Chapter 2

Philosophy of Science

All men by nature desire knowledge.

—**Aristotle**

Man, being the servant and interpreter of Nature, can do and understand so much and so much only as he has observed in fact or in thought of the course of nature. Beyond this he neither knows anything nor can do anything.

—**Francis Bacon**

2.1 INTRODUCTION

This chapter is intended to provide a brief introduction to the philosophy of science. The question "what is philosophy of science" cannot be answered in a straightforward way. Right from the beginning of the scientific investigations various philosophers like Aristotle, Francis Bacon, Bertrand Russell, Karl Popper and Thomas Kuhn put forward various philosophical theories. A scientist adopts various methods for solving a problem. The main function of philosophy of science, as one could see, is to analyze the scientific methods. Philosophy of science presents a "view" and argues that the scientific theories should be based on these views. In a sense philosophy of science always questions the scientists. As John Losee points, "philosophy of science is a discipline in which the concepts and theories of the sciences are analyzed and clarified" [1]. The philosophy of science analyzes the characteristics of scientific inquiry, scientific procedure, conditions satisfied by the scientific explanations and cognitive status of scientific laws and principles [2]. Thus, philosophy of science is thinking over science and scientific methodology and it is different from doing science.

Philosophy of science is broadly classified into two:

- Epistemology, and
- Metaphysics.

Epistemology deals with the scientific claims and metaphysics deals with the philosophical features of the world described by the science. That is, epistemology is the reality and metaphysics refers to the possibility. Epistemology deals with the problem that occurs when practising science. James Ladyman defines epistemology as [3]:

It is to be noted that there is no absolute scientific truth. Therefore, all scientific statements are not equally valid or equally useful. Rather, the probability of the statement is important. All statements are not equally probable. Nobody doubts the probability of the statement '*sun rises in the east'*, but the statement '*ripe apples are red'* has less probability. Such statements are often regarded as *statistical statements*. Also, some statements are more reliable and some others are more useful. For example, the statement '*sun rises in the east'* is more reliable whereas the statement '*use of CF lamp reduces the power consumption'* is more useful. A scientific statement when attains universal acceptance it becomes a *fact* and a generalization of facts leads to a *law*.

2.3 THE CLASSICAL APPROACH

The origin of philosophy of science can be traced back to Greece during the period of Aristotle and his contemporaries. As a philosopher Aristotle relied on logical reasoning for arriving at a conclusion. This is called *classical approach* which is the first systematic treatment of the principles of correct reasoning. In this approach the validity of the conclusion depends upon the strength of the argument. There is nothing to surprise that Aristotle did not use any experimentation because he was a philosopher and he had confidence in his philosophy. But as Lee (2000) pointed out this could work very well in mathematics and logic, but science is different [4]. The reality may be different from our perception. Aristotle says at the beginning of his *Physics* "the best way to reach information about the '*science of nature*' is to advance from universals to particulars, because universals are easier for us to grasp with the help of our senses. The tool used by Aristotle for this was the *deductive reasoning* in the form of *syllogisms*. Using syllogisms one could infer new truths from established ones.

In syllogism one examines two statements, say, a major statement and a minor statement and says whether or not a third statement (conclusion) follows from the first two statements.

EXAMPLE

Statement 1: A is true for all B.
Statement 2: B is true for all C.
Inference: A is true for all C.

This deduction is meaningful and its validity does not require any proof. But the question rests in the validity of the statements (premises). How can we find true premises which are the foundational principles of given science? Aristotle himself addressed this problem. He realized that the knowledge already present in our mind is not sufficient to recognize the premises in many of the situations.

Instead, the foundational premises must be acquired through experiences derived from perceptions and memories of perceptions. After repeatedly assembled various perceptions into memories and then, processing these memories, one can comprehend the first principle.

Consider the following example.

Statement 1: All balls in the box are red.

Statement 2: I took two balls from the box.

Inference: Therefore balls in my hands are red.

The inference is necessarily true since the argument is sound. But the deductive reasoning does not always a valid inference. As already mentioned, the validity of the conclusion depends on the correctness of the premises. It is clear in the following example.

Statement 1: Aristotle advocates deductive reasoning.

Statement 2: Aristotle was a philosopher.

Inference: Therefore a philosopher advocate deductive reasoning.

The statements are true but the inference is not necessarily true.

Aristotle's philosophy and methodology worked well, especially for developing a taxonomical framework for biology. Many scientists like Archimedes and Euclid adopted Aristotle's method for proving their laws. Euclidian geometry can be regarded as a paradigm of deductive reasoning in science. Euclid and his followers formed numerous theorems on the properties of geometrical figures starting from a small number of premises. This methodology was mainly focused in developing the basic concepts of science but it became inadequate after some time, especially in physics and chemistry. This limitation was eventual and it does not degrade the methodology which ruled the scientific world for centuries.

In spite of its ability to discover universals by generalization Aristotle was not in favour of induction because as he believed it was not sufficient in identifying the cause.

2.4 EMPIRICISM

In the previous section we have seen the classical method based on deductive reasoning. This method was purely based on logic. During the course of development of science this became inadequate and the methodology broke out of Aristotelian framework. This happened during Renaissance in the western world and science became oriented towards the quantitative verification of hypotheses. New methodology called *empiricism* emerged up. According to empiricism reason alone is not sufficient in drawing conclusion; but all ideas must be tested through experimentation by making observations and measurements and subsequent analysis. Therefore, empiricism relies on experimentation for acquiring the scientific knowledge. In words of Ladyman:

The simplest form of induction is called *enumerative induction*. Here we observe a large number of instances of a particular phenomenon which has some characteristics and conclude that the phenomenon always has that characteristic. This happens in the case of many medicines, they give relief; but how it works may not be known.

2.4.2 Hume's Problem of Induction

Bacon's method revolutionized the scientific world. Many scientists like Galileo and Newton worked on Bacon's framework and devised a number of theorems and laws. The wide acceptance gained by Bacon's method did not mean that it is absolutely correct. Nobody was worried about this until David Hume (1711 – 1776) pointed out the problem of induction in his work *An Enquiry Concerning Human Understanding*. Two simple questions were asked [10].

1. What justifies the faith we place in induction?
2. How should we go about persuading someone, who refuses to reason inductively, that they are wrong?

Hume presented a simple answer to these questions. According to Hume the use of induction cannot be rationally justified. We use induction all the time in everyday life and in science, but Hume insisted this was a matter of brute animal habit. If anybody challenged to provide a good reason for using induction, we cannot give a satisfactory answer.

To explain his arguments Hume attributed a "*uniformity of nature*" characteristic to the inductive inferences. By uniformity of nature Hume means the inference is valid also for the unexamined objects or instances. Hume argued that we cannot strictly prove the truth of *uniformity of nature* but we might hope to find a good empirical evidence for its truth. Samir Okasha (2002) puts this in another way: "it is an established fact that nature has behaved largely up to now; but we cannot appeal to this fact to argue that the nature will continue to be uniform. Because this assumes that what has happened in the past is a reliable guide to what will happen in the future: which is the *uniformity of nature* assumption. The argument for *uniformity of nature* on empirical grounds, we end up reasoning in a circle" [11]. An elaborate discussion on Hume's problem can be found in *Understanding Philosophy of Science*"by James Ladyman (2002) and also in *Philosophy of Science – An Encyclopedia*, by Sahotra Sarkar and Jessica Pfeifer (2005).

2.4.3 Deduction

Imagine that four 3″ × 5″ cards are on the table. You can see that each card has a single letter or number on its top: one has the letter 'A', one has 'B', one has the number '4', and one has the number '7'. You may assume that each card contains a single letter on one side and a single numeral on the other side.

What cards is it necessary to turn over, to evaluate the validity of this rule: 'If a card has an A on one side, then it has a 4 on the other side'?

This was a problem put forward by Wason (1996, cited in Richard D Jarrard, p.71). This is a good example where the deductive reasoning can be employed to obtain the answer. This seems to be a very simple question and many answered in a minute or two; A and 4. But the correct answer is A and 7. The justification is as follows:

- Certainly card B is not useful, because it cannot support and prove or disprove the rule regardless of the number written on the other side.
- In case of card 4, even if it has an *A* on the other side, it supports but neither proves nor disproves the rule.
- But the flipping of card 7 tests the rule. If the other side is *A* then the rule will be disproved.

This answer can be analyzed philosophically and scientifically. Philosophers interpret the answer *A* and *4* as a conformation bias. The chooser of the card 4 is expecting a result that confirms the rule, rather than choosing the card 7 and possibly disproving the hypothesis. Scientists may justify choice of the card *4* as a search for patterns where they are most likely to be found. As Richard D Jarrard (2001) pointed out this particular problem illustrates [12]:

- Confirmation bias is present in science, but to some extent it is a normal consequence of our pervasive search for patterns.
- Many people's 'deductive thinking' may actually be inductive pattern recognition of a familiar deductive form.

A description of deductive logic is given in section 2.3. In deductive logic, each statement in the argument is either true or false. For the conclusion to be true, the following two conditions must be satisfied:

1. The premises must be true.
2. The form of the argument must be valid.

A valid deductive argument is one in which the conclusion is necessarily true if the premises are true. The validity or invalidity of a deductive argument is totally independent of the correctness of the premises; *it depends only on the form of the argument* [13]. Consider the following classical examples:

EXAMPLE 1

Statement 1: All dogs are cats.

Statement 2: All cats are animals.

Conclusion: Therefore, all dogs are animals.

In this example the form is valid but one premise is false. Therefore, even though the conclusion happens to be correct; the argument is incorrect.

EXAMPLE 2

Statement 1: All dogs are mammals.

Statement 2: All mammals are animals.

Conclusion: Therefore, all dogs are animals.

Here the form is valid and the premises are true. So the argument is correct and the conclusion must be true.

EXAMPLE 3

Statement 1: All dogs are mammals.

Statement 2: All cats are mammals.

Conclusion: Therefore, all dogs are cats.

In this case the premises are true but the form of the argument is not valid. Therefore, it does not yield a correct conclusion.

From these examples it is clear that in deductive reasoning one should consider the correctness of the premises and form of the argument. The evaluation of premises is subjective based on local expertise and that of argument form is objective [14].

Deduction and induction constitute the two branches of scientific logic. In general, deduction is developing a theory from the general to the particular, whereas induction is moving from the particular to the general. It is believed that deduction is more efficient than induction, as it probably does not mislead the scientist. In fact ,induction is found to be more productive than deduction. René Descartes argued that science should be confined to the deduction whereas Francis Bacon advocated induction, as majority of scientific discoveries were empirical. Isaac Newton rejected Descartes and was in favour of Bacon's empiricism. But in the course of rapid scientific progress it was realized that both deduction and induction are necessary aspects of science; both deduction and induction have their own place in the methodology of science. The question of superiority is a fallacy.

The difference between the deductive and inductive arguments can be put in a single sentence. In a deductive argument, the conclusion follows necessarily from the premises whereas in an inductive argument, the conclusion follows probably from the premises (Richard D Jarrard, 2001). As a result deductive arguments are judged as valid or invalid: in a valid deductive argument, *if the premises are true, then the conclusion must be true.* Inductive arguments are judged as strong or weak according to the likelihood that true premises imply a correct conclusion.

2.5 POSITIVISM

Positivism is the most widely accepted scientific method. Positivism is a philosophy of science originated with David Hume in the early modern era which developed into *logical positivism* in 1930s. The term "*positivism"* was used for the first time by Saint-Simon to designate the method of the sciences and was taken over by Auguste Comte for his philosophy. According to Comte positivism referred to the last "scientific stage" in the development of "mind" which evolves through three stages: *theological*, *metaphysical*, and *positive*. In theological stage mind believes in religious superstition, which is the most primitive stage of the mind. In metaphysical stage such superstitious are replaced by impersonal forces such as gravity and are still considered mysterious. In positivism metaphysical forces are replaced by observational concepts. Comte suggests three defining characteristics of positivism.

1. Metaphysical and fictitious ideas should not be a part of science.
2. We should seek causes in Hume's sense, that is, as "invariable relations of succession and resemblance". (Comte was very much influenced by Hume and Emmanuel Kant through their empiricist approach.)
3. The explanation of facts is simply the establishment of a connection between single phenomena and some general facts.

There are several alternatives to positivism like falsification and realism. As Levin (1988) says positivists believe that reality is stable and can be observed and described from an objective viewpoint. They argued that the phenomena should be isolated and emphasis is given to the repeatability of the observations. Hirschheim (1985) observed that: "positivism has a long and rich historical tradition. It is so embedded in our society that knowledge claims not grounded in positivist thought are simply dismissed as 'ascientific' and therefore invalid".

This observation was supported by many people and, in general, the empirical studies were positivist in approach. As mentioned, positivism relies on observation and experimentation. In the words of Anne B Ryan "positivist researchers believe that they can reach a full understanding based on experiment and observation. Concepts and knowledge are held to be the product of straightforward experience, interpreted through rational deduction. Positivism seeks to reduce everything to abstract and universal principles, and tends to fragment human experience rather than treat it as a complex whole" [15]. Thus, positivism provides a framework to explore reality as a concrete, given entity which can be understood objectively.

Positivist approach holds certain beliefs:

- *Prediction and control:* There are general patterns of cause-and-effect that can be used as a basis for predicting and controlling natural phenomena. The goal is to discover these patterns.

- *Empirical verification:* We can rely on our perceptions of the world to provide us with accurate data.
- *Research is value-free:* A strict methodological protocol is followed; research will be free of subjective bias and objectivity will be achieved.

The various steps involved in positivism can be summarized as follows.

First, the scientist identifies a problem or phenomena for study. As a second step a hypotheses is set up. A hypothesis represents a possible explanation of the phenomenon. Usually, hypothesis is based on the observation of the present situation, past experience of the scientist or based on some established knowledge. The next task is to test the correctness of the hypotheses. This is done by experiments through careful collection of data and analysis. Various methods can be used for the collection and analyzing data. The experiments can be performed under controlled conditions such as in a laboratory or outside the laboratory (field). If the hypothesis fails the test, then it is to be modified in view of the observations and is to be tested again. If the hypothesis passes the test, the scientist can go ahead and it can again be tested under new conditions for a refinement. It is advised that the scientist should keep on testing the hypothesis so that it becomes more and more accurate and closer to the reality.

Within positivism the knowledge is treated as [16]:

- Only methodologies by which knowledge is arrived at are important. These methodologies must be objective, empirical and scientific.
- Only certain topics are worthy of enquiry, namely those that exist in the public world.
- The relationship between the self and knowledge has been largely denied – knowledge is regarded as separate from the person who constructs it.
- Mathematics, science and technical knowledge are given high status, because they are regarded as objective; separate from the person and the private world.
- Knowledge is construed as being something discovered, not produced by human beings.

Positivism is founded on an epistemological base which has some limitations. Positivism faces many challenges from various fields like anthropology, ethnography and critical psychology and from developments in qualitative research. Kuhn (1962) opinioned that positivist visions of science do not always reflect the actual practice of doing science. Nevertheless positivism is still a dominant model for research.

During the twentieth century positivism got its new birth as logical positivism. It was primarily concerned with theory of knowledge (epistemology), mathematical logic, and philosophy of science. As Robert Klee observes: ‘the logical positivists had a peculiar “spirit,” an overriding set of intellectual and philosophical attitudes, preferences, and commitments’ [17]. Positivists depend strongly on mathematical logic because they understood mathematical logic has a universally applicability in understanding difficult-to-understand concepts, problems and issues. Klee continues: "…mathematical logic contains enough power and precision to allow us to capture and express in a useful and understandable way the most important causal and explanatory relationships that occur out in the real world, that is, in the domain of investigation in which a given scientist works" [18]. In logical positivism, a statement can be true only if it is a self-evident analytical, deductive truth as is found in mathematics and formal logic or if the statement describes reality precisely [19]. Logical positivists practised a healthy skepticism and specific methodology that was employed in the analysis of philosophical problems.

2.6 FALSIFICATIONISM

"*In so far as a scientific statement speaks about reality, it must be falsifiable; and in so far as it is not falsifiable, it does not speak about reality*".

—**Karl Popper**

Falsification is a modification of positivist approach and it was introduced by Karl Popper who had a considerable influence in the philosophy of science during twentieth century. It is developed on the idea that "no matter how many times a theory passes attest, scientists can never be sure that it will pass all future tests" [20].

Initially Popper had a study on Marxism of Carl Marx and psychoanalysis of Sigmund Freud. Popper considered these to be pseudosciences. Popper made important remark on these as: "it was easy to think of both these theories as very successful sciences if one assumed that scientific knowledge proceeds, and is justified, by the accumulation of positive instances of theories and laws" [21]. Popper noticed that, when the theory is so general it is too easy to accumulate positive instances to support a theory. For example, consider the statement "all metals expand on heating". One can give a number of examples, but it is hard to find a disproving situation. In other words the idea of conformation is fundamental to the scientific method. By this Popper means if we are thorough in a particular scientific method it is very easy to find confirming situations.

Popper was always impressed by novel predictions that were risky of being turned out to be false. A number of such predictions can be seen in science. Some are given below.

Einstein's prediction of gravitational lensing based on general theory of relativity.

- Newton's prediction on the return of Halley's comet during 1758.
- Mendeleeff's prediction of the existence of the unknown elements of gallium and selenium derived from the structure of the Periodic Table of the elements.

- *Some legitimate parts of science seem not to be falsifiable:* Probabilistic statements such as about the half-life period of a radioactive element, existential statements like statement about the existence of a black hole, unfalsifiable scientific principles like the conservation energy law, second law of thermodynamics and Newton's theory of gravitation and hypothesis of natural selection are beyond falsification.
- *Falsificationism is not itself falsifiable:* This was admitted by Popper himself; his theory is not a scientific theory. Instead, it is a philosophical or logical theory of the scientific method.
- *The notion of degree of falsifiability is problematic:* There cannot be an absolute measure of falsifiability, but only relative one. This is because for a universal generalization there can be infinite set of falsifiers. For example, Einstein's theory of gravitation is supposed to be more falsifiable than Newton's theory of gravitation.
- *Scientists sometimes ignore falsification:* It is often observed that scientists are never ready to abandon theory that they cherish. Scientists thought up modifications or extra assumptions to save it. This happened in the prediction of the orbit of Uranus. Instead of regarding their theory as falsified, most scientists of the time assumed that one of the basic parameters like knowledge about mass, position and motion was wrong, and some other scientists proposed the existence of another planet to accommodate the data.

Popper started with the question "When should a theory be ranked as scientific?" or "Is there a criterion for the scientific character or status of a theory?", and ended up with the idea of falsification. From a philosophical point of view Popper's idea is more relevant but for a scientist positivism works well; scientists look for verification rather than falsification.

Both positivism and falsification tests the hypothesis through experiments. If the hypothesis passes the test the scientist becomes confident on the validity of the hypothesis and he can go for further tests. On the other hand if the hypothesis fails a test then a modification of the hypothesis is required. For example, the prediction of the orbits of the mercury based on Newtonian theory was a failure; but could predict correctly based on Einstein's theory of relativity. When a hypothesis passes almost all convincible tests it becomes a law. It is to be noted that there is no specific criteria for a hypothesis to be regarded as a law; it becomes a law when almost all scientists familiar with it agree upon it.

2.6.1 The Duhem Problem

Popper's idea of falsification got wide acceptance among the scientific community as it seemed to be logically consistent. A single instance of failure was sufficient to reject a hypothesis. In 1954 Pierre Duhem pointed out a major limitation of this method. To quote Duhem's words:

"*The physicist can never submit an isolated hypothesis to the control of experiment, but only a whole group of hypotheses. When experiment is in disagreement with his predictions, it teaches him that one at least of the hypotheses that constitute this group is wrong and must be modified. But experiment does not show him the one that must be changed*".

(P Duhem, 1954, *The Aim and Structure of Physical Theory*, p. 185)

The idea of this statement is that it is impossible to test a scientific hypothesis in isolation, because an empirical test of the hypothesis requires background assumptions about background conditions, the reliability of measurements, the initial conditions of a system, etc. These background assumptions are called auxiliary assumptions or auxiliary hypotheses.

Duhem problem poses two problems before the philosophers of science.

1. There is no reason to suppose the fault lie with the hypothesis under test.
3. Which of the background conditions used to derive a predicted consequence should be rejected or disconfirmed when experiment disagrees with that prediction.

According to Duhem it is impossible to isolate a single hypothesis; but a hypothesis and its background assumptions as a *bundle* can be tested against the empirical world and be falsified if it fails the test. In order to test the hypotheses under consideration we assume that these background assumptions are correct. This is essential because a hypotheses by itself is incapable of making predictions. Thus, if there is a failure in the test we can validly infer that the conjunction (of the test hypothesis and auxiliary hypothesis) is false. But we cannot tell whether it is the test hypothesis or the auxiliary hypothesis that is responsible for the test failure. An American philosopher Willard van Orman Quine (1961) put forward the argument that "it would be quite reasonable to reject a law of logic, or change the meaning of our terms, if it was more convenient than rejecting a particular theory (James Ladyman, p. 79). This means under a condition of a falsifying evidence we should reject the hypothesis rather than rejecting a theory. To put this in other words when we have rational reasons to accept the background assumptions such as scientific theories as true, we will have rational reasons to conclude that the hypothesis tested is probably wrong under a falsifying evidence. This is a kind of Bayesian approach (named after Thomas Bayes, an English Mathematitcian, 1702-1761). In 1979 Jon Dorling presented a Bayesian analysis of Duhem problem where *Dorling* showed that "if a Bayesian personalist reconstruction is adopted then a natural and instructive resolution of Duhem's problem is automatically available to us" [27].

Duhem problem can be easily understood in a wider sense. That is, in any scientific experiment to test a hypothesis the entire physical world is involved. The experimental design, methods of data collection or observation, interpretation of the outcomes, etc., involve principles of optics, thermodynamics, electromagnetism and so on. If the hypothesis is falsified under an experimental test, then it is easy to conclude that the hypothesis might be wrong. However, from a logical point of view one can argue that any of the other principles might be faulted. In other words "no principled way exists to localize the bearing of evidence" [28]. This statement is often called Duhem-Quine thesis.

Paradigm and Paradigm shift (Scientific revolution)

"In science, as in the playing card experiment, novelty emerges only with difficulty, manifested by resistance, against a background provided by expectation".

—Thomas Kuhn (1962, p. 76)

The principles paradigm and paradigm shift was introduced by Thomas Kuhn through the book *The structure of Scientific Revolution* published in 1962. In this book Kuhn presented a historical study of the development of science. Before Kuhn science was considered a rational endeavour in which progress and knowledge are achieved through the steady, painstaking accumulation of experimental data, accredited facts and new discoveries [29]. This was the *normal science* according to Kuhn. He used the word *paradigm* to represent *a conceptual model or intellectual framework within which scientists conduct their research and experimentation*. The exercise of scholarly activities is subject to the prevailing paradigm. All scientists of a particular field consider the problems within the framework set by the paradigm. Kuhn describes the two essential characteristics of paradigms [30]:

1. Their achievement was sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity.
2. They were sufficiently open-ended to leave all sorts of problems for the redefined group of practitioners to resolve.

Examples of such paradigm includes: Ptolemaic astronomy, Copernican astronomy, Aristotelian dynamics, Newtonian dynamics, corpuscular optics, wave optics, quantum mechanics, etc.

The way of normal science is to seek and create a model that will account for as many observations as possible within a paradigm. The observation of instances that does not fit within the paradigm and a courageous attempt on the part of the scientist to move out of the paradigm to seek a solution indicates the beginning of a change. The history of science shows that a paradigm is subjected for a change at any time.

The paradigm shift or Scientific Revolution is usually said to have occurred after the middle-sixteenth century during the Renaissance. The Renaissance inspired a spirit of curiosity in the minds of people. Scholars began to question many beliefs that had been accepted for hundreds of years. The new ways of thinking started the new real science. Scientists began to replace old concepts with new theories, which were proved through the scientific method of observation and experimentation. A new approach to science has emerged. The Scientific Revolution was a new way of thinking about the natural world and it was based upon careful observation and a courageous and curious mind to question accepted beliefs.

It is to be noted that unlike a political revolution scientific revolution developed gradually over a period of time. It began in the sixteenth century and is still continuing. The most important changes in seventeenth-century science took place in the fields of astronomy, physics, chemistry, and biology. Copernicus, Keppler and Galileo redefined the concept of the universe. Isaac Newton proved that gravity acts on every object in the universe. William Harvey discovered how blood circulates. Revolutionary thinkers like Francis Bacon and Rene Descartes came up with their scientific methods. Kuhn argued that true breakthroughs arise in a totally different way: when the discovery of anomalies leads scientists to question the paradigm, and this in turn leads to a scientific revolution that he termed paradigm shift.

New model of universe–an example of scientific revolution

The consequences of new rational thinking were first reflected in astronomy. Scientists started questioning the widely accepted geocentric theory of Ptolemy. Nicolas Copernicus (1473 – 1543) came up with the heliocentric theory after studying the movements of planets for about 25 years. He reasoned that the earth and other planets are revolving around the sun. Copernicus did not publish his findings *On the Revolutions of the Heavenly Bodies*, until 1543, the last year of his life because he was aware that his theory contradicts the religious belief and will be rejected.

Based on the foundations laid by Copernicus, Danish Astronomer Tycho Brahe (1546–1601) carefully recorded the movements of planets for many years.

After the death of Tycho Brahe, Johannes Kepler (1571 – 1630) continued his work. After analyzing the data provided by Brahe, Kepler identified that some law governs the planetary motion. Kepler formulated three laws governing the orbital motion of planets. These laws showed that the Copernicus's basic ideas were true. These laws indeed, say that all planets are revolving around the sun in an elliptical orbit with specific time period.

Galileo Galilei (1564–1642) was a contemporary of Kepler, and was convinced by Copernicus's heliocentric model of the planetary system. He was the first to use the telescope to study the heavenly bodies. Using telescope he discovered the mountains and craters on the moon, and the four moons of the Jupiter. He observed that the planet Venus went through phases just as the Moon does. An important point to be mentioned is that Galileo is regarded as the *father of modern scientific method* because he was the first to apply scientific methods systematically. He was the first experimental scientist.

The discussion will be incomplete unless we say a few words about Isaac Newton (1642–1727). Isaac Newton is the most important contributor to the development of modern science. Newton's great discovery was that the same force determines the motions of the planets, the pendulum, and all matter on the earth and in space; the *force of gravity*. Newton formulated the universal law of gravitation. It says "every object in the universe attracts every other object and the strength of attraction depends on the mass of the objects and the distance between them". Newton published his discoveries in *Mathematical Principles of Natural Philosophy* in 1687. A nice description of the development of science all around the world is presented in *An Introduction to the History and Philosophy of Science*" by *R.V.G.Menon* (Dorling Kindersley India Pvt. Ltd, 2010).

Scientific revolution had its impact on every sphere of science. Medicine and chemistry also witnessed major discoveries during this period, for example, circulation of blood, vaccine for small pox, discovery of oxygen, development of Boyle's law, etc.,. A large number of scientific instruments were also developed. Discovery of microscope, X-ray, Laser etc. had great impact on the scientific studies. In fact, scientific revolution is an ongoing process.

Many people identify the following three internal causes for scientific revolution [31]:

- The research into motion conducted by natural philosophers in the fourteenth century;
- The scientific investigations conducted by Renaissance humanists; and
- The collapse of the dominant conceptual frameworks, or paradigms, that had governed scientific inquiry and research for centuries.

The third point is very important and needs a little bit elaboration. As already mentioned Kuhn regarded the scientific revolution as a paradigm shift. A scientific revolution occurs when the old paradigm collapses and a new paradigm replaces it. In astronomy the antiquity and the middle-age people worked on the paradigm of Ptolemaic model. Later on during the sixteenth century this became inadequate in providing satisfactory explanations for the material universe and Copernicus came with the new paradigm of heliocentric model within which Kepler, Galileo, and Newton all worked. Some more examples are listed below.

- Newtonian mechanics
- Huygens's wave theory of light

line (Müller–Lyer illusion). We can measure the length of the lines and see that they are the same. Even then we perceive one to be longer than the other.

Thus, what we observe is not neutral with respect to the theories and beliefs. In other words, the content of observation (data) is a function of the theories that the observer believes. Since the observations are theory-laden, science also is often regarded as *theory-laden*. James Ladyman makes wonderful observation regarding paradigm in this context. "…all observations are contaminated by background theories then the merits of each paradigm cannot be compared by subjecting them to experimental test because the proponents of the competing paradigms will not necessarily agree about what is observed ". Kuhn compares the paradigm shift to a Gestalt shift.

The theory-ladenness of observation, supports the so called *incommensurability* (which has a literary meaning *lack of common measure*) of two competing paradigm. In Kuhn's words "…the choice between competing paradigms proves to be a choice between incompatible modes of community life" (Kuhn, 1962, p. 94). The concepts ontology, etc., of different paradigm will be different. The incommensurability manifests in two ways:

- Meaning incommensurability, and
- Eeference incommensurability [33].

Meaning incommensurability refers to the fact that theories within different paradigms are incommensurable. This means that the terms and concepts in the scientific theories in different paradigms are not mutually intertranslatable. The *reference incommensurability* means that a particular term in a paradigm', for example, '*atom'* may refer to a different thing in the second paradigm. Thus, the term incommensurability provides the idea that *different theories correspond to the different worlds of different theories, and the proponents of competing paradigms inhabit different worlds; for example, the world of Einstein is literally a different world from that of Newton* [34]. This observation has important consequences, for example, nobody can say Ptolemy was wrong and Copernicus is correct because Ptolemy's earth was a different object from Copernicus's. This is the beginning point of the idea of social constructivism of reality.

Interpretivism or Anti-positivism

"Interpretivism holds the belief that truth is a construct invented or influenced by the observer and that reality is relative and not separate from the individual who observes it".

—Sean

Interpretivism denies what positivism asserts. Interpretivists argue that the reality can be fully understood only through the subjective interpretation of the reality and through an intervention in it. The interpretivist philosophy demands the study of phenomena in their natural environment. They acknowledge that scientists cannot avoid affecting those phenomena they study. Therefore, as opposed to positivism where objectivity has a key role, interpretivism has a subjective element. They are not ignorant of the fact that there may be many interpretations of reality and consider all these interpretations as a part of scientific knowledge. They argue that data have to be interpreted; it does not present explanations by itself. Interpretation is supposed to be the ability to extract meaning from observation and this is different from the process of following scientific method. As the followers if interpretivism argues:

"Subjectivity at its best has a link to creativity".

Creativity represents new ways of thinking and understanding. The creativity can work out more effectively in subjective interpretations. Many times achievements are made by stepping out of the rules of scientific methods and relying on inspiration. Anti-positivists like Wilhelm Dilthey (1833-1911) and Max Weber (1864-1920) pointed out the positivist failure to "appreciate the fundamental experience of life, and instead favour physical and mental regularities, neglecting the meaningful experience that was really the defining characteristic of human phenomena". Interpretivism relies on interviews and subjective observation.

Interpretivism is developed based on the idea that there are fundamental differences between the natural world and the social world and hence the logic and methods of science cannot be applied as such to the society. Scientific methods aim to generate knowledge based on cause-effect relationship whereas social sciences focus on the subjective experience. By its very nature interpretivism is a qualitative research paradigm in which exploration and insight into the subjective experience are valued. People like Hammersley, Mackenzie & Knipe (2006) agree on the fact that researchers should recognize that all participants involved, including the researcher, bring their own unique interpretations of the world or construction of the situation to the research and the researcher needs to be open to the attitudes and values of the participants or, more actively, suspend prior cultural assumptions. Therefore, the researcher himself becomes a part of interaction with the subject of research and this allows him to communicate with the cultural background of a society. The inferences then drawn by the researcher will be more realistic because his understanding is from personal experience rather than from a manipulation of collected data.

2.7 POST-POSITIVISM

"The world is not what I think, but what I live through. I am open to the world, I have no doubt that I am in communication with it, but I do not possess it; it is inexhaustible".

—Merleau Ponty

The basic philosophical assumptions that define research paradigms according to Guba and Lincoln (1994); can be summarized from the responses to three fundamental and sequential questions [35]:

1. The ontological question: What is the form and nature of reality and what can be known about it?
2. The epistemological question: What is the nature of the relationship between the knower or would-be knower and what can be known?
3. The methodological question: How can the inquirer go about finding out whatever he or she believes can be known?

The various perspectives of research paradigms like positivism, interpretivism, post-positivism, etc., are discussed in response to these questions.

Post-positivism emerged as a critique of empiricism. Positivism argues that the reality can be discovered by conducting scientific research. The experiments can be repeated to prove the validity of the result. Post-positivism is considered an empirical, explanatory approach that maintains belief in observables (Gortner, 1999). Post-positivism has emerged from the recognition that [36]:

- True reality is not apprehensible,
- Objective and subjective realities are not mutually exclusive,
- Findings cannot be proven to be true, and
- Inquiry is not value free.

According to Popper (1937) post-positivists argue that one can never be sure that the next research study will not be the one that shows your theory is wrong. This simply means that one can never confirm that a theory is absolutely correct. This is the essence of falsification. When a theory is falsified the researcher should go for a modification of the theory. Nowadays, falsification is not practiced in its complete meaning. Post-positivists employ a modified version of falsification. The occurrence of a negative instance is sometimes attributed to instrumentation, misinterpretation of the data, misapplication of the theory, poor sampling, etc. Therefore, from a one-time failure one cannot conclude that the theory is wrong.

It is quite interesting to notice the arguments of post-positivists. In positivism theory is derived from careful observations. The essence is being the assumption that the data are independent of the theory. Post-positivists are against this concept. According to them any collection of data is based on theory. They share the view that a single study is not sufficient to find out the truth, and it requires a number of attempts; each time attaining a closer approach to the truth. The post-positivist approach is widely employed in social sciences research. As Anne B Ryan observes: “post-positivist research principles emphasize meaning and the creation of new knowledge, and are able to support committed social movements, that is, movements that aspire to change the world and contribute towards social justice" [37]. Further Anne B Ryan points out the following characteristics of post-positivist approach.

- Research is broad rather than specialized–lots of different things qualify as research.
- Theory and practice cannot be kept separate. We cannot afford to ignore theory for the sake of 'just the facts' [38].
- The researcher's motivations for and commitment to research are central and crucial to the enterprise (Schratz and Walker, 1995: 1, 2, as cited in Anne B Ryan p. 13).
- The idea that research is concerned only with correct techniques for collecting and categorizing information is now inadequate (Schratz and Walker, 1995: 3, as cited in Anne B Ryan p. 13).

Post-positivism places the researcher in a key position and provides full freedom for conducting the research as opposed to positivism where strict scientific methods are to be followed. Post-positivism provides an opportunity to investigate the epistemology followed by the researcher himself. "The post-positivist stance asserts the value of values, passion and politics in research. Research in this mode requires the ability to see the whole picture, to take a distanced view or an overview. But this kind of objectivity is different from 'just the facts', devoid of context – it does not mean judging from nowhere" (Eagleton, 2003: 135, cited in Anne B Ryan, p.18).

It is to be noted that post-positivism does not set an aim like '*finding the absolute truth'*. This is due to the fact that they had the realization that the world and experiences are very complex and such a search will prove meaningless. They only acknowledge the reaching of a valuable conclusion as there are no universal solutions to the problems. As Frances E Racher and Stevan Robinson (2002) puts the goal of research is explanation, prediction, and control and involves making generalizations and cause-effect linkages. Knowledge may be gleaned through a variety of quantitative and qualitative research methods that may complement each other and move knowledge closer to the truth, which can never be fully verified [39].

2.8 RELATIVISM

"Relativism is tantamount to the denial of the principle of non-contradiction for if man is the measure of all things, then different people would assign the value true or false to the same assertion rendering it both true and false. Such a move, however, contravenes the principle of non-contradiction, the most certain of all basic principles and a presupposition of all thought and speech".

—Aristotle

The relativism can be viewed, in social context; as *ethical relativism* and *cultural relativism*.

Ethical relativism is a view against the ethical universalization. This means there are no universal moral judgments. The judgments can be relative to either individual or culture. Ruth Benedict (1887-1948) views morality as dependent on the varying histories and environments of different cultures. It is a generally accepted fact that the concept of ethical universalization is very weak whereas the ethical relativism is hard to defend. To prove it false one has to present a moral judgment that has universal acceptance.

Further, the morality is sometimes related to our culture. Cultural relativism includes many things. The attitude, belief, taste, etc., of people are greatly influenced by the culture. The actions are counted as right or wrong accordingly whether they obey the cultural norms. As Maria Baghramian writes "the doctrine of cultural relativism, inspired by the work of social anthropologists, where it is argued that there can be no such thing as a culturally neutral criterion for adjudicating between conflicting claims arising from different cultural contexts, has become one of the best known forms of relativism and has shaped not only the theoretical framework of the social sciences but also the ethical and political outlooks of many non-specialists" [45].

Conceptual relativism, on the other hand, is form of relativism where ontology is related to conceptual schemes or scientific paradigms. Relativism is again viewed as *ontic*, *cognitive* and *aesthetic* in various contexts.

2.9 SCIENTIFIC REALISM

"Nothing is divine but what is agreeable to reason".

—Immanuel Kant

In modern science many phenomena were explained by postulating entities that we do not observe. Many entities like electrons, radiation, dark matter, electric and magnetic fields, etc., fall under this category. We are unable to observe them directly and this raises the question whether they really exist and if so how? This question divided the philosophers of science into two categories: *realists* and *anti-realists* or *instrumentalists*. Scientific realism is subscribed to the idea that theoretical entities or scientific objects do exist. Instrumentalists do not agree with this; for them theoretical postulates are just instruments for generating predictions [46].

Realist philosopher Christopher Norris (2004, cited in T Jayaraman, 2007) describes scientific realism as: "scientific realism, broadly speaking, accepts the existence of objective reality as a fundamental premise. This objective reality exists independent of our theories and descriptions, and beliefs and thoughts concerning the same. These theories and descriptions acquire the status of truths or falsehoods depending on how they stand with respect to that objective reality, rather than on whether they coincide with systems of beliefs, some favoured paradigms and the like. Among this limitless set of truths, there are some that we know now, some that we don't know now and will find out later and some that may lie beyond the furthest reach of our knowledge-seeking powers" [47].

Stathis Psillos (2000) describes the three dimensions of scientific realism as:

- The metaphysical thesis,
- The semantic thesis, and
- The epistemic thesis.

The *metaphysical thesis* implies that the world has a definite and mind independent structure. This implies that if the unobservable natural kind s posited by theories exist at all , they exist independently of our ability to be in a position to know, verify, recognize, etc., that they do [48]. It distinguishes the scientific realism from all sort of anti-realism. The *semantic thesis* implies that scientific theories should be taken at phase values because they are true descriptions of the observable and unobservable. The theories can be turned out to be true or false. If the theory is true the unobservable they suggest represent the real world. The *epistemic thesis* implies that established and predictively successful scientific theories are approximately true of the world. It is meant to distinguish scientific realism from agnostic or skeptical versions of empiricism. It emphasizes that science can deliver both theoretical and observational truth at an equal extent [49].

[Note: The rejection of any of the above commitments results in anti-realism. So we have a variety of anti-realisms in practice. For example, skeptics deny metaphysical thesis, social constructivists deny semantic thesis and reductive empiricists deny epistemic thesis.]

According to scientific realism scientific theories are approximations of universal truths about reality. Lee explains this in another way: "realism is based on the idea that there is a real world which is separate from our perception of it and that the methods of science allow us to get closer to understanding that reality, even the unobservable parts" (Lee, p.21). Scientific realism holds that scientific theories go beyond data to posit the existence of non-observable entities, such as quarks, mental representations, and social cognition; which actually exist (Thagard, 2002, cited in John T Cacioppo et.al., 2004). The attempt is to describe the world as it really is. Realists argue that the product of scientific research is the knowledge which is independent of theory or methodology [50].

Realists justify their argument by saying that if a theory provides the best explanation of evidence then the theory must be true. For example, the evidence for the existence of the electron came through the various results available about the behaviour of cathode rays – their deflection, their power of penetration, the fact that they can do 'work'. Electrons were the best explanation of these results.

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