AN EVALUATION OF THOMAS KUHN'S CONCEPT OF PARADIGM SHIFT IN SCIENCE

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TITLE PAGE

AN EVALUATION OF THOMAS KUHN'S CONCEPT OF PARADIGM SHIFT IN SCIENCE

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DEDICATION

To my wife, Nkiruka and our children: Chiamaka, Chinenye and Chidera; and Late Ma Orie Nwa Odo

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ABSTRACT

The purpose of this study is to expose and evaluate Thomas Kuhnôs concept of paradigm shift in science with a view to showing that scientific progress is not achieved by appealing to traditional methods of doing science only. Scholars who uphold the traditional idea of science like Rudolf Carnap, are of the view that scientific innovations must exist within a tradition. They forgot that science can also be driven by moral, political and religious beliefs which according to Harding takes social science, not physics as its foundation. For the new paradigm, there is no single, universal, all-embracing method that explains science. Kuhn was a supporter of this view and so posited his idea of paradigm shift where he said that there are two poles to scientific discovery: stasis (tradition) and episodic change (innovation). According to Kuhn, the struggle for eminence between these two poles generates tension or crisis in which scientists practise. A science in crisis is unstable if the central theory and paradigm which it is part are in serious doubt. Then the paradigm will no longer be a suitable vehicle for guiding scientific research. At this stage, a new paradigm is needed, one not beset in the same way by serious and intractable anomalies. During a crises period, the usual conservative structures relax somewhat, and truly innovative ideas and practices may emerge as serious alternatives. The repeated failure of established normal scientists to handle the crisis situation, together with the emergence of a promising new approach may trigger a revolution or paradigm shift. These achievements not withstanding, Kuhn failed to reconcile the duo of tradition and innovation. To achieve this reconciliation, this study made use of qualitative research design. Data were got from books, journals and the Internet. Data collected were subjected to conceptual analyses and philosophical hermeneutics (interpretation). From the analyses and interpretation, this study argues that for any society to make progress in science, the duo of tradition and innovation must be consulted.

TABLE OF CONTENTS

Title Page --- --- --- --- --- --- --- --- --- --- i

Approval Page --- --- --- --- --- --- --- --- --- ii

Certification --- --- --- --- --- --- --- --- --- --- iii

Dedication --- --- --- --- --- --- --- --- --- --- iv

Acknowledgements --- --- --- --- --- --- --- --- --- v

Abstract --- --- --- --- --- --- --- --- --- --- vi

Table of Contents --- --- --- --- --- --- --- --- --- vii

CHAPTER ONE: INTRODUCTION --- --- --- --- --- --- 1

1.1 Background of the Study --- --- --- --- --- --- --- 1
1.2 Statement of the Problem --- --- --- --- --- --- --- 3
1.3 Thesis of the Study --- --- --- --- --- --- --- --- 4
1.4 Purpose of the Study --- --- --- --- --- --- --- --- 4
1.5 Scope of the Study --- --- --- --- --- --- --- --- 4
1.6 Significance of the Study --- --- --- --- --- --- --- 4
1.7 Research Method --- --- --- --- --- --- --- --- 4
1.8 Explanation of Concepts: Abnormal Science, Crisis, Exemplars, Incommensurability, Immature Science, Mature Science, Normal Science, Paradigm, Revolution, Science, Scientific Progress, Scientific Revolution and Theory Choice --- --- 5

CHAPTER TWO: LITERATURE REVIEW --- --- --- --- --- 9

Metaphysics by Aristotle --- --- --- --- --- --- --- --- 9
Posteriori Analytics by Aristotle --- --- --- --- --- --- --- 11
The New Organon by Francis Bacon --- --- --- --- --- --- --- 12
Discourse on Method by Rene Descartes --- --- --- --- --- --- 14
Philosophical Writings by Wilhelm Leibniz --- --- --- --- --- --- 15
On the Revolution of Heavenly Spheres by Nicolaus Copernicus --- --- --- 16
The Origin of Species by Charles Darwin --- --- --- --- --- --- 18
Conjectures and Refutations by Karl Popper --- --- --- --- --- --- 25
The Logic of Scientific Discovery by Karl Popper --- --- --- --- --- 26
The Aims of Education by Alfred North Whitehead --- --- --- --- --- 29

CHAPTER THREE: KUHN'S CONCEPT OF PARADIGM SHIFT IN SCIENCE 33

3.1 The Biography of Thomas Samuel Kuhn --- --- --- --- --- 33
3.2 Thomas Kuhn and the Copernican Revolution --- --- --- --- --- 38
3.2.1 The Essential Tension in Kuhn --- --- --- --- --- --- --- 40
3.2.2 Pre-Paradigm Science in Kuhn --- --- --- --- --- --- --- 42
3.2.3 Extraordinary Science in Kuhn --- --- --- --- --- --- --- 43
3.2.4 Paradigm Science in Kuhn --- --- --- --- --- --- --- 44
3.2.5 Normal Science in Kuhn --- --- --- --- --- --- --- 45
3.2.6 Anomaly in Kuhn --- --- --- --- --- --- --- --- 47
3.3.1 Kuhn and Paradigm Shift/Scientific Revolution --- --- --- --- 48
3.3.2 Changes of World View in Kuhn --- --- --- --- --- --- 51
3.3.3 Resolution of Revolutions in Kuhn --- --- --- --- --- --- 51
3.4 Kuhn on Social Construction of Scientific Knowledge --- --- --- --- 52
3.5 The Scientific Community in Kuhn --- --- --- --- --- --- 55
3.6 Textbook Science: Kuhn and the Nature of Education in the Natural Sciences 58

CHAPTER FOUR: EVALUATION OF KUHN'S CONCEPT OF PARADIGM SHIFT --- --- --- --- --- --- --- --- --- --- --- 65

4.1 The Strengths of Kuhnœs Concept of Paradigm Shift in Science --- --- 65
4.2 The Weaknesses of Kuhnœs Concept of Paradigm Shift in Science --- --- 69
4.3 Kuhnœs Defence/Response to Critics --- --- --- --- --- --- 83
4.4 Kuhnœs Legacy --- --- --- --- --- --- --- --- --- 86
4.4.1 Philosophy of Science --- --- --- --- --- --- --- --- 88
4.4.2 Sociology --- --- --- --- --- --- --- --- --- 89
4.4.3 Science Education --- --- --- --- --- --- --- --- 90
4.4.4 Religion --- --- --- --- --- --- --- --- --- --- 91
4.5 Implications of Kuhnœs Paradigm Shift for Africa --- --- --- --- 94

CHAPTER FIVE: SUMMARY AND CONCLUSION --- --- --- --- 106

5.1 Summary--- --- --- --- --- --- --- --- --- --- 106
5.2 Conclusion --- --- --- --- --- --- --- --- --- 107

ENDNOTES
BIBLIOGRAPHY --- --- --- --- --- --- --- --- --- 110

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Several factors influenced the choice of this particular topic. These factors are related to scientific progress and change. First, this researcher was always interested in scientific activities though not a scientist *per se.* Second, as a secondary school student, one realized that what the science teachers taught were either exactly what their teachers taught them, or what they read in books and have taught same, year in, year out. So, what these teachers taught students were stereotyped and it appeared they could not be changed. Each time one compared notes with the senior students, it was seen that the notes they had when they were in that class were the same in content with what one had in oneǿs notebooks, if not *verbatim*. It was always surprising. There was no change in content. There was no change in terms. There was no change in structure.

As one advanced, it became obvious that those topics taught then in class had no place in them for the contribution of social variables in the development of science. Again, when this researcher gained admission into the university, the sciences that were taught had no place in them for any change at all. There was no essential difference between the topics taught and the topics taught before and after, semester after semester. Also, in all these experiences, there was never a place where it was discussed in the science textbooks that social variables play significant roles in scientific progress. The teachers did not discuss it either. But one later realized that these social variables play significant roles in scientific progress. One also understood that changes do occur and that what presuppose these changes are changes in standards of doing things or changes in theories. So it was decided that Kuhnǿs notion of paradigm shift be used to discuss the roles of social variables, crises, revolutionary science, the scientific community and so on, in scientific progress and development.

Paradigm shift, as a term, has been a source of concern to philosophers, scientists and even sociologists, especially as it has to do with science. This is because professionals from different fields see science as emanating only from the physical sciences. They hold that empirical science proceeds by progressively embedding natural phenomena in an ordered sequence of relational structures as mathematical representations of these phenomena are articulated and refined.[1] But a good knowledge of science will enable one to understand that the technical practice of science is a ñsocial practice wherein what any scientist does is always bound up with and influenced by what other scientists are doing.ò[2] So, what is called science did not originate from emptiness. It is anchored on some traditional elements. This does not rule out the idea of innovation. Innovation is part of scientific development. But upholders of the traditional idea of science, like Rudolf Carnap, are of the view that innovations must exist within a tradition. All innovations, according to them, must be anchored on traditional systems. Thomas Kuhn came in here and held that there are two poles for scientific discovery. One he called episodic change (innovation). The other is stasis (tradition). According to him, the struggle for eminence between these two poles generates tension in which scientists practice.[3] It is this tension that brings about shift and revolution in science.

Moreover, paradigm shift in science involves a social process without which nothing serious can be achieved. It can now be stated that there are old and modern ways of doing science. The old one was the one championed by members of the Vienna Circle which took physics as its foundation. The new science is the one which is directed by moral and political beliefs, and thus, according to Harding, takes social science, not physics, as its foundation.[4] According to the New Paradigm, there is no single, universal, all-encompassing scientific method that explains development. Rather the absence of scientific method suggests that scientific change is not driven by the rational choices of scientists. Instead, it is to be explained by historical and sociological factors.

Furthermore, paradigm shift in science involves the creation of a new and better way of doing science. This implies evolving a new standard. Sometimes, some scientific theories emanate from knowledge of elementary particles. The structure of Kuhnðs *Structure of Scientific Revolution* incorporates the existence of elementary particles (immaterial objects) in his philosophy of science. This is captured in his systematic illustration which runs as follows: pre-paradigm science -- normal science -- extra ordinary science -- new normal science. The step from pre-paradigm science to normal science involves the convergence of community consensus around a single paradigm, when there was no prior consensus.[5]

Every philosopher is a child of his time and Kuhn could not fail to be one of them. Hence he used the notion of paradigm shift in science to address some of the scientific problems of his time. It is based on this that this researcher decided to evaluate Kuhnðs notion of paradigm shift in science with a view to demonstrating that pre-paradigm periods are metaphysical periods which are always occasioned by social, economic, cultural and political factors that give room for healthy scientific methods and understanding.

1.2 Statement of the Problem

Thomas Kuhnðs claim that real scientific progress/breakthrough is only possible through a deviation from the conventional methods of doing science runs against the popular assumption in the world of science. Though experience, to a large extent has proven Kuhnøs claim to be true, his claim encourages individualism and the emergence of reactionary elements against established authorities.

Also, there may is the need to fashion out a new approach to scientific studies with reference to textbook science. Though it is impossible to do science without standard textbooks, the attitude of the teachers should not be so dogmatic and stereotyped. The teachers should find a way of making science to be in flux and to be in tune with dictates of regional ontologies. But this may give rise to having more than one theory regulating the practice of a particular science.

1.3 Thesis of the Study

The thesis asserted by this study is that in some cases, deviation from the traditionally accepted methods of doing science makes for more creativity and scientific progress/breakthrough than a dogmatic adherence to the conventional methods of science.

1.4 Purpose of the Study

The main purpose of this study is to expose and evaluate Thomas Kuhnøs concept of paradigm shift in science with a view to showing that scientific progress is not achieved by appealing to traditional methods of doing science only. Breakthroughs in science are achieved by making appeals to some social variables. Other objectives of the study include:

1. to expound the idea that local factors should be considered when doing science;
2. to explain that hermeneutic contextualism is necessary in building scientific theories;
3. to make people have belief in their indigenous *episteme* as a tool for scientific progress;
4. to establish that regional ontologies should be seen as the basis for scientific progress.

1.5 Scope of the Study

The study is limited to Thomas Kuhnös Concept of Paradigm Shift in Science. Ideas of other philosophers will be brought in for purposes of clarifications and comparative analyses.

1.6 Significance of the Study

This work is significant at two levels: theory and practice. At the level of theory, it will add to the existing literature of commentaries on the philosophy of Thomas Kuhn and philosophy of science in general. At the level of practice, it will be of benefit to human societies because it draws attention to the fact that for progress to become manifest in science, there is the need for shift from one scientific standard to another. Also, it makes man appreciate his indigenous *episteme* and realize the importance of getting ideas from oneös locality.

1.7 Research Method

The study employed qualitative research design. Data for this work was obtained from books, journals, periodicals, and the Internet. Our methodology consists of comparative, historical, expository, critical and prescriptive methods. The comparative method was used to compare Kuhnös notion of paradigm shift with other philosophersô ideas of paradigm shift. The historical method was deployed to situate Kuhnös idea in a proper historical context. While the expository method was used to showcase Kuhnös ideas in their raw form, the critical and prescriptive methods were applied to engage the work in exercise of careful judgment as well as make some recommendations.

1.8 Explanation of Concepts

It is necessary that we define our terms explicitly so that the average reader will not find any difficulty in going through the work. Précising definition will be used as it will help to eliminate vagueness. The concepts to be defined are:

Abnormal Science: Abnormal Science arises when someone, for whatever reason, speaks in a manner contrary to the consensus of normal science, (as when Galileo said that the earth is not at rest). This typically occurs in response to a perceived ñcrisisò in the paradigm guiding normal science.[6]

Crisis: A Community is said to be in crisis when the strength of expectation is weakened to such an extent that a good proportion of the community has begun to doubt whether solutions to anomalous puzzles will be forthcoming that resemble the exemplary solution, then consensus breaks down.[7] Crisis is said to be a sort of ówarô existing between tradition (stasis) and innovation.

Exemplars: Exemplars are ñconcrete problem solutions, accepted by a group of scientists as, in a quite usual sense, paradigmaticò.[8]

Incommensurability: Incommensurability is a term from mathematics which means ñlack of common measure.ò Theories are said to be incommensurable if they cannot be compared to each other in other to determine which is more accurate. In 1962, Thomas Kuhn and Paul Feyerabend both independently introduced the idea of incommensurability to the philosophy of science.

Immature Science: This is that initial period in the history of a science that occurs when for the first time sufficient interest in a phenomenon or set of related phenomena crystallizes distinct groups or schools around particular theories or approaches; the schools not only pursue research on the basis of their favored ideas but also compete with one another for intellectual, social and professional supremacy.[9] Immature science is science at pre-paradigm stage.

Mature Science: Science reaches maturity when it satisfies requirements such as coherence with the basic principles of theories in other domains, and possessions of a well-entrenched set of basic principles which define the domain of the science and the appropriate methods for it, and the limits the sort of theories that can be proposed.[10]

Normal Science: ñThe normal is what is common, over a given period, to a collectivity of specialists in a university or other academic institutions.ò[11] Normal science occurs when scientists are in sufficient agreement on fundamentals to allow the evaluation of contested claims by shared standards.[12] Science that is governed by a paradigm Kuhn called normal science. It consists in the search for solutions to problems set by the paradigm within a framework laid down by that paradigm. Most science is what Kuhn called ônormal scienceö because it is conducted within an established paradigm.

Paradigm: A paradigm is the result of choice by those who use it. Paradigms are exemplary ways of conceptualizing particular situations. They are resources for use as models and as points of reference for analogy.[13]

Revolution: Kuhnös standard definition says that a revolution is any revision to a paradigm. Revolutions are precisely those episodes that involve change to core beliefs, techniques and practices. Kuhn thinks that revolutions thus defined are usually those changes brought about by a crisis and which engender incommensurability with earlier theories. They are basically changes in theoretical beliefs.

Science: The word *science* comes from the Latin word *scientia,* which means knowledge. It is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe. In an older and closely related meaning *science* also refers to a body of knowledge itself, of the type that can be rationally explained and reliably applied.

Scientific Progress: Progress is made when an old theory is replaced by a new one that has greater verisimilitude ï truth likeness.[14]

Scientific Revolution: This is when scientists make decisions to choose some newer theory in preference to a previously established one.

Theory Choice: Theory choice involves judgment based not only on objective criteria but also on subjective values.[15] The direction for answering questions about theory choice is to determine the values, such as simplicity and precision, which play a role in the process.

Endnotes

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CHAPTER TWO

LITERATURE REVIEW

This review of literature begins with the extraordinary revolution started by Thales, regarded as the first philosopher on record. Before Thales, Milesians accepted without questions the answers they have been given by religious authorities. Milesians trusted religious authorities the way young children trust their parents. It was not only that they merely believed what the priests said, it never occurred to them to question their authority. As far as they were concerned, the knowledge of the priests came directly from God. It was like this until one day, a priest, famous throughout the whole of Asia Minor for his wisdom and great deeds announced that he would reveal the ultimate truth about all things.[1] People came to listen to him and Thales appeared. There and then, he told them that everything was made of water.

In the *Metaphysics* Aristotle called Thales an ñinitiator of philosophyò. Aristotle writing on Thales said that;

> Thales, the founder of this school of philosophy, says that the principle is water (for which reason he declared that the earth rests on water), getting the notion perhaps from seeing that the nutriment of all things is moist and that heat itself is generated from the moist and kept alive by it (and that from which they come to be is a principle of all things). He got this notion from this fact, and from the fact that the seeds of all things have moist nature, and that water is the origin of the nature of moist things.[2]

This testimony of Aristotle is supported by other arguments. First of all, Thales while appearing in the list of seven sages ï Thales, Biantes, Pittacus, Solon, Cleobule, Mison and Chilon ï was the first to be considered in the sources as a philosopher.[3] Composta quoted

Theodore Gomperz, who after having affirmed Thalesô detachment from myth, salutes him as ña happy precursor of Lavoisier.ò[4]

It should be borne in mind that Thales, through his *Nautical Star Guide* made possible traveling by ship at night. He taught pilots how to navigate using the stars and how to estimate the distance of a ship at sea by triangulating from two points on land. He was able to calculate the height of a pyramid by measuring its shadow at the time of the day when a manôs shadow is equal to his height. He also predicted the solar eclipse of May 28, 585 B.C.E. During the Persian war, he showed the army how to cross a wide river by building a dam and diverting its flow into two narrower rivers, across which bridges could then be built.[5] Thales was wise by every standard.

Thales did not just say something profound and enlightening. He showed something. In a sense, he sacrificed himself as an authority so that one can begin to think for himself. What Thales said cannot be accepted at its face value. Some may say that Thales spoke only metaphorically, that he was just trying to communicate some profound truth to others, but he was also trying to make them profoundly aware that no one has a perfect monopoly of the truth.

There are at least two things to be learnt in Thalesô position. First, as a person in authority, he has shown people that to be wise, they must become seekers of truth. Second, not only has Thales evoked in people the desire to prove him wrong; they, the ordinary people can do so. This second point is as revolutionary as the first. Instead of being given a monologue that you are expected to obediently accept, you can, not only enter into a dialogue, you are by your own wits forced into reacting, thinking, responding, debating, disagreeing, and so on. This was a very profound shift. This was a shift from the belief in the gods as the basic stuff of reality to the belief in water (material substance) as the basic stuff of reality.

For Aristotle in one of his treatises *Posterior Analytics,* ñall teaching and all intellectual learning come from already existing knowledge.ò[6] This is evident if things are considered in every case; for the mathematical sciences are acquired in this fashion, and so is each of the other arts. The Aristotelian conception of knowledge (or *scientia*) restricts the domain of what is knowable to what is necessary and cannot be otherwise.

Generally, the Greeks attached more importance to deduction as a source of knowledge than modern philosophers do.[7] In the treatise, *Posterior Analytics,* Aristotle repeatedly admitted the importance of induction, and he devoted considerable attention to the question: how do we know the first premises from which deduction must start? Aristotle answered the question by saying that, ñboth deductive and inductive arguments proceed in this way; for both produce their teaching through what we are already aware of, the former getting their premises as from men who grasp them, the later proving the universal through the particulars being clear.ò[8]

Aristotle believed that the only way a person could understand anything was through deduction. He went further to say that one can also understand through demonstration. He wrote, ñBy demonstration I mean a scientific deduction; and by scientific deduction I mean one in virtue of which, by having it, we understand something.ò[9] By implication, for one to have any demonstrable scientific knowledge, such knowledge must come by way of deduction. This is because it is necessary for demonstrative understanding in particular to depend on things which are, ñtrue and primitive and immediate and more familiar than and prior to and explanatory of the conclusionò.[10] Aristotle went on to say with such awareness, ñthere will be deduction even without these conditions, but there will not be demonstration; for it will not produce understanding.ò[11] So, things that are primitive should be depended upon because it implies depending on appropriate principles. For Aristotle, whatever should be proven scientifically should be proven by way of deduction.

Francis Bacon in his *Novum Organon,* or *The New Organon,* argued that Aristotleôs logic was unsuitable for the pursuit of knowledge in the modern age. Accordingly, *The New Organon* propounds a system of reasoning to supersede Aristotleôs; suitable for the pursuit of knowledge in the age of science. Where Aristotleôs inferential system based on syllogisms could reliably derive conclusions which were logically consistent with an argumentôs premises, Baconôs system was designed to investigate the fundamental premises themselves. Aristotleôs logic proposed certainty, based on incontrovertible premises accepted unquestioningly as true; Bacon proposed an inductive inference, based upon a return to the raw evidence of the natural world. From painstakingly collected assemblages of data, the scientific investigator would use *The New Organon* to nudge his way gradually towards higher probability.[12] The process of induction would finally allow mankind unlimited powers to control the natural world not by coercion but by complete understanding:

> For man is natureôs agent and interpreter; he does and understands only as much as he has observed of the order of Nature in work or by inference; he does not know and cannot do more. No strength exists that can interrupt or break the chain of causes; and nature is conquered by obedience.[13]

Number XIV of *The New Organon* holds that syllogism is made up of propositions and propositions consist of words and words are counters for notions. ñHence if the notions themselves (this is the basis of the matter) are confused and abstracted from things without care, there is nothing sound in what is built on them. The only hope is true induction.ò[14] Referring to the logic of Aristotle, Bacon observed that because the sciences in their present state are useless for the discovery of works, so logic in its present state is useless for the discovery of sciences.[15] He went on to say that Aristotelian logic ñis not useful, it is positively harmful.ò[16]

What distinguishes the New Baconian view of science from that of his predecessors is, indeed, his clear commitment to the role of observation and experiment as a prerequisite for the construction of scientific theory itself. Earlier scientists had thought of observation and experiment as demonstrating a conclusion anticipated by systematic deductive reasoning, or as determining a detail or filling in a gap, as required to extend as existing theory. Bacon, by contrast, regarded observation and experiment ï particularly experiments designed to test how nature would behave under previously unobserved circumstances ï as the very foundation of science and generalized methodology. He expected that the process itself of organizing the mass data collected into natural and experimental histories, ñwould lead to an entirely new and largely unforeseen scientific theory.ò[17]

Book One of *The New Organon* clears away the intellectual debris of existing assumptions which distort the perceptions and cloud the judgment of the would-be philosophers. Bacon says that readers should not place their trust in existing authorities, nor to rush to a fashionable new system of knowledge. ñA new beginning (to learning) has to be made from the lowest foundation unless one is content to go round the circle for ever.ò[18]

To this end, Bacon first discards the cornerstone of traditional logic, the syllogism, because anyone using it can only arrive at conclusions consistent with existing, given premises. These premises themselves - the assertions on which the process of reasoning is based - must be taken on trust as true and incontrovertible. Thus, for Bacon, the entire current system of reasoning fails. In place of deduction, Bacon gave notice that his own logic will be an induction or gradual ascent from sense data to generalization.

In that same Book One of *The New Organon,* a good portion of it discussed what Bacon called Idols or Illusions which are impediments of various kinds that interfere with the process of human reasoning. These Idols are of four kinds: Idols of the Tribe, Idols of the Cave, Idols of the Marketplace and Idols of the Theatre.

The Idols of the Tribe are errors in perception itself, caused by the limitations of the human senses which give access to the data of nature.[19] The Idols of the Cave are errors introduced by each individualꞌs personal prejudices and attachment to particular styles or models of explanation.[20] The Idols of the Marketplace are directly from the shared use of language and from commerce between people. Here, at the most basic level, the ascription of names to things, in ordinary language usage, fails to discriminate properly between distinctive phenomena, or names of abstract entities ‹vaguely›, so as to give rise to false beliefs about them.[21] Finally there are illusions which have made their homes in menꞌs minds from the various dogmas of different philosophies, and even from mistaken rules of demonstration. These Idols, Bacon called Idols of the Theatre. For Bacon, these illusions can be avoided if inductive method is used in scientific research.

Like Bacon who said that a new beginning (to learning) has to be made from the lowest foundation, Descartes like many of his contemporaries in *Discourse on Method* said that as soon as he finished the whole course of studies at the end of which he was admitted among the ranks of the learned, he found himself embarrassed by so many doubts and errors. He said that the only profit he had from his efforts to acquire knowledge was the progressive discovery of his own ignorance. In 1629, having grown disillusioned with the ñbook of the worldò, Descartes flew to Holland where he could continue developing his own iconoclastic philosophy in solitude. Having been inspired by Bacon that the entire work of the understanding must be begun afresh, he said that the right method must be used in the search for truth.

So, for certain and indubitable knowledge to occur, a number of steps must be taken to enable men establish this. These steps include:

1. never to accept anything as true if one does not have evident knowledge of its being so.
2. divide each problem into as many parts as possible as that is the basis of its solution.
3. directing ones thought in orderly way beginning from the simplest ideas to the complex ideas.
4. making complete enumerations and general surveys that nothing will be left out.[22]

For Descartes, his kind of philosophy is such that allows no mistake. Once the steps are followed, it means that certain and indubitable knowledge is assured.

Another change in the scientific universe came in the *Philosophical Writings* of Leibniz. In the book, Leibniz made an improvement over the Cartesian system. He began with a marriage between the Cartesian concept of extended, continuous substance and the atomistsô concept of reality in terms of simple, indivisible, eternal units ï atoms ï but according to their essentially materialist conception, the atoms are lifeless lumps of matter.

Leibniz started by saying that the principles of science are dogmatic and historical.[23] Kuhn also held this position. He said that science, ñalso includes ontology, or the science of something and nothing, being and not being, the thing and its mode, and substance and accident.ò[24] The departmentalization of the science does not matter because all the sciences are continuous body, like the ocean. In this world of science, there is a certain Unity which is dominant. That which is dominant is the monad. For Leibniz, there is nothing real in the world save the monads and their representations which are ideas and perceptions.

Leibniz emphasized that substance must contain life or a dynamic force. Whereas Democritusô material atom would have to be acted upon from outside itself in order to move or become part of a larger cluster, Leibniz said that a simple substance, the monad, is capable of action. He added that compound substance is the collection of monads. *Monas* is a Greek word which signifies unity or that which is one. According to Leibniz, ñThe *monad,* of which we shall speak here, is nothing but a simple substance which enters into compounds; *simple,* that is to say, without parts.ò[25]

Each monad is independent of other monads, and they do not have any causal relation to each other. Essentially, the monads are logically prior to any corporeal form. It is from the simple substances, the monad that the compound substances are derived for according to Leibniz, ñthe compound is nothing but a collection or *aggregatum* of simple substances.ò[26]

So for Leibniz, scientific improvement is as a result of gradual improvement of the monads from simple to compound substance.

What really triggered off shifts in paradigms in modern scientific discourse was *On the Revolution of Heavenly Spheres* written by Nicolaus Copernicus. In it, he offered an explanation of the possibility that the sun, not the earth, is at the centre of the solar system. The public was shocked as when Thales said that everything was made of water. How could anyone think that anything like that was possible? How could anyone think that the earth moves, that it is not the centre of the universe?

Before Copernicus, almost everyone believed that the earth did not move and that the sun, the moon, the stars all revolved round the earth. It is true that most people believed in geocentrism. This belief was not fully because of religion or superstition. They believed it because that was what their senses told them. Their reason also confirmed it.

In his letter to His Holiness, Pope Paul III, Copernicus wrote that he was aware that a philosopherôs ideas are not subject to the judgment of ordinary persons, because it is his endeavour to seek the truth in all things, to the extent that was permitted to human reason by God. He held that completely erroneous views should be shunned. He also said that those who believed that consensus had sanctioned geocentrism would think he was mad by propounding heliocentrism. So, he debated within himself whether to publish the volume which he wrote to prove the earthôs motion or ñto follow the example of the Pythagoreans and certain others, who used to transmit philosophyôs secret only to kinsmen and friends, not in writing but by word of mouth.ò[27]

Copernicus said he was compelled to a different system of deducing the motion of the universeös spheres for no other reason than the realization that astronomers do not agree among themselves in their investigations of the subject. It was based on this that he undertook the task of rereading the works of past philosophers to find out whether anyone had ever proposed other motions of the universeös spheres than those expounded by the teachers of astronomy in the schools. In Cicero, [28] he found that Hicetas supposed the earth to move. Plutarch also held that the earth moved. According to Copernicus, Plutarch wrote that while some thought that the earth remained at rest, Philolaus, the Pythagorean believes that, like the sun and moon, the earth revolves around the fire in an oblique circle. Also, Heraclitus of Pontus and Ecphantus the Pythagorean made the earth move, not in a progressive motion, but like a wheel in a rotation from West to East about its own centre.[29]

It was when he had read these sources that he began to consider the mobility of the earth. The point we are focusing on is that what Copernicus did under the employ of the church was to generate alternative hypotheses and theories. This Copernican revolution really influenced many ideas and many changes started occurring in the scientific world. Such influence had serious effect on Charles Darwin who moved from the long held view of creationism to evolutionism.

It is nice to recall that the pre-Socratics like Thales, who has been examined, looked for natural explanations of the processes of nature. They distanced themselves from ancient mythological explanation. Charles Darwin, in his *The Origin of Species,* had to distance himself from the Churchös view of creation of man and beast. Darwin was a biologist and a natural scientist. He was the scientist of recent time who has most openly challenged the Biblical view of manös place in creation. When Charles was a pupil, his headmaster described him as a boy who was always flying around, fooling about with stuff and nonsense, and never doing a stroke of anything that was useful. By ‹useful›, the headmaster meant cramming Greek and Latin verbs as was the case at that time.

But while still at college, he became a known natural scientist, because of his interest in geology. Upon graduation in theology, he went to study rock formations and to search for fossils. In August, 1831, when he was just twenty two years old, he received a letter which was to determine the course of his whole life. His friend and teacher, John Steven Henslow wrote him requesting him to be a companion to Captain Fitzroy, who has been commissioned by the government to survey the southern coast of South America. The ship that they went by was Naval vessel HMS Beagle. The voyage on board the Beagle was without doubt the most important event in Darwin's life. As the Beagle sailed up and down the coast of South America, Darwin was familiarizing himself with the continent. The expedition's many forays into the Galapagos Island in the Pacific west of South America were of decisive significance as well. He was able to collect and send to England vast amounts of material. However, he kept his reflections on nature and evolution of life to himself. When he returned home, he found himself a renowned scientist. At that point, he had an inwardly picture of what was to become his theory of evolution.

In *The Origin of Species,* Darwin advanced two theories. First, he proposed that all existing vegetable and animal forms were descended from earlier, more primitive forms by way of biological evolution. Secondly, he said that evolution was the result of natural selection. This idea of evolution was not even original to him. The idea of biological evolution began to be widely accepted in some circles as early as 1800. The leading spokesman for this idea was the French Zoologist, Lamarck. Even before him, Darwin's own grandfather, Erasmus Darwin, had suggested that plants and animals had evolved from some few primitive species. But none of them had come up with an acceptable explanation as to how this evolution happened. They were therefore not considered by churchmen to be of any great threat.

But Darwin was considered a threat by churchmen because in both ecclesiastic and scientific circles, the Biblical doctrine of the immutability of all vegetables and animals species was strictly adhered to. The Christian view was moreover in harmony with the teachings of Plato and Aristotle. Platoøs ideas presupposed that all animal species were immutable because they were made after patterns of eternal ideas or forms. The immutability of animal species was also one of the cornerstones of Aristotleøs philosophy. But during the time of Darwin, there were a number of observations and finds which were putting traditional beliefs to test. It was these observations and finds that really made him shift from the traditional paradigm to a new paradigm that aligns with scientific thinking and observations.

Part of the observations and finds were that an increasing number of fossils were being dug out. There were also finds of large fossil bones from extinct animals. Darwin was puzzled to find traces of sea creatures far inland. In South America, he made similar discoveries high up in the mountains of Andes. So, he was surprised to see sea creatures in the Andes. These sea creatures, some believed, were just thrown away there by humans and animals. Others believed that God had created the fossils and sea creatures to lead the ungodly astray.

But most geologists swore to ócatastrophe theoryô, according to which the earth had been subjected to gigantic flood, earthquakes, and other catastrophes that had destroyed life.

So, the fossils were imprints of earlier life forms that had been wiped out after these gigantic catastrophes. When Darwin set sail on the Beagle, he had with him Lyellös *Principle of Geology*. Lyell held that the present geology of the earth, with its mountains and valleys, was the result of an interminably long and gradual evolution. His point was that even small changes could cause huge geological upheavals, considering the aeons of time that have elapsed. The changes Lyell was thinking of were the same forces that prevail today: wind and weather, melting ice, earthquake and elevations of the ground level. Lyell believed that similar tiny and gradual changes over the ages could alter the face of nature completely. However, this theory alone could not explain why Darwin found the remains of sea creatures high up in the Andes. But Darwin always remembered that *tiny gradual changes* could result in dramatic alterations if they were given sufficient time.

A decisive factor in Lyellös theory was the age of the earth. In Darwinös time, it was widely believed that about six thousand years had elapsed since God created the earth. That figure had been arrived at counting the generations of Adam and Eve. But Darwin figured the age of the earth to be three hundred million years. One thing, at least, was clear: neither Lyellös theory of gradual geological evolution nor Darwinös own theory of evolution had any validity unless one reckoned with tremendously long period of time.

Having looked at one of Darwinös arguments for biological evolution, namely, the *stratified deposit of fossils* in various layers of rock, another argument was the *geographic distribution* of living species. This was where Darwinös scientific voyage could contribute new and extremely comprehensive data. He had seen with his own eyes that the individual of a single species of animal within the same region could differ from each other in only the minutest detail. He made some very interesting observations on the Galapagos Islands, west of Ecuador, in particular. The Galapagos Islands are a compact group of volcanic Islands. There were therefore no great differences in the plant and animal life there. But Darwin was interested in the tiny differences. On the Islands, he came across giant tortoises that were slightly different from one island to another. Had God really created a separate race of tortoises for each and every island? Of course, this is doubtful.

Darwinôs observations of bird life on the Galapagos were even more striking. The Galapagos finches were clearly varied from island to island, especially as regards the shape of the beak. Darwin demonstrated that these variations were closely linked to the way the finches found their food on the different islands. The ground finches with steeply profiled beaks lived on termites extracted from bark and branches. Each and every one of the species had a beak that was perfectly adapted to its own food intake. Could all the finches be descended from one and the same species? And had the finches adapted to their surroundings on the different islands over the ages in such a way that new species of finches evolved?

It was on the Galapagos Islands that Darwin became a óDarwinistô. He also saw that the Fauna there bore a strong resemblance to many of the species he had seen in South America. Had God once and for all really created all these animals slightly different from each other, or had evolution taken place? Increasingly, he began to doubt that all species were immutable. But he still had no viable explanation as to how such evolution had occurred. But there was one more factor to indicate that all the animals on earth might be related. That was found in the development of embryo in mammals. If the embryos of the dogs, bats, rabbits, and animals are compared at an early stage, it will be discovered that they look alike. You cannot distinguish between a human embryo and a rabbit embryo until a very late stage.

At this stage, he had no explanation of how evolution happened. He pondered constantly on Lyellôs theory of the minute changes that could have great effect over a long time. But he could find no explanation that would apply as a general principle. He was familiar with the theory of the French Zoologist Lamarck, who had shown that the different species had developed characteristics they needed. Giraffes, for example, had developed long necks because for generations they had reached for leaves in the trees. Lamarck believed that the characteristics each individual acquires through his own effort are passed on to the next generation. But this idea of the heredity of óacquired characteristicsô was rejected by Darwin because Lamarck had no proof of his bold claims.

Along the line, Darwin saw the actual mechanism behind the evolution of species in his theory of artificial selection. For instance, if you had three cows, but only enough fodder to keep two of them alive, what you will do is to slaughter one of them. In the course of the slaughtering, it is logical that you slaughter the one that gave the least milk. If you wanted one of them to calve, you will choose the one that was the best milker. Then its calf will probably be a good milker too. That is exactly what mankind had done for thousands of years. Hens did not always lay five eggs a week, sheep did not always yield as much wool, and horses were not always as strong and swift as they are now. Breeders have made artificial selection.

So now Darwin had to ask himself: could a similar mechanism be at work in nature? Is it possible that nature makes a natural selection as to which individuals are to survive? And could such a selection over a long period of time create new species of individuals? In the words of Darwin:

> Can it, then, be thought improbable, seeing that variations useful to man have undoubtedly occurred, that other variations useful in some way to each being in the great and complex battle of life, should occur in the course of many successive generations. If such do occur, can we doubt (remembering that many more individuals are born than can possibly survive) that individuals having any advantage, however slight, over others, would have the best chance of surviving and of procreating their kind?[30]

Darwin said that the theory of natural selection should be understood by taking the case of a country undergoing some slight physical change, for instance, of climate.ò The proportional members of its inhabitants will almost immediately undergo a change and some species will probably become extinct.ò[31] Having seen the intimate and complex manner in which the inhabitants of each country are bound together, he concluded that any change in the numerical proportion of the inhabitants, independently of the change of climate itself, would seriously affect the others.[32]

But Darwin could still not imagine how such a natural selection could take place. But in October 1838, exactly two years after his return from the Beagle, by chance, he came across a little book by the specialist in population studies, Thomas Malthus. The book was called *An Essay on the Principle of Population.* Malthus got the idea for his essay from Benjamin Franklin, the American who invented lightening conductor. Franklin made the point that if there were no limiting factors in nature, one single species of plants or animal would spread over the entire globe. But because there are many species, they keep each other in balance. Malthus developed this idea and applied it to the worldôs population. He believed that mankindôs ability to procreate is so great that there are always more children born than can survive. Since the production of food can never keep pace with the increase in population, he believed that huge numbers were destined to succumb in the struggle for existence. Those who survived to grow up - and perpetuate the race - would therefore be those who came out best in the struggle for survival.

This was actually the survival mechanism that Darwin had been searching for. Here was the explanation of how evolution happens. It was due to natural selection in the struggle for life, in which those that were best adapted to their surroundings would survive and perpetuate the race. Darwin further proposed that the struggle for survival is frequently hardest among species that resemble each other the most. They have to fight for the same food. The more bitter the struggle for survival, the quicker will be the evolution of new species, so that only the very best adapted will survive and others will die out. The less food there is and the bigger the brood, the quicker evolution happens.

But it is not only a question of food. It can be just as vital to avoid being eaten by other animals. For example, it can be a matter of survival to have a protective camouflage, the ability to run swiftly, to recognize hostile animals, or, if the worse comes to the worst, to have a repellent taste. The ability to reproduce is also of fundamental importance. Darwin studied the ingenuity of plant pollination in great details. Flowers grow in glorious hues and exude delirious scents to attract the insects which are instrumental to pollination. A placid or melancholy bull with no interest in cows will have no interest in genealogy either, since with characteristics like these its line will die at one. The bullǿs sole purpose in life is to grow to sexual maturity and reproduce in order to propagate the race. Those that for this reason or another are unable to pass their genes are continually discarded, and in that way the race is continually refined. So, everything gets better and better.

For the human race, man has the ability to adapt to different conditions of life. One of the things that amazed Darwin was the way the Indians in Tierra del fuego managed to live under such terrible climatic conditions. But that does not mean that all human beings are alike. Those who live near the equator have darker skins than people in the same northerly climes because their dark skin protects them from the sun. White people who expose themselves to the sun for long periods are more prone to skin cancer.

Summarily, one can say that the óraw materialô behind the evolution of life on earth was the continual variation of individuals within the same species, plus the *large number* of progeny, which meant that only a fraction of them survived. The actual ómechanismô or driving force behind evolution was thus the natural selection in the struggle for survival. This selection ensured that the strongest, or the ófittestö, survived.

The Origin of Species was received amidst controversies. The church protested vehemently and the scientific world was sharply divided. That was not surprising; after all, he had distanced God a good way from the act of creation, although there were admittedly some who claimed it was surely greater to have created something with its own innate evolutionary potential than simply to create a fixed entity.[33]

Karl Popper had a considerable influence in philosophy of science during the 20^{th} century and many scientists took up his ideas. His interest in philosophy of science began with the search for a demarcation between science and pseudo-science. He tried to work out what the difference was between theories he greatly admired in physics, and theories he thought were unscientific in psychology and sociology, and soon came to the conclusion that part of the reason people erroneously thought that mere pseudo-sciences were scientific was that they had a mistaken view about what made physics scientific.

In *Conjectures and Refutations*, Popper argues that his solution to the problem of induction is simply that induction does not show that scientific knowledge is justified. This is because for him science does not depend on induction at all. Popper pointed out that there is a logical asymmetry between confirmation and falsification of a universal generalization. The problem of induction arises because no matter how many positive instances of generalization that are observed, it is possible that the instance will falsify it. He argued that science is fundamentally about falsifying rather than confirming theories, and so he thought science could proceed without induction because the inference from a falsifying instance to the falsity of a theory is purely deductive. Hence, his theory of scientific method is called falsificationism. He argued that a theory that was, in principle, unfalsifiable by experience was unscientific.

Having distinguished between falsifiable and unfalisifiable hypotheses, Popper argued that science proceeds not by testing a theory and accumulating positive inductive support for it, but by trying to falsify theories. The true way to test a theory is not to try and show that it is true but to try and show that it is false. Once a hypothesis has been developed, predictions must be deduced from it so that it can be subjected to experimental testing. If it is falsified, then it is abandoned, but if it is not falsified, this just means it ought to be subjected to ever more stringent tests and ingenious attempts to falsify it. So what we call confirmation is, according to Popper, really just unsuccessful falsification.

> Falsificationists like myself much prefer an attempt to solve an interesting problem by a bold conjecture, even (and especially) if it

> soon turns out to be false, to any recital of a sequence of irrelevant truisms. We prefer this because we believe that this is the way, in which we can learn from our mistakes; and that in finding that our conjecture was false we shall have learnt much about the truth, and shall have got nearer to the truth.[34]

This is why Popperôs methodology of science is often called the method of conjectures and refutations. óBoldô conjectures are those from which we can deduce the sort of novel predictions discussed above. According to Popper, science proceeds by something like natural selection and scientists learn only from their mistakes. There is no positive support for the fittest theories, rather they are just those that repeatedly survive attempts to falsify them and so are ones that are retained by the scientific community. It is always possible that our best theories will be falsified tomorrow and so their status is that of conjectures that have not yet been refuted rather than that of confirmed theories.

In another book of his, *The Logic of Scientific Discovery,* Popper demands of scientists that they specify in advance under what experimental conditions they would give up their most basic assumptions. For him, everything in science is provisional and subject to correction and replacement:

> We must not look upon science as a óbody of knowledgeô, but rather as a system of hypotheses which in principle cannot be justified, but with which we work as long as they stand up to tests, and of which we are never justified in saying that we know they are ótrueô or ómore or less certainô or even óprobableô.[35]

Like Descartes held, the view that knowledge must be certain, a matter of proof and not subject to error has a long history in philosophy. However, from Popper, we learnt that we should always have a critical attitude to our best scientific theories.

Popper therefore, fully endorsed the philosophical position known as falliblism according to which all our knowledge of the world is provisional and subject to correction in the future. His theory of knowledge is totally anti-authoritarian and this is linked to his critique of totalitarian systems of government. In his view, the programmes to create ideal societies proposed by the likes of Plato and Marx demanded rigid adherence to a single fixed ideology and the repressing of all dissenting views. On the contrary, Popper thought that science flourished in an atmosphere where nothing is sacred and scientists can be extremely adventurous in the theories they propose. It was in the light of this that Lakatos wrote in *Criticism and the Methodology of Scientific Research Programmes* that according to Popper, ‑virtue lies not in caution in avoiding errors but in ruthlessness in eliminating themò.[36] This is in line with the familiar idea that scientists should be ready to challenge any dogma if experiment demands it.

It is important to note that, unlike logical positivists, Popper did not offer a way of distinguishing from meaningless statements and then argued that pseudo-science is meaningless. On the contrary, he thought that only what is falsifiable was helpful and productive even within science. Hence, he did not think that unfalsifiable metaphysical theories ought to be rejected altogether, for he recognized that sometimes, scientists might be inspired to make interesting body conjectures by beliefs that are themselves unscientific. So, for example, many scientists have been influenced by their belief in God, or by their belief in the simplicity of the basic of physics, but clearly neither the proposition that God exists nor that the fundamental structure of the world is simple, is falsifiable by experience. Popperøs theory of the scientific method allows such beliefs to play a role in scientific life even though they are not themselves scientific hypotheses. Kuhn also held this view.

Popper was one of the first philosophers of science to emphasize that scientists may draw upon diverse sources of inspirations, such as metaphysical beliefs, dreams, religious teachings and so on, when they are trying to formulate a theory. But according to him, the kind of speculation and imagination that scientists need to employ cannot be formalized or reduced to a set of rules. In a way this makes the sciences closer to the arts than they might otherwise seem. On the other hand, the sciences differ from the arts in being subject to testing by experience and this must be the final arbiter of any scientific dispute. Popper thought that the task of philosophy of science was to undertake the logical analysis of the testing of scientific theories by observation and experiment rather than to explain how theories are developed.

In Popperȏs view, there are two contexts in which we might investigate the history of science and the story of how certain theories come to be developed and accepted. They are the context of discovery and the context of justification. The view accords with an intuition about the autonomy of ideas from the people that have them. In general, the evidence in favor of a hypothesis is independent of who believes it and who does not, and whether an idea is really a good one is not at all dependent on whether it is a genius or a fool who first thinks of it. It seems plausible to argue than evaluation of the evidence for a hypothesis ought to take no account of how, why and by whom the hypothesis was conceived. Some such distinction between the causal origins of scientific theories and their degree of confirmation is often thought to be important for the defense of the objectivity of scientific knowledge.

If we assume the distinction between the production of scientific theories and their subsequent testing, then we need not be troubled by the problems Baconȏs theory of scientific method faced with the impossibility of freeing ourselves of all presuppositions when making observations, and the need for scientists to use background theories in the development of new ones. In fact, Bacon himself distinguished between óblindô and ódesignedô experiments and suggested that the later were more useful in science because they will allow us to choose between two rival hypotheses that equally account for the data we have so far. The idea is that scientists faced with a choice between two seemingly equally good rival theories ought to construct an experimental situation about which the hypotheses will predict different outcomes. This is just the sort of thing Popper emphasized.

Also in *The Aims of Education,* Alfred North Whitehead wrote that science cannot progress without metaphysics. He said that the basic feature of physical science is that it ignores all judgments of value like aesthetic or moral judgment.[37] Scientists think that physical science is purely matter-of-fact. He held that the sphere of thought left for physical science should include ontology which is ñthe determination of the nature of what truly exists; in other words Metaphysicsò.[38] He went on to say that the no inclusion of metaphysics in scientific enquiry is a pity. Such an enquiry is a necessary critique of the worth of science. Science is separated from metaphysics simply because of practical reasons; namely, because we can agree about science, after due debate, whereas in respect to metaphysics debate has hitherto accentuated disagreement.

But Whitehead noticed a problem. He asked, ñHow can mankind agree about science without a preliminary determination of what really is?ò[39] He said that the answer must be found in an analysis of the facts which form the field of scientific activity. Mankind perceives, and finds itself thinking about its perception. It is the thought that matters and not that element of perception which is not thought. When the immediate judgment has been formed, for instance *red*, it should be borne in mind that *red* is an element of an object. So, something has to exist before being *red*. At this point, one can say that metaphysics presupposes physics.

Thomas Kuhn, just like Karl Popper, also reasoned that scientific ideas cannot exist without some presuppositions. We now turn to Thomas Kuhn so as to find out his position on some scientific matters. That way, we shall be able to discover where he agreed or disagreed with the philosophers who have been reviewed.

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CHAPTER THREE

KUHN'S CONCEPT OF PARADIGM SHIFT IN SCIENCE

3.1 The Biography of Thomas Kuhn

Thomas Kuhn was born in Cincinnati, Ohio, on 18 July 1922. That was the year Moritz Schlick moved from Kiel to Vienna, thus inaugurating the Vienna circle. He was the first of the two children born to Samuel L. and Minette (nee Stroock) Kuhn, with a brother Roger, born several years later. His father was a native Cincinnatian and his mother a native New Yorker. When Kuhn was six months old, the family moved to New York. But other members of Kuhnôs family, including a favorite aunt, Emma (nee Kuhn) Fisher, Samôs younger sister remained in Cincinnati. Aunt Emma was a source of inspiration to Kuhn. In fact, Kuhn inscribed a copy of *Structure* to her with these words: ñfor Emmy -- who as Aunt Emma -- helped me find what I was and liked.ò[1]

Kuhnôs father, Sam, was a hydraulic engineer, trained at Harvard University and at Massachusetts Institute of Technology prior to World War I. He entered the army and served in the Army Corps of Engineers. For Kuhn, these were the best years of his fatherôs life. He later left the armed services and returned to Cincinnati to help his recently widowed mother, Setty (nee Swartz) Kuhn. His fatherôs career after moving to New York, however, was a disappointment, as Kuhn later remembered: ñhe was never, I think, the kind of success he had expected to be and under the circumstances might have been.ò[2] But Kuhn admired his father and considered him one of the brightest people he knew, next to Conant.

Kuhnôs mother, Minette, was a liberally educated person, who did professional editing. She came from an affluent family and her stepfather was a lawyer. Minetteôs biological father died from tuberculosis shortly after her birth. Although Kuhn thought of his mother as more of an intellectual than his father, in that she was well read, he considered her not as bright as his father. Later, Kuhn recalled that everyone claimed he took after his father and his brother after their mother. But he later saw that the opposite was true. ñI finally realized,ò recollected Kuhn, ñthat it was because theoretical physics was more nearly an intellectual activity and I was following my mother at this point, not my fatherò.[3] Minette took an active interest in her sonôs career and read and discussed his books with him.

Kuhnôs early education reflected the familyôs liberal progressiveness. In 1927, Kuhn started schooling as a kindergartener at the Progressive Lincoln School in Manhattan. ñProgressive educationò, according to Kuhn, ñwas a movement which é emphasized subject matter less than it emphasized independence of mind, confidence in ability to use oneôs mindò.[4] Kuhn, from a very early stage, was taught to think independently. Kuhn remembered that by the second grade, for instance, he was unable to read proficiently, to the consternation of his parents.

When Kuhn was in the sixth grade, his family moved to Crotonïonï Hudson, a small town about fifty miles from Manhattan, and the adolescent Kuhn attended the progressive Hessian Hills School. The school, according to Kuhn was staffed by left-oriented radical teachers who taught the students pacifism. When he left the school after the ninth grade, Kuhn felt he was a bright and independent thinker. After spending an inspired year at the preparatory school at Solebury in Pennsylvania, Kuhn spent his last two years of high school at the Yale-preparatory Taft school in Watertown, Connecticut. He was even less enthusiastic for it, but felt that it gave him ñmore formal trainingò.[5] Kuhn graduated third in his class of one hundred and five students and was inducted into the National Honour Society. He also received the prestigious Rensselaer Alumni Association Medal.[6]

Kuhn later gained admission to study physics at Harvard. There, he was to acquire a better sense of himself socially by participating in various organizations. In his first year at Harvard, Kuhn took a year-long course in philosophy. In the first semester, he studied Plato and Aristotle. In the second semester, he studied Descartes, Spinoza, Hume and Kant. Although he found them stimulating and challenging, it was Kant that was a ñrevelationò, especially Kantôs categories and the synthetic a priori.[7] He wanted to take more courses in philosophy but could not find the time. He did, however, attend several of George Sartonôs lectures on the history of science, but found them ñturgid and dullò.[8] In the spring of 1943, Kuhn graduated from Harvard College with an S.B. (Summa cum laude) and was invited to present the Phi Beta Kappa address. In his speech, Kuhn began by affirming the importance of liberal arts education.

After the V.E. Day (Victory in Europe Day was the public holiday celebrated on 8 May 1945 to mark the formal acceptance by the Allies of World War II of Nazi Germany's unconditional surrender of its armed forces), Kuhn returned to Harvard. As the war started to abate with the dropping of the atomic bombs in Japan, Kuhn activated an earlier acceptance into graduate school and began studies in physics department. At this point, he convinced the department to allow him to take philosophy courses during his first year. He said that he took two courses, relational logic and metaphysics and realized that there was a lot of philosophy that he had not been taught, and did not understand.[9] As a graduate student, he was a tutor in Kirkland House. In 1946, he passed the general examination and received a masterôs degree in physics. Immediately after that, he began dissertation research on theoretical solid-state physics, under the direction of James Van Vleck. The dissertation title was, ñThe Cohesive

Energy for Monovalent Metals as a Function of Their Atomic Quantum Defectsò. He was awarded a doctorate in 1949.

On 27 November 1948, Kuhn married Kathryn Muhs. She was born in Reading, Pennsylvania in 1923. She attended Vassar College where she graduated in 1944. They had three children: Sarah (b. 1952), Elizabeth (b. 1954), and Nathaniel (b. 1958). Kuhnôs wife was supportive of his career. She typed his doctoral dissertation and encouraged his passion for scholarly work. Kuhn called her his favorite epistemologist. He had a warm and caring relationship with his three children.

In 1950, the trustee of the Lowell Institute, Ralph Lowell, invited Kuhn to deliver the 1950-1951 Lowell lectures. The Institute was founded by John Lowell Jr in 1936. Although previous lecturers were well-known persons, such as Alfred North Whitehead, by the time Kuhn gave the lectures they were usually drawn from the Harvard Fellows.

A friend of Kuhn, who was also a tutor at Harvardôs Kirkland House, knew Steven Pepper who was chair of the philosophy department at the University of California at Berkeley. Kuhnôs friend told Pepper that Kuhn was looking for an academic position. Pepperôs department was searching for someone to establish a program in the history and philosophy of science. Kuhn was eventually offered a position in the philosophy department and later asked if he also wanted an appointment in the history department. Kuhn accepted both positions and joined the faculty at Berkeley as an assistant professor in 1956. Kuhn wrote a book on the Copernican revolution. The book appeared in 1957 and in it he expounded a narrative in which both astronomical and non-astronomical factors shaped the revolution. In 1958, he was promoted to associate professor.[10]

In 1960, The Johns Hopkins offered Kuhn a position as full professor at a substantially higher salary. Although he found the offer attractive, he decided to remain at Berkeley since he was only there for a few years and found his colleagues stimulating. However, he used the offer to negotiate for expansion of the program. Berkeleyôs administration agreed to hire another faculty member. In 1961, Kuhn was made a full professor, but only in the history department. Members of philosophy department voted to deny him promotion in their department, a denial that angered and hurt Kuhn tremendously. Years later in an interview, Kuhn confessed that the hurt ñhas never altogether gone awayò.[11] He eventually took a position elsewhere.

While he was in Copenhagen, Princeton University offered Kuhn an appointment to join its faculty. The University had recently inaugurated a history and philosophy of science program. Upon returning to the United States in 1963, Kuhn and his wife visited Princeton. They decided to accept the offer and Kuhn joined its faculty in 1964. He became the programôs director in 1967 and the following year was appointed the Moses Taylor Pyne Professor of History.

In 1979, Kuhn was appointed a professor in MITôs Department of Linguistics and Philosophy, which was housed in wooden military barracks built during World War II. In 1983, he was appointed Laurence S. Rockefeller Professor of Philosophy, the first to hold that position. In 1982, he married Jehane Burns, whom he met at a dinner party in 1979. From 1989 to 1990, Kuhn was president of the Philosophy of Science Association. In 1990, he delivered the presidential address.

During Kuhnӧs career he received numerous awards and accolades. He was the recipient of honorary degrees from around a dozen academic institutions, such as University of Chicago, Columbia University, University of Padua, and University of Notre Dame. He was elected a member of the National Academy of Science ï the most prestigious society for U.S. scientists ï and was an honorary life member of the New York Academy of Science and a corresponding fellow of the British Academy. He was president of the History of Science Society from 1968 to 1970 and was awarded the highest honor, the Sarton Medal in 1982. Kuhn was also the recipient in 1977 of the Howard T. Behrman Award for distinguished achievement in the humanities and in 1983 of the celebrated John Desmond Bernal award.

Kuhn died on 17 June 1996 in Cambridge, Massachusetts, after suffering for two years from cancer of the throat and bronchial tubes. He was an inveterate cigarette smoker.

3.2 Thomas Kuhn and the Copernican Revolution

Kuhn claimed he identified an important feature of the Copernican revolution which previous scholars missed: its plurality. What Kuhn meant by plurality is that Copernicusô *On the Revolution of Heavenly Spheres* ñconsists principally of mathematical formulas, tables, and diagrams, it could only be assimilated by men able to create a new physics, a new conception of space, and a new idea of manӧs relation to God.ò[12] Kuhn was interested in the new worlds the revolution promoted. A methodological corollary to this insight was Kuhnӧs breach of institutional limits that separate the physical sciences from the humanities, which gave the appearance that his book is really two: ñone dealing with science, the other with intellectual history.ò[13] So, Kuhnӧs methodological insight is found in his combination of science and intellectual history. He is of the opinion that scientists have philosophical and religious commitments, which are important for the development of scientific knowledge. This stance was anathema to traditional philosophers of science, who believed that such commitments played little if any role in the development of scientific knowledge.

For Kuhn, ñthe Copernican revolution was a revolution in ideas, a transformation in manøs conception of the universe and of his own relation to it.ò[17] The Revolution was not only concerned with astronomical reforms. Other radical alterations in manøs understanding of nature followed the publication of Copernicusô *On the Revolution of Heavenly Spheres.* Such alterations have given rise to the idea that science progresses by replacing old theories with new ones.

The genesis of Kuhnøs study of the Copernican revolution was the lectures he delivered in a science course for non-majors at Harvard. His approach to the course was to situate the scientific information within an historical and a philosophical context. He defended his pedagogical method, claiming that students are better motivated to learn the material when they see the connections of science with culture at large. Also, Kuhnøs concern with the Copernican revolution was not only pedagogical but also professional. He stated that if one can discover the origins of some modern scientific concepts and the way in which they supplanted the concepts of an earlier age, then one is more likely to evaluate intelligently their chances of survival.[15]

Scientifically, in *On the Revolution of Heavenly Spheres,* Copernicus revised the mathematical model for the motion of the earth by making the earth a planet that moves around the sun. Essentially, Copernicus maintained the Aristotelian-Ptolemaic universe but exchanged the earth for the sun. There were disagreements among philosophers and scientists on whether to accept geocentrism or heliocentrism. After sometime, there was agreement among scientists and philosophers that heliocentrism should be accepted as a working model. Though accepted, Copernicus still faced serious resistance from Christianity owing to, ña subconscious reluctance to assent in the destruction of a cosmology that for centuries had been the basis of everyday practical and spiritual life.ò[16] Religious resistance continued long after the seventeenth century; but, as Kuhn pointed out, ñold conceptual scheme do fade away.ò[17]

Kuhn held a position, which is that scientific progress is not in linear process, as defended by traditional ñphilosophers of science, in which facts are stockpiled in a scientific warehouse. Rather, it is the repeated destruction and replacement of scientific theories which comes up as a result of conflict or tension between two opposing sides.

3.2.1 The Essential Tension in Kuhn

At a point in revolution, there is what may be called a crisis generating level. In the development of a particular paradigm, there is bound to be a battle between tradition (stasis) and innovation. Discovery does not have to do with staying permanently with a particular tradition. Discovery commences with the awareness of anomaly. Such awareness induces crises. A science is said to be in crisis when its practitioners are no longer convinced that the current paradigm has the resources to allow for the resolution of the mounting tide of anomalies. During normal science the inability of a scientist to solve a particular problem will reflect primarily on the capacities of the scientist.[18]

A science in crisis is unstable if the central theory and paradigm which it is a part are in serious doubt, then the paradigm will no longer be a suitable vehicle for guiding further research. A new paradigm is needed, one not beset in the same way by serious and intractable anomalies. During a crisis period the usual conservative structures relax somewhat, and truly innovative ideas and practices may emerge as serious alternatives. The repeated failure of established normal scientists to handle the crisis situation, together with the emergence of a promising new approach may trigger a revolution.

Crisis does not result merely because scientists cannot agree on what to believe about some phenomena. Scientists readily accommodate such uncertainty because they expect it to be resolved by further research. Crisis results only when scientists become unsure of how to proceed ï which research is worth pursuing, which background assumptions may be unreliable, and which concepts and models are reliable guides for further work.[19] Crisis is always partial for without some sense of how to proceed, research would collapse altogether. There would be no coherent field of possibilities to explore. But crisis expand and blurs the bounds of the field, and thereby makes uncertain the significance of oneǿs own activity. It makes sense to try more and different things, but it is less clear what sense these explorations may have.

Further explanations show that according to Kuhn, scientific exploration may proceed in one of two ways. The first may result in increasing the scope and precision of the existing meaning system. He noted that this type of activity occurs during periods when a particular orientation or predisposition is operating. This is the constructive period in scientific development, in which the older meaning system is replaced by a newer one. Then the crisis period is reached, in which the older meaning system is no longer sufficient to guide research. Rather, disputes over the meaning of terms arise, with eventual divergence over the meaning of those terms. Kuhn claimed that these crisis periods lead to scientific revolutions, which in turn, terminate with new central cores of meaning for natural languages. For Kuhn the replacing of one paradigm by another is a scientific revolution. These scientific revolutions are simultaneously destructive and creative scientific orientation, behavioral worlds, and meaning systems.

Just as anomalies are critical for the discovery of new facts, so they are essential for the invention of novel theories. Although facts and theories are intertwined, the emergence of novel facts and theories is the result of crisis which is a period of pronounced professional insecurity.[20] The insecurity is the result of the paradigms breakdown or inability to provide a solution to a puzzle or solution to several puzzles. The community then begins to harbour questions about the ability of the paradigm to guide research, which has profound impact upon the community. The chief characteristic of crisis is the proliferation of theories. As members of a community in crisis attempt to resolve the anomalies, they offer more and varied theories to solve the problems. Interestingly, the problems that are responsible for anomalous data are not necessarily new problems that arose after consensus but may have been present all along. This helps to explain why the anomalies lead to a period of crisis in the first place. The paradigm promised resolution of the problems but was unable to fulfill its promise. The overall effect is a return to a situation very similar to pre-paradigm science.

Closure of a crisis occurs in one of these three possible ways, according to Kuhn. First, is when the paradigm is sufficiently robust to resolve the anomaly and to restore normal scientific practice. Second, is when the anomaly is not resolved even by the most radical method. Under these circumstances, the community tables the anomaly until future investigation and analysis. Third, is when the crisis is resolved with the replacement of the old paradigm by a new one but only after a period of pre-paradigm or extraordinary science.[21]

3.2.2 Pre-paradigm Science in Kuhn

In pre-paradigm science, scientists start from ground zero and attempt to build a science from scratch. Because there is no paradigm to organize the data, all facts seem equally relevant. So, science begins from simple data collection with no real organizing principle. For Kuhn, the road to a firm research consensus is extremely arduous.[22] That road begins for a scientific discipline, with the identification of a natural phenomenon that is then investigated experimentally and explained theoretically. But each member of that nascent discipline is at cross purpose with each other, for each member often represents a school working from different foundations. Scientists working under these conditions share no theoretical concepts, experimental techniques, or phenomenal entities. Rather, each school is in competition for monetary and social resources and for the allegiance of the professional guild. An outcome of this lack of consensus is that all facts seem equally relevant to the problem at hand and fact-gathering itself is often a random activity. There is then a proliferation of facts and hence little progress in solving problems under these conditions because of the competition among the various schools. The overall result of this situation, insisted Kuhn, appears to be ñsomething less than science.ò[23]

This state of affair, Kuhn called pre-paradigm (or immature) science. In other words, there is no single paradigm that defines the discipline and dictates its practices. Pre-paradigm science is non-directed and flexible, offering a community of practitioners little guidance. Kuhn illustrated the pre-paradigm pattern with physical optics prior to Newton.

> Being able to take a common body of belief for granted, each writer on physical optics felt forced to build his field anew from its foundation. In doing so, his choice of supporting observation was relatively free, for there was no standard set of methods or of

> phenomena that every optical writer felt forced to employ or explain. Under these circumstances, the dialogue of the resulting books was often directed as much to the members of other schools as it was to nature.[24]

3.2.3 Extraordinary Science in Kuhn

Extraordinary science is created by the problems left over by normal science. The movement from normal science to extraordinary science involves two key events. First, the paradigmôs boundaries become blurred when faced with recalcitrant anomalies; and second, its rules are relaxed, leading to a proliferation of theories and ultimately to the emergence of a new paradigm. Often the relaxing of rules allows the practitioners to see exactly where the problem is and how to go about solving it. This state of affair has a tremendous impact upon the communityôs practitioners, similar to that during pre-paradigm science. An extraordinary scientist, according to Kuhn, is a person

> searching at random, trying experiments just to see what will happen, looking for an effect whose nature he cannot quite guess. Simultaneously, since no experiment can be conceived without some sort of theory, the scientist in crisis will constantly try to generate speculative theories that, if successful, may disclose the road to a new paradigm, and if unsuccessful, can be surrendered with relative ease.[25]

For Kuhn, this type of behavior is more open to psychological than logical analysis. Moreover, during periods of extraordinary science, practitioners may even examine the philosophical foundations of their discipline. To that end, they analyze their assumptions, in order to loosen the old paradigmôs grip on the community and to suggest alternative approaches to the generation of a new paradigm.

Although the process of extraordinary science is convoluted and complex, a replacement paradigm may ñemerge all at once, sometimes in the middle of the night, in the mind of the man deeply immersed in crisis.ö[26] Often, the source of that inspiration is rooted in the practice of extraordinary science itself, in terms of the interconnections among various anomalies. Quoting Herbert Butterfield, Kuhn claimed that the scientist who experiences a change in paradigm is like a person ñpicking up the other end of the stick.ö[27] That other end of the stick represents a scientific revolution.

3.2.4 Paradigm Science in Kuhn

Perhaps the most fundamental concept in Kuhnøs philosophy is that of the scientific paradigm. Two closely related application of paradigm can be inferred from Kuhnøs philosophy. They are paradigm as *disciplinary matrix* and paradigm as exemplar. Kuhn argues that before scientific inquiry can even begin in some domain, the scientific community in question has to agree upon answers to fundamental questions about, for example: what kind of things exist in the universe, how do they interact with each other and our senses, what kind of questions may legitimately be asked about these things, what techniques are appropriate for answering those questions, what counts as evidence for a theory, what questions are central to the science, what counts as an explanation of some phenomenon, and so on.

A *disciplinary matrix* is a set of answers to such questions that are learned by scientists in the course of the education that prepares them for research, and that provides the framework within which the science operates. It is important that different aspects of the disciplinary matrix may be more or less explicit, and some of it are constituted by the shared values of scientists, in that they prefer certain types of explanation over others and so on.[28]

Exemplars on the other hand, are those successful parts of science that all beginning scientists learn, and provide them with a model for the future development of their subject. Anyone familiar with a modern scientific discipline will recognize that teaching by example plays an important role in the training of scientists. Textbooks are full of standard problems and their solutions, and students are given exercises that require them to adapt the techniques in the examples to new situations. The idea is that by repeating the process, eventually, if they have the attitude for it, students will learn how to apply these techniques to new kinds of problems that nobody has yet managed to solve.

The notion of paradigm loomed large in Kuhnøs new image of science. He defined paradigm not only in terms of the communityøs concrete achievements but also in terms of its ñaccepted examples of actual scientific practice ï examples which include law, theory, application, and instrumentation.ò[29]

3.2.5 Normal Science in Kuhn

Most science is what Kuhn calls ónormal scienceô, because it is conducted within an established paradigm. It involves elaborating and extending the success of the paradigm, for example, by gathering lots of new observations and accommodating them within the accepted theory, and trying to solve minor problems with the paradigm. Hence, normal science is often said to be a ópuzzle-solvingô activity, where the rules for solving puzzles are quite strict and determined by the paradigm. According to Kuhn, most of everyday practice of science is a fairly conservative activity in so far as, during periods of normal science, scientists do not question the fundamental principles of their discipline.[30]

To achieve the status of science, a discipline must reach consensus with respect to a single paradigm. That transition is realized when, during the competition involved in pre-paradigm science, one school makes a stunning achievement that catches the professional communityôs attention. The achievement must exhibit two characteristics to affect the transition. First, the ñachievement was sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity.ò[31] Second, ñit was sufficiently open-ended to leave all sorts of problems for the refined group of practitioners to solve.ò[32] To be accepted as a paradigm, claimed Kuhn, a theory must seem better than its competitors, but it needs not, and in fact never does, explain all the facts with which it can be confronted. By the term *better*, he meant that the candidate for paradigm status does a far more effective and efficient job in determining the problems worth solving. The candidate paradigm then elicits the communityôs confidence that the problems are solvable with precision and in detail. ñParadigms gain their statusò, explained Kuhn, ñbecause they are more successful than their competitors in solving a few problems that the group of practitioners has come to recognize as acute.ò[33] The communityôs confidence in a paradigm is based on the ñconversionò of its members, who are now committed to the paradigm.

Once consensus is achieved, Kuhn claimed that scientists are now in the position to commence with the practice of normal science, which is, ñresearch firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice.ò[34] The prerequisites for normal science include a commitment to a shared paradigm that defines the rules and standard by which science is practised. Whereas pre-paradigm science is non-directed and flexible, normal science is highly directed and rigid. Based on that directedness and rigidity, normal scientists are able to make the strides they do because

> those restrictions born from confidence in the paradigm, turn out to be essential to the development of science. By focusing attention upon a small range of relatively esoteric problems, the paradigm forces scientists to investigate some parts of nature in a detail that would otherwise be unimaginable.[35]

Normal scientists are not out to make new discoveries or to invent new theories, outside the paradigm aegis. Rather, they are involved in using the paradigm to understand nature more precisely and in greater detail. Besides the assured solution, Kuhnõs notion of puzzle also involved the ñrules that limit both the nature of the acceptable solution and the steps by which they are to be obtained.ò[36]

3.2.6 Anomaly in Kuhn

Although scientists engaged in normal science do not intentionally attempt to make unexpected discoveries, such discoveries do occur. Their paradigms are imperfect and rifts in the match between paradigm and nature are inevitable: ñto be admirably successful is never, for a scientific theory, to be completely successful.ò[37] For Kuhn, discoveries not only occur in terms of new facts but there are also inventions in terms of novel theories. Both discovery of new facts and inventions begin with anomalies, ñwith the recognition that nature has somehow violated the paradigm-induced expectation that govern normal science.ò[38] Anomalies, then, are violations of paradigm expectations during the practice of normal science and can lead to unexpected discoveries. It must be noted that the detection of anomalies can only occur due to the background provided by a paradigm.

Because of allegiance to a paradigm, scientists are loath to abandon it simply because of an anomaly or even several anomalies. In other words, anomalies are not considered counter-instances and they certainly do not falsify a paradigm. Simply put, practitioners of normal science may discover that certain things are intractable and resist solution within a paradigm. In the course of normal science new phenomena may be discovered that cannot be explained using the resources of the paradigm. Such problems and phenomena are anomalies.

3.3.1 Kuhn and Paradigm Shift/Scientific Revolutions

The transition from extraordinary science to a new normal science is through paradigm shift or scientific revolution. According to Kuhn, paradigm shift or scientific revolutions are ñnon-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one.ò[39] They can come in two sizes: major revolutions such as the shift from geocentric universe to heliocentric universe or minor revolutions such as the discovery of X-rays or oxygen. But whether big or small, all revolutions have the same structure: generation of crisis through irresolvable anomalies and establishment of a new paradigm that resolves the crisis-producing anomalies.

Also, the term *revolution* is apt in two respects. First, it reflects the cyclical nature of change in mature science. The adoption of a new paradigm as a result of a scientific revolution inaugurates a new period of normal science. The cycle -- normal science, crises, revolution, new paradigm, and normal science -- is complete. Secondly, there is an intended analogy between scientific revolutions and political revolutions.[40]

In a stable society, there are established mechanisms for resolving social and political conflicts, such as elections and parliamentary debate, or even the will of a powerful autocrat.

But whatever means, laws will be made and recognized as laws. These mechanisms may be laid down in a written constitution, as in the United States, or may in part be given to us by established and accepted practice, as in Britainȏs unwritten constitution. The life of a stable society is analogous to the practice of normal science under a paradigm. It may be however, that political conflicts arise that cannot be resolved in the normal fashion. Should these be sufficient, political and social tensions may grow to an extent that they can be addressed not by change within the existing system but only by change of the system, just as science in crisis requires a change of paradigm.

In a normal political conflict, all concerned agree with what mechanisms of resolution are and what counts as a satisfactory outcome. Thus, a government may appeal to the support of the people in election, and if it is defeated, it will accept the result, passing the rein of power to some other party, as required by the constitution. But if these mechanisms fail to answer the problem in question, they will themselves be regarded as part of the problem. A revolution does not operate within a constitution. Therefore, when a new political order and a new constitution are being sought, the old way of doing things and the old constitution will provide no way of determining which new order should be put in place and will provide it with no legitimacy. A revolution is necessarily unconstitutional. Hence supporters of a particular new system will have to resort to other means to ensure its victory of rival proposal. They will have to resort to force or propaganda.

Similarly, the transition to a new paradigm cannot be constrained by the old paradigm in the way that normal science used to be constrained by it. Crisis has discredited the old paradigm as a model for new theoretical development. The analogy with political revolutions has tempted commentators into thinking of a scientific revolution as a thorough and radical break with the past whose outcome is determined by highly contingent factors ï the equivalent of the revolutionary mob, propaganda, coercion and so on. Correspondingly, they think that while in normal science what counts as a rational preference among competing theories is determined by reference to the paradigm. In the revolution, the absence of a paradigm means there will be no agreed standard of rationality; revolution is irrational. They pick up on Kuhnôs remark that ñexternalò factors, that is, developments outside the science in question, and ñidiosyncrasies of autobiography and personalityò, [41] may play a major part in determining the nature of the new paradigm. Kuhn also mentioned that even the rationality or the prior reputation of the innovator and his teachers can sometimes play a significant role.

The ultimate source for the establishment of a new paradigm during a crisis period is community consensus, that is, when enough community members are persuaded by the techniques of the argument and not simply by empirical evidence or logical analysis. Moreover, to accept the new paradigm, a community of practitioners must be convinced that there is no chance for the old paradigm ever to solve the anomalies.

Why persuasion loomed large in Kuhnôs scientific revolution was that the new paradigm solves the anomalies the old paradigm could not. Thus, the two paradigms are radically different from each other, often with little overlap between them. For Kuhn, the new theory can only be accepted if the community considers the old theory wrong.

The radical difference between the old and new paradigms, such that the old cannot be derived from the new is the basis for the incommensurability thesis. The revised paradigm may have some utility, for example, pedagogically, but it could not be used to guide the communityôs research. According to Marcum, the older paradigm is like a fossil; it reminds the community of its history but it can no longer direct its future.[42]

An interesting feature of scientific revolution, according to Kuhn, is their invisibility. What he meant by this is that in the process of writing textbooks, popular scientific essays, and even philosophy of science, the path to the current paradigm appear as if it was in some sense born mature.

One important effect of a revolution, which is related to a paradigm shift, is a shift in the communityôs view of science: ñthe reception of a new paradigm often necessitates a redefinition of the corresponding science.ò[43] The change in the image of science should be no surprise, since the prevailing paradigm defines the nature of science. Change that paradigm and science itself changes, or at least how it is practised. In other words, the shift in scienceôs image is a result of a change in the communityôs standard for what constitutes its problems and its problemôs solution. Besides transforming science, revolutions also transform the world that scientists investigate.

3.3.2 Changes of World View in Kuhn

One of the major impacts of a scientific revolution is a change to the world in which scientists practise their trade. According to Kuhn, ñParadigm change does cause scientists to see the world of their research engagement differently. In so far as their only recourse to the world is through what they see and do, we may want to say that after a revolution, scientists are responding to a different world.ò[44] Kuhnôs ñworld changesò thesis, as it has become known, is certainly one of his most radical and controversial ideas, besides the associated incommensurability thesis. The issue here is how far ontologically does the change go, or is it simply an epistemological ploy to reinforce the comprehensive effects of scientific revolution? In other words, does the world really change or simply the world view, that is, oneøs perspective of the world?

3.3.3 Resolution of Revolutions in Kuhn

It is only after a period of intense competition among rival paradigms, does the community choose a new paradigm and scientists are transformed from paradigm testers to puzzle solvers. The resolution of a scientific revolution is not a straight-forward process that depends only upon reason or evidence. ñThe competition between paradigms,ò contended Kuhn, ñis not the sort of battle that can be resolved by proofs.ò[45] Part of the problem is that proponents of competing paradigms cannot agree on the relevant evidence or proof or even on the relevant anomalies needed to be solved, since their paradigms are incommensurable.

Another factor that leads to difficulties in resolving scientific revolutions is that communication among members in crisis is only partial. This is the result of the new paradigmøs theoretical terms and concepts and laboratory protocol being initially borrowed from the old paradigm. Although they share the same vocabulary and technology, the new paradigm gives new meaning and uses to them. It should be remembered that members of each competing paradigm live in a different world from their competitors. The result is that members of a competing paradigm talk past one another when debating the relative merits of respective paradigms.[46] Moreover, the change in paradigm is not a gradual process in which different parts of the paradigm are changed piecemeal; rather, the change must be as a whole and occur suddenly. Convincing scientists to make such a wholesome transformation takes time.

How then does one segment of the community convince another to switch paradigm? For members who worked for decades under the old paradigm, they may never accept the new paradigm. The resistance of mature members to the new paradigm, ñis not a violation of scientific standard but an index to the nature of scientific research itselfé the assurance that the older paradigm will ultimately solve all its problems, that nature can be shoved into the box the paradigm provides.ò[47] Rather, it is often the younger members who accept the new paradigm through something like a conversion that cannot be forced.[48] The conversion is based rather on faith, especially in the potential of the new paradigm to solve future problems.

3.4 Kuhn on Social Construction of Scientific knowledge

According to Giere, R.N. as quoted in *Thomas Kuhn's Revolution: An Historical Philosophy of Science,* ñIt was never part of Kuhnôs project to show science to be globally rational.ò[49] Kuhn really did not demonstrate that every scientific knowledge has a universal application. He was a stickler to contextualism. Kuhn was more interested in showing that science is historically or locally rational. Here, historical for Kuhn does not just mean using case studies of past scientific activity and practice to score philosophical points. Rather, Kuhnôs use of history is to demonstrate the local nature of rationality and scientific knowledge. By this is meant that scientific knowledge is situated in a particular time and location. Marcum opines that ñif we are to understand the science of a particular time and locationé we must climb into the heads of the practitionersò.[50] One may wonder whether Kuhn was moving towards irrationality. His method is not irrational since logic and reason are certainly required to understand a text. It was at this juncture that he mentioned hermeneutic contextualism as a way of understanding scientific knowledge.

Scientific knowledge, therefore, is not universal or absolute, which can be justified by a global rationality. Rather, the generation and development of scientific knowledge, according to Kuhn depends on a specific set of practices and ideas (paradigms) which are unique to a specific place and to a particular time. According to MIT report as quoted by Marcum, science progresses ñby a series of circular attempts to apply differing orientations or points to view the natural world.ò[51] Kuhnôs idea of science was dynamic as against the static image provided by traditional analysis. Here was Kuhnôs revolution in nascent form and it has to be borne in mind that it was this revolution that gave rise to his social construction of scientific knowledge. Some have argued that social relations between scientists are among the factors that determine which theories get accepted. Indeed, they claim that the very kinds of thought a scientist has are culturally or socially determined.

If one thinks that scientific change is driven by sociology not by rationality then one is likely to doubt that such change converges on the objective truth. One might think that this would require a commitment to skepticism -- if science does not get us close to the truth, it doesnôt give us knowledge. In fact, the New Paradigm tended to embrace less skepticism than relativism. In giving up on our access to objective truth and hence to objective knowledge, the New Paradigm replaced these with relative truth and relative knowledge. Here, ñrelativeò means ñrelative to some social environment.ò Thus, some propositions might be true relative to one community, and ñknownò in that community, while ñfalseò and ñnot knownò in another community.

So if, reality is just what facts there are, and facts are community-relative, then what ñrealityò is, is dependent on the community. This extreme relativism is one strand of social ñconstructivismò, holding that reality is not something that exists by and large independently of what the community thinks of it, but is constituted by the communityǿs beliefs. It must be emphasized that Kuhn repudiated this view, but it is nonetheless true that Kuhnǿs work certainly gave encouragement to it, and it will be interesting to see whether mild relativism and radical social constructivism can be kept apart.[52]

Our theories are often about the world-in-itself. And those theories change. Skepticism suggests that the explanation of why a particular new theory is adapted cannot be that the evidence makes the choice rationally inevitable. So, what explains why some theories are preferred to other possibilities lies in social constructivism, what sometimes is called social constructionism. Scientists are largely mistaken in thinking that they are making choices rationally dependent on the evidence (and thence on the world itself) that lead them to the truth and give them knowledge. Choices are instead explained by the political allegiances of scientists, class interests, indoctrination, nationalistic sentiment, social relations with other scientists, desire for professional advancement, and so on. It is because of all these that Kuhn is called a social constructivist.

3.5 The Scientific Community in Kuhn

Epistemology cannot ignore the historical process of discovery and hence cannot ignore the contribution of the social. To enable discussion on this, Fleck introduced his key notion of ñthought collectiveò (*Denkkollectiv*). This, Fleck defined as, ña community of persons mutually exchanging ideas, or maintaining intellectual interaction.ò[53] As a definition, this may seem somewhat loose. But even so, it is not impotent, since important conditions have to be met before exchange of ideas and intellectual interactions are possible. To be able to exchange a scientific idea, two persons must share the same scientific vocabulary, accept the same fundamental theories, recognize the same acknowledged facts; they must have similar notions of what a fruitful idea looks like and whether it could fit appropriately with extant ideas; they must agree on the significance of the idea and on what would count as establishing it as an accepted fact. This set of shared beliefs and dispositions, Fleck names a ñthought styleò (*Denkstil*).

The thought-community cannot be reduced to a set of individuals, nor can the process of cognition, knowledge production, be characterized as a sequence of the thoughts of individuals. Despite the fact that much of the history of science is written in that manner, it gives us as realistic and informative a picture as, in Fleckôs analogy, a report of a soccer game that lists the individual kicks one by one. Just as one must understand the play as the performance of a team, as a unit trained for co-operation, knowledge production must be conceived as an essentially collective activity. The knowledge of the thought-collective is more than any individual does or could possess, let alone conscious of possessing.

What explains the possibility of normal science is the existence of a certain consensus among the community of scientists. It is the consensus that breaks down during crisis and which is rebuilt in the wake of a revolution. To clarify the notion of paradigm, Kuhn discussed the nature of scientific communities; for the nature of paradigm is intimately connected with the nature of scientific communities. Kuhn noted that members of a scientific community are joined by common elements in their education and apprenticeship, and they see themselves and are seen by others as men responsible for the pursuit of a set of shared goals.[54]

Scientific communities vary in size, often defined by their subject matter, with the smallest and more specialized communities representing the basic taxonomic units. Practitioners may often belong to more than one unit. From these units, communities expand to include the largest unit: all natural scientists. Kuhn insisted that the scientific communities are ñthe producers and validators of scientific knowledge.ò[55]

From the analysis of scientific community, Kuhn asked: ñWhat do its members share that accounts for the relative unanimity of their professional judgments?ò[56] The answer obviously is paradigm or a set of them. Paradigms govern the shared community life and not the subject matter.

Entrance into the scientific community requires acquisition of its lexicon. Kuhn also addressed a problem that involves communication among communities, who hold incommensurable theories, or across historical divide. Kuhn noted that once ña communityôs lexicon has changed, some of the communityôs constituted beliefs can no longer even be described.ò[57] But this does not deter members from reconstructing their past in the current lexiconôs vocabulary. For communication to occur between different communities, they must share the same lexicon. Kuhn specified the means by which community members acquire a lexicon and the nature and status of the knowledge of nature that possession of a lexicon necessarily provides. For Kuhn, there are five ways by which members acquire a lexicon. First, they must already possess a vocabulary about physical entities and forces. Next, definitions play little, if any role in learning new terms; rather, those terms are acquired through ostensive examples, especially through problem-solving and laboratory demonstration. The learning that results from such a process, explained Kuhn, is not, however, about words alone but equally about the world in which they function. Third, a single example is inadequate to learn the meaning of a term; rather multiple examples are required. Fourth, acquisition of a new term within a statement also requires acquisition of other new terms within that statement. Lastly, students can acquire the terms of a lexicon through different routes.

Nickles quoted Merton as describing scientific communities as status groups, possessing their own distinctive lifestyles and sharing a sense of their own special honor. Kuhn also focused on the recruitment and training of new members of the community and the policing of its boundaries. In these and other respects, Kuhn suggested that the scientific community operates surprisingly like a medieval guild: (1) it is a community of practitioners who possess expert knowledge. (2) The community sharply distinguished itself from the non-expert, lay public, including other expert scientific communities. Boundaries are maintained by the high cost of admission and expulsion, enforced by professors, journal editors, peer reviewers, and other ñgatekeepersò. (3) There is a standard training procedure for novices in a given specialty area. They are trained on the same problems, using the same or similar textbooks and laboratory exercises. At advanced stages, the training typically involves something akin to a master-apprentice relation. (4) The knowledge is imparted by example more than by rule. (5) Hence, the critical knowledge that distinguishes an expert from a well-read novice remains largely tacit, inarticulate, and more knowing-how than knowing that. It means teaching by showing and knowing by doing. (6) Strong personal commitment to the imparted tradition is expected. Being too critical of community presuppositions and practices threatens both the community and oneỗs own career prospects.

3.6 Textbook Science: Kuhn and the Nature of Education in the Natural Sciences

In *The Essential Tension,* Kuhn wrote that unlike what is obtainable in the arts and social sciences, students of natural sciences have ñemphasized abilities in the areas of convergent thinkingé often at the expense of development in the area of divergent thinkingò.[58] Students have been taught how to arrive at ócorrectô answers that the present civilization has taught are correct. Kuhn wrote that outside the arts and some disciplines in the social sciences, the development of divergent-thinking abilities have generally been discouraged unintentionally. The single most striking feature of science education is that, to some extent totally unknown in other creative fields, it is conducted entirely through textbooks.

Typically, undergraduate and graduate students of chemistry, physics, astronomy, geology, or biology acquire the substance of their fields from books written especially for students. Until the students are ready or very nearly ready, to start work on their own dissertations, they are neither asked to attempt trial research projects nor exposed to the immediate products of research done by others. In short, there are no collections of ñreadingsò in the natural sciences.[59] Besides, the students are not encouraged to read the historical classics of their fields -- works in which they might discover other ways of regarding the problems discussed in their books, and in which they would also meet problems, concepts, and standards of solution.

In contrast, the various textbooks that the student does encounter display different subject matters, rather than, as in many of the social sciences, exemplifying different approaches to a single problem field. Even books that compete for adoption in a single course differ mainly in level and in pedagogic detail, not in substance and conceptual structure. Most important of all is the characteristic technique available for their solution. These books exhibit concrete problem solutions that the profession has come to accept as paradigms, and they ask the students, either with a pencil and paper or in the laboratory, to solve for himself problems very closely related in both method and substance to those through which the textbook or the accompanying lecture has led him. He mentioned that nothing could be better calculated to produce ñmental setsò or *Einstellungen*.[60] It is only in their most elementary courses do other academic fields offer as much as partial parallel.

Kuhn agrees that even the most faintly liberal educational theory must view this pedagogic technique as anathema. Students, we should all agree, must begin by learning a good deal of what is already known, but it should be insisted that education give them vastly more. They must learn to judge the relevance of these techniques and to evaluate the possibly partial solutions which they can provide.

In summary, Kuhnôs view is this: Scientists, typically as students, are exposed to exemplary problem solution. Such exposure habituates scientists so that they directly perceive some new proposed solution as being similar to, or different from, the exemplars and thus accordingly a good or bad solution. Since the exemplars are common to members of the relevant community, members will have typically the same habituated dispositions.

In education, how do agreements come about? The key to this is the nature of education and training. Learning to be a scientist requires training in the use of exemplars. Students spend much of their time engaged in various kinds of exercise. Some might be formal such as questions in textbooks; others may be practical such as laboratory exercises.

In both cases, there will be worked-out problems to follow, either fully worked problems in the textbook, or demonstrations in the laboratory. Such exercises and practicals will typically not be common just to the students in that university but will be found throughout the world. The uniformity in scientific education is remarkable, especially when compared with what is held in different places to be a satisfactory artistic or even philosophical education. There are of course good professional reasons for this - failure to train students in standard techniques will prevent them from being accepted into the large scientific community. Their puzzle-solutions will not be deemed adequate since they will not bear the appropriate resemblance to the exemplary solutions accepted by everyone else. Their papers will not be published - peer review in journals being a powerful force for uniformity. They will not land the jobs they desire and so will not be able to pass their approach to others.[61]

Kuhn moved on to hold that the world in which the student enters is fixed once and for all by the nature of the environment, on the one hand, and science on the other. The world of the student is determined jointly by the environment and the particular normal scientific tradition that the student has been trained to pursue.ò[62] So, observation is theory-laden.

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CHAPTER FOUR

EVALUATION OF KUHN'S CONCEPT OF PARADIGM SHIFT

Having made an exposition of Kuhnôs concept of paradigm shift in science, attempts will be made, in this chapter, to critically evaluate the subject. Here, both the strengths and weaknesses of Kuhnôs concept of paradigm shift will be made bare. Also, attention will be drawn to Kuhnôs own response to his critics and his legacy.

4.1 The Strengths of Kuhn's Concept of Paradigm Shift in Science

In 1962 and 1963, several dozen reviews of *The Structure of Scientific Revolutions*, which can as well be referred to as *Structure*, appeared in a variety of professional journals and were, for the most part, favorable to Kuhnôs new image of science. One of his first reviewers was his former chair at Princeton, Charles Gillispie. Gillispie acknowledged that Kuhn wrote not a typical history of science but one that offers a new image of science drawn from historical, philosophical, sociological, and scientific sources. Moreover, rather than being a traditional philosophy of science text ñin the usual Anglo-American sense of a study of logical problems found in scientific proceedings or systemsé it is a sketch for a genetic philosophy of science.[1]

Many other reviewers focused on segments of *Structure* that overlapped with their own discipline ï a focus not to be expected. For example, sociologists recognized *Structure* as a contribution to the sociology of knowledge, which Kuhn claimed for in the book itself. Bernard Barber lauded Kuhnôs attempt to present a ñsociology of scientific discovery, but branded Kuhnôs attempt as being ñquasi-sociologicalò because the ñsociological analysis of the process of scientific discovery was not as theoretically explicit as we might wish it, nor does it include some sociological factors that would improve his analysis by enlarging it.ò[2]

Apart from reviews, Kuhn also received many letters after the publication of *Structure*. The authors were mostly supportive of the paradigm notion and solicited assistance from Kuhn in applying the notion to their particular project and discipline. One of the earlier requests, for example, was from R.A. McConnell, who wrote Kuhn to request help with a book proposal on parapsychology. According to McConnell, ñKuhnôs discussion creates a framework in which there is a place for parapsychology as a characteristically scientific undertaking.ò[3] Moreover, McConnell recognized the importance of *Structure*. For him, ñThe book represents a new perspective of science that may lead to a revolution in the historiography of science and that may in time deeply alter the education of scientists and the administration of scientific research.ò[4]

One may agree with Kuhn that a communityôs consensus determines what their words mean. Just as when a scientific community determines which paradigm to follow, a community has the right to give something any name it wants just to achieve a desired end. For example, a big wild animal of the antelope family known as the *Nehil Gae* was causing extensive damage to crops in the field. But the farmers would not harm it because *Nehil Gae* means *Blue Cow,* and the cow is sacred to the Hindu. So the Indian government changed the name to *Nehil Goa* which means *Blue Horse.* Horses are not sacred, and so now can be killed to protect the crops.[5] This is a demonstration of the fact that knowledge is socially constructed according to Kuhn.

As found in Kuhnôs philosophy of science, cases of irrationality abound in science, most especially when scientists fail to give up belief in a favorite theory despite contrary evidence. Frank Sulloway reported evidence from psychological studies which shows that a scientistôs background, even whether he or she is a first or later born child, has an influence on his or her attitude towards a hypothesis. He cited an instance in which he said that among Victorian scientists, those who were first born were less quick to accept Darwinism than those who were later born.[6] It is likely that these are small tendencies to irrationality in everybody, scientists being no exception.

It is an empirical question how extensive the effects of irrationality are in science. On the one hand, research such as Sullowayôs does suggest that unalloyed reason might not be the norm. Furthermore, Kuhnôs lesson about the functioning of paradigms as exemplars is that we at the very least have to be careful about what we mean by ñrationalityò. If we think that rationality characterizes certain rules of rational thinking, then much of the productive thought in science is not rational. It is quasi-intuitive, instead. At the same time, such thinking is not irrational either; it does not go against what reason tells us. On the other hand, we might see rationality as pervasive. We could have a concept of rationality that ties it less to rules and more to the mechanisms that generate justified belief. And if there are tendencies to irrationality, there are tendencies to rationality too; and the later usually predominate, especially when it matters that we get things right. Even in Sullowayôs Darwinism case the first born came round once the weight of evidence was strong enough[7].

Furthermore, the social organization of science, as described by Kuhn, is well placed to minimize the effects of individual irrationality. Science as an institution may be more rational than its practitioners. It seems therefore that in the explanation of the history of science, we may find we need to appeal to irrationality less than in everyday life.

There is therefore no requirement for an absolute symmetry in treatment between what we think of as rational and irrational thoughts. Nonetheless, we do need an active methodological principle of clarity that enjoins us not to be too quick to treat as irrational the thinking of historical scientists whose beliefs we find difficult to understand. That we find ideas difficult to understand does not make them irrational. Careful attention to their paradigms makes it clear what they really meant and why it made sense to think as they did. Still less should we dismiss a belief as irrational, just because it is false? In this case, a very mild form of relativism is appropriate for the concept of justification, and correspondingly for rationality too. The fact of disagreement among scientists is perfectly inconsistent with their all being rational.

Furthermore as Wittgenstein said of the attempt to fix the correct use of the term with such a rule, ñThat was our paradox: no course of action could be determined by a rule, because every action can be made out to accord with the ruleò[8] Here, Kuhn seemed to agree. For him, it is a truism that anything is similar to, and also different from anything else.[9] By this is meant that rules can be fashioned and chiseled to suit any proposition, even when such rules and such propositions are far apart in terms of relationship. Besides, what scientists call irrationality may just be another strand or shade of rationality. That there may be levels of rationality and irrationality may just be one of such levels.

Also, Kuhn and Feyerabend were of the view that there is no single, epistemologically privileged scientific method. This method is fully endorsed by naturalized epistemology. Instead there is motley of rules of thumb, inferences, procedures, methods and processes that play a part in forming belief. The role of science is just to add to them.[10] Cognitive psychology can also tell us which ways of forming beliefs are unreliable: research suggests that interviews are often poor ways of getting to know whether a candidate is suitable for a job and well-informed firms have adjusted their recruitment policies accordingly. So, there cannot be any one set standard for determining how interviews should be conducted. Interviews should be conducted according to condition which involves place, time and some other social factors.

It is established that theory or theories already held by an individual can influence the way a scientist approaches issues. This was demonstrated in a study conducted by Robert Rosenthal. In the study, students were asked to carry out an experiment on two groups of rats, a ñmaze-brightò group and a ñmaze-dullò group, which they were told differed genetically in their ability to navigate mazes. Sure enough, the students found significant differences in the times the rats took to find their way about mazes. In fact, Rosenthal had selected all the rats from one and the same strain. The difference in the studentsô results originated not in the rats but in their belief about the rats.[11]

However, there are still some other arguments which challenge the above mentioned strengths of Kuhnôs concept of paradigm shift in science.

4.2 The Weaknesses of Kuhn's Concept of Paradigm Shift

Philip Weiner criticized Kuhnôs notion of scientific progress, which he considered to be an important logical problem in the philosophy of science. Weiner argued that current scientific theories do not ñdestroyò previous theories, ñif ódestroyô means eliminating them completely along with their confirmatory evidence,ò but rather they ñcorrectò them by situating them in a larger explanatory context. Moreover for Weiner, a logical continuity exists between the data of the previous theory and the more precise data and enlarged framework of the current theory; hence a current theoretical ñexplanation is part of the cumulative growth of scientific explanationò.[12] Although Weiner held a traditional notion of cumulative scientific progress, he appreciated Kuhnôs historical turn for the philosophy of science, ñIf the philosopher of science is more than a logical analyst by also considering the cultural implications of fundamental changes in scientific worldviewsé ò[13]

Another complaint leveled by numerous critics of *Structure* was based on Kuhnôs imprecise use of paradigm. In a creative and sympathetic analysis of Kuhnôs sense of paradigm, Margaret Masterman identified twenty one senses of it. Her motivation for understanding the analysis was that:

> actual scientists are now, increasingly reading Kuhn instead of Popper: to such an extent, indeed, that in new scientific fields particularly, ñparadigmò and not ñhypothesisò is now the ñO.K. wordò. It is thus scientifically urgent, as well as philosophically important, to try to find out what a Kuhnian paradigm is[14].

After identifying the different senses in which Kuhn used paradigm in *Structure*, she grouped them into three categories. The first is the metaphysical paradigm or ñmetaparadigm,ò which provides the theoretical basis for scientific practice and includes a set of belief, a map, a standard, a metaphysical speculation or notion of entity, an organizing principle that shapes perception, or a way of determining large areas of reality. The second category is the sociological paradigm, which directs the behavior of scientific communities and their members and includes a universally accepted achievement, a set of political institutions, or a device in common law. The final category is the artifact or construct paradigm which involved concrete puzzle solution and includes a textbook or classic work in the discipline, a source of tool for conducting experimental investigation, a machine-tool, or a gestalt figure that can be seen in two ways. Masterman concluded her analysis by inviting others to join in articulating further Kuhnôs notion of paradigm, for ñif we retreat from all further considerations of Kuhnôs new image of science, we run the risk of totally disconnecting the new-style realistic history of science from its old-style philosophy: a disaster.ò[15]

Another problem is that Kuhn is accused of being unsystematic in his works especially in *The Structure of Scientific Revolutions.* This is because, according to critics, Kuhn was never thoroughly trained as a philosopher. His undergraduate and graduate training were as a physicist, not as a philosopher, even if he described himself as a philosophically inclined physicist. Although he retired as a professor of philosophy at MIT, Kuhn was a professor of history of science at Berkeley when he published *The Structure of Scientific Revolutions* in 1962. Kuhnôs treatment of philosophical ideas is neither systematic nor rigorous. He rarely engaged in the stock-in-trade of modern philosophersô views, the careful and precise analysis of other philosophersô views and when he did so, the results were not encouraging.

This is not to say that Kuhn was a bad philosopher or that we should be suspicious of his philosophical opinion ï we might expect the grand, synoptic view to be characteristic of an important revolutionary thinker while the analysis of individual arguments might be cast as philosophyôs parallel to ñnormal scienceò. Even so, for a philosopher whose main achievement in the eyes of many is to have undermined a whole philosophical tradition (that of logical positivism, or more broadly logical empiricism), it is perhaps surprising that he makes little direct reference to the claims of that tradition; even less does he give chapter and verse to establish that such-and-such is what the logical positivists did indeed think. ñThis fact I think is further evidence that *The Structure of Scientific Revolutions* is primarily something other than philosophyé ò according to Alexander Bird.[16] Of the one hundred and fifty footnotes in the first edition of that book only thirteen included references to philosophers and almost all of these are to philosophers, whose views are in agreement with Kuhnøs. The vast bulk of the remaining references are to historians. The importance of these remarks on Kuhnøs relationship to the practice of philosophy is that the imprecise nature of the latter makes it much more different to access exactly where Kuhnøs differences with positivism lie, how deep and extensive they were and how justified they should be judged to be. The usual assessment, especially in the light of Kuhnøs huge impact, is that ñthe break must be massive, a root and branch rejection, a thorough revolution.ò[17]

This is wrong. A central thesis of *The Structure of Scientific Revolutions* is that in important respects Kuhn failed to break entirely with the preceding tradition. From the naturalistic philosophy that has developed in ñcore philosophyò during the last two to three decades, which in due course spread to the philosophy of science, Kuhnøs views are shot through with commitments to the Cartesian and empiricist traditions he saw himself to be rejecting. Furthermore, it is the only partial rejection of positivism and empiricism that explains the radical appearance of the Kuhnian viewpoint ï incommensurability, the conception of progress, the world change thesis, and all consequences of positivist and empiricist views that Kuhn retained. Had Kuhn gone the whole hog and really rejected empiricism, then the result, although superficially less dramatic, would have been in fact a more truly profound revolution. As hinted, many philosophers, including philosophers of science now find themselves in the position of being rather less empiricist than Kuhn.

Another source of weakness in Kuhnøs philosophy of science is that he has been accused of introducing the duo of irrationalism and subjectivity in science. The transition to a new paradigm cannot be constrained by the old paradigm in the way that normal science used to be constrained by it. Crisis has discredited the old paradigm as a model for a new theoretical development. The analogy between scientific revolutions and political revolutions has tempted commentators into thinking of a scientific revolution as a thorough and radical break with the past whose outcome is determined by highly contingent factors -- the equivalent of the revolutionary mob, propaganda, coercion and so on. Correspondingly, they think that while in normal science, what counts as a rational preference among competing theories is determined by reference to the paradigm, in the revolution the absence of a paradigm means there will be no agreed standard of rationality. This is to say that revolutions are irrational.

Also critics pick on Kuhnôs remark that ñexternalò factors, that is, developments outside the science in question, and ñidiosyncrasies of autobiography and personalityò[18] may play a major part in determining the nature of the new paradigm. Alexander Bird added his voice here by saying that, ñEven the rationality or the prior reputation of the innovator and his teachers can sometimes play a significant role.[19]ò This is one of the features of Kuhnôs thoughts that has attracted most controversy. On the one hand, it has led detractors to accuse Kuhn of making scientific development an exercise in irrationality. On the other hand, it has acted as a spur to the sociology of science, both in its micro form, investigating the way, for example, attitudes of the directors of research centres and chairmen of grant-awarding bodies influence paradigm acceptance, and its macro form, looking at the political, economic and social determinants of the content of science.

There is another feature of Kuhnôs thought that tends to attract the charge of irrationalism. Since the paradigm not only supplies the framework for the development of puzzle-solutions but also the standard by which they are judged, once a paradigm has been overthrown and the rivals to replace it are in competition, our usual standard for scientific evaluation is unavailable. There is no universal or common measure for theories ï in the jargon, they are incommensurable.[20] In other words, before a new paradigm is accepted, it means that there will be a gap. There will be no paradigm guiding or regulating the activities of scientists because the old theory has been jettisoned and no replacement has been found.

For the fact that the process of recognizing similarity is non-intellectual, Kuhn has been accused of introducing ñsubjectivity and irrationalityò into science. ñSome readersò, Kuhn wrote, ñhave felt that I was trying to make science rest on unanalyzable individual intuition rather than on logic and law.ò[21] If it is right in taking Kuhn to be indicating features of human psychology that cognitive science has since been able to articulate and explain more fully, then such criticism is misplaced and he is right in rejecting these charges. While it is true that the use of ñlogic and lawò is downplayed by Kuhn, it does not follow that the result is subjectivity or irrationality.

We need now to see how the concept of paradigm as exemplar may help us explain not only how normal science may persist -- and break down -- but also how it may be re-established. Some of Kuhnôs critics have seen this as reinforcing their view that theory-change for Kuhn is irrational, a matter of mob rule. In this interpretation, the rejection and replacement of a paradigm is wholesale. And once a paradigm is rejected there is then no basis for choosing a new one. If there is no accepted paradigm, how does the new signal achievement around which a new consensus is to crystallize recognized as such? It is tempting to elevate Kuhnôs few isolated hints about the possible significance of external social and political conditions into the claim that it is these factors and these alone that determine the choice of new paradigm. There are some other factors apart from social and political ones that determine the choice of a new paradigm.

Kuhn was also criticized on what he said that normal science is low on innovation and high on dogma. Kuhn was keen to emphasize that normal science, whether experimental or theoretical is low on innovation and high on dogma.[22] This must be implicitly a relative judgment. Although some normal science involves the literal repetition of experiments performed before, even that is likely to be related to something new, such as the replication of a newly reported experimental effect, most of what is described as research under normal science led to the discovery of new theories, new laws or new facts, even if only ñoldò facts with new accuracy. So there must be an intended comparison next to which this research seems conservative. The comparison is naturally, revolutionary research. According to Bird, the ñnew in normal science is the embellishment of existing theory; in revolutionary science, it is the replacement of existing theory.[23]ò In normal science, the theory is not up for debate. Research takes it for granted. It has therefore the status of dogma. Kuhn does not intend this characterization pejoratively. On the contrary, normal science could not progress without the unquestioned acceptance of a theoretical foundation, just as a civil society could not function without constitutional consensus.

Another major criticism leveled against Kuhn is that he made science to be a ruleless enterprise. Kuhn may be forgiven for wanting to draw his contrast with the logical empiricist emphasis on rules as strongly as possible. While one would not accuse Kuhn of being ignorant of platitudinous facts about scientific thinking, one may suggest that in appealing to a model that has no need for rules, he makes it unclear how reflective judgment can play a role. This lack of discussion of how reflection fits in means that Kuhnôs story is sorely incomplete. So, the attendant question must be whether there is room for additional claims about the role of reflection. If not, Kuhnôs account is implausible; if there is, it stands the need of supplementation.

There are two ways in which one might fuse reflection and intuition in a broadly Kuhnian way. The first suggestion is that the intuition of similarity is preceded by reflection and reasoning, but these are not sufficient to fix an answer to the question: how good is this hypothesis? Reflections can do things such as determining whether the evidence might be explained by the hypothesis, whether a certain claim is statistically likely, ñwhether the calculations of the projected path of a comet have been carried out correctly.ò[24] These things are reflected upon and determined before we can answer the question of the quality of the hypothesis. But there is no rule that takes us from our answers to the reflective questions to an answer to the quality question. There comes a point at which we must say something like ñAll things considered, I judge this to be a plausible but not yet fully convincing hypothesisò, which contrasts with, for example, a mathematical case where one may say something like, ñHaving seen the proof, I see that it follows logically that the theorem must be true.[25]ò What this means is that without paradigms, issues are not certain, but with paradigms, they are certain.

Canguilhem was one of the critics who was bent on using the concept of rulessness to pull down Kuhnôs scientific ideas. He criticized Kuhn on the account of scientific norms because, in his view, Kuhn derived them from a contingent, merely psychological agreement that has no genuine regulative force.[26]

One of the major critics of Kuhn who detailed a number of problems with Kuhnôs paradigm notion was Shapere. Shapere pointed out that the notion was too imprecise. For him anything that allows science to accomplish anything can be part of (or somehow involved in) a paradigm. Shapere also expressed concern that the expansive nature of paradigm may obscure significant divergence among scientific practices. Shapere then discussed what he considers a ñdeeperò problem with Kuhnôs notion of paradigm, the change in the meaning of terms during paradigm shift. Shapere was bothered by Kuhnôs argument that a fundamental change of a termôs meaning, such as the term ñmassò, occurs after a scientific revolution (from Newton to Einstein). Marcum quoted Shapere as saying that, ñThe real trouble with such arguments arises with regard to the é difference between the saying, in such cases, that the ómeaningô has changed as opposed to saying that the ómeaningô has remained the same though the óapplicationô has changed.ò[27]

Shapere believed Kuhn failed to make this subtle distinction. This problem led to Shapereôs critique of incommensurability. If two competing paradigms are incommensurable, ñ if they disagree as to what the facts are, and even as to the real problems to be faced and the standards which a successful theory must meet then what are the two paradigms disagreeing about? And why does one win?ò [28] Shapere believed Kuhn had no ready answer for these questions. Moreover, he argued that Kuhnôs incommensurability thesis reduces scientific progress to mere change, which raises the issue of how paradigms can be compared in the first place.

The upshot of Shapereôs critique of both the paradigm and incommensurability notions was the charge that Kuhnôs new image of science is relativistic. ñFor Kuhnò, claimed Shapere, ñhas told us that the decision of a scientific group to adopt a new paradigm is not based on good reason; on the contrary, what counts as good reason is determined by the decision.ò [29] Shapere acknowledged that the appearance of this type of relativism in philosophy of science was only a matter of time, given the direction of current historiography, and warned philosophers of science to cast a jaundice eye towards it, ñuntil historians of science achieve a more balanced approach to their subject ï neither too positivistic nor relativistic.ò[30]

Alexander Bird differed from Kuhn in the incommensurability thesis. For him, old paradigms do play a part in determining the nature of their successors; the new paradigm must have some similarity to its predecessor, just as a normal puzzle-solution must. So, what is characteristic of revolutionary research is that the evidence cannot be sufficient to compel rational assent to the new hypothesis. It is always open to the acolyte of the older theory to argue that the older theory will in due course solve all the puzzles that the innovating theorist regards as anomalous counterexamples. No new theory is perfect, and so the traditionalist will often be able to point to problems in the new theory that are absent in the old.[31]

Furthermore, Alexander Bird was of the view that there may be no important distinction between normal and revolutionary science. There may instead be a continuum from small, insignificant cumulative additions to belief through moderately important changes involving a fair amount of belief revision to epoch- making revolutions.[32]

Kuhnõs concept of exemplar was also criticized. One of such criticisms is that Kuhnõs notion of exemplar may not work in all cases. This is because, not all scientific projects have exemplary predecessors. Another criticism against Kuhnian exemplars is that they work only for a suitably trained community of experts. But could there be any such community for science in general? Whether or not anyone could possess such broad expertise is doubtful, yet policy makers are often placed in this position. For them, the Kuhnian suggestion is to take concrete historical examples more seriously than general rules. For Thomas Nickles, perhaps, this was Harvard President James B. Conantôs original idea behind the case study-based history of science course that he developed and for which he consequently recruited Kuhn as a graduate student.[33]

On how relativistic Kuhnôs philosophy appeared, Shapere was one of those concerned over the issue of relativism which he said arose from Kuhnôs notions of paradigm and incommensurability.[34] Some scholars who reviewed Kuhnôs *The Structure of Scientific Revolutions* did justice to Kuhnôs understanding of relativism. In *Scientific American*, Kuhnôs book received a harsh review. An Anonymous reviewer, as noted by Marcum, claimed that Kuhnôs central thesis was common knowledge and that Kuhn distorted this thesis with his relativism. The reviewer also criticized Kuhnôs use of paradigm, and claimed that the effects of incommensurability ñare at best wild exagerations.ò[35] Marcum wrote that Kuhn never quite forgot the treatment he received in the pages of this magazine.

Still on relativism, the central element of Kuhnôs epistemological outlook is his neutralism about truth. Methodologically, this is acceptable. But there is no justification for elevating it into a metaphysical principle. Kuhnôs arguments against the concept of absolute truth are confused. In mitigation, it must be said that this is a confusion he shared with his positivist predecessors. But there is yet additional evidence for the contestations that Kuhn retained many positivist and empiricist assumptions and that their retention is in large part responsible for some of the more radical views of his pronouncements. The attack on truth is tantamount to a deep, metaphysical form of skepticism or in the context of incommensurability and lexicon-relative truth or relativism.

Kuhn rejected the views of science as achieving increased verisimilitude and as accumulating knowledge. He is a skeptic with regard to absolute knowledge (A-knowledge); there is no knowledge where knowledge is taken to entail A-knowledge.[36] To a considerable extent knowledge and indeed justified belief drop right out of the picture, since for Kuhn the object of epistemic assessment is not belief but belief change.

Watkins criticized Kuhn by rejecting Kuhnös normal science as an accurate conception of science. He contrasted the two different communities of practitioners with the Kuhnian community reflecting how scientists act as a ñclosed society, the intermittently shaken by collective nervous breakdowns followed by restored mental unison.ò[37] By this Watkins meant movement from normal science, through crisis to a new normal science. Watkins contrasted Kuhnös ideas with the Popperian community reflecting how scientists should (and do) act as an ñopen society in which no theory... is ever sacred.ò[38] Watkinös strategy was to turn the table on Kuhn and to assist him see through Popperian glasses that normal science is no science at all.

Watkinsô final blow to normal science was that it cannot be responsible for the emergence of revolutionary science. For him, inspection of the historical record of scientific development reveals that new theories emerge not all at once but over a lengthy period in response to continuous, critical challenges to a theory. Watkins credited Kuhnös misconception to the comparison of the emergence of new theories to gestalt switches. Scientists are not prisoners of a theory. They are free to challenge it at any time. Watkins in conclusion compared science to religion. He said that if science is likened to religion, then ñheretical thinking must have been going on for a long time before paradigm change can occuré which means that the scientific community is not after all, a closed society whose chief characteristic is óthe abandonment of critical discourse.ôò[39]

Another major concern of critics is that for some of them, Kuhn was highly conservative. Bloor was one of those who characterized Kuhn as a conservative thinker. There are a number of senses, not all related to one another, in which Kuhn might be thought of as a conservative. For Bloor, Kuhn is a conservative in the Mannheimian sense according to which the conservative stresses the importance of tradition.[40] This is certainly a fruitful approach to understanding Kuhn, especially in contrast to the Old Rationalists who exemplified what Mannheim calls the ñnatural law ideologyò. Natural law ideologists emphasize reason conceived of as the application of general and sempiternal rules of judgment; the conservative appealed to history and local factors.[41] Kuhn can be said to be a conservative person because he appeals to history and local factors. Kuhnôs conservative alternative depicts science as made up largely of disunited practices that progress according to the rule-less impetus of their current paradigms, adjusted not with a view of representing the facts but with the aim of making the best local improvement to the existing tradition.

Steve Fuller also accused Kuhn of being a conservative, more explicitly on political count.[42] Fullerôs criticism has strands. *The Structure of Scientific Revolutions* must be seen, he says, against the educational background that caused Kuhn to write it. In the early 1950s, Kuhn taught the general education in science curriculum at Harvard. This programme had been devised by Harvard president, James Conant, as a way of informing students, humanities students in particular, about the nature of science and its history. Conant was a central figure in the liberal-conservative establishment, a supporter of Big Science, who left Harvard to become the first US ambassador to West Germany. The motivation behind the programme was to build in the minds of Americaôs future leaders a particular image of science: science as an autonomous institution. Science needed to be protected from government interference, and so the elite needed to be reminded that the dynamics of science is generated internally, not externally. Science also needed to be defended from criticism directed at the uses of science such as the application in the design of nuclear weapons. So, it can be seen that Kuhn was only trying to conserve Conantôs ideals without really establishing ôhis ownô image of science.

Another reason to reinforce the autonomy of science is directed towards scienceôs public legitimization. Science needed to be divorced in the public mind from technology. Kuhnôs image of science certainly fulfils these requirements. Science generates its own puzzles; good science occurs when it sets its own agenda. And what drives science is the desire to solve these puzzles, not the need to produce inventions however beneficial or deadly. If a puzzle-solution happens to be of use in some way then putting it to that use is part not of science but of technology.[43] Fullerôs other criticism concerns what he called ñdouble truthò doctrine. The general idea is that the masses are not given the same message as the elite if to do so would be socially destabilizing. Moreover, far from encouraging critical attitudes towards science (which he repudiated), Kuhnôs work blunted criticism. In general the progress of crisis, revolution, replacement of an old paradigm by a new one, revisionary paradigm, shows that science has its own mechanism for self-criticism, change, and renewal. Hence external criticism is unnecessary.

In particular, philosophical criticism is blunted, first, because the emphasis laid on dogma in normal science is highly conservative especially when compared to Popperôs critical rationalism, and secondly, because the empirical and the historical attitudes towards science remove the normative element from the philosophy of science. At the same time, *The Structure of Scientific Revolutions* encouraged social theorists to see themselves as scientists rather than critics of science.

Another sense in which Kuhn could be characterized as conservative is represented by the idea that despite radical appearances to the contrary, Kuhnφs unstated presuppositions are really not so different from those of the positivists, empiricists and Cartesians he took himself to be criticizing. It should be remembered that Kuhn started his professional career as an historian but finished as a philosopher. Kuhnφs contributions to philosophy should be seen as consequences of his attempts to treat history of science in a theoretical manner. He stated that revolutions are often brought about by those who come to the field from outside, and his works would certainly seem to illustrate that. As has been seen, scientific revolutions are not root-and-branch revisions of belief, and as has been emphasized at the outset Kuhnφs own revolution retained much from the logical empiricism against which he was reacting.

Kuhn can be likened to Copernicus who, while striking the first serious blow that brought down the Ptolemaic-Aristotelian world-view, was also irrevocably steeped in that way of thinking. As retold by Bird, Kuhn himself said of Copernicusφs revolution that it was like the midpoint of a bend on a road: from one perspective it is the last point of one stretch of road and from another, it is the beginning of the next.[44] Similarly, Kuhn can both be seen as among the last of the empiricists and also be regarded as the first of empiricismφs successors.

Kuhn also received letters that were critical of *The Structure of Scieintific Revolutions* especially in connection with the notion of paradigm. For example, Mendel Sachs, from the

Department of Physics and Astronomy at the State University of New York, Buffalo, wrote Kuhn disagreeing with the role of paradigm in science. Defining paradigm as a ñbandwagonò, Sachs declared: ñFrom my own experience, as a theoretical physicist, I am quite convinced that these bandwagons have been stumbling blocks to progress. They provide crunches for individual scientists to lean on, instead of thinking for themselves!ò[45]

4.3 Kuhn's Defence/Response to Critics

Kuhn, while alive, defended some of the positions he held. He often responded to critics by trying to help them see through the differences between their criticisms and what he was trying to say. For example, in his reply to Sach, Kuhn wrote, ñHow does one tell a óbandwagonô effect from a decision made by a large number of individuals to turn their attention to what they individually believe to be a promising new area of research?ò[46] Kuhn continued to receive correspondence concerning *The Structure of Scientific Revolutions* throughout his career and patiently addressed it as best as he could. The sheer volume of his correspondence alone witnesses to the importance and impact his classic *The Structure of Scientific Revolution* had, not only on the history and the philosophy of science but on many other disciplines as well.

Kuhn also believed that he and his critics had, ñpartial or incomplete communication ð the talking-through-each-other that regularly characterizes discourse between participants in incommensurable points of viewò.[47] Kuhn believed that he and his critics have talked passed one another on three different sets of issues: methodology, normal science and paradigm shift.

With respect to methodology, Kuhn observed that critics see his method as historical or social psychological or descriptive while their own is logical and normative. Kuhn claimed that this is a misperception since all the participants in the colloquium where he presented a paper entitled *Reflection on My Critics* engaged historical case studies and the behavior of scientists both individually and collectively. With respect to the historical dimension of his method, Kuhn wrote:

> I am no less concerned with rational reconstruction, with the discovery of essentials, than are philosophers of science. My objective, too, is an understanding of science, of the reasons for its special efficacy, of the cognitive status of its theories. But unlike most philosophers of science, I began as an historian of science, examining closely the facts of scientific life.[48]

Kuhnôs defense of the social psychological dimension of his method relied on the insufficiency of rules to dictate human behavior. For theory choice, for instance, Kuhn reaffirmed that community ñbehavior will be affected decisively by the shared commitments, and the prior pattern of professional research.ò[49] Finally for the descriptive-normative distinction, Kuhn argued that this new image of science has normative implications for the practice of science:

> Scientists behave in the following ways; those modes of behavior have (here theory enters) the following essential functions; in the absence of an alternate mode that would serve their similar functions, scientists should behave essentially as they do if their concern is to improve scientific knowledge.[50]

Kuhn next took up the defence of normal science. He believed that criticsô denial of normal science and classifying it as uninteresting compared to revolutionary or critical science were unusual ploys. As for the non-existence of normal science, Kuhn claimed that revolutionary science demands it. ñBy their natureò, insisted Kuhn, ñrevolution cannot be the whole of science: something different must necessarily go on in between.ò[51] The notion of revolution itself dictates against all science being revolutionary all the time. Normal science, with its period of stasis in which theories do not proliferate and scientists do not criticize their foundations, provide the scientific backdrop for revolutions to occur and to be recognized.

The problem of recognizing normal science or of distinguishing between normal and revolutionary science requires an appropriate understanding of the scientific community. By knowing what a community deems valuable, then the question of whether an historical period of scientific research is revolutionary or normal can be answered. ñThe gist of the problem,ò claimed Kuhn, ñis that to answer the question ónormal or revolutionary?ô one must first ask ófor whom?ôò[52] Moreover, science is palpable from history, asserted Kuhn, even from the case studies critics used to deny its existence. Finally, for the coinage of science, normal science is a necessary obverse to the revolutionary converse in that it provides the stasis required for detailed scientific progress.

Kuhn then considered criticsô charge that his position concerning theory choice or paradigm or paradigm shift depends on irrationalism, relativism, and mob rule. Kuhn categorically denied the charge:

> To say that, in matters of theory-choice, the force of logic and observation cannot in principle be compelling is neither to discard logic and observation nor to suggest that there are not good reasons for favoring one theory over another. To say that trained scientists are, in such matters, the highest court of appeal is neither to defend mob rule nor to suggest that scientists could have decided to accept any theory at all.[53]

In his defence of the charge of irrationalism, Kuhn wrote, ñWhat I am denying is neither the existence of good reasons nor that those reasons are of the sort usually described. I am however, insisting that such reasons constitute values to be used in making choices rather than rules of choice.ö[54]

Kuhn also contended that his evolutionary notion of scientific development is not relativistic for in the selection of one theory over another: ñOne scientific theory is not as good as another for doing what scientists normally do.ö [55] Finally, in terms of the charge of mob rule, Kuhn appealed to the fact that in terms of mob psychology there is generally a rejection of community values; but if the scientific community rejects its values, ñthen science is already past saving.ö[56]

Furthermore, Kuhn realized that his position on values caused critics, such as Shapere and Scheffler, to charge him of subjectivity and irrationality. Kuhn addressed this charge, arguing that value judgments in any discipline are critical determinants of community behavior regardless of individual appropriation of values and serves important functions in the community such as distributing risk. Far from being subjective and irrational, Kuhn insisted that values assure scienceøs success by affording a certain amount of plasticity to its practice.

Again, in his defence, Kuhn felt that the reviewers of *The Structure of Scientific Revolutions* were good.[57] His chief concern remained the tag of irrationalism. ñI was not saying howeverö, stated Kuhn, ñthat there arenøt good reasons in scientific proofs, good but never conclusive reasons.ö[58] He was also concerned with the charge of relativism, at least a pernicious kind. He felt that the charge was inaccurate. He proposed that science does not progress towards, a pre-determined goal but, like evolutionary change, one theory replaces another with a better fit between theory and nature *vis-à-vis* competitors. Kuhn believed that the use of the Darwinian metaphor was the correct framework for discussing scienceôs progress. But he felt no one took that metaphor seriously.

4.4 Kuhn's Legacy

The Structure of Scientific Revolutions had little direct influence on the functioning of the natural sciences but its impact on social science was enormous. This impact had two aspects: the first was a change in the social sciencesô self perception, the second was a suggestion of a new role and subject matter for the social sciences. Kuhnôs cyclical pattern provided a template whereby the histories of the social sciences, almost entirely ignored in *The Structure of Scientific Revolutions* itself, could be described. The significance of this was not so much the furthering of historical research; rather it was the provision of a tool for validating social sciences as true sciences. Two important and obvious characteristics of the leading natural sciences -- physics, chemistry and biology (taken to include the biomedical and agricultural sciences) -- were absent from the social science and thus seemed to mark the former as genuine sciences and the latter as impostors. The first characteristic was that the natural sciences had vast and powerful technological applications. While many social scientists did believe in the possibility and value of social ñengineeringò and other applications of social research in areas of social policy, they found little in the way of unequivocal success. Kuhnôs description of science had nothing to say at all about the application of science. He scarcely mentioned the thought that technology might be a source of problems and puzzles for scientific research; ñstill less did he regard the possibility of technological application as any kind of sciencehood.ò[59] Rather, the mark of being a science was that a discipline should have a certain sort of internal dynamic -- puzzle-solving research governed by a paradigm, interrupted by crises and revolutions -- a dynamic that could be possessed by a discipline however bereft of associated technology.

The fact that Kuhn has no place for the truth of theories in his description and explanation of this dynamic idea, plus the central place given to revolutions that reject or revise existing beliefs, is a further reason why the social sciences should not, after all, be faulted in comparison to the established natural sciences. The latter seemed to have impressive histories populated by heroic figures, histories that had generated great tracts of accepted knowledge and whose continuing progress is governed by well-established methodologies. This was the second apparent sign of sciencehood. The social sciences, by contrast, were young, had few acknowledged heroes, and produced little in the way of knowledge that was widely accepted, and seemed exercised less by the need to make progress than the desire to engage in methodological disputes.[60] *The Structure of Scientific Revolutions* rendered the contrast less acute. On the one hand, it undermined the positive image the contrast ascribed to the natural sciences -- knowledge is not cumulative. The difference between the heroes and those they vanquished is not that between truth and falsehood or rationality and irrationality. On the other hand, the unflattering contrast afforded to the social sciences need not refute their claims to sciencehood. Even if methodological and other disputes do predominate in a field, that is compatible with its being in a state of revolution or, more plausibly, in a state of immature science, which Kuhn says, is no less truly scientific for all that.

The jettisoning of the Whiggish, Old Rationalist idea for scientific development and its replacement by an evolutionary account opened up the possibility of more particular, local explanations of change in place of the global scientific method. In particular, many were impressed by the hints Kuhn gave that explanations of revolutionary change need not be entirely intra-scientific. He held that political, social, religious and personal motivations might play a much larger part in the history of science than had previously been admitted.

It is safe to say that there is no academic discipline that has not been influenced by Kuhnös paradigm. ñLike a virusò, observed Horgan, ñthe word had spread beyond the history and philosophy of science and infected intellectual community at large, where it came to mean virtually any dominant idea.ò[61] Kuhn recognized that part of the reason other disciplines appropriated his ideas, especially paradigm and paradigm shift, was that it provided them with a means to claim a status comparable to that for the natural sciences. Now, attempts shall be made to see the impact of Kuhn on selected disciplines:

4.4.1 Philosophy of Science

In homage to Kuhn, Micheal Friedman acknowledged that:

> Thomas Kuhnös *The Structure of Scientific Revolutions (*1962) forever changed our appreciation of the philosophical importance of the history of science. Reacting against what he perceived as the naively empiricist, formalist, and a historical conception of science, Kuhn presented an alternative conception of science in flux.[62]

The current position in the philosophy of science is that the alternative conception of science has superseded the traditional conception. By exploring the relationship between the history of science and the development of modern philosophy, Friedman came to the conclusion, however, that ñthe currently popular diagnosis of the failure of logical positivism (a diagnosis due largely to the work of Kuhn and his followers) is fundamentally misleading.ò[63]

4.4.2 Sociology

Besides general sociology, Kuhnøs philosophy of science was instrumental in terms of a new sociology of science called sociology of scientific knowledge or SSK.[64] As sociologists acknowledged, they are not interested in praising the natural sciences but want to turn them onto themselves. Thus, the agenda of SSK was to shake the very foundations of these sciences and to question their privileged position in society, in terms of both their access to and pronouncements on the natural world. From their analysis of the natural sciences, SSK scholars concluded that scientific knowledge is not discovered but constructed, created or manufactured.

An outgrowth of SSK was the science wars.[65] Scientists and their sympathizers eventually responded to SSK. Paul Gross and Norman Levitt, for example, provided a highly publicized ï and rather sensational ï response to SSKøs cultural constructivism. From their critique of SSKøs constructivism, they concluded: õthis point of view rigorously applied leaves no ground whatsoever for distinguishing reliable knowledge from superstition.ö[66] They located part of the blame for constructivism with a distorted interpretation of Kuhnøs philosophy of science. SSK scholars responded to Gross and Levitt. For example, Andrew Ross decried the caricature of the cultural and social studies of science. Ross defended the post modern position(s), declaring that the

> class-soaked pronouncements about the return of Dark Ages among the ill-educated masses are intended to reinforce the myth of scientists as a beleaguered and isolated minority of truth-seekers, armed only with objective reasoning and standing firm against a tide of superstition.[67]

4.4.3 Science Education

By the 1980s, Kuhnôs new image of science became the standard within science pedagogy. For example, Isaac Abimola, in discussing the relevance of the ñnewò philosophy of science for science education, used Kuhn as a source for many of its characteristics. He concluded that this new philosophy may ñprovide the necessary guidance to upgrade science education and research.ò[68] Paul Wagner also utilized Kuhnôs philosophy of science to address science pedagogy. He agreed with Kuhn that the ñessenceò of scientific activity is puzzle-solving. ñConsequentlyò wrote Wagner, ñScience education ought to equip science students with the skills necessary for puzzle-solving in specific scientific domainsò[69] According to Marcum, Wagner went on to outline three goals for science curriculum based on Kuhnôs philosophy. Briefly, students should be taught the particular vocabulary, pattern, and critical spirit associated with a specific paradigm.

Derek Hodson proposed a three-stage scientific curriculum constructed along Kuhnian lines. The first stage is pre-paradigmatic education in which the students are taught the vocabulary and concepts of a particular scientific domain. The next stage is ñwithin-paradigm science education.ò Hodson wrote that the major goals of this stage would focus on learning the substantive structure of science and on acquiring and practicing the skills and procedures of normal science. The final stage is revolutionary science education. During this stage, students are taught the creation of new theoretical ideas and investigation of the ways in which choices are made by the scientific community between rival theories.[70]

Kuhn continued to be discussed among science educators in the 1990s, with a more balanced use of Kuhnôs philosophy of science emerging by the end of the decade. For example, Juli Eflin, Stuart Glennan and George Reisch encouraged science educators to expose students to Kuhnøs philosophy of science, especially paradigm competition and the role of commitments and values in science. However, they cautioned that students õshould be made aware that some interpretations of Kuhnøs views are extreme and not persuasive (such as the popular claim of radical incommensurability between paradigm).ö[71]

Finally, Mathews discussed the lessons learned from Kuhnøs impact on science education, especially in terms of constructivism. The chief lesson, according to Matthews was that the science education community should be more effectively engaged with ongoing debates and analysis in the history and philosophy of science.ö[72]

4.4.4 Religion

Ian Barbour was one of the first theologians to apply Kuhnøs philosophy of science to religion. Barbour discussed commitment to religious paradigms, stressing the importance of the religious communityøs traditions and exemplars. Both traditions and exemplars are important for defining the community and for initiating members into it. For religious communities, observed Barbour, they often revolve around a specific individual. Moreover, rather than rules for choosing among religious paradigms there are criteria of religious communities that include trust and loyalty, which often engender a deeper commitment to doctrines than criteria of scientific communities that engender commitment to theories. However, such subjective factors do not preclude critical analysis and reflection on oneøs religious faith. In other words, Barbour recognized a reciprocal relation between commitment and reflection for religious communities defined by a paradigm. õCommitment alone without enquiring,ò insisted Babour, ñtends to become fanaticism or narrow dogmatism; reflection alone without commitment tends to become trivial speculation unrelated to real life.ò[73]

Others also used Kuhnôs philosophy of science to address religious issues. For example, Henry Veatch claimed that Kuhn and other contemporary philosophers of science provided a novel means by which to conduct apologetics especially under the yoke of Popperôs philosophy of science. According to Popper, religious statements fall on the wrong side of the demarcation divide. But Veatch invoked Kuhn to question Popperôs demarcation principle and to turn the tables on Popper. For Veatch, ñIt would seem to be scientific truth that can claim to be more than a truth about appearances, whereas the very logic of theological truth, when rightly understood, can in all propriety claim to be a factual truth and a truth about the way things really are.ò[74] For Veatch, religious doctrines are necessarily true, while scientific theories are merely invented.

The Roman Catholic theologian Hans Küng from Tübingen used Kuhnôs paradigm concept to address the question of consensus in modern Christian theology. (Kung along with another Catholic theologian David Tracy, organized an ecumenical symposium at the University of Tübingen in May 1983 to explore the role of paradigm in theological consensus. Kuhn, along with Toulmin, was invited to participate in the symposium but Kuhn was unable to attend because of prior commitment).[75]

Küng claimed that theology exhibits ñnormalò practice guided by paradigm. Its paradigm can break down leading to a crisis period. He held that a theological paradigm is replaced only when a better one is available and acceptance of a new paradigm depends also on extra-rational factors and thereby resembles a conversion. A new paradigm, if successful, becomes the new tradition. Küng reconstructed Church history in terms of six paradigms: the early Christian Apocalyptic Paradigm, Patristic-Hellenistic Paradigm, Medieval-Roman Catholic Paradigm, Reformation-Protestant Paradigm, Modern-Enlightenment Paradigm and the emerging contemporary paradigm.

Küng believed that theology is currently experiencing a crisis, precipitated by several contemporary issues such as end of western hegemony, the ambiguity of science such as its creative and destructive capacities, and especially ñan undermining of Christianityôs dominance as the óone trueô óabsoluteô religion.ò[76] Küngôs concern was for a more conscious attempt by theologians to birth a new paradigm.[77] But he was not advocating a monolithic paradigm. ñOur aim is not a rigid canon of unchangeable truth,ò claimed Küng, ñbut a historically changing canon of fundamental conditions which have to be fulfilled if theology is to take its contemporary character seriously.ò[78] To that end, he signifies four conditions or dimensions of the new paradigm, including biblical, historical, ecumenical and political.

In response to Küngôs new paradigm for theology, Toulmin cautioned theologians to remain ñparadigmlessò.[79] Erich Von Dietze claimed that Küngôs reliance on paradigm change ignores the problems associated with incommensurability. ñIf different religions or theologies are (or contain) different paradigms,ò argued Dietze, ñthen Küng must explain how he has the ability to transcend incommensurability and how he is able to make comparisons and hold dialogueò.[80]

In the 1989-1991 Gifford Lectures, Babour extended his earlier discussion of Kuhnôs notion of paradigm for reconstructing religious experience. ñAs in the scientific case; claimed Babour, ña religious tradition transmits a broad set of metaphysical and methodological assumptions that we can call a paradigm.ö[81] Theologians, both professionals and lay who operate within a given paradigm, are working within a ñnormal religion,ò analogous to ñnormal scienceò. Babour identified three key features of normal religion: paradigm dependence of religious experience, resistance of religious paradigms to falsificationism, and no rules or algorithm for choice among competing religious paradigms. Finally he noted that theologians from different traditions do not

> seem to have a loyalty to an overarching and universal religious community, with shared criteria and values comparable to those shared by all scientists. In a global village, could such a wider loyalties be encouraged, without undermining the distinctiveness of each religious tradition?[82]

4.5 Implications of Kuhn's Paradigm Shift for Africa

Kuhnôs ideas are in accordance with the fact that science should be a product of culture. Culture also should be a product of nature. Any culture, whether medical, political, scientific, economic, social, religious and so on that is not in accordance with the nature of a people is bound to fail. Kuhnôs notion of science adheres to the rules of contextualism, regional ontologies[83], perspectivism and personalism. All these rolled into one can lead to an authentic African science.

African science has received so many derogatory names like pseudo-science, non-science, supernatural science, and so on. This derogatory attitude stems from the fact that to the óChristianô Africans, whatever is traditional or local is a product of a local deity and therefore, should either not be touched or discussed or should be abandoned. This attitude is very surprising. A look at some events in Igbo thought may be of help here.

To the traditional Igbo, the reality of the spirit world is a sure thing and if they are challenged, a lot of evidence is marshaled forward to prove the existence of these spiritual entities. In the first place, one is likely to be told that the knowledge of the spirits is beyond the capacity of the uninitiated. The Igbo may go to the extent of saying that our natural or human knowledge is limited and as such will not be able to understand the essence of the spiritual world. They hold that human eyes are not mature enough to see the spirits. So, the people will say that one needs to have a special knowledge or faculty and, of course, a certain initiation before one can óseeô with the eyes of the diviner. That is, it is only by means of mystical intuition or sensibility that knowledge of the spirit is possible.

But everywhere, the shrines and symbol of deities and ancestors are littered and they are there for all to see. One may be shown a tree which has just been struck down by a deity, say *Amadioha* (the god of lightening) as evidence of the presence and reality of that deity. Also, the people may bring a newly born baby with a mark. The mark may also have been borne by the dead grandfather when he was alive. This may be a proof that the newborn baby is a reincarnate of the grandfather; a fact which the diviner must have claimed too.

The Igbo also refer to the numerous instances when the words of the deities and ancestors have been confirmed by events happening as they foretold them. For instance, a man is in need of a son and goes to the diviner. The diviner tells him what he must do to appease whichever spirit that has made it impossible for him to, for instance, have a son. The diviner also tells him which doctor (*dibia*) to go to, for medication for the wife after he had propitiated the spiritual power. The man does these things and sooner or later his wife conceives and gives him a son. What other proof does he need to sustain his confidence in the validity of such metaphysical order?

Diviners occupy a very important place in Igbo traditional thought and throughout Igboland, divination cults abound. From early morning till perhaps the end of the day, one finds in chamber of the diviner, several people, waiting in turns, (as if in a waiting room of a medical consultant) to consult the oracle. People want to know why a relation is sick, or why another has died, why a strange thing happened (such as the appearance of a swarm of bees in the house or a long millipede or giant rat is seen in the day, and so on). People want to know which of their dead parents or dead relations returned to them through the birth of their new baby. They want to know if a business venture would be successful or not and when it would be best to embark on it; what to do to achieve something; who stole their missing property; who owns a disputed piece of land; why a new born baby cried throughout the night, or even why a husband beat up his wife. He has never done so before that time. Does he have woman-friend or has the other wife given him medicine to drive the first one away?

These and other problems are referred to the diviners. The diviner usually is not told why a client has come to consult him. By a process of manipulation of his divining songs and esoteric lyrics, and some processes akin to extra-sensory perception, he stumbles on the clientøs problem and how to solve it. The commonest solution is sacrifice to the deity responsible for the problem. From here a priest or a medicine-man takes over, unless the diviner is himself a priest and medicine-man also. If the problem is not solved the client comes back to him or as often happens, he goes to another diviner.

These beliefs hover between traditional science and traditional metaphysics. Knowledge of herbs, roots and other materials that have medicinal effects are available, no matter how imprecise, to the traditional man. Precise quantification and statistical knowledge is very limited. However, through practice, they come to possess vast amount of medical knowledge and were able to solve peopleõs problems to reasonable extent.

Concepts such as *occult* or *speculation* are used to describe knowledge that is scientifically imprecise. But what cannot be doubted is that there is a good deal of success in what the traditional man claims to know and do. A young Norwegian Scholar, Magne Karlsen, who carried out a research in Obosi in Anambra State, Nigeria, had this to write about his experience and encounter with an Igbo traditional diviner:

> I went to Nnabuike for divination about what was about to happen… you donõt ask any questions here. The spirits will tell you what you need to know, and they will tell me what you came here for. You donõt have to tell me anything… Without further notice he started to shake the bowl, thereby turning the items inside in random directions. After every throw, he talked for the spirits. This is where the situation was getting weird. In trying to establish the fact that the spirits were telling me the truth, he started with my family background. I was told that I was the only child, that my parents somehow got divorced and that I did not know my father. That I had a daughter was also revealed, and he found that I was somehow divorced from the mother, just like my own parents. It was also known that the woman now has another child as well, and that her husband was not from my own town, as he said. After all this he went on with the divination about my personal problems. My personality was examined, and so were dreams, my future wife, and my prospects both in Obosi and elsewhere. The funny thing is that the observations revealed to me were as correct as they could be. As it has yet to happen, I cannot say much about this divination about my future. But knowing his accuracy about my past, I fear that this part of the divination may also be correct.[84]

Through the process of induction, Magne Karlsen knew that if what the diviner told him about his past were true, then that of his future would also be true. The traditional theory and practice of divination and the institution of Oracles, *Ogwu* and traditional medicine were critical factors in the attainment of cosmic and social balance as well as in the psychological development and adjustment of individual in traditional society. They are major embodiments in the traditional world-view (*Omenala*) and still remain influential factors in the world-view and life of the modern Igboman.

To a very great extent, Igbo (African) science, though a product of mysticism as has been revealed, serves the needs of the people because it draws from the local content. Igbo (African) science is not a one-way affair, that is, it is not a scheme that has a universal method. It is not as dogmatic as the Western science, which is of the view that there are accepted theories or laws that must be followed strictly. In African science, if an individual is not satisfied with the result he has been given, he may go to another place.

Also, just like the Africans, the Kuhnian paradigms are not dogmatic creeds. Paradigms are not rigid, deductive, logical structures that all practitioners must believe in, articulate, and justify in the same way.[85] Each subspecialty (and people) should develop its local paradigm, as well as its own practical understanding of the global paradigm that characterizes the scientific field as a whole.

Turning to the question of social norms, as those Bachelard sees as governing scientific practice, Canguilhem noted that there are important ways in which societies are similar to organisms and that social norms can have the same sort of necessary force that biological norms do. The biological analogy works, however, only for so-called traditional societies, where there is a set of norms that defines, once and for all, the essential nature and purpose of the society. Modern societies have no such ñintrinsic finality,ò since the question of what should be their fundamental question is contested in principle. A distinguishing feature of a modern society such as ours is dissent regarding basic norms.[86]

Africans can climb high in scientific innovations and ideas by being consistent with the evolution and practice of ideas from local contents. Kuhnǫs account of scientific research is of form wherein continuing competence entails continuing participation, wherein ǿto grasp the relevant technical considerations entails no less than becoming a recognized practitioner in the relevant scientific field.[87]

It was based on the fact that every society ought to evolve her own science, science that agrees with the nature of the people that made Peter Barker, Xiang Chen and Hanne Andersen to agree with Kuhn in terms of science teaching. For them, Kuhn decided that science teaching is built almost exclusively on exemplary problems and concrete solutions rather than on abstract descriptions and definitions.[88] So, Science as a practice is geared towards solving individual, concrete problems and such problems need individual, contextual, concrete solutions.

Science should be a product of locality and culture. In the medical science for instance, two patients from different climes or environments may go for diagnosis. It could be discovered that each of them has fever. The two of them might have coincidentally gone to the same doctor for the diagnosis and subsequent treatment. Because of the universal knowledge of medicine which the doctor has, he may just prescribe to the two of them the same type of medicine. This he may do without considering some factors: the type of food each of them eats, the condition of weather in their environments, the type of clothe each of them puts on, and so on.

It could be discovered that after the receiving treatment, one of them may be cured and the other will still be having that fever. This may be as a result of the fact that their different environments were not óconsultedô while treatment lasted. So, local factors are very important in scientific progress. This can be properly exemplified in Darwin. The same kind of animals were developing different instincts and organs for survival in different environments. The uniqueness of a people is what should define their science, if they want their science to work.

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CHAPTER FIVE

SUMMARY AND CONCLUSION

5.1 Summary

It can be deduced from the foregoing that Kuhnô analysis of scientific progress is premised on his background which is liberal education. This made him to take note of so many things which include:

1. his recognition of the plurality of the Copernican revolution, which according to him, was missed by other scholars;
2. his idea of essential tension, which is seen as a battle between stasis (tradition) and innovation;
3. his pre-paradigm science where scientists start from zero and attempt to build a science from the scratch;
4. his extra-ordinary science, which is created by problems left over by normal science;
5. Kuhnô paradigm science which is agreed upon answers to fundamental questions such as: What kind of things exist in the universe? How do they interact with each other and our senses? What kind of questions may legitimately be asked about these things? What techniques are appropriate for answering these questions? and so on;
6. his ónormal scienceô which is often conducted within an established paradigm;
7. his concept of scientific community, which he defined as a community of persons mutually exchanging ideas, or maintaining intellectual interaction;
8. his idea of textbook science, which Kuhn claimed has been responsible for stifling divergent thinking in favor of convergent thinking.

Also, Kuhnôs concept of paradigm shift was evaluated with the intention of exposing the strengths and weaknesses of his ideas. Kuhnôs defence/response to critics was made bare to really make people understand why he took certain positions. His legacies and the implications of his concept of paradigm shift for Africa were as well looked into.

5.2 Conclusion

In *Heidegger's Philosophy of Science*, Trish Glazerbrook referred to *Basic Problems of Phenomenology* by Heidegger, which states that the object of fundamental ontology as Heidegger envisioned it is being, and the task is the investigation of being in order to secure the sciences in their regional ontology. Regional ontology is the condition for the possibility of any science.[1] Heidegger had held explicitly since *Basic Problems of Phenomenology* that sciences proceed through a regional ontology, that is, a science investigates an object that has been determined beforehand. In this prior determination of its object, a science has its source and its essence.[2] From this, one can infer that the essence of any science is found in a cultural milieu.

In this regard, Chike Aniakor quoting V.Y. Madimbe asks, ñWhy does Africa depend on western epistemological constructions? Does it mean that Africans cannot re-excavate their usable past for the formulation of an African episteme?ò So, for Aniakor, Africa is a product of the epistemological construction of the other. Africans study Europe, but not Africa itself. But to some extent, Africans should not be blamed because for Aniakor, the history of Africa is invariably colored by colonial experience.[3] Chinweizu once wrote that the problem of the 21st century is not the problem of African unity, nor the problem of color line, ñbut the problem of Black African power: how to build it, and enough of it to stop the extermination of Blacks that is now in progress, and to compel the respect of all humanity and guarantee the survival, dignity and sovereign autonomy of the Black African World.ò[4]

For there to be Black African Power that will lead to the survival, dignity and sovereign autonomy of the Black World, Kuhnôs notion of paradigm shift should be acknowledged and practiced. In *Faith and the Politics of Terrorism*, Ayi Kwei Armah reminded Africans that

> The Scholars Chancellor Williams, Cheikh Anta Diop, and Theophilus Obenga have over the past few decades pointed out that the intellectual history of Africa contains enormous reserves of information, some of which could help us make sense of the present and work out strategies for the futureé The information exists. Some of it puts in clear perspective the burning issues of our day, including monotheism, unipolarity, imperialism, globalization, and the culture of terrorism. We can retrieve it by going directly to the languages in which the concepts and images were developed. Knowledge thus retrieved would change our perception of Africa, and our self-perception as Africans, enabling us to leave the suffocating hold in which European domination has locked us, to begin life as a new type of being -- conscious, self-determining, innovative Africans.ò[5]

Africans therefore, need a new African studies that does not just, as Nkrumah recommended in 1963, ñassert the glories and achievements of our African past,ò but a new African Studies that goes beyond that to also guide us to return to the source; to return to pre-colonial African mentality, culturally, spiritually, philosophically and morally; that teaches us to ñdialogue with African culture,ò so that we can draw inspiration from the very heritage that makes people Africans. We need an African Studies that teaches us ancestral models for creating new ways of being African in the world.[6]

The fact is that African research follows closely the symmetry of Western epistemology and constructions. But there is need to discover an adaptive African epistemological locus in indigenous knowledge as a response to global changes in Africa. Kuhnös concept of paradigm shift fits in here and his ideas should be sought for the construction of an *episteme* and science for Africa.

Endnotes

1. Trish Glazebrook, *Heidegger's Philosophy of Science,* (New York: Fordham University Press 2000), 14-15.
2. Trish Glazebrook, *Heidegger's Philosophy of Science,* 240
3. Chike Aniakor, ñGlobal Changes in Africa and Indigenous Knowledge: Towards Its interrogation and contestationò in S.M. Onuigbo (ed.), *Indigenous Knowledge and Global Changes in Africa: History, Concepts and Logic,* (Nsukka: Institute of African Studies, UNN, 2011), 55-56.
4. Chinweizu, ñAfrican Studies, Indigenous Knowledge and the Buildings of a Black superpower in Africaò in S. M. Onuigbo, (ed.), *Indigenous Knowledge and Global Changes in Africa: History, Concepts and Logic,* 39.
5. Ayi Kwei Armah, *Faith and the Politics of Terrorism*. http://globalbreakingnews.com/news/3908/82/faith-and-the-politics-of-terrorism. Accessed on13-10-2015.
6. Chinweizu, ñAfrican Studies, Indigenous Knowledge and the Buildings of a Black Superpower in Africaò in S. M. Onuigbo, (ed.), *Indigenous Knowledge and Global Changes in Africa: History, Concepts and Logic,* 45-46.

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