PHL 433: PHILOSOPHY OF SCIENCE

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PHL 433: Philosophy of Science

General Introduction

PHL 433: Philosophy of Science; is a two-credit unit course for 400 level undergraduates of philosophy in the National Open University of Nigeria. The material is developed to equip the student with the requisite philosophical knowledge of science; its foundations, issues, progress and social functions. The course guide gives an over-view of the course; it informs the students of what the course is all about, and provides information on the organisation and requirements of the course. The course consists of three modules that is made up of 14 units.

The first module will examine the nature of science, the origin and foundations of science, the role of the renaissance in the development of modern science including the separation of science from philosophy. This module will also examine the aims of science, the assumptions of science, the methods of science including the meaning, and aims of philosophy of science. The module will equally analyse the different methods of science. The second module will examine the basic issues in the philosophy of science such as scientific truth, explanation in science, scientific theories amongst others. The third module will look at the progress of science as enunciated by some notable philosophers such as falsificationism by Karl Popper, paradigm shift by Thomas Kuhn, methodological anarchism by Paul Feyerabend amongst others. The social functions of philosophy of science will also be examined in this module.

What you will learn in this Course

The overall aims of PHL 433: Philosophy of science; is to introduce the student to fundamental issues, theories, principles and questions that bother the philosopher and non-philosophers about science. The metaphysical, epistemological and axiological issues concerning science will be espoused through philosophical scrutiny. The understanding of these fundamentals will enable the student to appreciate, explain and critic some basic concepts and issues in and about science.

Course Objectives:

By the end of this course, the student will be able to:

- Understand the meaning, origin and subject matter of science
- Understand the basic assumptions, aims and methods of science
- Establish the link between philosophy and science
- Understand the meaning, aims and purpose of philosophy of science
- Trace the origin and the role of the logical positivists in the evolution of philosophy of science
- Identify some of the basic issues and questions that are raised in philosophy of science
- Understand the notion of explanation in science
- Differentiate between scientific laws and theories
- Note some scientific laws and theories that have shaped the world of modern science
- Identify the different ways by which scientific knowledge can progress and is progressing
- Discuss the contributions of some notable philosophers of science to the growth of scientific knowledge
- Identify the philosophies of science and the social functions of philosophy of science

Working through the course

To successfully complete this course, you will be required to read and study the whole unit and read suggested books and other related materials. Each unit will contain self-assessment exercises. You will be required to do these exercises. The exercises are meant to aid you in understanding the concepts under consideration. At the end of each unit, you will be required to submit worked assignment for assessment. At the end of the course, there will be an examination. The time and venue of the examination shall be communicated to you through your study centre. You will be required to present yourself for the examination.

Course Materials

The major components and materials for this course include:

(i) Course guide

(ii) Study guide

(iii) Text books

(iv) Assignment file

Study units

There are 14 units in this course and it is divided into 3 modules. The first module shall focus on the nature of science and the origin of philosophy of science. The second module will analyse some fundamental issues in the philosophy of science, while the remaining module shall focus on issues concerning the mechanisms of progression in science. The modules and units are presented as follows:

Module 1 The Nature of Science and the Origin of Philosophy of Science

Unit 1 The Nature of Science and the Origin of Philosophy of Science

Unit 2 Philosophy and Modern Science

Unit 3 Methods of Science

Unit 4 The Philosophy of Science

Unit 5 Philosophers of Science – Ancients, Modern and Contemporary

Module 2 Fundamental Issues in the Philosophy of Science

Unit 1	Facts, Truth and Laws in Science
Unit 2	Scientific Theories
Unit 3	Realism, Instrumentalism and Objectivity in Science
Unit 4	Explanation in Science
Module 3	**The growth of scientific Knowledge**
Unit 1	Demarcation between Science and Non-science
Unit 2	Phases of Scientific Growth
Units 3	Anarchist and Holist Notion of Scientific Growth
Unit 4	The Unity of Science
Unit 5	Social Functions of Philosophy of Science

Presentation Schedule

This course has two presentations: one at the middle of the semester and the other towards the end of the semester. At the beginning of the semester, each student undertaking this course will be assigned a topic by the course facilitator which will be made available in due time for individual presentation during forum discussions. On one hand, each presenter will have 15 minutes (10 minutes for presentation and 5 minutes for Question and Answer). On the other hand, students will be divided by the course facilitator into different groups. Each group would be expected to come up with a topic to work on and to submit same topic to the facilitator via the recommended medium. Both will attract 5% of the total marks.

Note: Students are required to submit both papers via the recommended channel for further examination and grading. Both will attract 5% of the total marks.

Assessment

In addition to the discussion forum presentations, two other papers are required in this course. The paper should not exceed 6 pages and should not be less than 5 pages (including works cited), typewritten in 12 fonts, double line spacing, and Times New Roman. The preferred reference is MLA 6th edition (you can download a copy online). The paper topics will be made available in due time. Each paper carries 10% of the total marks.

To avoid plagiarism, students should use the followings links to test-run their papers before submission:

- http://plagiarism.org/
- http://www.library.arizona.edu/help/tutorials/plagiarism/index.html

Finally, all students taking this course MUST take the final exam which attracts 70% of the total marks.

How to Get the Most Out of this Course

- Have 75% of attendance through active participations in both forum discussions and facilitations.
- Read each topic in the course materials before it is treated in the class.
- Submit every assignment as at when due; failure to do so will attract a penalty.
- Discuss and share ideas among class members / peers; this will help in understanding the course more.
- Download videos, podcasts and summary of group discussions for personal consumption.
- Attempt each self-assessment exercises in the main course material.
- Take the final exam.

- Approach the course facilitator whenever you have any challenge in any aspect of the course.

Facilitation

This course operates a learner-centered online facilitation. To support the student's learning process, the course facilitator will: 1. Introduce each topic under discussion; 2. Open the floor for discussion. Each student is expected to read the course materials, as well as other related literatures, and raise critical issues which he/she shall bring forth in the forum discussion for further dissection; 3. Summarize forum discussions; 4. Upload materials, videos and podcasts to the forums; 5. Disseminate information via email and SMS if need be.

References and Further Readings

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MODULE 1: The Nature of Science and the Origin of Philosophy of Science

Unit 1: The Meaning and Origin of Science

1.1 Introduction

What is science, what is its nature and how did it originate? Why did the early philosophers question the veracity of myths in knowledge acquisition and what role did the renaissance scientists play in separating science from philosophy? Is science one or many? This unit will try to give answers to these questions. The unit will take you through a brief historical development of what is today called science. It will consider the role of mythology in the shaping of the contemporary notion of science. The unit will also analyse the role played by the renaissance movement that finally culminated in the separation of science from philosophy. The various branches to which science separated into would also be made clear.

1.2 Objectives

It is expected that after studying this unit, the student will be able to:

1. Understand the meaning of science
2. Trace and connect the mythological origin of science
3. Understand the role of the renaissance in the development of modern science
4. Understand the functions of particular branches of science

1.3 Main Course Contents: The Meaning and Origin of Science

1.3.1 The Meaning of science

Etymologically, the word science is derived from the Latin word *Scientia* which means knowledge. Hornby defines science as knowledge about the structure and behaviour of the natural and physical world based on facts that you can prove by experiments (1051). According to Chambers, scientific knowledge is proven knowledge. For him, scientific theories are derived in some rigorous way from the facts of experience acquired by observation and experiment; it is based on what we can see and hear and touch (1). It should however be noted that there are many definitions of science as there are scientists and philosophers, but they all agree that science is about knowledge of the natural world and man's ability to test out the knowledge to confirm or disconfirm what is believed to be known. Thus, on the simplest level, science can be defined as knowledge obtained by observation and testing of facts. Science as presently conceived is a large body of knowledge that can be misunderstood if one is not properly guided.

1.3.2 Different conceptions of science

There are three basic ways by which science can be conceived. These include: as a body of knowledge, as a method of acquiring knowledge and as an institution.

1. **Science as a body of knowledge**

   As a body of knowledge, science is made up of the various subjects studied in schools such as physics, chemistry, biology, mathematics, micro-biology, pharmacy and medicine. These subjects differ from others such as religion and arts in both content and form.

2. **Science as a method of Acquiring of Knowledge**

   As a method of acquiring knowledge, science has well-defined and known procedures for obtaining knowledge. This procedure is called the scientific method. The method involves a step-by-step approach to solving a natural problem. Anyone that uses these steps in solving empirical problem is said to be engaged in a scientific activity.

3. **Science as an institution**

   As an institution, science is seen as comprising millions of experts involved in scientific activities. The cooperation and interaction among scientists make the development of science possible and reliable. These body of experts helps to regulate the activities of scientist in any given field of science. For example, there is the "International Council for

Sciences" – which is the umbrella body for all science associations and unions in the world. In Nigeria, there is the Nigerian Academy of Science.

1.3.3 The Nature of Science

Science is said to be empirical in nature. What this means is that science deals with empirical phenomena. Here, emphasis is laid on ideas, principles, theories and symbols including the understanding of the behaviour of physical objects. In other words, science is basically concerned with the material and physical world; it is concerned with what could be experienced with the physical senses. Whatever could not be perceived with the sense of sight (eye), touch (skin), sound (ear), taste (tongue) and smell (nose) cannot be considered as science. The empirical nature of science reveals its characteristics and the peculiarities that forms its core mandate.

1.3.4 The Characteristics of Science

For any discipline to be called or included among the sciences, it must embody certain characteristics that will distinguish it from non-science disciplines. These characteristics are basic to science disciplines. They include concreteness, objectivity and universality. Some authors may stretch these characteristics to as much as four, five or six. These three however, encapsulates all that should be present before any discipline can be called a science discipline.

1. **Concreteness –** This characteristic implies that science deals with concrete aspects of reality; aspects that are specific, perceptible and experiential. In other words, components of reality such as rocks, trees, the family, society, man, and so on; are some of the things that can be concretely studied. But spirits, ghosts, angels, witch, wizard,

magic and other imperceptible entities that cannot be empirically studied cannot be called science.

2. **Objectivity –** This characteristic implies that science tries to obtain knowledge of facts. A fact is a proven or verifiable piece of information about things that exist or events that have occurred. This means that what science says about these facts does not depend on one's beliefs, political affiliation, religion or any of the affective dimensions of human beings. Knowledge acquired by science is *out there*. It is not in *us*. It is impersonal and will continually remain so.
3. **Universality** - This characteristic implies that the methods and conclusions of science are open to public scrutiny and practice and can be done in any part of the universe. In other words, anyone that wishes can follow the same methods and procedures that have been publicized to arrive at the same conclusion in any part of the world. The methods and procedures used in America, Europe or Asia to achieve a particular result, if used in Africa or any part of the world, the same result will be achieved; that is the universality of science.

1.4 The Mythological Origin of Science

Science, like every phenomenon in nature, has a beginning. Some authors trace this beginning from a metaphysical perspective, some others trace it from a cosmological perspective while some others, including this author, are of the opinion that the origin of science should be traced through its mythological perspective. Tracing the origin of science from its mythology affords one the honour to understand that scientific knowledge is not the exclusive preserve of any particular region of the world. It makes you to realize that every culture, from the very beginning of time, had a seed of science ingrained in their system by their use of stories to explain their cosmogony, beliefs and natural occurrences.

There are many irregularities in nature that mankind has had to recognize for survival since the emergence of Homo sapiens. For example, the sun and the moon periodically repeat their movements. Some motions like the daily motions of the sun are simple to observe; day and night provide the basic rhythm of human existence; the seasons determine the migration of animals upon which humans depended for ages for survival. With the invention of agriculture, the seasons became even more crucial because failure to recognize the proper time for planting could lead to poor harvest. From this time onward, men began to observe, interpret, experiment and formulate explanations for their observations and experiments. L.W. Pears (32) made a point that the spectacle of the heavens with the clearly discernible order and regularity of most heavenly bodies highlighted by extraordinary events such as comets and the peculiar motions of the planets obviously was an irresistible intellectual puzzle to early mankind and in its search for order and regularity could, do no better than to seize upon the heavens as the paradigm of certain knowledge.

This recourse upon the heavens as the paradigm of certain knowledge by the ancients was manifested in the stories they told. These stories which are today described as myths were used by the ancients to make sense out of complex situations within their cosmological and sociological matrix. And just as science is universal; so is myth. Both are used to make meaning of the many absurdities in the world. However, the period of mythology in the history of Greek philosophy began to change when men such as Thales, Anaximander, Anaximenes, Heraclitus, and Pythagoras amongst others, began to take exception to the activities of the gods in the myths told by Homer and Hesiod. They began to question the plausibility of the claims of the myths and at the same time, they began to speculate and tell contrary stories of their own using the things in nature to describe and explain the occurrences and things in nature which gradually led to the development of modern science. We can therefore surmise that myth was used by the ancients for the explanation of their perception of natural phenomena. Thus, myth can be said to be ways of studying and understanding the world from the primitive stage of observing important regularities in nature to the epochal revolution in the notion of what constitute science in this contemporary time.

In the words of Mark Schorer (355), myths are instruments by which we continually struggle to make our experience intelligible to ourselves. It is a large controlling image that gives philosophical meaning to the facts of ordinary life that has organizing value for experience. For Schorer, it is the chaos of experience that creates myths and they are intended to rectify the chaos of experience. They unify experience in a way that is satisfactory to the whole culture and to the whole personality. The unification of experience in a way that may be satisfactory to the whole culture of a people via mythic imagery also reveals the important function of myth – that of organizing the values and explanations of their myths from their experiences in order to rectify the chaos therein and make sense out of a seeming chaotic experience. In this instance the pre-Socratic philosophers readily come to mind. For example, W.K.C Guthrie made reference to a discussion about the custom of a certain people who abstain from eating fish and how the discussant recounts Anaximander's myth of creation. According to this account:

> Anaximander of Miletus said that in his opinion there arose out of the water and earth, when warmed, either fish or creature resembling fish. In these creatures, men were formed and the young were retained within until the time of puberty; then at last the creatures were broken open and men and women emerged already capable of finding their own nourishment (103-104).

This myth tries to make the point that human embryos grew inside the bodies of fish-like creatures, and later emerged as fully formed men and women in their puberty. This account proceeds by deduction from the hypothesis that all life had its origin in moist slime that is acted on by the heat of the sun, this being in its turn only a particular stage in the evolution of the cosmos by the interaction of opposites. The first living creatures must therefore have been of a kind suited to a moist habitat, perhaps rather like the prickly sea-urchin. A human infant could hardly have survived under these conditions unless some special protection was devised and here the example of the fish came to his mind as a possible solution. So, Anaximander, having shown the fish to be the common father and mother of men, put men off eating fish.

The images painted by Anaximander's myth and the explanation given, show some important functions of myths in its attempt to rectify the experiences and curiosities of a people. First, is the sociological importance; this explains why the people of this particular society abstain from eating certain types of fish. Second is the scientific aspect; here, after a careful observation of the care and nourishment of an infant, Anaximander surmised that man in his formative stages could not have survived the cold, moist and heat inherent in the cosmos alone. Myths were therefore, attempts by the ancients to logically explain their curiosities. The same role science has assumed today.

Myth is a universal phenomenon by which societies explain their experiences of nature and establish their distinct cultural peculiarities. The universality, similarity of concepts and imagery; as well as the historical and pedagogical character of myths establishes the point that myths are indeed the foundation of science from the very beginning. Similarly, it establishes the fact that man has long and persistently been concerned to achieve some understanding of the enormously diverse; often perplexing and sometimes threatening occurrences in the world around him. By his manifold myths and metaphors man has made effort to account for the very existence of life and death, for the motions of the heavenly bodies, for the regular sequence of day and night, for the changing seasons, for thunder and lightning, and sunshine and rain. Some of these explanatory ideas are based on anthropomorphic conceptions of the forces of nature; others invoke metaphysical powers or agents, still others refer to God's inscrutable plans or fate and their duty according to Levi-Strauss (14) is to "play the part of conceptual thinking" and when put into practice, becomes science. But in all these, there is that universal intent by myth makers (whether ancient or modern) to explain nature which incidentally has become the major functions of modern science.

Etymologically myth is derived from the Greek word *mythos* which means 'word' or 'tale' or 'true narrative'; referring not only to the means by which it is transmitted but also by its being rooted in truth. Joseph Campbell opines that "myths offer life models, but the models have to be appropriate to the time in which you are living" (31). For Kees, the functions of models in physics, biology, medicine and other sciences resembles that of myth as paradigms or patterns of the human world. Once a model has gained acceptance, it is difficult to replace and, in this respect, it resembles a myth while at the same time just as in myth, there may be a great variety of interpretation (715-732). That is why for Levi Strauss (21) 'myths give impetus to what we call science'. For Popper, the similarity between science and myth lies in their ability to give explanation for the regularities or otherwise of nature while their differences lie in the attitude with which one accepts or criticizes them (Conjectures,171).

The early philosophers began the tradition of questioning the truth and validity of myths and this led to confining the myths to fictional tales or symbolic stories which has remained the perception of most authors about myth today. It is however pertinent to note here that a traditional story should not be assumed false or irrelevant simply because the proof or evidence to support it has not been found. It is possible that if the story is subjected to empirical investigation, then its plausibility may be established thereby adding to the corpus of the sciences; bearing in mind that myths were means by which the ancients tried to tell, explain or make meaning of complex and perplexing situations of their time. To show that myths could be investigated empirically, Ishaya (2016) in *Myths and the Evolution of Science* cites John Black who writes of the discovery of the city of Troy (a myth in Homer's *Iliad*) in 1868 by the archeologist - Heinrich Schliemann. The discovery of the actual site of the city of Troy elevated the myth to a place in history thereby proving the authenticity of the story. The point here according to Ishaya is that the subjection of a particular myth to empirical or analytical investigation may at the end prove to be of high hermeneutic and analytical importance to the growth of scientific knowledge (218).

1.5 The Renaissance and the Birth of Modern Science

The renaissance was a time of discovery and emancipation. It was a means of enlarging the frontiers of human knowledge and the place of man in the matrix of existence. The Renaissance was a fervent period of European cultural, artistic, political and economic "rebirth". Generally described as taking place from the 14th century to the 17th century, the Renaissance promoted the rediscovery of classical philosophy, literature and art. Some of the greatest thinkers, authors, statesmen, scientists and artists in human history thrived during this era, while global exploration opened up new lands and cultures to European commerce. The Renaissance is credited with bridging the gap between the Middle Ages and modern-day civilization. Some of the most famous and groundbreaking Renaissance intellectuals, artists, scientists and writers include the likes of: Leonardo da Vinci (1452–1519): Italian painter, architect, inventor and "Renaissance man" responsible for painting "The Mona Lisa" and "The Last Supper. Desiderius Erasmus (1466–1536): Scholar from Holland who defined the humanist movement in Northern Europe and translator of the New Testament into Greek. Nicolaus Copernicus (1473–1543): Mathematician and astronomer who made first modern scientific argument for the concept of a heliocentric solar system. During this period, scientific discoveries led to major shifts in thinking. Galileo Galilei (1564-1642): Italian astronomer, physicist and engineer whose pioneering work with telescopes enabled him to describes the moons of Jupiter and rings of Saturn. Placed under house arrest for his views of a heliocentric universe. Rene Descartes (1596–1650): French philosopher and mathematician regarded as the father of modern philosophy and famous for stating, "I think; therefore, I am". Galileo and Descartes presented a new view of astronomy and mathematics, while Copernicus proposed that the Sun, not the Earth, was the center of the solar system, Galileo demonstrated practically with his telescope that Copernicus' proposal was after all real; Descartes on the other hand built a mathematical foundation for the sciences that has remained a fulcrum upon which both philosophy and science is built.

By the early 17th century, the Renaissance movement had died out, giving way to the Age of enlightenment and science. Natural science was now born in its modern form with its emphasis on observation and mathematics. The renaissance was therefore a time when many individuals from different parts of the world exhibited new modes of freedom and expression that brought about discontinuity with the past while changing the emphasis in areas where continuity with the past could be preserved. From this period, mankind looked unto his ability for explanation of events and issues devoid of mythology; whether revealed or imagined and philosophy was roundly separated from theology. This new perspective and attitude to knowledge ushered in the dawn of modern philosophy that gave birth to modern science.

1.6 The Separation of Science from Philosophy

Before the advent of modern science, all knowledge was domiciled under philosophy.

Those aspects of investigations that dealt with physical elements of nature was called natural philosophy. Philosophy and science began to separate with the emergence of the renaissance scientists who brought about fundamental alterations in the world of thought and they achieved this feat by devising a new method of discovering knowledge – the Hypothetico-deductive method. The hypothetico-deductive method is a procedure for constructing a scientific theory that will account for results obtained through direct observation and experimentation. This method laid great emphasis upon observation and the formation of temporary hypothesis. To enhance the exactness of their investigations, they invented various scientific instruments such as the telescope by the Dutchman Tippershey which was refined by Galileo Galilei and put to dramatic use in confirming Copernicus' hypothesis that the sun is the centre of the universe and that the earth rotates daily and revolves around the sun annually. The works of Rene Descartes in 1637 went a long way to formalize the separation of science from philosophy. Philosophy and science finally went their separate way beginning from the 19th century with Mathematics and Physics being the first to leave and followed by other disciplines as the years went by.

1.7 Branches of Science

The sciences can be broadly grouped into two major compartments – The formal and the empirical sciences.

Formal sciences: formal sciences are those sciences that employ some form of calculations to ascertain the validly or otherwise of their conclusions. They include mathematics, logic, theoretical physics and statistics. Formal sciences have a formal and deductive character. Science is formal if its contents, arguments and procedures obey certain rules. Thus, the result and conclusions of such sciences are valid and authentic if and only if they conform to the rules of the discipline. For example, to get any mathematical problem resolved, the rules of addition, subtraction, division or multiplication (BODMAS) must be followed strictly for example, (8+12) – (10+8). The result of the above problem will only be valid and authentic if the mathematical rule of BODMAS is followed. Formal sciences have systematic and deductive character.

Empirical sciences: Empirical science comprise of physics, chemistry, biology, psychology botany, zoology, biochemistry, microbiology, geology, medical sciences, Agricultural sciences, psychology, economics, sociology amongst others. These disciplines study objects and natural phenomena which can be observed through any of the senses and which can be tested with instruments such as telescope, microscope, ruler, binoculars, tapes and scales. Anything that cannot be observed with the five senses of touch, sight, sound, taste, and smell or cannot be tested with instruments is said to be outside the domains of empirical science.

The empirical sciences are further divided into two based on the objects or phenomena they study – namely, the natural sciences and the social sciences.

1.8 Classification of Empirical Science in the Order of Object they Study

The Natural Sciences – These deal with natural objects; not man-made.

Under the natural sciences include: physical science; biological science; medical science; and pharmaceutical science.

2. **The Social Sciences** – This branch of science deals with the study of human society; its institutional creations, behaviour and interpersonal relationship of individuals as members of society. They include: Economics; Social psychology; Geography; Sociology and anthropology; and political science.

1.9 Conclusion

In this unit, we defined science as knowledge obtained by observation and testing of facts. The different conceptions of science were also analysed. This includes science as a body of knowledge, as a method of acquiring knowledge and as institution. The basic characteristics of science that distinguishes science from non-science was also x-rayed in the unit. The origin of science was traced from myths. Myth was defined as the stories told in ancient cultures to explain a practice, belief or natural occurrence. The relevance of myth to knowledge acquisition was halted by the renaissance philosophers whose philosophies and activities led to the separation of philosophy from science and the subsequent disintegration of science into several branches beginning with mathematics and physics in the 19^{th} century.

1.10 Summary

Etymologically, the word science is derived from the Latin word *Scientia* which means knowledge. It is knowledge obtained by observation and testing of facts. The three basic characteristics of science include concreteness, objectivity and universality. Myths are stories told in ancient cultures and used to explain a practice or natural occurrence. It is what gave impetus to what we call science today. The renaissance was a time when many individuals from different parts of the world exhibited new modes of freedom and expression that brought about discontinuity with the past. Science separated from philosophy in the 19^{th} century beginning with mathematics and physics. Science is divided into branches that include formal and empirical sciences

1.11 Self-Assessment Exercise

2. What is science?
3. Explain the role of mythology in the development of science
4. What is your understanding of the renaissance?

5. What is the difference between formal science and empirical science?

1.12 Model Essay Answer to Question 1:

Etymologically, science comes from the Latin word – Scientia. Scientia in Latin means knowledge. It is therefore defined as knowledge obtained by observation and testing of facts. What this means is that scientific knowledge is based on what is seen, experienced and tested. Science has some characteristics that distinguishes it from other knowledge disciplines, they include; concreteness, objectivity and universality. Concreteness means that science studies what is physical, objectivity means that it deals with facts, not fictions; universality means that products of science is universal.

1.13 Tutor Marked Assignment

1. Science is derived from _____ word? A. Chinese B. Spanish C. Latin D. French
2. Empirical Science is divided into 2 namely: A. Natural science and social science B. Natural science and formal science C. Natural science and biological science D. Natural science and theoretical physics
3. What method did the renaissance scientist bring for the discovery of knowledge: A. Speculative method B. Critical method C. Inductive method D. Hypothetico-deductive method
4. Which were the first science disciplines to be separated from philosophy? A. Chemistry B. Mathematics and Physics C. Economics B. Psychology

Answers: 1 – C. 2 – A. 3 – D. 4 – B

1.14 Works Cited/Further readings

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MODULE 1: The Nature of Science and the Origin of Philosophy of Science

Unit 2 Philosophy and Modern Science

2.1 Introduction

What is the nature of philosophy and why is it critical in knowledge acquisition? How and why was the transition from philosophy to science championed by philosophers? What was the contention of the empiricists against the rationalists in founding a firm foundation for science? What are the aims and assumptions of science? This unit will try to give answers to these questions. The unit will take you through a brief analysis of the nature of philosophy and the notion of modern science. Here, the rationalist and empiricists contributions to the development of modern science will be elucidated. The aims and assumptions of science shall be critically analysed.

2.2 Objectives

It is expected that after studying this unit the student will be able to:

5. Understand the nature of philosophy
6. Explain the notion of modern science
7. Identify the role of rationalism and empiricism in modern science
8. Differentiate between the aims and the assumptions of science

2.3 Main Course Contents: Philosophy and Modern Science

2.3.1 The nature of Philosophy

Philosophy began when humans began to wonder and ask fundamental questions such as what are things really like and how can we explain the process of change in things? What prompted these questions according to Stumpf was the gradual recognition that things are not exactly what they seem to be, that appearance differ from reality (1). Thus, the nature of philosophy is the nature of wonder and curiosity. A philosopher is one that takes more than a passing glance at issues and makes effort to rationally and critically proffer solution to identified problems.

As a rational enterprise, philosophy seeks to eradicate every taint and vestige of ignorance, superstition, prejudice, blind acceptance of ideas and any form of irrationality from humans using human faculty of reason. With reasoning, philosophy challenges ideas, analyzes them and tests them in light of evidence and arguments. While the different sciences deal with different aspects of reality, philosophy endeavors to connect a synthesis of the entire universe with all its elements and aspects and their interconnectedness. It is not contented with a partial view of the world; it rather seeks to have a synoptic view of the whole of reality.

As a critical enterprise, philosophy does a critical and analytical study of the general problems that arise from metaphysical, conventional, and traditional beliefs, including epistemological claims and practices. This aspect of philosophy explains its core areas of interests of study that include (1) metaphysics – the study of being and reality (2) epistemology - the study of knowledge and (3) axiology – the study of values; moral and aesthetic. It carries out these studies using logic as a tool. Logic is the tool the philosopher uses to distinguish incorrect reasoning from correct reasoning. The notion of modern science is founded on the principles of logic.

2.3.2 The Notion of Modern Science

The modern period of science began with the renaissance. Before the renaissance, there was the Pre-Socratic period, the Socratic period, and the medieval period. Modern science is a phrase used to describe a period when science developed its own methods of discovering reality different from the inconsistencies of previous periods. This was the period according to Ozumba, "that philosophy once again stepped out of the trammels of authority worship and took on the garb of criticality". The evolution of the heliocentric perception of reality against the geocentric perception of the ancients and the church marked a revolutionary turning point in intellectual advancement and inquiry. The Ptolemaic tradition had held sway before now, putting the earth at the centre of the universe. The astronomical calculations and observations done with the aid of telescope provided what was considered a better view of reality. A view based on evidence and not tainted with mythic imagery. Now, the sun became the centre of the universe with the earth and other planets rotating around it.

Thus, the modern period was a period marked with an avalanche of tradition-demolishing inventions and theories. During this period, scholars were determined in their bid to give the world a method of discovering knowledge that was different from mythology, scholasticism and philosophy. For example, Francis Bacon who Stumpf described as the advocate of modern method of science made a case for disengagement from the moribund philosophy of the scholastics and the slavish attachment to the authorities of Plato and Aristotle to a scientific method of learning. He identified certain distempers of learning that clog the advancement of knowledge. These distempers include: (a) fantastical learning – the practice in intellectualism that emphasizes the use of ambiguous words than matter, (b) delicate learning – undue reference and acceptance of earlier authors such as Plato and Aristotle, and (c) contentious learning – basing one's views uncritically on the beliefs, positions and world views of earlier thinkers.

Francis Bacon believes that the impediment to knowledge growth apart from the distempers is the corruption of the human mind by idols; idols that make it difficult for man to freely exercise his liberty in thought. These idols of the mind include; the tribe, the cave, the market and the theater. The idols of the tribe are humanity's preoccupation with opinions following from the false assertion that the sense of man is the measure of all things. Here, according to Stumpf, Bacon wanted to make the point that simply looking at things is no guarantee that we shall see them as they really are because we bring our hopes and fears, prejudices and impatience to things and thereby affect our understanding of them. The idol of the cave is an appropriation of Plato's allegory of the cave. Here, Bacon implies the limitations of the untrained mind which is shut in the cave of its own environment of customs, myths, traditions and opinions. The idol of the market place stands for the words people use in the activities of daily life, words that are common in daily conversation. In spite of their usefulness, words according to Bacon can weaken knowledge because they are not created with care and precision. Finally, the idols of the theater are the systematic dogmas of longstanding philosophic treatises representing worlds of their own creation after an unreal scenic fashion. Stumpf makes the point that Bacon wants to include here not only whole systems but all principles or axioms in science that by tradition, credulity and negligence have come to be received. Having explained these idols as inhibitions to knowledge, Bacon therefore counsels that there is need to keep the mind clean of the encumbrances of these idols (223).

2.3.3 The Rationalist

One philosopher that seems to have taken the admonition of Bacon to heart is Rene Descartes. He gave himself the task of constructing a firm foundation for the sciences. In his *Discourse on Methods*, Descartes felt disappointed at his education. This disappointment set the agenda for his philosophy. As a graduate of one of the best schools of his day and seeing himself among the ranks of the learned, he was embarrassed by doubts and errors, and came to the conclusion that there was no scholarship in the world as he had been made to hope and that in all he had been taught; nothing was indispensable. According to him "I found myself involved in so many doubts and errors that I was convinced I had advanced no farther in all my attempts at leaning than the discovering at every turn at my own ignorance".

With this discovery, Descartes concluded that apart from mathematics, because of the certainty and self-evidence of its reasoning, every other subject was dispensable. Therefore, he decided to set mechanisms in order to establish a firm foundation for indubitable knowledge especially in the sciences. And the outcome was the methodic doubt. Using this method, Descartes vowed to dispense with all his previous learning, arguing that the confusion in the sciences arose from the fact that they had been built up by many people over a long period of time. Asserting that there is usually no order or plan in houses or cities built by successive generations in contradistinction to those that are the work of one man. He therefore decided that to bring clarity and system into the sciences; the best way to start, was to make a clean sweep of the old and begin anew. Stating that: “I finally believe that in this way I should much better succeed in the conduct of my life than if I built only upon old foundation, and leant upon principles which in my youth I had taken upon trust”.

Descartes desire to build on a new foundation made by himself had many implications which he was prepared to surmount. One of such implications was the overthrow and rejection of the authority and reputation of traditions long established. Not even the authority of Aristotle could dissuade him from pulling down the knowledge edifice. For him, everything should be doubted and treated provisionally as false in order to reach the truth. He avers:

> Because I wish to give myself entirely to the search after truth, I thought that it was necessary for me to adopt an apparently opposite course and to reject as absolutely false everything concerning which I could imagine the least ground of doubt in order to see whether afterwards there remained anything in my beliefs which was entirely certain.

Through this process, Descartes established some foundational blocks upon which to commence the reconstruction of his new knowledge edifice but not without setting in place rules that will guide the builders. He decides:

First: Never to accept anything as true if I had no evident knowledge of it being so; that is, to accept only what presented itself to my mind so clearly and evidently.

Second: To divide each of the difficulties under examination into as many parts possible and as might be necessary for its adequate solution.

Third: To conduct my thoughts in such order that by commencing with objects the simplest and easiest to know, I might ascend by little and little … to the knowledge of the more complex….

Fourth: In every case to make enumerations so complete, and reviews so general that I might be assured that nothing was omitted.

With these guidelines, Descartes averred that the chief ground of his satisfaction with this method was the assurance he had of thereby exercising his reason in all matters, if not with absolute perfection, at least with the greatest attainable by him. Besides, he was conscious that by its use, his mind was becoming gradually habituated to clearer and more distinct conception of objects. Thus, with this method, Descartes was sure of arriving at certain and indubitable truth in the sciences or any area of knowledge claim. But before it could be applied to the sciences, he decides to experiment it by ascertaining the certainty of his personhood. He found this certainty in the affirmation – *Cogito ergo sum* - 'I think therefore I am'. This truth was for him, so solid and so certain that all the most extravagant suppositions of the sceptics were incapable of upsetting it and he judged he could receive it without scruples as the first principle of the philosophy he sought. No matter how much he could doubt, he must exist without which he cannot doubt. In *cogito ergo sum,* Descartes found a doubt-proof truth that cannot suffer the corroding influence of both natural and hyperbolical doubts. Descartes' view is that even if he is deceived, he must exist in order to be deceived and if he is dreaming, he has to exist in order to dream.

In his *The Principles of Philosophy*, Descartes states that 'I think therefore I exist' is the first and most certain of all which occur to one who philosophize in an orderly way. It is an indubitable truth, solid and firm enough and on which he proposed to build his philosophy. The success of this method earned him the sobriquet – father of modern philosophy. This method of arriving at scientific truth is known as rationalism. Other rationalists after Descartes include; Baruch Spinoza, and Gottfried Leibniz

Arguments against Descartes: the place of background knowledge

But the question that quickly comes to mind following Bacon's admonition and Descartes methodic doubt is: will the rejection and abandonment of the myths, traditions and authorities of the past lead to certain knowledge that will be devoid of the corruptible tendencies of context, space and time? We shall answer in the negative. This is because we believe that myths of the ancients are important background knowledge for the development of new ideas. Myths should not be seen as servile enslavement but as fidelity; that is, the acknowledgement of the contributions of the past and as a source of background knowledge for the advancement of the frontiers of knowledge.

2.3.4 The Empiricist

The acknowledgement of past experiences as the fulcrum of knowledge growth by philosophers outside the rationalist bent is known as empiricism. Empiricists believe that experience should be the guiding principle in knowledge acquisition and growth. Empiricists include John Locke, David Hume and George Berkeley. In the *Essay Concerning Human Understanding*, John Locke set out to inquire into the origin, certainty, and extent of human knowledge. He assumed, according to Stumpf (267) that if he could describe what knowledge consists of and how it is obtained, then he could determine the limits of knowledge and decide what constitute intellectual certainty. He arrived at the conclusion that knowledge is restricted to ideas, not Plato's ideas or forms, but ideas that are generated by objects of experience. For him, the origin of ideas is experience. This experience takes two forms – sensation and reflection. All ideas come to us through the senses whereby we experience the world external to us and through reflection upon these ideas which is an experience internal to us. In other words, we cannot have the experience of reflection until we have had the experience of sensation.

Locke was opposed to the existence of innate ideas; being aware of Descartes' arguments of the *cogito ergo sum*, he felt that the issue of innate ideas – the notion that in some way, we all come into the world with a standard stock of ideas built into the mind – should be discountenanced. He assumed, against the rationalist concept of innate ideas, that it is experience that furnishes the mind with knowledge. Arguing that if the mind was equipped with innate knowledge as the rationalist posits; then idiots and even children will not have to wait till maturity to be knowledgeable about things and issues. For him, experience is the means by which knowledge is obtained. According to him, "Let us then suppose the mind to be as we say, white paper, void of all characters, without any ideas: - How comes it to be furnished? …whence has it all the materials of reason and knowledge? To this I answer, in one word, from EXPERIENCE". Experience is what furnishes man with all the materials of reason and knowledge. Locke believes that man will grow in his quest for the advancement of knowledge if he looks outward to find truth rather than looking inward like the rationalists for certainty.

2.4 Basic Assumptions of Science

Science as already established in this unit, is a consequence of the renaissance; it should however be conceded that its development was a gradual process that began from the ancient period through the medieval period to a strong foundation in the modern period. From the very earliest beginnings, reality was (is) very complex and complicated. No one could claim to know everything or was (is) able to have a complete understanding of everything. So, to have a base from which experiments and research could be initiated, scientists assumes that nature operates in some presupposed fashion. A scientific assumption is the pre-supposition that the physical world operates in a predictable fashion. It is by these assumptions that philosophers of science raise metaphysical, ethical and axiological questions. These assumptions include that:

1. **Nature operates uniformly throughout the universe in time and space:** When we speak of the uniformity of nature, we speak in terms of regularity, pattern, and structure. For example, when we look at the seasons (rain and dry) we assume that it is not just a random behaviour. We justify this assumption through observation by noting the patterns of behaviour, and thereby come to conclusions about their behaviour. The same applies to other natural phenomena in time and space.
2. **The world is real:** The physical universe exists apart from our physical experiences. Natural science assumes that the physical world is real and that we can learn about the world and natural law through observing it.
3. **All phenomena have natural causes:** Natural science assumes that nothing we see is unnatural. If it occurs within nature, then it is a natural occurrence, and if it is a natural occurrence, then we assume that it obeys some natural law, and that by observing it, we can learn about it.
4. **Nothing is self-evident:** The advancement of knowledge requires that we assume something we know could be wrong, and if that is the case, we should test it to see if it is true.
5. **Knowledge is derived from acquisition of experience:** Science assumes that learning is done through experience or observation. For example, we observe the season every year, and so predict that, based on past experiences, the rainy season will come and then the dry season.
6. **Knowledge is power:** This is a motivational assumption postulated by Francis Bacon. In this postulation, natural science assumes that knowledge of nature gives one power and

mastery over it. Knowing more is better than knowing less. This is why we have schools and universities to transmit knowledge from one generation to another generation.

These assumptions of science are common-sensible, and they have held true over the years. After all, if these assumptions were not assumed to be true, then science itself could not have been successful in generating knowledge. We should note however that these are only the broad assumptions that natural science is based. There are other, far more specific assumptions that come into play in specific existential situations. (The Basic Assumptions of Science is a part of a paper I published in the Cape Coast journal of Humanities, 2020).

2.5 Aims of Science

From the beginning of time, man has made serious effort to understand himself and his environment. He sees the world around him which has remained the same world and yet is full of change, motion and objects. There are very many different things in the world; minerals, plants and human beings. There are nights and day, births and deaths, the earth and seas among several phenomena that are too wonderful to comprehend. The desire to comprehend and in most cases alter the many complexities of the universe encapsulates the aims of science. Thus, science aims to explain, predict, discover, control and help society to develop and overcome the perplexities of nature.

Explanation: Science aims to enable man explain how the world, events and objects around him originate, develop, operate or function.

Prediction: Science aims to enable man predict the future. For example, meteorologist predicts weather conditions. Medical sciences predict possible out breaks of disease in specific conditions and environment.

Discovery: science aims to discover the principles of nature. The discoveries help man to improve his knowledge of the world for example, the principle of gravitation, relativity and quantum mechanics.

Control - science enables man to control the behavior of objects and phenomena in nature.

Development - Science aims to help the growth and development of people and society via the use and application of its knowledge.

2.6 Conclusion

In this unit, we looked at the nature of philosophy and affirmed that philosophy has the nature of wonder and curiosity, rationality and criticality. That a philosopher is one that takes more than a passing glance at issues and makes efforts to rationally and critically proffer solutions to them. The notion of modern science was also elaborated including the rationalist and empiricists conceptions of reality that formed the fulcrum of what is today known as modern science. The assumptions of science were analysed including the aims of science. Among the aims of science is the growth and development of human beings and society.

2.7 Summary

Philosophy is a rational and critical discipline that has the nature of wonder and curiosity and modern science is a phrase used to describe a period when science began to develop its own method of discovering reality. Francis Bacon was of the opinion that there is need to keep the mind clean of the encumbrances of idols. Rene Descartes and John Locke represents the rationalist and empiricists methods of arriving at the true knowledge of nature. Scientific assumption is the presupposition that the physical world operates in a predictable fashion. Science aims to explain, predict, discover and control the complexities of nature.

2.8 Self-Assessment Exercise

1. Examine the nature of philosophy
2. How did modern science begin?
3. Describe Francis Bacon's distempers of learning and the idols of the mind.
4. What is the difference between Rene Descartes and John Locke's methods of discovering reality?
5. State and explain 4 assumptions of science.
6. Identify and discuss the aims of science.

Model Essay Answer to question 5

The assumptions of science are the presupposition that the physical world operates in a predictable fashion. The following are the basic assumptions of science: 1. That nature operates uniformly in time and space 2. That the world is real. 3. That all phenomena have a natural course. 4. That knowledge comes from experience. This can be explained thus; 1. That nature operates uniformly is in terms of the regularity, pattern and structure observed in the universe. 2. Science assumes that the physical world and things in it are real. 3. Everything that happens in nature have a cause. 4. Science assumes that knowledge can only be gotten from experience.

2.9 Tutor marked Assignment

1. Modern science is the offshoot of __________ period of philosophy? A. Medieval B. Pre-Socratic C. Renaissance D. Socratic

2. The following are the distempers of learning according to Francis Bacon except: A. Fantastical learning B. Delicate learning C. Contentious learning D. Empirical learning

3. Rationalism is to Rene Descartes while empiricism is to _________ A. Baruch Spinoza B. Gottfried Leibniz. C. John Locke. D. Karl Marx

4. Science aims at the following except: A. Explanation B. Prediction C. Aesthetic judgement D – Discovery

Model Answers: **1 – C. 2 – D. 3 – C. 4 – C**.

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MODULE 1: The Nature of Science and the Origin of Philosophy of Science

Unit 3: Methods of Science

3.1 Introduction

Beginning from the renaissance, modern philosophy was no longer about abstract reasoning, it was more of a process of investigating nature with reason and sense derived from experience. A number of philosophers had begun to warn against blind faith in old authorities – be it religious doctrine or the natural philosophy of Aristotle. The belief that investigation of natural phenomena must be based on particular methods was taking shape especially after the works of

Francis Bacon and Rene Descartes. The modern philosophers and scientists were of the firm belief that the acquisition of knowledge should not be a haphazard affair; that it should be done methodically. But what is a method? What is a scientific method? Is the scientific method one or many? What is the motivation of the scientist in his / her quest to interpret nature methodically? Attempts shall be made to answer these questions in this unit.

3.2 Objectives

It is expected that after studying this unit the student will be able to:

9. Understand the notion of method and the scientific method
10. Differentiate between deductive and inductive methods of science
11. Identify other types of methods used in the sciences
12. Identify elements of the scientific method
13. Understand the motivations of the scientist

3.3 Main Course Contents: Methods of Science

3.3.1 What is a method?

Scientists tell us that the earth is flat and revolves around the sun; that bodies in the universe exerts a gravitational attraction on every other body. But how do scientists reach these conclusions? The answer of course is that scientists arrive at these kinds of conclusions by a process called the scientific method. The word method comes from the Latin word – *methodus* which means a systematic procedure, technique or mode of inquiry employed by a particular discipline.

3.3.2 The Scientific Method

The scientific method is the systematic procedure for the correct interpretation of natural phenomena. Also known as scientific reasoning, the scientific method is a series of steps followed by scientific investigators to answer specific questions in specific ways about the natural world. In other words, the scientific method is organized in such a manner that it helps the scientist to identify problems as well as the process to getting the problems resolved. It is simply the general procedures of carrying out research in the sciences. These procedures may include a number of steps or phases. For example, Aigbodioh (24) notes the differences in the procedures of the scientific method between Ackoff, R.L et-al and A. D'Abro. Acknoff et-al identifies; observation, generalization and experimentation as the three traditional phases of scientific research while D'Abro list observational stage, experimental stage, theoretical and mathematical stage as his own variant of the scientific method. From these examples, we can deduce that scholars and researchers are not unanimous about the exact number of research stages in scientific methodology. The point to note however is that no matter the number of stages or procedural steps taken by a particular researcher or scientist, the underlying aim always is to provide a clearer picture of reality. The challenge of providing a clearer picture of reality using a dedicated method started with the early philosophers. The history is traced from the Ionian thinkers – Thales, Anaximander and Anaximenes, the Atomists, the Pythagoreans, the Socratics, the Rationalists, the Empiricists, the Logical positivists and philosophers of science of contemporary times such as Popper, Kuhn, Feyerabend amongst others. It is however important to note that the scientific method is hinged on two fundamental methods championed by Aristotle – the deductive and inductive methods. These two methods are central and pivotal to other methods or procedures adopted by modern scientists.

3.3.3 The Deductive Method

This is the method used to explore and investigate a known theory or phenomena to test if the theory is correct in a given circumstance. It is a method of drawing conclusions from general principles to particular instances or from cause to effect. The basic elements of the deductive method according to Stumpf were analysed and systematically organized by Aristotle for the first time through his doctrine of syllogism. Aristotle defines syllogism as "discourse in which certain things being stated, something other than what is stated follows of necessity from their being so. This is the principle of implication; Aristotle was concerned that scientific discourse should proceed from one valid step to another with precision. Although Aristotle's doctrine of syllogism is a tool for determining which relationships between premises and conclusion have consistency, his chief interest in developing the syllogism was not simply to assure consistent reasoning but to provide an instrument for scientific demonstration (86). A typical example of the deductive method as developed by Aristotle can be expressed thus:

All Nigerians drink Pepsi cola

Okon is a Nigerian

Therefore, Okon drinks Pepsi cola

That Okon drinks Pepsi cola is a deductive inference because the argument has the following property: if the premises are true, then the conclusion must be true too. In other words, if it is true that all Nigerians drink Pepsi cola, and Okon is a Nigerian, then it follows that Okon does indeed drink Pepsi cola. What makes the inference deductive is the existence of an appropriate relationship between premises and conclusion namely that if the premises are true, then, the conclusion must be true too. Deduction begins with an expected pattern that is tested against observation. It is often described as following a 'top-to-bottom approach'. This is because you start with a theory, narrow it down to a hypothesis, observe the hypothesis and ultimately reach a logical affirmation. Its major advantage is that it tries to explain causal relationships between concepts and variables. Also, the conclusions of deductive reasoning are almost and always guaranteed to be true if all the original premises are true in all situations and if the reasoning applied is correct. For example, the argument that:

All men are mortal

Socrates is a man

Therefore, Socrates is mortal

will always be true to the extent that no mortal man has yet been found to be immortal.

3.3.4 The Inductive Method

The Inductive method is a method that involves drawing conclusions from detailed facts to general principles. The method starts with many observations of nature with the aim of finding a few logical statements about how nature works. In inductive methodology, we move from premises about objects we have examined to conclusions about objects we have not examined. Just like the deductive method, Aristotle equally played a major role in analysing induction systematically even though it is argued that there are about four different senses to his type of induction (Galik, Researchgate). The inductive method is often called a 'bottom-up-approach' because you start from a particular observation, detect patterns, formulate a hypothesis and then reach a general conclusion. In inductive reasoning, the truth of the premises does not mean that the conclusion is true as well. For example:

The first six star-apples in the basket were rotten

All the star-apples have the same expiry date stamped on them

Therefore, the seventh star-apple will be rotten too.

A look at the argument above may tend to look like a true state of affairs with all the star-apples in the basket. But it is not. Even if the first six star-apples are indeed rotten and all of them do indeed have the same expiry date stamped on them, this does not guarantee that the seventh star-apple will be rotten too. It is quiet probable that the seventh star-apple will be perfectly good. In other words, it is possible for the premises to be true and yet the conclusion is false. In the example above, the conclusion will be false if it is found that the seventh star-apple is in good condition. The conclusions of inductive method of science are always probable. But between deductive and inductive methods, scientist tend to make more use of the inductive method because they use it to form hypothesis and theories. And then use the deductive method to apply the theories to specific situations.

3.3.5 Other Methods of Science.

There are other methods that can be used or is used by scientists to achieve specific results. These other methods include the historical method and Marxist method amongst others.

The Historical Method

The historical method of science employs the systematic study of historical facts to explain human, political and social behaviour. This method uses comparison to recapture details, personalities and ideas of years gone-by. There is however a difference of opinion regarding the acceptance of the historical method as a truly scientific method because it does not permit enough precision and objectivity; yet there is a consensus that historical research has much to contribute in the field of library and information science. Among the criticisms against the historical method is the argument from silence – the reasoning in which the failure of a known source to mention a particular fact or event is used as a ground of inference to conclude that the supposed fact or event is untrue or did not happen. Another criticism is that it is easy to read the present into the past.

The Marxist Method

Marxism is a method of socio-economic analysis that uses a materialist interpretation of historical development known as historical materialism to understand class relations and social conflicts as well as dialectical perspective to view social transformation. It originates from the works of Karl Marx and Friedrich Engels. Marx thought that the human sciences and the natural sciences are governed by essentially the same methods, that natural-scientific theories give us enhanced insight into reality, and that our most fundamental views are subject to revision through scientific inquiry. While traditional empiricists emphasize the economical description of empirical regularities which could, in principle, be used to predict the occurrence of observable phenomena, Marx and Engels emphasises that science itself moves in a dialectical way from induction to deduction, from analysis to synthesis and from concrete to the abstract and back again (culturematters.com). The two processes of induction and deduction for them are inseparable and lead to a progressive refinement of theory as the best explanation of society supported by the scientific community.

3.3.6 Elements of Scientific Method

The elements of scientific method involve a series of processes. It could be three or more processes depending on the nature of the research. These processes are characterized by sequence of steps that enable scientists to approach objective truth as near as possible. These steps which can be described as the basic elements of the scientific method include amongst others the following: observation, problem definition, hypothesis formulation, experimentation, conclusion and theory formulation.

Observation – There are two types of observation: direct and indirect observations. Direct observation is made with the aid of the five human senses of sight, touch, feeling, sound, and taste. Indirect observation is made with the aid of instruments such as telescope, microscope and so on. For instance, atomic nuclei and magnetism cannot be perceived directly with the sense organs but their effects can be observed with instruments.

Definition of Problem – Here, the observed phenomenon is defined and pertinent questions raised. For questions posed to be of value and relevant to science; such questions must be testable.

Formulation of Hypothesis – A hypothesis is a guess or proposal made to explain questions about observed facts. Many possible guesses are made and carefully tested to ascertain the most possible solution to a problem.

Experimentation – This is the act of conducting a controlled testing of an idea or guess. Experimentation can provide necessary evidence and anyone who undertakes the experimentation of given hypotheses becomes truly 'scientific' in his/her approach.

Conclusion – This step in the process is the stage where the questions raised in the second step is answered after a successful experimentation. The problem is pronounced temporarily solved. The solution is temporary because there is no absolute truth in science.

Theory formulation – A scientific theory is an explanation of the cause or causes of a broad range of related phenomena. A theory is proposed when a hypothesis has been supported by convincing evidence. In other words, when an experimentation confirms a specific hypothesis and a conclusion reached, then a theory is proposed based on the evidence of the experiment. This evidence could be obtained in laboratories and by many independent researchers in any part of the world. A theory can be discarded as soon as a new and contrary information is observed. For example, the Ptolemaic geocentric theory of the universe was replaced by the Copernican heliocentric theory. The geocentric theory held that the earth is the center of the universe whereas the heliocentric theory argues that the sun, rather than the earth is the center of the universe. The Heliocentric theory is still valid to date. The beauty of science however, is that its methods and processes are not etched on stone – a scientist can begin with any method or step deemed necessary to achieve a particular purpose.

3.3.7 The Motivation of the Scientist

There is always a driving force behind any extra-ordinary efforts to investigate, explain or change the course of nature. The scientists' quest to investigate, explain, control and change the course of nature is stimulated by the following:

1. **Curiosity** – what drives the scientist when he/she is acting as one is the longing to know and understand. He/she is curious to understand the workings and wonders of nature.
2. **Demand for verification** – the scientist is not content with the outcomes of stories, or events, rather, he/she desires always, to verify the cause, effect, authenticity or plausibility of a story, event or phenomenon.
3. **Respect for logic** – the scientist is always motivated by the logicality of explanations. Scientific explanations are logical. The scientist has no regard for disjointed and illogical explanations.

These motivations are essentially good for young people to embrace and that is where the use of philosophical skills becomes very imperative. Philosophy enhances one's curiosity, teaches one the art of dialectics and logical competence. This is why no nation can develop above its philosophy. To motivate the youths to think scientifically and to ask pertinent questions, philosophy must be the chief cornerstone.

3.4 Conclusion

In this unit we discussed the notion of method and the scientific method. The scientific method is a systematic procedure for the correct interpretation of natural phenomena. The different types of scientific methods were unveiled including the deductive and inductive methods which we agreed are the two fundamental methods of the sciences. The elements of the scientific method were also analysed. These elements consist of steps or processes by which scientists arrive at the conclusions of their findings or research. These processes are not etched on stones; a scientist can begin from any of the steps to achieve a set goal. We equally discussed the motivations of the scientist that include curiosity, demand for verification and respect for logic.

3.5 Summary

The word method comes from the Latin word – *methodus*. It means a systematic procedure, technique or mode of inquiry employed by a particular discipline. There are two basic methods of the sciences: the deductive method and the inductive method. Other methods include the historical and Marxist methods. The scientific methods have elements that involve a series of processes that include – observation, definition of problem, formulation of hypothesis, experimentation, conclusion and theory formulation. The motivation of the scientist include: curiosity, demand for verification, and respect for logic

3.6 Self-Assessment Exercise

1. Define the scientific method.
2. Differentiate between deductive and inductive methods?
3. What are the criticisms against the historical method? Do you agree with the criticisms?
4. State and explain the elements of scientific methods.
5. Evaluate the motivations of the scientist.

Model Essay Answer to Question 3

The criticisms against the historical method of science include; 1. The argument from silence and 2. Reading the present into the past. The first argument implies that the failure of a known source to mention a particular event is used as a ground to conclude that the supposed event did not happen. The second criticism implies that one can deductively use present events to conclude that since the same event happened in the past, all things being equal, the past, is therefore responsible for the present events. I agree with the second criticism but disagrees with the first because the failure to mention a previous fact should not be used as a ground to reject a present fact.

3.7 Tutor Marked Assignment

1. The scientific method is a systematic procedure for the correct _________ of natural phenomena. A. Discovery B. Interpretation. C. Invention. D. Experimentation.
2. The following are elements of the scientific methods except: A. Observation. B. Experimentation. C. Criticism. D. Theory formulation.

3. The Marxist method was developed by ______ A. Karl Marx and Friedrich Engels. B. Karl Marx and Friedrich Hegel. C. Karl Popper and Imre Lakatos. D. Thomas Kuhn and Paul Feyerabend.

4. The scientist is motivated by __________ A. Discovery B. Invention C. Experimentation. D. Curiosity

Answers: 1. – B. 2. – C. 3. – A. 4. – D

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MODULE 1: The Nature of Science and the Origin of Philosophy of Science

Unit 4: The Philosophy of Science

4.1 Introduction

Before the final separation of science from philosophy, every branch of knowledge including science were all called philosophy. There was no sharp distinction between science and philosophy. For example, ancient Greek thinkers like Thales, Anaximander, Pythagoras and so on were both philosophers and scientist even though their science was not as sophisticated as we have it today. In the days of the Socratic philosophers, the physical sciences especially physics was called natural philosophy. At the turn of the 19^{th} century, some of the areas of study called natural philosophy began to break away from philosophy to be designated core and independent science disciplines. Mathematics and physics were the first to break away. With this separation, philosophy was again left to concentrate on identifying general principles about phenomena while the sciences concerned themselves with discovering facts about phenomena. In early 20th century, the need to interrogate the methods and concepts used by the sciences was again thrust at the philosophers and this became the foundation upon which the philosophy of science as a second-order discipline under philosophy as the mother discipline was built. Does philosophy still have anything to do with science after their separation? What is the nature of this relationship if any? Is the relationship sustainable? In this unit, we shall attempt to answer these questions by looking at the link between philosophy and science; analyse the notion of second-order discipline in philosophy and trace the origin and birth of philosophy of science including the role played by the logical positivists in its birth. The meaning and objectives of the philosophy of science will also be discussed.

4.2 Objectives

It is expected that after studying this unit the student will be able to:

14. Understand the link between philosophy and science
15. Analyse the notion of second-order discipline
16. Trace the origin and birth of philosophy of science
17. Understand the notion of philosophy of science
18. Identify the core scope and characteristics of philosophy of science

4.3 Main Course Contents: The Philosophy of Science

4.3.1 The Relationship between Philosophy and Science

Most great scientists were great philosophers and all the greatest philosophers made their marks in science. For example, Galileo Galilei, Isaac Newton and Albert Einstein were all great scientists, philosophers and so also were Aristotle, Francis Bacon, Rene Descartes and Baruch Spinoza who were all great philosophers and scientists too. With the use of language, philosophers articulate their intuitions. This is because philosophy can be said to be the formalization of intuition whereas science is the formalization of evidence. Philosophers articulate their intuitions while the scientists articulate the evidence they gather and with the aid of mathematics make their articulations universally compatible with other evidences. Philosophy is mostly abduction followed by deduction while science is mostly abstraction followed by induction. Philosophy looks beyond what is observable while science focus on what is observable.

Philosophy influences the sciences by inventing intellectual thought, logical and rigorous reasoning. It frames the questions and sets the groundwork for debate. It does this by exploring what might be true and figuring out how different approaches to truth interrelate thereby bringing to light the weaknesses of science and its applications. It carries out this function by;

1. Studying the methods of science – Philosophy examines the methods and procedures of other disciplines for their consistency or otherwise in dealing with their specific subject matter.
2. Examining the assumptions of science concerning the nature of reality.
3. Carrying out conceptual analysis – this is done by philosophers to define concepts or problems in such a way as to make it amenable to scientific study.

4. Carrying out conceptual and ideational synthesis – this is the attempt to fuse the findings of the various branches of science into one consistent view of reality.

Through their works and activities, philosophers provided concepts and insights to science that finally led to its independence while still maintaining a distinct but cordial relationship. One of the most important relationships between philosophy and science is that while science explains how things occur, philosophy explains why things occur. This is because, in trying to explain why things and events happen in the physical world, one is also confronted with question of how the events happen. In other words, both science and philosophy are basically concerned about realities and the nature of things in the physical universe. They do these by inquiring deeply into the principles of nature and causes of things in nature as well as provide valid and reliable explanations and information to the various questions that agitate the minds of human beings. In their attempts to provide reliable explanation of the nature of reality, science deals with facts while philosophy deals with the general principles or ultimate nature of reality. While one explains with facts, the other explains the general principles behind the facts. This is one of the ways in which philosophy and science relate. Another area of relationship between science and philosophy is in the area of judgement and evaluation. According to Uduigwomen, it is the scientist who judges one theory to be superior to another, but it is the philosopher who evaluates the criteria of acceptability implied in the judgement of the scientist (10). In other words, philosophy evaluates the claims of the scientist including the knowledge claims of other disciplines. It is important to note that since every other discipline of study is an off shoot of philosophy, philosophy as a mother discipline now act as a watch dog over them by studying their activities and claims, and ensuring that the facts they present follows the logical principles of nature. This philosophical study of other disciplines is what is known as 'second order studies' in philosophy.

4.3.2 Second Order Studies

An ordinary question such as “what is X?” is called a first-order question. A question about a first-order question is called a second-order question. Second-order questions are also called meta-questions or “talk about talk” (Ed. Miller 7). Philosophy asks first-order question such as what is reality? What are the basic stuffs of the universe? What is knowledge? What is beauty? But it begins to ask second-order questions when it ask questions such as what does the scientist mean by atoms? Are scientific theories real? Or what is the purpose of law and so on. These kinds of questions are epistemological, metaphysical and axiological. Philosophy does this in relation to other disciplines that study those core subject-matters. The study of other disciplines by philosophy falls under “the philosophy of” category: for example, the philosophy of law, the philosophy of education, the philosophy of medicine, the philosophy of history, the philosophy of mathematics, the philosophy of science and so on. In the second-order studies, the philosopher is concerned with issues that border on the nature of the ‘other’ discipline’s subject matter under examination, the adequacy of its methodology is examined; the meaning and clarification of its concepts is undertaken and analysed, its logical coherence and relation to and implication for society is critically analysed. Thus, the relationship of philosophy to other disciplines is on the second-order basis. Second-order studies, that is, the “Philosophy of category”, are basically studies about studies. For example, if one takes a course in philosophy of science; one would not light a Bunsen-burner in a laboratory or dissect a frog, rather, one will be engaged in thinking, analysing, and trying to clarify scientific concepts, claims and the methodology of the scientist.

4.3.3 The Logical Positivists

The need to provide a philosophical foundation for the clarification of scientific concepts and language led to the emergence of a movement in philosophy that questioned and criticized the claims of science. Logical positivism which was later called logical empiricism, was a movement in Western philosophy whose central thesis was the ‘verification principle’. This thesis holds that only statements that are verifiable through direct observation or logical proof are meaningful in terms of conveying truth value, information or factual content. The movement sought to prevent confusion rooted in unclear language and unverifiable claims by converting philosophy into "scientific philosophy", which, according to them, ought to share the bases and structures of empirical sciences'.

Logical positivism started in Vienna, Austria in the 1920s with members from various disciplines such as philosophy, mathematics and science. The term – logical positivism according to Uduigwomen (65) was coined in 1931 by A.E Blumberg and H. Feigl to designate a set of philosophical ideas postulated by members of the movement who styled themselves the ‘Vienna Circle’. The Logical positivists rejected the whole enterprise of metaphysics because of their scientific orientations and rigorous empirical approach to issues. Their aim was the unification of all science and consequently to have a unified system of meaningful and valid knowledge. They completely embraced Wittgenstein’s view that ‘what can be stated at all must be stated clearly and whereof one cannot speak, thereof, one must be silent’. This led them to formulate the verification principle. The verification principle consists in the notion that the meaning of a statement is dependent on the method of its verification. In other words, verification of a proposition must always rest upon empirical observation, that is, in sense experience. For them any proposition that could not be verified by the method of observation would be said to be meaningless. Thus, all metaphysical concepts that could not pass the test of meaningfulness with the logical positivists were excused from the sciences.

But the verification principle came under severe criticism that eventually led to its demise. Also, the internal defect of the principle namely the difficulty of formulating the criterion of sense experience without falling into solipsism and the impossibility of verifying general statements especially its blanket rejection of metaphysics contributed to its failure (Stumpf, 453). From this period, philosophers especially philosophers with particular interest in science began to investigate the viability or otherwise of metaphysical concepts to knowledge growth and the quest to demarcate between the real sciences and the sciences with metaphysical garbs. This new attitude to science by philosophy gave birth to the philosophy of science. Some authors are of the opinion that after the second world war, the positivists shed much of their earlier, revolutionary zeal. No longer crusading to revise traditional philosophy into a new scientific philosophy, they became respectable members of a new philosophy subdiscipline, philosophy of science.

Among the fore-runners of philosophy of science were the members of the Vienna circle that include Moritz Schlick, Rudolf Carnap, Hans Reichenbach, Herbert Feigl, Philip Frank, Kurt Grelling, Hans Hahn, Carl Gustav Hempel, Victor Kraft, Otto Neurath and Friedrich Waismann. Others include Karl Popper, Thomas Kuhn, Paul Feyerabend, Imre Lakatos, Hilary Putnam, W.V.O. Quine amongst others. Karl Popper especially played a significant role in laying the ground works for the development of philosophy of science as a second order discipline in philosophy with the publication of his magnus opus – The Logic of Scientific Discovery. For him, metaphysical concepts and ideas may have helped, even in their early forms to bring order into man's picture of the world. He believes that most scientific theories originate in myths and cites the Copernican system that was inspired by a Neo-Platonic worship of the Sun. Thus, it would be strange according to him; to call metaphysical statements meaningless. Beliefs such as these put paid to logical positivism and ushered in the dawn of deliberate philosophical investigations and critical study of the sciences by philosophers. It was the dawn of philosophy of science.

4.3.4 The Philosophy of science

Philosophy of science can be defined as the philosophical analysis and evaluation of scientific methodologies and fundamental concepts connected to science (Boersema, 20). The philosophy of science emerged as a child of necessity to provide a philosophical foundation for the activities of the scientist. As a second-order discipline, philosophy of science analyses the theories and concepts of science. It wrestles with two aspects of inquiry namely, epistemological and ontological inquiries. Its questions include: (1) What distinguishes the method of science from other disciplines (2) Are scientific theories probable or akin to provisional conjectures? (3) Can scientific theories be verified or falsified? (4) What distinguishes good explanation from bad explanation? (5) What is the demarcation between science and pseudo-science? Philosophers of science questions and criticizes the claims of science. Members of the logical positivists for example questioned and rejected the use of metaphysical terms and concepts by scientist. They argued that metaphysical concepts are meaningless since they cannot be empirically verified. Philosophy of science however does not reject any knowledge claim like the logical positivists, rather, it is concerned with the investigation of questions that arise from reflection about science and scientific practices. Put differently, Philosophy of Science is the analysis and evaluation of basic concepts and practices within science and about science. There are four conceptions about the task of philosophy of science according to Uduigwomen (56) that include:

1. Formulation of Worldviews – Philosophy of science consists in the formulation of worldviews that are consistent with findings in science or based on scientific laws and theories.
2. Uncovering the presuppositions and predispositions of the scientist – This conception is born out of the fact that philosophy is a presuppositionless and predispositionless discipline
3. Clarification and analysis of scientific theories and concepts – The aim here is to make their scientific usage clear.
4. Second-order role – Philosophy of science plays a second-order role by answering questions bordering on the meaning of scientific concepts such as law, theory, explanation and the nature and claims about scientific knowledge, including the logic and procedure of scientific explanations and the cognitive status of scientific laws and principles.

These four conceptions identified by Uduigwomen is exhaustive and captures to a large extent most philosophers conception of exactly what the philosopher of science does. Uduigwomen however thinks some of these conceptions are not without some weaknesses. For him, the notion that philosophy of science consists of formulation of worldviews that are consistent with scientific findings may look good but if critically analysed, one would discover that it is not fit for a working definition for philosophy of science. This is because the formulation of worldviews cannot be the function of philosophy of science because it is inconsistent with the principal function of philosophy which are reflection and analysis. Also, to say that philosophy of science has the task of formulating worldviews based on important scientific theories tend to project the philosopher of science as one who has nothing to do except and until scientific theories are formulated. For him, the interest of the philosopher of science goes beyond pointing out the implications of theories.

On the issue of presuppositions and predispositions, the philosopher of science does not presuppose or predispose any knowledge claim, instead he/she strives to unveil the presupposition and predispositions of other disciplines. For example, science presupposes that there are regularities in nature which can be discovered by the scientist. The task of the philosopher of science is to uncover presuppositions or predispositions such as this. On the conception of clarification and analysis of scientific concepts, Uduigwomen argues that this conception tends to portray the scientist as one who has no regard for meaning as he /she does for facts and so he/she needs the philosopher of science to explain the meaning of the concepts he/she uses for him/her. But the fact is that scientists do inquire into the relations of a particular concept to other concepts. The point to note however is that although analysis of scientific concepts is among the business of philosophy of science, it is not all conceptual analysis carried out in science that qualifies as philosophy of science.

Uduigwomen sees the fourth conception, that is the second-order role as the best of all the conceptions outlined because in it you have the traditional distinction between 'is' and 'ought', that is, between doing science and thinking about science. Following from this, science is to be seen as a discipline that is concerned with the explanation of facts, while philosophy of science is to be seen as a second-order discipline concerned with the analysis of not only the concepts and theories of science but also the procedures and logic of scientific explanation (59).

4.3.5 The Scope of Philosophy of Science

Philosophy of science embraces and covers a very broad range of scientific activities. It is not an empirical study of science. It is rather a critical and reflective investigations of the activities of science. Philosophers of science do not engage in empirical research beyond learning something about different branches of science and their history. It attempts to answer questions such as: what is science? What is the purpose of science? How do we arrive at scientific truth? Thus, the scope of philosophy of science lies within the subject matter of all sciences. In other words, philosophy of science deals with all the claims, assumptions and presuppositions of science. Hence philosophy of science is interested in anything science is interested in, but in a critical reflective, rational and philosophical manner.

4.3.6 The Characteristics of Philosophy of Science

The characteristics of philosophy of science can be summed up as follows:

1. Clarification of scientific language and concepts for example, "atom", molecule", wave particles and so on, including explaining what explanation is or, what it means when we say that one thing "explains" another.
2. It is normative in that it asks whether the methods that scientist use and the conclusions that they draw using those methods are justified.
3. It seeks to give a clearer explanation of the activities of the sciences.
4. It studies the history and progress of science
5. It takes a special interest in the concepts other discipline take for granted.
6. It employs critical and evaluative approach in its investigations of the sciences
7. It studies, investigates and analyses the effects of scientific inventions on man and society.

4.4 Conclusion

In this unit we looked at the relationship between philosophy and science. It was seen that their relationship is symbiotic and implicit in their core mandates; science for example, explains how things occur while philosophy explains why things occur. Science deal with facts of nature while philosophy is concerned with the general principles of nature. The notion of second-order studies was also discussed. Philosophy of science is a second-order discipline because it asks metaphysical, epistemological and axiological questions. The logical positivists and their role in the birth of philosophy of science as a second-order studies were also discussed. The logical positivist criticized the claims and language of science with their verification thesis. The demise of the verification principle ushered in the dawn of the philosophy of science. We defined the philosophy of science as the philosophical study of the foundations, assumptions, nature and implications of science to nature. Its scope covers all aspects of scientific activities while its characteristics include clarification of scientific language and concepts.

4.5 Summary

Science explains how things occur while philosophy explains why things occur. Philosophy of science is a second-order discipline. Philosophy of science is the study of the foundations, nature, assumptions and implications of science to nature. And it covers all aspect of scientific activities. The logical positivist played a significant role in the birth of philosophy of science. The characteristic of philosophy of science includes the clarification of scientific language and concepts.

4.6 Self-Assessment Exercise

1. Analyse the relationship between science and philosophy
2. Discuss the role logical positivism played in the emergence of philosophy of science.
3. Explain three conceptions of philosophy of science and the criticism arising therefrom.
4. What is a second-order studies? Why is philosophy of science a second-order discipline?
5. Discuss the limits of philosophy of science
6. State and explain three characteristics of philosophy of science

Model answer to question 4

The study of other discipline by a particular discipline is called a second-order studies. A first-order studies asks questions such as 'what is X?' While a second-order studies asks questions such as 'what is the value of X or is X real? The study of other disciplines by philosophy falls under the 'philosophy of category'. For example, the philosophy of law, the philosophy of medicine and so on. The philosophy of science is therefore a second-order studies because it is the philosophical study of the sciences. It is concerned with the analysis and evaluation of scientific methodologies and fundamental concepts connected to science.

4.7 Tutor Marked Assignment

1. Philosophy explains why things occur while science explains _________ things occur. A. Where. B. When. C. How D. If.

2. Logical positivism as a movement began in: A. Vienna, Austria. B. Victoria, Australia. C. Berlin, Germany. D. London, England.

3. Philosophy of science is a __________ studies. A. First-Order. B. Rational Order. C. Metaphysical Order. D. Second-Order.

4. The following are the characteristics of philosophy of science except: A. Clearer explanation of scientific activities. B. Experimentation of scientific facts. C. Study of the history and progress of science. D. Clarification of scientific language.

Model Answers: 1. – C. 2. – A. 3. – D. 4. – B.

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MODULE 1: The Nature of Science and the Origin of Philosophy of Science

Unit 5: The Philosophers of Science: Ancient, Modern and Contemporary

5.1 Introduction

5.2 Objectives

5.3 Main Course contents: Philosophers of Science: Ancient; Modern and Contemporary

5.3.1 The notion of First Principles

5.4 The Pre-Socratics

5.4.1. The Milesians

5.4.2 The Pythagoreans

5.4.3 The Atomists

5.5 The Socratics

5.5.1 Aristotle

5.6 The Modern

5.6.1 Francis Bacon

5.6.2 Rene Descartes

5.6.3 David Hume

5.6.4 Albert Einstein

5.7 The Contemporary

5.7.1 Rudolf Carnap

5.7.2 Karl Popper

5.7.3 Thomas Kuhn

5.8 Conclusion

5.9 Summary

5.1 Introduction

What does philosophers mean by first principles? Why are philosophers concerned about first principles? Does being a philosopher make one a philosopher of science? What qualifies one to be addressed as a philosopher of science? Who are the philosophers of science? And what are their contributions to the growth of science and the philosophy of science? We shall attempt to answer these questions in this unit knowing that from its very beginning, philosophy was a rational and intellectual activity. That it was not just a matter of seeing or believing but of thinking and philosophical thinking meant thinking about fundamental questions in a free and systematic way calculated to achieve results. The records of the history of philosophy shows an array of great minds that have toiled to proffer rational solutions to a plethora of perplexing metaphysical and natural problems of our universe. Their intellectual reasonings and the concepts they developed gave impetus to what is today called science. Some of them however, went beyond developing concepts to equally seek to discover the first principles that underlie the concepts. These group of philosophers that placed premium in discovering the first principles that underlie their science contributed significantly in founding what is today called the philosophy of science. In this unit, we shall be examining the notion of first principles and some of the philosophers whose works and concepts contributed to the evolution of the philosophy of science. We shall begin from the Pre-Socratics, to the Socratics, to the Modern period and finally, to the Contemporary periods. We shall also briefly analyse their contributions to the growth of philosophy, science and the philosophy of science.

5.2 Objectives

It is expected that after studying this unit the student will be able to:

19. Understand the notion of 'first principle' in philosophy
20. Identify first principles in the works of philosophers of interest
21. Identify the individual contributions of philosophers of different epochs to the development of philosophy of science

5.3 Main Course Contents: The Philosophers of Science: Ancient; Modern and Contemporary

5.3.1 The Notion of general Principles in Philosophy

A first principle is a basic assumption that cannot be deduced any further. Aristotle defined 'first principle as 'the first basis from which a thing is known'. First principle is a strategy used to break down complicated problems and generate original solutions. It is the act of breaking down a process to the fundamental parts that you know are true and then building up from there. In philosophy "first principles" are from First Cause attitudes commonly referred to as *a priori* terms and arguments. *A priori* terms are reasonings or argument that proceed from particular to general or from cause to effect, which are contrasted to *a posteriori* terms, or arguments. In *a priori* arguments, a phenomenon is simply assumed and exists prior to the reasoning process; for example, 'all bachelors are unmarried. While an *a posteriori* argument is deduced or inferred after the initial reasoning process, for example, 'John is married'. The first cause attitude is the belief that the observable order of causation is not self-explanatory, that it can only be accounted for by the existence of a first cause in the whole series of observable causes. That bachelors are unmarried men is an argument that cannot be deduced further but which can be explained by being married. According to Aristotle:

> In every systematic inquiry where there are first principles, or causes, or elements; knowledge and science result from acquiring knowledge of these; for we think we know something just in case we acquire knowledge of the primary causes, the primary first principles, all the way to the elements. It is clear, then, that in the science of nature as elsewhere, we should try first to determine questions about the first principles. (Cited in Terence).

The search for first principles is not peculiar to philosophy; philosophy shares this aim with biological, meteorological, and historical inquiries, among others. But Aristotle's references to first principles in the opening passage of his *Physics* and at the start of other philosophical inquiries imply that it is a primary task of philosophy. Philosophers seek to discover the first principles behind their investigations so as to use it as a foundation to build their knowledge edifice. Reasoning by first principles removes the impurity of assumptions and conventions leaving you with the essentials that allows you to see where reasoning by analogy might lead you astray.

5.4. The Pre-Socratics

5.4.1 Thales of Miletus (624 – 546 BC)

Thales was a Greek mathematician, and astronomer from Miletus in Ionia, Asia Minor. He is regarded as the first philosopher in the Greek tradition and he is otherwise historically recognized as the first individual known to have entertained and engaged in scientific philosophy. He is often referred to as the Father of Science. Thales is recognized for breaking from the use of mythology to explain the world and the universe. He explained natural objects and phenomena by offering naturalistic theories and hypothesis. Almost all the other Pre- Socratic philosophers followed him in explaining nature as deriving from a unity of everything based on the existence of a single ultimate substance instead of using mythological explanations. Thales' most famous philosophical position was his cosmological thesis about the nature of all matter. He opined that the first principle of nature was a single material substance and that substance is water.

Aristotle had conjectured that Thales reached his conclusion that the first principle of nature was water by contemplating that the "nourishment of all things is moist and that even the hot is created from the wet and lives by it." While Aristotle's conjecture on why Thales held water as the first principle of matter is his own thinking, his statement that Thales held it as water is generally accepted as genuinely originating with Thales. According to Stumpf (6), the accuracy of Thales analysis of the composition of things is far less important than the fact that he raised the question concerning the nature of the world. His question had set the stage for a new kind of inquiry. For him, Thales shifted the basis of thought from a mythological base to one of scientific inquiry, and from his primitive starting point, others were to follow him with alternative thesis. These other philosophers in his days include Anaximander and Anaximenes.

5.4.2 Pythagoras of Samos (570 – 500BC)

Pythagoras was a Greek philosopher, mathematician, and founder of the Pythagorean brotherhood that was religious in nature but formulated principles that contributed to the development of mathematics and Western philosophy. Pythagoras had a following and his followers and himself were generally referred to as the Pythagoreans. The Pythagoreans devoted themselves to mathematics, they were the first to advance the study of mathematics. They believed that mathematical principles were the first principles of all things. In contrast to the Milesians, that is, Thales, Anaximander and Anaximenes, the Pythagoreans said that all things consist of numbers. They averred that the order and unity in the cosmos was mathematical in nature; therefore, numbers lie at the base of reality. According to Lawhead, they believed that numbers have a reality of their own. According to the Pythagoreans, mathematical points produce lines, conjunctions of lines create plane figures and multiple plane figures form solids. Hence from mathematical points, we can understand our entire universe (13). For them mathematic or numbers is the first principle that underlie all reality.

5.4.3 The Atomists

The only two known Pre-Socratic atomists were Leucippus and his student Democritus. Unfortunately, very little is known about Leucippus who is the founder of the atomic theory. Democritus was the student of Leucippus and he is the figure through whom atomism has been transmitted to later generations. It is not known how much of his theory is simply a repetition of Leucippus's teaching and how much of it is original to him. He was however, the one that brought atomism to public attention and who made it a matter of philosophical study. He believed that atomism could be usefully applied to all aspects of the world including ethics and politics.

The atomist believed that the nature of things consists of an infinite number of particles or units called atoms and that each one atom is completely full, contains no empty space and thus completely hard and indivisible. Since these atoms are eternal, they did not have to be created. Nature consists therefore of two things only; space and atoms. The atoms move about in space and motion leads them to form the objects we experience in the world. Thus, the world can be explained as the motion of atoms; their geometrical properties produce various interactions and combinations that produce all the qualities found in sense experience. For example, solid matter is as a result of atoms that have rough surfaces that hooks or become interlocked. Liquids are made up of spherical atoms with smooth surfaces that continually roll over one another. Sweet-tasting substances are made up of smooth atoms, while bitter herbs are made up of atoms with sharp points that irritate the mouth atoms. According to Lawhead, for Democritus, there is no ordering principle in the world, what patterns there seem to be are simply products of material properties of atoms and the chance collisions that results from their motions (25).

5.5 The Socratics

The Socratic philosophers were philosophers that paid attention to human nature in their philosophies. Instead of debating about alternative theories and first principles of nature like the Pre-Socratics, they addressed themselves to the problem of human knowledge, asking whether it was possible for the human mind to discover any universal truth. The Socratic philosophers include The Sophists, Socrates, Plato, and Aristotle. Aristotle is particularly important for our study here because he was majorly interested in establishing a scientific tradition for the acquisition of knowledge guided by first principles.

5.5.1 Aristotle (384 – 322 BC)

Aristotle was particularly of the opinion that the discovery of certain truth can only be by the use of first principles. According to him in book 1 of Physics "when the objects of an inquiry in any department have principles, conditions or elements, it is through acquaintance with these, that knowledge, that is to say, scientific knowledge is attained. For we do not think that we know a thing until we are acquainted with its primary conditions or first principles and have carried our analysis as far as its simplest elements". He made the point that it is not everything that can be deductively demonstrated because if we insist on demonstrating everything, we would end up in an infinite regress. So, before we can deductively prove anything, we must start with premises or axioms that stand on their own feet and do not depend on anything else. Aristotle calls these the first principles. But the question according to Lawhead, is 'how do we arrive at these first principle? Aristotle says it is by the process of induction and intuition. Through induction we become acquainted with the universal and necessary features within the changing world of particulars. Induction can enable us to make generalizations but cannot lead us to the first principles and that is where intuition comes in. Aristotle is of the opinion that the world consists of a rational order; that experience alone cannot demonstrate this order to us but it can acquaint us with it. However, only through some sort of intellectual intuition do we see the universal and necessary truth that are the foundation of all genuine knowledge. For example, two apples plus two apples and two oranges plus two oranges may trigger the intellectual insight that $2 + 2 = 4$. This $2 + 2 = 4$ is a universal mathematical truth that is not based on the changing world of apples and oranges. It is axiomatic or self-evident. The concrete experience however, provoked the intellectual intuition. For Aristotle then, intuition is an additional step beyond the process of induction. He uses mathematics in demonstrating the place of induction and intuition in arriving at first principles but equally emphasises that physics, medicine, ethics and any other special science is likewise based on intuitively discovered and necessary first principles.

5.6 The Modern Era

Modern philosophy is the philosophy that developed in the modern era that began in 1600 and ended in the 18^{th} century and is associated with modernity. Along with significant scientific and political revolutions, the modern era ushered in a plethora of new philosophical schools and movements that includes rationalism, empiricism, utilitarianism amongst others. The trail blazers of this era include Francis Bacon, Thomas Hobbes, Rene Descartes, John Locke and so many others. We shall however briefly consider the contributions of Bacon and Descartes in this section of the work.

5.6.1 Francis Bacon (1561 – 1625)

Francis Bacon gave himself the task to totally reconstruct the sciences, arts and all human knowledge and to place them on a proper foundation for development. Lawhead opines that Bacon's self-imposed task expressed the two themes that were typical of his age which include *a radical criticism of the past* – we must sweep away the cobwebs of medieval thought and the rubble of tradition before we can do anything else; and *a heady optimism for the future* – the right method will lead us into an intellectual and social utopia (213). Bacon was critical of the learning of his day because it had become stagnant because philosophy was still dominated by Plato and Aristotle whose teachings he denounced as shadows and phantoms. He emphasised the utility of knowledge and declared that knowledge is power. He challenged the mixing of up of science with superstition and theology and rejected it as an approach to scientific discovery because it had no adequate method for discovering what nature and its workings are really like.

Bacon advocated wiping of the slate of human knowledge clean and starting over again using a new method for assembling and explaining facts. He considered the mind as being like a mirror which had been made rough and uneven both by natural tendencies of passions as well as the errors of traditional learning - what he calls the distempers of learning and the idols of the mind. To make the mind reflect accurate truth, he devised a way to free science from entrenched and traditional learning; and separate scientific truth from revealed truth of theology, and fashion a new philosophy based upon a new method of observation and interpretation of nature (Stumpf 221).

5.6.2 Rene Descartes (1596 – 1650)

While Bacon was concerned about reconstructing the sciences and arts, Rene Descartes was concerned about building a firm foundation for the sciences using mathematics as the base. According to Lawhead, his work as a philosopher revolved around three goals that include 1. To find certainty. 2. To discover a universal science and 3. To reconcile the mechanistic view of the world found in science with human freedom and his own religious perspective (228). Rene Descartes developed basic philosophical notions that were in consonant with the new approach of the natural sciences. He distinguished between two main kinds of substance that include; mind and matter. For him matter extends and one of the characteristics of extended matter is that it can be measured and scientific observation concerns mainly measurable things. What is measured can be compared, related to things with the help of mathematical formulae or through logical relations. Unlike Bacon, Descartes was successful in finding a firm foundation for the sciences which is among the reasons he is known as the father of modern philosophy. Other philosophers in the modern area with contributions to the development of philosophy of science include John Locke and David Hume.

5.7 The Contemporary

The contemporary era of philosophy is a phrase used to describe the current era of philosophy that began from the late 19^{th} century to the present 21^{st} century. Sometimes it is divided into analytic and continental philosophy because of the approach adopted by concerned philosophers of the era. Analytic philosophy focuses on clarity of language and precision in its argument and is based on formal logic. Analytic philosophy has a lot in common with researchers in science and mathematics because of their focus on logical and mathematical precision. Analytic philosophers include Gottlob Frege, Bertrand Russell, Ludwig Wittgenstein amongst others. Continental philosophy on the other hand is a philosophy that is not analytic. Its style is less precise and logical but more literary than analytic philosophy. Its adherents include; Schopenhauer, Nietzsche, Marx and so on (David Boyles). Analytic philosophers however played significant role in the development of philosophy of science. The philosophers here include Moritz Schlick, Rudolf Carnap, Karl Popper amongst others.

5.7.1 Rudolf Carnap (1891 – 1970)

Rudolf Carnap was a leading and founding member of Logical positivism which later became known as Logical Empiricism. He was one of the originators of the philosophy of science and later a leading contributor to Semantic and Inductive Logic. Stanford Encyclopedia asserts that ‘although his views underwent significant changes at various times, he continued to reaffirm the basic tenets of logical empiricism and is still identified with him. His influence declined when logical empiricism lost its dominance in the 1950s and 60s (Stanford).

5.7.2 Karl Popper (1902 – 1994)

Karl Popper is generally regarded as one of the greatest philosophers of science of the twentieth century. He was also a social and political philosopher of considerable stature, a self-professed critical-rationalist, a dedicated opponent of all forms of scepticism and relativism in science and in human affairs generally and a committed advocate and staunch defender of the “Open Society”. He shared with logical positivists an interest in the foundations and the methodology of the natural sciences. Popper came to fame with his first book – the logic of scientific discovering. In this work, he over turns the traditional attempts to found scientific method in the support that experience gives to suitably formed generalizations and theories. He made significant contributions to the debates concerning scientific methodology and the demarcation of science from non-science including the nature of probability and quantum mechanics. His work is notable for its influence both with philosophy of science and with the social sciences (Stanford).

5.8 Conclusion

In this unit, we looked at the notion of first principles and arrived at the conclusion that Philosophers seek to discover the first principles behind their investigations so as to use them as a foundation to build their knowledge edifice. First principle was defined as a basic assumption that cannot be deduced further. We also examined some of the philosophers of science and their contributions to the development of philosophy of science.

5.9 Summary

First principle is a strategy used to break down complicated problems and generating original solutions. Thales is regarded as the first philosopher in the Greek tradition and is historically recognized as the first individual known to have engaged in scientific philosophy. Aristotle was particularly of the opinion that the discovery of certain truth can only be by the use of first principles. Rene Descartes was concerned about building a firm foundation for the sciences using mathematics as the base. The contemporary era of philosophy is a phrase used to describe the current era of philosophy that began from the late 19th century to the present 21st century.

5.10 Self-Assessment Exercise

1. Why is Thales of Miletus regarded as the father of modern science?

2. Why did Pythagoras and his followers consider mathematics as the first principle that underlie all reality?

3. Why did the atomist consider atoms as the first principle of nature?

4. Discuss Aristotle's assertion that first principles can be arrived at through the process of deduction and intuition

5. What is the significance of the contemporary era of philosophy to philosophy of science?

Model Answer to question number 1

Thales of Miletus is regarded as the father of modern science because he was the first philosopher in the Greek tradition to have engaged in scientific philosophy. He is also recognized for breaking away from the use of mythology to explain the world and the universe. He explained natural objects and phenomena by offering naturalistic theories and hypothesis. Thales' most famous philosophical position was his cosmological thesis about the nature of all matter. He opined that the first principle of nature was a single material substance and that substance for him, is water.

5.11 Tutor marked Assignment

1. What is first principle? A. Axiomatic expression. B. Deductive observation. C. Basic assumptions that cannot be deduced further. D. Basic assumptions that can be deduced further

2. Who is the founder of the atomic theory? A. Democritus. B. Leucippus. C. Rene Descartes. D. Albert Einstein

3. Francis Bacon fashioned a new philosophy based upon _____________ A. Reason. B. Observation and interpretation of nature. C. Phantoms and shadows. D. Enumeration

4. ______________ is regarded as one of the greatest philosophers of science of the twentieth century? A. Karl Popper. B. Carl Hempel. C. Thomas Kuhn. D. Paul Feyerabend

Model Answers: 1 – C. 2 – B. 3 – B. 4 – A

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MODULE 2: FUNDAMENTAL ISSUES IN THE PHILOSOPHY OF SCIENCE

UNIT 1: Fact; Truth and Laws in Science

1.1 Introduction

Is there a difference between facts and scientific facts? What indeed is a fact? Are facts theory laden? What is a scientific truth? What makes a truth, truth? What is law in the realm of science? Attempts will be made to find answers to some of these questions in this unit. For first timers in the study of philosophy and especially the philosophy of science, there are some very important concepts that are germane for one to be versed in historical and contemporary issues in philosophy of science. The knowledge, understanding and deployment of these concepts in the analysis and explanations of scientific issues places the philosopher in a vantage position to properly dissect metaphysical, epistemological and axiological issues in the growth and progress of science. These concepts include but not limited to: scientific facts, scientific laws, scientific truths, scientific theories amongst others. We shall however focus attention on facts, truth and laws in this unit.

1.2 Objectives

It is expected that after studying this unit the student will be able to:

22. Understand the meaning of fact and scientific fact
23. Differentiate between scientific fact and other kinds of facts
24. Properly analyse the concept of truth
25. Understand the notion of scientific laws

1.3 Main Course Contents: Facts; Truth and Laws in Science

1.3.1 Scientific Facts

A fact is a proven or verifiable piece of information about things that exist or events that have occurred. It is something that is the case; a state of affairs. A scientific fact on the other hand is an objective and verifiable observation which is intended to explain or interpret a state of affairs. There are different kinds of facts, for example – "Wa, Zo and Bia" all mean 'come' in Yoruba, Hausa and Ibo languages of Nigeria respectively – this is a linguistic fact". The sun is a star" is a cosmological fact while Dr Goodluck Jonathan was the president of Nigeria from 2010 - 2015 is a historical fact. It is important to note that facts transcend belief and serve as a certain description of a state of affairs on which beliefs can later be attributed. Scientific facts differ from linguistic, cosmological and historical facts because it is a repeatable, careful observation or measurement of phenomena that has been confirmed repeatedly and is accepted as true even though its truth is never final or absolute.

John Hospers' Two Senses of Facts

John Hospers in "An introduction to philosophical analysis" distinguished two senses of "facts". In the first sense – "facts" means a true proposition such as when one says "there are six persons in the next room". The second sense sees fact" as the actual-state-of-affairs". This refers to the configuration of things around us, how that objects or events in the world happen to be. These two senses as put forward by Hospers have however generated salient and important philosophical questions. According to Jack Aigbodioh, to which of the two senses of "facts" do scientists refer when they claim to rely on facts? Are there pure and naked facts which when observed are unaffected by human preconceptions and prejudices? Do scientific facts represent accurate reports or observations? Or are there theoretical (propositional or judgmental) approximations of what the real state of affairs might be? (36).

To answer these questions some arguments were used. First is that by David Hume who argued that it is doubtful that the senses can guarantee that objects have independent and continued existence when they are not being perceived. Therefore, it is doubtful too if what scientists usually refer to as "natural facts" are genuine reports of the actual state of affairs. The conclusion of all the arguments or doubts about what the scientists really mean when they present a statement of fact is that it is theory-laden.

Theory-ladenness - In philosophy of science, observations or scientific claims are said to be theory-laden when the statement is affected or influenced by the theoretical presuppositions held by the investigator. It is argued that statement of facts lacks objectivity because it is influenced in one way or another by personal feelings, background and biases of the scientist. Thus, according to Aigbodioh, “insofar as facts are ultimately propositional, they are *ipso facto* theoretical because they involve judgments”. For example, the theory-laden nature of observation holds that everything one observes is interpreted through a prior understanding of other theories and concepts. In this instance, whenever one describes one’s observations, one is constantly utilizing terms and measurements that the society has adopted. Therefore, it would be impossible for someone else to understand these observations if they are not familiar with the theories that these terms are ladened with.

Characteristics of a scientific fact

1. The statement or phenomenon must exist
2. It must be observable
3. It must be verifiable
4. It must be susceptible to measurement
5. It must be capable of being communicated
6. It must be generalizable
7. It should be possible to predict its occurrence

1.3.2 Scientific Truth:

Philosophers have been interested in truth from the very beginning and have made efforts to understand the meaning and nature of truth. The principal issue always is – what is truth? In the first century AD, Pontius Pilate asked Jesus the same question – what is truth? (John 18:38).

Ordinarily, truth refers to what is verifiable by everyone or that on which everyone has reached an agreement. Truth is therefore universal. It is objective and public. Truth is not subjective or private.

The Nature of Scientific Truth

Science is a systematic process of searching for truth about nature in its various forms. Scientific truth may start with a subjective speculation. This speculation is then subjected to logical, theoretical and empirical tests. If the tests confirm or validate it, then it is retained as a tentative truth. It is tentative because future observation or tests may invalidate it. For example, it was some time held that the earth was flat, but after some empirical tests which involved sailing around the world; it was refuted that the earth is not flat. We also remember the geocentric and heliocentric theories of the universe. It should be noted that once a speculation is confirmed, a new truth is added to the stock of knowledge and thus contributes to progress in science. Science therefore aims or strives to discover truth. It does not invent truth and cannot invent truth. Getting scientific truth is based on pure and clear observation of physical reality. We can therefore conclude by saying that explanations and theories that correctly predict new results from observations or experiments brings us closer to a true understanding of nature and the rules by which it operates. This true understanding of nature is what is called scientific truth.

1.3.3 Determination of Truth in Science

How is truth determined in science? It is determined by carrying outs tests to confirm or refute a claim. The following are types of tests that can be used to test the validity or otherwise of a scientific claim:

1. Correspondence test
2. Coherence test
3. Pragmatic test

Correspondence test: It should be noted that the correspondence theory of truth has a long history of being the first and oldest test of truth; it was Bertrand Russell who made it popular in his writings. According to this theory, truth is simply a correspondence of a belief or proposition with a fact, a state of affairs or reality. Reality is what actually exists, while truth is our test estimation of reality or what we agree that exists. Hence, what we hold to be true reflects reality or that which exists. Advocates of this theory include Aristotle, G. E. Moore and Alfred Taski. Alfred Taski for example considers truth as a property of sentences and involves a relationship between a sentence and reality. For example, the sentence "it is raining" is true if and only if it is indeed raining out there.

Coherence Test: This theory holds that a statement or theory is true if and only if it agrees or is logically consistent with other statements or theories of the system. Every statement is related to other statements by implication. One argument in favour of this theory is its use in evaluating the truth content of statements or ideas. For instance, if someone tells us that he saw a witch flying across his room, we may not accept the story because it does not agree or cohere with the test of our experience. In other words, majority of people will confirm that they have not seen a witch flying in reality and since the claim does not cohere with reality, it cannot be accepted as true. The advocates of this theory include rationalists such as Spinoza, Leibniz, Hegel and F. H. Bradley. Some logical positivists such as Otto-Neurath and Carl – Hempel are in support of this theory.

Pragmatic Test: Pragmatism was a dominant force in American Philosophy during the first half of the 20th century and it is regarded as America's contribution to Western philosophy. The major advocates were Charles Sanders Pierce, William James and John Dewey. It is believed that the pragmatists, shared in the general attitude of the Americans towards theoretical activity without cash value. By cash value they mean the use to which an idea can be put. For them whether a theory is true or false is unimportant, what matters is whether it affects someone's life or actions.

Theories they believe, are mere instruments for solving one's problems and their success is evaluated in terms of performing this function. Thus, a theory is true if and only if it works or is useful and satisfies certain needs. In testing a theory, a scientist designs an experiment which determines whether the theory works under specified conditions. The theory can only be true if the experiment is successful. Truth for the pragmatist is what works in practice now. Ideas remain true as long as they work, and false as long as they fail to work.

1.3.4 Scientific laws

Scientific laws are statements that describe or predict a range of phenomena based on repeated experiments or observations. It is meant to explain in concise terms, actions or a set of actions and is generally accepted to be true and universal. Scientific laws are scientific knowledge that experiments have repeatedly verified and never falsified. Their accuracy does not change when new theories are worked out, but rather, the scope of application, since the equation (if any) representing the law does not change. As with other scientific knowledge, scientific laws do not have absolute certainty as mathematical theorem, and it is always possible for a law to be overturned by future observations. In science, sometimes a law is called a principle. Scientists postulate laws as a working principle that helps them work out ordered and systematic method of investigating nature. Scientific laws are formulated based on observation rather than theory. In other words, before the formulation of a scientific law, there must be an existing conceptual framework from which the scientist draws experience that will give him/her a direction provided he has something in mind to achieve. The law or principle may describe only an occurrence and predict it as well. However, a law does not make explanations about natural occurrence; a theory does that. A scientific law can be reduced to a mathematical formulae or statement such as $E=mc^2$ which Einstein used to explain his special theory of relativity in 1905. It is normally a specific statement based on empirical data and its truth is usually confined to a certain set of conditions. For example, in the case of $E=mc^2$.

E = is energy

M = is mass

C = is speed of light squared, i.e., C^2

Scientific laws may be classified into 2: Universal and probabilistic.

Universal laws – These are scientific laws that exhibit a uniform system. A universal law ensures a uniform connection between different aspects of empirical phenomenon. When used to describe a state of affair, it asserts that whenever a specified condition **A** occurs, the corresponding effect **B** will follow without exception. For example, in Newton's first law of motion, it is stated that "a body at rest continues to be at rest and a body in motion continues to be in motion at uniform velocity unless acted upon by an external force". This law applies universally provided that the condition is the same.

Probabilistic laws – This second type of scientific law do not have a universal, constant and repetitive operation. Its statements are probable. The results of their observation or statements may be contradictory as against universal laws that have high confirmatory evidence. For example, the fact that Okoro was afflicted with Covid-19 could be explained by asserting that he contracted it from Cocoette. Here the connection between Okoro and Cocoette cannot be explained by a law of universal form because it is not every case of contact with a Covid-19 carrier that results in an infection to another person but it can however be argued that exposure to a Covid-19 carrier provides a high probability of one contracting the deadly virus.

Characteristics of scientific laws

1. Basically, scientific laws come from physics and most can be represented as an equation i.e., a mathematical formula. The formula can be used to predict an outcome. Specifically, once applied, the formula predicts that a new observation will conform to the law.
2. Scientific law does not have absolute certainty – nothing in science is absolute. It could be over turned by future observations. For example, Newton's law of gravitational force was later found to only apply in weak gravitational fields. But it is a good example of a scientific law especially the laws of motion.
3. Scientific laws provide rules for how nature will behave under certain conditions.
4. Scientific laws are not invented, they are discovered. It is naturally established by God; it takes the diligent to find it. Psalm 25:14.

1.3.5 Examples of some scientific laws

1. **Kepler's Law of Planetary Motion** – in classical physics, these laws describe the motions of the planets in the solar system. They were discovered by Johannes Kepler – a German astronomer in 1609 for the first two and 1618 for the last law. These laws include:
    a. Laws of orbits – states that all planets move about the sun in elliptical orbits
    b. Laws of areas – states that a line connecting a planet to the sun covers an equal area over equal periods of time.

    c. Laws of periods – states that there is a relationship between a planet’s orbital period and its distance from the sun.

2. **Universal law of Gravitation** – This law was formulated by Isaac Newton in 1687. It states that any two objects, no matter their mass, exert gravitational force towards one another.
3. **Laws of motion** – these laws describe the relationships between the forces acting on a body and the motion of the body. There were formulated in 1687 by Isaac Newton. The laws include:
    a. First law - The law of inertia – states that an object in motion will continue to be in motion unless acted upon by an outside force.
    b. Second law – The law of mass and acceleration – states that the net force on a body is equal to the mass multiplied by the acceleration. Equated as **F = ma**.
    c. Third law – The law of action and reaction – states that for every action, there is equal and opposite reaction.

It is important to reiterate that scientific laws do not hold for all time. This is because science is ever developing, hence new discoveries are made and they introduce new laws that render old laws inadequate. For example, Newton’s law of universal gravitation has been proved an inadequate account of gravitation by Einstein’s general theory of relativity. Also, laws of classical mechanics have been shown to be an inadequate representation of reality as shown by the laws of quantum mechanics.

Please note: Classical physics is a term used to describe physics that does not make use of quantum mechanics or the theory of relativity. It describes a group of theories of physics that predates modern theories of physics. Examples include; Newtonian mechanics, thermodynamics and the theory of electromagnetism. Classical mechanics on the other hand deals with question of how an object moves when it is subjected to various forces and also with the question of what forces act on an object which is not moving.

1.6 Conclusion

In this unit we looked at the notion of scientific facts. It was agreed that a scientific fact is an objective and verifiable observation which is intended to explain or interpret a state of affairs. It is different from other types of facts such as linguistic, cosmological or historical facts. In this unit attempts were also made to answer the question what is a scientific truth? Scientific truth is simply a true understanding of nature. Scientific truth may start with a subjective speculation. This speculation is then subjected to logical, theoretical and empirical tests. If the tests confirm or validate it, then it is retained as a tentative truth. It is tentative because future observation or tests may invalidate it. Three ways by which scientists determine truth was analysed including, correspondence, coherence and pragmatic tests. The unit also considered laws in science. Scientific laws are statements that describe or predict a range of phenomena based on repeated experiments or observations. It is meant to explain in concise terms, actions or a set of actions and is generally accepted to be true and universal. Examples of scientific laws include the law of planetary motion, universal law of gravitation and the laws of motion.

1.7 Summary

A scientific fact is an objective and verifiable observation which is intended to explain or interpret a state of affairs. Scientific fact is different from other types of facts such as linguistic, cosmological or historical facts. Scientific truth is a true understanding of nature. It is guided by logical, theoretical and empirical tests. Scientific truth can be determined by correspondence, coherence or pragmatic tests. Scientific laws are statements that predict a range of phenomena based on repeated experiments or observations. It explains in concise terms, actions or a set of actions and is generally accepted to be true and universal.

1.8 Self-Assessment Exercises

1. Define the notion of fact and explain the difference between scientific fact and any other type of fact.
2. Explain the saying that 'Truth is a true understanding of nature'
3. State and explain the ways by which Truth is determined
4. What does the pragmatist mean by 'cash value'.
5. Why is Newtonian physics described as classical physics?

Model answer to question no 4

By cash value the Pragmatist mean the use to which an idea can be put. Pragmatists, share the general attitude of the Americans towards theoretical activity without cash value. Pragmatism is America's contribution to Western philosophy. They believe that theories are mere instruments for solving one's problems and their success is evaluated in terms of performing this function. Thus, a theory or idea is true if and only if it works and satisfies certain needs. Therefore, Truth for the pragmatist is ideas that works in practice and can solve man's existential needs now.

1.9 Tutor Marked Assignment

1. Scientific facts differ from other types of facts because _______________ A. It is repeatable. B. It is deductive. C. It is subjective. C. It is objective
2. Scientific claims are said to be theory-laden when ____________________ A. It is unaffected by presupposition. B. It is influenced by presupposition. C. The theory is not observable. D. The claim is false

3. The following are determinants of truth except ____________ A. Correspondence test. B. Coherence test. C. Inductive test. D. Pragmatic test.
4. Scientific laws may be classified into _____________ A. Objective and subjective laws. B. Deductive and inductive laws. C. Valid and invalid laws. D. Universal and Probabilistic laws.

Model answers. 1. – A. 2. – B. 3. – C. 4. – D.

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MODULE 2: FUNDAMENTAL ISSUES IN THE PHILOSOPHY OF SCIENCE

UNIT 2: Scientific Theories

2.1 Introduction

What is a theory? What is the use of a theory? What are the major theories of science that have changed and shaped the modern world? All these questions shall be answered in this unit. Providing simplified answers to these questions will be of great benefit to students in the departments of philosophy and other related disciplines because it will greatly clear the confusion and misunderstanding that arise amongst students from vague and ambiguous explanations of scientific theories to non-science students by most teachers and authors. In this unit, simple explanations will be given about identified theories and in some cases, illustrations will be used to buttress a given explanation.

2.2 Objectives

It is expected that after studying this unit the student will be able to:

1. Understand what is meant by theory and its functions
2. Identify the characteristics of a theory
3. Identify the major theories of science
4. Understand the meanings of the major theories of science
5. Differentiate between a scientific law and a scientific theory

2.3 Main Course Contents: Scientific Theories

2.3.1 The Notion of a scientific Theory?

A theory is an explanation of the cause or causes of a broad range of related phenomena. It can also be defined as a well substantiated explanation of some aspect of the natural world. A scientific theory on the other hand is an explanation of an aspect of the natural world and universe that has been repeatedly tested and corroborated in accordance with the scientific method using accepted protocols of observation, measurement and evaluation of results. In other words, scientific theory goes deeper than other theories in that the scientific method is strictly followed in arriving at an acceptable theory. Scientific theories start as hypotheses or tentative formulations meant to explain the phenomenon under investigation; when a hypothesis is confirmed through experimentation, it becomes a theory. They take various forms which may be by diagrams, equations, statistical or propositional formulations. Theory is heuristic, that is, it serves as an aid to learning and discovery; it guides and stimulates the further development of knowledge.

2.3.2 Functions of a theory and Characteristics of a Theory

Functions of a Theory

1. To describe phenomena – a theory is used to describe natural events or phenomenon.
2. To explain phenomena – a theory is used to provide general explanation for phenomenon.
3. To predicts phenomena – a theory is used to predict and guide actions by providing the basis for making decisions about every day questions.
4. To control phenomena – theories provide conceptual underpinnings for the development of hypothesis to control phenomenon.

Characteristic of a theory

1. Extensiveness – it correlates a large number of phenomena.
2. Fecundity – it is fruitful i.e.; a good theory should stimulate and generate new questions and new research.
3. Predict and explain – theories do not simply describe phenomena that we encounter, but it gives a basis for making predictions and provides a basis for explaining the phenomena that is encountered.
4. Simplicity – Everything being equal, a simple theory is better than a more complex theory.
5. Plasticity – this means the modifiability of a theory to accommodate new information e.g., evolutionary theory of Darwin.

6. Coherent – This means that a theory should be internally consistent i.e., it does not contradict itself. Also, it should be externally consistent; it coheres with other established facts, laws and theories.
7. Quantitative – the content of the theory should be essentially expressible in quantitative, mathematical formulae (Boersema).

2.4 Major Theories of Science

1. Theory of evolution by natural selection – Charles Darwin - 1859
2. Quantum theory – Max Plank - - 1900
3. Theory of relativity (special/general) - Albert Einstein - 1905/1915

2.4.1 Theory of Evolution by Natural Selection

Evolution is the process of change in all forms of life over generations. Evolution does not attempt to explain the origin of life on earth but it does explain how early lifeforms evolved into the complex ecosystem that we see today. Based on the similarities between all present-day organisms, all life on earth is assumed to have originated through a common descent from a last universal ancestor from which all known species have diverged through the process of evolution. The modern understanding of evolution began with the 1859 publication of Charles Darwin's *On the Origin of Species.*

Charles Darwin was an English man educated and trained in the discipline of natural history. Such natural historians collect, catalogue, describe and study the vast collections of specimens stored and managed by curators at museums. Darwin served as a ship's naturalist on board HMS *Beagle*, assigned to a five-year research expedition around the world. During his voyage, he observed and collected an abundance of organisms, being very interested in the diverse forms of life along the coasts of South America and the neighbouring Galápagos Islands.

Darwin gained extensive experience as he collected and studied the natural history of life forms from distant places. Through his studies, he formulated the idea that each species had developed from ancestors with similar features. In 1838, he described how a process he called natural selection would make this happen. According to him, the size of a population depends on how much and how many resources are able to support it. For the population to remain the same size year after year, there must be an equilibrium, or balance between the population size and available resources. Since organisms produce more offspring than their environment can support, not all individuals can survive out of each generation. There must be a competitive struggle for resources that aid in survival. As a result, Darwin realized that it was not chance alone that determined survival. Instead, survival of an organism depends on the differences of each individual organism, or "traits," that aid or hinder survival and reproduction. Well-adapted individuals are likely to leave more offspring than their less well-adapted competitors. Traits that hinder survival and reproduction would disappear over generations. Traits that help an organism survive and reproduce would accumulate over generations. Darwin realized that the unequal ability of individuals to survive and reproduce could cause gradual changes in the population and used the term *natural selection* to describe this process. Natural selection is therefore a mechanism of evolution where organisms that are more adapted to their environment are more likely to survive and pass on the gene that aided their survival. This process causes species to change and diverge over time.

Darwin was still researching and experimenting with his ideas on natural selection when he received a letter from Alfred Russel Wallace describing a theory very similar to his own. This led to an immediate joint publication of both theories. Both Wallace and Darwin saw the history of life like a family tree, with each fork in the tree's limbs being a common ancestor. The tips of the limbs represented modern species and the branches represented the common ancestors that are shared amongst many different species. To explain these relationships, Darwin said that all living things were related, and this meant that all life must be descended from a few forms, or even from a single common ancestor. He called this process descent with modification.

Darwin published his theory of evolution by natural selection in *On the Origin of Species* in 1859. His theory means that all life, including humanity, is a product of continuing natural processes. The implication that all life on Earth has a common ancestor has met with objections from some religious groups. Their objections are in contrast to the level of support for the theory by many within the scientific community today. Natural selection is commonly equated with *survival of the fittest*, but this expression originated in Herbert Spencer's *Principles of Biology* in 1864, five years after Charles Darwin published his original works. *Survival of the fittest* describes the process of natural selection incorrectly, because natural selection is not only about survival and it is not always the fittest that survives.

2.4.2 Quantum Theory

Quantum theory is the theoretical basis of modern physics that explains the nature and behavior of matter and energy on the atomic and subatomic levels. It focuses only on the three non-gravitational forces for understanding the universe in regions of both very small scale and low mass, for example, subatomic particles, atoms, molecules and so on. The nature and behavior of matter and energy at these levels is sometimes referred to as quantum physics and quantum mechanics. Quantum mechanics is a subfield of physics that describes the behavior of particles such as atom, electrons, photons and almost everything in the molecular and sub-molecular realm. In other words, Quantum mechanics is the branch of physics that deals with the very small things of nature.

Development of Quantum Theory

In 1900, physicist Max Planck presented his quantum theory to the German Physical Society. Planck had sought to discover the reason that radiation from a glowing body change in color from red to orange, and finally, to blue as its temperature rises. He found that by making the assumption that energy existed in individual units in the same way that matter does, rather than just as a constant electromagnetic wave - as had been formerly assumed - and was therefore *quantifiable*, he could find the answer to his question. The existence of these units became the first assumption of quantum theory. These individual units of energy are what Planck described as quanta. In his explanation of the mathematical equation of the quanta, Planck opined that at certain discrete temperature levels, energy from a glowing body will occupy different areas of the color spectrum. Planck assumed there was a theory yet to emerge from the discovery of quanta, but, in fact, their very existence implied a completely new and fundamental understanding of the laws of nature. Planck won the Nobel Prize in Physics for his theory in 1918, but developments by various scientists including Planck, Einstein, Broglie, Heisenberg, Bohr, and Schrodinger over a thirty-year period all contributed to the modern understanding of quantum theory.

Interpretation of Quantum Theory: Copenhagen and Many-Worlds

The two major interpretations of quantum theory's implications for the nature of reality are the Copenhagen interpretation and the many-worlds theory. Niels Bohr proposed the Copenhagen interpretation of quantum theory, which asserts that a particle is whatever it is measured to be; for example, a wave or a particle, but that it cannot be assumed to have specific properties, or even to exist, until it is measured. In short, Bohr was saying that objective reality does not exist. This translates to a principle called Superposition that claims that while we do not know what the state of any object is, it is actually in all possible states simultaneously, as long as we don't look to check.

To illustrate this theory, Erwin Schrodinger proposed in 1935 the famous Schrodinger's Cat analogy. According to this analogy, first, we have a living cat and place it in a thick lead box. At this stage, there is no question that the cat is alive. We then throw in a vial of cyanide and seal the box. We do not know if the cat is alive or if the cyanide capsule has broken and the cat has died. Since we do not know, the cat is both dead and alive, according to quantum theory - in a *Superposition* of states. It is only when we break open the box and see what condition the cat is that the Superposition is lost, and the cat must be either alive or dead.

The second interpretation of quantum theory is the *many-worlds* or *multiverse* theory. It holds that as soon as a potential exists for any object to be in any state, the universe of that object transmutes into a series of parallel universes equal to the number of possible states in which that the object can exist, with each universe containing a unique single possible state of that object. Furthermore, there is a mechanism for interaction between these universes that somehow permits all states to be accessible in some way and for all possible states to be affected in some manner. Stephen Hawking and Richard Feynman are among the scientists who have expressed a preference for the many-worlds theory.

The Influence of Quantum Theory

Quantum theory's principles have repeatedly been supported by experimentation, even when the scientists were trying to disprove them. Quantum theory and Einstein's theory of relativity form the basis for modern physics. The principles of quantum physics are being applied in an increasing number of areas, including quantum optics, quantum chemistry, quantum computing, and quantum cryptography (Wigmore, techgate.com).

2.4.3 The Theory of Relativity

The theory of relativity was developed by Albert Einstein first in 1905 as the special theory of relativity and modified in 1915 as the general theory of relativity. Einstein's theory of relativity is an explanation of how speed affects mass, time and space.

The Special Theory of Relativity (1905)

As the title suggests, special theory of relativity applies to special cases. It is mostly used when discussing huge energies, ultra-fast speeds and astronomical distances and without the complications of gravity. The special theory deals with only objects or systems that are either moving at constant velocity with respect to one another (unaccelerated systems) or which are not moving at all (with a constant velocity of zero). One of the many implications of Einstein's special theory of relativity is that time moves relative to the observer. An object in motion experiences time dilation – meaning that when an object is moving very fast, it experiences time more slowly more that when it is at rest. This phenomenon is explained clearly using two postulates: 1, that all motion is relative and 2, that the velocity of light is always constant relative to an observer.

The Two Postulates of Special Theory of Relativity

1. All Motion is Relative

This postulate relates to reference frame. In other words, all velocities are measured relative to some frame of reference. For example, a car's motion is measured relative to its starting point or the road that it is moving on. What this means is that we cannot speak of absolute motion but only of motion relative to something else. We cannot say that an object has velocity of such and such, rather, we say that an object has a velocity of such-and-such relative to such-and-such.

Please note that this is not done for objects on the earth because it is taken for granted that their velocities are relative to the earth. According to Coleman (48) a speed limit of 50 miles an hour, for example is understood to mean 50 miles an hour relative to the earth. In other words, if a vehicle takes off from Uyo with a speed of 50 miles per hour to Port Harcourt, the speed with which it is going would be calculated relative to its starting point in Uyo and its arrival time in Port Harcourt. But out away from the earth, a velocity by itself has no meaning except in relative to something in space. Velocity means speed.

2. The Velocity of Light is always Constant Relative to an Observer

The speed of light is 300,000 kilometers per second through the vacuum of empty space. Einstein is of the view that light from a moving source has the same velocity as light from a stationary source. For example, beams from a light house, beams from a speeding car's headlights and beams from the lights on a supersonic jet all travel at a constant rate as measured by observers despite differences in how fast the sources of these beams move. The special theory of relativity is based on the recognition that the speed of light does not change even when the source of the light moves. Light from a stationary source travel at 300,000km/sec. Light from a moving source also travels at 300,000 km/sec. Therefore, the speed of light is always constant and does not depend on the speed of the source of the light.

The General theory of Relativity

The general theory of relativity is a major building block of modern physics that was developed in 1915 and presented in 1916 by Einstein; the theory explains gravity based on the way space can 'curve'. In other words, it associates the force of gravity with changing geometry of space-time. The theory expanded the special theory that was presented 10 years earlier. The special theory of relativity argues that space and time are inextricably connected, but the theory did not acknowledge the existence of gravity. The general theory was therefore developed to explain the apparent conflict between the postulates of relativity and the law of gravity. The need to resolve this conflict led Einstein to develop a new conception of gravity based on the principle of equivalence.

The Principle of Equivalence

The principle of equivalence holds that at a single point in space, the effects of gravitation and accelerated motion are equivalent and cannot be distinguished from each other. In the theory of special relativity, Einstein had explained that the person in a closed car, driving on a smooth rail track could not determine by any conceivable experiment whether he is at rest or in uniform motion. But in the theory of general relativity, Einstein states that if the car sped up or slowed down or driven around a curve, the occupant could not tell whether the forces produced were due to gravitation or whether they were acceleration forces brought into play by pressure on the accelerator or on the brake or by the car turning sharply to the right or to the left. The essence of this illustration is to show that there is no way of distinguishing between acceleration or gravitational pull of a nearby mass. This is what is known according to Einstein as the equivalence principle. It is the notion that 'at a single point in space, the effects of gravitation and accelerated motion are equivalent and cannot be distinguished from each other'.

2.5 Difference between scientific Laws and Theories

1. A scientific law is discovered while a theory is constructed, devised or designed. The ability to construct a theory is a function more of the imaginative faculty than of observable or experimental facts. That is why scientific theories are often regarded as the free creation of the human mind.
2. A scientific law state experimentally observable fact about particular natural events or properties or relations of objects. A theory is wider in scope, generalization and comprehensiveness. Their difference is also seen in their relative degree of universality. For example, the terms of a scientific law are directly explicable by reference to observable or observed facts whereas, some of the terms in a theory do not directly signify any observable thing in experience.
3. Scientific laws are usually inductively established whereas scientific theories are not inductively established.
4. While a law can be stated in a single statement, a theory usually takes a system of related statements to express. That is why theories are usually more comprehensive than laws.
5. Theories possess more predictive power than laws.
6. A scientific law provides rules for how nature will behave under certain conditions

Summary of the Difference between scientific laws and Scientific theories

S/N	Scientific Law	Scientific Theory
1	Scientific law is discovered	Scientific theory is constructed, devised or designed
2	State experimentally observable facts about particular natural event	A theory is wider in scope, generalization and comprehensiveness
3	Scientific laws are inductively established	Theories are not inductively established
4	Scientific laws can be stated in a single statement or equation	A theory takes a system of related statements to express
5	A scientific law possesses less predictive power	A scientific theory possesses more predictive power
6	Scientific laws provide rules for how nature will behave under certain conditions.	Scientific theories provide explanation for how nature will behave under certain condition.

2.6 Conclusion

In this unit, we analysed the notion of theory, its functions and characteristics. We defined a scientific theory as an explanation of an aspect of the natural world and universe that has been repeatedly tested and corroborated in accordance with the scientific method using accepted protocols of observation, measurement and evaluation of results. Some of the notable theories of science were also analysed. The difference between scientific laws and scientific theories were also unveiled.

2.7 Summary

Scientific theory is an explanation of an aspect of the natural world and universe that has been repeatedly tested and corroborated in accordance with the scientific method using accepted protocols of observation, measurement and evaluation of results. The functions of a theory include amongst others: to describe phenomena and to explain phenomena. The characteristics of a theory include; Extensiveness, Fecundity, Simplicity, Plasticity. The major scientific theories are: theory of evolution, quantum theory and the theory of relativity.

2.8 Self-Assessment Exercise

1. What is a scientific theory? State and explain 3 functions of a theory.
2. Examine 4 characteristics of a theory.
3. Explain the idea of natural selection in the theory of evolution
4. What does quantum mechanics study?
5. Examine the two postulates of the special theory of relativity
6. State 3 differences each between scientific theories and scientific laws.

Model Essay Answer to Question 1

A scientific theory is an explanation of an aspect of the natural world and universe that has been repeatedly tested in accordance with the scientific method using accepted protocols of observation, measurement and evaluation of results. Its functions include; To describe phenomena – a theory is used to describe natural events or phenomenon; To explain phenomena – a theory is used to provide general explanation for phenomenon. To predicts phenomena – a theory is used to predict and guide actions by providing the basis for making decisions about every day questions.

2.9 Tutor Marked Assignment

1. The following are true of a scientific theory except: A. It is constructed. B. It is inductively established. C. It is discovered. D. It possesses more predictive power
2. The theory of relativity was propounded by: A. Charles Darwin. B. Oliver Twist. C. Albert Einstein. D. Isaac Newton
3. The two interpretations of quantum theory are: A. Copenhagen and Many-worlds. B. Corporation and one world. C. Copenhagen and Schrodinger. D. Copenhagen and Neils Bohr
4. _______________ is the process of change in all forms of life over generations. A. Modernization. B. Pasteurization. C. Evolution. D. Regression

Model Answers – 1.- C. 2. – C. 3 – A. 4 – C

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MODULE 2: FUNDAMENTAL ISSUES IN THE PHILOSOPHY OF SCIENCE

UNIT 3: Realism, Instrumentalism and Objectivity in Science

3.1 Introduction

In this unit we shall be looking at very fundamental issues that have given philosophers of science concerns for years on end and seems not to be abating. The questions of whether scientific concepts are real or mere instruments for understanding nature? Are atoms real? Who determines whether they are real or not? The realist argues that scientific theories and their concepts are as real as the fingers I am using to type this on my computer but the anti-realist argues otherwise. There is also the question of instruments used by scientist; what is the place of instruments in the growth of science and knowledge? Are they merely a form of constructivism? Beside the issue of instrumentalism and constructivism is the issue of objectivity in science. How objective is science especially going by the arguments of realism, instrumentalism and constructivism? The answer to these questions shall be our focus in this unit.

3.2 Objectives

It is expected that after studying this unit the student will be able to:

1. Understand the core issues at the heart of philosophy of science
2. Identify the arguments of realism and its opposite – anti-realism
3. Identify different variants of anti-realism
4. Understand the notion of objectivity in science

3.3 Main Course Contents: Realism, Instrumentalism and Objectivity in Science

3.3.1 Realism

There is the ancient debate in philosophy between two opposing schools of thought known as realism and idealism. Realism on the one hand holds that the physical world exists independently of human thought and perception. Idealism on the other hand holds that the physical world is in some way dependent on the conscious activity of the human mind. This agelong debate has however spiraled into modern science. In modern science the debate is between the scientific realists and the anti-realists. Realism and anti-realism are the standard opposition between those that affirm and those that deny the real existence of some kind of thing or some kind of fact or state of affairs. For the realists in science, the aim of science is to provide a true description of the world. But for anti-realists, the aim of science is to provide a description of a certain part of the world – the observable part. As for the unobservable part, it makes no difference whether what science says is true or not. Almost any area of scientific discourse may be the focus of this dispute including the external world, the past and the future, other minds, mathematical objects, scientific concepts, universals, and ethical categories amongst others.

Scientific Realism

Scientific realism is the view that there is a real world out there, independent of our theories, schools of thought and beliefs about it. The job of science is to discover what that real world is really like. It holds that the entities, states and processes described by scientific theories really do exist: atoms, protons, photons, field of force and black holes are as real as mango trees, motor cars, floods and so on. According to Chakravarty in Stanford encyclopedia of philosophy, realism more generally is associated with any position that endorses belief in the reality of something. Thus, one might be a realist about one's perceptions of tables and chairs (sense datum realism), or about tables and chairs themselves (external world realism), or about mathematical entities such as numbers and sets (mathematical realism), and so on. Scientific realism is a realism about whatever is described by our best scientific theories. For Chakravarty, there are three dimensions to which realism can be understood. They include: metaphysical or ontological dimension; semantic dimension; and epistemological dimension.

Metaphysical Dimension

Metaphysically, realism is committed to the mind-independent existence of the world investigated by the sciences. This idea is best clarified when considered from positions that deny it. For instance, it is denied by any position that falls under the traditional heading of "idealism", including some forms of phenomenology, according to which there is no world external to and thus independent of the mind. The contention here is that the world investigated by the sciences is in some sense dependent on the ideas one brings to scientific investigation, which may include, for example, theoretical assumptions and perceptual training. It is important to note in this connection that human convention in scientific taxonomy is compatible with mind-independence.

Semantic Dimension

Semantically, realism is committed to a literal interpretation of scientific claims about the world. In common parlance, realists take theoretical statements at "face value". According to realism, claims about scientific objects, events, processes, properties, and relations, whether they be observable or unobservable, should be construed literally as having truth values, whether true or false. This semantic interpretation contrasts primarily with those of "instrumentalist" epistemologies of science, which interpret descriptions of unobservable entities simply as instruments for the prediction of observable phenomena, or for systematizing observation reports. Traditionally, instrumentalism holds that claims about unobservable things have no literal meaning at all. Some antirealists contend that claims involving unobservable entities should not be interpreted literally, but as elliptical for corresponding claims about observables.

Epistemological Dimension

In epistemological dimension, realism is the idea that theoretical claims constitute knowledge of the world. This contrasts with skeptical positions which, even if they grant the metaphysical and semantic dimensions of realism, doubt that scientific investigation is epistemologically powerful enough to yield such knowledge, or, as in the case of some antirealist positions, insist that it is only powerful enough to yield knowledge regarding observables. The epistemological dimension of realism, though shared by realists generally, is sometimes described more specifically in contrary ways.

Amidst these differences, however, a general recipe for realism is widely shared: our best scientific theories give true or approximately true descriptions of observable and unobservable aspects of a mind-independent world. The point to note from the above is that the things and events and processes that scientific models and theories talk about and refer to for example, electrons, genes and electromagnetic fields are really "out there" in the world and they correctly identify, describe and make use of these things, events and processes.

3.3.2 Anti-realism

The term anti-realism encompasses any position that is opposed to realism along one or more of the dimensions; the metaphysical dimension, the semantic dimension and the epistemological dimensions. As a result, there are many different positions that qualify as anti-realism. They include instrumentalism constructivism, and conventionalism amongst others. Instrumentalism regards the objects of knowledge pragmatically, as tools for various human purposes, and so takes reliability (or empirical adequacy) rather than truth as scientifically central. A version of this, fictionalism, contests the existence of many of the objects favoured by the realist and regards them as merely expedient means to useful ends. Constructivism maintains that scientific knowledge is socially constituted, that 'facts' are made by us. Thus, it challenges the objectivity of knowledge, as the realist understands objectivity, and the independent existence that realism is after. Conventionalism, on the other hand holds that the truths of science ultimately rest on man-made conventions.

Anti-realism says the opposite of realism. Anti-realists disagree with the different aspects of the characterizations of realism. For them, there are no such things as electrons, genes etc. Though they are the phenomena of electricity and inheritance; theories about these states, process and entities are only constructed in order to predict and produce event that interests us. The electrons and genes are fictions. Theories about them are tools or instruments for thinking. Theories are adequate or useful or warranted or even applicable, but no matter how much we admire the speculative or technological triumph of natural science, we should not regard even its most telling stories as true. Some anti-realist argue that theories should only be taken literally because there is no other way to understand them, because we do not have compelling reasons to believe that they are right or true.

3.3.3 Instrumentalism in science

Instrumentalism is the view that scientific theories should be thought of primarily as tools for solving practical problems rather than as meaningful descriptions of the natural world. Indeed, instrumentalists typically call into question whether it even makes sense to think of theoretical terms as corresponding to external reality. In that sense, instrumentalism is directly opposed to scientific realism which is the view that the point of scientific theories is not merely to generate reliable predictions but to describe the world accurately.

Instrumentalism is a form of philosophical pragmatism as it applies to the philosophy of science. The term itself comes from the American philosopher - John Dewey. It is the name for his own general brand of pragmatism according to which the value of any idea is determined by its usefulness in helping people to adapt to the world around them. Along this line of reasoning, Simon Blackburn opines that instrumentalism should be regarded as an instrument for producing new predictions or new techniques for controlling events, but not as itself capable of literal truth or falsity (187).

For Robert de Neufville, instrumentalism in the philosophy of science is motivated at least in part by the idea that scientific theories are necessarily underdetermined by the available data and that in fact no finite amount of empirical evidence could rule out the possibility of an alternate explanation for observed phenomena. Because in that view there is no way to determine conclusively that one theory more closely approaches the truth than its rivals, the main criterion for evaluating theories should be how well they perform. Indeed, the fact that no amount of evidence can decisively show that a given theory is true begs the question of whether it is meaningful to say that a theory is "true" or "false." It is not that instrumentalists believe that no theory is better than any other; rather, they doubt that there is any sense in which a theory can be said to be true or false (or better or worse) apart from the extent to which it is useful in solving scientific problems.

In support of that view, instrumentalists commonly point out that the history of science is replete with examples of theories that were at one time widely considered true but are now almost universally rejected. Scientists no longer believe, for example, that light propagates through the ether or even that there is such a thing as the ether at all. Whereas realists argue that, as theories are modified to accommodate more and more evidence, they more and more closely approximate the truth, instrumentalists argue that, if some of the best historical theories have been discarded, there is no reason to suppose that the most widely accepted theories of the present day will hold up any better. Nor is there necessarily any reason to believe that the best current theories approximate the truth any better than the ether theory did.

There may nevertheless be a sense according to Neufville, in which the instrumentalist and realist positions are not as far apart as they sometimes seem. For it is difficult to say precisely what the distinction is between accepting the usefulness of a theoretical statement and actually believing it to be true. Still, even if the difference between the two views is in some sense only semantic, or one of emphasis, the fact is that most people intuitively do make a distinction between the truth and the practical usefulness of scientific theories.

3.3.4 Constructivism

Constructivism is a view about the nature of scientific knowledge held by many philosophers of science. Constructivists maintain that scientific knowledge is made by scientists and not determined by the world. This makes constructivists anti-realists. In philosophy of science constructivism is the view that scientific knowledge is constructed by the scientific community which seeks to measure and construct models of the natural world. According to constructivists, natural science therefore, consists of mental constructs that aim to explain sensory experience and measurements. For the constructivists, the world is independent of human minds, but knowledge of the world is always a human and social construction. Constructivism opposes the philosophy of objectivism, embracing rather, the belief that a human can come to know the truth about the natural world not mediated by scientific approximations with different degrees of validity and accuracy. According to constructivists, there is no single valid methodology in science but rather a diversity of useful methods.

Thomas Kuhn argued that changes in scientists' views of reality does not only contain subjective elements but result from group dynamics, "revolutions" in scientific practice, and changes in paradigms. As an example, Kuhn pointed to the Sun-centric Copernican revolution that replaced the Earth-centric views of Ptolemy not because of empirical failures but because of a new "paradigm" that exerted control over what scientists felt to be the more fruitful way to pursue their goals. In Stephen Downes' perspective, most constructivist research involves empirical study of a historical or a contemporary episode in science, with the aim of learning how scientists experiment and theorize. Constructivists try not to bias their case studies with presuppositions about how scientific research is directed. Thus, their approach contrasts with approaches in philosophy of science that assume scientists are guided by a particular method. From their case studies, constructivists have concluded that scientific practice is not guided by any one set of methods. For him, constructivism is relativist or antirationalist.

There are two familiar and related criticisms of constructivism. First, since constructivists are self-avowed relativists, some philosophers argue that constructivism fails for the same reasons that relativism fails. But many philosophers of science note that relativism can be characterized in various ways and that versions of relativism can be useful in the interpretation of science. Therefore, constructivism's relativism does not by itself render it unacceptable. Second, constructivists are accused of believing that scientists literally 'make the world', in the way some make houses or cars. This is probably not the best way to understand constructivism. Rather, constructivism requires only the weaker thesis that scientific knowledge is 'produced' primarily by scientists and only to a lesser extent determined by fixed structures in the world. This interprets constructivism as a thesis about our access to the world via scientific representations. For example, constructivists claim that the way we represent the structure of DNA is a result of many interrelated scientific practices and is not dictated by some ultimate underlying structure of reality.

3.3.5 Objectivity in Science

Objectivity in science is the notion that scientific claims, methods, results and the scientists themselves are not and should not be influenced by particular perspectives, value judgements, tradition or personal interest. In everyday discussions of axiology, being objective usually refers to applying the rules fairly and treating everyone the same rather than showing favoritism to one party or another. It is connected to applying "the rules" of science fairly and not letting bias creep into the production of scientific knowledge. To say that something is objective implies that it has a certain importance and that we approve of it. The authority that science enjoys in public life according to Reiss and Julian, stems to a large extent from the view that science is objective or at least more objective than other modes of inquiry. Understanding scientific objectivity is therefore central to understanding the nature of science and the role it plays in society. There are two different ways to understand objectivity in science: product objectivity and process objectivity.

Product objectivity - According to this understanding, science is objective in that, or to the extent that, its products—theories, laws, experimental results and observations—constitute accurate representations of the external world. In other words, the products of science are not tainted by human desires, goals, capabilities or experiences.

Process objectivity - holds that science is objective in that, or to the extent that, the processes and methods that it is characterized neither depend on contingent social and ethical values, nor on the individual bias of a scientist. Objectivity emphasises the importance of facts as against sentiments or prejudices. The aim of objectivity in science is to ensure precision and certainty in the effort to discover scientific truth. Here the scientist is presumed to perceive facts at all cost. There are three ways according to Reiss and Julian that objectivity can be perceived; objectivity as faithfulness to fact; objectivity as absence of normative commitments and the value-free ideal; objectivity as freedom from personal bias

Objectivity as Faithfulness to Fact

Objectivity as faithfulness to fact implies that scientific claims are objective in so far as they faithfully describe facts about the world. The philosophical rationale underlying this conception of objectivity is the view that there are facts 'out there' in the world and that it is the task of a scientist to discover, analyse and systematize them. Following from this view, science is objective to the extent that it succeeds in discovering and generalizing facts in spite of the perspective of the individual scientist. Thus, for a scientific claim to be objective, it means it has successfully captured some aspects and features of the world. For Reiss and Julian, few philosophers have endorsed this conception of scientific objectivity, the idea however figures recurrently in the works of prominent 20th century philosophers of science such as Rudolf Carnap, Carl Hempel, Karl Popper, amongst others. This view, in a way, is related to the claims of scientific realism, according to which it is the goal of science to find out the truths about the world, and according to which we have reason to believe in the truth of our best-confirmed scientific theories.

Objectivity as Absence of Normative Commitments and Value-free Ideal

Objectivity as absence of normative commitments and value-free ideal implies that science should be value-free and that scientific claims or practices are objective to the extent that they are free of moral, political and social values. But the dilemma of this conception is the question of the freedom of science from moral, political or even social values. This is because it is a given that governments across the world sponsor and fund scientific programmes and to that extent, the possibility of taking away political considerations from the outcomes of scientific discoveries may be impossible thus begging the question of the objectivity of such a scientific discovery.

Objectivity as Freedom from Personal Bias.

Objectivity as freedom from personal bias is the view that, science is objective to the extent that personal biases are absent from scientific reasoning. Although it may be argued that all science is necessarily a matter of ones' perspective. But we cannot sensibly draw scientific inferences without a host of background assumptions, which may include assumptions about values. But objectivity implies that scientific results should certainly not depend on researchers' personal preferences or idiosyncratic experiences. Because, among other things, it is what distinguishes science from the arts and other more individualistic human activities. Paradigmatic ways to achieve objectivity in this sense are measurement and quantification. What has been measured and quantified has been verified relative to a standard. The truth, for instance, that the classroom is 14FT by 14FT meters is relative to a standard unit and conventions about how to use certain instruments such as the tape, so it is neither a perspectival nor free from assumptions, but it is independent of the person making the measurement.

3.6 Conclusion

In this unit, we looked at scientific realism and anti-realism as the standard opposition between those that affirm and those that deny the existence of some kind of scientific concepts and theories. For the realists, the aim of science is to provide a true description of the world. But for the anti-realists, the aim of science is to provide a description of the observable part of the world only. Instrumentalism and constructivism which are strands of anti-realism argues differently in support of anti-realism. We also did a careful analysis of the notion of objectivity in science including the different conceptions by which it is perceived.

3.7 Summary

Scientific realism is the view that there is a real world out there, independent of our theories, schools of thought and beliefs about it. The job of science is to discover what that real world is really like. Anti-realism encompasses any position that is opposed to realism along one or more of the dimensions; the metaphysical dimension, the semantic dimension and the epistemological dimensions. There are many different positions that qualify as anti-realism. They include instrumentalism, constructivism, and conventionalism amongst others. Objectivity in science is the notion that scientific claims, methods, results and the scientists themselves are not and should not be influenced by particular perspectives, value judgements, tradition or personal interest. There are three ways that objectivity can be perceived, they include; objectivity as faithfulness to fact; objectivity as absence of normative commitments and value-free ideal; and objectivity as freedom from personal bias

3.8 Self-Assessment Exercises

1. Examine the realist and anti-realist thesis in science

2. Identify and explain 2 variants of anti-realism

3. Differentiate between instrumentalism and constructivism

4. Discuss the notion of objectivity in science and explain any two ways by which it is perceived.

5. What is product objectivity and process objectivity?

Model Essay Answer to Question 1

Scientific realism is the view that there is a real world out there, independent of our theories, schools of thought and beliefs about it. The job of science is to discover what that real world is really like. It holds that the entities, states and processes described by scientific theories really do exist: atoms, protons, photons, field of force and black holes are as real as mango trees, motor cars, floods and so on. On the other hand, anti-realism encompasses any position that is opposed to scientific realism. As a result, there are many different positions that qualify as anti-realism. They include instrumentalism constructivism, and conventionalism.

3.9 Tutor Marked Assignment

1. The following are the different dimensions of realism except: A. Metaphysical realism. B. Psychological realism. C. Semantic realism. D. Epistemological realism

2. Constructivism is the view that scientific knowledge is made by scientist and not determined by the world. True or False

3. ______________ is one of the ways by which objectivity is perceived. A. Objectivity as faithfulness to facts. B. Objectivity as faithfulness to hypothesis. C. Objectivity as faithfulness to theories. D. Objectivity as faithfulness to deductions

4. Product objectivity is the view that: A. The products of science are tainted by human desires. B. The products of science are metaphysical in nature. C. The products of science constitute accurate representations of the external world. D. The products of science are tainted with hypocrisy.

Model answers: 1. – B. 2. – True. 3. – A. 4. – C

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MODULE 2: FUNDAMENTAL ISSUES IN THE PHILOSOPHY OF SCIENCE

UNIT 4: Explanation in Science

4.1 Introduction

In this unit we shall be considering the notion of explanation. What does it mean to explain something to some other person? Is scientific explanation different from other forms of explanations? How do we know that something has been explained? We shall answer these questions in this unit.

4.2 Objectives

It is expected that after studying this unit the student will be able to:

5. Understand the notion of explanation
6. Identify the main characteristics of a scientific explanation
7. Identify the different models of scientific explanation
8. Note the specificity of application of the different models of scientific explanation

4.3 Main Course Contents: Explanation in Science

4.3.1 The Notion of Explanation

Explanation is the attempt by one person to produce understanding in another by answering a certain kind of question in a certain kind of way. The synonyms for explanation include: expound, explicate, elucidate and interpret. In due cause, an explanation may be shown to be false or affirmed to be true. For example, it was earlier explained that the apparent movement of the sun across the sky was due to the sun moving round the earth until 1543 when Copernicus published an alternative explanation to the effect that it is the earth that rotates on its axis round the sun; leading as it where, to the heliocentric conception of the universe against the earlier held geocentric view. An explanation may be, historical, psychological, sociological, scientific or teleological. Our focus in this unit shall be on scientific explanation.

4.3.2 Scientific Explanation

Scientific explanation is distinct and different from other types of explanation such as sociological, teleological, and psychological or historical explanations. It is the attempts by scientists to answer the question ‘why’ rather than the question “what”. However, there are special epistemic requirement which an explanation must meet before it can be called a scientific explanation; first, it must have explanatory relevance. That is to say, that the explanatory information adduced must afford good grounds for believing that the phenomenon to be explained did occur. Second, it must be testable; here, the statement constituting a scientific explanation must be capable of empirical rest.

4.4 Models of Explanation in Science

There are several models of explanation used by scientists to explain phenomena. This includes the covering law model, the probabilistic model, the teleological model, and the causal models.

4.4.1 The Covering Law Model

Within the philosophy of science movement, there have been competing ideas about what constitute a credible explanation in the empirical sciences. There are however, a conflict of ideas in regard to what constitute a durable scientific explanation and the characteristics inherent in such explanations. Historically, explanation is associated with causation. Here, to explain an event or phenomenon is to identify its cause. Unfortunately, David Hume challenged this process of explanation in the 18th century, asserting that this process is as a result of our habit of association (Stumpf 283). But, with the growth and development of philosophy of science in the 20th century, the concept of explanation began to receive more rigorous and specific analysis.

Of particular concern were theories that posited the existence of unobservable entities and processes such as atoms, electrons, quarks etc. These posed a dilemma: on the one hand, the anti-realists had to reject unobservable entities as a matter of principle but on the other hand, theories that appealed to unobservable entities were clearly producing results. Consequently, philosophers sought ways to explain the obvious values of these theories without compromising the empiricist principles deemed central to scientific rationality.

In a 1948 paper published in the Philosophy of Science journal entitled *Studies in the Logic of Explanation* co-authored by Carl Hempel and Paul Oppenheim, they opined that since so much of life both inside and outside the classroom is concerned with finding explanation for things, therefore, it would be desirable to have a concept of what a good scientific explanation should entail. They felt that the criteria for a good scientific explanation ought to be found in the logical relationship between the *explanans* (that which does the explaining) and the *explanandum* (that which is explained). This approach gave birth to the covering law model.

The covering law model is a model of explanation that has two sorts of explanations: the Deductive – Nomological model (D.N. model) and the Inductive – Statistical model (I.S model). Both deductive nomological and inductive statistical models have the same structure. Their premises each contain statements of two types: antecedent condition 'C' and law-like generalizations 'L', the conclusion is the event 'E'. Example:

Antecedent condition	-	$C_1, C_2 \ldots, C_k$
Particular fact	-	$L_1, L_2 \ldots, L_r$
Conclusion	-	E.

The covering law thesis holds that for a scientific explanation to be genuine, it must have three types of components. First, it must incorporate one or more general principles or law. Second, there must be a statement of particular facts and third, there must be a statement describing whatever it is to be explained. What the explanation does is to show that the thing to be explained follows logically from the general principles, given that the particular fact holds (Vernon Pratt 70).

The Deductive Nomology of the Covering Law Model

The basic idea of the covering law model is hinged on what Hempel describes as the basic patterns of scientific explanation. He calls these patterns '…the general characteristic of scientific explanation'. These patterns are divided into two namely, the *explanandum* and the *explanans*. The implication here, according to Hempel's thesis is that a scientific explanation should have two main components; the *explanandum* and the *explanans*.

The Explanandum on the one hand is the sentence that describes the phenomenon being explained. **The Explanans:** on the other hand, are classes of sentences advanced to account for the phenomenon being explained. The *explanans* according to Hempel falls into two subclasses:

1. C_1, C_2, …C_k
2. L_1, L_2 … K_r

C_1, C_2,…C_k contain certain sentences and they state specific antecedent conditions.

L_1, L_2 … L_r are sets of sentences that represent general laws or principles.

Schematically, we have:

Logical deductions: C_1, C_2, …C_k – Statement of antecedent condition } **Explanans**

L_1, L_2 … L_r – Statement of general laws

⟶ E, …Description of the empirical phenomenon to be explained **Explanandum**

Hempel asserts that if a proposed explanation is to be sound, its constituents have to satisfy certain conditions of adequacy. These conditions stipulate that:

1. The explanation must be a logical consequence of the *explanans*; in other words, the *explanandum* must be logically deducible from the information contained in the *explanans*. Otherwise, the *explanans* would not constitute adequate ground for the *explanandum*.

2. The *explanans* must contain general laws and these must actually be required for the derivation of the *explanandum*.

3. The *explanans* must have empirical content i.e., it must be capable of being tested by experiment or observation.

4. The sentences constituting the explanans must be true.

What these conditions of adequacy imply is that for the explanans to successfully explain the *explanandum*, the following conditions should be in place. First, the *explanandum* must be a logical consequence of the *explanans* and must be true. This means that the *explanandum* should take the form of a sound deductive argument in which the *explanandum* follows as a logical consequence from the premises of the *explanans*. This sequence is known as the Deductive Nomological model of the Covering Law Thesis. An example will suffice here. The attempt to explain why a child has Down's syndrome can be done deductively in this logical format:

Particular fact – C_1 – Baby Tamuno's cells have three copies of chromosome 21

General Law – L_1 – Any baby whose cells have three copies of chromosome 21 has Down's syndrome

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Phenomenon to be explained – E – Therefore baby Tamuno has Down's syndrome

The above example shows the **deductive** component of the deductive nomological model. For the **nomological** component, the explanation must contain at least one law of nature and this must be an essential premise in the derivation in the sense that the derivation of the *explanandum* would not be valid if this premise is omitted. For example, in the case of baby Tamuno, if premise

L_1 (any baby whose cells have 3 copies of chromosome 21 has Down's syndrome) is removed, the conclusion that baby Tamuno has Down's syndrome would become invalid because there would be no general principles or law of nature that validates the nomological relation between the particular facts and the phenomenon being explained or as Samir Okasha puts it, 'the task of an account of scientific explanation becomes the task of characterizing precisely the relation that must hold between a set of premises and a conclusion'(41). Nomological means 'lawful'.

4.4.2 The Inductive Statistical Model

The inductive statistical model is the second type of explanation under the covering law model. In this model, the relationship between the *explanans* and the *explanandum* is inductive rather than deductive. The underlying idea here is that an inductive statistical model of scientific explanation will be good or successful to the extent that its *explanans* confers high probability on the *explanandum's* outcome. The implication here is that the inductive statistical model obeys the law of induction in that its conclusions are probable. It does not have the trait of certainty as obtained in the conclusions of deductive derivation.

The difference between the D.N model and the I.S model is that the laws in a D.N model are universal generalizations whereas the laws in I.S model have the form of statistical generalizations that makes them highly probable. For Vernon Pratt, '… they are statistical in character; asserting not what always happens in certain circumstances but what often happens' (70). For Hempel, the I.S model is explanatory just to the extent that it approximates explanation by conferring a high probability on the event to be explained. According to him:

> Suppose that a certain phenomenon was explained at an earlier stage of science by means of an explanation which was well supported by the evidence then at hand but had been highly disconfirmed by more recent findings. In such a case, we would have to say that originally, the explanatory account was a correct explanation but

> that it ceased to be one later when unfavourable evidence was discovered … which directs us to say that on the basis of the limited initial evidence, the truth of the *explanans* and thus the soundness of the explanation had been quite probable, but that the ampler evidence now available made it highly probable that the *explanans* was not and had never been a correct explanation (138).

Following from Hempel's assertion, an example will suffice. If for instance, it has been found that Eze, an enthusiastic science student derives pleasure from killing harmless pet animals for his scientific experiments and just recently, six cats belonging to persons living in the neighborhood were found dead at Eze's backyard. The probable conclusion will be that given past statistics, Eze had probably killed the cats for his experiments. But this conclusion can be faulted by later information that Eze had travelled out of the state in the last three weeks for his annual holidays. Consequently, it is always possible according to Curtis Brown that a proposed inductive-statistical explanation, even if the premises are true, would fail to predict the fact in question and thus, have no explanatory significance for the case at hand (www.scientificexplanatory.com).

The Role of Laws in the Covering Law Model

According to Hempel, the explanation of a phenomenon consists in its subsumption under laws or under a theory. Going by Hempel's assertion it follows that laws play essential role in the covering law model. They provide the link between particular facts or circumstances and can serve to explain the occurrence of a given event. For Hempel, the decisive requirements for every sound explanation remains that it subsumes the *explanandum* under a general law. This is because explanatory power never resides in a concept, but always in the general law in which it functions. Apart from being true, a law according to Hempel will have to satisfy a number of additional conditions, one of which is that a sentence is law-like if it has all the characteristics of a general law with the possible exception of truth. Hence, every law is a law-like sentence but not conversely (152). Hempel here is saying that the truth alone should not be the characteristic of a general law.

The law for him will have to incorporate and satisfy other conditions. One of which is that a sentence meant for explanation should be law-like in character. In other words, it has to have the characteristic of a general law without necessarily being true.

Critique of the Covering Law Model

Although the covering law thesis captures to a large extent the structure of many scientific explanations, it has however attracted some criticisms. These criticisms can be grouped into two main classes. On the one hand are cases of genuine scientific explanations that do not fit into the covering law model. These cases according to Okasha suggest that Hempel's model is too strict in that it excludes some bonafide scientific explanations. On the other hand, there are cases of things that do fit into the covering law model, but intuitively do not count as genuine scientific explanation. These cases give the impression that Hempel's model is too liberal in that it allows things that should not be allowed (44). Michael Scriven puts it more succinctly when he said that Hempel's model is too restrictive in that it excludes their own examples and almost every ordinary scientific one and too inclusive in that it admits entirely non explanatory schema (67). These criticisms fall under two headings – asymmetry and irrelevance. But we shall consider just one – irrelevance. You can read further from works for further reading.

The Case of Irrelevance

This argument against the covering law model posits that many deductive nomological propositions with true premises do not appear to be explanatory. According to Curtis Brown "…some counter examples seem to show that an explanation could satisfy all of the criteria listed in the D.N. model even though the explanatory information was completely irrelevant to the explanation" (web). Here we shall refer to Okasha for an example of what Curtis Brown calls - a case of complete irrelevance.

Suppose a young child is in a hospital, in a room filled with pregnant women. The child notices that one person in the room – who is a man called John is not pregnant and asks the Doctor why John is not pregnant. The Doctor replies that John has been taking birth control pills regularly for the last few years and people who take birth control pills regularly never become pregnant. Schematically we have:

General law - - - People who take birth control pills regularly do not get pregnant.

Particular fact - - - John takes birth control pills regularly.

Phenomenon to be explained – Therefore, John cannot be pregnant.

If for the sake of argument that what the Doctor says is true, that is, John is mentally deranged and does indeed take birth-control pills which he believes helps him. Even so, the Doctor's explanation to the child is not very helpful. The correct explanation of why John cannot be pregnant obviously is that he is a man and men do not get pregnant. The point however, is that the explanation the doctor has given the child fits the covering law model perfectly. The doctor deduces the phenomenon to be explained, that is, that John is not pregnant – from the general law that people who take birth-control pills do not become pregnant and the particular fact that John has been taking birth-control pills.

Since both the general law and particular facts are true and since they indeed entail the *explanandum*; according to the covering law model, the doctor has given a perfectly adequate explanation of why John is not pregnant. But the absurdity is that he has not. The general moral according to Okasha (47) is that a good explanation of a phenomenon should contain information that is relevant to the phenomena's occurrence. This is where the doctor's reply to the child goes wrong. Although what the doctor tells the child is true, the fact is; that John has been taking birth-control pills is irrelevant to his not being pregnant because he would not have been pregnant even if he was not taking the pills. This is why the doctor's reply does not constitute a good explanation to the child's question, leading Mayes (web) as it were, to conclude that "…this reasoning qualifies as explanatory on Hempel's theory despite the fact that the premises seem to be explanatorily irrelevant to the conclusion". Thus, the covering law model is criticized for allowing things to serve as scientific explanation even when it will be irrelevant to the desired conclusion.

4.4.3 Probabilistic Model of Explanation

Probabilistic explanation is a form of explanation that considers either the likeliness of an event happening or the strength of ones' belief about an event or issue coming to play. This kind of explanations are usually encountered when the explanatory premises (explanans) contain a statistical assumption about some class of elements, while the explanandum is a singular statement about a given individual member of that class. For example, if Mr. Okon has chickenpox and Miss. Glory comes in contact with Mr. Okon and afterwards is also diagnosed of chickenpox, there is every probability to conclude that Miss. Glory got her chickenpox from her contact with Mr. Okon. Arguments may be made to the effect that chickenpox is contagious but the link may not be sufficient to conclude that a contact with an infected person will affect another. There might be a connection between one getting exposed to chickenpox and then contracting the disease but the connection does not have a universal application. This is because there are cases where such contacts or exposures in the past did not result in infection. The only position that would be justified as an explanation for a possible cause of infection is that of probability. That is to say that there is a high probability of one contracting chickenpox if one is exposed or comes in contact with an infected person. Probabilistic explanations do not sound a bell of finality on its conclusions. Conclusions are probable.

4.4.4 Teleological Model of Scientific Explanation

This kind of explanation is also known as functional model of explanation. It was Aristotle who first defined teleological explanation as an explanation of something in terms of what that thing is for the sake of. What it is, for something to be for the sake of something else, is for it to be a means to the end of that thing; that is, a way of achieving that thing. Carl Hempel, cited in Lessnoff, had opined that a functional explanation is valid if and only if it shows that some item is essential to the functioning of the system to which it belongs. In teleological explanations, there is an explicit reference to future state or event in terms of which the existence of a thing or the occurrence of an act is explained.

4.5 Conclusion

In this unit, we studied the notion of explanation, and saw that explanation is much more than creating understanding in another person. That scientific explanation is the attempts by scientists to answer the question 'why' rather than the question "what". That there are special epistemic requirements which an explanation must meet before it can be called a scientific explanation; it must have explanatory relevance. That is to say, that the explanatory information adduced must afford good grounds for believing that the phenomenon to be explained did occur. And it must be testable; here, the statement constituting a scientific explanation must be capable of empirical rest. Different models of explanations were also unveiled and analysed including the covering law model, the probabilistic model and the teleological model.

4.6 Summary

Explanation is the attempt by one person to produce understanding in another by answering a certain kind of question in a certain kind of way. The synonyms for explanation include: expound, explicate, elucidate and interpret. Scientific explanation is distinct and different from other types of explanation such as sociological, teleological, and psychological or historical explanations. It is the attempts by scientists to answer the question 'why' rather than the question "what". There are several models of scientific explanation. They include; the covering law model, the probabilistic model, and the teleological model. The covering law model holds that for a scientific explanation to be genuine, it must have three types of components; first, it must incorporate one or more general principles or law. Second, there must be a statement of particular facts and third, there must be a statement describing whatever is to be explained. The inductive statistical model is the second type of explanation under the covering law model. In this model, the relationship between the *explanans* and the *explanandum* is inductive rather than deductive. Probabilistic explanation is a form of explanation that considers either the likeliness of an event happening or the strength of ones' belief about an event or issue coming to play. Teleological explanation is also known as functional model of explanation. It is an explanation of something in terms of what that thing is for the sake of.

4.7 Self-Assessment Exercises

1. What is explanation? Explain the difference between scientific explanation and other kinds of explanation

2. Identify and explain 2 models of scientific explanations.

3. Who developed the Covering law model of scientific explanation and what is the main thesis of the covering law model?

4. Explain the critic of irrelevance against the covering law model

5. What is the difference between the probabilistic and teleological models of scientific explanation.

Model Essay Answer to Question 3

The covering law model was developed by Carl Hempel and Paul Oppenheim in their 1948 publication entitled Studies in the Logic of Explanation. The covering law thesis holds that for a scientific explanation to be genuine it must have three types of components; it must incorporate one or more general principles or law; there must be a statement of particular facts and there must be a statement describing whatever is to be explained. What the explanation does is to show that the thing to be explained follows logically from the general principles, given that the particular fact holds.

4.8 Tutor Marked Assignment

1. Explanation is the attempt by one person to produce _________ in another person by answering a certain kind of question in a certain kind of way. A. Relationship. B. Understanding. C. Acknowledgement. D. Criticism

2. The class of sentences advanced to account for the phenomenon being explained is called _______________ A. Explanandum. B. Explicanda. C. Explanans. D. Elucidates.

3. The Studies in the Logic of Explanation was published by Carl Hempel and Paul Oppenheim in _________ A. 1848. B. 1928. C. 1968. D. 1948.

4. Functional explanation is ____________ if and only if, it shows that some item is essential to the functioning of the system to which it belongs. A. Valid. B. Sound. C. True. D. Invalid.

Model Answers: 1. – B. 2. – C. 3. – D. 4. – A

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MODULE 3: THE GROWTH OF SCIENTIFIC KNOWLEDGE

UNIT 1: Demarcation Between Science and Non-science

1.1 Introduction

In this unit we shall be considering the long-time debate of what constitute real science. What really is the demarcation between science and non-science? What makes a discipline a pseudo-science? What are the criterions of demarcation between science and pseudo-science? In philosophy of science and epistemology the demarcation problem is the question of how to distinguish between science and non-science. It examines the boundaries between science, pseudo-science, and other products of human activity, like art and literature and beliefs. The debate has continued from the days of the Pre-Socratics, reinvigorated by David Hume in the modern periods and kept on the burner by contemporary philosophers of science and scientists in various fields. These criterions have turned out to be the pathways that has continued to lead the way for the growth of science. The criterions of demarcation set by different philosophers of science of different epochs shall be examined in this unit.

1.2 Objectives

It is expected that after studying this unit the student will be able to:

9. Understand the reasons for the demand for demarcation between science and non-science
10. Identify the main characteristics of a pseudo-science
11. Identify the different criterions for demarcation between science and pseudo-science
12. Note the trail and proponents of demarcation between science and pseudo-science

1.3 Main Course Contents: Demarcation Between Science and Non-science

1.3.1 Science and Non-science

An early attempt at demarcation between science and non-science is seen in the efforts of early Greek philosophers to distinguish their methods and their accounts of nature from the mythological or mystical accounts of their predecessors and contemporaries. Thales for instance abandoned the myths of Homer and Hesiod to empirically inquire into the ultimate stuff of the world based on existential realities.

Aristotle had to decisively stir away from the metaphysical path of his teacher – Plato to describe at length what was involved in having scientific knowledge of something. To be scientific, he said, one must deal with causes, one must use logical demonstration, and one must identify the universals which 'inhere' in the particulars of sense. But above all, to be scientific one must have *apodictic certainty* that is, logical certainty that is also demonstrable. It is the last feature which, for Aristotle, most clearly distinguished the scientific way of knowing. (Larry Laudan,111 – 127)

After Aristotle, the demarcation of science from non-science was among the major programmes of post-medieval scholarship. Medieval scholarship sought to demarcate between theology and philosophy, between faith and reason. The systematic decline of medieval synthesis between theology and philosophy and between faith and reason created the way, according to Stumpf, for the renaissance interlude that sought to differentiate science from religion and faith from reason (86). With the modern philosophers embracing reason and outrightly rejecting religion and faith, focus was now on how to draw the lines between illusion and intelligibility, between metaphysics and sophistry. David Hume drew the first blood, when he announced that anything outside reason and matter of fact should be set aflame. For him, anything that does not contain numbers or experimental reasoning has no place in scholarship. In his words:

> When we run over libraries persuaded of these principles, what havoc must we make if we take in our hands any volume of divinity or school metaphysics for instance; let us ask, does it contain any abstract reasoning concerning quantity or number? No. does it contain any experimental reasoning concerning matter of facts and existence? No. commit them to the flames for it can contain nothing but sophistry and illusions. (Hume, cited in Lawhead, 314).

These attitude to knowledge outside experience and experiment by modern philosophers set the stage for the search for a criterion by which the demarcation between science and non -science could be based. Criterions such as the inductivism of Bacon, the verifiability principle by the Logical positivists, the deducibility criterion of Ayer, and the falsifiability criterion of Karl Popper amongst others were developed. These became necessary following the attempt by every discipline to attach the science appellation to its nomenclature leading as it were to some scholars branding such disciplines as pseudo-science.

1.3.2 Pseudo-science

Pseudo-science consists of theories, ideas, or explanations that are represented as scientific but that are not derived from science or the scientific method. In other words, Pseudo-science consists of statements, beliefs, or practices that claim to be both scientific and factual but are incompatible with the scientific method. Scientific statements are specific and well defined while pseudo-science is vague and variable. One of the key differences between science and pseudo-science is that a scientific statement or theory is stated in such a way as to be falsifiable. While pseudo-scientific statements are usually not falsifiable. Pseudoscience provides no room for challenge and tends to dismiss contradictory evidence or to selectively decide what evidence to accept. Thus, pseudo-science is usually nothing more than a claim, belief, or opinion that is falsely presented as a valid scientific theory or fact.

The Oxford English Dictionary (OED) defines pseudoscience as 'a pretended or spurious science; a collection of related beliefs about the world mistakenly regarded as being based on scientific method or as having the status that scientific truths now have. Many writers on pseudoscience have emphasized that pseudo-science is non-science posing as science. According to Brian Baigrie (438), "what is objectionable about these beliefs is that they masquerade as genuinely scientific ones." These and many other authors assume that to be pseudo-scientific, an activity or a teaching has to satisfy the following two criteria: 1. It is not scientific, and 2. Its major proponents try to create the impression that it is scientific. These two criteria are of important concerns to philosophers of science. Proponents of pseudo-science often attempt to mimic science by arranging conferences, journals, and even form associations that share many of the superficial characteristics of science, but do not satisfy its quality criteria. There are some characteristics that may be used to identify a pseudo-science. They include but no limited to the following:

Characteristics of Pseudo-science

1. Use of vague, exaggerated and untestable claims – They use assertions of scientific claims that are vague rather than precise and these claims lacks specific measurements.
2. Improper collection of data – They use myths, religious texts, and personal testimonials as if they were facts.
3. Lack of openness to evaluation by other experts – They evade peer review before publishing their results and also fail to provide adequate information for other researchers to evaluate or reproduce their claims.
4. Absence of progress – They lack growth and progress because their claims remain unaltered for centuries on end despite contrary evidences. Scientific research programmes make mistakes but they tend to correct themselves over time.
5. Use of misleading language – Pseudo-science create scientific sounding words to persuade non-experts to believe statements that may be false, misleading and sometimes meaningless.

Some of the disciplines that suffer the denigrating appellation of pseudo-science include Astrology, Cosmology, Psychology and Psychoanalysis.

1.4 The Criterion of Demarcation

1.4.1 Inductivism

Inductivism is the view that scientific knowledge is derived from induction. Induction is a method that involves drawing conclusions from detailed facts to general principles. The method starts with many observations of nature with the aim of finding a few logical statements about how nature works. In inductive methodology, we move from premises about objects we have examined to conclusions about objects we have not examined. Induction emerged from the works of Francis Bacon in 1620 entitled Novum Organum. He had argued in the *Novum Organum* that our only hope for building true knowledge is through the careful method of induction. He was the first to put up an intellectual and systematic criterion by which scientific investigation can be pursued and, in a way, demarcate science from non-science. It was Bacon's dissatisfaction with Aristotelian syllogism and the desire to stir science away from authority worship that spurred his search for method that is different from Aristotle's. He maintained that the aim of the scientist is to move further and further away from ignorance. To achieve this, the scientist begins by carrying out experiments. Bacon's method begins with description of the requirements for making the careful, systematic observations necessary to produce quality facts. He then proceeds to use induction, the ability to generalise from a set of facts to one or more axioms. However, he stresses the necessity of not generalising beyond what the facts truly demonstrate. The next step may be to gather additional data, or the researcher may use existing data and the new axioms to establish additional axioms. Specific types of facts can be particularly useful, such as negative instances, exceptional instances and data from experiments. The whole process is repeated in a stepwise fashion to build an increasingly complex base of knowledge, but one which is always supported by observed facts, or more generally speaking, empirical data. Bacon's induction had some weaknesses according to Stumpf (224), because he had no grasp of what modern scientist mean by hypothesis. He assumed that if one looked at enough facts, hypothesis would suggest itself, whereas modern scientist knows that it is necessary to have a hypothesis before one inspects facts in order to have some guide in the selection of facts relevant to the experiment.

1.4.2 Verificationism

The Verifiability criterion holds that a statement is meaningful if and only if it is either empirically verifiable or tautological (that is, such that its truth arises entirely from the meanings of its terms). Thus, the criterion discards as meaningless the metaphysical statements of traditional philosophy as well as other kinds of statements—such as ethical, aesthetic or religious principles—asserted as true but neither tautological nor known from experience. Such statements may have meaning in the sense of being able to influence feelings, beliefs, or conduct but not in the sense of being true or false and hence of imparting knowledge. According to the principle, a non-tautological statement has meaning only if some set of observable conditions is relevant to determining its truth or falsity. So stated, it reflects the view that the meaning of a statement is the set of conditions under which it would be true. The verifiability criterion was formulated by the logical positivists.

Logical positivism is a philosophical movement that arose in Vienna in the 1920s. Positivists holds that only statements about matters of fact or logical relations between concepts are meaningful. All other statements lack sense and are labelled metaphysics. They believe that scientific knowledge is the only kind of factual knowledge and that all traditional metaphysical doctrines are to be rejected as meaningless. According to A. J. Ayer “metaphysicians make statements which claim to have "knowledge of a reality which transcends the phenomenal world". Ayer, a member of the Vienna Circle, argued that making any statements about the world beyond one's immediate sense-perception is impossible. This is because even metaphysicians' first premises will necessarily begin with observations made through sense-perception.

Ayer implied that the line of demarcation is characterized as the place at which statements become "factually significant". To be "factually significant", a statement must be verifiable. In order to be verifiable, the statement must be verifiable in the observable world, or facts that can be induced from "derived experience". This is referred to as the "verifiability" criterion.

This distinction between science, which in the view of the Vienna Circle possessed empirically verifiable statements, and metaphysics, which lacked such statements, can be seen as representing another aspect of the demarcation problem. The basic idea was that a scientific statement could be distinguished from a metaphysical statement by being at least in principle possible to verify. This standpoint was associated with the view that the meaning of a proposition is its method of verification.

The principal criticism against the verifiability principle has been that, because it is not an empirical proposition, it is itself, on its own terms either meaningless or tautologically true as an arbitrary definition of meaningfulness. In response, it has been argued both that the principle is indeed a tautology, though a nonarbitrary one in that it reflects actual usage and that it is strictly meaningless but to be taken as a recommendation for the conduct of scientific inquiry.

1.4.3 Falsificationism

Falsificationism which is the central theme in the philosophy of Karl Popper, holds that for a theory to be considered scientific, it must be able to be tested and proven false. It suggests that the central nerve of science, as opposed to pseudo-science, is not that it puts forward hypotheses that are confirmed by evidence to some high degree, but that, its hypotheses are capable of being refuted by evidence. That is, that they genuinely face the possibility of test and rejection through not conforming to experience. For example, the hypothesis that all Southerners of Nigeria eat dog meat can be falsified by observing a Southerner who does not eat dog meat. Thus, for Popper, the criterion for demarcation should be based on the refutability or falsifiability of a given hypothesis or theory. According to him;

> There clearly was a need for a different criterion of demarcation and I proposed that the refutability or falsifiability of a theoretical system should be taken as the criterion of demarcation. According to this view, which I still uphold, a system is to be considered scientific only if it makes assertions which may clash with observations; and a system is in fact, tested by attempts to produce such clashes; that is to say, by attempts to refute it. Thus, testability is the same as refutability, and can therefore likewise be taken as a criterion of demarcation (345).

The point here, according to Popper, is that scientific theories should make predictions which can be tested, and the theory rejected if these predictions are shown not to be correct.

Popper gives the following example. Europeans for thousands of years had observed millions of white swans. Using inductive evidence, we could come up with the theory that all swans are white. However, exploration of Australasia introduced Europeans to black swans. Popper’s point here according to Mcleod (web) is this: no matter how many observations are made which confirm a theory, there is always the possibility that a future observation could refute it. For him induction as a method of science cannot yield certainty. He argues that science would best progress using deductive reasoning as its primary emphasis. He calls this primary emphasis critical rationalism.

Popper's demarcation criterion has been criticized both for excluding legitimate science ... and for giving some pseudo-sciences the status of being scientific ... According to Larry Laudan (121), it "has the untoward consequence of countenancing as 'scientific' every crank claim which makes ascertainably false assertions". Astrology, rightly taken by Popper as an unusually clear example of a pseudo-science, has in fact been tested and thoroughly refuted ... Similarly, the major threats to the scientific status of psychoanalysis, another of his major targets, do not come from claims that it is untestable but from claims that it has been tested and failed the tests.

1.5 Critical Rationalism

Critical rationalism is the name Karl Popper gave to his work where he tried to explain the growth of knowledge through the elimination of errors. In his Conjectures, he made the following declaration:

> The proper answer to my question 'how can we hope to detect and eliminate error?' is, I believe, by criticizing the theories or guesses of others. This answer sums up a position which I propose to call critical rationalism. It is a view, an attitude and a tradition… (34).

He asserts that the critical rationalism which he proposes is a product of the early Greek philosophers and completely different from the rationalism or intellectualism of Descartes and very different from the epistemology of Kant, except that in the field of ethics Kant approached it with his *principle of autonomy*. This principle according to Popper expresses realization that we must not accept the command of an authority however exalted as the basis of ethics. For whenever we are faced with a command by an authority, it is for us to judge critically whether it is moral or immoral to obey. The authority may have power to enforce its command and we may be powerless to resist. But if we have the physical power of choice then the ultimate responsibility remains with us. It is our critical decision whether to obey a command or submit to an authority. In the field of religion, Kant also approached it with the critical attitude when he averred that the deity should be made known to you and even … if He should reveal Himself to you; it is you … who must judge whether you are permitted to believe in Him and to worship Him (Conjectures, 35).

This Kantian attitude towards authority or deity for Popper is critical rationalism. For him, "rationalists are those people who are ready to challenge and to criticize everything including their own tradition. They are ready to put question marks to anything … they will not submit blindly to any tradition" (Conjectures, 164). But this rationalist attitude differs from the critical rationalist attitude. Kant's rationalism which is properly called critical philosophy is different from the critical rationalism of Popper because critical philosophy asks questions such as "what and how much, can understanding and reason know apart from experience?" Its task is the critical appraisal of the capacities of human reason; whereas, critical rationalism seeks to detect and eliminate errors in human reasoning.

Critical rationalists hold that scientific theory or any other claim to knowledge can and should be rationally criticized and if they have empirical content can and should be subjected to tests which may falsify them. Thus, claims to knowledge may be contrastively and normatively evaluated. They are either falsifiable and thus empirical or not falsifiable and thus non empirical. Those claims to knowledge that are potentially falsifiable can then be admitted to the body of empirical science and then further differentiated according to whether they are retained or indeed are actually falsified. If retained, then further differentiation may be made on the basis of how much subjection to criticism they have received; how severe such criticism has been and how probable the theory is, with the least probable theory that still withstands attempts to falsify it being the one to be preferred. That it is the least probable theory that is to be preferred is one of the contrasting differences between critical rationalism and classical views on science such as positivism which holds that one should instead accept the most probable theory.

As the name may suggest, Karl Popper in the Open Society and Its Enemies regards a critical attitude as the most important virtue a philosopher could possess. Indeed, he called criticism "the life blood of all rational thought" (39). He made the point that all criticism consists largely in pointing out contradictions or discrepancies and that scientific progress consists largely in the elimination of contradictions wherever they may be found. He asserts that nothing is exempt from criticism.

Popper's notion of critical rationalism is an offshoot of his notion of *falsificationism*. The notion is hinged on the principles of *conjectures* and *refutations*. By conjectures Popper means unjustified and unjustifiable anticipations, guesses, myths and tentative solutions to problems. He asserts that the scientific knowledge progresses by conjectures. These conjectures are on the other hand controlled by criticism, that is, by attempted refutations. These refutations include severe critical test that are performed on the conjectures (Conjectures, xix).

Popper opines that all knowledge is human and therefore mixed with human errors, prejudices, dreams and hopes. And that all we can do is to grope for truth even though it is beyond our reach. For if we admit that there is no authority beyond the reach of criticism to be found within the whole province of knowledge then we can retain without danger the idea that truth is beyond human authority. Popper believes that the quest for objective truth can only be achieved through critical appraisal and tests of past knowledge claims using critical rationalism as a frame work (Conjectures, 39).

Critical rationalists believe that scientific theories or any claim to knowledge should be subjected to tests which may falsify them. Popper regards the critical attitude as the most important virtue anyone desirous for knowledge could possess. He made the point that all criticism consists in pointing out contradictions or discrepancies and that scientific progress consists largely in the elimination of contradictions wherever they may be found; that there is no ultimate source of knowledge: every source, every suggestion is welcome and every suggestion is open to critical examination.

Critical rationalism challenges people to take a second look at their knowledge claims, theories, cultures, traditions and beliefs. It also creates the awareness of what Ucheaga (1) describes as "other's positions". It abhors historicism because it closes doors to ideas other than antecedent norms and beliefs. Historicism is the tendency to regard every argument or idea as completely accounted for by its historical context as opposed to assessing it by its merit.

1.6 The Critical Attitude

Popper used the Athenian philosophers as an example of what is meant by a critical attitude. The Athenian philosophers were willing to question old explanations and then try to improve them. They did not just accept old explanations but were willing to challenge them, invent new alternatives and debate more than one explanation. In other words, the critical attitude is the attitude of critically discussing existential matters without bias or prejudice. Popper posits:

> The Greek philosophers invented a new tradition - the tradition of adopting a critical attitude towards the myths; the tradition of discussing them; the tradition of not only telling a myth, but also of being challenged by the man to whom it is told. Telling their myth, they were ready in their turn to listen to what their listener thought about it – admitting thereby the possibility that he might have a better explanation than they (Conjectures 170).

The above is the description of the critical attitude also referred as the rational attitude or the scientific attitude. This attitude of looking at things by the early Greek philosophers was something according to Popper that had not happened before, and it brought a new way of asking questions. The emergence of the critical attitude followed a pattern according to him, together with the explanation, the question would arise such as; 'can you give me a better account? and another philosopher might say; 'I do not know whether I can give you a better one, but I can give you a very different account which does just as well' (Conjectures, 170).

The Greek philosophers were never content with just accepting the explanation of any theory, neither were they content at rejecting any. They believed in further discussions to see whether their explanations do really account for the things about which they already know or even for something which they have so far overlooked. Socrates exemplified this attitude in Plato's dialogues (see The Apology) and Popper in The Open Society, (128) made the point that 'this is the true scientific spirit'. In his Logic of Scientific Discovery (xix), he made the point that criticism will be fruitful if and only if problems are stated as clearly as possible and solutions put in a sufficiently definite form – a form in which it can be critically discussed. (Critical rationalism is part of a work I published in Sapientia Journal of Philosophy, Vol.11, 2019.)

One of the most prominent critics of critical rationalism is Paul Feyerabend. After a careful analysis of critical rationalism, Feyerabend raised two questions against the theory. He asks; (1) is it desirable to live in accordance with the rules of critical rationalism? And (2) is it possible to have both a science as we know it and these rules? For the answers to his questions, he averred that we would be proceeding in the worst possible fashion if we adopt critical rationalism as a method. He believes that science as it is known today will create a monster if any particular method is adopted by the sciences. He therefore proposed a reform of the sciences that makes them anarchic and more subjective. Asserting that it is not possible to have both a science as we know it and the rules of critical rationalism.

1.7 Conclusion

In this unit we traced the demarcation between science and non-science from the time the Pre-Socratics jettisoned mythology and began to use natural phenomenon as objects of explanation instead of clinging to mythic imageries. Aristotle parted ways with Plato's idealism in order to focus the first principles of nature and its causes. After the renaissance, it was now clear that there should be a demarcation between faith and reason. Reason won. Science was born. But what shall be the criterion of demarcation between science and non-science especially between some studies that are pretending to be science – the pseudo-sciences. Some of the criterion analysed in the unit include; Inductivism, Verificationism, and Falsificationism including its off-shoot - Critical rationalism.

1.8 Summary

Attempt at demarcation between science and non-science is seen in the efforts of early Greek philosophers to distinguish their methods and accounts of nature from the mythological accounts of their predecessors. After Aristotle, the demarcation of science from non-science was among the major programmes of post-medieval scholarship. Pseudo-science consists of statements, beliefs, or practices that claim to be both scientific and factual but are incompatible with the scientific method. The criterions of demarcation include: Inductivism - the view that scientific knowledge is derived from induction. Induction is a method that involves drawing conclusions from detailed facts to general principles; Verificationism – the view that a statement is meaningful if and only if it is either empirically verifiable or tautological and Falsificationism – which is the view that for a theory to be considered scientific, it must be able to be tested and proven false. Critical rationalism is an off-shoot of the falsifiability criterion and holds that scientific theory or any other claim to knowledge can and should be rationally criticized and if they have empirical content can and should be subjected to tests which may falsify them.

1.9 Self-Assessment Exercise

1. How did the early Greek philosophers kick-start the demarcation process between science and non-science?
2. What is Pseudo-science and what are the disciplines that presently bear the appellation?
3. Identify and explain two criterions of demarcation between science and pseudo-science
4. Explain the notion of critical rationalism
5. What is your understanding of the critical attitude?

Model Essay Answer to question 5

The critical attitude is the attitude of critically discussing existential matters without bias or prejudice. It is the attitude of not accepting old explanations but the willingness to challenge them, invent new alternatives and debate more than one explanation. The emergence of the critical attitude followed a pattern according to Karl Popper, together with the explanation, the question would arise such as; 'can you give me a better account? and another philosopher might say; 'I do not know whether I can give you a better one, but I can give you a very different account which does just as well'.

1.10 Tutor Marked Assignment

1. David Hume advocated that anything that does not contain numbers or experimental reasoning should be ___________ A. Set aside. B. Rejected. C. Abandoned. D. Set aflame
2. The characteristics of Pseudo-science include the following except: A. Use of vague and untestable claims. B. Improper collection of data. C. Openness to evaluation by other experts. D. Use of misleading language.

3. Identify the odd one among the following: A. Inductivism. B. Verisimilitude. C. Falsificationism. D. Verificationism

4. Inductivism emerged from the publication entitled __________ written by _________ A. The Organon / Aristotle. B. Conjectures and Refutations / Popper. C. Novum Organum / Bacon. D. The Republic / Plato

Model Answers: 1. – D. 2. – C. 3. – B. 4. – C

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MODULE 3: THE GROWTH OF SCIENTIFIC KNOWLEDGE

UNIT 2: Phases of Scientific Growth

2.1 Introduction

How does science grow? Karl Popper thinks it is by conjectures and refutations. But some philosophers and scientists think otherwise. In this unit we shall be considering the objections to Popper's notion of theory of falsificationism and its role in the growth and progress of science and the suggested alternatives of the critics of the theory. Imre Lakatos and Thomas Kuhn are among the critics of Popper's theory. Should the criterion of demarcation between science and pseudo-science be based on falsifiability of a given theory? Should the progress and growth of science be anchored on conjectures and refutations as theorized by Popper and his followers? If the answer is in the negative, then what better options does science and scientists have for the growth of scientific knowledge? Imre Lakatos suggests a research programme while Thomas Kuhn believes that science goes through phases of growth that culminates into a revolution. The revolution according to him, takes science to another level of growth. We shall scrutinize these options in this unit.

2.2 Objectives

It is expected that after studying this unit the student will be able to:

1. Identify some issues that bug the philosophers of science concerning the growth of scientific knowledge.
2. Appreciate some of the criticisms against the falsificationist criterion of demarcation.
3. Identify the notable critics of falsificationism and the alternatives they suggest.
4. Understand the notion of paradigm change and its phases
5. Understand the idea of a research programme

2.3 Main Course Contents: Phases of Scientific Growth

2.3.1 Issues about the growth of science

Most people are aware and agree that we know more about the natural world now more than we did 2000 years ago or even 100 years ago. For example, in 1900, we did not know anything about Einstein's relativity theory and how it could change the world of physics. We also did not know anything about molecular genetics and the place of the DNA in human affairs. Nobody even imagined that man could walk the surface of the moon a few years before it was achieved. The list can go on and on. So, there has been unquestionable changes in our scientific view of the world with respect to the content of our scientific theories and what we take as established facts. In addition to established facts, there has been scientific changes in terms of the methods used to investigate the world and the criteria and standards for evaluating scientific claims.

Not only would most people agree that there has been changes in our scientific understanding of the world in terms of content, method and evaluative criteria, but most people would agree that this change has been one of progress, that is, that our scientific understanding is not simply different than it used to be but that it is better than it used to be. For most people, according to Boersema, the sciences have made progress toward the goal of understanding the world (239). But there are philosophical issues over the question of progress. What is the nature of scientific change, how does science progress from one phase to another? For example, Karl Popper believes that the way scientific knowledge progresses are by unjustified anticipations, by guesses, by tentative solutions to our problems and by conjectures. These conjectures according to him are controlled by criticism; that is, by attempted refutations which include severe critical test. This is how we become better acquainted with our problem and is able to propose more mature solutions: the very refutation of a theory is always a step forward that takes us nearer to the truth. And this is how we learn from our mistakes. And as we learn from our mistakes, our knowledge grows even though we may never know for certain. And since we can never know for certain, there can be no authority here for any claim to authority. Those among our theories which turn out to be highly resistant to criticism and which appear to us at that moment of time to be better approximations to truth than other known theories, may be described, together with the reports of their test as the science of that time (xi).

2.3.2 The Notion of Verisimilitude and Corroboration

Popper asserts that in the comparison of theories of science, there was to be a criterion of potential progression that judges a theory with a greater amount of empirical information. He believes that the goal of science should be how to get closer to truth since we cannot attain certain truth. The idea of getting closer to truth rather than looking for certain truth is what he termed verisimilitude. For, according to him, 'looking at the progress of scientific knowledge, many people have been moved to say that even though we do not know how near to or how far from the truth we are, we can, and often do, approach more and more closely to the truth' (313). Verisimilitude, therefore, is an approximation to truth; it is getting closer and closer to the truth.

Etymologically, verisimilitude gets its roots from the Greek word, *eoikotōs*, which in English means, 'like the truth'. This informs the suggested synonym, often used interchangeably for verisimilitude, as truth-likeness. Verisimilitude concerns itself with being more similar to the truth, rather than seeming true. Verisimilitude according to Popper represents the idea of approaching comprehensive truth (320). At commonsense level, some propositions seem closer to the truth than others. While some truths are closer to the whole truth than other truths, even some falsehoods seem closer to the truth than some truths. The idea behind verisimilitude is that the assertions or hypothesis of scientific theories can be objectively measured with respect to the amount of truth and falsity that they imply. And in this way, one theory can be evaluated as more or less true as another on a quantitative basis. The notion of verisimilitude offers science the ability to make comparisons between two or more scientific theories, given their relative closeness to the truth. But this is not enough. Popper opines that we are often guided by the corroboration of a theory.

Popper sees corroboration as the degree to which a theory is falsifiable. Given some initial conditions, we can proceed to deduce statements from scientific theories. Agreed test according to Uduigwomen are the determinants of the truth of these statements. If the statements withstand the tests, then the theory is corroborated. And when a theory is corroborated, we feel more justified to adhere to it than before. On the other hand, if statements are falsified, theories themselves are falsified, and once theories are falsified, they must be abandoned. Thus, for Uduigwomen, Popper seems to conceive of scientific change in the light of the indications of hypothetico-deductive methodology that is often called the falsificationist methodology (91). Popper himself contend that corroboration of scientific theories is essential 'if scientific progress is to continue' (330). The point to note from the foregoing exposition is that Popper's falsificationism apart from critical rationalism has other elements that are instrumental to achieving progress in science without falling into the rationalist trap of trying to achieve certainty of knowledge. This analogy is the summary of Popper's Falsification thesis that is driven by critical rationalism. Some philosophers however, objects to Popper's idea of how science progresses or should progress.

2.4 Paradigm shift

Thomas Kuhn objected to Popper's theory of falsificationism as a criterion for the growth of science. For him, scientists work in a series of paradigms and that falsificationist methodologies would make science impossible. For him, no theory ever solves all puzzles with which it is confronted at a given time; nor is the solutions already achieved offer perfect solutions. On the contrary it is just the incompleteness and imperfection of existing data theory-fit, that, at any given time, define many of the puzzles that characterize normal science. According to him, if any and every failure to fit were ground for theory rejection, all theories ought to be rejected at all times. On the other hand, if only severe failure to fit justifies theory rejection, then according to him, the Popperians will require some criterion of improbability or of degree of falsification. In developing one, they will almost certainly encounter the same network of difficulties that has haunted the advocates of the various probabilistic verification theories. Kuhn believes that 'no process yet disclosed by the historical study of scientific development resembles the methodological stereotype of falsification by direct comparison with nature'. in effect, according to Ojong (78), Khun's theory of science was developed as an attempt to give a theory of science that is more in keeping with the historical situation in science as he saw it and following from that perception of what actual scientific practice is, he proceeded to develop a view of scientific practice that is sociological in nature.

Paradigms in Science

Thomas Kuhn, in his 1962 book, *The Structure of Scientific Revolution* challenged the view that the history of science is characterized by the study of cumulative discovery. His idea of how science develops differs from the standard account. Where the standard account saw steady cumulative progress, he saw discontinuities. Kuhn's central claim is that development in any scientific field happens via a series of phases. The first phase is pre-paradigm science, then normal science. Followed by the season of anomalies, and then succeeded by a period of crises. The crises are then resolved by a revolutionary change in world view resulting in paradigm shift. The paradigm shift leads to a period of mature science; after this, the scientific field returns to normal science, based on this framework, the circle goes on and on.

Therefore, change and progress in science for Kuhn is a matter of replacement of paradigms and not the result of a cumulative collection of facts that result from value-free observation and theories inductively inferred from those observations or of bold conjectures with articulated falsifiability. A paradigm simply means a model, a pattern or a pattern of something that may be copied by other people. Kuhn defined scientific paradigm as 'a universally recognized scientific achievement that for a time provide model problems and solutions for a community of practitioners. A paradigm transforms a group into a profession or a discipline, from this you have specialized journals and professional societies and so on.

Paradigms are defined sociologically from the perspective of scientific communities. A scientific community is a particular community, united by education professional interaction and communication, as well as similar interests in problems of a certain sort, and acceptance of a particular range of possible solutions to such problems. The scientific community, like other communities, defines what is required for membership in the group. A scientific community shares a particular paradigm in the sense that those members of the community point to the same or similar scientific examples (or achievements) – for example, a Newtonian paradigm rests on a commitment to absolute space and time, whereas Einsteinian paradigm does not.

Phases of Kuhnian Paradigm

1. Pre-paradigm phase – here, there are many schools of thought competing for general acceptance. In this period; facts are gathered almost randomly without reference to a theoretical structure. But as one theoretical system gradually receives general acceptance, a paradigm is established.

2 Normal science - Normal science means research 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 practice. During normal science, rather than attempt to falsify theories, scientists, engage in puzzle-solving activities. Their faith in the underlying theory is such that anomalies are not treated as falsifying instances of the theory but as puzzles to be solved. The

failure to solve a puzzle is not attributed to the inadequacy of experiment or the incapability of the scientist.

3. Anomalies - These are results from experiments and theories of normal science that no longer fit the paradigm of normal science. The anomalies phase is the time that the number of inconsistencies with a given paradigm that adhoc hypothesis can no longer contain them. Therefore, most members of the scientific community will begin to lose faith in the paradigm. This loss of faith leads to crisis period within the scientific community.

4. Crises phase - This is a period in the life of a paradigm when there is a loss of confidence by most members of a scientific community in that paradigm. This happens mostly when there is the articulation of several other alternative theoretical structures to overcome perceived anomalies.

5. Paradigm shift - When one of the alternative theoretical structures achieves general acceptance, by the scientific community, then, there occurs what Kuhn calls paradigm shift. A shift from the old to the new. This shift from the old to the new is what Kuhn describes as a scientific revolution which is the violent overthrow of the old paradigm by a scientific community.

6. Mature science - The adoption of a new paradigm brings about the phase of mature science. Mature science is when the scientific community settles down with a new paradigm after a revolution and begins to carry out their scientific business on its frame work. Mature science leads to normal science and the circle continues on and on and on.

Scientific revolution

Kuhn sees scientific revolution as those non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one (92). Scientific revolutions on which progress in science is measured entails a reconstruction that alters the theoretical generalizations as well as many of the paradigms and methods of application of a research field. According to Kuhn, during revolutions, scientists see new and different things when looking with familiar instruments in places they have looked before. It is as if the professional community had been transported to another planet where familiar objects are seen in a different light and are joined by unfamiliar ones as well. The point he is making here is that paradigm changes do cause scientists to see the world of their research-engagement differently and thus after a revolution, scientists begin to respond to a different world, … a world were ducks in the scientist's world before the revolution become rabbits afterwards (111).

2.5 Methodology of Scientific Research Programme (MSRP)

Imre Lakatos was a Hungarian philosopher of mathematics and science known for introducing the concept of research programme. Lakatos, according to Ojong developed his picture of science in an attempt to improve and overcome Karl Popper's philosophy of science that is anchored on falsificationism. He undertook a critical appraisal of other methodologies of science including that of Thomas Kuhn before eventually presenting his own conception of the method that is fitted best for the growth and progress of science. He criticized Popper's falsificationism because it assumes the provability of propositions from facts. For example, if a theory states that – All Ducks are white' and it happens that in the cause of investigation, one Duck is found that is black, then the theory stands falsified. Also, the principle of falsificationism requires that the theory be jettisoned. For him, the Popperian falsificationism requires some extra-methodological inductive principles in order to give epistemological weight to its postulates.

The desire for extra-methodological inductive principle to counter some critics of Popper's falsificationism gave birth to his Methodology of Scientific Research Programme (MSRP) in 1968. He had opined that historical study reveals that the evolution and progress of science exhibits a structure that is not captured by the inductivist and the falsificationist accounts of science. For him, scientific theories are embedded in some kind of organized programmes. According to Ojong, 'while other philosophers of science like Popper and Kuhn for instance, examined the growth of knowledge in terms of the success of single theories, Lakatos' assessment of such growth is based on research programme that present an organized structure of scientific theories' (66). The point here, is that Lakatos does not subscribe to Popper's view that a theory should be abandoned immediately it has generated some anomalies. He rather thinks that an assessment of the relative merits of competing theories should be delayed until proponents of the theories have had time to explore modifications in their theories which might make them better able to cope with anomalies. This line of thinking according to Uduigwomen (94) led Lakatos to conclude that the unit of appraisal in science must not be a single theory but many related theories arranged in such a sequence that each one is generated by modifying the one preceding it. This method of modification is what Lakatos called 'the Methodology of Scientific Research Programme.

How the MSRP Operates

Many authors are of the view that the methodology of scientific research programme (MRSP) was developed by Lakatos as a Popperian response to Kuhn's criticism of falsificationism. His purpose was to build a theory that shows that scientist does not abandon their theories when they encounter anomalies. Thus, Lakatos research programme is essentially a sequence of theories within a domain of scientific inquiry. Each theory is held to make an advance over its predecessor. The move from one theory to its successor within a research programme is called 'problem shift'. In Lakatos' research programme, theories are seen as entities existing over time. They get changed as new information is gathered. Theories are adjusted to fit the facts as the facts are obtained. What this means is that theories are not rejected when tested predictions fails. Instead, the theory is fixed in order to account for the failure. He uses the following example to make clear his point. According to him:

> Suppose that a physicist – **P**, in the late 18th century use Newtonian mechanics to derive the orbit of a newly discovered planet – **L**. Astronomers find that **L** deviates from the path predicted for it by **P**. Has Newtonian mechanics been falsified? Should it be given up? Not at all. Instead, physicist P postulates the existence of planet M, which is the cause of the deviation. **P** is able to use Newtonian mechanics to predict exactly where **M** will be. However, **M** is so small that contemporary telescope cannot find it. So, opticians have to build a better telescope. Better telescope does not reveal planet **M**. Should **P** now give up Newtonian mechanics? Not at all. **P** claims that there is some cosmic dust interfering with the telescope. Now we can continue the story into present times. We send a satellite into space to confirm the existence of the cosmic dust. The satellite however, finds no dust. Perhaps a magnetic field or some kind of radiation is affecting the instrument of the satellite… (Lakatos cited in Zucker 166).

The point of the illustration above according to Lakatos is to show that there is no way for just one fact to refute a theory.

Components of MSRP

Lakatos' research programme has three main component that is made up of – the hard core, the negative heuristic and the positive heuristic.

The hard-core – this is made up of the theoretical assumptions (the first principle) which any theory that is a part of programme must share from. The scientists involved in a programme will attempt to shield the hard-core from falsification attempts behind a protective belt of auxiliary hypotheses. All scientific research programmes may be characterized by their hard-core. The negative heuristics of the programme forbids us to direct the modus tollens at this hard-core. Instead, we must use our ingenuity to articulate even auxiliary hypothesis which forms a protective belt around this core (Lakatos 133).

Note: Modus Tollens is a mode of reasoning from a hypothetical proposition according to which if the consequent is denied, the antecedent too is denied. For example: if **A** is true, then **B** is true. But **B** is false, therefore **A** is false.

The negative heuristic – this consists of a methodological principle which stipulates that the basic assumptions underlying the research programme, that is, its hard-core, must not be rejected or modified when confronted with anomalies. The negative heuristic forbids scientists to question or criticize the hard-core of a research programme.

The positive heuristic – this consists of rough guidelines which indicate how the research programme might be developed. It gives guidance as to what is to be done in the face of anomalies. The research policy or the order of the research is set out in more or less detail in the positive heuristic of the research programme.

Lakatos's MSRP advocates that when a research programme is progressively changing, then it should be worth keeping but if it is progressively degenerating, then it is time for a new research programme to be chosen. A research programme is progressive if its theoretical growth anticipates its empirical growth, that is, as long as it keeps predicting new facts with some measure of success. Examples here include, biochemical genetics, and germ theory of disease. On the other hand, a research programme is degenerating if its theoretical growth lags behind its empirical growth. Example here is astrology. Astrology is said to be degenerating because it has not changed since its inception many centuries ago (Zucker 168).

Lakatos' research programme is criticized according Aigbodioh (68) for ignoring the fact that choice of what is progressive or otherwise does not depend on any universalizable fixed principle but on individual feelings, taste and interest. In other words, there is no criteria on which a choice between progressive and degenerative theories can be made.

2. 6 Conclusion

In this unit we identified the issues that bug philosophers of science concerning the growth and progress of scientific knowledge. Popper's notion of verisimilitude was used as a stepping stone to analysing the efforts of philosophers and scientists at getting closer to truth. For Thomas Kuhn, scientific progress should be by a shift in paradigms that will bring about a revolution in theories that are facing crisis. Imre Lakatos however disagreed with Popper and Kuhn on how science makes progress. For him, the progress of science should be based on a research programme he calls methodological scientific research programme (MSRP).

2.7 Summary

Verisimilitude is an approximation to truth; it is getting closer and closer to the truth about nature. Kuhn's central claim is that development in any scientific field happens via a series of phases. Kuhn defined scientific paradigm as 'a universally recognized scientific achievement that for a time provide model problems and solutions for a community of practitioners. Scientific revolution is the violent overthrow of old paradigm by a scientific community. Lakatos research programme is essentially a sequence of theories within a domain of scientific inquiry. Each theory is held to make an advance over its predecessor. The move from one theory to its successor within a research programme is called 'problem shift'. In Lakatos research programme, theories are seen as entities existing over time. They get changed as new information is gathered. Theories are adjusted to fit the facts as the facts are obtained. MSRP advocates that when a research programme is progressively changing, then it should be worth keeping but if it is progressively degenerating, then it is time for a new research programme to be chosen.

2.8 Self-Assessment Exercise

1. What is the essence of Popper's notion of verisimilitude and corroboration?
2. State and explain Kuhn's phases of paradigm shift
3. Examine the notion of scientific revolution
4. Identify and explain the 3 components of MSRP
5. What does scientist do when a theory is progressively changing or progressively degenerating according the principle of MSRP.

Model Essay Answer to Question 5

A scientist using the research programme should keep a theory that is progressively changing but if it is progressively degenerating, then he should abandon it for a new research programme. A research programme is progressive if it keeps predicting new facts with some measure of success. Example include, biochemical genetics, and germ theory of disease. On the other hand, a research programme is degenerating if its theoretical growth lags behind its empirical growth. Astrology is said to be degenerating because it has not changed since its inception several centuries ago.

2.9 Tutor Marked Assignment

1. Verisimilitude is a _____________ word. A. French. B. Russian. C. Latin. D. Greek.

2. The following are the phases of Kuhnian paradigm except. A. Abnormal phase. B. Pre-paradigm phase. C. Normal phase. D. Paradigm shift.

3. Paradigm shift was postulated in Kuhn's book entitled _______ and published in _____ A. Structure of science / 1960. B. The Structure of scientific revolution / 1962. C. Structure of paradigm shift / 1972. D. Structure of semantic revolution / 1962.

4. MRSP is an acronym for: A. Method of scientific research programme. B. Methodology and scientific research programme. C. Methodology of structural repair programme. D. Methodology of scientific research programme.

Model Answers: 1. – D. 2. – A. 3. – B. 4. – D.

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MODULE 3: THE GROWTH OF SCIENTIFIC KNOWLEDGE

UNIT 3: Anarchist and Holist Notion of Scientific Growth

3.1 Introduction

Should the growth and development of science be based on a particular method? Who decrees the particular method into universal patronage? Or which particular region of the world should the decree come from? These are some of the fundamental questions that surround the growth and progress of science; philosophers of science have however, tried very much to explain the necessity of a suitable method that will enhance and enrich the growth of science over time. Although there is no agreement among philosophers on the most suitable method for this purpose but there have been proposals. Popper had proposed Conjectures and Refutations, Kuhn thinks recourse to Paradigms will create better pathways that will lead to scientific revolutions, Imre Lakatos on his part propounded his Methodology of Scientific Research Programme. Paul Feyerabend took a radical position in his own postulation of a methodology for the sciences. For him, anything should go for a method so long as desired result is achieved. Then there is Larry Laudan who questions Kuhn's holist picture of scientific change. In this unit we shall be considering Paul Feyerabend and Larry Laudan's argument for and against the ideology of method as a principle for scientific growth and change.

3.2 Objectives

It is expected that after studying this unit, the student should be able to:

1. Understand the notion of anarchism and holism in science
2. Identify the philosophers that hold these notions
3. To explain the notion of scientific anarchism
4. To appraise the principle of 'anything goes'
5. Evaluate the notion of holism as an ideology of scientific change.

3.3 Main Course Contents: Anarchist and Holist Notion of Scientific Growth

3.3.1 The Notion of Scientific Anarchism

Anarchy means absence of government or governmental control; it is a state of confusion, chaos and disorder. Anarchism on the other hand is a political theory that holds that all forms of governmental authority is unnecessary and undesirable. Anarchists advocates a society that is based on voluntary cooperation and free association of individual groups. From its literal meanings above, it would be seen that anarchism projects unhindered freedom in everything whether social, religion or science. In science, anarchism is the freedom of the scientist to use any method of his/her choice to arrive at a desired conclusion or to investigate a particular phenomenon. Paul Feyerabend is the progenitor of scientific anarchism; he believes that the whole notion of a methodology of science is an illusion. He acknowledges the fact that anarchism may not be a desirable political philosophy, but at the same time, he thinks it is an excellent panacea for science and the philosophy of science. For him, theoretical anarchism is desirable because it is more humanitarian than other systems of organisation by not imposing rigid rules on scientists. According to him:

> Is it not possible that science as we know it today or a search for the truth in the style of traditional philosophy create a monster? Is it not possible that an objective approach that frowns upon personal connections between the entities examined will harm people, turn them into miserable, unfriendly, self-righteous mechanisms without charm or humor? Is it not possible that my activity as an objective observer of nature will weaken my strength as a human being? I suspect that the answer to many of these questions is affirmative and I believe that a reform of the sciences that make them more anarchic and more subjective is urgently needed (154).

Feyerabend did not just suggest an anarchic reform of the sciences; he laid out a path in which that reform could be actualized. His position though, was seen as radical in the philosophy of science circles because it implies that philosophy can neither succeed in providing a general description of science nor devise a method for the growth of the scientific enterprise.

3.3.2 Scientific Methodology as Illusion

The issue at stake that Feyerabend's anarchism was meant to solve is the assumption by Western philosophers and scientists that the excellence of science is due to the fact that it uses the right method. He objects to this assumption because as he asserts in his *Science in a Free Society*:

> There is no scientific method, there is no single procedure or set of rules that underlies every piece of research and guarantees that it is scientific and therefore trustworthy. Every project, every theory, every procedure has to be judged on its own merit and by standard adapted to the process with which it deals. The idea of a universal and stable method that is an unchanging measure of adequacy … is as unrealistic as the idea of a universal and stable measuring instrument that measures every magnitude, no matter what circumference (98).

To support his position that methodological rules do not contribute to scientific progress and counter the claim that good science operates according to a certain fixed method; he cites the Copernican revolution and argues that the Copernican revolution violated all common prescriptive rules of science of those days. If Copernicus, according to him, had applied the rules of method of his time, it would have prevented the scientific revolution that happened. Feyerabend, according to Ojong, was worried about the false belief in the existence of a universal method by which scientific knowledge is acquired; he rather believes that science should proceed by many and different methods. This is because all methods have their limitations hence his preference for a reform that will bring about an anarchistic methodology and a corresponding anarchistic science.

In a seeming defense of Feyerabend's anarchism, Ojong opines that Feyerabend is not against the adoption of standards or methodological procedures in scientific research; he is rather against a rigid conformity to a particular procedural rule irrespective of what one confronts in nature (91). For Feyerabend, the scientist should approach the study of nature with an open mind and a liberal attitude to procedures in probing the complexities of nature. The violation of procedural rules should therefore not be seen as an accidental event but as a necessary condition for progress to be continually achieved in science (AM, 93).

3.3.3 The Notion of 'Anything Goes'

Having objected to sticking to a particular method in the sciences, Feyerabend took a step further to recommend a way out of an impending quagmire in his conception of the sciences. He recommended the principle of 'anything goes' for the sciences. Anything goes is meant that the scientist should not be boxed into a particular method in carrying out their scientific investigations or research. Any method or trick that could give them desired result is welcome. According to him:

> The idea that science can and should be run according to fixed and universal rule is both unrealistic and pernicious. It is unrealistic, for it takes too simple a view of the talents of man and the circumstances which encourage or cause their development. And it is pernicious, for the attempt to enforce the rules is bound to increase our professional qualifications at the expense of our humanity. In addition, the idea is detrimental to science, for it neglects the complex physical and historical conditions which influence scientific change. … case studies such as those reported in the preceding chapters … speak against the universal validity of any rule. All methodologies have their limitations and the only rule that survives is 'anything goes' (AM, 296).

For Feyerabend, new theories came to be accepted not because of their accord with scientific method, but because their supports made use of any trick – whether rational, rhetorical or ribald, in order to advance their cause. Without a fixed ideology or the introduction of religious tendencies, the only approach which does not inhibit progress is anything goes. Anything goes for him is not a principle he holds but the terrified exclamation of a rationalist who takes a clear look of history.

Feyerabend is of the view that myths, dogmas of theology and metaphysics are some of the many ways of constructing a worldview. For him, a fruitful exchange between science and non-scientific worldviews will be in even greater need of anarchism than is science itself. This because anarchism is not only possible, it is necessary both for the internal growth of science and for the development of our culture as a whole. The realization according to him that science is not sacrosanct and the debate between science and myth has ceased without having been won by either side further strengthens the case for anarchism (AM, 171).

3.3.4 Criticisms Against Anarchism

Among the criticism against Feyerabend's anarchism is his comparison of science with myth, voodoo, witchcraft, astrology and the like. According to Uduigwomen, this an unholy comparison. His reason being that these non-scientific subjects do not have well defined objectives and the methods for achieving those objectives as does science. The second reason for him is that these non-scientific subjects do not constitute a pressing problem to our contemporary society as do science and technology. So, the question of a free choice between science and witchcraft or astrology or voodoo is irrelevant (118).

However, it was not all about objection to Feyerabend's 'anything goes theory', for example, Hugo Meynell as cited in Ojong, argues that Feyerabend is not methodically against method as such. He observed that Feyerabend methodically argued against method with the primary intent of exposing the frightening realities that the methods of science are hardly without limitations. Meynell was convinced that Feyerabend's anarchism has one fundamental goal and that is to encourage plurality of methods and of opinions. Meynell believes that this approach to scientific research is beneficial in the quest for truth. Hence, he opines that Feyerabend's position if properly understood and applied in the process of connecting theories and explanations in science would show that "fertility in the construction of hypothesis and theories is a virtually necessary condition of discovery of truth, even if it is in no way of sufficient reason"

On his part, Ojong agrees with Meynell, asserting that with Meynell's opinion which seeks a good interpretation to Feyerabend's seemingly negative conceptions of scientific methodology. Even Feyerabend himself was conscious of the possible misunderstanding of his position on scientific methodology affirming that:

> I regard anarchism as excellent medicine for epistemology and philosophy of science. Note the qualification. I do not say that epistemology should become anarchic or that philosophy of science should become anarchic. I say that both disciplines should receive anarchism as a medicine (SFS 127)

For Ojong, generally speaking, we know that it is only the sick that are in need of a physician. A careful reading of Feyerabend's numerous works would therefore reveal that he did not just recommend methodological anarchism for the sake of it. Rather, it was his unfeigned concern about the glaring limitations inherent in the popular traditional approaches to scientific inquiry that led him to recommend that the only principle that does not inhibit progress is: anything goes (147-149).

3.4 The Notion of Holism: Laudan's Objection

If Lakatos developed his Methodology of Scientific Research Programme as a response to Kuhn's criticism of Popper's Falsificationism, then Larry Laudan did what could be described as a radical dissection of Kuhn's paradigm shift theory. According to Arthur Zucker, Laudan criticized Kuhn for many infractions on his views about how changes occur in science. In a paper entitled *Dissecting the Holist Picture of Scientific Change*, Laudan accused Kuhn's paradigm theory of having three inextricably related parts – 1. A conceptual framework, 2. Rules that specify methods and techniques, and 3. Cognitive goals or ideas. According to him, we do not shift all three at once, contrary to what Kuhn claims. Rationality is not as paradigm-relative as Kuhn believes; for him, Kuhn does not accurately reflect the history of science because theories, methodological rules and cognitive goals are logically separate as history can show; that is, Kuhn's holism regarding science is at best oversimplified.

Laudan suggests that there is an interrelation among the three parts of a paradigm. He calls these parts the reticulated view – a view that allows for negotiation about whether all three parts have to be dropped at once. Laudan wants Kuhn's uncompromising holism rejected because it stresses the impossibility of giving up the hard-core of the paradigm and the requirement that the three parts of a paradigm must stand or fall together. Laudan wants a careful re-examination of the history of science because he is sure that Kuhn's description of revolutions is shaped by his insistence that there are no gradual changes in science.

For Laudan, what appear to be large-scale and immediate paradigm shifts may have occurred peace-meal. For example, first, some ontological claims may be revised, then some goals may be shifted, and then some methodological rules may have to change. All of this may be a gradual accumulation over a fairly long period of time. For Laudan, if we approach the history of science certain that the three are inextricably bound, then that is what we will find but we will miss the small changes and see only the result that will appear to be a Kuhnian-style paradigm shift. Laudan believes that some Kuhnian revolutions may have occurred, but scientific change is generally gradual. There is always a possibility that scientists can use rationality to decide between rival explanations (174).

3.4.1 Scientific Holism

The sum of Laudan's rejection of Kuhn's paradigm shift theory is that Kuhn did not realize that science has adjudicatory mechanisms that is also among the rules of holism. For according to him:

> We must bear in mind that it has never been established that such instances of holistic change constitute more than a tiny fraction of scientific disagreement. Because such cases are arguably so atypical, it follows that those sociologists and philosophers of science who predicate their theories of scientific change and cognition on the presumed ubiquity of irresolvable standoffs between monolithic worldviews run the risk of failing to recognize the complex ways in which rival theories typically share important background assumption in common… The problem of consensus formation which I earlier suggested was the great Kuhnian enigma, can be resolved, but only if we realize that science has adjudicatory mechanisms whose existence has gone unnoticed by Kuhn and other holists (Laudan, 185).

But the question now is what is holism in science? Is it another type of method? How will it enhance the growth of scientific knowledge? How is it that Kuhn and some other holists did not recognize its importance in consensus building for the growth of the sciences? Holism is a theory that holds that the whole is more than the sum of the part. Put differently, holism is a theory that holds that you cannot break things down to study them, but instead that everything has to be understood in relation to the whole or sum of its parts. It is an approach to research that emphasizes the study of complex systems. Holists believe that the only way to study the behaviour of a complex system is to treat it as a whole, and not merely to analyze the structure and behaviour of its component parts. Systems are approached as coherent wholes whose component parts are best understood in context and in relation to both each other and to the whole. Scientific holism is an approach to research that emphasize the study of complex system as a whole and not just the component parts.

Holism is premised on the bases that there is a possible qualitative difference between an entire system and its parts. As applied to science, holists assert that this difference can warrant the kind of rigorous scrutiny typical of scientific inquiry. The distinction of approach then lies not so much in the subjects chosen for study, but in the methods and assumptions used to study them. Though considered by some as alternative, holistic methods are not generally at odds with the classical scientific method. Where holistic scientists come from a standard science background, holistic work in science tends to be to varying degree, a combination of the two approaches. When terms are used constructively in the context of science, holism and reductionism refer to how empirical evidence is interpreted and not only to the methods used to produce such evidence. The Britannica encyclopedia defines reductionism as a view that holds that entities of a given kind are identical to, or are collections or combinations of entities of another kind or that expressions denoting such entities are definable in terms of expressions denoting other entities. Thus, the ideas that physical bodies are collections of atoms or that a given mental state is identical to a particular physical entity are examples of reductionism. Two very general forms of reductionism have been held by contemporary philosophers: (1) Logical positivists maintained that expressions referring to existing things or to states of affairs are definable in terms of directly observable objects, or sense-data, and that any nontrivial statement of fact is equivalent to some set of statements that are, at least in principle, empirically verifiable. In particular, it was held that the theoretical entities of science are definable in terms of observable physical phenomena, so that scientific laws are equivalent to combinations of observation reports. (2) Proponents of the unity of science held that the theoretical entities of particular sciences, such as biology or psychology are definable in terms of the entities of some more basic science, such as physics or that the laws of these sciences can be explained by those of the more basic science. Thus, reductionism is different from holism. We shall analyse the notion of reductionism in the next unit.

There are two central aspects of holism that include, as captured, by wikipsychology: 1. The way of doing: which sometimes focuses on an observation of the specimen within its ecosystem first before breaking down to study any part of the specimen-sometimes called "whole –to –parts". 2. The idea that the scientist is not a passive observer of an external universe; that there is no objective truth; but that the individual is in a reciprocal, participatory relationship with nature and that the observer's contributions to the process is valuable.

3.4.2 Opposition to Holism

Many scientific disciplines used the holistic paradigms in pursuit of research. Some of these disciplines are accepted as part of main stream science, while others are considered to be pseudo-scientific. For example, quantum physics. Wiki psychology.com asserts that David Bohm put forward a holistic interpretation of quantum theory that reconciles it with an idea of the universe as an undivided whole, any division of which can only be arbitrary. Holism as a method of science is however controversial. Larry Laudan criticized Kuhn's paradigm change theory because of his believe that the theory does not see scientific change as a piecemeal process because according to him value changes do not always accompany nor are they always accompanied by changes in scientific paradigms. One other opposing view is that holism as a method is pseudo-science because it does not rigorously follow the scientific method despite the use of a scientifically sounding language. But from our earlier expositions, Feyerabend would not agree to this. He believes that any method is as good so long as desired result is achieved, hence his anarchistic proposal for the sciences.

3.5 Conclusion

In this unit, we considered the proposals of Paul Feyerabend for a method of science and Larry Laudan's critic of Thomas Kuhn's holism. Feyerabend believes that the best method for the sciences should be an anarchistic method; there should be no rule that restrains any scientist from adopting any method they deem fit for achieving a desired goal. His proposal is the method of 'anything goes'. For him whether it be mythology, witchcraft or voodoo, the most important thing is the final result that is obtained from using such mediums. On the other hand, Larry Laudan questioned Kuhn's holistic paradigm change theory, accusing him of failing to realize that scientific change is a piecemeal process. We defined scientific holism as an approach to research that emphasizes the study of complex systems. Holists believe that the only way to study the behaviour of a complex system is to treat it as a whole and not merely to analyze the structure and behaviour of its component parts. It was also posited that holism is not the same as reductionism in philosophy of science.

3.6 Summary

Anarchism is a political theory that holds that all forms of governmental authority is unnecessary and undesirable. Scientific anarchism is the freedom of the scientist to use any method of his/her choice to arrive at a desired conclusion or to investigate a particular phenomenon. Paul Feyerabend is the progenitor of scientific anarchism. Feyerabend recommended the principle of 'anything goes' for the sciences. Anything goes is meant that the scientist should not be boxed into a particular method in carrying out their scientific investigations or research. Any method or trick that could give them desired result is welcome. Feyerabend is criticized for comparing science with myth, voodoo, witchcraft, and astrology. For Uduigwomen, this is an unholy comparison. Laudan accuses Kuhn of over simplifying science and suggests that there is an interrelation among the three parts of a paradigm that Kuhn overlooked. Holism is a theory that holds that you cannot break things down to study them, but instead that everything has to be understood in relation to the whole or sum of its parts. Laudan wants a careful re-examination of the history of science because Kuhn's description of revolutions is shaped by his insistence that there are no gradual changes in science. One opposing view is that holism as a method is pseudo-scientific because it does not rigorously follow the scientific method despite the use of a scientifically sounding language.

3.7 Self-Assessment Exercise

1. Differentiate between social anarchism and scientific anarchism.
2. Examine Feyerabend's notion of 'anything goes'
3. What is your personal view of Feyerabend's anarchistic method.
4. What is Larry Laudan's objection to Kuhn's paradigm shift theory?
5. Examine the notion of scientific holism

Model Essay Answer to Question 2

Feyerabend recommends the principle of 'anything goes' for the sciences. Anything goes is meant that the scientist should not be boxed into a particular method in carrying out their scientific investigations or research. Any method or trick that could give them desired result is welcome. For Feyerabend, without a fixed ideology or the introduction of religious tendencies, the only approach which does not inhibit progress is anything goes. Anything goes for him is not a principle he holds but the terrified exclamation of a rationalist who takes a clear look of history.

3.8 Tutor Marked Assignment

1. Scientific anarchism is the _________ of the scientist to use any medium of choice to achieve scientific result. A. Freedom. B. Rationality. C. Failure. D. Desire.

2. The theory of 'anything goes' was propounded by: A. Larry Laudan. B. Thomas Kuhn. C. Paul Feyerabend. D. Pope John Paul.

3. Larry Laudan accused Thomas Kuhn of oversimplifying ___________ with his notion of paradigm shift. A. Concepts. B. Science. C. Methods. D. Entities

4. One opposition to holism is that, as a method, it is ___________ A. Relative. B. Reductive. C. Selective. D. Pseudo-scientific.

Model Answer: 1. - A. 2. – C. 3. - B. 4. – D.

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MODULE 3: THE GROWTH OF SCIENTIFIC KNOWLEDGE

UNIT 4: The Unity of Science: Reductionism and Tacit Knowledge

4.1 Introduction

One of the aims of science is to construct an account of the phenomena of the world in such a way as to yield the most accurate and coherent account possible. If there is therefore, a way the world is, then, there is or there should be a single, correct scientific account of the world. But the puzzling question now is; is there the possibility of a single explanation of phenomena? Can all phenomena in the world be reduced to one single explanation? Can science reduce a complex scientific explanation to a less complex explanation? What does the philosophers of science mean by the unity of science and scientific reductionism? In this unit, attempts shall be made to give answers to some of these questions by considering the very important issue of the unity of science and the implications of reducing complex scientific explanations to less-complex explanations. We shall also consider the notion of tacit knowledge and its role in the understanding of scientific concepts and knowledge. The works of Paul Oppenheim and Hillary Putnam, and that of Michael Polanyi shall be our guide.

4.2 Objectives

It is expected that after studying this unit, the student should be able to:

1. Understand what is meant by the unity of science
2. Identify the different conceptions of the unity of science
3. Understand the notion of reductionism in science
4. Identify different types of reductionism
5. Understand the place of tacit knowledge in the apprehension of scientific knowledge

4.3 Main Course Contents: The Unity of Science

4.3.1 The Notion of the Unity of Science

The unity of science is the view that all branches of scientific inquiry have a common epistemological base. That the sciences become unified when the laws of one theory are shown to be derivable from those of another theory. This allows one to see that there is only one basic set of principles that is required to account for the other truths in the theories. The sciences may become unified when the observations explained by one theory are shown to be also explainable by another theory. This allows one to see that only one of the theories is really necessary to explain the class of phenomena earlier thought to need the resources of two theories to explain. However, some people, according to Boersema, claim that there is no unity in science because the various sciences have different contents, methods, and goals. For example, many biologists think of explanation in terms of functional explanation that is, some phenomena are goal-directed such as the function of the heart is to circulate blood. And physics does not speak of functional explanation. So, it is not everyone that thinks that there can be a single, unified science, even if there is a single unified world of phenomena. On the other hand, among the philosophers and scientist who believe in the unity of science, there is the claim that such a unity is a matter of reducing higher-level sciences to more basic sciences. They believe that all other sciences can be reduced to physics. In the early twentieth century, for example, key logical positivists attempted to achieve the unity of science from a reductionist perspective. Following their line of thought, it was often argued that fundamental chemistry is based on physics, fundamental biology and geology are based on chemistry, psychology is based on biology, sociology is based on psychology, and political science, and anthropology and even economics are based on sociology.

In a paper entitled, *Unity of Science as a Working Hypothesis*, Paul Oppenheim and Hillary Putnam tried to formulate a precise concept of the Unity of science different from what the positivist started and to examine to what extent, that unity can be attained. First, they gave a working definition of what they mean by unity of science. According to them, the unity of science will be used in two senses to refer first: to an ideal state of science and second, to a pervasive trend within science. In the first sense, unity of science means the state of unitary science. It involves the unity of vocabulary, or the unity of language; and unity of explanatory principles, or unity of laws. That the unity of science in this sense, can be fully realized constitutes an over-arching meta-scientific hypothesis which enables one to see a unity in scientific activities that might otherwise appear disconnected or unrelated and which encourages the construction of a unified body of knowledge. In the second sense, unity of science exists as a trend within scientific inquiry, whether or not unitary science is ever attained, and not withstanding the simultaneous existence of other even incompatible trends. They distinguished three concepts of unity of science:

1. Unity of science in the weakest sense – this is attained to the extent to which all the terms of science are reduced to the terms of some other discipline such as physics or psychology. This concept is based on the unity of language.
2. Unity of science in the stronger sense – this is attained to the extent to which the laws of science become reduced to the laws of some other discipline. If the ideal of such an all-encompassing explanatory system were realized, one could call it unitary science. Here, the exact meaning of 'unity of laws' depends on the concept of reduction employed. This is represented by the unity of laws.
3. Unity of science in the strongest sense – this is realized if the laws of science are not only reduced to the laws of some other discipline, but the laws of that discipline are in some intuitive sense 'unified' or 'connected'.

The main focus of Oppenheim and Putnam were two questions: first, how can unity of science be attained, and second, can unity of science be attained? Their answer to the first question is that unity of science can be attained by what they called – micro-reduction. Micro-reduction is the notion that there is 'part-whole' relation used by a given science for example, we conceive of the whole of something as composed of the parts that make it up and can be understood in terms of what is true about those parts. For them 'the only method of attaining the unity of science that appears to be seriously available at present is micro-reduction. The second question – can the unity of science be attained? They assert that they do not wish to maintain that it has been established; that this is the case. But that it does not follow that a tentative acceptance of the hypothesis that unitary science can be attained is therefore a mere ‘act of faith’. They believe that it is in accord with the standards of reasonable scientific judgement to tentatively accept this hypothesis and to work on the assumption that further progress can be made in that direction without claiming that its truth has been established or denying that success may finally elude us (Oppenheim and Putnam in Boersema 219 -223).

4.3.2 The Notion of Reductionism

The question of the unity of science is hinged on the notion of reductionism. Reductionism is an approach to understanding the nature of complex things by reducing them to simpler or more fundamental things. It can also be described as the philosophical position that a complex system is nothing but the sum of its parts, and that an account of it can be reduced to accounts for its individual constituents. The idea of Reductionism was first introduced by Rene Descartes in Part V of his *Discourses* of 1637, where he argued that the world was like a machine, its pieces like clockwork mechanisms, and that the machine could be understood by taking its pieces apart, studying them, and then putting them back together to see the larger picture.

Reductionist thinking and methods are the basis for many of the well-developed areas of modern science, including much of physics, chemistry and cell biology. However, while it is commonly accepted that, for example, most aspects of chemistry are based on physics, it is less clear that sociology or economics can be based on psychology. The general goal of a theoretical reduction is to promote the *unity of scien*ce.

4.3.3 Types of Reductionism

Ontological Reductionism

Ontological reduction is the view that one kind of phenomenon is shown to be really an instance of another more basic kind of phenomenon. That one thing or set of things can be reduced to some other, more basic thing or set of things. Consider a particular example: The population of Uyo is nothing more than Okon, Okoro, Alice, Annie and so on. In this claim, a thing (the population of Uyo) is reduced to a set of individuals. The idea is that these set of people is all there is to "the population," and everything that is true about the latter comes down to something that is true about the former. For example, if it is true that the population is shrinking, this might be explained by saying that Okon, Okoro and Alice has left town.

Note that there's an asymmetry in the relation between those two facts: If Okon and Okoro leave town (and everyone else stays put), then it is necessarily true that the population of Uyo is shrinking. But if the population of Uyo is shrinking, it is not necessarily true that Okon and Okoro left; it might instead be the case that Alice and Annie left. This asymmetry is indicative of the fact that the set of people is more "basic" than the population. So, the reductionist claim doesn't merely state that there is some close relation between the two, it further claims that one is more fundamental. You can understand everything about the population by understanding what is going on with Okon, Okoro, Alice, and Annie, but not the other way around.

One subtle issue about ontological reductionism is whether one 'reduces away' the thing or things in question. In the above example, it intuitively seems that even though the population reduces to the set of people, the population still exists. The point here is that the idea of ontological reductionism is hinged on the fact that complex phenomena are constituted by smaller and simpler phenomena, such that what is actually real are the smaller, simpler constituents. (Adapted from newworldencyclopedia.org).

Epistemological Reductionism

Epistemological reduction is the reduction of one model or set of laws to another model or set of laws. There are many concepts, models, theories and so on that scientist use to explore and explain phenomena. The various types of concepts or model or theories that scientist use to explore and explain phenomena can themselves be reduced to the concepts, models and theories of the more basic sciences (physics, chemistry and so on). For example, Kepler's three laws of planetary motion were one instance of Newton's broader law of motion and gravitation. In other words, Kepler's theory could be fully explained and derived from Newton's theory but not vice versa. Newton's theory is said then, to reduce Kepler's theory. Here we are not talking about ontological reduction that is, that the planets are reduced to simpler things, but about epistemological reduction – in this instance, a reduction of one model or set of laws to another model or set of laws (Boersema 213).

4.4 The Notion of Tacit Knowledge

In 1958 Polanyi introduced the concept of tacit knowledge in his work *Personal Knowledge: Towards a Post-Critical Philosophy*. One of Polanyi's motives for working with this concept according to Klaus Nielsen, was to make it function as a strategic concept. Polanyi was a professor of chemistry and concerned with the growing political influence on science. In that context he developed the concept of tacit knowledge to ensure that science would remain independent and not be governed by external interests.

According to Polanyi, the concept of personal knowledge is a combination of subjective experience and collective rules for action embedded in various traditions. For instance, in court the judge's sentence is based on an expert opinion within the legal tradition of that particular area. This means that another judge who experiences a similar situation and a similar case, will rule in nearly the same way and reach the same result. It is still a matter of the judge's personal opinion which is based on how he or she applies the various rules in practice. This opinion, or professional assessment, is the personal dimension of the acts which the judge carries out in connection with his or her professional duties. On Polanyi's account, the concept of tacit knowledge is a central characteristic of personal knowledge emphasizing that it is partly tacit. According to Polanyi, tacit knowledge always involves epistemology. He also suggests that tacit knowledge is to be understood as a combination of concept and sense impression. An individual's experiences are based on his or her own activities and combined with concepts passed down by tradition. Tradition is passed down through the concepts of language and by using language as a tool in different situations. Language as such has no directions for use, but tradition has. Tradition implies a number of tacit rules for how to use a language. Thus, language becomes the place where tradition and individual experience meet. According to Polanyi, tacit knowledge is acquired through apprenticeship. In many ways, apprenticeship becomes the paradigmatic illustration of learning because tradition is passed down through learning by doing, by submitting to authority and trusting the experienced practitioner. The important point here is that Polanyi's interpretation of tacit knowledge is socially based on tradition and embedded in a number of implicit rules which can, in principle and if necessary, become explicit.

The central theme of Michael Polanyi's philosophy was the belief that creative acts (especially acts of discovery) are motivated by strong personal feelings and commitments and that is why he sought to critically interrogate the 'tacit' forms of knowing. Polanyi's argument is that the informed guesses, hunches and imaginings that are part of exploratory acts are motivated by what he describes as passions. They might well be aimed at discovering 'truth', but they are not necessarily in a form that can be stated in propositional or formal terms. In another of his work entitled – *The Tacit Dimension,* he clinically analysed his theory of tacit knowledge, according to him:

> I shall reconsider human knowledge starting from the fact that we can know more than we can tell. This fact seems obvious enough; but it is not easy to say exactly what it means. Take for example, we know a person's face, and can recognize it among a thousand, indeed a million. Yet we usually cannot tell how we recognize a face we know. So, most of this knowledge cannot be put into words (4).

He termed this pre-logical phase of knowing as 'tacit knowledge'. Tacit knowledge comprises a range of conceptual and sensory information and images that can be brought to bear in an attempt to make sense of something. Many bits of tacit knowledge can be brought together to help form a new model or theory.

Tacit knowledge for Polanyi in *Tacit Dimension,* is shown to account for 1. A valid knowledge of a problem. 2. For the scientist capacity to pursue it. 3. For a valid anticipation of the yet indeterminate implications of the discovery arrived at in the end. This type of indeterminate commitments is necessarily involved in any act of knowing based on indwelling. For such an act relies on interiorizing particulars to which we are not attending and which therefore we may not be able to specify and relies further on our attending from these unspecifiable particulars to a comprehensive entity connecting them in a way we cannot define. This kind of knowing according to Polanyi, makes it possible for us to know something indeterminate as a problem or a hunch, but when the use of this faculty turns out to be an indispensable element of all knowing, we are forced to conclude that all knowledge is of the same kind as the knowledge of a problem. Thus, we must conclude that the paradigmatic case of scientific knowledge in which all the faculties that are necessary for finding and holding scientific knowledge are fully developed, is the knowledge of an approaching discovery. To hold such knowledge is an act deeply committed to the conviction that there is something there to be discovered. It is personal, in the sense of involving the personality of him who holds it and also in the sense of being, as a rule, solitary; but there is no trace in it of self-indulgence.

The discoverer is filled with a compelling sense of responsibility for the pursuit of a hidden truth, which demands his services for revealing it. His act of knowing exercises a personal judgement in relating evidence to an external reality, an aspect of which he is seeking to apprehend. The anticipation of discovery, like discovery itself may turn out to be a delusion. But it is futile to seek for strictly impersonal criterion of its validity, as positivistic philosophies of science have been trying to do for the past eighty years or so. To accept the pursuit of science as a reasonable and successful enterprise is to share the kind of commitment on which scientists enter by undertaking this enterprise. You cannot formalize the act of commitment, for you cannot express your commitment non-commitally. To attempt this, is to exercise the kind of lucidity of the positivist movement in the philosophy of science. The difficulty is to find a stable alternative to its ideal of objectivity. This is indeed the task for which the theory of tacit knowing should prepare us (23-25).

4.4.1 Proximal and Distal Terms of Tacit Knowledge

Tacit knowledge involves two kinds of terms; we know the first term only by relying on our awareness of it for attending to the second. In tacit knowledge we attend from something, for attending to something else, namely from the first term to the second term of the tacit revelation. In many ways, the first term of this relation will prove to be nearer to us, while the second term will be further away from us. The first term is proximal while the second is distal. It is the proximal term, then, of which we have knowledge that we may not be able to tell. That is tacit knowledge.

One criticism against Polanyi's tacit knowledge is that it can be used to explain a host of very diverse phenomena which on closer inspection actually turn out to involve something else, and this according to Paul Nightingale suggest a substantial weakness in how the concept is used. Notwithstanding the criticism, Michael Polanyi made a profound contribution to both the philosophy of science and the social sciences. In philosophy of science, it can be argued that Michael Polanyi influenced Thomas Kuhn's groundbreaking work on the structure of scientific revolutions.

4.5 Conclusion

In this unit, we considered the notion of the unity of science which is the view that all scientific inquiry has a common epistemological base. That the sciences may become unified when the observations explained by one theory are shown to be explainable by another theory. Paul Oppenheim and Hillary Putnam's Unity of Science as a Working Hypothesis thesis was used to analyse the idea of the unity of science that is hinged on the notion of reductionism. Ontological and epistemological types of reductionism were identified. While Oppenheim and Putnam believe in the unity of the sciences, Polanyi makes a case for a clearer understanding of scientific concepts. He developed the theory of tacit knowledge where he argued that we can know more than we can tell.

4. 6 Summary

Unity of science is the view that all branches of scientific inquiry have a common epistemological base. That the sciences become unified when the laws of one theory are shown to be derivable from those of another theory. The main focus of Oppenheim and Putnam were two questions: first, how can unity of science be attained, and second, can unity of science be attained? Their answer to the first question is that unity of science can be attained by what they called – micro-reduction. Micro-reduction is the notion that there is 'part-whole' relation used by a given science. Reductionism is an approach to understanding the nature of complex things by reducing them to simpler or more fundamental things. It can also be described as the philosophical position that a complex system is nothing but the sum of its parts, and that an account of it can be reduced to accounts for its individual constituents. Polanyi's tacit knowledge is socially based on tradition and embedded in a number of implicit rules which can, in principle and if necessary, become explicit. Tacit knowledge is a central characteristic of personal knowledge that it is partly tacit. According to Polanyi, tacit knowledge always involves epistemology and it is to be understood as a combination of concept and sense impression. The criticism against Polanyi's tacit knowledge is that it can be used to explain a host of very diverse phenomena which on closer inspection actually turn out to involve something else.

4.7 Self-Assessment Exercises

1. Examine the notion of the unity of science; Is this achievable?
2. Explain micro-reduction according to Oppenheim and Putnam
3. What is reductionism in philosophy of science
4. Examine the three concepts developed by Oppenheim and Putnam to distinguish the unity of science.

5. What is tacit knowledge? Would you agree that its diverse interpretations are its major weakness?

Model Essay Answer to Question 2

Paul Oppenheim and Hillary Putnam used the notion of micro-reduction to answer one of two questions they asked which is: how can the unity of science be attained? Their answer to the question is that the unity of science can be attained using micro-reduction. Micro-reduction is the notion that there is 'part-whole' relation used by a given science; for example, we conceive of the whole of something as composed of the parts that make it up and can be understood in terms of what is true about those parts. For them 'the only method of attaining the unity of science that appears to be seriously available at present is micro-reduction.

4.8 Tutor Marked Assignment

1. Proximal and Distal terms are associated with: A. Tacit Knowledge. B. Empirical Knowledge. C. Reductionism. D. Relativism

2. The knowledge that cannot be put into words according to Polanyi is called ________ A. Semantic knowledge. B. Ontological knowledge. C. Epistemology. D. Tacit knowledge

3. Tacit Dimension is to __________ while Unity of Science as a Working Hypothesis is to _________ A. John Locke / Larry Laudan and Karl Popper. B. Rene Descartes / David Hume and Hillary Putnam. C. Carl Hempel / Paul Oppenheim and Michael Polanyi. D. Michael Polanyi / Paul Oppenheim and Hillary Putnam.

4. One of the following is not a concept in the unity of science ____________ A. Unity of science in the weakest sense. B. Unity of science in the stronger sense. C. Unity of science in the horrible sense. D. Unity of science in the strongest sense.

Model Answers: 1. – A. 2. – D. 3. – D. 4. - C

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MODULE 3: THE GROWTH OF SCIENTIFIC KNOWLEDGE

UNIT 5: Social Functions of Philosophy of Science

5.1 Introduction

Science has brought very significant changes to the world of sense and reason since the Ionian philosophers looked away from mythology to contemplate and speculate with logical reasoning the ultimate constituents of the universe and their usefulness to the well-being of mankind. Since then, science through its application in technology has transformed primitive hunting and gathering agriculture into a mechanized system of farming. Communication is now at the speed of light with a touch of a glass screen. Health and medicine have been revolutionized to the extent that prior deadly diseases have been eliminated and emerging ones arrested before they could do colossal havoc. What about transportation, entertainment and so many other areas of life that have all been transformed to the amazement of even man himself. Science has brought so much good to humanity that one cannot but appreciate the ingenuity of philosophers and scientists that have made these achievements possible. But there is another side to the story; the negative impact of science and its application in technology to human society. Science has brought death, poverty, climate change, loss of ethical / moral values, inequality on a humongous scale and so many other negative tendencies never seen before to the world. In this unit, we shall be considering the social functions of philosophy of science in relation to the positive and negative impacts of science to society. Questions such as; how does the scientist get a feed-back from the society about their inventions and discoveries? What are the ethical implications of the scientist's works to the social environment and the society? And the question of who checkmates science and the scientist would be given attention.

5.2 Objectives

It is expected that after studying this unit, the student should be able to:

1. Realize that the impact of science to society is two-sided.
2. Identify the positive and negative impacts of science to humanity
3. Understand the role of the philosopher of science in checkmating the activities of the scientist.
4. Identify several disciplines through which philosophy of science performs its social functions.

5. Understand the notion of interdisciplinary research and collaboration.

5.3 Main Course Contents: Social Functions of Philosophy of Science

5.3.1 Science and its Inventions

There is a marked difference between science and technology which is most time overshadowed by their close-knit relationship. Science is both the process and product of investigation and research. The process of science involves research, while its product is a set of ideas, principles and theories. Technology on the other hand is the practical application of the ideas, theories and research of science with the aim of developing products for man's use and enjoyment. Technology consists of the practical knowledge of what can be done and how it should be done. According to Boersema, the aim of science is to know, while that of technology is to do (370). So, the various changes that have taken place over the years that have steadily improved the living standards of humanity are purely the products of science. These changes are seen in agriculture, medicine, transportation and communication amongst others. First, we consider the positive impacts of these products of science to society.

5.3.2 Positive Impact of Science to Society

Agriculture – In the past, the production of food was very minimal because of the labour that was required for large scale farming. There was also the problem of preserving the foods that were produced. But in today's world, science has helped man to discover how to preserve food and increase food production. Agricultural mechanization has also led to the production of plants and animal species that are highly resistant to diseases through hybridization. Resources such as fertilizers and manure which enhance food production were made possible through science. Human beings are now able to control and prevent food wastage through the invention of scientific preservative agents, machines and methods. Science has also seen to the invention of chemicals and drugs for prevention, curing of diseases and pests that attack crops and lives stocks.

Communication - In the olden days and in some present remote societies, communication was or is through town-criers, messengers, beating of drums, wooden gongs, smoke signals and symbols. These means of communication have so much short comings: first, it took several days for massages to get to its destinations through the use of messengers; town criers might be inaudible, making it difficult for people to understand the massage; the massage being sent through the beating of drums or wooden gong may not convey the exact information intended and symbols were usually misinterpreted. However, all these are no longer used in modern societies. Science has brought lots of improvements in communication such that messages and information can get to their destination within few seconds instead of several days. This is made possible through the invention of telephone, television, cell phones, computer and the internet.

Health and Medicine – Before the advent of science, healthcare delivery and medicine were quite undeveloped. Treatment of illnesses were dependent on native herbs which most often did not bring cure to some ailments. However, with the application of scientific knowledge, many diseases now have a cure and this has greatly increased life expectancy and reduced death rate as well as infant mortality which was very rampant in the olden days. Science led to the discovery of various ways and means of enhancing life and ensuring a healthy society. This includes new and more effective drugs developed for various diseases such as malaria, diabetes, typhoid fever, hypertension, and sexually transmitted diseases amongst others. Science has greatly improved health not only in curing diseases but also in preventing diseases through immunization. Things that were considered impossible in healthcare before now, such as heart transplant, kidney transplant and artificial limbs are now made very possible through the advancement of science.

Transport – In the days of old, human beings used to trek from place to place on foot or used horses, camels and donkeys for transportation. These types of transportation were very slow and usually last for days, weeks and even months before getting to their destinations. But in today's world, science has made it possible for man to travel across the globe in just few hours. The invention of airplanes, ships, jets, speed trains, cars and so on have improved the transportation sector and enables man to travel easily in comfort and with speed.

Entertainment – Science has played a significant a role in the entertainment industry. With the invention of radio, television, compact disks, video tape players, and so on. Entertainment is now closer to the people. Science has improved so much that even cell phones are designed to play music, watch movies and play games.

The point is that science has exerted tremendous influence on the life of man so much that man has continued to use science to advance his life and his society. In sum, science has raised man's standard of living, reduced the amount of labour needed to produce goods and services, increased productivity and has made labour easier. But this is not the end of the story. There is another side to science; the negative side of the story.

5.3.3 The Negative Impact of Science

Science has impacted positively in all areas of man's life and environment, but it has also created very serious problems for man and the environment. Many scientific processes produce unwanted pollutants and deplete the earth's natural resources. Beside this, various implementations of science influence values of society and new inventions often raises new ethical questions. For instance, the problem of regulation of the social media. The problems that come as a result of scientific achievements has raised fundamental questions among philosophers of science. The debate now is whether science improves human life and environment or whether it worsens both. The following examples will suffice:

Poverty – science has brought about severe poverty to developing nations whose scientific and technological growth is not at par with the developed nations. This is due to the fact that food and other resources are not increasing at the same rate as population. The poor countries are increasing in population due to improved medical and health services but are poor economically. Also, the use of tractors and other farm implement is denying most people that were dependent on working as peasant farmers and farm hands to have nothing to do. Equally of note is the pollution of land and water that has driven most people out of their means of livelihood.

Threat to world peace –science is now a threat to world peace and stability. The development of Weapons of Mass Destruction (WMD) has placed the earth on a precarious situation and fear of imminent destruction by the owners of these weapons. The First World War 1914-1918 witnessed a massive destruction of lives and property in a scale never imagined because of the invention of various canons and automatic rifles but the Second World War 1939-1945 saw an unprecedented annihilation of entire cities via the use of atomic bombs. In Hiroshima and Nagasaki - two Japanese cities for example, the U.S air force dropped atomic bombs that wiped off every living thing in those cities after the Japanese forces killed two thousand four hundred and three Americans in Pearl Harbor attacks. Today these nations now boast of nuclear bombs which is known to be more lethal than the atomic bombs and with their space stations in orbit, it is very certain that these lethal weapons can be unleashed on any part of the earth at the slightest provocation. The point is that science has enabled man to build and equip himself with dangerous weapons of varying destructive degrees and capacities for his own destruction. Nuclear weapons pose grave danger and threat to humanity, this is because one atomic or hydrogen bomb is capable of wiping out an entire nation in few minutes.

Crimes – Crime have been on the increase since science made it possible for the production of devices such as guns, explosives and other dangerous weapons. The use of computer and the internet and other communication techniques have greatly assisted fraudsters to steal and dupe their victims easily. As a result of computerization of the banking industry, the banks are now target of hackers and fraudsters who specialize in duping banks and stealing from the account of depositors.

Unemployment – There is growing unemployment across the world as a result of the deployment and use of scientific inventions to various aspects of human endeavours. This happens when the work that should have been done by people are done by machines and robots. The mechanization of labour leads to the replacement of human workers with machines which reduces and sometimes eliminate the chances of human workers been engaged.

Environmental pollution – Scientific activities has brought about severe damages to the human environment. Industrialization and oil exploration is to blame for the degradation and depletion of the earths' resources. Pollution of water sources, elimination of aquatic lives and pollution of air is a source of concern to everyone on the earth today, no thanks to science. Pollution is the release of substance or energy such as carbon (iv) oxide, carbon (iii) oxide from internal combustion engines, radioactive rays, smoke, soot, crude oil and so on into the environment in great quantities. These substances are capable of polluting the soil and water thereby endangering the lives of animals and plants. It is one of the most harmful effects of industrialization. Pollutants are capable of causing ill health, and in severe cases death of man, animals and plants may occur. Pollution may also be in form of sound such as siren, loud speakers, airplanes and supersonic jets.

Environmental Degradation – Pollution leads to the degradation of the environment that causes acid rains in some regions of the earth, global warming and depletion of the ozone layer. The ozone layer is a very important component of the atmosphere because it shades and protect human beings from direct contact with the heat of the sun. When the ozone layer is depleted as a result of environmental pollution, human beings will be exposed to direct sunshine which is very harmful to the human skin because it can cause skin cancer on humans. Also, solid waste such as broken bottles and glasses, sachet water bags, polythene bags and other non-degradable materials are capable of killing the soil and destroying the environment.

Science as we have seen has contributed significantly to the growth and development of human society. But unfortunately, it is equally constituting the biggest threat to the lives of human beings, plants and the soil of the earth. How can this trend be halted? Who takes the lead?

5.4 The Social Function of Philosophy of Science

The most important social function of philosophy of science is to make the public to understand the way of science. It works to make the public see science not as an isolated specialist exercise but as a part of a broader cultural history. A history about how through evidence on ground, the world is progressing towards unravelling truth about our universe. According to John Bernal, 'unless people at large know what the scientist is about, they can hardly be expected to provide assistance which the scientist feels his work demands in return for its probable benefit to humanity' (88). The point is that the philosophy of science has this social function of letting the intellectual community, the political community, the corporate community, and the scientist themselves know what science and scientist is about. It performs this function through interdisciplinary and multi-disciplinary approaches. One of the main values of interdisciplinary research is to cross disciplinary bridges and transfer knowledge from one field into another one, or to integrate diverse disciplinary fields so as to gain a better understanding of complex phenomena or how to integrate different kinds of knowledge to produce new knowledge. Interdisciplinary research matters because it allows us to identify possible inferential strategies, methodological approaches and patterns common to very diverse research fields, as well as to investigate the epistemic limits and fruitfulness of these universal features in any specific field of inquiry. The goal of interdisciplinary research is to engage critically with a discipline. This is done by investigating the foundational problems in particular sciences and also examining the implications of their activities and the impact of such activities to society at large.

5.4.1 The Philosophies of Science

The philosophies of science are the group of particular sciences studied under the second - order studies of philosophy of science. Some of these particular sciences include:

Philosophy of Mathematics

Philosophy of mathematics is concerned with the philosophical foundations and implications of mathematics. The central questions are whether numbers, triangles, and other mathematical entities exist independently of the human mind and what is the nature of mathematical propositions. Is asking whether "1+1=2" is true fundamentally different from asking whether a ball is red? Was calculus invented or discovered? A related question is whether learning mathematics requires experience or reason alone. What does it mean to prove a mathematical theorem and how does one know whether a mathematical proof is correct? Philosophers of mathematics also aim to clarify the relationships between mathematics and logic, human capabilities such as intuition and the material universe.

Philosophy of Physics

Philosophy of physics is the study of the fundamental, philosophical questions underlying modern physics, the study of matter and energy and how they interact. The main questions concern the nature of space and time, atoms and atomism. Also included are the predictions of cosmology and the interpretation of quantum mechanics, the foundations of statistical mechanics, causality, determinism and the nature of physical laws.

Philosophy of Chemistry

Philosophy of chemistry is the philosophical study of the methodology and content of the science of chemistry. It includes research on general philosophy of science issues as applied to chemistry. For example, can all chemical phenomena be explained by quantum mechanics or is it not possible to reduce chemistry to physics? Philosophers have also sought to clarify the meaning of chemical concepts which do not refer to specific physical entities, such as chemical bonds.

Philosophy of Biology

Philosophy of biology deals with epistemological, metaphysical and ethical issues in the biological and biomedical sciences. Although philosophers of science and philosophers generally have long been interested in biology. Philosophers of science pay increasing attention to developments in biology, from the rise of the modern synthesis in the 1930s and 1940s to the discovery of the structure of deoxyribonucleic acid (DNA) in 1953 to more recent advances in genetic engineering.

Philosophy of Medicine

Beyond medical ethics and bioethics, the philosophy of medicine is a branch of philosophy that includes the epistemology and ontology of medicine. Within the epistemology of medicine, evidence-based medicine has attracted attention, most notably the roles of randomization, binding, and placebo controls. Philosophers of medicine might not only be interested in how medical knowledge is generated, but also in the nature of such phenomena. Causation is of interest because the purpose of much medical research is to establish causal relationships, for example, what causes disease, or what causes people to get better.

Philosophy of Psychiatry

Philosophy of psychiatry explores philosophical questions relating to psychiatry and mental illness. It entails the examination of the concepts employed in discussion of mental illness, including the experience of mental illness, and the normative questions it raises.

Philosophy of Social Science

The philosophy of social science is the study of the logic and method of the social sciences, such as sociology and cultural anthropology. Philosophers of social science are concerned with the differences and similarities between the social and the natural sciences, and the causal relationships between social phenomena.

From the studies of these particular philosophies of science, one can see that even though it is the job of scientists to discover scientific facts in their particular fields; it is the job of philosophers of science to work alongside the scientists to explore how the facts are used to draw conclusions about issues that affects society. It is part of the social function of philosophy of science to work alongside the relevant sciences to build narratives about scientific facts and its use to for political decision-making and public policy. Michela Massimi (web) describes this function as ‘the enabling role’ of philosophy of science in its social function. In this sense according to her, philosophy of science is continuous with the sciences, in other words, philosophy of science tag along with the sciences in their research and inventions. For her, our enabling role is to contribute to interdisciplinary discussions with the conceptual tools and methodological sensitivity that we have, as well as to help scientists obtain in the public sphere and to the public eye what Bernal aptly described as ‘that assistance which the scientist feels his work demands in return for its probable benefit to humanity’.

5.4.2 Public Policy and The Philosophy of Science

While the adverse effects of science seem horrendous and outweighs its positive effect is because society looks spell-bound at the amazing discoveries of science, accept its inventions without a critical assessment of its social or epistemic values. Philosophy of science questions the epistemic, metaphysical and axiological values of science including state sponsored researches and policies. Questions such as what are the moral and ethical values of scientific inventions? What effects if any, negative or positive, will these inventions have on man and the society? are raised. Answers to these questions will definitely help the scientist and society to formulate policies that can guide the scientist in the pursuit of their chosen careers. The society must reciprocate the ingenuity of the scientist by showing critical interest in their activities and making them accountable to the people. The people should be told the effect (negative or positive) of state sponsored scientific researches. In other words, the people should know and have a say in what the scientist produces for the use of society. The philosophers of science are trained to be the eye and voice of society in relation to scientific research and inventions. This is among the social functions of philosophy of science.

5.5 Conclusion

In this unit we considered science and its inventions. The purpose was to identify the positive and negative impacts of science on man and society. Some of the positive impacts of scientific inventions include mechanized agriculture, improved communication, faster and comfortable transportation amongst others. On the other hand, are the negative impacts that include unemployment, climate change, weapons of mass destructions amongst other. The social functions of philosophy of science were also considered. The particular sciences and their usefulness in interdisciplinary research were identified. Philosophers of science were also seen as those trained to interrogate scientific inventions and public policies that concern science and its inventions.

5.6 Summary

Science has brought changes that have steadily improved the living standards of humanity These changes are seen in agriculture, medicine, transportation and communication amongst others. Apart from its positive impacts, science has also created very serious problems for man and the environment. Many scientific processes produce unwanted pollutants that deplete the earth's natural resources. Besides this, various implementations of science influence values of society and new inventions often raises new ethical questions. Scientists discover scientific facts but it is the job of philosophers of science to investigate how the facts are used to draw conclusions about issues that affects society. It is also part of the social function of philosophy of science to work alongside the relevant sciences to build narratives about scientific facts and its use to formulate public policy.

5.7 Self-Assessment Exercises

1. Identify and explain 4 scientific inventions that have impacted positively on humanity

2. Discuss the implications of weapons of mass destruction to humanity

3. What is the most important social function of philosophy of science

4. Identify and explain 3 philosophies of science

5. How does philosophy of science affect public policy formulations on matters of science?

Model Essay Answer to Question 2

A Weapons of Mass Destruction is a nuclear, chemical or biological device that is capable of harming or destroying a large number of people and assets. In the olden days, weapons used for hunting and wars were limited to clubs, spears, and machetes. But these has progressed to bombs and nuclear, chemical and biological weapons. The implication is that science has enabled man to build and equip himself with dangerous weapons. Weapons of mass destruction pose grave danger and threat to humanity; this is because one atomic or hydrogen bomb is capable of wiping out a whole nation in few minutes.

5.8 Tutor Marked Assignment

1. Identify the odd one among the following: A. Agriculture. B. Communication. C. Pollution. D. Health and Medicine.

2. The negative impact of science includes the following except; A. Crime. B. Unemployment. C. Pollution. D. Increase in food production.

3. The most important social function of philosophy of science is to make the public ______ the way of science. A. Understand. B. Replicate. C. Presume. D. Interrogate

4. The following are particular philosophies of science except: Philosophy of Mathematics. B. Philosophy of Law. C. Philosophy of Physics. D. Philosophy of Biology.

Model Answers: 1. – C. 2. – D. 3. – A. 4. – B

5.9 Works Cited/Further Readings

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