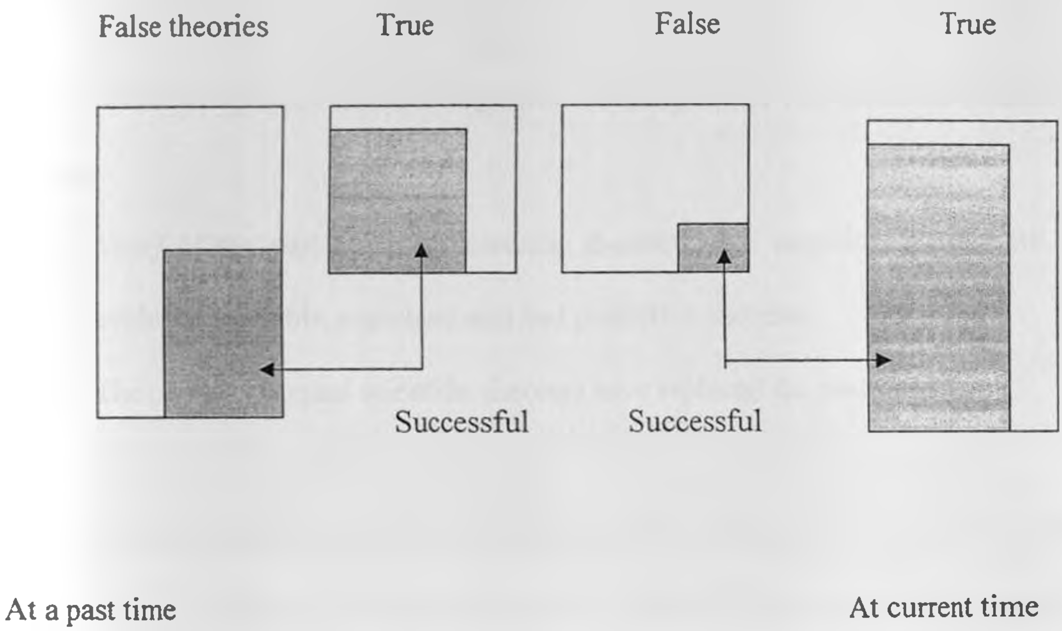
Another aspect of the argument is that even if 99% of the theories proposed have not undergone any change, and 1% of the theories have undergone change many times, the advocates of PMI will claim theory-change for the whole enterprise of science. For example, if a company has 100 employees and 99 of them have been working with the company for over 10 years and one position, say of the receptionist has had 20 changes in the same period. The PMI arguer will claim a turnover of 20 employees for the company and paint an unstable picture. This can be termed as a fallacy of hasty generalization.

Juha Saatsi (2001) quotes another argument against PMI by Peter Lewis. For Lewis the problem is that '*the premise that many false past theories were successful does not warrant the assertion that success is not a reliable test for truth* (p374).

It is possible that in the past, a very large number of proposed theories, that were later found to be false, were successful. That goes to show that there was a scarcity of true theories at the time and cannot be taken as evidence against reliability of success as a test to truth.

With a greater empirical data and means of observation available, our current scientific theories are closer to truth. Even if all the successful theories are not true, the true theories have to be successful. Success is a necessary condition for truth.

Lewis's argument can be represented diagrammatically as follows:-



In the diagram, the shaded area represents the successful theories. In the past a larger proportion of successful theories were found to be false whereas in the current times lesser such theories are false. But every true theory has to be successful.

Lewis faces some problems with his argument. There is no clear criterion of selection of false and unsuccessful theories of the past or present times. Do we consider all the theories proposed and published or only the ones proposed by eminent scientists? The force of the argument depends upon the criterion of selection. Though Lewis proposes his argument to support scientific realism, but the same argument goes against NMA for realism as the success of false theories cannot warrant our belief in the unobservables, which scientific realism claims. Lewis's argument does clarify a relationship between success and truth.

Let us revisit the part of the PMI argument which poses a real threat to scientific realism.

a) Many of the past accepted scientific theories were empirically adequate to evidence available, explained and had predictive success.
b) The current accepted scientific theories have replaced the past ones.

The theoretical entities of the past theories have been found, not to exist and their structures are not part of the current theories. Scientific realists assert that we can know the real infrastructure and workings of the world, from its observable and empirical part. That is why they believe that the scientific theories postulated from empirical data are truth-like or approximately true and that the empirical success and predictive powers of the theories can only be explained by the realist thesis. The problem is that realists cannot explain the truth-likeness of the past theories and the current theories that replaced them, simultaneously. The theories were rejected or falsified and superseded because the theoretical entities they posited do not exist, like the phlogiston and ether or the workings or mechanisms attributed to them were false. There are some questions that beg to be answered before we accept the validity of the above argument. Some of the theories that were accepted in the past and superseded later had empirical and predictive success. For example Fresnel's theory of diffraction, successfully predicted that an opaque disk would have a bright spot in its shadow. Laplace on the other hand, predicted the law of propagation of sound in air by the hypothesis that sound travels by adiabatic process. Now, what explains the successes of the superseded theories?

There must have been some element of "truth" in the falsified and superseded theories. In other words the theories must have latched on to some truth. Falsification of a theory does not mean that all that the theory is saying is false. The only thing that PMI argument says is that *all* that the theory was saying is not true. If the realists can show that the whole of the scientific theory is not falsified and rejected; the rejected part was the "idle" or a neutral part, then they can counter PMI. To salvage scientific realism, it has to be shown that the 'truth content' of a superseded theory is the one that explained its predictive powers and is the part that is retained in the superseding theory.

In other words, realists need to show that the theoretical constituents responsible for empirical success of falsified theories have been retained in current theories thereby increasing the possibility of truth likeness of this theoretical part. It would show that the theoretical contents have survived various 'revolutions' and indeed are the stable, true part of the modern scientific worldview. Philip Kitcher (1993) has suggested that scientific realism can best be defended by using the generation of stable and invariant elements of our evolving scientific image to claim that those elements represent the theoretical workings and laws of nature.

Scientific realism can be salvaged by characterizing which kind of statements do not add value and are abandoned as false and which are retained and carried forward. Kitcher (*ibid*) suggests these statements as "presuppositional posits" and "working posits". The distinction between the two is meant to capture the difference between referring and non-referring terms. Working posits are *the putative referents of terms that occur in problem-solving schemata* while presuppotional posits are *those entities apparently have to exist if the instances of the schemata are to be true.* (*ibid* 149).

The above scheme does not work all the times. An example can illustrate it better. Gustav Kirchoff predicted accurate diffraction patterns in 1882 while working in ether paradigm (Saatsi 2010). His predictions were accurate although he was taking the amplitude of light waves much higher than they actually are. Realists conclude that Kirchoff must have latched on to some truth or posits which were carried forward to Maxwell's theory. Our current knowledge of optics tells us that certain radically different assumptions about wave amplitudes *can* lead to same results. Therefore the case in question is that of *local underdetermination* and *not* of working posits.

A problem is faced when distinguishing between the two types of posits, that "occur" and that "have to exist" for empirical success of theories. For example, "ether" had to exist for the working of the theories containing it, but was later abandoned. Here, realists are accused of using hindsight to detect between idle and relevant posits. They can select the retained theoretical posits and call them the "working posits" that transcend theory change and this is an 'ad hoc' move to claim that "the eliminable posits are the ones that get abandoned". Psillos (1999: 108) suggests that the distinction is made all the times by practicing, eminent scientists. The retained theoretical constituents are the ones which scientists themselves believed to contribute to the success of their theories.

The problem can be understood by considering the pool of beliefs available to the scientists when the posits are conceptualized. If the conceptualization is based on false beliefs; the posits may not refer. Such presuppositional posits are warranted by the false beliefs. Error in postulation is due to lack of true beliefs available at the time and not due to epistemic community's inability to conceptualize. Scientific method can detect the errors made and can provide true beliefs.

2.7 Realism or Anti-realism ?

Anti-realists are 'realists' at the level where direct observations are possible. They draw a clear observable-unobservable distinction. To them all unobservables are theoretical and scientific theories are calculational devices or instruments. Michael Redhead (1995) says that it is like treating a theory as a mystery box. You feed it with observational input and the observational output is produced. You are not allowed to open the box and have a look at the workings inside. The observable-unobservable distinction has come under a barrage of attack by philosophers of science. On one extreme are the skeptics of even what is observable, arguing that it is theory-laden. On the other extreme are the believers in all that a theory claims.

Main thrust of the anti-realists' argument is that sense data provide a strong basis for all our knowledge of the physical world. Anthony Quinton (2001) says "today sense-data are more or less a philosophical heritage site". Today the epistemologists are looking for more moderate foundationalism, which does not require infallible foundations. Coherence is seen as a provider of justification and knowledge. Another line of reasoning being explored is the social character of knowledge. Popper had argued that scientific knowledge requires a community of investigators to keep a check on each other. Language is social and is an integral part of scientific statements. Van Fraassen's constructive empiricism takes scientific statements literally (although not believing in them fully).

I will discuss some more difficulties faced by anti-realists, while providing a background to entity-realism in chapter four of this thesis. It is generally felt that realism is the dominant philosophy today. Isaac Levy (1978) writes 'My own view is that the coffin of empiricism is already sealed tight.' But the arguments forwarded by the empiricists keep the realists on their toes to look for justifications for their beliefs.

I think that the mystery box (instrumental approach) of the anti-realists mentioned above, should be opened and the claims or the mechanisms of scientific theories be evaluated. Belief should be apportioned according to the strength of arguments. This is a scientific realist approach. Let us, next see what are the difficulties faced by adopting such an approach.

2.8 Challenges to scientific realism

From the foregoing discussion of the scientific realism debate, it is clear that the realist position faces some obstacles. The following are some of the challenges that we identified:

A. No Miracle Argument

It has to be shown, why the success of science needs explanation and that the scientific realism provides a better explanation than any other position.

B. Under-Determination of Theory by Evidence

Scientific realism should provide a clear method of choosing the most epistemically warranted theory, from among many empirically equivalent theories.

C. Pessimistic Meta-Induction

The history of science needs to be accounted for. It must be shown that some components of the unobservable theoretical posits, that survived, contributed to the success of their theories.

D. Justification

Scientific anti-realist positions accept the belief in the theories up to their empirical adequacy. For scientific realism to argue for belief over and above empirical adequacy, some methods of justification for the beliefs must be proposed and defended.

In light of the challenges facing scientific realism, some philosophers of science find that the most defensible and promising form of realism can be reached by adopting a policy of selective optimism. That means believing in some, but not all aspects of scientific theories. It can also be called selective skeptism and can be achieved by believing only in those parts of unobservable world, which can be justified. The two partial realist positions viz structural realism and entity realism adopt this strategy.

2.9 The partial realist positions

As against total realism, the partial realist positions of structural realism and entity realism impose distinction between the different types of theoretical components. The entity realists are realists about entities, claiming that the theories may be false. The structural realists, on the other hand, are realists about structures, claiming that theoretical entities and non-structural parts of theories are suspicious. The two positions are incompatible and disagree on their epistemic claims. Niiniluoto (1999: 139), calls them "diametrically opposite".

As mentioned above, the partial realists claim that we can have knowledge of only some components of the unobservable realm. In other words, the partial realists argue that we cannot have knowledge of some aspects of the unobservable world. The anti-realists in general believe that we cannot have knowledge of any aspects of the unobservable world. The partial realist positions, therefore, fall between the realist and the anti-realist stances. These positions are spearheaded by Nancy Cartwright, Ian Hacking and John Worrall and are the subject of the next two chapters.

2.10 Conclusion

From the foregoing, it is clear that the scientific realism-antirealism debate with regard to theories and the unobservable posits is far from settled. The discussion in this chapter shows that the central arguments for the two positions are getting more sophisticated. Philosophers from both sides of the divide are addressing each other and adjusting their positions. That does not mean that we are nearing the end of the debate, but some partial realist positions with reconciliatory epistemic attitude have been proposed. Structural realism and entity realism are two such positions. Structural realism is the subject of the next chapter.

CHAPTER THREE

STRUCTURAL REALISM

3.0 Introduction

In the last chapter it was shown that scientific realism faces some serious challenges from the anti-realist arguments. This chapter traces the development of structural realism as a partial realist position within the scientific realism debate.

Generally speaking, structuralism emphasizes the importance of relations. Among the pioneers of the structuralist program are Henri Poincare, Pierre Duhem and Bertrand Russell. Grover Maxwell took the program further and it was revived in the last two decades by philosophers like Anjan Chakravartty, Michael Redhead, John Worrall and Elie Zahar.

The modern structural realist position is the brain child of John Worrall. Worrall proposed it as a defense of scientific realism. As we saw in the last chapter, the success of the past falsified theories needs to be explained but at the same time the falsification of previously accepted theories needs to be accounted for. Worrall argues that the two can be achieved by structural realism. He invokes the history of science to show that it is the structural part of a theory that transcends theory-change, and explains its success; we cannot have knowledge of the unobservable entities, and that accounts for the falsification of previously accepted theories.

The structuralism of Poincare, Duhem, Russell and Grover Maxwell provides a background to Worrall's position. To understand and appreciate the need for proposing a concept like ether, a short history of optics and that of development of ether are given in this chapter. Reactions of various philosophers, for and against Worrall's stance are discussed before concluding the chapter.

3.1 Structuralism

The general feeling, in the beginning of the twentieth century was that science can provide knowledge about the physical world. The philosophic attitude towards science was that of realism. This was followed by logical positivism. The positivists found support for their instrumentalist version of anti-realism in the revolutions in physics. Pierre Duhem and Henri Poincare had made a compelling case that the history of science is punctuated by rejection of hitherto accepted theories. Logical positivists largely ignored these historical considerations, giving rise to the assumption that the scientific knowledge was cumulative and progressive.

During the 1960s this assumption was brought into question by Thomas Kuhn (1962, 1996), Paul Feyerabend (1962, 1965), and other philosophers of science. Kuhn in particular, argued that during scientific revolutions, a shift in paradigms takes place. The competing paradigms have very different theoretical concepts and their meanings. According to Kuhn's incommensurability thesis there is not only a discontinuity between competing scientific theories, but also it is not possible to compare them. Kuhn, therefore claims that theory-change involves extreme shifts in which theoretical components i.e. entities and their structures are thrown away thus the scientific knowledge is neither cumulative nor progressive.

Realists reacted to these historical arguments by launching an offensive against the ideas of scientific revolutions, paradigms and incommensurability by claiming that these are vague. Lakatos's "Methodology of Scientific Research Programmes" (1970) replaced the concept of paradigm with that of scientific research programme. The latter paints a more rational picture of theory-change in the history of science.

Larry Laudan (1981) attacked scientific realism for implying that predictive and explanatory success of a theory guarantees its truth-likeness or the reference of its theoretical terms. This argument is not an inductive one like the pessimistic meta-induction (PMI), though it is similar. Laudan's argument is a *modus tollens* (Lyons 2006), an argument against the method of reasoning. The reasoning, that truth can be deduced from the premise of explanatory and predictive powers, according to Laudan is faulty.

Philosophers of science like Hardin and Rosenberg (1982) and Psillos (1996) have attacked the PMI argument itself as we have discussed in the second chapter of this thesis. Others have engaged in historical case studies as an attempt to show that history supports scientific realism. This is achieved by showing that the rejected theoretical components were not essential for the success of their theories. And that the theoretical components that survive the change are the ones that accounted for the success of abandoned theory.

A structure can be understood as a system of related elements. Structuralism focuses attention on the relations as different from those elements that constitute the structure. For example a painting is a structure, made up of related or ‘structured’ strokes of paint brush. Similarly a house is a structure of ‘related bricks”. If the elements of two structures have an isomorphic relation, then knowing one can lead to the knowledge of the other. Structuralists give different arguments for their belief in abstract structures as against their constituents. Some of the prominent philosophers under this banner are discussed below.

3.1.1 Poincare

Jules Henri Poincare was a French mathematician and philosopher of science. He noted that scientific theories enjoy some years of prosperity, which means that they are empirically successful and explain the phenomena and are later found to be false and another theory replaces them. This new theory also is empirically successful and explains the phenomena like its predecessors. The falsification of successful theories was seen as a sign of “bankruptcy of science” in France during the early twentieth century. Poincare noted that failure of scientific theories does not mean the failure of scientific enterprise and that scientific theories are fallible. He says:

> For a superficial observer, scientific truth is beyond the possibility of doubt; the logic of science is infallible and if the scientists are

> sometimes mistaken, this is only from their mistaking its rules. ([1905] 1952: 160).

In his address to the congress of physics in 1900 he said:

> The man of the world is struck to see how ephemeral scientific theories are. After some years of prosperity, he sees them successively abandoned; he sees ruin accumulated on ruins; he predicts that the theories in vogue today will in a short time succumb in their turn, and he concludes that they are absolutely in vain. This is what he calls the bankruptcy of science. His skeptism is superficial; he does not understand either the aim or the role of scientific theories; without this he would understand that ruins can still be good for something. (1900: 14).

Now, for a scientific instrumentalist, the above shift of one theory (instrument) by another is not a serious problem. For the instrumentalist, a scientific theory should lead to empirical laws and predictions. As Poincare says: "Fresnel's theory enables us to (predict optical phenomena) as well as it did before Maxwell's time" ([1905] 1952: 161).

Poincare suggested an intermediate position. According to him, scientific theories are not merely practical, useful tools, instead, the successful ones can tell something about the unobservable world. He was influenced by Kant and believed that unobservable theoretical entities are the Kantian noumena. But unlike Kant, he thought that it is possible to gain some knowledge about these "things-in-themselves". In Poincare's words "*...the aim of science is not things themselves,* as *the dogmatists in their simplicity imagine, but the relations between things; outside those relations there is no reality knowable".* ([1905] 1952: XXIV). Poincare believed in the existence of those entities but not in their knowledge. He says. *"The true relations between those real objects are the only reality we can attain.* (*ibid* 161). Poincare found confirmation of his ideas in the retention of mathematical part of Fresnel's theory. It is the mathematical equations which represent the true structure of relations between the unobservable entities; the entities (Kant's noumena) are not knowable.

Poincare did not argue against the existence of the theoretical entities. He advised agnosticism towards the first order properties of the entities and argued that we, the epistemic community can have justified true belief about the second order properties only. According to Poincare, a falsified theory is not a complete 'ruin', rather it has some valuable truth content.

It is the pessimistic induction argument against which, Poincare attempted to defend the practice of science. It was seen that 'empirical success' and 'explanatory power' of a theory were not enough warrant against its infallibility. A scientific theory is proposed to explain some empirical data, so, the explanatory power and empirical adequacy are obvious. It is the new empirical data which falsifies a theory and is incorporated to formulate a new theory. According to the realist thesis, the epistemic community can know the real, mind independent world. The human capacity to 'know' must enable them to latch on to some truth about the unobservable world. Poincare believed that the material of which the world is made up, the 'things in themselves' are not knowable. Therefore, it is the relations between those 'things' which are real, and true in a successful theory. All the theories may not have mathematical content. No clear criteria are provided for selecting the theory which has true structural content. Poincare does not provide any justification for his belief that the unobservable entities are not knowable.

3.1.2 Duhem

Pierre Duhem (1861-1916), the French philosopher of science, was against mechanistic models of explanation and developed a holistic conception of scientific theories. He said that individual empirical propositions are not tested in isolation but only in conjunction with other theoretical claims. That means, that there are no crucial experiments, deciding for or against any given theory. Acceptance of a theory, according to Duhem is a matter of convention.

Duhem made a distinction between explanatory and representative parts of a scientific theory. The explanatory part proposes to take hold of reality underlying a phenomenon. The representative part proposes to classify the scientific laws. It is the inductively derived laws of nature that are represented by a theory and do the predictions. The conceptualizations by the scientists, about the possible realities, do the explanation and are falsified by evidence.

Duhem made his stance very clear, that scientists' desire to know the unobservable theoretical entities brings error to a theory and so, is responsible for the falsification of theories. The meta-physical theoretical posits are not the real material of the world. Duhem, like Poincare believed that we cannot know the real entities which make up the world. He says:

> It is not to this explanatory part that theory owes its power and fertility; far from it. Everything good in the theory, by virtue of which it appears as a natural classification and confers on it the power to anticipate experience, is found in the representative part …. On the other hand, whatever is false in the theory and contradicted by the facts, is found above all in the explanatory part; the physicist has brought error into it, led by his desire to take hold of realities ([1914] 1991: 32).

To label him a structuralist, we have to show that Duhem believes that we can know the unobservable structure of the world. He says that it is the representative part of a theory that does "everything good". That means he relates the structure of the unobservable world to the representative part of a theory. But what, according to Duhem is the epistemic worth of this representative part?

Duhem says about the physical theory:

"....the more complete it becomes.... the more we suspect that the relations it establishes among the data of observation correspond to real relations among things" (*ibid* 26). In other words, the structure of the unobservable world can be known from the structure of the observable world, through mature scientific theory. And further that these relations postulated by the scientific theories "...correspond to kindered relations among substances themselves, whose nature remains deeply hidden but whose reality does not seem doubtful" (*ibid* 29).

The quotations, unambiguously, make Duhem's view clear that 'the thing in itself', the Kant's noumena, exist and cannot be known but its structure can be known. Further, he says that this structure, transcends theory change, as he clearly puts it :

When the progress of experimental physics goes counter to a theory and compels it to be modified or transformed, the purely representative part enters nearly whole in the new theory, bringing to it the inheritance of all the valuable possessions of the old theory (*ibid* 32)

Though Duhem believes that the relationships observed between the physical objects transcend to those between the unobservable theoretical entities, he clarifies that this belief is "intuitive" and cannot be proved. In other words, Duhem does not provide any arguments for his structuralist stance.

3.1.3 Russell

In his book, *The Problems of Philosophy*, Bertrand Russell says that the items of perception are the foundations of all knowledge. Those sense-data are caused by the physical objects. On the question of what can science tell us about physical objects, he says:

> We can know the properties of the relations required to preserve the correspondence with sense-data, but we cannot know the nature of the terms between which the relations hold (1912: 15).

That means Russell believes that we can know only the properties of the relations (and not the relations), that the physical objects have, and not their intrinsic nature. His view on our inability to know the Kant's *noumena* is similar to that of Poincare's. The difference comes on their views about the relations between the things in themselves. Whereas Poincare says that we can know those relations, Russell says that we can only know the properties of those relations.

It is also important to note that whereas Poincare's motivation for structural realism came from the history of science, Russell's was from objectivity. The sense-data of an individual observer are private and not transmissible and therefore they are subjective. Even Poincare says that "nothing is objective which is not transmissible, and consequently that the relations between the sensations can alone have an objective value" ([1913]1946: 348). Russell argued that we can "infer a great deal as to the structure of the physical world, but not to its intrinsic character" (1927: 400). His reasoning was, that the structure of our perceptions is at most isomorphic to the structure of the physical world.

3.1.4 Objections to Russell

Russell's assertion that we can only know the abstract structure of the external world has attracted objections from M.H.A. Newman. Newman finds this assertion trivializing scientific knowledge (1928: 137). According to Newman, Russell's argument is: if we know the observable objects and the relations between them, then the relations between the entities that cause the sense-datum of the observed objects can be known. It is because, according to Russell, the two relations are isomorphic. But this type of reasoning is *a priori* and undermines or ignores the scientific method of empirical investigation.

Now, to strengthen Russell's argument, one has to specify the particular relations that hold for a structure. According to structural realism, the aim of science is to know the structure of the world. But if the observable phenomena reflects that structure of the real, unobservable world, according to Russell, then structural realist position collapses into phenomenalism.

Russell provides a commonsense view. Reflected light from an object, falls on our retina, the impressions are converted into electric signals and processed in the brain. The perceptions so formed from the sense-data, cannot tell us anything about the intrinsic nature of the object. But we do have some knowledge of the world in which we live. This knowledge, therefore, is the knowledge of the properties of the relationships that the objects have. It does not tell us about the nature of the properties that science can reveal.

3.1.5 Maxwell

Grover Maxwell's structuralism is derived from the views of Poincare, Schlick, Wittgenstein and Russell. Under the influence of Kant, he says that we cannot have direct knowledge of the world. About the phenomena, he says *these are wholly in the mind* (in our senses). Of the phenomena and only of the phenomena do we have *direct knowledge* (1968:155). Similar to Russell's sense-data, Maxwell says of the knowledge of the world that it is wholly in our mind. He says "all of the external world, including even our own bodies is unobserved and unobservable" (*ibid* 152).

According to Maxwell, the physical objects of the world, that we 'see' cause some sensation in our bodies and are "wholly in our mind". Because the knowledge of those external objects has reached our mind "via" our senses, those objects are called unobserved and unobservable by Maxwell. But this knowledge is direct. He does not distinguish between micro and macro physical objects for observability. That means, according to Maxwell, all the external world is unobservable. There is no observable-unobservable distinction, the type that the empiricts make. Therefore, for Maxwell seeing directly or through a scientific instrument is the same.

The obvious question that arises is: how is the knowledge of an unobservable world possible? The answer, according to Maxwell, is that the physical objects and their sense impressions (Russell's sense-data) may not be identical but some features are isomorphic. In his own words:

It is not essential to the position (of structuralism) that the sense impressions... 'resemble' the physical objects which may be among their causal antecedents (1968: 155) and further that *...at least a certain subset of the features of the (sense) impressions are isomorphic with a subset of the features of the physical object* (*ibid* 156).

Just like Russell, Maxwell's reason for believing in the causal link from the object to its sense impression is the preservation of the structure. Besides the every day common sense experience of similarity between the two, we have no warrant of this claim. Maxwell concedes this lack of warrant when he says that "there are no purely logical or purely conceptual reasons that there be structural similarities between objects in the external world and items in our experience" (*ibid* 25) and further that "if such (structural) similarities were fewer or, even virtually non-existent, knowledge of the physical realm would be more difficult to come by but not necessarily impossible" (*ibid* 25).

Colours of objects are their first order properties. It has been known that the colour that we perceive depends upon the wavelengths of light falling on the object and the wave lengths that are reflected back. We cannot know the 'actual' colour of the object. Maxwell claims that we cannot know the first order properties of physical objects and can know only their second or third order properties or the "structural properties". He says "what holds of colours must also be true of all of the first order properties that we perceive directly" (*ibid* 1a)

Maxwell praises Russell's approach of knowing the external world by acquaintance or by description. Acquaintance is the empirical, verifiability method of observation. This satisfies the positivists. Description means knowing something by describing it, for example theoretically. Knowledge by description is attempted when it is not available by acquaintance and is a scientific realist approach.

Maxwell links the above approach of knowledge to structuralism. He claims that all descriptive terms in a meaningful sentence must refer to items of our acquaintance. This is the Ramsey-sentence approach. For a sentence to be meaningful, its theoretical terms must be expressed in terms of observational terms. In other words the meaningful sentence tells us only about the structure of the world. The existence of theoretical terms is not denied, it is their knowledge which is denied and is replaced by their observable effects.

3.1.6 Objections to Maxwell

A scientific theory explains the observable phenomena by postulating some unobservable theoretical posits. In Ramsey-sentence approach, these unobservable posits are replaced by their observable effects. For example, an electron can be expressed as "that, which causes a silver-grey trail in a cloud chamber".

Maxwell attempts to show Russell's structuralism as a form of Ramsey-sentence approach. He attempts to bring in the modern notion of a scientific theory, which he equates to Russell's description of the world. And then from this description, he replaces the 'theoretical' terms with those of acquaintance or observational terms. Now, what remains in the theory is only the structural part. Maxwell then infers that this is Russell's form of structuralism: some sort of marriage between realism and positivism.

Maxwell's attempt does not tally with Russell's own belief. Russell insisted that our senses perceive the structure of the world, which we, then know. Because, the structure that our senses perceive is isomorphic to the structure of physical world; our knowledge of the physical world is that of the structure.

Russell brought out the "vicious-circle" antinomies such as the property of those properties that are not properties of themselves. Such paradoxes can be thought of as resulting when logical distinctions are not made between different types of entities and in particular, between different types of properties and relations that might exist between the entities (Cocchiarella 2005). Maxwell replaced the theoretical terms with the observational terms to resolve the paradox, but the move does not capture Russell's view. It is because according to Russell, the theoretical term cannot be known, but its observational term is the sense-data and is isomorphic to the term's structural properties which are knowable. Maxwell's approach, on the other hand, tells us about the causal properties of the theoretical terms. The causal properties can lead to the knowledge of the unobservable entities, which goes against Russellian belief. The causal approach to knowledge is followed by Nancy Cartwright and is discussed in detail in the next chapter.

3.2 From Structuralism to Structural Realism

According to the structuralists, we can know the structure of the world, i.e. the relations that hold and not to the relata, the entities between which these relations hold. Redhead conveys this point of view: "Informally a structure is a system of related items, and structuralism is a point of view which focuses attention on the relations between elements as distinct from the elements themselves" (2001a: 74). This thinking has shaped the structural realist philosophy of science. Poincare had invoked the history of science, particularly the case from Fresnel's to Maxwell's theory for propagation of light to assert that we can know the structure of the world. He noted that the mathematical equations which represented the structure transcended the theory-change.

To argue for a scientific realist stance with the arguments of structuralism, one has to reconcile two main arguments within the scientific realism debate. These are the Pessimistic Meta Induction (PMI) and the No Miracle Argument (NMA).

John Worrall explains the success of science by our knowledge of the structure of the unobservable world. He accounts for the falsification of past accepted theories by asserting that we cannot have knowledge of the unobservable entities and quotes the historical case of theory-change from Fresnel's ether theory to Maxwell's electromagnetic theory to argue for his position.

In what follows, it is shown how the No Miracle and the Pessimistic Meta Induction arguments are reconciled to salvage scientific realism. After that, Fresnel's theory for the propagation of light is discussed in detail, giving a brief history of optics, the need for proposing ether and its falsification.

3.3 Reconciling Pessimistic Meta-Induction and No Miracle Arguments

PMI is the main argument against scientific realism. It attacks the scientific realists' assertion that scientific theories can be approximately true or truth-like. According to PMI if we take the current scientific theories as truth-like then our past theories are not truth-like because they posited entities and their behavior which have been abandoned. (And in the past also, realists claimed truth for their theories). On the other hand, NMA is a strong argument in favor of scientific realism. According to NMA, science is a successful enterprise therefore scientific theories must be approximately true or truth-like. But PMI eats into NMA by suggesting that some of the past successful theories, which were empirically adequate and explained, have been shown to be false and abandoned. In other words empirical success and explanatory powers do not warrant truth- likeness.

In simple terms, the two arguments (for scientific theories), can be expressed as:

NMA

Empirical success → Truth-ness

PMI

Falsification of empirically successful past ones → Falsification of empirically successful current ones

Poincare suggested an intermediate position. According to this position, scientific theories are not merely practical, useful tools, instead the successful ones can tell something about the unobservable world.

In view of the Poincarean position, we can look at the two arguments as follows:

NMA

Empirical success

Of scientific theories → some parts of the scientific theories are true.

PMI

Empirically successful theories have been found to be false.

→ Some parts of the empirically successful theories were not true.

→ Some parts of the current theories may not be true.

In its softer version, PMI does not relinquish the whole of a scientific theory when it is falsified and abandoned and NMA does not claim the truth for the whole scientific theory when it is found to be empirically successful. The new negotiated position for the two arguments, divides a scientific theory into two parts. One part, that explains the empirical success of a theory, and the second part, which is responsible for its falsification. If it can be shown that the part of a scientific theory, responsible for its falsification is not the part that explains its empirical success, then we can be successful in salvaging scientific realism.

Theory-shift from Fresnel's to Maxwell's provides an example for this approach of salvaging scientific realism. In order to understand the shift in the theory in optics, I go through the theories of light briefly.

3.4 Theories about propagation of light

3.4.1 A short history of optics

Philosophers have always speculated about the nature of light. They were familiar with some properties of light like its rectilinear propagation, reflection and refraction. The Greek philosopher and mathematician Euclid (300 BC) wrote systematically about his findings on optics. In 1621 Willebrord Snel discovered the law of refraction experimentally. According to the law, the angles of incidence and refraction of a ray of light are related by the formula:

$$\text{Sin } i / \text{Sin } r = k$$

Where k is a constant, depending on the refracting material.

In 1657 Pierre de Fermat explained the principle of Least Time which states that "nature always acts by the shortest course". According to this teleological method of explanation, light always follows that path which brings it to its destination in the shortest time. Isaac Newton (*[1726]1999*) discovered that light could be split up into component colours by means of a prism. Newton was convinced that the wave theory of light could not account for the rectilinear propagation of light and the phenomenon of polarization; therefore he devoted himself to the corpuscular theory, according to which light is made up of minute particles. In 1675 Olaf Roemer (1676) showed that light travels at a finite speed. Christian Huygens (1690) explained the principle according to which every point of ether, on which the luminous disturbance falls may be regarded as the centre of a new disturbance propagated in the form of spherical waves. Huygens conducted experiments on the velocities of light in air and in denser mediums like water and concluded that light travels in waves. Further research was done on developing an elastic ether theory. The theory suggested that all matter consists of countless particles exerting on each other forces along the lines joining them.

From this brief history, we notice that all the theories of light attempted to account for the observed phenomena of light in mechanical terms. The scientific method of experimentation revealed the wave nature of light, but the mechanical constraints demanded some medium. This demand was fulfilled by suggesting a theoretical entity called ether. The hypothetical entity ether was attributed some properties like elasticity to account for the observations made. Objections were raised against ether, as an 'elastic solid' by such question as: "how do the planets travel through such a solid at enormous speeds?" But some *ad hoc* explanations were given to such and other objections.

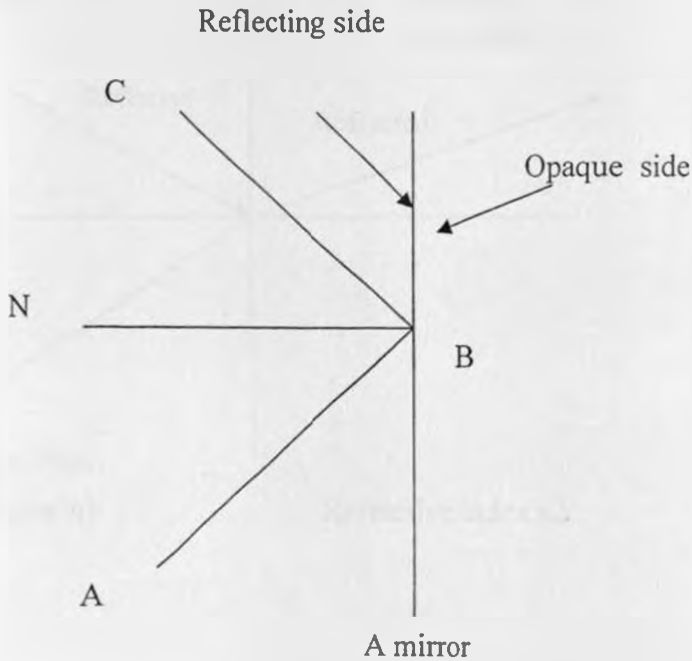
During the nineteenth century, scientists were working on other fields like electricity and magnetism, quite independently of optics. Michael Faraday and James Clerk Maxwell had successfully summed up all previous experiments in this field in a system of equations (Crump, 110). These mathematical equations established the possibility of electromagnetic waves propagated at a finite speed. The velocity of these electromagnetic waves was found to be same as that of light. This led Maxwell to conjecture that light could be an electromagnetic wave. This conjecture was confirmed experimentally in 1888 by Heinrich Hertz ([1893]1962: 55). The electromagnetic fields do not need a medium and cannot be expressed by mechanical models.

The above brief history serves our purpose as a background to understand the theory-change from the "ether theory" to "electromagnetic theory" for light. This account of history shows the development of concepts from Newton's corpuscles to mechanical waves in ether to electromagnetic waves. With each concept, some observable phenomena are explained and some new observations have to be explained and accounted for. The unexplained phenomena demand development of newer concepts.

Just like its predecessors the "corpuscular" and "ether" theories, the electromagnetic theory also does not explain all the phenomena. It does not explain the processes of emission and absorption of light. These are the processes where matter and electromagnetic fields come into contact and so, there is need for newer concepts.

The fact that each theory-change, gives rise to a better theory, which explains and saves more phenomena, shows that science is a successful and progressive enterprise. At each stage new and better concepts are developed which help unearth and discover the reality of nature and the world around.

Let us, now understand in simplest possible terms, what the Fresnel's theory is. When a beam of light falls on a reflecting surface, like that of a mirror, it is reflected back. (Optics, an online physics textbook, Benjamin Crowell (2007))



AB - The incident ray

BC - The reflected ray

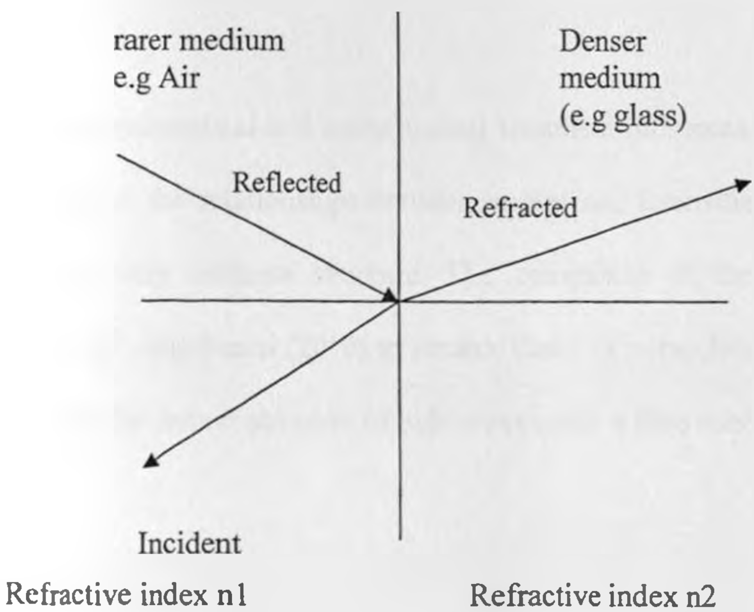
NB - A line perpendicular to the surface of the mirror

θi - Angle of incidence

θr - Angle of reflection

These two angles are equal.

If the surface on which the incident ray AB falls, is not a mirror, but, is a substance through which light can pass, say water or glass, then some of the light ray, will be reflected back and some of it will get into the other medium (water or glass). Now how much (intensity) of the light ray will be reflected and how much of it will pass through (refracted), depends upon the refractive index (roughly density) of the mediums and angle of incidence. A simple diagram of the phenomenon can be given as follows:-



R – Fraction of intensity of incident light that is reflected.

T – Fraction of intensity of incident ray that is refracted

R and T can be calculated or have a mathematical relation with the angles of incidence and refraction which can be expressed as:

$$R_s = \left[\frac{Sin(\theta_t - \theta_i)}{Sin(\theta_t - \theta_i)}\right]^2 = \left[\frac{n_1 Cos\theta_i - n_2 Cos\theta_t}{n_1 Cos\theta_i + n_2 Cos\theta_t}\right]^2$$

$$R_p = \left[\frac{\tan(\theta_t - \theta_i)}{\tan(\theta_t - \theta_i)}\right]^2 = \left[\frac{n_1 Cos\theta_t - n_2 Cos\theta_i}{n_1 Cos\theta_t + n_2 Cos\theta_i}\right]^2$$

Rs and Rp are the values of R depending upon the polarization of the incident ray, in such a way that

$$R = \frac{R_s + R_p}{2}$$

The diagrammatical and mathematical treatment illustrates, what Fresnel's equations tell, about the relationships between angles and intensities of light. The equations express very intricate structure. The complexity of the mathematical equations prompted Juha Saatsi (2010) to remark that it is miraculous that Fresnel could come up with the correct structure of light waves with a false concept.

3.4.2 Ether – The Proposition

During the 19^{th} century, it was generally agreed that there had to be a medium for light to travel. This medium was conjectured as luminiferous or light-carrying ether. The qualities attributed to ether had to account for its observed behavior. It was observed that the heavenly bodies pass through this medium, so ether was "completely undisturbed by matter moving through it". Upon considering the phenomenon of the aberration of the stars it was believed, that the luminiforous ether pervades the substance of all material bodies with little or no resistance. "Upon considering the phenomena of the aberration of the stars I am disposed to believe, that the luminiferous ether pervades the substance of all material bodies with little or no resistance, as freely perhaps as the wind passes through a grove of trees" (Young 1804: 12).

To account for refraction, the ether had to be "dragged along" the transparent matter because all transparent bodies on the surface of earth are moving with earth.

The phenomenon of stellar aberration had been observed as early as 1720 by James Bradley (1692-1762). A star is seen at different positions, when viewed at different times during the year because of different locations of earth during its rotation along its orbit around the sun. In simple words, the sighting of a fixed star, at different places had to be accounted for by two factors, "movement of earth" and "movement of light". Almost everything about the movement of earth was known, so, from the observed phenomenon of stellar aberration, nature of light and its medium were hypothesized.

In 1845 George Gabriel Stokes (1819-1903) accounted for stellar aberration on the basis of a theory in which earth drags along the ether in its vicinity. That means, the light is actually refracted on entering the earth's atmosphere.

Augustine Jean Fresnel (1788-1827), who had proposed the wave theory for light, had originally thought of light waves as similar to sound waves and so, thought of ether as a fluid medium. But sound travels in longitudinal waves and these waves cannot account for the phenomenon of polarization of light. Polarization could be explained better by the corpuscular or particle theory. For Fresnel's wave theory to be better, it had to explain all the observed phenomena better! Therefore, Fresnel postulated light as transverse wave, but then the medium ether, in which these transverse waves move could not remain fluid. In order to allow transverse waves to pass through it, ether needed to have enough rigidity to supply the forces to oppose the distortions produced by the waves. In other words, ether had to be a solid. Augustine Louis Catchy (1789-1857) suggested that ether could be a flexible solid.

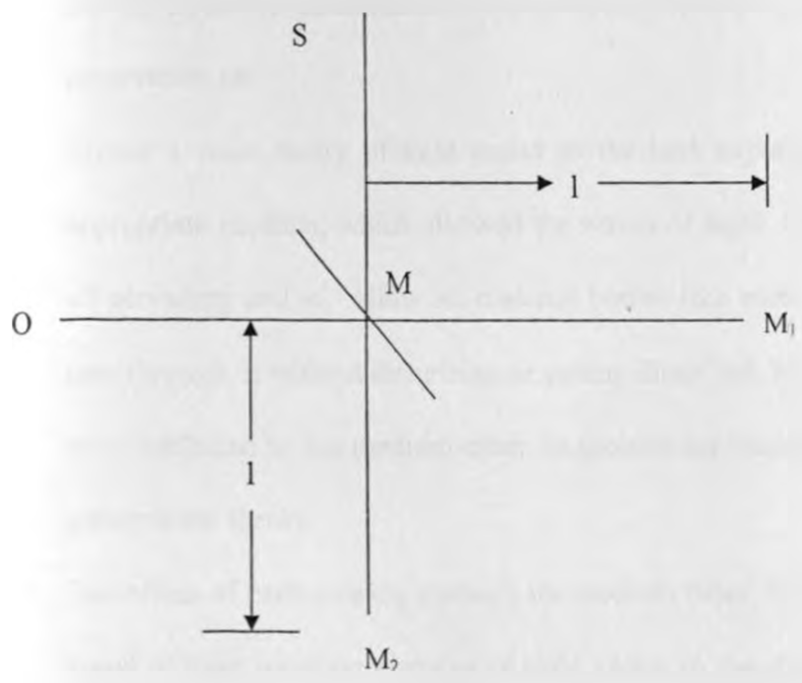
A model of ether was put forward called "silly putty" model (Schaeffer 1972: 66) in which ether behaves as a rigid solid for the high frequency oscillations of light waves and as a fluid for the slower motions of heavenly bodies moving through it. At the surface of earth, ether remains at rest relative to it.

The brief history of optics throws light on how science progresses by trial and error. Observations are accounted for by concepts. The concepts are adjusted to explain new observations. The ability of these unobservable concepts to account for observable phenomena and make correct predictions, gives rise to a realist attitude towards science. Errors are frequently made in proposing concepts but this episode concerning ether shows the ability of scientific method to recognize and rectify the errors.

3.4.3 Ether – the falsification

Michelson Morley experiment

Albert Abraham Michelson (1852-1931) was an officer in US, Navy who had measured the velocity of light using his high precision instruments. He designed an instrument, now known as Michelson inferometer.



I have drawn a simple diagram to explain the working of the inferometer. The instrument consisted of two equal lengths of tubes MM_1 and MM_2 at right angle to each other. A source of light S, sends a light beam, which is divided into two at M. Both travel the same distance but at right angle to each other and meet at O. if the speed of light in one length is even very slightly different from the other, it can be noted at O by the principle of inference. Michelson repeated the experiment by keeping one length along the direction of earth's movement and the other perpendicular. There was no difference in speeds of light, thus confirming the absence of drag and hence of ether.

From the above discussion of the events in the history of optics, we notice the following:-

1. Attempts were made to put forward a theory about light which could account for the observed phenomena of reflection, refraction, polarization, stellar observation etc
2. Fresnel's wave theory of light could do the best explaining, but needed an appropriate medium, which allowed the waves of light to pass through it, be all pervading and so, allow all material bodies like earth, planets etc also to pass through it without disturbing or getting disturbed. Many *ad hoc* qualities were attributed to this medium ether, to account for observations made and to preserve the theory.
3. One effect of earth passing through the medium ether, would be difference in speed of light traveling along or at right angles to the direction of earth. The

experiment conducted to confirm this difference in speeds, gave negative results.

4. Under normal circumstances, some further *ad hoc* changes would have been made to the ether theory to counter or account for the negative result.

But by this time an alternative theory, “Maxwell’s electromagnetic theory” for light had been proposed. Maxwell’s theory accepted light as a wave-phenomenon, but did not need a material medium.

This shift from Fresnel’s to Maxwell’s makes an interesting case study for philosophy of science. Scientists were struggling to put forward a theory which could account for all observed phenomena using the hitherto known concepts. The problem was resolved by a new concept, that transverse waves are possible, in an electromagnetic field without a material medium. The theoretical entity ether was not a satisfactory posit, but it was not rejected until an alternative explanation for the phenomena concerned, was found.

In 1905 Jules Henri Poincare quoted this episode of shift from Fresnel’s to Maxwell’s to show that a rejected theory, which was once accepted, had latched on to some truth. In 1989 John Worrall used the same episode to argue for his structural realist position and is discussed next.

3.5 Worrall's structural realism

In the preceding pages, the Fresnel's theory of light was discussed in detail. It was shown how and why ether was proposed as a medium and how it was shown not to exist by the Michelson Morley experiment. Fresnel's theory was replaced by Maxwell's theory of the electromagnetic field. With respect to this transition in the nineteenth century optics, Worrall argues that:

> There was an important element of continuity in the shift from Fresnel to Maxwell – and this was much more than a simple question of carrying over the successful empirical content into the new theory. At the same time it was rather less than a carrying over of the full theoretical content or full theoretical mechanism (even in "approximate" form)… there was continuity or accumulation in the shift but the continuity is one of form or structure, not of content *(1989: 117).*

Worrall is suggesting that we should not be blue blooded scientific realists asserting that the nature of unobservable objects, that cause the phenomena we observe, is described by our best theories. Worrall does not suggest that we should be anti-realists ether. He advises us to epistemically commit ourselves only to the structural or mathematical content of our theories. The reason for his assertion is the retention of structure across theory change.

Worrall's Structural realism avoids the force of pessimistic meta-induction argument by showing that structural part of the replaced theory is carried forward and we are not committed to the belief in the (falsified) description of entities. Also, structural realism does not make the success of science seen miraculous by committing us to the claim that it is the theory's structure that describes the world.

Worrall argues, if we look at theory-change solely from the perspective of mathematical equations, Fresnel to Maxwell change counts as evidence for the cumulative development of science. It shows that it is reasonable to hold that what survives theory change is what is actually latched on to the world. Worrall believes that Fresnel was completely wrong about the nature of light i.e. that light needs medium 'ether' to travel in. However, Fresnel was right about the structure of light as expressed by the mathematical equations.

3.5.1 Doubts on generalization.

Worrall does not generalize from this episode of history of science. He uses it to argue for structural realism. His is a two pronged assertion as follows:

1. We can know the structure of the unobservable world, which can be expressed mathematically. For example, the mathematical structure of Fresnel's theory transcended the theory-change to Maxwell's.

2. We cannot know the unobservable theoretical entities. For example theoretical entity ether postulated in Fresnel's theory was found not to exist and caused the theory's falsification.

It is generalization of the assertion that can be doubted as follows:

(1) In some areas of scientific enterprise, mathematical representations of unobservable structure transcend theory-change. It cannot be claimed that all scientific theories have mathematical structure and all unobservable structures can be expressed mathematically. Quite often the equations of an older theory appear in the newer theory as a limiting case. For example the Newtonian equation for the relation between force of attraction and masses and distances between objects is a limiting case for Einsteinian equations at low velocities. But it may not be the case for all theory-changes.

(2) Worrall's assertion that we cannot know the theoretical entities will be attacked from different angles in detail in chapter five of this dissertation. He has used ether as an example to show that we cannot know the theoretical entities. That the material, of which this world is made, is epistemically inaccessible to us. But ether was not a satisfactory and accepted theoretical posit. As shown in the history of optics on the preceding pages, scientists were aware of serious contradictions involved in accepting it. Ether did not explain the observed phenomena satisfactorily, which is a scientific realist requirement. Rejection of ether should not be construed as

evidence against scientific realism. Even if ether is considered a 'rejected' theoretical entity because it was part of Fresnel's theory, Worrall's assertion cannot be generalized. Cartwright and Hacking have provided justification for belief in some unobservable entities, which makes the subject of next chapter.

Let us now discuss the views of some of modern philosophers on Worrall's structural realism.

3.5.2 Redhead

M.L.G Redhead (2001a) defends structural realism against the argument that the new scientific structures are very different from the classical scientific structures or the structures do not transcend theory-change. For example, theory of relativity is alleged to imply that the reality is subjective. What one individual perceives depends upon her spatio-temporal location and no other individual can have the same perception. That means, that structure of the natural world is different for different observers, which in turn implies that there is no objective reality. Redhead cites the cases from the history of science where the structural continuity between the old and the new is not maintained but one can be derived mathematically from the other. One is the case of relationship between Einsteinian and Galilean space-time. Redhead says that even in classical Galilean mechanics there are relative relations. For example if an object is moving with a velocity Vo relative to a frame of reference O, then if we consider another frame O' moving relative to O with a velocity U, the velocity of the object as assessed by O' is given by the formula:

$$Vo' = Vo - U$$

The relation between the two velocities in reference to two frames, in Galilean mechanics, is relative. The real difference between classical Galilean and Einsteinian accounts is not that one theory denies and the other accepts relativity. In the former, spatial distances and temporal durations are not relative whereas in the latter speed of light is absolute (not relative to anything). Redhead argues that the theoretical structure postulated by one can be mathematically derived from the other.

The second case involves the relation between the Poisson and Moyal bracket formulation of classical and quantum mechanics respectively. The latter generalizes the former by introducing non-cumulative multiplication for phase space function. For the value of Planck's constant as zero, the commutativity is recovered and Poisson formulation is obtained.

In both these cases there is an abrupt qualitative discontinuity between the old and the new. In spite of this discontinuity, Redhead finds an apparent affinity between the two structures:

> Qualitatively new structures emerge, but there is a definite sense in which the new structures grow naturally, although discontinuously, out of the old structures. To the mathematician introducing a metric in geometry, or non-commutativity in algebra are very natural moves. So looked at from the right

> perspective, the new structures do seem to arise in a natural, if not inescapable way out of the old structures (*ibid* 19).

Redhead is saying that however discontinuous the structure may be from the old to the new, it is still a natural leap mathematically. The structural realist position can be strengthened if the correspondence between the old and the new can be concretized. Redhead's argument seems similar to making a theory empirically adequate to new evidence by adding some auxiliary hypotheses. Mathematics is a versatile tool and can be applied to exaggerate similarities between structures. Moreover a move which is natural to a mathematician may produce very different physical results. The examples that Redhead quotes are not of mathematical structures transcending theory-change; rather of using mathematics to observe structural continuity.

3.5.3 Zahar

Ellie Zahar claims that the language is so interwoven for the knowledge about the entities and their structures that it does not do justice to the structural realist position. By interpreting relations only through their relata, standard semantics fails to give priority to the relations. Zahar says:

> ……according to structural realism, we often have a good reason for supposing that 'R' (a specific relation) reflects a real connection between elements about whose intrinsic nature we know next to nothing (2001: 38).

This is an association between knowledge of the intrinsic nature of objects and classical semantics. Zahar advocates the rejection of classical semantics along with the knowledge of the objects. The association is not very clear and direct. There is nothing wrong with knowing the relations without knowing the relata. We can however, stick to Russelian view that we can know the objects only up to isomorphism.

Zahar's comment touches on the issue of ontological status of theoretical entities. Epistemic structural realism does not deny the existence of such entities. It denies our epistemic access to them. It cannot be denied that language has some limitations but Zahar's remark that language is interwoven for the knowledge about the entities and their structures can be interpreted differently. It is the knowledge about the structures which is so interlinked with that of the entities that language reflects that fact.

The issue raised by Zahar can be resolved. We, the epistemic community know the physical world through scientific statements which have truth values. These statements are semantically objective. Zahar's issue is that statements about relations are dependent upon entities. A structural realist wants to apportion belief to the former without any belief in the latter. Empiricists face the same problem, when they believe in the observables in a scientific theory, without believing in the unobservable entities that do the explaining. Van Fraassen resolved the issue by taking the unobservable theoretical entities literally without believing in them. Structural realists can also believe in relations without believing in the elements between which the relations hold.

3.5.4 Papineau

David Papineau argues that "restriction of belief to structural claims is in fact no restriction at all" (1996: 12). If a distinction cannot be made between the two ingredients, entity and structure of a scientific theory, then structural realism gains no advantage over traditional realism with the problem of theory-change. We cannot distinguish the structural claims of theories from their claims about content.

Papineau's objection to structural realism is based on our inability to distinguish between relations and relata. His objection is valid until the structural realists show, where our epistemic access to the two, parts ways.

3.5.5 Chakravartty

Anjan Chakravartty points out that mathematical structure is often lost in theory-change too (2004: 164). Structural realism asserts that the scientific theories truly represent relations whereas scientific realism claims that we should believe in what our best theories say about the entities also, because even in theory-change, the empirical content of the old theory is retained. The retained empirical content represents both, the entities and their structures.

Chakravartty's point is not too different from those made by Redhead and Cartwright. As discussed on the previous pages, Redhead notes that qualitatively new structures emerge discontinuously out of the old structures. But if we look from one perspective, the two seem to be similar. One can subtly infer, that looked at from a different perspective, the original mathematical structure is altered. We will see in the next chapter that Cartwright quotes six different mathematical equations for one laser-phenomenon. All the equations represent different theories. The point being stressed here, is that mathematisation is no assurance of truth.

Ontological structural realism claims that we can either not know the theoretical entities or they simply do not exist. The considerations are derived from quantum physics and compel us to abandon the idea of a world made up of unobservable entities with some intrinsic properties. Physicists tell us that certain aspects of the world would be unknowable. The fourth principle of quantum merchants is "in quantum measurements, the result is always undetermined". It is important to note that Chakravartty is not denying the transcendence of structural relations during theory-change in some cases. He is arguing against the generalization.

3.5.6 McMullin

Structural realism asserts that we can only know the structure, the question remains: structure of (between) what? It is argued that it is impossible to conceive of relational structures without making models of the individuals. Ernan McMullin attempts a reply:

> Imaginability must not be made the test for ontology. The realist claim is that the scientist is discovering the structure of the world; it is not required in addition that these structures be imaginable in the categories of the macro world (1984: 422).

McMullin has raised a very interesting point. Realists assert that we can know the mind-independent world. This knowledge about the world is expressed through scientific theories. A scientific theory starts as a hypothesis which is put forward to account for some observed phenomena. A scientist observes the phenomena and conjectures. This hypothesisation or conjecturing is in the mind. Even if the new conjuncture or concept is not in the macro world, like most scientific concepts, it still has to be imagined. And if it cannot be imagined, it does not mean that it does not exist.

Psillos (1999) and Chakravartti (2004) argue for the necessity of entities or objects for a meaningful conception of causation, and for explanation of change. A possible answer is, that the structures represent the relationships among phenomena that pertains to necessity, possibility, potentiality and probability.

Structural realism emphasizes that it is the mathematical content of a theory that is carried forward in theory-change and the main case study is from the history of science, in optics. It means structural realism only applies to mathematical sciences, but Ladyman and Ross (2007) have defended structural realist position as applied to social sciences, which are non-mathematical.

McMullin's argument that we cannot know the entities because we cannot imagine them, cannot hold. A theoretical entity is the one which has been "theorized" or imagined. The argument does hold for ontological status of the entities i.e. what is imaginable (or, has been imagined), may not exist. Moreover quantum physics has shown that the scientists' imagination transcends the categories of the macro world.

3.5.7 Psillos

Stathis Psillos argues against structural realism, especially as proposed by Russell, Maxwell and Worrall. His criticisms can be stated as follows:

1. "Structural realism commits us only to uninterpreted equations but these are not by themselves enough to produce predictions" (1999: 153).

2. "Structural continuity through theory-change can be explained better by traditional scientific realism than by structural realism. And that some non-structural theoretical content is retained in theory-change" (1999: 147).

Psillos' view is that scientists use mathematical equations as a convenient labour saving device. They build upon the work of their predecessors, which does not mean that the equations represent some permanent feature of the world.

In response to Worrall's structural realism, Psillos' says:

1. Yes structure transcends theory-change,
2. This transcendence needs to be explained,
3. Worrall does not show clearly that what transcends is more than mathematisation and what is its epistemic worth.

The gist of Psillos' argument is that there is need to show that the part that transcends theory-change *is* the part that latches onto the truth about the world.

The general claim, that any accepted scientific theory latches on to some truth is made by scientific realism, anyway. And further that every theory-change is an improvement upon its predecessor and therefore we are converging towards truth. The structural realists' claim can be substantiated by showing beyond doubt that it is the structure and nothing but the structure that transcends theory-change and latches on to truth.

Psillos quotes three assumptions that Fresnel used in his theory of light, which are non-structural and transcended theory-change:

A. *Minimal mathematical assumption* that the velocity of the displacement of the molecules of ether is proportional to amplitude of light wave.
B. *The principle of conservation of energy* during propagation in the two media.
C. *A geometrical analysis* of the configuration of the light rays (*ibid* 158 abbreviated).

Psillo's arguments are valid. The traditional scientific realism explains the structural continuity better and also the continuity of nonstructural part. The continuity does not show, beyond doubt that the structure theorized is the true structure of the world. Indeed the arguments facing traditional realism also seem to face structural realism.

3.5.8 Votsis

Ioannis Votsis, in his PhD thesis defends Worrall against Psillos' arguments which we discussed in the previous page. Psillos had asserted that some non-structural theoretical content is also retained in theory-change from Fresnel's to Maxwell's. Fresnel had assumed that velocity of displacement of the molecules of the medium (ether) is proportional to the amplitude of the (light) wave. The assumption remains valid even if the medium, in this case ether, is found out not to exist. Votsis says that the assumption *is thought to be false because of the reference it makes to the ether* (2005: 75).

Votsis argues that all the three assumptions made by Fresnel and argued by Psillos as non-structural, are actually structural and expressible mathematically. In response to (B) as mentioned on the previous page, Votsis argues that energy conservation is known to be a structural feature of the world and can be expressed mathematically. I think Votsis' argument is not strong because heat is a form of energy and its exchange or conservation is understood or known through the molecular theory. The claim to knowledge of molecular theory entails the knowledge of molecules which are entity and not structure. Mathematical expression of conservation of energy may show it as a structural feature, but entails belief in theoretical entities.

Psillos says in (C), that Fresnel used the geometrical analysis of the configuration of the light rays in the interface of the two media in his theory. This use of geometry, according to Psillos is non-structural and was carried forward to Maxwell's theory and is the true-ingredient in the two theories. If we take Fresnel, through his theory as claiming that the world is such that it gives rise to the phenomenon of geometrical configuration; then Psillos' argument is correct that the world itself is not geometrically configured; only its expression is. Because it is the true knowledge of the world, that transcends theory-change, according to Worrall's structural realism. On the other hand, if Fresnel's theory claims that the real world itself is geometrically configured, then Votsis' objection, that the geometric analysis is structural, is valid.

Psillos criticized Worrall for not clarifying "what exactly the distinction he wants to draw, is" (1999: 155). Is it the structure of the entity or process versus its nature, if so what is nature?

All the structural realists; Poincare, Russell, Maxwell and Worrall are influenced by Kant. It is Kant's noumena or the 'thing in itself' which is true, but not knowable. Our direct access is only up to our perception or the visible phenomena. We can, however, have indirect knowledge of the structure.

Psillos says "the nature and structure of an entity form a continuum and the nature of an entity, process or physical mechanism is no less knowable than its structure" (*ibid* 155).

Votsis defends the structural realists by saying that the structure represents the logico-mathematical properties of the physical objects. There can be no overlap, according to Votsis, between logico-mathematical and "all" the properties of an entity; they may coincide but do not form a continuum. He takes continuum, as a line extension with the two extreme ends.

Votsis is saying that an entity has many properties; some of them are logico-mathematical. Only the latter represent its structure and are knowable, the rest are not knowable. Continuum means at some stage they fuse together that means a property of its nature is same as that of its structure. Votsis avoids this contradiction, and suggests that the properties may only coincide.

Worrall himself holds a different opinion. In his various talks, according to Votsis (2005: 83), he says that all theoretical assertions are structural, so the talk of non-structural content is meaningless. If Worrall argues that all the theoretical assertions are structural, then what is it that falsified Fresnel's theory? It was the theoretical entity ether, posited to account for the phenomena. In fact Worrall suggested structural realism as the best of both the worlds. It accounted for PMI by blaming the theoretical entities proposed in the scientific theories. So, the theories do have non-structural contents, which according to Worrall, are the reasons for the theories' falsification.

3.6 Conclusion

Duhem, Poincare, Russell and Maxwell floated the idea of preservation of knowledge about the structure of the world during theory-change in science. Duhem, however said that the belief that the structure of observed phenomenon is similar to the structure of the unobserved reality is intuitive and unprovable. Russell said that there is an isomorphism between the relations or structures at observable and unobservable level. His assertions are derived from objectivity of knowledge about the world. Grover Maxwell's views on our knowledge of the unobservable world are similar to Russell's though he is skeptic even about the knowledge from our own senses.

Poincare's motivation for our knowledge about the structural part of the world came from the history of science. He noted that a falsified theory had some truth content which is carried forward to the new accepted theory. Worrall took this idea further and claimed that it is only the structural part of a theory which is knowable. He attributed the falsification of an accepted theory to its non-structural content. Worrall's structural realism attempts to reconcile the two strong arguments within scientific realism-antirealism debate, namely the Pessimistic Meta Induction (PMI) and the No Miracle (NMA). Worrall's assertion that we can know the structure and not the entities of the world, to find the best stance, invites many objections. He divides the knowledge of the unobservable world into two mutually exclusive sets, of structures and entities.

The argument for transcendence of our knowledge of structure invokes mathematics. But all theories do not have mathematical content. Although mathematical knowledge itself is *apriori* and the mathematical equations do not change; mathematization of natural phenomena involves apportioning values to the variables. If the values are probabilistic, then more than one different equations can represent the same phenomenon, as in quantum physics. Thus mathematisation is not a guarantee of truth. Moreover 'structure' can be expressed mathematically, but not the material of the entities. Thus the justificatory tool of mathematization, is selective in favour of our knowledge of the structure of the world.

Ether is quoted as an example of the theoretical entity which was part of an accepted theory and caused its falsification. But history of optics shows that ether never explained the observed phenomena satisfactorily. It was accepted in the absence of a better posit. So the fact that ether was found not to exist does not prove our epistemic inaccessibility to all theoretical entities. Epistemic import of the episode of theory-change from Fresnel's to Maxwell's in optics, does not warrant the conclusion that we cannot know the material of the natural world.

Worrall does not deny the existence of theoretical entities but the assertion, that we can know the structure without knowing anything about the constituents of that structure is arguable. It questions the scope and capability of scientific method to know the material of the world.

Worrall's structural realist assertions do not hold for the whole enterprise of science. There can be instances where structural content transcended theory-change, similarly some of our current accepted theoretical entities may be found out not to exist. The arguments advanced, do not warrant the general conclusion of our selective epistemic access to the unobservable world.

CHAPTER FOUR

ENTITY REALISM

4.0 Introduction

Entity realism is the philosophic position that scientific theories may not be true but the theoretical entities proposed therein do exist and can be known. This chapter traces the development of entity realist position. The main proponents of this school of thought are Nancy Cartwright and Ian Hacking. Nancy Cartwright has argued against the truth of scientific theories and in favor of causality as a means of ascertaining the existence and knowledge about the unobservable theoretical entities. Ian Hacking, on the other hand, introduces the scientific method of intervention and manipulation, using the scientific instruments to justify beliefs in the entities. Both, Cartwright and Hacking claim that if an entity causes a phenomenon and the causal link can be established, then the entity exists and can be known.

4.1 Background to entity realism

In classical physics the realist-antirealist debate can be understood in terms of observable-unobservable distinction, even if this distinction is not very clear. It has always been felt that the observable phenomena are different from the unobservable reality. For example observable relations between pressure, volume and temperature of a gas in a sealed container can be explained by unobservable molecules. The same molecules explain the random movement of suspended particles in a fluid, called Brownian motion. The unobservable molecules with some properties (e.g. random, continuous movement) could explain the observable phenomena. In other words, gap between observables (believed by both realists and antirealists) and unobservables (believed by realists) in scientific statements was one step. Unlike in classical physics, the reality proposed by quantum physics goes beyond observable (by unaided eyes) vs. unobservable distinction.

The molecular theory demands belief in the unobservable molecules. Behavior of molecules is explained by their constituents; atoms. Atoms in turn are made up of neutrons, protons and electrons. Neutrons and protons are claimed to be made up of other subatomic particles like bosons. Electrons are theorized as orbiting around the nucleus of the atom in different orbits at varying energy levels. When an electron jumps from high level to lower level orbit, it releases a quantum of energy. These quanta of energy make up lasers which have very many applications and are an expression of success of science and a warrant for belief in the molecular theory.

In laboratories scientists isolate the electrons and maneuver them in a variety of ways. The electrons move at the speed of light and even their immediate effects are not observable unaided. For example in a cloud chamber electrons impart their negative charge to the particles, and water vapor condenses around the particles which in turn are observed as a trail. Unlike the unobservable molecules causing the observable

Brownian motion, the quantum phenomena are connected to observable phenomena by a long chain of theoretical events.

The phenomenon of optics discussed in last chapter, consists of exact angles and refractive indices. For exact input, mathematical equations provide exact output. Quantum events are expressed as probabilities and more than one equations are possible for the same event. Unlike in classical physics, mathematization is not a warrant for truth in quantum physics. The developments in some branches of science, like quantum physics, demand other means for justifying beliefs. The entity realist position, as advanced by Nancy Cartwright and Ian Hacking proposes some alternative philosophic means of tracing truth.

4.2 The Entity Realist Positions

Towards the end of twentieth century, philosophers of science started looking for alterative basis for justifying scientific beliefs. These attempts led some of them to justify belief in the unobservable theoretical entities. Two such schools of thought that developed into entity realism are credited to Nancy Cartwright and Ian Hacking. Cartwright argues for the reality of causes and justifies her belief through the scientific experimentations. She argues against the scientific realist view that explanations lead to truth. Hacking argues that scientific beliefs are formed and justified by the scientific method of interfering and manipulating the unboservables and not by reasoning alone. The beliefs so formed, lead one to believe in the theoretical entities.

In the second chapter of this thesis, scientific realism and anti-realism were defined and discussed. Broadly speaking scientific realism is the philosophic position that the scientific theories are true and the unobservable theoretical entities exist as proposed. Current scientific anti-realism is the philosophic position that scientific theories are at most empirically adequate and the unobservable theoretical entities cannot be known. The entity realist position can be arrived at, in two steps from the more well known and understood positions of scientific realism and scientific anti-realism.

Step 1: From scientific realism, by retaining the part that the theoretical entities exist and are knowable, and showing that the theories are false.

Step 2: From scientific anti-realism, by retaining the part that the theories may not be true and showing that the theoretical entities posited therein exist and can be known.

Cartwright argues using both steps. She argues against the truth of scientific theories and also for the legitimacy in accepting causal explanations that link the phenomena with the theoretical entities. Hacking argues for belief in the entities even without the scientific theories. Their arguments complement each other.

Two of the common explanations in science are causal and Deductive-Nomological (D-N). The D.N model needs some covering laws to do the explaining. According to Cartwright, there are not enough true covering laws available in physics. The laws of physics are *ceteris paribus,* which is an assumption and is not met in nature. In nature, at phenomenal level, more than one forces are at play with different causes. Even if a super law can be proposed, the different causes that do the explaining remain different and the super-law cannot explain correctly.

Scientific theories are postulated to account for the regularities in nature or the laws of nature. The 'explaining' is done by the theoretical posits in the theories. The scientific realists take these posits as real because they do the best 'explaining' in the accepted theories. This is inference to the best explanation (IBE). Nancy Cartwright invokes under-determination by evidence (UTE) argument and says that there can be many mutually exclusive explanations for the same phenomenon (regularity). The inference that 'one' of those explanations is true is not correct. She advises us to infer to the best cause instead, because, for one effect there is only one cause. Cartwright`s argument is that the unobservable theoretical entities, which cause the phenomena, are real.

Scientists quantify the variables in nature, so that these variables can be used mathematically. Quantification depends upon measurement, which is always an approximation. The variables in nature, which represent quality and which cannot be quantified, are ignored. Cartwright argues that although mathematization of physical sciences helps them grow, the theoretical equations are true only to models and not to reality of nature. Moreover, the equations only describe the phenomena and more than one set of equations can be accepted for the same phenomenon. On the other hand, scientists accept only one cause for a phenomenon.

As discussed above Cartwright argues for our epistemic access to the entities while arguing against the justification of our beliefs in the scientific theories. But, it is the scientific theories that lead us to the possible causes and the entities. Hacking differs with Cartwright on her use of theories to identify the entities. Instead he claims that we can know the entities even without the theories.

Hacking argues that the unobservable theoretical entities, which can be manipulated to produce a phenomenon and to learn about hitherto unknown entities, do exist and are known. He quotes an experiment in subatomic physics in detail, to justify our belief in the theoretical entity 'electron'. He argues against the general beliefs that all observations are theory-laden and that all the phenomena occur in nature and then explained by scientists. He says that the hypothetico-deductive model of science is not the only model for progress of science. There are other scientific experimental methods for the justification of beliefs, to achieve knowledge. Scientists do not only form beliefs by reasoning, but also from interference, manipulation and creation of phenomenon.

It is the causal powers of the theoretical entities, which, both Cartwright and Hacking invoke to justify the claims for their reality. Cartwright's arguments complement those of Hacking. In what follows, I examine Cartwright's version of entity realism in first part followed by Hacking's in the second. Their arguments are critically evaluated in chapter five of this dissertation.

4.3 Nancy Cartwright's Entity-Realism

Observations of natural phenomena lead to laws of nature. These laws of nature describe the happenings in nature. From the descriptions, scientific theories are hypothesized and the theoretical entities posited in the theories explain the phenomena.

Nancy Cartwright argues that the individual laws of physics are for individual forces in nature whereas the phenomena in nature are the effect of many forces. Scientific theories which attempt to explain such phenomena cannot be true. She argues that if each force in nature is considered a potential cause and the phenomena, the effect of joint causes; then true inferences can be drawn. She asserts that such inferences can have epistemic import of the unobservable entities.

Cartwright (1983) argues for her version of entity realism in the following steps:

(1) Scientific theories cannot explain. Scientific explanations need universal laws; the laws available in science are not true and all the true laws are not available. (2) Contrary to the general belief, laws of physics do not describe. In nature, many forces are at play. What needs to be described is the combined effect of those forces, so any one law individually cannot describe. (3) Laws of physics should not be understood

as describing the observable phenomena; rather as the causal powers that the forces in nature have. (4) It is the causes which are real unlike the explanations which are approximations and even these are not always available. (5) More than one theoretical explanations are possible for the same phenomenon but only one causal explanation is accepted. (6) Inferences can be drawn to the best causes because the causes connect to their effects which are the phenomena to be explained. (7) Contrary to the empiricists' contention that explanations cannot lead to truth; all explanations are not devoid of truth content. (8) Causes provide justification for belief in the theoretical entities.

The first three steps explain why the scientific theories cannot be true. The last five steps argue for causality as justification for truth of belief in theoretical entities. In what follows I examine Cartwright's arguments in the same order.

4.3.1 Scientific theories cannot explain

Scientific realists believe that scientific laws describe the nature of the physical world. The explanatory function is supposed to follow from the true description of nature. The laws available in physics are conditional on "everything else being equal". This is an ideal condition which is not met in nature. The assumption that the happenings in ideal conditions can tell us truth about happenings in not-so-ideal conditions may not be correct. Science is broken into different domains and each of the domains has laws applicable within those domains. We do not have laws for the situations where more than one domains intersect. There are situations, where explanations can be given without any laws. Science seems to be organizing phenomena by coming up with different laws. We don't have any reason to believe that the principles that organize the phenomena are true and that the true principles will organize the phenomena.

C. G. Hempel (1966) gives a simple deductive-nomological (DN) model for scientific explanation. According to the DN model, if we know the laws of nature, then with the use of deductive logic we can do the explaining. One of the objections to Hempel's model is that it lets in too much i.e. there are phenomena which do not need explaining but D-N model explains them. For example, D-N model can "explain" why a man taking birth control pills does not get pregnant.

Against the view that D-N model lets in too much, Cartwright says that the model explains very little. It is because there are few covering laws available to explain a vast variety of phenomena in nature. And many phenomena which do have good scientific explanations are not covered by any laws.

Cartwright (1983) gives the example of Snell's law for refraction of light waves:

$$\frac{\text{Sin}\, i}{\text{Sin}\, r} = \frac{n_1}{n_2}$$

Where i and r are the angle of incidence and angle of refraction, n_1 and n_2 are the refractive indices for the two media (Klein 1970: 21). This law is ideally valid for media whose optical properties are isotropic. For anistropic media, there will generally be two transmitted waves. Though Snell's law, as stated above is taken as true; in reality it is not, because most media are anisotropic.

We assume that we can understand the happenings in nearly-ideal or not-so-ideal situations by understanding what happens in ideal situations. When *ceteris paribus* generalizations are applied, it is assumed that there is continuity in nature. This assumption is delicate. It is not derived from our knowledge of the laws of nature. For the users of D-N model of explanation, *ceteris paribus* laws provide explanations, which are close enough to the ones provided by the true laws. Our theories do not have the true laws, which can be stated or tested. In the absence of true laws, true explanations cannot be derived.

Cartwright argues that science is broken into various distinct domains like dynamics, hydrodynamics, optics and genetics. There are detailed and sophisticated theories for happenings within these domains. But we don't have theories about the happenings where these domains meet. For example, adding salt to water increases its boiling point and taking water to higher altitude decreases it. But it is not clearly known what happens when we add salt to water and take it to higher altitude.

Besides the non-availability of true laws to do the explaining; in many situations explaining is done without covering laws. In most real life cases, all the facts are not known. Judgments about matters of fact are beset with uncertainty. In spite of the uncertainties we have some confidence in our explanations. According to Cartwright it is the job of science to tell us what kinds of explanations are admissible.

It is also possible that there are no deterministic laws in nature. In such situation, different laws will describe what is happening but not explain. Here, the world runs on probabilistic principles. We would talk of probability of certain events but could not explain a particular happening.

Cartwright's arguments against the explanatory powers of scientific theories cannot go unchallenged. There are regularities in nature. These regularities become prominent, clear and moreover useful for scientific purposes of prediction and further exploration of nature, only after applying the *ceteris paribus* conditions. There is a trade-off between truth and convenience. Already, there is some truth compromised when a generalization is made from a few observed cases to the formation of a law which applies to all the cases. These compromises are worth making for the overall benefit of the enterprise of science.

Assumption of continuity of nature is necessary for the practice of science. An observed regularity can become a law of nature, however limited in scope, based on this continuity. Scientists' belief that what is true in ideal conditions is very close to truth in not-so-ideal conditions, is founded on the same assumption.

In most cases, we are not certain if our theories are true even after applying the *ceteris paribus* conditions. The modern realists do not claim truth for the accepted theories; these are only approximately true. Moreover, the explanatory power gained by moving closer to truth is not enormous. The approximate truth does explain enough, as confirmed by the success of science, thus far achieved. According to Cartwright, the onus of selection of explanations is upon science. Realist philosophers of science agree and add that the best explanation actually leads to truth (ref. Inference to the Best Explanation).

4.3.2 The laws of physics do not describe

An interesting question arises from her claim that the laws of physics do not describe: if the fundamental laws of physics do not describe how the things in nature behave, then, what do they do? She quotes Richard Feynman as saying*: there is a rhythm and a pattern between the phenomena of nature which is not apparent to the eye, but only to the eye of analysis; and it is these rhythms and patterns which we call physics (1967: 14).* Feynman does not claim that the laws of physics describe the facts.

The claim that explanatory laws of physics do not describe reality sounds like anti-realism. But it is quite different from the modern anti-realist views like that of Bas van Fraassen and Hilary Putnam who believe that epistemic import of a hypothesis (explanatory law) is exclusively tied to its empirical content. Van Fraassen does not believe in any scientific evidence for the existence and behaviour of theoretical entities whereas what Cartwright is trying to show here, is that *explanatory laws* do not tell us about the theoretical entities.

In almost all real life situations in nature, more than one causes bring about the phenomena that we observe. *Ceteris paribus* modifier is supposed to precede all such general or fundamental laws of physics that attempt to explain any phenomenon.

For example, the law of universal gravitation, in the words of Feynman states:

> *The law of gravitation is that two bodies exert a force between each other which varies inversely as the square of the distance between them, and varies directly as the product of their masses. (ibid14)*

This law cannot truly describe the behavior of bodies; it is because electricity also exerts a similar force. In the words of Feynman:

Electricity exerts forces inversely as the square of the distance, this time between charges... (ibid 14)

Therefore, it is not true that the gravitational law applies in general and on all bodies. For the bodies which are charged, the force of attraction cannot be given as Gmm/r^2. In fact the force of attraction between two charged bodies is the combined effect of the two forces. None of the two laws, of gravitational attraction and electrical attraction can by itself truly describe the behavior of bodies. Charged bodies do not behave as dictated by the law of universal gravitation and similarly two heavy masses do not fully obey the law of electrical attraction.

We can therefore claim that these two laws are not true, and further that they are not even approximately true. A good example can be given as that of attraction between electrons and protons where the law of electrical attraction almost completely takes over. The true law of universal gravitation therefore should have the *ceteris paribus* modifier as:

"If there are no forces other than the gravitational force at work, then two bodies exert a force as given by the law".

The law as stated now, is true, but of very little use. It can explain phenomena, the type of which, hardly occur in nature. Because, it is very rare in nature, that no other forces are acting on any two bodies.

Complex phenomena are explained by reducing them to the simpler components. In the words of John Stuart Mill (1893) it is *explanation by composition of causes.*

When explanation is provided by a composition of causes, the individual laws employed cannot describe reality truly. But, for the purpose of explanation it is assumed that each law acts separately. In other words it is assumed that each law used in explanation has the same form whether alone or in combination. And it is not possible because the actual behavior of the object in question is the resultant of individual laws in combination.

In order, to be 'true' the law must describe what actually happens, i.e. the resultant action. In order to be explanatory (ref D-N model) the law must describe what happens when it acts alone. The law looses its explanatory power when it is applicable to one of the composite causes and looses its descriptive power for the joint effect.

Description and explanation are interrelated. My arguments given in the last subsection, also apply to this subsection.

4.3.3 Descriptive vs. Causal

In the last two subsections it was shown that the laws of physics cannot explain and describe simultaneously. Now we examine how Cartwright takes her argument further. She suggests that the issue can be resolved by considering the laws as the potential causal powers that the bodies in nature have.

Forces have two dimensions. One is the intensity and the other direction. Two or more forces can be "added" vectorially. For example, when two forces of equal intensity act on an object in the north and east direction, the resultant force will be in the north-eastern direction. As in the above mentioned example, when gravitational and electrical forces act on bodies, the forces are produced according to the two respective laws. As each law is accurate, the resultant force is the vectorial addition of the two forces. In nature, the two forces are not produced separately and then added vectorially (and then put into action to produce the resultant action as observed!)

Taken separately, each law does not and cannot describe the resultant action produced. According to law of gravitation a force of Gmm'/r^2 is produced (m and m' are masses at a distance r) and according to the law of electrical attractions a force of qq'/r^2 is produced (q &q' are the charges on the two bodies). But in actual practice, the two forces are not produced, instead one single resultant force is produced and this resultant force is none of the two individual forces. According to vectorial addition, the two forces are produced but do not exist.

The vectorial addition of the two forces namely gravitational and electrical can be understood, not in the descriptive way but as the causal powers that the bodies have. The main point which is brought home in this section is, that laws of physics may not be seen as only description of what actually happens, rather as description of the causal powers that bodies have.

Cartwright proposes causal power instead of description. Whenever we talk of causes, the name that comes to mind is that of David Hume. In this context Hume is on record as saying: "The distinction, which we often make between *power* and t*he exercise of it, is ... without foundation*." [Italics as in original] (Bigge 1978:311). In the following subsections I explain how Cartwright builds her case.

4.3.4 Reality of causes

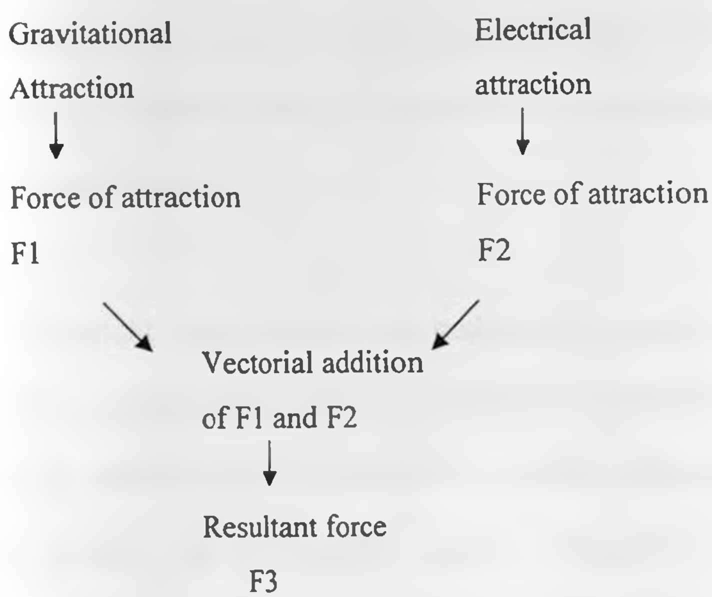
In this subsection, we follow how Cartwright shows the drawbacks of considering that many forces produce an intermediate force, which brings about the observed effect and explains.

Lewis Creary (1981) claims that there are two different kinds of laws applicable for explanations where causes compose.

1. Laws of causal influence.
2. Laws of causal action.

Laws of causal influence tell us what forces operate and the laws of causal action tell us what the results are, of those influences, either singly or combined.

In the diagram below, F1 and F2 are the two forces that influence the two charged bodies, one due to gravity and the other due to charge. The actual force that acts is the resultant force F3, which is obtained by vectorially adding F1 and F2.



The phenomenon is explained by the resultant force F3 (*ibid*155).

Cartwright argues that there are drawbacks in this explanation. In most cases there are no general laws of interaction like that of vectorial addition in dynamics. For example in cases of irreversible processes like heat exchange or diffusion, there are no simple laws for "adding" the forces. There are laws available to calculate the rates of diffusion and rates of heat exchange separately. There are no clear laws, when the causes combine; for example when two fluids, at different temperatures, diffuse. In other words the equations representing fundamental laws are subject to *ceteris paribus* qualifier.

Even in the cases like dynamics, where such laws are available (e.g. vectorial additions), there is a problem. As shown in the diagram above, the two influences, F1 and F2 produce an intermediate force F3. This force is a theoretical entity postulated to explain what happens when two bodies are acted upon by two different causes. This theoretical entity cannot be confirmed experimentally. Cartwright argues that an entity which is admitted should be grounded in experimentation, so that its causal structure can be known.

Nancy Cartwright acknowledges, that traditionally, empiricists do not believe in causes. They accept scientific laws as generalization of observed facts. In the modern sciences, the scientific laws are expressed as elaborate mathematical equations which in turn, become part of scientific theories. Examples of such equations are Schrödinger's equations, Hamilton's equations and equations of general relativity. These equations tell us "what happens" without saying anything about "why" and "causes" or "effects". This is the distinction between anti-realists and realists. The latter attempt to know a true story; they form beliefs and justify them. It will be shown that causes play a more important part in sciences than just telling "what happens". More so, in modem physics, it makes sense to believe in causal claims of the theories than in their explanations.

4.3.5 Explanations by causes

Entity realism is the view that we can have justified true belief in the theoretical entities. Cartwright has argued that the laws of physics cannot describe and explain the phenomena truly. These laws cannot lead us to true entities. For true theoretical entities, true explanations are a requisite. In this subsection her arguments for causal explanations are examined.

She says that explaining can be done in various ways but the two of the main types are:

1. By citing causes.
2. By referring to accepted laws (e.g. DN model).

Modem physics has laws which are in the form of complex mathematical equations. These equations help in making precise calculations about "what happens". But just stating the phenomena, is not explanation. Difference between explanations and causes is brought out by Rene Thom, when he writes:

> *Descartes with his vortices, his hooked atoms and the like explained everything and calculated nothing; Newton with the inverse square of gravitation, calculated everything and explained nothing.* (1972: 5)

Thom is saying that it is the causes that do the explaining and not just stating the laws (or doing the calculations). The main point which is being brought home is that Newton's laws are useful instruments and not statements of truth. On the other hand, if Descarte's explanations are accepted, then the causes he cites, like hooked atoms do exist.

According to Cartwright it is fine if empiricists do not believe in the truth of scientific theories, but they should believe in the theoretical entities which do the explaining of the phenomena, and are the causes.

For the scientific realists, a different approach is required. They believe in more than what is essential. For the realists, the best explanations lead us to the inference of truth. The more a law explains, the more it is likely to be true. It would be a miracle if the law explained a wide variety of phenomena and not be true. It will now be argued, that explanation by citing causes can lead us to truth whereas explanation by referring to scientific laws may not.

According to inference to the best explanation (IBE) argument as proposed by Gilbert Harman (1965), we can infer truth from the best explanation. But what if there are more than one equally good (best) explanations of the same phenomenon? Given the scarcity of other empirical evidence, as in the case with quantum physics, it becomes impossible to infer the truth. But that is not the problem with causal explanations. In modern physics an acceptable casual story does not have competing stories.

Cartwright argues that a cause connects with its effect and makes it happen. A cause brings about its effect which is the observable phenomenon. In physics, phenomena are named as effects e.g. the Zeeman Effect, the Sobert Effect, the Hall Effect. The effect is peculiarly caused by a particular cause. Nature of cause can be inferred from the nature of effect; the phenomena. In other words inference can be drawn from the explanation provided by a cause.

A scientific theory attempts to explain many different laws, which in turn represent the regularities in nature. These laws are "true-to" the phenomena they represent. For example, the law of gravitational attraction is quite true to the phenomena it represents, but becomes approximate in extreme situations when speeds approach that of light or at quantum level. Similarly, approximations crop up when a scientific theory attempts to explain varied laws. We have seen in the preceding sub-sections, in situation where more than one laws apply, none of them remains true. The more a theory attempts to explain, the more accepted and general it becomes but in the process it looses its truthness and application to the phenomena. In quantum physics, the equations do the explaining but do not bring about the phenomena. The equations are derived from the accepted theories for ease of calculations and to treat different phenomena in a similar way.

From the above discussion, it becomes clear, that the causal explanations can lead us to truth and not the theoretical explanations. Nancy Cartwright (1983: 78) shows by using two examples, one is the example from the theory about lasers, where many theoretical explanations coexist but only one causal explanation suffices. The second example about Avogadro's number shows how more than one casual explanations are unacceptable.

<u>Example 1 Lasers</u>

Atoms are made up of neutrons and protons in the nucleus and electrons rotating around the nucleus, in different orbits. Electrons in different orbits are at different energy levels. When an electron moves from high energy level to a lower energy level, it emits a photon. The frequencies of the emitted photons depend upon the energy levels of the atom. The emitted photons can be seen on a spectroscope screen as a line. If the photons emitted, are all at one frequency level, the line observed on the spectroscope is a very thin. The line observed on the screen, with photons emitted from de-exciting atoms has a finite width, showing that the photons are of different frequencies.

The explanation given by the physicists for the different frequencies of the photons emitted is:

The atom is emitting and absorbing photons continually giving rise to emissions at different energy levels which cause the broadening of line on the spectroscope (The explanation is from a text book by William Louisell 1973). This is a causal explanation; the cause, being emission and absorption of photons. On the other hand G.S Agarwal (1974) summarizes the mathematical treatment of the phenomenon of line broadening, by six different approaches. All the six mathematical treatments described by Agarwal provide accurate calculations for the shape and width of the line, (all the six cannot be true!).

The example strengthens Cartwright's argument that causal explanations and not theoretical explanations can lead us to truth. She claims that the link between cause and its effect can be confirmed experimentally and gives an example of a radiometer to augment her claim.

A radiometer was introduced by William Crookes in 1873, but its working is still not clear. A radiometer is made up of vanes, with dark and light sides which can rotate on an axis and enclosed in vacuum. When light falls on the vanes, it starts rotating. There are two main explanations for the rotation:

1. The gas in the radiometer puts perpendicular pressure on the vanes.
2. The gas puts tangential pressure on the edges of the vanes.

Both the explanations may be correct, as the vanes can move due to both the perpendicular and tangential pressures, simultaneously. But each of the proponents, of the above two explanations, claim that the factor cited by him is the single significant factor. An experiment is being constructed for the radiometer, to decide on which of the two causal explanations given above is correct.

Compared to explanations by reference to a theory, the causal explanations are more objective because the casual claims can be confirmed or rejected by setting up appropriate experiments.

Example 2 Avogadro's number

Nancy Cartwright provides another example to bring home the uniqueness of causality to trace truth. There is a hypothesis in physics that there are a fixed number of molecules in any gram-mole of a fluid. Jean Perrin (1916) conducted systematic experiments on Brownian motion and convinced the scientific community that atoms exist. He gives thirteen quite different physical situations which yield the determination of Avogadro's number (the number of molecules in one gram-mole). According to Perrin, with thirteen different kinds of evidence, all pointing to the same value we should be convinced that atoms exist and Avogadro's number is correct. Perrin's reasoning is not an inference to the best explanation. It is the case of inference to the most probable cause.

An experiment is designed on the basis of the structure of the cause to be studied. If the structure is not clearly understood or is incorrect, the results obtained cannot be accurate. Prior to Perrin, scientists focused on the sizes and velocities of the suspended particles for Brownian motion and got inaccurate results. Perrin recorded the height distribution of Brownian particles at equilibrium and calculated the Avogadro's number extremely accurately. He was able to find specific effects which were peculiar to the exact character of the cause. Character of the effect (the phenomenon) can lead to the character of the cause through a well constructed experiment.

The thirteen physical situations that Perrin refers to are each, a case of inferring a concrete cause from a concrete effect. The cause in each case is the number of molecules in a gram-mole of fluid, the Avogadro's number. The effects are different, depending upon the model of experiment chosen, and point to the same cause and hence coincidence and confirmation of Avogadro's number.

Although philosophers of science generally believe in the laws and theories while denying the causes; the actual practice in sciences, particularly in physics, is different. Cartwright claims that in physics, different and varied theoretical treatments are common but only a single causal story is allowed.

4.3.6 Causal explanations can lead to inference

Nancy Cartwright's version of entity realism depends upon two assertions:

1. Truth cannot be derived from theoretical explanations.
2. Truth regarding theoretical entities can be derived from causal explanations.

She finds support for her first assertion in the arguments provided by Pierre Duhem and van Fraassen. For her second assertion, she argues that their arguments are not against explanations in general.

The issue at hand is: what is an explanation for? The answer separates scientific realists from anti-realists. For the realists if our explanation is good enough and better than any other available, it can lead us to truth. They argue how could something explain if it were not true? For the anti-realists, explanations have a different purpose. The purpose is to organize efficiently the huge volume of detailed knowledge that we have, of the phenomena. The anti-realist reasons: how can organizing power lead to truth?

A prominent anti-realist view is given by van Fraassen and it has been discussed in the second chapter of this dissertation. Pierre Duhem ([1914] 1991) accepts the scientific laws because they can be confirmed inductively. He does not accept the scientific theories because the only thing the theories do is to "explain" the laws. Both van Fraassen and Duhem reject the theories because they disagree with the inference to the best explanation. Their rejection of inference to the best explanation argument, Cartwright argues, does not mean that they are opposed to inference in general.

Cartwright says that Duhem and van Fraassen present an epistemological view that the scientific explanations cannot lead us to scientific knowledge. They allow inferences drawn from more reasonable grounds. Their sceptism should be limited to the scientific theories and should not extend to the theoretical entities, which have a causal explanation. Inferences drawn from effects to causes, she stresses, are legitimate.

Cartwright argues that one can provide a reason for believing in the theoretical entities by claiming that the real regularities of nature are at the theoretical entity level. It is this regularity that brings about the regularities we observe at the phenomenal level and further explains the anomalies.

Van Fraassen's argument is: the theories regarding the theoretical entities are empirically adequate; does not prove that the entities actually exist and the theories containing them are true. Van Fraassen and Duhem, both deny the jump from empirical adequacy to truth. In other words, they doubt the inference of truth by explanation of saving the phenomena. History of science provides examples of good explanations which were not true. Ptolemy's astronomy is just one example.

Another argument against inferring truth from explanation is that more than one (mutually incompatible) explanations are possible, for the same phenomenon, and all cannot lead to the truth. That shows that the truth is independent of explanatory power. Cartwright challenges the argument as follows:

Duhem accepts the phenomenological laws, which can be tested inductively. From a few observations, a law is proposed and it is confirmed by more observations; from the same 'a few' observations, different laws can be postulated. Even here, we can have different incompatible laws, which are empirically adequate.

The point made by Cartwright is, that when reasoning inductively, more than one inferences are possible. But that does not mean that all are devoid of truth, and that truth is an external characteristic of explanation. Her argument is that all explanations are not devoid of truth or in other words some explanations can lead us to truth. Her justificatory story for the reality of unobservable entities depends on the explanations provided by causes.

4.3.7 Existence of theoretical entities

Cartwright argues that truth is part and parcel of causal explanations. When an inference is made from the effect (phenomenon) to a cause, the cause has to exist. When accepting a causal explanation, we are accepting the existence of the cause. The following two examples can make the point very clear.

(a) Example of 'observable' cause

Cartwright gives an interesting example of an observable cause (1983: 91). Suppose there is a tree in a planter. It is noticed that the tree is not doing well; its leaves are yellowing and dropping off. The experts explain the phenomena by saying that the planter has accumulated excess water at the base. Water is the cause of the disease. A hole is drilled at the bottom of the planter and fowl water is seen flowing out. The tree starts doing well. The causal explanation, had the cause (water) built into it. For casual explanation to be correct the cause must exist

(b) Example of 'unobservable' cause

Cartwright (*ibid* 93) quotes Millikan's experiment, in which two brass plates are put horizontally at short distance in a vacuum. These plates are given opposite electric charge. Very light oil droplets are introduced between the plates. These droplets acquire negative charge by ionization, and have two forces acting on them. One is the force of gravity and the other one is the force of electrical attraction. The electric force can be adjusted, so that the two forces acting on a droplet equalize and the drop stays still. In this case:

Effect: Drop staying still and not falling due to gravity.

Explanation: The drop has electrons on it, which are acted on by the given electric charge and the electric force counters the force due to gravity.

Cause: Electrons, on the drop.

Now, unlike the previous example, we cannot observe the cause by drilling a hole and seeing the electrons flowing out. But the presence of electrons can be confirmed by indirect means. If the drop is sprayed with positrons, which wipe out the electrons, the drop looses its negative charge and starts falling due to gravity.

In both these examples, inferences are drawn from the best explanations. But the explanation is not provided by the scientific theories, rather it is provided by something more specific, it is the theoretical entity in the second example. The electron may be part of many different, incompatible scientific theories, but what we infer is its existence.

Cartwright has argued that even if we have belief in the truth of a theory, we may not have a strong justification for that belief. But the cause provides a reason for our belief in the existence of theoretical entities.

4.3.8 Comments on Cartwright's position

Nancy Cartwright makes a case for her version of entity realism in two steps. First she argues that the laws of nature do not describe truthfully and these descriptions cannot lead us to correct explanations. Scientific realists infer from such explanations, which cannot be true. In the second step she argues that the causal explanations can lead us to true entities. But the laws and explanations are susceptible to falsity and are not the foundations of scientific knowledge as alleged by Cartwright. Moreover, the causal explanations are better, only in cases where the cause and effect can be correlated beyond doubt.

Description of nature is beset with difficulties. There are regularities in nature but all regularities are not laws of nature. The "rhythms" (Feynmann 1967) quoted by Cartwright is a rather general term. Scientists choose those regularities which have some common explanations. For example regularity of attraction due to gravity and due to electric charge, are treated separately. Yes, laws of nature are out there, which nature herself follows; it is up to us to decipher the regularity and formulate theories, and that is the human part and is subject to errors. For example, scientists divide all the elements in nature according to their atomic numbers, which is the number of electrons or protons in an atom. But this choice of regularity (by atomic number) leads to anomalies because there are elements with different characteristics but the same atomic numbers (isotopes). In spite of the anomalies or difficulties, the chemical theories relying on atomic numbers are quite successful. Alexander Bird (2005:7) says that the sign of a successful theory is not the absence of problems, rather its ability to solve them.

From a few observations, regularities are inductively derived. Laws of nature formulated from these regularities cannot be logically certain. The laws attempt to tell us a lot new and more, than what is observed. If a compromise is made between certainty and generality, it is worth making. Bird says that observations, regularities, laws of nature and even explanations are not the basis of science; these are only the starting point (2005:119). A scientific theory is a conjecture, which is subject to refutations (Popper 1963). It is the attempt to falsify a theory that takes it towards certainty and truth. Strength of scientific method does not lie in how the beliefs are formed, rather in how they are justified (van Fraassen in [Monton2007]).

Her assertion that laws of physics lie is contentious. There are different forces in nature; scientists propose their laws and affirm them inductively. These laws are confirmed in the laboratories, under controlled conditions. Cartwright contends that these laws lie because they do not individually, apply in nature. She argues for the truth of causal connections even if these can also be confirmed only under controlled conditions. If a scientific statement is applicable and confirmed under controlled conditions; it is not a lie. She construes "under controlled conditions" selectively.

Cartwright argues against scientific theories, but it is the same theories which tell us of the possible causes. Her claim that causes lead to true theoretical entities is valid selectively. It applies only where such causes can be hypothesized and further, where experiments can be designed to confirm the connection.

There is indeed, some epistemic difference between explanations derived from laws of nature and those derived causally. The former have to be the best explanation of the phenomenon in question and that is not always possible to ascertain. On the other hand the causal explanation cites a salient feature of the background conditions. Cartwright cites the unobservable entities as the causal explanation, which may be a better option; albeit only in the cases where a relation can be established between the cause and its effect: the phenomenon to be explained.

I concur with Cartwright, that cause is one of the explanations for a phenomenon that can lead to truth. I disagree with her that the 'causal' is the only explanation that can track the truth about nature.

4.4 Ian Hacking's Entity Realism

Let us now turn to Ian Hacking's version of entity realism. Hacking's version of entity realism is inspired by actual happenings in the scientific research laboratories. He takes the philosopher to the laboratory and asks: How do scientists form and justify their beliefs?

To make a case for his entity realism, Hacking argues for our epistemic access to the unobservable theoretical entities, independent of the scientific theories. He argues against the belief that all observations are theory-laden and that the sole purpose of scientific experiments is to verify scientific theories. The theories are representations of the physical world, and according to Hacking, are not hooked up to the world. Philosophers of science, he argues, are obsessed with representation of the world through rationality, thinking and scientific theories while ignoring intervention and experimentations. Hacking quotes Karl Popper who says that reality has to do with causation and manipulation:

'I suppose that the most central usage of the term 'real' is its use to characterize material things of ordinary size ..... it is further extended of course to liquids and then also to air, to gases and to molecules and atoms. .....the entities which we conjecture to be real should be able to exert causal effect upon the prima facie real things' (1977: 9)

Hacking challenges empiricists' assertion of limiting our knowledge of the physical world to empirical adequacy and our beliefs to what is observable with naked eyes. In the modern science almost all the phenomena, to be to be explained, are unobservable. Hacking suggests alternative methods for justification of belief. He advises the shift from "seeing is believing" to "interfering is believing".

Unlike Nancy Cartwright who argues against the truth of scientific theories, Hacking is agnostic towards them. He augments the Hypothetico-Deductive (H-D) model for the theories and introduces mathematization between theory and observation so that the model accommodates modern scientific practices. What Hacking argues against, is the belief that H-D is the only model for gaining knowledge in science.

Gist of Hacking's entity realism is, that so far, scientific realists have argued for belief in the unobservable entities, as hypothetical, metaphysical posits. Justification for belief in them came from their explanatory and predictive powers or their empirical deductions. The justifications were subject to anti-realists' skeptism and impotency of empirical evidence against under-determination. Hacking proposes the entities as tools for manipulating and investigating nature to elicit more information. The new information may need further justification, but the tools employed cannot be doubted. They exist and we know enough about them to have used them as tools.

There seem to be two distinct origins of the idea of 'reality'. One is the reality of scientific theories and the other; the idea of what affects us and what we can affect. According to Hacking, we can count as real what we can use to intervene in this world to affect something else or what the world can use to affect us. It is only in the last about three hundred years that natural science has started interlocking the representing and intervening. Now we can philosophize on this interlocking.

Ian Hacking (1983) argues for his version of entity-realism in the following steps:

1. Scientific experiments do not always depend upon theories. The two can be independent or may supplement each other.
2. Empiricists limit the observability by the epistemic community's physiological make-up while the realists consider it theory-laden. Modern scientific practices transcend both these views.
3. Justification for belief in the observations made, does not come from "seeing" through a microscope or the theories on which it is built. Rather it comes from the manipulations that the scientists perform with it. Hacking picks up microscope to represent all the complex scientific instruments to argue his case.

4. According to the Hypothetico-Deductive model of science, some initial observations lead to hypotheses, which are verified from their empirical deductions. For example Newton observed the apple falling and hypothesized the theory about gravitation. But all the phenomena in nature are not observable. Scientists create phenomena in the laboratories. In modern physics, abnormal workings of the instruments provide observations to be explained.
5. Measurements involve experimentation and reality precedes measurements. Moreover measurements give rise to anomalies which need to be explained by new theories and this is how science progresses.
6. In line with Cartwright's views, it is the causal properties of the entities which are used as input in the experiments. Such experiments justify our epistemic claims about the entities.

Hacking's arguments are examined in detail on the following pages.

4.4.1 Experiments

Ian Hacking (1983) says that history of science has given more importance to the scientific theories and the people who theorized, at the expense of the experimenters. There is a clear bias. In the past the experiments were constructed and conducted by the people from lower social rank compared to those who theorized.

There are different views on the roles of experiments in science. One is that experiments lead to discovery and growth of knowledge. As Humphrey Davy (1778-1829) puts it:

The foundations of chemical philosophy, are observation, experiment and analogy....in the progression of knowledge, observation, guided by analogy, leads to experiment, and analogy confirmed by experiment, becomes scientific truth (1812: 2).

Not every chemist shared Davy's inductive view of science. Justus von Liebig (1863) said: "*In science all investigation is deductive or a priori. Experiment is only an aid to thought, like a calculation ..*" *(186: 49)*

Against Davy's view, Liebig was of the opinion that an experiment must be preceded by a theory. Or, in its stronger version, an experiment is conducted to confirm or reject a theory. Hacking disagrees with this view and asserts that an experiment, with or without a theory, offers an observation that can lead to theorizing or further experiments, or a new discovery. Most of the original observations in nature were made by curious, inquisitive and reflective people. These were not mind-less empiricists without an 'idea'. They formulated theories out of what they had observed.

There are some chance encounters with unique phenomena and keen observers take it up. The observations lead to theorizing. In some cases, situations are manipulated to make new observations or creating a phenomenon which does not occur in nature. Hacking (1983: 157) gives an example. E.L.Malus (1775-1812) a colonel in Napoleon's army was observing light reflected from the window of a nearby church. This light passed through an Iceland spar when the spar was kept in vertical position, but was blocked when the same spar was kept in horizontal position. The Iceland-spar is a natural stone which refracts and polarizes light. With the manipulation of a transparent stone, Malus observed the phenomenon of polarization of light.

Science attempts to give us knowledge of the physical world, and the 'expression' of the physical world is, what we observe: the phenomenon. Malus's observation of polarization of light is that first step towards knowledge. It can be called a "virgin" observation.

The common view is, that the initial observations lead to theorizing, and then all further observations are theory-laden. But there are many examples where, even with a wrong theory or no theory, experimenters manipulated nature and observed and noted the results. David Brewster (1781-1866) studied and determined the laws of reflection and refraction for polarized light. He discovered biaxial double refraction and published sine and tangent laws for intensity of reflected polarized light, five years before Fresnel's treatment of the same within wave theory. His work helped develop wave theory, but he himself was a believer of corpuscular theory of light. He was not comparing or confirming theories. He was trying to find out how light behaves.

Brewster's case does not prove theory-independence of observation or experimentation as intended by Hacking. A false (corpuscular) theory may have some truth content. If the experiment involves that content, then the theory's falsity does not affect it. The empirical content of a falsified theory is carried in the successful one.

(a) Brownian motion

An observed phenomenon gains its meaning only when one can see what it means or how it connects with other known phenomena. Hacking (1983) says that Robert Brown, in 1827 observed an haphazard movement of pollen in water, the same must have been observed by others, but in the absence of any explanation or utility, was ignored. Brown made detailed observations of the movement, but could not explain. It was not until the beginning of the twentieth century when experimenters like J. Perrin and theoreticians like Einstein explained the irregular movement of pollen suspended in water, by the kinetic molecular theory. The phenomenon of Brownian motion was 'meaningless' until then.

It shows that some understanding or theory is indeed required for experimental work. But it has not been shown that truly fundamental research is not possible without a relevant theory. However we can never know which research is fundamental. Moreover Brownian motion is a good example of vague-ness of observation without a theory.

(b) When theory and observation meet

Some observations and experiments lead to theories and also some theories guide key experiments. If a theory is entirely metaphysical, it may not succeed simply for lack of empirical evidence. Similarly an observation of some phenomena remains meaningless for lack of theory. History of science tells us of instances when an observation or experiment meets with a theory unexpectedly and they click perfectly.

Hacking narrates an episode from history of science. In 1965 two radio astronomers Arno Penzias and R. W. Wilson (*ibid* 159) used a special radio-telescope to identify different energy sources in the universe. Besides what they were observing, they also observed a small amount of energy which was distributed uniformly all over the universe. It was noticed to be in the form of a temperature of 3^0k, i.e. 3^0 above the absolute zero.

Almost at the same time, a group of theoreticians working at Princeton suggested that if the Big Bang happened as theorized, then there should be an energy level equivalent to the temperature of 3k in the universe. This is the residue of cooling down of the universe after the Bang and could be detected in the form of radio signals.

Now, the experimental work of Wilson and Penzias matched very well with the theoretical work at Princeton. On their own, the radio observation and the theory were of little value, or just speculation.

The point stressed here, is that Wilson and Penzias were not refuting or confirming any theory. They were just exploring. I think this is the case of observing nature as a forerunner to knowledge. This is the first step in the long chain of observation, regularity, laws, theories and their justifications.

(c) Invention

Another form of experimentation and observation leads to invention. A good example is that of an engine. The idea of an engine came out from observations of the power of steam. It was converted into the mechanical or dynamical force to do 'work'. The economic desire of maximizing output from a given input pushed the experimenters to device an efficient engine. In the process the laws of thermodynamics and Carnot cycles were developed. Once again it shows that the experiments were not conducted to refute or to confirm a theory. The experiments were trials conducted for the sake of technology.

Although Hacking had set out to bring experimental work at par with the theories, his arguments have not dented the theory's supremacy. A chance-observation however important cannot undermine the importance of theoretical background in general. Experiments can have a life of their own, independent of any theory. We cannot generalize any relationship between theory and experiment. Hacking is not refuting that scientific theories can be true. He is not against the view that some experiments are conducted to verify certain theories. He is arguing against the general notion of subordination of all experiments to the theories. He has argued that experiments are conducted or initiated for non-theoretical motives also. And further, experiments can provide opportunities of theory-neutral observations.

4.4.2 Observable – Unobservable

In this subsection, Hacking's arguments for the importance of observation for scientific progress are examined. For experimental observation, the acumen for observing what is expected is less important than observing the unexpected and also the setting up of the appropriate equipment. The purpose is to bring about the appropriate phenomenon. Although empiricists like van Fraassen talk of "unaided observations," such observations are almost non-existent in modern day sciences.

(a) 'Observation' for positivists and realists

In the positivist philosophy of science, observation is of utmost importance. Hacking says that the positivists are against causes, against explanations, against metaphysics and against theoretical entities. With the help of observable reality, the positivists can attempt to understand the world. Logical positivists used logic to reduce theories to express the facts and organize the thoughts on what can be observed. Constructive empiricists take the theories literally, but do not believe in them. For the positivists, a theory is accepted because it saves the 'observable' and helps in prediction. Unobservable theoretical entities, suggested by a theory are not to be believed in.

Grover Maxwell (1962) responds to positivists by saying that there is continuity between what is observable and what is theoretical. His argument attacks the positivist belief in associating observable with 'existing and real' and unobservable with 'theoretical and un-real'.

The epistemic community, the observer, for whom the knowledge of nature (science) is meant, has the technological capabilities to enhance his own observation and observe the 'unobservable'. That means with the advancement of technology, more 'unobservable' can become 'observable'. Because the theoretical entities lie in the realm of unobservable, they can become observable with sufficient advance of technology. We have a concrete example of genes, which were once theoretical entity but can be observed with the help of instruments now.

(b) Theory-independence of observation

Experiment and observation are not the same thing. Some exceptional situations lend themselves for exceptional observations which are not experiment. Hacking (1983) gives example of Dr Beauchamp, who in 1812 observed a patient's digestive system, over a long period of time. The patient had suffered a horrible wound and his digestive system was unnaturally exposed (*ibid* 173).

Hacking gives another example of William Herschel, who was a keen observer of the skies. While observing the effect of light coming from different stars, he noticed a different phenomenon. It was the radiated heat. This heat-effect was initially associated with the different colours of the spectrum, but was later found to extend beyond the spectrum. He guessed that both visible and invisible rays are emitted by the sun and this guess of his is a belief today. Lack of instruments to measure heat accurately made Herschel to abandon detailed study of heat radiation. Macedonio Melloni (1798-1854) invented a thermocouple in 1830 (*ibid* 178), which can measure heat radiation. With the help of thermocouple, the wave theory of light gained momentum and Newton's corpuscular theory faded. This is a case of observation provoking a theory and shows the importance of instruments. Scientific instruments enhance observability. Dudle Shapere defines observable as:

x is directly observed if (1) information is received by an appropriate receptor and (2) that information is transmitted directly, i.e. without interference, to the receptor from the entity x (which is the source of information). (1982: 231)

According to Shapere whether or not something is directly observable depends upon the current state of knowledge. Our theories of workings of receptors or transmitters are heavily theory-laden. As a theory becomes more accepted, we extend the realm of observation. For something to be observed it should fulfill Shapere's criterion. Also that theories involved, should not rely on the facts to be observed. This last condition makes the observation independent.

Knowledge is ultimately founded upon observation, but the fact that observations depends upon theories, does not make it irrational. Van Fraassen also notes, in passing, that theory may delimit the bounds of observation. A philosophy of experimental science cannot allow theory-dominated philosophy to make the very concept of observation become suspect.

I think philosophy must keep pace with what is philosophized. For science to progress, some belief must be apportioned to observations made with instruments. Hacking has argued that in some cases theory-dependence of observation does not become an obstacle in gaining knowledge of the unobservable reality. He has not convinced the empiricists to extend belief in unobservables. Scientific instruments are built on some accepted theories; these theories are only empirically adequate. The observations made with these instruments cannot warrant truth. But if something cannot be observed with unaided eyes; does not imply that it does not exist or cannot be known. Hacking has prepared ground to suggest alternative means of justification in unobservable entities that transcend observable-unobservable dichotomy.

4.4.3 Microscopes

Nucleus or the hard-core of hacking's arguments for justifying beliefs in the unobservable entities (entity realism) lies in showing that when we can interfere with or manipulate an entity, then for sure it exists and can be known. Manipulation of unobservable entities can be 'experienced' through microscopes. It is important for philosophers, according to Hacking, to know the workings of microscopes because it is one way of finding out about the real world. They philosophize on perception to get an insight into what is observed whereas a microscopist has far too many ways to help perception. We should have some understanding of microscopes which augment our vision and observation power. Scientists conceptualized the gene and developed instruments to let us see it.

It is the telescopes which are quoted most often in the history of science. Galileo invited his critics to come and watch through his telescope. Pierre Duhem quoted a telescope to bring home his famous thesis that no theory need ever be rejected, because if the phenomena observed do not fit the theory, *blame the telescope!*

In this sub-section different aspects of microscopes are discussed to demonstrate the legitimacy of belief provided by them.

(a) <u>For and against the microscope</u>

Ernst Abbe (1840-1905) explained that there can be no comparison between microscopic and macroscopic vision because the images of very small objects are not simply delineated by the microscope according to the simple laws of refraction. In fact what is seen through a microscope cannot be "seen" without the knowledge of the theory involved. Gustav Bergman (1943) the American positivist said 'microscopic objects are not physical things in literal sense, but merely by courtesy of language and pictorial imagination'

Grover Maxwell (1962) presents the realist view, when he says that there is a continuum from looking through a window looking through a window pane, looking through glasses, looking through binoculars, looking through a low powered microscope, looking through a high powered microscope, etc. He is stressing that an entity which is unobservable at one stage becomes visible with the aid of technology. However the claimed continuum is not really very continuous. A low powered microscope may 'enlarge' the view but a high powered one creates a picture, which cannot be understood without the theory behind the microscope.

Ontology is independent of observability. If an entity exists out there, its existence is not dependent upon the humans' ability to see it! Both realists and anti-realists agree that the world exists independently of the humans. It is the next stage, the epistemological stage, where they differ. The anti-realists claim that we cannot know what is unobservable and the realists insist that technology helps us go beyond observable, deep into the realm of unobservables.

(b) Don't just peer: interfere

Hacking argues that our day-to-day understanding of what we see comes through our moving around and intervening. A scuba diver learns to see under water only by swimming around. Similarly we learn to see through a microscope by 'doing things' under it. We can observe different organs of an insect only if we start viewing it under the microscope, then we dissect it and view the part as a 'part' of the 'whole'. Peering alone without interfering will not help in observing.

Through simple light-diffraction microscopes, the physical interaction between the specimen and light beam are identical for image formation in the microscope and in the eye. The higher powered microscopes use ultraviolet light or x-rays or electrons as radiation instead of the normal light. Our eyes cannot see those other radiations. The question is: Is the image created with such radiation the same as the object? It is a map of interactions between the specimen and the imaging radiation.

Undoubtedly all the microscopes use theory to work. Some use simple reflection, refraction and diffractions of plain light and others use radiation and rays of electrons. In spite of the microscope using theories for its working, any statements about what is seen with microscopes, is not theory-loaded. In other words you don't need theory to observe or understand what a microscope has done. The conviction or belief that what you are observing through a microscope is real, comes from actually using one. Let us take the example of a cell, which is unobservable by a naked eye. To study a particular section of this cell, it is put under the microscope and an ultra thin microscopic glass needle is used to inject a dye into it. You can see the needle piercing the cell-section and pushing the dye in, through the microscope. All this is unobservable to the naked eye. The conviction, in this case, comes from the similarity between microscopic and macroscopic views.

(c) Errors and remedies

Hacking explains that making and observing is not a straight forward business in microscopy. Preparing a specimen for it to be observed under a microscope is a technical job. Errors come in due to different reasons. Two of the main causes for aberrations are: due to shape of glass lenses, the spherical aberration and due to different wave lengths of colours within light, the chromatic aberration. These are remedied by using a combination of transparent materials.

Normal biological specimen, are transparent and cannot be observed by the light transmitted through them. Coloured dyes are injected into them for visibility. But most of those dyes "kill" the specimen, resulting in a very dead cell or damaged specimen. Polarization is a property of normal light and an analyzer can 'pick up' the level of polarization at angles between 0 and 90. In this case the 'seeing' is not the same as our natural seeing, where our retina uses reflected light to make visual images; rather different properties of light are used.

The point made from the above deliberation is that there are challenges in "observing" through microscopes. The philosopher is made aware of the steps taken and reasons for taking those steps. In the next subsections we learn the reasons for belief.

(d) Grounds for belief

The part that theory plays in building microscopes is minimal. It is ingenuity of the planner, the quality of the technicians to fiddle with different possibilities and the engineering that count. What is it that counts when it comes to confidence in the same-ness of what we see through the microscope and the way things actually are?

The following example will show that the confidence does not emanate from the theory.

F. A. Kekule (1829-96) had postulated that the molecule of benzene consists of rings, involving six carbon atoms and it is a large molecule. Visual representations of large molecules are produced by field emission microscopes. Original theory about the field emission microscopes was that one was seeing the absorption phenomenon. Later it was found out that the phenomenon was actually diffraction; but it makes absolutely no difference. People kept on regarding the images produced as the correct representations. Microscopists do not use theories to sort artifacts (errors) from the real thing. The purpose is, to get an accurate representation; irrespective of the theory.

(e) Coincidence and comparison

Coincidence and comparison play an important part in distinguishing artifacts from the real thing. A low resolution electron microscope is about the same power as a high resolution light microscope. Slices of blood platelets are fixed on a grid and kept under both, the electron and light microscopes. If the spots are observed on both the micrographs, then they are real otherwise artifacts. The comparison or 'second opinion' settles the matter instantly.

Hacking says that an argument for entity-realism can be compared with that for normal scientific realism for the theories. No miracle argument for the latter claims that it would be a miracle if the theory, that explains and predicts, is not true and the theoretical entities it proposes do not exist. But in general, anti-realists take the theoretical entities as non-existing and instruments to aid thought. The above argument cannot convince them. Now consider the argument as forwarded by entity-realists: All the phenomena that the theory explains and predicts must be caused by the theoretical entities proposed by the theory, and as the phenomena occur as specified by the theory, the entities must exist.

With the microscope, we have clear observable dots on the micrograph. The issue at hand is: are those brought about by some phenomena other than the object being studied or by the specimen under the microscope. The possibility of these dots not being from the specimen can be ruled out by seeing the specimen under another microscope which uses a different physical system. It would be an extreme coincidence (miracle) if two totally different kinds of physical systems were to produce exactly the same arrangements of dots on micrograph, and still were not the character of the specimen.

I think that although the above argument, as phrased by Hacking is more convincing than the No Miracle argument for theories, it still misses the mark. Anti-realist can demand evidence for the claim that "the entity" that is proposed by the theory **is** the entity which is causing the "observable dots". The link between the unobservable cause (entity) and its effect (dots) is evasive. Moreover, not all the theoretical entities lend themselves to be studied under microscopes.

(f) The grid

A grid is a very minute metallic piece, with labeled squares. The sample to be studied with a microscope is fixed on it. When seen through the microscope, the enlarged specimen is seen against the background of the indexed grid. It makes the comparison possible, when the same sample with the same grid is studied under different types of microscopes using different physical systems.

The grid is prepared from the macroscopic scale and then shrunk to very small size using reliable technologies. The strength of the belief in the observation through microscopes comes from coincidence. It would be an extreme coincidence if all microscopes working on different principles produced the same 'false' result.

Philosophically, I find the use of grid by the experimentalists very innovative and convincing. Constructive empiricists do not believe in anything which cannot be observed with unaided senses. Moons of Jupiter are considered 'seen' if one goes near Jupiter and sees them. Unlike the moons of Jupiter which can be observed by going near that planet, the epistemic community cannot go into the microscopic realm. The only nearest thing possible is to send a macroscopic (observable unaided) object into the microscopic realm. A grid is constructed macroscopically and then shrunk to microscopic scale. A specimen is put on this grid and observed with microscope. The microscope enlarges the grid to the original size, with the specimen on it. Belief in the enlarged version of the specimen is derived from the belief in the grid. The grid has not undergone any changes before and after being made unobservable to naked eyes, so the version of the specimen is believed as enlarged to observable state unaltered.

(g) Use of sound waves

Sound travels through a medium in longitudinal waves, unlike the transverse waves for light. It has very different properties from the beams of electrons or waves of light. Use of ultrasound is common in medical practices. An acoustic microscope works on simple principles. A very high frequency sound wave is produced electronically. The wave passes through the specimen to be studied, and is again converted into electric impulses. The difference between the electric impulses, with and without the specimen is due to the specimen.

What and how the sound waves scan depends upon the properties of sound waves. For example the sound waves are more sensitive to changes in refractive indices of the medium; can pass through completely opaque substances and do not damage the living cells instantly. But for sure, we are not 'seeing' through an acoustic microscope; in the sense our 'seeing' the phenomena in the world!

Hacking is bringing in a new version of "observing". Empiricists stress that all our knowledge of the external world comes through our unaided senses. What is seen through an acoustic microscope is not a part of the natural, observable external world. Our belief in what is seen is laden with our belief in theories about acoustics.

Let me explain with examples. Bats use sound waves for "seeing". If in future, humans develop such abilities of seeing, then our belief-systems will also change. I mention this to stress the importance of our physiology in deciding what we know, for empiricists. Now consider another example: we don't have wings, but we fly using instruments (air planes), which are also theory-laden! But we cannot pin the empiricists down for believing and using air-planes and not believing in the acoustic microscopes, even though both are theory-laden. It is because constructive empiricists accept the theories as empirically adequate. That means the empiricist believes that the observable effect of the theory of fluid dynamics (air-plane) will be as demanded by the theory. On the other hand the acoustic microscope demands belief in the unobservable entities, which the empiricists do not grant. The empiricist will however concede that there is a difference between the oscillograph readings, with and without the specimen; but will be skeptical about the claim that the difference is due to *the* specimen.

(h) Seeing through and seeing with

When a specimen is put under a microscope we see through the eye piece of the microscope. If we now, record a picture of the specimen as seen through the microscope and manipulate the picture to get a better view, then we are seeing with a microscope. Digital manipulation is often done on the micrographs to improve the quality and also to enhance the features of interest.

Hacking gives example of digital manipulation in a field different from microscopy. For a very fast flying jet at low altitudes, knowledge of altitude is extremely vital. A thousand of a second error to vertical speed can land the plane literally into the earth. Such planes are fitted with a device which digitally displays the enhanced altitude and reduced distance. Does the pilot "see" the terrain through such a device? The answer should be, no he does not see 'through' the device but yes he sees the actual, true terrain 'with' the device.

I believe it is similar to seeing a live concert not "through" but "with" the help of a television. It is because different cameras at different positions and angles take the pictures; these are simultaneously selected for maximum effect and transmitted. A spectator in the audience is "seeing" whereas one in front of the TV is seeing "with" TV. Similarly for a soccer match; "with" the TV you are always at the vantage point. The point being made here is, that the reality of the concert or the match or the specimen is not affected by such adjustments by instruments; they only enhance your comprehension. Similarly the scientific instruments are made to exaggerate the aspects under study to provide better understanding of the unobservable world.

Our reasons for belief in what we observe through a microscope are:

1. We can interfere. For example by injecting the specimen and observing the whole process of the needle, piercing the specimen and dye entering it and the after-effects.

2. What we observe using a high powered light microscope is corroborated by an electron microscope and again separately by acoustic microscope.
3. We fully comprehend the working and make-up of a microscope and the scientific theory employed. Though the physical theory (of microscope) plays lesser part than the theories concerning the nature of specimen.

Van Fraassen says that we can form beliefs for a variety of reasons; it is the justification of those beliefs which makes them knowledge. Hacking endorses that view and says that we believe in the observations made through scientific instruments and then justify that belief by coincidence and comparison.

4.4.4 Refined hypothetico-deductive model

It is commonly believed that scientific method is hypothetico-deductive. Scientists propose a hypothesis or a theory, and then they deduce the possible empirical effects. If the actual observations match with the theoretical deductions, the theory is accepted. Hacking says that in real practice of science such deductions are rare; many theories do not provide empirical deductions. Even if such deductions are available, the observations do not fully match and the theories are given ad-hoc alterations. In other cases appropriate tools of confirmation are not available. Scientific theories have to wait for technological advances. Scientists attempt to make approximate models of the theories. Also approximate models of the actual phenomena are made. Between the actual phenomena and the theories there are many different, even mutually incompatible models.

Most of the modern quantum mechanical theories are in the form of mathematical equations. The variables in the equations are given certain values derived from experiments. If the equations do not balance, additional terms are added on ad-hoc basis. The tripartite division of activities can be that of speculation, calculation and experimentation

Experimentation is the process of creating the phenomena in controlled conditions of a lab. This is not always possible for the lack of technology. An experiment is then articulated. Calculation, the word as used above denotes two kinds of things, the articulation of theory and the articulation of experiment. A phenomenon is commonly an event or process of a certain type that occurs regularly under definite circumstances. It can also mean a unique event that is of special interest. When the regularity in the phenomenon is known it is expressed as a phenomenological law.

Hacking gives an example. E.H. Hall (1879) conducted an experiment. The experiment consisted in passing electric current through a gold leaf and exposing the leaf to a magnetic field at right angles to it. He noticed a potential difference, at right angles to both the magnetic field and the current. Hall described the effect as a phenomenon. What Hall did was not confirmation or rejection of a theory.

The phenomenon created by Hall does not exist in nature in its pure form. What exists in nature is resultant of many different and varied laws. The scientists analyze the result, and explain it using laws. The phenomenon created by Hall was a human creation using human technology; it did not exist earlier. For another example, lasers did not exist before scientists created the phenomena in lab and now they are commonplace. Most of the phenomena of modern physics are manufactured. We know the nature through the phenomena created in the laboratories. Sometimes the phenomena are created first and then the theories follow. Other times a phenomenon is created to follow up a theory.

The experiments are expected to be repeatable because they represent the regularities of nature. But this is not what actually happens. To experiment is to create, produce, refine and stabilize phenomena. The experiments are normally not repeated. Serious repetitions of an experiment are attempts to do something better, to produce more stable phenomena. A repetition uses different types of equipment for the same phenomena. Experiments need to be repeated when making precise measurements.

In the beginning of this chapter, I have explained the need for alternative means of justification of scientific beliefs. In modern physics the phenomena to be saved are unobservable. These are not "observed" in the empiricist's sense. The entities theorized to save such phenomena are also unobservable. Scientists deduce the empirical effects of the theory and then construct experiments. Both, the theory and the phenomenon may need adjustments to "fit" each other. That brings out the importance of calculations (adjustments) between them.

Whereas in classical physics, the phenomena are observable, only the theory (hypothetical entities and structures) is on shaky grounds; in quantum physics, both the phenomena and the theory are on shaky grounds. By "shaky grounds" I mean: theory-laden with the theories whose truth cannot be ascertained; both the *explanas* and the *explanandum* are unobservable. As the frontiers of physical sciences are pushed forward, the language and tools of mathematics are used to express and explore. They also provide a link between the hypotheses and their deductions.

4.4.5 Measurements

Scientists do not only observe; they measure. Some of the questions that need to be addressed are: is measurement an inherent part of scientific mind or it stands for a philosophical position? Do measurements measure anything real in nature or they are just artifacts of our theories?

Hacking writes that in 1798 Cavendish attempted to measure the weight of earth. In 1908 Millikan set up an experiment to measure the charge on an electron. Cavendish's weighing the earth, was a triumph because he had attempted to measure an unimaginable quantity. The same had been measured using a plumb line and its deflection near high mountains. Cavendish's attempt was important because it started the experimental technique, using artificial weights instead of natural ones like mountains. The experiments provide a means of measurements which in turn can be used□to confirm or falsify theories. Hacking argues that, it is therefore wrong to assert that experiments only confirm or falsify a theory.

How the measurement helps

Lord Kelvin (1889) said 'I often say that when you can measure what you are speaking about, you know something about it; when you cannot measure it… your knowledge is of meager and unsatisfactory kind' (Thompson 1889:73).

Measurement is a means of testing theories; because precise measured numbers are likely to conflict with the conjectured or predicted ones. A precise predicted number provides a potential falsifier for a theory. Therefore measurements are important for Popper's views on science. For Kuhn, measurement is part of normal science. Good measurements need new technology and so involve puzzle solving of experimental type. Measurements articulate details of known material.

Experiments devise ingenious systems of measurement and occasionally different experimental results do not agree with each other. Such an anomaly is sometimes called an 'effect'. The greater the accuracy of measurements, the more often such anomalies occur. These anomalies present situations for problem solving. A new theory has to explain such situations. These anomalies provide the quick tests that the new theory must pass. In other words these are the verification techniques.

Hacking has made two important points. One is that measurements are not done for the sole purpose of confirming or falsifying a theory. Instead they can give rise to new phenomena in lab situations, as discussed in the last subsection. The theories then follow. The second point is that once a specific numerical value is given to a theoretical entity, then it has to exist and is known. Millikan's measuring the charge of an electron, confirmed it epistemecally. Although the skeptic will ask: How do you know that it is the charge of *the electron* ?

4.4.6 Experimentation and entity-realism

The main thrust of Hacking's arguments is that experimentation offers the best evidence for scientific realism. Experiments confirm the theoretical entities as postulated in the theories. But, here we have stronger evidence. The evidence is the fact that the unobservable entities are used as tools which are manipulated to produce new phenomena. The unobservable theoretical entities are instruments for doing and not only for thinking as suggested by speculative metaphysics.

In 1887, J. J. Thomson noticed the corpuscles from a cathode (Hacking1983: 262). The first experiments he performed were to measure the charge on these particles. He also calculated their charge-to-mass ratio. Millikan followed up and calculated the charge more accurately. These measurements of the constants show that the scientists had full belief that the electrons exist. What they were doing through their experiments was interaction with them, and finding more information about them. The first step understood the causal properties of electrons. By using these causal powers, other devices could be built to understand newer aspects of nature. When we use electrons to manipulate other parts of nature in a systematic way, the electrons are no more theoretical entities, rather they become experimental.

The argument being by pushed by Hacking is that we can experiment on an entity without fully believing in its existence. But when we manipulate an entity in order to experiment on something else, then we have to believe in its existence. If you can make electrons behave in a particular, systematic way then electrons become your tools. These can then be used to elicit more about nature by creating phenomena.

Belief in current scientific theories, as a scientific realist, is laden with certain values. But believing in entities like electrons is value-free. Because a scientific realist believes in a not-so-perfect theory, with the belief that it would lead him to truth in future. But the entity-realist believes in the existence and characteristics of an entity for what he knows now, in present. Experimenters are entity realists about the entities they manipulate. They may not have belief in the theories putating such entities. Different members of a team working on an experiment may have different and incompatible beliefs about theories on the same entity.

Making of an experiment

There are many ways of making instruments that rely on the causal properties of electrons in order to produce the effects of great precision. The reality of electrons is not inferred from the success of the experiment, as is the case with inference for the validity of scientific hypotheses. We design experiments and build apparatus relying on the truths about electrons in order to produce the phenomena to be investigated. The instrument should isolate, physically, the properties of the entities which we are going to use and eliminate or minimize all others. In Ian Hacking's words:

We are completely convinced of the reality of electrons when we regularly set out to build – and often enough succeed in building – new kinds of device that use various well-understood causal properties of electrons to interfere in other hypothetical parts of nature. (1983: 265), [italics as in original].

Hacking gives example of an experiment to argue for his position. In 1978, an electron gun PEGGY was used in a fundamental experiment. Two terms "parity" and "neutral current" need to be understood to appreciate the significance of the experiment.

Electrons have a spin. Imagine your right hand wrapped around a spinning particle with fingers pointing in the direction of the spin. Then your thumb is pointing in the direction of spin vector. If all the particles have their spin vector in the same direction as the direction in which they are travelling, then they have right handed linear polarization. If the direction of movement of electron is opposite to its spin vector, then it has left-handed polarization. Parity is said to be violated when the direction of spin changes.

The speculations of quantum electro-dynamics theory are that there are four fundamental forces in nature. Two of them are gravity and electromagnetisms. The other two are at quantum level and are called strong and weak forces. Strong forces act at very small distances, at most the diameter of a proton and act on 'hadrons' like protons, neutrons but not on electrons. The weak forces are one millionth of the strong forces in strength and act over one hundredth distance of strong forces, but act on both hadrons and electrons.

Quantum electro-dynamics supposes that all the forces are 'carried' by some sort of particles. Photons carry the electromagnetic forces and gravitons are hypothesized for gravity. In the case of interactions involving weak forces there are charged currents. In 1970s there arose a possibility that there could also be weak 'neutral' currents in which no charge is exchanged.

It had been found that parity violations occur for weak **charged** interactions. What needed to be found was, if the parity violations also occur for weak **neutral** interactions. It had also been found that one kind of product of particle decay exists only in left hand polarization and never in right-hand polarization.

According to a theory, independently proposed by Stephen Weinberg in 1967 and A. Salam in 1968, a minute violation of parity should occur in weak **neutral** interactions (*ibid* 267). That means if polarized electrons are made to hit a certain target, then slightly more left handed electrons will scatter than the right handed electrons. The difference between the two 'scatterings' is one in ten thousand. In other words, if one million polarized electrons of each type hit a target, then the difference between scatterings should be one hundred.

The experiment is conducted as follows:

A laser bursts red-light towards the target.

1. The light goes through a polarizer to create linearly polarized light.
2. The linearly polarized light or the linearly polarized photons go through a device which converts them into circularly polarized. It also changes the circular polarity at random to avoid instrumental errors.
3. The circularly polarized beam of photons hits the target resulting in a beam of linearly polarized beam of electrons.
4. The beam passes through a device that checks on a proportion of polarization.

From the data thus generated, errors of different types are statistically removed. It was found that left-handed polarized electrons were scattered more frequently than the right handed electrons. This was the first convincing example of parity violation in a weak neutral current interaction.

From the above experiment and the observations made, Hacking infers the following stages in confirming our belief in electrons.

1. Electrons explained many phenomena. Lorenz explained the Faraday Effect with electron theory.
2. J. J. Thomson produced electrons.
3. J. J. Thomson measured their mass and 'charge to mass' ratio.
4. Millikan calculated their charge very accurately.

Today, we don't need the explanatory success to confirm the existence of electrons. Electrons are still the unobservable entity. But we have a family of their causal properties which are used by experimenters to investigate something else.

The neutral currents mentioned above are produced by the hypothetical, unobservable entity called boson. Their behavior and properties are hypothesized from the hypotheses about the neutral currents. The hypothetical entity, boson, will be considered real when it will be used to investigate something else.

Anti-realism about atoms was sensible about a century ago. Today, the direct proof for sub-microscopic entities is our ability to manipulate them using well understood causal properties. It is not claimed here that reality is constituted by human manipulability. The best kind of evidence for realty of a hypothetical entity is our understanding of its causal powers and using them. Therefore engineering and not theorizing is the best proof of scientific realism about entities.

4.4.7 Comments on Hacking's entity realism

Scientific realists believe in the existence and knowledge of unobservable entities as postulated in the scientific theories. Ian Hacking has provided another method for forming and justifying beliefs in the unobservable entities. Belief in our epistemic access to the unobservables existed; it is supplemented.

Hacking starts by showing the supremacy of observation over theory by quoting examples from the period when physical sciences, as we know them today, were at infancy stage. Science tells us about the physical world and the physical world, to start with, is what we observe in our day-to-day life. So, the initial observed phenomenon to be explained is obviously theory-independent. Importance of a keen and explanation-seeking observer cannot be over-emphasized. James Watt was not the first to observe a kettle rattling due to steam and Newton was not the first to observe an apple fall! Observations, whether unaided or aided, direct or in-direct seek explanations. The explanations in turn, need to be justified by further observations. This shows their inter-dependence. There is no epistemic gain in showing supremacy of one over the other.

Role of measurements for scientific progress has been brought out by many philosophers of science. Hacking demonstrates the importance of experimentation for measurements and further to argue that if an entity can be measured, it is real.

In the background to entity realism I have mentioned that most of the modern scientific phenomena being investigated are in the unobservable realm. Scientists infer, from what is observed through the instruments. The 'phenomena to be explained' can also be provided by the 'abnormal' working of the instruments. Scientists are always on the lookout for new phenomena. Hacking stresses this point to argue that experiments are not always conducted to confirm theories. However his arguments to bring out the theory-independence of observations through microscopes, by interference and manipulation are strong. Belief is justified by interfering and not by just peering. Manipulation has twice the justificatory power. Firstly because it involves interference and secondly the manipulated entity can be used to investigate further. The experiment PEGGY, where unobservable electrons are used as input, to investigate unobservable bosons, justifies Hacking's claim.

However, Hacking's arguments have not converted the empiricists into realists. For example, when a positively charged nibodium ball becomes neutral after it is sprayed by electrons; Hacking claims existence and our belief in the electrons, but the empiricist says that the nibodium ball behaves *as if* it is sprayed with electrons as suggested by the theory.

Andre Kukla (1998: 90) equates Hacking's argument "if you can spray them, they are real" for epistemic significance, to other virtues like simplicity and explanatoriness for scientific theories. He claims that the only consideration appealed to, is the reader's intuition. I beg to differ with Kukla. The realist arguments of simplicity and explanatoriness have a logical, metaphysical appeal. Although empiricists do not accept their epistemic worth, they do consider them for resolving underdetermination between empirically equivalent theories. Sprayability or manipulatability, on the other hand, has a twin appeal. First is to the "effect" on the nibodium ball, which is sprayed and can be understood at instrumental level, as discussed above. Second is to the "causal" property of the electrons and has an empirical flavor. The empiricist believes in "observable" i.e. in something which affects her (senses). She is being persuaded to believe in something which *she* can affect. We can affect something predictably if we know it and it exists. Intuitions are based on feelings and not on facts. The causal powers of electrons are based on verifiable facts. As detailed above, scientists produce electrons and count their spins in the experiment PEGGY. If the proportion of polarization of electrons is as predicted by *a theory* then *the theory* is verified. Anti-realists may accept the theory as only empirically adequate but the input (the cause controlled by scientists) electrons, warrants some epistemic import.

Hacking does not claim that his arguments apply sweepingly across the whole enterprise of science. He argues against the notion that all scientific knowledge is theory-dependent and suggests alternative methods of forming and justifying scientific beliefs. The shift from "peering" to "interfering" for epistemic access is a strong argument for scientific realism but not strong enough to penetrate the empiricists' instrumental attitude.

4.4.8 Conclusion

The entity realists Nancy Cartwright and Ian Hacking have argued for their partial-realist position by addressing both the realists and anti-realists. Whereas against scientific realism, their arguments are targeted on the truth of scientific theories, against anti-realism they argue for the justification of beliefs in the unobservable entities.

Cartwright takes the truth of scientific theories head-on. She attacks the foundations of theories, which are the laws of nature. Theories are explanations for the laws of nature and if the laws can be shown to be un-true, the theories cannot be true. She argues that the individual laws of nature do not actually apply in nature. Cartwright's claim that these laws "lie", because of the adjustments made, is an exaggerated accusation. For the overall success of science, it is preferred to have a few laws that apply approximately, across the board than very large number of laws that apply accurately but selectively. Moreover the truth of scientific theories is not derived solely from the accuracy of the laws of nature as depicted by Cartwright. Scientific theories are accepted as knowledge, only after the beliefs provided by the laws are found to be true and justified.

Hacking plays down the role of theories for scientific investigation. His argument that observations can be theory-neutral, apply mostly to the early stages of scientific enquiry. Almost all the modern scientific observations, whether exploratory or justificatory, are theory-laden. However Hacking demonstrates the theory-independence of interfering, using microscopes. We can 'play' with the unobservables and this experience is independent of the theories on which the microscopes are built. Belief in what we observe through a microscope is enhanced by eliminating the possible errors that may occur due to the theories employed.

For the existence of unobservable entities, Cartwright argues against theoretical explanations and in favor of causal explanations. It is because the former can underdetermine and are based on false laws whereas the latter are unique, connect to their effect, make it happen and quote some salient feature. But the question is: how do we know of a potential cause? A cause is a conjecture, a theoretical posit and part of a theory. That means causes are parasitic on the theories, which Cartwright is arguing against. Also the unobservable links are subject to empiricists' instrumental caveats.

The justificatory power of causes that Cartwright invokes is valid, albeit only in the cases where a causal link can be established. That means where a cause can be 'seen' to be causing its effect. Hacking takes the causal argument further. He says that in actual practice of science, not only is a cause seen to be causing but also exploring. The exploratory power confers a status of reality to the unobservable cause.

Both Cartwright and Hacking construe that it is the existence of the unobservable entity which is justified by cause-effect relation. The justificatory capability is not explored for the truth of theories or the structures.

The entity realists' arguments for belief in the unobservable entities depend heavily on the use of scientific instruments. The instruments, in turn depend on the scientific theories, which are accepted, but may not be true. The anti-realists are therefore not swayed. The dis-belief is in line with their skeptism towards everything unobservable. They do not compromise certainty. However, Hacking appeals to the actual scientific justificatory techniques. Philosophers of science have concentrated more on the logical, conceptual parts of theory constructions and not as much on the experimental part. It is the experimental part of scientific endeavour that, sometimes, even creates a phenomenon and accounts for it Modern science has left the observable-unobservable threshold for belief behind. Philosophy of science cannot overlook the current scientific practices and the resultant success.

The arguments forwarded by the entity realists are strong and demand belief in the entities, where they apply. Both Cartwright and Hacking have chosen electron to demonstrate an unobservable entity that can be known. But most of the unobservable entities in nature, unlike electrons, do not lend themselves to be manipulated, to reveal their causal or exploratory powers. In conclusion, the entity realists' arguments, however strong, do not apply across the whole of scientific enterprise.

CHAPTER FIVE

RESOLVING THE TENSION BETWEEN STRUCTURAL REALISM AND ENTITY REALISM

5.0 Introduction

The two partial realist positions, structural realism and entity realism argue that we can justify some of our epistemic claims about the unobservable part of the world. Structural realism appeals to the history of science and *a priori* nature of mathematics to argue for the structuralist claims. It attempts to barter our epistemic access to the material of the world with reprieve from PMI argument. Entity realism shows how the scientific theories may not be true and argues for the epistemic import of causation and manipulatability for the unobservable entities. Individually, the two positions defend scientific realism, but considered together, they create a tension. The tension emanates from the conflicting and opposite epistemic claims made by the two.

In this chapter I split the assertions made by the two positions into two statements each. This brings out the partial-ness of the two, vis-à-vis the whole scientific realist position. The mutually conflicting assertions of the two, which are the root of the tension, also become obvious. The arguments for the conflicting claims have been explained in the last two chapters. In what follows, these arguments are examined in the light of those of their adversaries. It is this examination that shows, that their arguments apply selectively in different areas of scientific enterprise and not against each other. Structural realism and entity realism can co-exist and the apparent tension between the two is resolved.

5.1 The Tension

Structural realist (SR) and entity realist (ER) assertions for the unobservable world can be expressed as follows:

SR1 We can know the structure.

SR2 We cannot know the entities.

ER1 We can know the entities.

E'R2 Non-entity part may not be knowable.

Worrall is reasonably clear about the claims of SR1 and SR2. Structure of the world is the relations that hold, in reality, within the processes or entities and is expressible mathematically. The unobservable entities are the material of which the world is made up, as proposed in scientific theories to explain the observable phenomena.

Nancy Cartwright and Ian Hacking are clear about ER1. They argue that we can know the unobservable entities which are causally connected to the phenomena. About E'R2, their arguments are against the truth of scientific theories. As scientific theories are made up of unobservable entities and their behavior, workings or structures, it is reasonable to state E'R2 as the claim that we cannot know the non-entity part of the unobservable reality. SR2 and ER1 are the diametrically opposite views on our knowledge about the unobservable theoretical entities. If E'R2 is taken to mean the structural part of the world, then SR1 and E'R2 are equally opposite views. E'R2 can be replaced by the assertion ER2 that we may not know the structure.

So far as the unobservable part of the world is concerned, the realists in general believe that we can know it and the anti realists believe that we cannot. The partial realists however divide the unobservable world along the structure and entities. It is their selective claims to our epistemic access that create the tension in the realist camp and can be grouped together as follows:

(A)

ER1 We can know the entities.

SR2 We cannot know the entities.

(B)

SR1 We can know the structure.

ER2 We may not know the structure.

(A) and (B) are the assertions that need to be addressed. In order to evaluate and verify the validity of these assertions, I will go through and critically examine the arguments put forward for them. It will be demonstrated that the arguments for the two conflicting assertions do not apply to each other.

5.2 The contradictory assertions (A)

5.2.1 (ER1) We can know the unobservable theoretical entities

The main arguments for this entity realist assertion are:

-- Unobservable theoretical entities are the cause of the phenomena and

-- These entities can be manipulated.

Unobservable theoretical entities are the cause of the phenomena.

In general, though in different ways, entity realists appeal to the epistemic significance of our casual connections to particular entities. Cartwright argues that the laws of physics are generalizations of phenomenological laws and cannot be true to reality. But those laws can be correctly used to infer the nature of the cause from the character of the effects. In the practice of sciences there can be various theories for the same phenomenon but only one causal story is permitted. Cartwright says "… one can reject theoretical laws without rejecting theoretical entities" (1983, 6).

(a) Explanation vs. cause

If it can be shown that a particular unobservable entity is the cause of the observed phenomenon then the truth of the observed phenomenon warrants the truth of this entity. The argument for causal explanation can be validated by showing the causal connection. This is achieved by the scientific method of experimentation i.e. observation under controlled conditions.

(b) Arguments against causal explanations

The question is: Is the conception of a causal explanation any different from that of a theoretical explanation? The answer is "no" because all the explanations originate from the regularities of natural phenomena, which are all the phenomenological laws at human disposal. Though, Cartwright says, that "casual explanations are different. We do not tell first one causal story then another, according to our convenience" (*ibid* 11). But in reality causal explanations do not seem to be any different. It can be shown that the causal explanations are derived from the theoretical explanations.

Take the example of radiometer that Cartwright has used repeatedly to argue her case and has been discussed in detail in chapter four of this dissertation. When the accepted theory for the propagation of light was the Newtonian corpuscular, the causal story for the rotation of vanes was "when the light falls on the radiometer, the vanes rotate" (*ibid* 5) i.e. the cause was supposed to be the "corpuscles". When molecular theory for gases gained ground it was noticed that the vacuum in the radiometer was not perfect 'because' the causal story demanded the presence of molecules in the glass bowl. Now, the cause 'became' the "molecules". The case of radiometer shows that the causal explanation is derived from the theoretical explanation (of the time).

(c) Showing the causal connection

According to Cartwright, once a causal connection is 'conceptualized', the next stage is to design an experiment to establish the causal link. But all the causes in nature are not observable and the link with the unobservable causes is subject to skeptism of the empiricists. David Hume objected to the idea that causation has any epistemic worth. His was an empiricist point of view (because the required causal connection is unobservable). Anjan Chakravartty (2007) says that Kant considered causation as a basic concept that humans have *a priori* for experience. According to Kant *noumena* cannot be known by the categories of understanding, and causation is one of them. Chakravartty (*ibid* 93) argues that realism about causation is objective i.e. it occurs in mind-independent world and therefore is not just an idea. Causation involves a necessity, so far as the cause-effect connection is concerned. It is this necessity that leads to the belief that there is more to causation than just 'constant conjunction'. Causation is a feature of the real physical world and can lead us to truth. It is this feature that Hacking exploits in claiming knowledge of the unobservable entities.

(d) The unobservable entities can be manipulated

Validity of a causal explanation comes from showing the causal connection between a cause and its observable effect. Microscopes provide opportunities to justify beliefs in the unobservable entities. Hacking's advise for belief in the observation through microscopes does not emanate from seeing through but seeing with them. We believe what we observe when we can interfere and our results concur using microscopes with different workings. Use of grid adds to the belief. Scientists 'experience' the entities by manipulating them and it is experience which is the origin of our knowledge of the natural world. Van Fraassen (2007) accepts the experimetal experiences of scientists as a source of knowledge. He writes:

Theory choice in the sciences involves a variety of values and criteria but what can be accepted as data is very strictly circumscribed in what counts as good experimental design. That is where we can find the cash-value of the claim 'scientific knowledge is based on experience' (Monton, 2007: 368).

Hacking's argument is, that when phenomena in pure form, are created or 'manufactured' in the laboratories, then the entities are the real tools used by the scientists; and not just hypothetical. Phenomena in nature are the 'problems' to be solved (explained) by the theoretical entities but when these problems are 'created' in the laboratories, we have known the solution (entities).

(e) Arguments against Hacking

A microscope does not provide an enlarged view. It just gives the result of interference between the specimen and the mediums like light waves, sound waves or electrons. The belief involved is that what is observed, in the form of graphs, statistical data, a mixture of shades and lights, originates from the specimen. At the most it gives an approximation of the specimen. We infer that the entity or the specimen under the microscope is being manipulated.

Van Fraassen does not consider inference as observation. For example, observation of silver line in the cloud chamber, though believed by realists to be caused by electron, is not observation of the electron. Because, there is a causal chain, from electrons to ionization of water droplets in the saturated cloud chamber, and hence their being observed.

Cartwright considers the belief in derivation of laws of nature by an approximation of phenomenological laws as a 'lie'. She considers *ceteris-paribus* laws as lies even if the effects are eliminated or adjusted. By the same reasoning, Cartwright should not consider the knowledge obtained by so many inferences and approximations through the microscopes, as knowledge about the actual theoretical entities.

(f) Example of electron

Van Fraassen's and Cartwright's arguments do not reduce the justificatory value of Hacking's arguments. There is considerable evidence to support the idea that when one manages to forge significant causal contact with entities, they are retained when theories involving them change, over time. Many theories involving electrons have been proposed and falsified since J. J. Thomson speculated on electrons through his 'cathode ray' experiments in 1897, but the entity electron still has a place in current theory. It is a strong case for the scientific realism and entity realism in the face of historical discontinuity. Hacking, only confirms the knowledge about the electron using 'direct' means. His argument has added to the realists' arsenal.

The empiricists consider the traditional realist Hypothetico-Deductive method, too metaphysical and speculative. Hacking argues from "doing" as against "thinking". If an effect is noticed, it must have a cause. But if a cause is voluntarily brought about, and results in anticipated effect, then the cause is definitely real.

Hacking argues: without the knowledge (justified true belief) of its properties, how can an entity be *used* ? For an entity to be used as an input, it must exist and at least some of its properties, known. The empiricist's agnosticism towards electron, just because of its unobservability by naked eyes, looses conviction.

However empiricists can argue that 'truth' is not a requirement for an entity to be used as input in an experiment. That means, even if we don't know everything (truth) about the entity, it can still be used in an experiment. Let me present Hacking's argument in two steps:

Step 1. Some unobservable theoretical constructs are suggested to account for observed phenomena. If their empirical deductions are found to match the predictions, then the realists consider them as approximately true and the anti-realists take them as empirically adequate.

Step 2. The same unobservable theoretical constructs are used as input to explore further into unobservable realm, and some empirical deductions are found to match the predictions. The realists take the constructs as "closer to truth'. But the anti-realists still take them as only empirically adequate.

The empiricists or the anti-realists have to account for these two stages of empirical adequacy. They cannot apportion the same amount of belief to all the unobservable constructs. I believe this area of empiricist epistemology calls for further research.

Hackings' argument for our epistemic access to unobservable entities, because of their use as a cause, is applicable where scientific enterprise has advanced enough and experiments, exploiting causal properties are possible.

It is clear from the above discussion that Cartwright's arguments in favour of causality and against the explanations are debatable because the former is parasitic on the latter. But her argument that once a causal relationship is established, then we can claim existence and knowledge of the cause, is strong. Her arguments are applicable where a cause can be hypothesized and experiments can be designed, constructed and executed. Hacking's argument that manipulation and interference provide justification for belief in the unobservable entities, is similarly strong, but subject to the same limitations as that of the Hypothetico-Deductive method. His arguments from "use as input" in experiments are applicable where scientists already have enough justification for belief in the unobservable "input". This condition is mostly met in the later part of studies in quantum physics, where scientists are advancing from first stage of unobservables to the next stage.

Having examined the arguments for the assertion that we can know the unobservable entities, let us now examine the arguments for its contradictory assertion.

5.2.2 We cannot know the unobservable entities.

As discussed in detail in chapter three of this dissertation, Worrall barters our knowledge of the unobservable theoretical entities with reprieve from Pessimistic Meta-Induction (P.M.I) argument against scientific realism.

Validity of Worrall's argument, in general, depends on the following two conditions:

a. PMI argument is a genuine and serious threat to scientific realism and
b. Scientific method cannot provide epistemic access to unobservable entities.

We have discussed in the second chapter of this thesis that PMI argument has been rebutted. The overall scientific image of the world is not changing dramatically. Theories underwent falsifications more frequently in the past than they do now. Even the falsified theories had some truth-content and that scientific method can illuminate the unobservable world. The contention that our present accepted theories may be false *because* many accepted theories in the past have been falsified, does not hold.

So far as (b) is concerned, there is enough evidence that some unobservable theoretical entities are reasonably known. To claim their knowledge, as demanded by the empiricists involves seeing them unaided; which may not be possible. A partial realist like Worrall can be convinced about our knowledge of the unobservable entities because he believes in the truth of unobservable structures of the world, without 'seeing' them unaided. His belief is rooted in mathematization and historical continuity. The former demands measurement and we have seen before in this thesis that mass and charge of an electron have been measured accurately. The argument from mathematization is: mathematical knowledge is unchanging; if an *entity* is given a mathematical value, then this attribute of the entity is unchanging and known. The entity electron passes the "historical-continuity" test also. Therefore, by Worrall's standards, the unobservable entity electron can be considered known.

Both the conditions (a) and (b) are not met. In mature sciences like physics, PMI is not a threat to realism. Similarly, in mature sciences, we have enough evidence for the truth of some unobservable entities.

Regarding falsification of Fresnel's theory, in subsection 3.5.1 we have seen that ether was not a mature, accepted and corroborated entity. Learning about unobservable entities is like groping in the dark. The conceptualized entity has to be empirically adequate to all the observed phenomena. With lesser background knowledge, false entities can be accepted. But history of science can be invoked to show that false unobservale entities do not 'last' for long. Such errors occur in the early stages of scientific enterprise. The scientific method has a mechanism of detecting errors. The claim, that we cannot know the unobservable theoretical entities, cannot be extended to the better understood and established unobservable theoretical entities.

In this subsection 5.2, we have examined the contradictory assertions made by entity realists (ER1) and structural realists (SR2) regarding our knowledge of the unobservable theoretical entities. In the sub-section that follows, we evaluate their arguments for and against our knowledge of the structure of the unobservable world.

5.3 The contradictory assertions (B)

SR1 We can know the structure of the unobservable world.

ER2 We may not know the structure of the unobservable world.

In what follows I examine the arguments for the former, followed by those of the latter.

5.3.1 We can know the structure of the unobservable world.

This assertion gives the impression that there is something special about the structure of the unobservable world that enables it to be epistemically accessible to us, the humans. Alternatively, our physiological and mental make-up permits us to know only the structure of the unobservable world. In what follows, I show that Worrall's claim does not hold for the whole enterprise of science.

The two main arguments for this assertion are the No Miracle argument and the mathematisation of structural relations.

(a) The No Miracle Argument

Worrall asserts that it is only the structure of the unobservable world, that is knowable, and further that this knowledge explains the success of science. That means, according to Worrall, knowledge of the unobservable structure is *all* that we need for the success of science. In other words: knowledge of structure is necessary and sufficient for the success of science. Let us examine these assertions further.

<u>(a1) Is the knowledge of structure, necessary for the success of science?</u>

Van Fraassen offers other, non-realist explanations for the success of science (1980,12). He makes an analogy between the practice of science and the theory of evolution. Scientific theories struggle for survival and only the fittest or the most successful ones survive. Success of science is at empirical level. It can best be explained by empirical adequacy of scientific theories and does not warrant true knowledge of structure.

For a scientific realist, coming true of a prediction made by a theory is an evidence for its truth. If the prediction is novel or heuristic, it simply stresses the same argument further. But, for a constructive empiricist, coming true of all the predictions, novel or heuristic, is a requirement for an empirically adequate theory. Empirical adequacy, as defined by van Fraassen, transcends time. A theory is empirically adequate, irrespective of *when* the observation is made.

(a2) Is the knowledge of structure only, sufficient for the success of science?

NMA is: Given the success of science, the scientific theories must be at least approximately true. Structural realism claims that knowledge is only possible, of the structure of the world. NMA therefore becomes, given the success of science our knowledge of the structure of the world is at least approximately true. That means knowledge of the structure alone, explains the success of science. At any given time t, science has reached certain success-level S; the overall knowledge of the world, which according to structural realism, is of the structure only, is say K. Now S and K may not be quantifiable. Every increase in knowledge may not give rise to corresponding increase in the success of science, because all knowledge does not translate into empirical success. Similarly, every increase in success may not warrant an increase in knowledge because of innovations from the existing knowledge and better applications. Hacking has given an example of an experiment, PEGGY, where a known theoretical entity is used as input to increase the scientific knowledge. The knowledge so gained will be used to further the success of science. This shows that the knowledge of theoretical entities is also required for the success of science and the knowledge of structure alone is not sufficient.

(a3) Cartwright's argument

Her assertions have been discussed in detail in chapter four of this thesis. Applied physics and engineering represent some of the empirical successes of science. It is the application of (phenomenological) laws of nature, that according to Cartwright, lead to success of science and therefore success of science can be better explained by these laws (and not theories or structure). It suffices to show that according to Cartwright, one does not need belief in the metaphysical structures to explain the success of science.

(a4) Hacking's argument

Hacking argues that Hypothetico-Deductive is not the only method for gaining knowledge about the physical world. The belief, that first a phenomenon is observed and then a hypothesis is postulated in all the cases, is false. In some situations, phenomenon itself is created in laboratories. He gives example of empirical success of science (electric motor) and shows that the success of science does not necessarily need any knowledge of unobservable structure.

It is the properties of the unobservables that are exploited as scientific knowhow. Worrall's argument that success of science is explained by our knowledge of the unobservable theoretical structure *only*, does not hold. Knowledge of unobservable entities, over and above the knowledge of the structure, is also required in some areas of the scientific enterprise.

(a5) Juha Saatsi,s argument.

In a very recent development on the scientific realism debate, Juha Saatsi (2010) questions Worrall's claim to the truth of structural relations, from their transcendence in the theory-shift. In subsection 2.3.1 of this thesis I have given the tenets proposed by Larry Lauden (1981) for scientific realism. The fifth tenet demands that the succeeding theory must explain the success of its predecessors. Saatsi argues, with good examples that some empirical successes of the falsified theories are not explained by the accepted (transcended) content. He says: *the kind of content found to be continuous across a theory-shift should also be explanatory* (*ibid* 6). Saatsi questions: how did Fresnel derive the true structure from a false assumption (ether)? It needs to be shown that it is the structure and nothing but the structure, that explains the success of Fresnel's theory; to satisfy the 'no miracle' argument for realism. Worrall, according to Saatsi, has not done justice to the Miracles argument. The real miracle, Saatsi says, is that Fresnel managed to derive the true equations with false assumptions. And this *miracle* has not been explained by Worrall.

Saatsi is bringing out the shortcomings of the current scientific realism debate where historical evidence is used for over-generalizations. It has to be shown, without reasonable doubt that scientific method deserves the credit for (Fresnel's) knowledge of the unobservable world.

Anjan Chakravartty (2007) has attempted an answer: Fresnel had known the real structure of light by detecting and manipulating the light rays. This detection led Fresnel to the disposition of light. But the dispositionery explanation, Saatsi laments, does not go as deep as the one demanded by the 'no miracles' argument for realism. The greater miracle that remains to be explained, is that *in spite of* false assumption, truth was revealed. It is because the 'no miracle' for realism, is a rather sweeping and very general argument.

(b) Argument from Mathematics

Worrall argues that we can know the structural part of the unobservable world, which is expressible in mathematical equations and transcends theory-change.

Cartwright says "my basic view is that fundamental equations do not govern objects in reality; they govern only objects in models" (*ibid* 129). Her argument is that 'tidy and simple' mathematical equations of abstract theory deal with ideal variables whereas in real life situations of turbo jet engines or helium-neon lasers we don't have the same ideal inputs for the same equations. She gives an example of lasers, which has been detailed in this thesis in chapter three. Six different mathematical equations, using different laws, account for the same phenomenon.

Worrall alludes that mathematization is somehow an indication of truth. Worrall's assertion can be interpreted in at least two ways as follows:

1. The structure of the unobservable world, as theorized is true therefore it is expressible mathematically and mathematical relations do not change

2. The structure of the unobservable world as theorized can be expressed mathematically, mathematical relations are true, and therefore the structural parts of the scientific theories are true.

The first interpretation explains the transcendence of the structural part of the Fresnel's theory to that of the Maxwell's. It assumes the truth of the theorized structure. The second interpretation derives the truth of the theoretical structure from its mathematical expression.

The assumption is that all the objects of scientific knowledge can be quantified and measured for mathematization. In classical mechanics for example, a measurement process can be represented as an interaction between two systems, a measuring instrument M and a measured system S. If a similar representation is attempted in quantum mechanics, it can be shown that for certain initial quantum states of M and S, the interaction will result in a quantum state for the combined system in which none of M and S has a determinate value. (Allen Stairs, Routledge encyclopedia 867). At quantum level, measurement is probabilistic. It suggests that the world is indefinite in odd ways; for example that things may not always have well defined positions or momenta or energies. That means measurements, as we understand, are not always possible.

Mathematics and logic are the tools that scientists use. The justification of scientific beliefs is not derived from the tools employed, rather it can be derived from the truth or accuracy of input, that is fed into such tools.

The physical quantities have to be measured in order to be fed into mathematical equations. This brings in the problem of representation i.e. justifying the assignment of numbers to objects or phenomena. We cannot literally take a number in our hands and "apply" it to a physical object. What can be done is, showing that the structure of a set of phenomena is same as the structure of some set of numbers under corresponding arithmetical operations. For example, assigning values to pressure, volume and temperature of a gas in a container does not tell us much. What we learn is the relationship between these assigned values. Irrespective of the scales used for measuring P (pressure), V (volume) and T (temperature) the relationship remains as:

$$PV/\ T=\text{constant}.$$

Structural realism stresses this point. That we may not know the entities postulated in the scientific theories, but we can know the relations that hold between them. The relations or the equations represent the structure of the unobservable world

Chakravartty argues that the same equations can support the constructive empiricist or even idealist positions. It is because one can interpret the equations to suit oneself. He says: "Without further clarification, the ambiguity of the appeal to equations renders it too weak to amount to a statement of realism" (2007: 36).

Mathematical knowledge is *a priori* and unchanging. It is the application of mathematical relations to physical quantities that is being questioned. It is possible that some true unobservable structures can be expressed mathematically and some mathematical equations represent true structures. But mathematization cannot be equated to episteme for the whole enterprise of science.

We have examined Worrall's assertion that we, the epistemic community can know the structure of the unobservable world. It has been shown that NMA and mathematization do not offer a warrant for that *general* assertion. It has not been concluded that we cannot have epistemic access to the unobservable structure of the world; rather it is the generalization of Worrall's claim that has been doubted. Entity realists have made a conflicting assertion. Let us now examine their arguments.

5.3.2 We may not know the structural part of the unobservable world.

Both, Nancy Cartwright and Ian Hacking make this assertion tangentially. The former argues against the truth of scientific theories whereas the latter plays down their importance. Both stress our epistemic access to the entities, so far the unobservable world is concerned. As scientific theories are made up of entities and their structures, it can be deduced that the entity realists assert against our knowledge of the structural part.

Scientific theories are hypothesized to explain laws of nature. These laws work with *ceteris paribus* conditions, which are not obtained in nature. Explanations of such laws, according to Cartwright, cannot lead us to truth. In other words, the unobservable structures suggested by the approximate laws of nature, cannot be the real structures of the world. This argument can be attacked in two different ways. First, that even the scientific realists do not claim absolute truth for their theories. These are taken as approximately true. These theories can undergo changes with new evidence available and with improved scientific world-view. The approximations brought about by *ceteris paribus* condition is just one of the many that scientists have to make. Secondly, science is accepted as a successful enterprise. The success that science has achieved so far, rides on the 'approximate' theories, therefore the theories which have enabled science to succeed cannot be completely untrue. It can be claimed that the structures of the unobservable world postulated in the successful theories are at least approximately true.

Cartwright further claims that mathematization of a phenomenon or a process is no warrant for truth of its structure. She has quoted six different mathematical equations for one quantum phenomenon as I have mentioned in chapter four. She is showing the impotency of mathematics to lead us to truth. Contrary to her claim, we have examined Worrall's argument of mathematization *for* the truth of unobservable structures in the last sub-section. He equates mathematization with truth. Cartwright's arguments apply in quantum physics whereas Worrall's in classical physics.

Hacking says that scientific theories have been given undue importance in illuminating the physical world. As discussed in chapter four, Hacking claims that scientific knowledge has been gained experimentally even without any theory and even with false theories. He advises an agnostic attitude towards the theories. That means, according to Hacking, the putative unobservable structures posited in the theories, may be true or may not be true; we can nevertheless gain knowledge of the entities. Hacking's argument cannot be construed as a claim that we cannot know the structure of the unobservable world. His claim does not contradict Worrall's claim for the same knowledge.

Cartwright takes the unobservable entities that cause the phenomena as knowable. It has been argued that the material of the unobservable entity and its structure form a continuum. Knowledge of an entity involves knowledge of some of its characteristics or structure. The claim to knowledge of the entity and not of its structure is questionable.

In this subsection 5.3, we have examined arguments for the contrary assertions made by the structural realists and entity realists. The former claimed that we can know the unobservable structure of the world while the latter adopted skepticism. It has been found that the structural realists' argument, that success of science can be explained by our knowledge of structure alone is wanting and the argument for truth by recourse to mathematics does not apply to the whole scientific enterprise. The arguments are not shown to be invalid; it is the limitation of their scope and application, which is brought out. Entity realists' arguments against the truth of theories and hence the putative structures are not convincing in the face of success of science. However the arguments may apply in the upcoming branches of science. Their arguments for our epistemic access to the entities irrespective of the same for structures, do not contradict the structural realists' claims.

5.4 Chakravartty's position (semi-realism)

Chakravartty (2007) develops a form of realism out of structural realism and entity realism which, according to him, *incorporates the best of their insights and avoids their defects* (p 13). Chakravartty's semi-realism claims epistemic access to unobservable structures by the entity realists' means.

Entity realism advises us to believe in the theoretical entities and not in the theories but it does not draw a clear line of demarcation between the entities and the theories they are embedded in. This is in spite of the fact that claims about the entities are existential and those others are theoretical because they are not easily separable when it comes to knowledge. The entities are not knowable in isolation. Their structure or relations vis-à-vis the instruments of observations or the manipulating agents or the aspects of phenomena in which they are manipulated have to be known. The unobservable entities are capable of those relations because of their specific properties. For example the charge of an electron is its inherent or first order property, which decides its relation to other charged particles. It is the properties and the relations or structures that the theories describe. The claim that the entities exist and we can know them and not their properties or structures becomes doubtful.

According to Chakravartty, the entity realist is asking us to believe in the entities while telling us to be skeptical about the very knowledge that gives us the reason to endorse that belief. Realism about entities is dependent upon realism about at least some aspects of theory also. In its address to PMI, the entity realist claims that at least the entity part of a theory transcends theory-change, and that there is continuity. Let's take the example of the electron again. A long line of experimenters interacted with the electron from Thomson to Robert Milliken to Ernest Rutherford and throughout the twentieth century. All of them did not manipulate the electron, as required by Hacking but nevertheless met the required standards of "knowing" the electron. Over time, scientists have believed in very different things about electrons and so to claim that they were talking of the 'same thing' is not very convincing on the strength of reference alone. The different generations of scientists had very different conceptions about electrons.

In the practice of science, we can notice a graded spectrum of commitments. There are certain things we can be quite sure of, due to their acute causal powers that can be exploited clearly. In the cases, where the causal connections are not very clear, the confidence reduces. Chakravartty argues that because an entity can be detected, by exploiting its causal properties, therefore all the "detectables" should be considered as "knowable". Detection, according to him can lead us to knowledge of the unobservable structures. It is because the causal process of detection exploits the "properties" of the detected entities. He calls his stance as 'semi-realism'. Whereas empiricists divide our epistemic access on the basis of observable-unobservable, the semi-realists do so, on the basis of detectable-undetectable.

I think detectability is a rather vague term. There can be different opinions on what is detectable and moreover 'what' is detectable is parasitic on what is imaginable and can explain a phenomenon. Semi-realism faces the same arguments as entity-realism. However it represents the modern scientific attitude and challenges.

Semi-realism endorses the entity realists' reliance on causation for tracing truth in the unobservable realm, but rejects the latter's claim to knowledge of the entities. Instead, the semi-realists reassert the structural realists' claim to the knowledge of the unobservable structures but do not endorse their arguments. Semi-realism does not contribute to dissolving the tension created by the two partial realist positions of structural realism and entity realism.

5.5 Dissolving the Tension

The two partial realist positions of structural realism and entity realism demarcate what in a theory is to be believed, from the part on which one may remain agnostic or even disbelieving. We have examined the arguments for and against their respective and contradictory assertions. In this subsection, I summarize the deliberations of the chapter with a view to dissolve the tension created by their assertions.

Entity realists argue for our knowledge of the unobservable entities because these are the cause of observed phenomena. A cause connects uniquely with its effect and has to exist. Their reasoning is: (even if) all our knowledge of the world comes through our senses; what is perceived with the senses is caused by the entities, so, even if unobservable, these entities exist and can be known. Crucial part of this reasoning is the causal link. Empiricist philosophers have argued against cause-effect certainty. The entity realists retort by saying that although nature of causation cannot be established by empirical investigation alone, it provides grounds for realist claims. Some modern philosophers of science base their arguments on the actual happenings in the laboratories. Scientific instruments like microscopes are a convincing example of gaining knowledge by 'doing' as against 'speculating'. Cutting edge of the entity realists' argument comes from showing the causal link without (or minimum) doubt. This is attempted by shifting the onus from "studying the" unobservable theoretical entity to "studying with" the entity. If the entity (in doubt), is the input or manipulating agent for studying something else, then the doubt dissolves.

Entity realists' arguments do not apply in general. Science as a method of enquiry has not developed equally in all areas of physical world. The reasons for advancement of science in certain fields of study more than the others, can be topic of another study. As discussed in chapter four, it is only in a few spheres of specialized study in quantum physics, that some unobservable entities are known enough to be used as input. Similarly, not many unobservable theoretical entities can lend themselves to be 'worked with' under a microscope. We have to know enough about an entity, to isolate it under a microscope and then make sure that it remains unaffected by the mode (electrons or sound waves) of observation. Justification for belief in the truth about the unobservable entities, as proposed by the entity realists is possible, only in some selected fields of the scientific enterprise.

Structural realists' arguments against our knowledge of the unobservable entities are rooted in Kant's conviction that *noumena* , the material of which the world is made up, is not knowable to us humans. They do not advance any tangible reason for our epistemic inaccessibility to such entities. They don't tell us that what is so special or mysterious about the material of the world that it will remain hidden from us. Nor do they point out any limiting feature of human cognitive capacity. They strengthen their conviction by invoking the history of science. The historical evidence against our knowledge of the unobservable entities applies to those entities which were not mature, or corroborated. The evidence applies where the scientific enterprise is at infancy stage and background knowledge is scarce.

Empiricists' reason against our knowledge of the unobservable entities is their epistemic caution. For them, all knowledge of the natural world is gained through our senses. This foundational belief of the empiricists has come under severe criticism and attack in the recent years from the experimentalist philosophers like Hacking. Recall my introduction to chapter four and the background to entity realism. In quantum physics, for example, beliefs are formed and justified without any direct recourse to sense data as required by empiricist epistemology. The empiricist skeptism is countered by the convincing justificatory experimental means. Van Fraassen concedes that it is the experimental design and methodology that provides 'experience' required for scientific knowledge. It is the actual happenings (in science labs) that need to be accounted for. Philosophers of science are adjusting their stances to explain the 'source' of the knowledge gained. Chakravartty (2007), for example, argues for acceptance of detection using scientific instruments, as a source of knowledge for unobservables.

From the above, it becomes clear that the entity realists' claim to knowledge of unobservable entities is valid in certain (advanced) areas of scientific endeavor albeit not across the board. Structural realists' arguments against our epistemic access to unobservable entities are similarly applicable selectively in certain (formative) stages of scientific enterprise. Arguments for the two positions do not contradict each other.

Arguments for the stance that we can know the structure of the unobservable world can be traced back to the ideas of structralists. The general feeling was that there is some sort of correspondence between the natural world and our sense experience of it. Fuelled by Kant's conviction that the 'things in themselves', or the material of the world is not knowable, it was concluded that our epistemic access is only up to the structure. Worrall took this reasoning further to argue that our knowledge of the structure alone, explains the success of science. He attributed the falsification of past accepted theories to the 'false' unobservable theoretical entities. We have seen in the previous subsections, that our knowledge of the structure of the physical world, plays a part towards the success of science; but accepting the scientific theories up to empirical adequacy only, is enough to explain that success. Moreover in some areas, success of science has been achieved due to our knowledge of the unobservable entities also. It shows that Worrall's argument that our knowledge of structure alone, explains the success of science, does not hold in general.

Mathematical knowledge is *a priori* and relations expressed in its language do not change. Worrall justifies the truth of the theoretical structure of the natural world because it can be expressed in mathematical equations. Mathematization of the theoretical structures is a strong argument for their truth in classical physics but does not apply in quantum physics. Even in the former, all scientific theories may not be expressed mathematically.

In actual practice of science the specification of 'structure' is not as clear-cut as in theory-change from Fresnel's to Maxwell's. Juha Saatsi (2010) points out that this case from the history of science is a case of major theoretical advance and not a frequent occurrence. The generalization that knowledge of structure transcends in all cases of theory-change, from one episode in the history of science, is too hasty.

Nancy Cartwright's arguments against our epistemic access to the structural part of the unobservable world are circumscribed in the mistrust towards the scientific theories. It can be construed that the structure of the world, according to Cartwright, can be known (at least) approximately. Hacking does not argue against the truth of scientific theories in general. He argues, instead, that we can know the unobservable entities without, or even with false, theories in some cases. The entity realists seem to play down the knowledge of structures and not deny it.

Upon critically evaluating the two partial realist positions of structural realism and entity realism, the following can be concluded:

1. Their arguments for our knowledge of structure and entities, of the unobservable world, apply in different areas and at different stages of development of scientific enterprise.

2. Structural realists' arguments against our knowledge of the unobservable entities are weak and entity realists do not argue directly against our knowledge of the structures.

Structural realism and entity realism can coexist and do not contradict each other. The tension created within the scientific realist camp by the two partial realist positions is found to be pseudo and stands resolved.

CHAPTER SIX

GENERAL CONCLUSION

Structural realism and entity realism have made conflicting and mutually exclusive claims about the knowledge that science can provide. It was hypothesized in this dissertation that the tension created by their contradictory assertions can be dissolved. Their arguments have been evaluated and it is found that they attempt to find out what is it that the scientific method can tell us with certainty. And also, what are the weaknesses of the method and what may not be knowable. Their arguments bring to light the heterogeneous character of the scientific enterprise. What we can know and what we cannot know varies within the enterprise. The two do not overlap.

In the first chapter of the thesis I have shown that the scientific realists endeavor to convince us of the truth of scientific theories by invoking the success of science, which is brought about by these theories. But our knowledge of the unobservable world results in the empirical adequacy of the theories; beyond empirical adequacy, we cannot be certain. The truth of our current accepted theories can be claimed only after explaining the failures of the past accepted theories which were also successful.

The challenges facing scientific realism have been made clear by showing how the underdetermination of theories by evidence (UDTE) gives rise to pessimistic meta-induction (PMI). The predictive power of a theory implies its empirical adequacy to the yet unobserved. Falsification of an accepted theory means that the evidence available at the time of its formulation was not sufficient to identify the truth. Or, that the evidence underdetermined. The new theory is empirically adequate to the old as well as new evidence; but this does not assure us that the new theory will be adequate to the yet unobserved evidence.

I have shown how the realists argue that the theory-shifts do not involve the falsification of the whole theory, rather it is a process of refinement and removal of errors. They concede that our current accepted theories can undergo some changes and that these are only approximately true. This move allows for adjustments of the theories to new evidence. The approach is in line with the realist belief that we are moving towards the truth.

The study has shown that the anti-realist stance does not represent the actual scientific practices. Although the anti-realists adjust their hard-line stance of accepting the theories as empirically adequate to 'what is observable' from 'what has been observed', thereby recommending belief in the evidence which may be obtained in future. The belief will be justified when (and if) the actual observation will be made. Even the justified belief will not qualify as knowledge. It is because truth can only be claimed after all the observations have been made and we can never be certain even if it happens. Therefore, according to the empiricist stance, we can never attain knowledge (justified true belief) of the physical world.

Even the modified empiricist position faces insurmountable difficulties. It is because the observation demanded by the empiricists, for empirical adequacy, whether of past, present or future is unaided or with naked eyes. In practice almost all the scientific beliefs are formed and justified with the observations made using instruments. The belief that (direct) experience is the only source of knowledge limits the scope of science. It presupposes that reality is somehow similar to what we can experience.

In this thesis I have discussed some experiments conducted at the frontier of the scientific activity and it is noted that to explain the phenomena in nature, one has to think beyond experience (outside the box). The concepts of quantum mechanics and warped space are difficult to imagine and comprehend (and experience), but, are accepted and closer to truth. If a conceptualized entity is found to be false, it does not show our epistemic inaccess, rather it shows the ability of scientific method to detect and rectify errors.

Although my research suggests a realist approach to science, the anti-realists' parsimony in apportioning belief and a quest for certainty, keeps the realists' claims (overconfidence) under control. All the different forms and shades of anti-realism agree that the unobservable world exists; it is its knowledge that they deny. The scientific realists, on the other hand stress that our current accepted theories are at least approximately true. That means that the unobservable theoretical entities exist and are structured as suggested by the theories putating them.

Structural realism versus entity realism debate is a domestic debate within realist camp. The former adopts a reconciliatory position and concedes that the theories are susceptible to falsification and that we cannot know the entities. It is only the structure of the unobservable world that we can know. Their arguments falsify the anti-realist assertion that nothing in the unobservable world can be known. At the same time the structural realists loose a lot of ground for the realist position.

Although, in my considered opinion there is no tangible and sustainable argument for our knowledge of the material of which the world is made, but the claim that we will never know it, is not only hasty but also shows a lack of confidence in the enterprise of science. Moreover, blaming all the falsifications of the scientific theories on the theoretical entities cannot be justified. History of science is full of instances where false structures were part of successful theories which were later falsified. Newtonian model of the universe is just one example.

In the fourth chapter I have shown how Nancy Cartwright brings out a dilemma faced by scientists. Accuracy and generality are both sought after qualities for laws of nature, but they vary inversely to each other. The accepted laws of nature are a compromise between the two and therefore cannot lead to the true scientific theories. Her conclusion tallies with the anti-realist tenets. But at the same time she retrieves the old controversial subject of causality as a means of justification for scientific beliefs. She questions the anti-realist skeptism of everything unobservable. The strength of her arguments and the conclusions drawn from them depend on establishing the cause-effect link, which is unobservable but leads to justification of beliefs regarding the theoretical entities.

For her entity-realist position, Cartwright first argues against the whole (theories) and then argues for part (entities). Her conclusion that the laws of physics lie, is general and more serious and damaging to realism than her arguments warrant. It undermines the scientific method of tracing truth. The causal arguments for justifying the beliefs about the entities are strong, both logically and by commonsense approach. But, the scope of such arguments is limited and moreover it is parasitic on the scientific theories, the truth of which Cartwright argues against. It is the scientific theories which tell us of the theoretical entities and further the instruments which establish the unobservable cause-effect links are designed on scientific theories.

Both Cartwright and Hacking have attempted to demonstrate the reality of unobservable entities. Whereas the former argues that the theories are false, the latter adopts a neutral approach. It is the reality of the physical world that the scientists and philosophers are seeking. Philosophers critique the justificatory methods employed by the scientists for their models of reality, expressed as scientific theories. Almost all the philosophers of science have taken the "thinking" and argumentative route to ascertain the truth regarding reality. Hacking introduces the commonsense approach of day-to-day macroscopic life. 'Real' is something which we can interact with, interfere and manipulate. Real objects are part of cause-effect relationships. If we can effect something by predetermined means, then it is real. But if we can use something to cause a predetermined or expected effect, then not only is it real, but also it is known.

Hacking makes a strong case for entity realism. The entities which qualify Hacking's conditions exist and the aspects or properties of the entities which are manipulated or used for manipulation can be attributed to the entities concerned. It is a strong argument for scientific realism against anti-realism and it by-passes various realist-antirealist metaphysical standoffs. However, the manipulations and interferences do not tell us the material of which the entities are made of and the techniques do not apply across the board for the whole of scientific enterprise.

I have demonstrated that both the partial realist positions use the vulnerability of scientific methods to show that we cannot know certain aspects of nature. A critical evaluation of their arguments reveals that structural realism and entity realism hold for different areas of scientific pursuit and bring out the heterogeneous character of science. They study our epistemic commitments in a piecemeal manner.

My conclusion is concordant with the views of some modern philosophers of science. David Papineau says: "… Or perhaps we should be theory realists in chemistry, entity realists in geology, and outright skeptics in plaeobiology …" (1996: 5). Juha Saatsi endorses that view and adds: "there is reason *not* to expect the same alternative to apply to every scientific discipline" (2010:13; stress as in original). Papineau and Saatsi have alluded to a heterogeneous view of science without elaborating. Anjan

Chakravartty (2007) adopts a structralist stance with entity realist arguments, showing that the two entail each other and do not contradict.

The objectives of my thesis are met by demonstrating that science is a heterogeneous activity but the conclusion raises some new questions. Is the heterogeneity of science precipitated by the justificatory means adopted by the two partial realist positions? Do the means limit what can be justified? The question calls for further research and can make the topic of another project. The project would involve studying if mathematization can lead us to truth about unobservable entities. And further if causality can justify structural beliefs.

The thesis had set out to critically evaluate the two partial realist positions. The two were viewed by some philosophers of science as diametrically opposite because one claimed the knowledge which the other denied. It created a tension within the scientific realist camp. It has been shown that their arguments are valid albeit apply selectively. The seemingly contradictory claims are limited in scope and mutually exclusive. The two partial realist stances can co-exist.

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