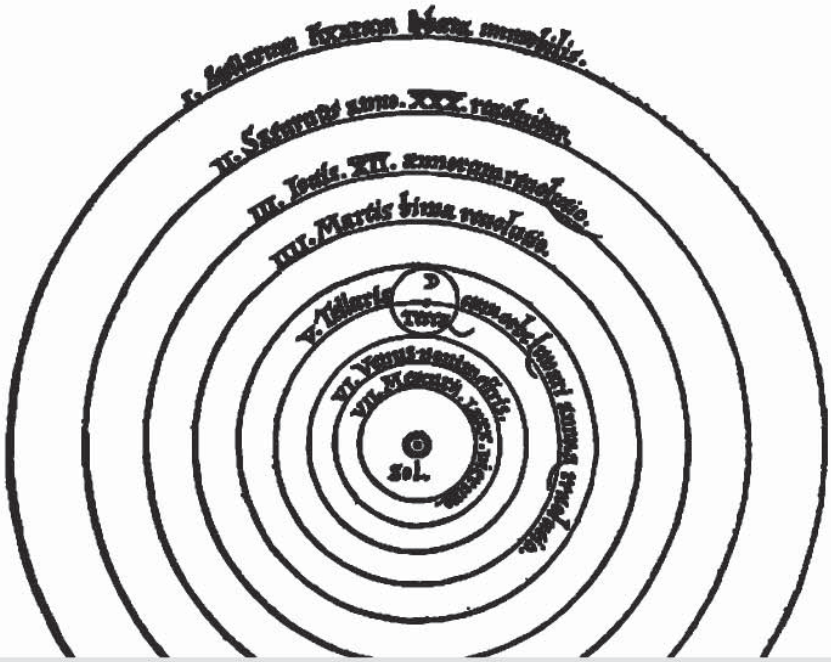


Philosophy of Science

Only study guide for
PLS2607

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Printed and published by the
University of South Africa
Mucklneuk, Pretoria

PLS2607/1/2016–2022

70266212

InDesign

Acknowledgements

The authors wish to acknowledge Emma Ruttkamp-Bloem, Wietske Kistner, and Mashuq Ally for their major contributions to previous editions of this study guide.

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We are particularly grateful to Hildegard van Zweel from the Department of Linguistics, Unisa, for her willingness to serve as internal critical reader in the development of this study material. Particular thanks are also due to Dee Cohen for serving as external critical reader, and to Dr Devan Govender, DCLD Education Consultant, for reviewing and providing detailed feedback on the study units.

Callum D Scott & Pascah Mungwini,

University of South Africa, City of Tshwane

March 2015

HSY_Style

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FOREWORD

> **"[T]o love wisdom is also to love science ..."**
>
> – Etienne Gilson (1990:257).

Philosophy of science covers a broad range of issues, and in this study guide only a few of them can be addressed, providing as it does only a cursory introduction to the field. It is hence essential that you should improve your background knowledge and orient yourself, and that you should use this guide in conjunction with the prescribed texts.

Philosophy of science is a fascinating discipline, as it centres on the complex relations between reality (i.e. the everyday world of experience), science (scientific theory, practise and processes), and philosophy.

GLOSSARY OF TERMS

A selection of the essential terms used in philosophy of science appears in the glossary at the end of this study guide.

BIBLIOGRAPHY

At the back of the study guide, you will also find a bibliography containing the publication details of sources consulted. It is recommended that you should read these sources, however this is not compulsory.

AIMS

Purpose of the module

Learners will be able to think about science and to integrate this capacity for second-order thinking into their application and practice of science.

OUTCOMES OF THIS MODULE

The three specific outcomes for this module are:

- Explore and thereafter analyse the key philosophical concepts, problems, and arguments relating to philosophy of science.
- Analyse and evaluate selected philosophical theories from within the philosophy of science.
- Appraise diverse theoretical positions – including the student's own – in relation to theories presented in the philosophy of science.

Outcomes are also provided at the beginning of each study unit. These outcomes specify what you should know, understand and be able to do after completing each of the study units.

ACTIVITIES AND ASSESSMENT

A. Activities

Some independent work is required of you. You are expected to do more than simply read passively; you should also join us in reflecting on the subject matter. Refer to the glossary at the back of this study guide if you come across new or unfamiliar terms, such as "ontology", "falsificationism", etc.

Points to ponder

Incorporated into the text are certain questions which we expect you to answer. These questions are located in boxes.

Reflection

At the end of each study unit you will find a section entitled "Reflection". These sections contain different activities for you to complete and questions to answer. Answers are provided to some of these questions, but not all. Answering the questions posed will help you engage with the material on a deeper level.

The nature of philosophy is to be critical. This means that texts are analysed and evaluated critically, but most importantly, this implies that there is always room for reanalysis and re-evaluation. The more you learn, the more your views might change. That is why we can never be satisfied when learners merely regurgitate text they have learned.

You must substantiate or motivate your questions and statements based on knowledge you have gained. The study material must be studied, but you should go a step further by critically reflecting on it.

B. Assessment

Assignments

As a students at the second level (NQF Level 6) of your studies, you should realise the importance of showing that you are able to interpret assignment questions against the background of your study material, and then illustrate – by citing examples, or otherwise – that you have sufficient understanding and knowledge of the study material to extract from it only those sections bearing directly on the assignment question.

Remember, though, that you are discussing a problem within a specific context, and that means that you have to relate the problem to relevant themes in the context you are working in.

You should use enough examples to illustrate your explanations of relevant terminology as well as the problem addressed by the assignment question, and to support your own conclusions.

Showing that you have insight into the critiques of certain issues offered in the prescribed material will also be essential should you wish to obtain a mark above 60%.

Marking rubric for assessments

0–40%	**POOR** You did not understand the question. You need to study the prescribed material again. You approached the question in the wrong way, not realising that you had to argue for or against a particular view. You did not answer the question. You did not refer to relevant prescribed material.
41–49%	**WEAK** You did not explain the problem. You did not evaluate the various arguments. You did not refer to relevant prescribed material. You offered no arguments of your own.
50–59%	**SATISFACTORY** You need to practise applying your reasoning skills to specific problems in order to improve your mark. You did not refer to the relevant prescribed material.
60–69%	**VERY SATISFACTORY** You have grasped the ideas, that is you understand the work. You need to explore key points in more detail. You have to show the implications of key points within the context of the question.
70–74%	**GOOD** You need to analyse arguments in more detail. You need to exploit the implications of these arguments further.
75%+	**EXCELLENT**

The examination

The examination will take place during **MAY/JUNE** (if you are registered for semester 1) and **OCTOBER/NOVEMBER** (if you are registered for semester 2).

Format of your examination paper

You will be writing a two-hour examination which will consist of FOUR essay-type questions. You will have to answer any TWO.

Comments on writing the examination

The structure of examination questions will be very similar to that of assignment questions. Take the time to read the entire examination paper before deciding which questions to tackle. Remember that you will need some time to glance over your answers at the end.

Examinations generally require exposition of parts of the relevant study material. Usually, this exposition has to be followed by a critical discussion of certain aspects or implications of the topics concerned. Where possible, illustrate the point you are trying to make by means of examples. Since examples are usually helpful aids to coming to grips with – and subsequently remembering key concepts of – study material and journal articles, your use of them will demonstrate your grasp of the points at issue.

Ensure that you answer the question and do not merely summarise a part of the study material!

PART A

SCIENCE, PHILOSOPHY, AND PHILOSOPHY OF SCIENCE

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STUDY UNIT 1

Introduction to philosophy of science

> **"[T]he hallmark of scientific behaviour is a certain scepticism even towards one's most cherished theories. Blind commitment to a theory is not an intellectual virtue: it is an intellectual crime.**"
>
> – Imre Lakatos (2009:514)

OUTCOMES

After completing this study unit, you should be able to

- be more reflective and analytical in your dealings with science, because you will understand the complexity of relations between "science", "technology" and "nature"
- differentiate between "science" and "philosophy of science"
- locate philosophy of science as a continuation of the tradition of natural philosophy
- distinguish between "natural science" and "social science"

1.1 WHAT IS "SCIENCE" AND "PHILOSOPHY OF SCIENCE"?

In this study unit, we briefly discuss the concept of *science*, distinguishing it from *technology*. This means that we define the distinction between the practice of science and critical reflection on it on the one hand, and between the practice of science and the practical application of scientific knowledge on the other.

Whilst the term "science" is often used, it would seem that the meaning of the term is only seldom considered!

> **Points to ponder**
>
> To what extent can academic disciplines that call themselves "scientific" be seen to share in the term?
>
> What causes science to be science?
>
> What makes "science" different from areas of study which could be labelled "non-science"?

This is known as the **problem of demarcation**. As Bortolotti points out, economics, psychology and anthropology are considered scientific by the scientists who practise them, yet these disciplines are not founded on the clear laws that physics is founded on (2008:5).

> **Point to ponder**
>
> In your view, could some disciplines be considered "more" scientific than others? Please motivate your answer.

The logical positivists, whom you will encounter early on in this module, attached a great deal of value to the process of science, regarding experiment, observation and logical discourse as the only sure paths to "scientific" knowledge. The bias they introduced into definitions of science continues to be evident in the attitude of many physical and natural scientists towards human and social scientists. It is also apparent in the methodological approaches of some social scientists, who embrace the positivist method. However, the famous Austrian-born philosopher of science, Paul Feyerabend, strongly opposed favouring "scientific" methodology over other means of obtaining knowledge (Bortolotti 2008:6).

Point to ponder

In your view, what criteria could be employed in differentiating a "science" from a "non-science"?

Consider the following definitions from the *South African student's dictionary*:

- "**Science** is the study of the natural world and the things that happen in it, through observation and experiment; **science** is also the knowledge gained by such study" (1996:850).
- "**Technology** is the study, or the use, of science for practical purposes, e.g. in industry, business, agriculture and medicine" (1996:1015).

Indeed, the positivist slant in the definition of "science" is apparent, in its being limited to only the "natural world", and as knowledge obtained "through observation and experiment" (1996:850). Such is the bane of the human and social sciences: having to justify themselves as "science" in the face of pervasive positivist assumption.

For the purpose of grasping the differences between *science* and *technology,* consider a scientist who studies the changes taking place in cancer cells. Here, she is practising *science*. The philosopher who studies the scientist's assumptions and arguments, however, is engaged in *critical reflection* on the practice of science. The pharmaceutical firm that develops treatment for cancer on the basis of the scientist's results, is producing *technology*. It is vital to distinguish between the *practice of science, critical reflection on science,* and the *production of technology*.

In this module we concentrate on the theory (or methodology) of science, that is, reflection on the practice of science. This is philosophy's role regarding science.

1.2 THE DEVELOPMENT OF THE PHILOSOPHY OF SCIENCE FROM NATURAL PHILOSOPHY

Both "science" and "philosophy of science" have their historical foundation in the "natural philosophy" of the Ancient Greeks. The development of philosophy of science is the story of one philosophical subsection after another separating from the parent discipline of philosophy, then surfacing as independent spheres of study (Rosenberg 2012:3).

Prior to the 18th century, the Latin root of the term "science" (namely "scientia") incorporated both what is currently known as "philosophy" and "science" (Gracias 1992:3). *"Scientia"* originated from "scio", which means "to know" (1992:3). "Philosophy" and "science" were thus envisaged as interchangeable. Aristotle, for example,

pointed out that: "The earliest philosophy is, on all subjects" (Metaphysics, A, Ch 9, 993a15).

The 17th century Cambridge scholar, Isaac Newton (famous for his identification of the three laws of motion and universal gravitation), wrote a monograph entitled: *"Philosophiae naturalis principia mathematica"* (dated to 1687), which can be translated into English as *"Mathematical principles of natural philosophy"* (Gracias 1992:3). From the title, the famous scientist considered that he was doing philosophy. However, with the development of the works of Newton, and the earlier works of Galileo and Kepler, physics eventually became independent from philosophy (Rosenberg 2012:3).

In the early 20th century, psychology, which also had its roots in philosophy, detached itself from philosophy through its specific focus on the human mind and behaviour (2012:5). In that century, too, computer science broke away from the philosophical pursuit of logic (2012:5). The examples of physics, psychology and computer science serve to support the earlier quoted Aristotelian claim!

Although their separation from philosophy has enabled these disciplines to develop in their own right, the unified tradition of natural philosophy as the source of science should not be forgotten. Indeed, in natural philosophy there is no categorical indication of where philosophy and science begin, end, merge or detach from one another (McMullin 1981:182). A continuum of knowledge is formed: where science can no longer explore and explain, metaphysics – that which transcends the explanatory power of the sciences – becomes relevant. McMullin (1981:182) states it thus:

> What may appear "philosophic" at one time may well turn out to be indisputably "scientific" at another, when theoretical formulations that are in one way or another empirically testable are in the making (1981:182).

The recent cosmological research of Stephen Hawking and Leonard Mlodinow (*The grand design,* 2010), for instance, has a natural philosophical penchant that transcends the limits of "hard" science: "[T]he authors themselves cannot resist engaging in evident philosophizing about the nature of theories and their relationship to reality" (Haldane 2011:44).

1.3 PHILOSOPHY IN SCIENCE

From the above discussion it seems that there is great complexity in the task of defining what "science" is, and indeed in clearly delineating what can be categorised as scientific. The demarcation problem raises questions such as:

- Are homeopathy and acupuncture branches of medicine that warrant serious consideration, or are they largely a matter of deceit or self-deception?
- Why is astronomy regarded as a science while astrology is not?

Point to ponder

Considering the philosophical roots of science, what factors should be included in demarcating science from non-science?

Philosophers are also aware of certain general philosophical questions which have a specific bearing on the sciences. Among these are:

- What is the relation between the sciences and our life-world?
- Can scientific researchers discover truths, or can they merely produce interesting and useful theories which, while successful, are neither true nor false because the "real" world is unknowable?
- If reality is unknowable can our theories give a progressively "better" description of it?
- Does science develop as history progresses?

The practise of science results in many philosophical questions arising, as Haldane (2011:44) emphasises in his critique of Hawking and Mlodinow. These scientists were – strictly speaking – engaging in physical science, yet considering problems of a metaphysical nature (2011:44).

1.4 NATURAL SCIENCE AND SOCIAL SCIENCE

Science is the discipline of the systematisation of basic knowledge. Moreover, for science to be credible, the results obtained must be verifiable according to some previously stated methodology.

Point to ponder

Motivate why each of the following is NOT a science in your opinion? Write four to five lines about each.

- soccer
- sculpture
- astrology
- motor mechanics
- farming
- teaching

Playing soccer may be systematic, but it does not lead to new knowledge. Sculpture often teaches us something about reality – for example, how to see it in a new way – but a sculptor's view cannot be empirically tested, and his or her activity cannot be called a systematisation of knowledge. Astrology may apply observations of planetary movement to provide a theoretical framework and make predictions about the future, but it does not stand up to empirical testing. Counter-instances, for example, of the "perfect" Virgo or "two-faced" Gemini, are easy to identify. Motor mechanics provides no new basic knowledge. The same is true of farming, which could be more accurately described as an application of the agricultural sciences. Teaching increases the personal knowledge of the learner, but does not add to the basic knowledge of humanity. Each of these activities thus lacks one or more of the features that characterise the practise of science.

The sciences have been divided into natural and social sciences. While the natural sciences have as their object of study non-reflecting nature (inanimate nature and the plant and animal worlds), the social sciences scrutinise all dimensions of human life. These include the human mind and human actions (psychology, history), society (sociology, anthropology), religion (theology), and the products of the human mind (literature, art, and music).

Social scientists must determine the situation of their subjects and their subjects' own interpretation of their situations. Thus the researcher may, for example, come

from a tradition in which a specific tree is regarded as a neutral object without special powers or forces. However, the people in the society the researcher is studying may regard the same tree as sacred, and as having a mysterious influence on the lives of those who approach it. To understand the behaviour of their subjects, researchers must be aware of their subjects' belief systems. They also need to be conscious of their own prejudices and biases, which inform their particular worldview.

The natural scientist does not have to contend with this type of complication, though, since non-reflecting nature does not have its own interpretation of situations. As a result of this basic difference between the social and the natural sciences, the philosopher who studies the natural sciences concentrates on issues that differ from those studied by a philosopher of the social sciences.

In this module we will be focusing upon natural science. Thus, the problems peculiar to the social sciences, such as conceptual analysis, the relation between the social contexts of researchers and their subjects, communication, etc., will not be our major concern.

1.5 PHILOSOPHY OF SCIENCE

Philosophy of science can be defined as a broad-range description of "the structure of scientific theories and the nature of scientific explanation, confirmation, intertheoretic reduction, and the like" (Ruetsche 2006:555). As noted with the example of Hawking and Mlodinow above, oftentimes physical scientists engage with themes of the philosophy of science (2006:556).

As a philosophical discipline, philosophy of science is concerned with posing and researching questions about the nature and validity of scientific knowledge and how that knowledge arose. Philosophy of science therefore asks questions such as the following:

- What are the methods of science?
- What are facts, laws and theories?
- What is "truth" in science?
- How does science progress – and does it indeed progress?
- What does the scientific process consist of?

Developments in philosophy of science have challenged the positivist assumption that science offers us certain, universally true and objective knowledge claims about the mechanisms of nature and society. Instead, more dynamic images of science have come to the fore. Among these, creativity, change, and contingency are characteristic, but objectivity – although never achievable – is a value striven for. In this view, scientific knowledge is tentative (not final), always evolving and open to the influence of social and cultural factors. The scientist who produces such knowledge is, after all, a person with subjective interests, influences, etc. The problem, though, is that once science is characterised as tentative, answering questions concerning the successes of science seems to become difficult: nothing is certain!

In philosophy of science, statements by natural scientists about phenomena in the world are studied. The natural scientist says that falling objects obey natural laws, such as those formulated by Galileo; the philosopher seeks to know what a natural law is. Where the scientist's statement applies the concept "natural law" (the scientist operates *with* it), the philosopher analyses the concept itself (the philosopher oper-

ates *on* it). The philosopher's statements are reflections upon the statements of the scientist; what the former says about a concept, must tally with the statements and actions of the latter. Philosophy of science must therefore always build upon natural science to develop "higher-order" statements.

Examples of philosophy of science are found in the history of the sciences (e.g. statements about the influence of Galileo on Kepler), in discourse on the ethics of certain aspects of the sciences (e.g. statements about animal experiments or nuclear tests), etc. In all these instances the "science about sciences" (i.e. philosophy of science) is illustrated. Contemporary research in philosophy of science pays great attention to the methodology, reasoning and presuppositions of scientists. Therefore, scientific theories and concepts cannot be discovered and explored without thoroughly studying the historical development of the sciences, and taking into account the social context of the scientific community. Historical research, as you will see in the study units, demonstrates that scientific theories cannot develop as rationally as they were previously thought to, and that extra-scientific circumstances should be considered, too. To establish the real nature of science, one should study the history of science. We shall encounter a representative of this particular approach in Thomas Kuhn.

Point to ponder

To what extent can you see objections to an historical approach to the study of philosophy of science being raised?

Before any historical observations can be made about the sciences, there must be clarity about the nature of science; about the criteria for science. Once again, conceptual analysis must precede empirical research.

Think about the following hypothetical case: a survey has shown that 90% of South Africa's population believe the earth to be flat. Can this finding be assumed to discredit the theory that the earth is spherical? Simply put, NO! Experts in this field of study need to be consulted: astronomers, geographers, etc. Even if they agree with the survey participants, they would still have failed to prove or disprove the theory that the earth is spherical. To prove a scientific theory, the standards of science itself must be employed, e.g. observation and logical deduction. Thus, whilst sociologists may gather factual data about sciences and scientists, the question of whether they can apply extra-scientific norms to determine what is "scientific" (here, in terms of the natural sciences because of the object of the study) is debatable.

Philosophy of science includes questions about the sciences as well as the ethics and metaphysics of science. This includes *methodology*, or the theory of science (the higher-order study and evaluation of scientific norms, procedures and concepts). Methodology is a study of the methods applied, clarification and definition of relevant concepts and the determination of scientific patterns of reasoning.

Point to ponder

Is methodological reflection purely a task for the philosopher of science, or should all engaged in science consider the theories underlying their disciplines?

Methodological study of the sciences cannot be the task of the philosopher only. Scientists should reflect on their own methods and objectives. Without such reflective

activity, it would not be possible to *do* science, for the methods, objectives and basic concepts would be unknown to these researchers. Nevertheless, there is a logical difference between the application of a method (or the use of a concept) and reflection on such application in the manner we have outlined.

To do philosophy of science, that is to reflect upon the method of science, philosophers must know something about the natural sciences: an awareness of context is a must. Thus, to consider the theory of the earth's roundness, for example, the philosopher of science must understand the theory in depth.

In the first half of the 20th century (especially during the 1920s and 1930s), philosophy of science reached its peak, supported by the logical positivists of the Vienna Circle (and to a lesser degree by the Berlin Circle). However, the writings of Popper, Kuhn, Lakatos and also Feyerabend paved the way for a "social" turn in philosophy of science, which began in the late 1960s and early 1970s. Knowledge, even scientific knowledge, came to be conceived as not absolute, objective, or value-free. Instead science, as every other human activity, came to be understood as influenced by the context, worldview, background, etc of the scientist. Meaning must always be envisaged as at least partially socially constructed.

Coincidentally, in the mid-20th century, a "linguistic" (hermeneutic) shift in epistemology (the theory of knowledge) occurred, coupled with the advent of post-modernity. Both these philosophical movements have applications in philosophy of science, for example Habermas and Rorty in hermeneutics, and Foucault and Lyotard in postmodern thought. Hence the mid-20th century hence saw the establishment of critiques of knowledge which have impacted upon the development of philosophy of science.

1.6 CONCLUSION

This module seeks to provide you with an historical introduction to the main paths of thought in philosophy of science during the past century. Our focus will be upon the history of logical positivism (the Vienna Circle), as well as on the reaction to its empirical verificationism by Popper, Kuhn, and Lakatos (as well as Feyerabend). We will pose the question of whether a "neutral" science (i.e. a value-free science) is possible, and explore the relevance of philosophy of science especially to the African context in which we find ourselves.

REFLECTION

Incorporated into the text are certain questions which we expect you to answer. These questions are located in boxes such as this one.

(1) It has been said that one can tell a technologist from a scientist by how keen they are to write articles. Technologists (e.g. people who work on new industrial developments) publish as little as possible, whereas "pure" scientists do exactly the opposite. Can you explain this difference?
(2) Name a few problems that you would classify under the philosophy of technology.
(3) What is your opinion of the view that scientific progress is the product of technical requirements? Medical knowledge, for example, developed because it was necessary to heal the sick, astronomy because of the need for a calendar, and so forth.
(4) Read the following observations very carefully and decide whether they belong to the field of science, technology, or philosophy of science.

(a) Tycho Brahe (1546–1601) made some major astronomical observations. In 1575 Frederick II of Denmark appointed him royal astrologer and gave him financial backing to build the instruments he needed. In turn, Tycho was to do astrological calculations for the royal family. In 1597, however, the king dismissed him because he "wasted too much time" on astronomy and did not pay enough attention to astrology.

(b) Moral views on values and freedom are not independent of the desire for technological development. From the earliest beginnings of modern thought, the new sciences and the new moral philosophy developed interdependently, so the basic premises of each were formulated in the light of the views held by the other.

(c) "As in Mathematicks, so in Natural Philosophy, the Investigation of difficult Things by the Method of Analysis, ought ever to precede the Method of Composition. This Analysis consists in making Experiments and Observations, and in drawing general Conclusions from them by Induction, and admitting of no Objections against the Conclusions, but such as are taken from Experiments, or other certain Truths. For Hypotheses are not to be regarded in experimental Philosophy. And although the arguing from Experiments and Observations by Induction be no Demonstration of general Conclusions; yet it is the best way of arguing which the Nature of Things admits of, and may be looked upon as so much the stronger, by how much the Induction is more general" (Isaac Newton, *Opticks,* Book III, Part I, Query 31, [1730]1952:404).

(d) Sensitivity is the most obvious specification for a receiver, and indicates the receiver's ability to receive weak or distant transmissions. If one lives close to an FM transmitter to which one wants to listen, sensitivity is relatively unimportant. If one lives in a fringe area, however, greater sensitivity may mean the difference between good and poor reception.

(e) A scientist should never refuse to give a reasoned reply to any theory, even if he or she believes that there is no scientific justification for it. It is inexcusable for a scientist or scientists to attempt to prevent the publication of a book purely on the grounds that it contains scientific "nonsense". On the other hand, no scientist should publish anything without scientific grounds; to falsify experimental results or present them in a distorted way is not only dishonest, it is a cardinal sin against the basic principles of science.

FEEDBACK ON REFLECTION

(1) The technologist develops new techniques and improves methods for the purpose of generating income. Because it is in the interest of a factory, a factory employee will not announce the details of every new development. Pure scientific researchers, on the other hand, earn recognition from their colleagues for new (original) work. To some extent their status depends on the number and calibre of the scientific articles they produce, and consequently they seek publication of their work.

(2) In principle, the philosophy of technology investigates all philosophical problems pertaining to technology (e.g. industrial development), that is conceptual, ethical, political, religious and metaphysical questions. Which authorities should decide on the subjects and financing of technological developmental research – the factory manager or the head of the factory's research department? On

what grounds are these decisions taken – economic or scientific (or even the desire for publicity and public acclaim)? And so on.

(3) Technical requirements are important, but another important incentive for scientists is the desire for knowledge for its own sake, without any ulterior practical motives. That is why we speak of "pure sciences". Many scientists, including Einstein, maintain that scientific theories have aesthetic appeal, and that a good theory is not only interesting but also beautiful.

(4) (a) This excerpt comes from the history of astronomy. Brahe was Kepler's mentor, and Kepler used much of Brahe's data in his own work.
(b) This refers to the ethics of science and technology.
(c) This quotation is a famous statement by Newton (1643–1727) concerning the general method that ought to be applied in the sciences. It is philosophy of science.
(d) This excerpt is technologically oriented. The real point at issue is the reception of FM transmissions.

STUDY UNIT 2

Objectivity and value-free science

> "**Objectivity is a subject's delusion that observing can be done without him. Involving objectivity is abrogating responsibility, hence its popularity.**"
>
> – Heinz von Foerster (in von Glasersfeld 1995:149)

OUTCOMES

After completing this study unit, you will be able to

- analyse the problem of science presented as "objective"
- identify and explain the subjective and social factors that play a role in the generation of scientific knowledge
- analsye science as the product of human engagement with the cosmos
- interrogate and explain the "value-laden" nature of science

2.1 THE OBJECTIVE SCIENTIST

There is little disagreement concerning the fact that science enjoys unparalleled prestige internationally when compared to other institutions. The traditional view of science is that it is an objective and value-free activity. The scientist's white coat has come to be taken as a sign of the purity of his/her motives, in the sense that he/she is devoted only to the pursuit of knowledge for its own sake. The scientist is portrayed as a detached and unbiased investigator carrying out an objective inquiry immune to psychological and cultural biases. He or she is an individual trained to allow facts to speak for themselves.

> **Point to ponder**
>
> List examples of how, where, and when you rely on the authority, purity and "unhampered" nobility of the action of a scientist.

Many people are likely to trust the word of the scientist compared to that of other people in society, such as politicians, journalists and even their own parents. This is because science is believed to be the *ultimate form* of objective and rational inquiry. Unlike other people, scientists are widely regarded as credible sources of information, because they are able to gather and process data in order to arrive at conclusions that are unbiased and based on facts. It is believed that the conclusions they arrive at are the product of the scientific method.

Since their work is supposedly not influenced by ideology or prejudice, the evidence provided by scientists is trusted across many spheres; their testimonies are even held as reliable evidence in courts of law. To make important decisions, governments and even ordinary people rely on the evidence provided by science.

2.2 THE LOGIC OF SCIENCE

Since science clearly has a powerful bearing on almost all aspects of our lives, it is crucial that we understand the thought processes and the logic that underlies scientific thinking.

Most people agree that it is the scientific method that makes science special; that this is what gives science its character and standing. Not only is science regarded as objective, it is also seen as rational. Science is rational when its processes effectively and efficiently achieve its goals: discovering truths, rejecting falsehoods, uncovering explanations, making precise and accurate predictions, etc. (Nozick 2001:303).

Point to ponder

In terms of the goals of science, to what extent is there only one universal rationality? Motivate your thoughts on this matter

Apparently science is highly esteemed because of the widely held belief that there is something special about science and its method. To claim that something is scientific and scientifically tested, is to accord it with some kind of merit and special reliability. Science is, therefore, regarded as the ultimate source of reliable and objective knowledge, and it is believed that scientists do not allow any room for biases, personal opinions or prejudice in their work.

Points to ponder

To what extent is science objective?
In what way is science objective?
To what extent is a value-free science possible?
What, if anything, is special about science?

These are some of the questions we seek to address in this unit.

Reflect on the following conversation or dispute between two individuals: a believer in science and her sceptic friend (Ladyman 2002:12–13):

Thomas: And you are just being naïve; anyway, even supposing that scientists really believe their theories, can't you see that science is just the modern religion?

Alice: What do you mean?

Thomas: Well, if you were living five hundred years ago you would believe in angels and saints and the Garden of Eden; science has just replaced religion as the dominant belief system of the West. If you were living in a tribe in the jungle somewhere you would believe in whatever creation myths the elders of the tribe passed down to you, but you happen to be living here and now, so you believe what the experts in our tribe, who happen to be the scientists, tell us.

Alice: You can't compare religious dogma and myth with science.

Thomas: Why not?

Alice: Because scientists develop and test their beliefs according to proper methods rather than just accepting what they are told.

Thomas: Well you are right that they claim to have a method that ensures their theories are accurate but I don't believe it myself, otherwise they would all come to the same conclusions and we know that scientists are always arguing with each other, like about whether salt or sugar is really bad for you.

Alice: Well it takes time for theories to be proven but they will find out eventually.

Thomas: Your faith is astounding – and you claim that science and religion are totally different. The scientific method is a myth put about by scientists who want us to believe their claims. Look at all the drugs that have been tested by scientific methods and pronounced safe only to be withdrawn a few years later when people find out how dangerous they are.

Alice: Yes but what about all the successful drugs and the other amazing things science has done.

Thomas: Trial and error, that's the only scientific method there is, it's as simple as that. The rest is just propaganda.

Alice: I can't believe that; scientific theories, like the Big Bang theory, are proved by experiments and observations, that is why we ought to believe them and that is what makes them different from creation myths and religious beliefs.

Thomas: So you say but how can experiments and observations prove a theory to be true?

Alice: I suppose I don't really know.

Thomas: Well let me know when you've found out.

Points to ponder

Who do you agree with? Why?

What conclusions can you draw from this dispute?

In your view, what is it that makes science unique compared with other forms of knowledge or beliefs or disciplines?

In the end Alice cannot answer all the questions of her sceptical friend.

Point to ponder

What kind of response would you give on Alice's behalf to Thomas's last question?

We are sure that there are many who share the views of the sceptic, and as you work through the study units of this module, you will be in a better position to respond to the sceptic.

Generally, progress in science is measured by its ability to achieve its goals, by its discovering more truths, accepting fewer falsehoods, uncovering deeper explanations, extending the domain of things that can be explained scientifically, and making more precise and more accurate predictions.

2.3 THE QUESTION OF "OBJECTIVITY"

There is a general belief that scientific inquiry, unlike other modes of inquiry, is by its nature objective. The value and prestige of science derives not only from its erudite and explanatory power, or from the technology it generates, but from its perceived objectivity.

According to Longino (1998:170), objectivity is a characteristic ascribed variously to beliefs, individuals, theories, observations, and methods of inquiry. It is generally thought to involve the willingness to allow our beliefs to be determined by "the facts" or based on some impartial and non-arbitrary criteria rather than by our wishes as to how things "ought" to be.

Point to ponder

What makes a claim objective in science?

A judgment or belief is held to be objective when it is reached by means of a certain sort of process – one that does not involve factors that bias or disturb or that lead belief away from the truth (Nozick 2001:287, 303).

Science is therefore objective when

- human factors do not systematically and irremediably point it away from certain kinds of truths or toward certain kinds of falsehoods
- no external factors divert it from accurately finding and reporting the truth

Objectivity may be conceived of/understood in two senses:

(1) To attribute objectivity to science is to claim that the view provided by science is an accurate description of the facts of the natural world *as they are*. It is a correct view of the objects to be found in the world and of their relations with each other. This view of objectivity is associated with scientific realism (Longino 1998:170).

(2) To attribute objectivity to science is to claim that the view provided by science is one achieved by reliance upon non-arbitrary and non-subjective criteria for developing, accepting, and rejecting the hypothesis and theories that make up the view. Here objectivity has to do with the modes of inquiry: it is about the method used by science (Longino 1998:170).

Whether or not a belief is objective, is determined by – and derived from – the nature of the process by which it arises. It is only because of the objectivity of the method that science employs that it is capable of reaching towards objective truths about the world. When scientists speak of the objectivity of the scientific method, they seem to imply that the information upon which their theories and hypothesis rest, has been obtained in such a way as to justify their reliance upon it. Objectivity about method also refers to the unbiased neutrality and impartiality of science.

According to Popper, scientific objectivity refers to the freedom and responsibility of the researcher to 1) pose refutable hypotheses, 2) test these hypotheses by means of relevant evidence, and 3) state the results in an unambiguous fashion accessible to any interested person. If these requirements are met, scientists can replicate each other's work and expect to come to the same conclusions. The method is an impersonal one. This is an appealing picture of science as a process entailing the formulation of theories that are open to empirical testing and refutation. This perception derives from the most basic assumptions of science, which hold that the real world exists independently of human cognition, and that theories and hypotheses about that world can be tested by means of controlled methods of observation and experimentation.

Longino (1998) argues that it is always important to distinguish between objectivity as a characteristic of the scientific method on the one hand and objectivity as a characteristic of individual scientists or their attitudes and practices on the other hand. We can speak of objectivity relating to the selection and application of the method by which knowledge is obtained. Science produces objectivity by escaping as much as possible from the shackles of ideology, passion and emotion.

Point to ponder

As a human, to what degree can the scientist cease to hold and experience ideologies, emotions, desires, etc?

The opposite of objectivity is *subjectivity*. In science, objectivity is guaranteed by accommodating criticism from alternative points of view. It is this process of subjecting hypotheses and evidence to critical scrutiny that minimises the effects of individual subjectivity, preferences and biases on scientific knowledge. The objectivity of science also derives from team work, in which theories and findings are subjected to peer review and criticism, thus allowing scientists in their individual capacities to respond to criticisms.

A method of inquiry is objective to the degree that it permits transformative criticism (Longino 1998:181). A scientific community operates objectively if (Longino 1998:181):

(1) there are recognised avenues for the criticism of evidence, methods, assumptions and reasoning
(2) there are shared standards that all critics can invoke or use
(3) the community as a whole takes that criticism seriously
(4) intellectual authority is shared equally among qualified practitioners

The above criteria are meant to deal with the dangers of subjectivity in science. It is believed that, by minimising or eliminating subjectivity and social influence, the scientific method yields knowledge that is both trustworthy and objective. If these requirements are met, scientists can replicate each other's work and expect to derive the same conclusions.

A common view is that scientific objectivity is a consequence of the application of standardised methods of quantitative observation and experimentation and scientists' ability to allow facts to speak for themselves. We can therefore reiterate that whether or not a belief is objective, is determined by – and derived from – the nature of the process by which it is arrived at. As Nozick (2001:288) would argue, if a belief is arrived at by a process in which biasing factors that lead one away from

the truth play a significant role, then that process will be less effective and efficient in arriving at truth.

2.4 IS "VALUE-FREE SCIENCE" POSSIBLE?

The place of values in science is an important question. The assumption that the sciences are value-free has long played a key role both in the self-understanding and the public image of science.

Questions about the relationship between facts and values form part of the history of philosophy. When the philosopher David Hume (1711–1776) asserted that *ought cannot be derived from is*, in other words values cannot be deduced from facts, Hume meant that one cannot make moral inferences from statements of fact.

Point to ponder

Consider the following statement of fact:

"The average height of men in South Africa is 1.69 m."

Now, a statement of value judgement regarding the aforementioned statement of fact:

"1.69 m is not a good height when compared to men from other African countries. South African men should be taller."

How would you conceptualise the difference between statements of fact and value judgements?

The ideal of value-free science prescribes that science should be objective and rational and should tell us about the way things are, not the way they ought to be. The value-free ideal sees science as neutral: it implies that scientific claims are either true or false, and that their truth or falsity depends on evidence independent of anyone's moral or political views. The job of science is to tell us the truth.

According to Hugh (1999:1), the view that science is value-free has two faces:

(1) It deals with how values do or do not, ought or ought not, interact with making theory choices and drawing consequences (logical and practical) from accepted theories, and the practical and institutional conditions in which they can or cannot do so.
(2) It deals with the place of science with respect to the values we hold, and with how it does or does not, can or cannot, serve the projects that express these values.

What ought to be value-free, are the methodologies of scientific practice and the scientific inferences we draw from the evidence we are researching or experimenting on.

Point to ponder

Identify some values that form the basis of science. Motivate the values you identified.

The common argument for value-free science follows the following path of argumentation:

Premise 1: *Science should be objective.*

Premise 2: *Values are not objective.*

Conclusion: *Therefore, values should not be introduced into science or play a role in its activity.*

The truth of this conclusion is sometimes contested by denying the second premise, namely, that values are not objective. It is argued that science could contain values, and even make value assertions, and still be objective *if* values themselves are objective.

Point to ponder

How can values be objective? Explain your answer.

This argument for a value-free science based upon the premise that values are not objective, implicitly assumes the following additional premise which might be called the "contamination premise": "When something that is not objective is introduced into a subject, or plays a role there, it makes the subject non-objective" (Nozick 2001:298).

The following position captures the most generally accepted view about the value-free nature of science (Wing 2003:1809):

> Despite the persistence of this view [of value-free science], historians, philosophers, and scientists themselves have shown that it does not provide an adequate account of the production of scientific knowledge (Harding 1991; Holtzman 1981; Kuhn 1970). There are several reasons why method cannot remove social influences from science. First, the content and methods of science are formed in relation to answering questions or testing hypotheses that are socially embedded. Second, scientific explanation requires language, concepts, and models that are cultural products. Although all sciences expend considerable effort to rationalize concepts and terminology, these tools of inquiry are inevitably shaped and transformed by historical forces. Therefore, scientists cannot even see the world, much less provide explanations of its workings, without a socially formed perspective. Ironically, the belief that science could attain objectivity through independence from social forces places science in the role of a religion's omniscient God.

Contemporary debates and questions about the nature of scientific rationality and scientific change, scientific realism, the role of culture and gender in science, and much, more are tied up with questions about the place of values in science. Arguments about the ethno-epistemologies and ethno-sciences in their varied ways represent those perspectives that they view science and, by extension, all knowledge as embedded in culture and therefore value-laden.

Point to ponder

Think about the manner in which science is done. What dimensions of culture can you determine as apparent in the scientific enterprise?

All over the world scientists need to consider not only the technical aspects of their discipline, but also its history, conceptual foundations, preconceptions, taboos, and the social forces that shape its content and application. This requires scientists to distinguish truth (in the form of statements about the world made by people)

from reality (the world itself) (Rorty 1989), and to be self-critical about the ways in which they create truths and facts in relation to the real world that they study (Wing 2003:1809).

REFLECTION

(1) Objectivity is a value esteemed by many scientists. How does this value in itself make the scientific enterprise value-laden at its most basic level?
(2) If the objectivity of science should be called into question, would science retain its authoritative position as a source of certain knowledge about reality?
(3) Compare and contrast the different understandings of "objectivity" (as related to science) discussed in this study unit. Could these approaches, for instance those of Nozick, Longino and Popper, be synthesised into one?

PART B

PHILOSOPHY OF SCIENCE IN THE EARLY 20TH CENTURY

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STUDY UNIT 3

The Vienna Circle and logical positivism

> "**[A] fabulous engine called the Scientific Method harvests evidence through observation and experimentation, discards subjective, error ridden chaff, and delivers objective, veridical residues from which to spin threads of knowledge. Unfortunately, that engine is literally fabulous.**"
>
> – J Bogen (2002:128)

OUTCOMES

After completing this study unit, you will be able to

- engage in discourse about the context and place of logical positivism within the historical development of philosophy of science
- show an appreciation of the role of observation in empirical scientific theory development
- distinguish between theoretical and observational languages in scientific theories
- apply the skill of critical interrogation of the philosophical approaches of instrumentalism and realism in philosophy of science as embedded in scientific theories

3.1 OBSERVATION AND THE LAWS OF NATURE

We as humans constantly observe our environment. But do we passively perceive everything around us, or do we actively interpret and select?

Point to ponder

Suppose you are walking down the street. Do you see everything there is to see, as a camera does, without distinguishing between what is important or unimportant to you? Do you consciously observe the facial expressions of passersby, the appearance of the pavement, the makes of passing cars, the clouds in the sky, the street numbers of the buildings on either side of the road, the bus stops and the street signs?

If you attempted afterwards to remember all you encountered, you would realise that you had concentrated more on certain aspects than on others. If you were looking for a particular address, you would have noted the numbers of the houses, for example. It is impossible to perceive "everything": we focus on what is meaningful in a particular situation. That we observe selectively shows that we see the environment in a specific way.

Scrutinise the following portrait painted by William Ely Hill in 1915:[1]

1 "My Wife and My Mother-in-Law", by William Ely Hill. *Puck*, 78(2018), (1915 Nov. 6), p. 11.



"My Wife and My Mother-in-Law", by WE Hill

Upon inspection of Hill's famous drawing, both an elderly lady (the "mother-in-law") and a young woman (the "wife") can be perceived. There is no absolute and no objective entity in this image. Rather, the perceived is determined by the context and the perceiver's prior knowledge. Perhaps, for example, one had encountered (or thought of) one's grandmother or girlfriend shortly before viewing this image.

Another example. People who know nothing about car engines, do not know what they are seeing when they look under a bonnet; they simply see a number of peculiarly shaped parts. The knowledgeable person, however, sees a radiator, air filter, battery, fan belt, spark plugs and so on. Those without mechanical knowledge ask questions such as "Which part performs what function?" and "If the car does not start, what is the cause?"

In observation, understanding is not limited to sight, but also plays a part in hearing, touch and the other senses. For Chalmers (2009:1), "observation" can be conceptualised as that which "we can see, hear and touch".

This broadened conception of observation is illustrated in the case of the motor mechanic, who can feel or hear when there is something wrong with an engine and identify the problem before another person has noticed anything. Simply put, in order to perceive, one needs to already know something. What we perceive the world to be does not consist of neutral facts. Everything that is perceived, is selected and interpreted. People do not live amid empirical data, for we experience situations. This applies equally to scientists practising their profession.

Observation is thus never neutral. There was a time – during the late 1920s and early 1930s – when it was generally accepted that we simply register what we see. It was believed that science is based on the objective collection of empirical data or facts. This was the view of the philosophers belonging to the "Vienna Circle", who supported a doctrine they called "logical positivism".

Point to ponder

Here we have examples illustrating how prior knowledge helps us to see the meaning of an observation – to see what is unusual about it and what therefore requires explanation.

Tick off the statements below that you believe to be self-explanatory, mark with a cross those that are unusual and need explaining, and add a zero if you do not know what the proposition (statement) is about and are therefore unable to say whether there is anything unusual about it or not:

(1) A quadrangle has four angles.
(2) John sees two moons in the sky.
(3) When the first man landed on the moon, there was no wind there.
(4) This vinegar is odourless.
(5) This *Dimorphotheca sinuata* is bright blue.
(6) The sky is blue.

FEEDBACK

Statement (1) does not require an explanation since it is tautologous: "quadrangle" means "figure with four angles". Statement (2) requires an explanation. Perhaps John's eyes are a bit uncoordinated, or else he could be looking at the two moons of the planet Mars through a telescope. Statement (3) would only require an explanation if it were false: because the moon has no atmosphere, there could never be any wind there.

As regards statement (4), we may ask why the vinegar is odourless in this particular case. Statement (5) requires additional information. The object referred to in Latin is the Namaqualand daisy. These flowers normally come in shades of white, yellow or orange, but never blue. Does statement (6) make you wonder why anyone would seek an explanation of such a familiar and everyday phenomenon as a sky that is blue (and not black, for example)? There is a factual explanation relating to the refraction of light in the atmosphere. Interestingly, the fact that the sky is black at night (and not brightly lit) does need an explanation. There is an infinity of stars all over the sky. If their light were not absorbed or blocked by anything, one would expect to see solid masses of stars when one looks up, some nearer and some further away.

From these examples we can tell that all empirical facts may require explaining at one time or another. Any empirical knowledge may be queried. Any doubt is expressed in the context of what we know for certain and actually expect. We can only doubt whether a train will be on time if there is some degree of certainty that watches are accurate, stations do not move, the distance between them does not change, etc.

When something does not fit our worldview, questions are asked. This is the origin of science. In principle, questions may be asked about all empirical facts, but we cannot explain everything at the same time: there always is a particular worldview that we have already accepted and against which questions become meaningful.

In terms of the scientific laws of nature, most are assumed to be universal in that they represent propositions about all objects or phenomena in a particular class.[2] Because laws are "universal" we can use them in conjunction with one or more propositions about special circumstances leading us to arrive at specific conclusions (predictions or test implications).

How do we recognise a law of nature? How does it differ from other universal propositions? Are all laws of nature equally abstract, or are some more theoretical than others?

We consider a few propositions as examples.

Point to ponder

Which of the following would you classify as laws of nature? Explain your selection.

(1) The moon is the earth's only satellite.
(2) All whales are mammals.
(3) At a constant temperature the pressure of a gas varies inversely to its volume.
(4) Some people have blue eyes.
(5) Every object continues in its state of rest or state of uniform motion in a straight line unless compelled by some external force to change.
(6) The average life expectancy of modern man is 62 years.
(7) One half of a given number of radium atoms will have disintegrated after the passage of 1 600 years.
(8) There is a minimum quantity of energy in existence.
(9) All persons in this room are taller than 1,50 m.

FEEDBACK

Statements (3), (5), (7) and (8) are laws of nature. Statements (1), (4), (6) and (9) express empirical facts; and (2) is a proposition following from the definitions of "whale" and "mammal".

Can laws of nature be identified by their form? Take another look at the above examples. Are all laws of nature generalisations?

No. At first glance only example (5) has a universal form, although example (3) may be rewritten as a generalisation ("It may be said of all gases that …"). However, (7) is formulated statistically and (8) is called an "existential statement" because it pronounces on "some" entities or "at least one" entity.

The examples further illustrate that other propositions may assume the same form as laws. Thus (2) and (9) are formulated as generalisations, whereas (4) is an existential and (6) a statistical proposition.

2 A "class" refers to a grouping with particular logical characteristics. For instance, the class of all objects which fall to the earth because of the attractive force (and indeed, law) of universal gravitation.

However, most laws of nature are written as generalisations. Of course, not all generalisations are laws of nature. Fundamentally, however, it should be pointed out that generalisations are problematic, even in terms of laws of nature: there could always be a moment of origin when A does not cause B. We simply do not know, as no human has the ability to gaze into the future (Carmap 2009:333):

> "A law about the world states that, in any particular case, at any place and any time, if one thing is true, another thing is true. Clearly this speaks about an infinity of possible instances. The actual instances may not be infinite, but there is an infinity of possible instances ... [W]e must say that there is an infinity of possible instances, all of which are covered by the law. And, if there is an infinity of instances, no number of finite observations, however large, can make the "universal" law certain.

Hume explored the generalised problem of the laws of nature by arguing that "causes" were merely the constant conjunction of phenomena.

We know from experience that the phenomenon "placing sugar in water" is invariably followed by the phenomenon "sugar dissolves", thus: *"B always follows A"*. However, this is not the same as *"A causes B"*. Sugar dissolves after having been placed in water, but does the water *cause* the sugar to dissolve? Is there more to the relationship between sugar and water? The forces that maintain chemical structure, for instance?

If causality is a problem in laws of nature, some other approaches can be used:

- One proposed way of distinguishing between laws of nature and accidental generalisations is by saying that laws are universally valid. They are supposed to be independent of time or place. The difference between "All people present are between the ages of 20 and 50" and "All people present are mortal" is that the former is purely accidental while the latter expresses a law. It has been demonstrated, however, that most laws of nature are not universally valid in an unrestricted sense. Kepler's laws, for instance, were designed only for the planets of our solar system.
- Another way of distinguishing between laws of nature and accidental generalisations, would be by regarding the laws as part of a system. The position a law occupies in a theory or system largely determines how we view it. Here it is a matter of the logical connection between the propositions of a system rather than the relation between the terms of an isolated statement. The logical relation determines the status of the law as law.

Consider Boyle's law:[3] PV = RT, which expresses the relation between pressure (P), volume (V) and the temperature (T) of a gas. R is a constant, in other words a fixed number. This law was later invoked to develop a redefinition of the concept "temperature". Hence laws and concepts are not unconnected: the new definition of temperature was in turn incorporated into other laws, which led to the establishment of a comprehensive, interrelated context in the physical sciences. Now let us sum up these views on the character of laws of nature. The following proposals were considered as answers to the question of what constitutes the difference between laws of nature and accidental generalisations:

3 Robert Boyle was a 17th century Anglo-Irish chemist and physicist.

- The difference lies in the relation between the terms of the proposition expressing the law. Although there appears to be some truth in the claim that laws express a relationship, this poses a number of problems.
- The difference lies in the unrestricted validity of laws as opposed to that of accidental generalisations, the validity of which is circumscribed. There are, however, too many counterexamples.
- Laws play a particular role in a scientific system. This would appear to be the most acceptable answer so far.

> **Point to ponder**
>
> In your opinion, to what extent are laws of nature dependent on theory? Explain your argument. Consider some further examples of laws of nature:

- All planets move in an elliptical orbit around the sun (Kepler).

In a closed system, energy cannot be created or destroyed (law of energy conservation). Are all these laws equally dependent on theory? To what extent can they be directly falsified by means of empirical facts? Not all these laws form part of abstract theories. Kepler's law can be directly falsified by means of empirical observation, in that it refers to entities such as planets, and the sun, and to the mathematical term "ellipse". This is an instance of what is known as an experimental law. Such laws mainly contain expressions that either refer to observable entities or are definable in terms of observations and operations. Hence they can be verified or falsified through observation. The law of energy conservation represents a theoretical law rather than an experimental law, in the sense that it can be understood only in terms of a theory (or theories). In the example of the law of energy conservation, the theoretical foundation is extensive. This law is so thoroughly interwoven with the whole scientific system that would be almost impossible to reject it. In this law we see an example of a pillar of scientific thought, which scientists would try their utmost to save as so many scientific theories are founded upon it.

> **Point to ponder**
>
> What is the difference between "theoretical laws" and "empirical laws"?

Kepler's laws were originally experimental in that they were devised in accordance with certain observations. Later on they could be inferred from Newton's laws, although this required certain corrections to Kepler's formulas, which were duly introduced. Kepler's laws were not sufficiently accurate, however, because a planet's orbit is influenced by the gravitational attraction of other planets – something that was not discovered until Newton thought of general gravitational attraction. Hence the experimental law was modified on theoretical grounds and not on the basis of observation. It was revised before it was falsified empirically. As we know, however, Newton's laws were considered unquestionable. Among these is the law of energy conservation, usually termed a "principle". We will discuss principles further in the next section.

> **Point to ponder**
>
> Conduct basic research (through a Google search or in any other way) and thereafter explain how a *law of nature* differs from a *principle*.

3.2 THE HIERARCHY OF SCIENCE

Science, as can be seen from these few examples, is a system in development; not merely a collection of laws and statements. A hierarchy of scientific theory development (as influenced by positivistic philosophy of science) may look like this:

At the lowest level of science in this hierarchy are **empirical data**, the product of observations. Empirical data describe specific facts. Consider these examples of "empirical statements":

- The rainbow I saw yesterday – let's call it rainbow B – had seven colours.
- Rainbow *B* took the form of a semicircle.
- Rainbow *B* was facing a setting sun.
- Two weeks ago, I saw a rainbow – I called it rainbow *A* – which had seven colours.
- Rainbow *A* was round in shape.
- Rainbow *A* was facing a rising sun.

By the process of induction, a generalised statement – the product of the empirical (in this case visual observation by means of sight) – may be inferred:

Therefore:

- All rainbows have seven colours.
- All rainbows are round.
- All rainbows are situated opposite the sun.

These are generalised (universal) statements in the sense that they are valid for any rainbow. Thus we summarise observations with the aid of these kinds of experimental laws. In the given example, the generalisations about the features of a rainbow have been made based on the theory of water droplets. Thus, they can be deduced from this theory, for the theory (itself founded in the observation and generalisation process) supports them and explains the empirical generalisations made about a specific phenomenon, namely rainbows.

Point to ponder

Describe the criteria used for the delineation of scientific theories.

Theories (which comprise science) are simply hypotheses. However, to systematise the process of theory generation as different from relying on imagination or dreams, rational criteria for the determination of scientific theories must exist. The three most important classes of rational criteria for scientific theories are:

- *Empirical adequacy:* The conformity between observations and theoretical terms, that is the success of empirical tests.
- *Logical criteria:* A theory that has high unifying power is strongly recommended, because it means that it has a wide explanatory range, promoting deep understanding. This kind of power is closely related to the deductive relation between a theory and that which it explains, as well as to the notion of background knowledge: the deeper the level of background knowledge a theory needs to be intelligible, the wider its explanatory range will be.
- *Predictive power:* Although theories are usually originally invented to explain certain phenomena, only a very weak theory would be restricted in this way, because that would mean that it had no added predictive power. A theory should be more

than the product of induction, because induction is limited to the phenomena explained. For instance, from a finite number of observations of rainbows, induction will predict that all rainbows are round. We can learn nothing else about other instances of light refraction from these particular instances, as they go beyond the information available.

For a theory therefore to be considered "scientific", it should at least conform to these criteria.

3.3 THE LOGICAL POSITIVISTS

The logical positivists formed a school of philosophy in Vienna, Austria and in Berlin, Germany during the 1920s and into the 1930s. The members of this school were focused upon the data observed in science and concerned themselves with the logical analysis of scientific knowledge. Influential members were Moritz, Carnap, Reichenbach, and Hempel, among others.

The logical positivists denied the soundness of metaphysics as well as other traditional research areas of philosophy, including ethics and aesthetics. They therefore relegated much philosophy to the graveyard of intellectual history. The positivists argued that many philosophical problems are meaningless. For them, a statement could only have meaning if it could be verified by means of experience/observation. Metaphysics and ethics obviously cannot be observed, and so cannot, according to them, be a reliable source of knowledge (Gracias 1992:11).

An ethical theory, for instance the view that abortion is the right and choice of the pregnant woman, could not have meaning for a logical positivist, as it cannot be verified empirically. It is impossible to empirically measure the morality of the value held.

While the positivists reject metaphysics, ethics, and the like, they nevertheless hold to the possibility of a person obtaining empirically verified knowledge of reality (Gracias 1992:10).

Point to ponder

As human constructs, to what extent are scientific theories filtered re-presentations of experience?

Until the 1950s, logical positivism was the leading philosophy of science, and it still influences the way in which philosophy is practised, as is apparent in the attention that is given to the analysis of scientific thought and in the impact of technical research on formal logic and the theory of probability. It remains as a foundational assumption in natural science, and is commonly held in social science, too.

The fundamental principles of positivism are verifiability, its consequence, the logical structure of scientific theories, and the meaning of probability.

Logical positivism acknowledges only two sources of knowledge: logical reasoning (which is analytic *a priori,* that is rational, without experience) and empirical experience (which is synthetic *a posteriori,* that is experiential). For the positivists, the synthetic *a priori* (a mixture of the rational and the experiential) does not exist, however. This denial is the core thesis of modern empiricism.

While logical knowledge includes mathematics (which is reducible to formal logic), empirical knowledge refers to physics, biology, psychology, applied linguistics, etc. Experience, according to logical positivism, is the only judge of scientific theory. However, the logical positivists accepted that scientific knowledge does not arise exclusively from experience, and so they acknowledged that scientific theories are genuine hypotheses that go beyond experience. Thus, they can be universalised.

However, it is not possible to establish a logically durable theory on verification (an observational statement or a statement based upon observation about immediate perception), since verification (by observation) disappears when the theory is created.

Nevertheless, logical positivism implies that a statement is meaningful if and only if it can be proved true or false – at least in principle – through experience. This is the *verifiability principle*. It is believed that the meaning of a statement is its method of verification; in other words that we know the meaning of a statement if we know the conditions under which the statement is true or false.

Point to ponder

When are we sure that the meaning of a question is clear? Explain.

If (and only if) we are able to describe exactly the conditions in which it is possible to answer yes or no. The meaning of a question is defined only through the specification of those conditions. The definition of the circumstances under which a statement is true, is *equivalent* to the definition of its meaning. Thus, a statement has meaning if and only if its truth can be verified (i.e. measured) in terms of experience.

Hence, metaphysical statements are forbidden, for they are meaningless. Philosophy is reduced to the role of clarifying the meaning of statements. On the other hand, the exploration of the real becomes the domain of science alone, so the philosopher is forever ousted from exploring reality!

Remember, the philosopher has now been relegated to the role of clarifying the meaning of linguistic statements. A scientific theory is a system that obtains an empirical interpretation through linguistic statements, called "rules of correspondence". The purpose of these rules is to establish a correlation between real objects or processes and the abstract concepts of the theory. The objects to which a linguistic statement refers are not contained in the theory, but are rather represented by the theory linguistically. Analysis reveals that the language in which a theory is written, includes two kinds of terms: *observational* terms and *theoretical* terms. Observational terms refer to objects or properties that can be directly observed or measured, while theoretical terms denote objects or properties we cannot observe or measure but can only infer from observations.

The statements of a theory are further divided into two groups: *analytic* and *synthetic*. Analytic statements are *a priori:* their truth is based on the rules of the language. Synthetic statements depend on experience (*a posteriori*): their truth can be acknowledged only by means of experience.

This analysis of the structure of scientific theories concerns what is perhaps the most enduring philosophical principle of logical positivism. It holds:

- the distinction between observational and theoretical terms
- the distinction between synthetic and analytic statements
- the distinction between theoretical axioms and rules of correspondence
- the deductive nature of scientific theories

These four points are linked. Rules of correspondence give an empirical meaning to theoretical terms and are analytic, while theoretical axioms[4] express the observational portion of the theory and are synthetic. A theory must be a deductive system, otherwise a formal distinction between the various kinds of sentences and terms would be impossible.

The distinction between observational and theoretical terms depends on the verifiability principle. A statement is meaningful only if it is verifiable (i.e. relative to the real). But, in scientific theories, there are many statements that are not verifiable. An example is an assertion dealing with quantum particles. Such statements cannot be directly tested. Hence, strictly (positivistically) speaking, they are meaningless.

To avoid such a consequence, two different approaches were proposed:

- According to Schlick (1931:19), the principles of a scientific theory are not statements, but **rules of inference**. Because they are not statements pertaining to a dimension of reality, the problem of their meaning does not arise.
- An alternative solution was proposed by Neurath (1931): the terms of the abstract language of a scientific theory are definable in a restricted language, the terms of which describe directly observable objects.

A distinction between observational and theoretical terms therefore came to be accepted. But soon, Carnap realised theoretical terms are not definable by means of observational ones. Initially, he proposed a partial reduction of theoretical to observational terms. Later, it was supposed that all theoretical terms could be eliminated from a scientific theory, thus leaving only observational terms.

3.4 OBSERVATION AND THEORY IN SCIENTIFIC THEORIES

According to the "two-language view of science", science describes reality in both *observation language* and *theoretical language*.

- The **observation language** is the *direct product of sense experience*, shared by all people, which describes phenomena according to features such as weight, colour, shape, and size.
- On the other hand, the terms of **theoretical language** are *invented* (e.g. "wavelength" and "atomic weight") *to explain phenomena* that cannot be observed by means of the senses, such as atoms, molecules, genes, electrons, radio waves, and so forth.

The aim of science is to organise available experiential data so that phenomena can be explained and predicted. However, the greatest advances in systematisation have resulted from laws referring to theoretical entities, events or properties as described in theoretical language. The expressions used to refer to such theoretical entities, events or properties are theoretical terms, whereas observational terms refer to observable entities, events or properties, information being perceived employing the senses.

As an example of an experimental "law" or generalisation, Hempel cites the following (1965:180): "Wood floats on water and iron sinks in water."

But not all wood floats, and hollow iron objects (such as ships) do not always sink! There is, however, a theoretical term – "specific gravity" – which indicates the ratio between the weight *(w)* and volume *(v)* of an object: $s = w/v$. Hence the imprecise

4 An "axiom" may be defined as a principle which is held as true.

observational generalisation "Wood floats on water and iron sinks in water" may be replaced by the more theoretical general law: "A solid body floats on a liquid if its specific gravity is less than that of the liquid". Because it indicates a property that is not directly observable, "specific gravity" is a theoretical term.

As explained above, positivists usually characterise terms contained in theories in two groups: theoretical and observational terms. Beginning by expressing a formal (logical) statement in which the primitive symbols (i.e. representations of the context, e.g. "atom" represented symbolically as "A") of the theory are set out, they then depict theory as a set of rules (*correspondence rules*). In these rules, empirical (observational) data is assigned to the logical calculus for at least some of the primitive and defined symbols of the calculus in terms of *pure* observational terms. In this way, theory and human sensory experience are linked.

For the positivists, a scientific theory is a linguistic representation of (actual and possible) human experience, consisting of a set of sentences possessing certain *"special logical features"* (Klee 1999:29). In these terms, a theory is supposed to "capture in linguistic form the causal regularities that hold within a domain of phenomena" (Klee 1999:28). The theories are created after observation, as an abstraction of the observed (Klee 1999:29).

The positivist claim is that observational terms are assigned their interpretation(s) independent of the theory. Theoretical terms, on the other hand, "acquire [their interpretation] through their connections with the observational terms", as a set of correspondence rules (Przelecki 1991:287 in Ruttkamp 2002):

> "The observational terms are thus said to be interpreted directly by ostensive (or operational) procedures, [and] the theoretical terms indirectly, by postulates relating them to the former".

Both kinds of interpretational procedure are problematic. The interpretation of observational terms is indeterminate because of their vague nature, and because the positivist procedure assigns interpretations to an observational term, each of which corresponds to a possible way of making the term precise. Theoretical terms *inherit* this indeterminacy, because their interpretational procedure implies that they are interpreted through postulates connecting them with the observational terms (Przelecki 1991:287). The requirement for a set of correspondence rules to connect theoretical terms to their observational counterparts was supposed to be the tool for actualising the positivist dream of rooting out all forms of pseudo-science. However, this turned into an enemy of the positivist ideal, since it is impossible to find a clear, unambiguous method by means of which to draw the observational/theoretical distinction.

Scientific terms have to be meaningful in that they must relate to observations or operations. Additionally, such relations must be construed for every scientific term.

This implies that the positivist cannot claim that using formalised correspondence rules expressed in the language of logic necessarily provides us with a unique and precise understanding of the relation between theoretical terms and observational terms they pursued so actively.

A blow to positivism was the prejudice in the interpretation of observation statements, which resulted in theoretical statements being less than absolute.

Points to ponder

To what extent is the positivistic scientist involved in the construction of theoretical statements from observation statements?

Are observation statements neutral?

3.5 CRITIQUE OF THE "TWO-LANGUAGE STRUCTURE"

The distinction made between the "two languages" has been criticised by many:

- **Popper**, for example, conceived of all scientific concepts as theoretical, for every assertion not only entails hypotheses but is hypothetical: uncertain and always falsifiable.
- **Quine** criticised both the observational-theoretical and analytic-synthetic distinctions.
- **Hempel** noted:
  - Observational terms do not exist. According to him, the only distinction possible is that between terms used in a given theory and new terms employed for the first time in a new scientific theory. For example, Bohr's atomic theory includes terms such as "quantum numbers", "quantum leap", and "steady state", and explains spectra described with the aid of "wavelength". Now "wavelength" is an "old term" while quantum number is a "new term". Thus the abstract concepts of atomic theory are linked with other abstract (but already given) concepts. All observations are mediated (through sensory experience and cognition) into statements, hence making them "theory-laden".
  - The meaning of theoretical terms is not defined by means of analytic statements that are true by convention. In fact, every statement is subject to empirical testing. In a scientific theory there is no room for "truth by convention".

- **Carnap** proposed a slightly different approach to the observational-theoretical distinction. His starting point is the difference between empirical and theoretical laws. According to him, it is possible to directly confirm (or disprove) an empirical law, while a theoretical law can be tested only through the empirical laws that are among its consequences. Moreover, an empirical law explains facts while a theoretical law explains empirical laws.

  Thus there are three levels:

  - empirical facts
  - empirical laws: simple generalisations we can directly test (which explain facts and are employed to forecast facts)
  - theoretical laws: general principles used to explain empirical laws

Point to ponder

To what extent has the problem of the relationship between theoretical and observational languages been solved or developed into an ever greater problem?

Empirical laws include observational terms, while theoretical terms occur in theoretical laws.

3.6 SYNTHETIC, ANALYTIC, *A PRIORI* AND *A POSTERIORI* STATEMENTS

The distinction between **analytic** statements (statements that are true by definition) and **synthetic** statements (statements in which the meaning of two terms are not necessarily contained within each other) is a consequence of the verifiability principle of the logical positivists. It is linked with the observational-theoretical distinction as well as with the axioms or rules of correspondence distinction.

According to the verifiability principle, an alleged synthetic a *priori* statement (one which is made prior to experience) does not have meaning, because its emergence is not observed. Hence there are only two kinds of assertions: either synthetic a *posteriori* (with experience) or analytic a *priori* (without/prior to experience).

> **Point to ponder**
>
> Can an analytic *a priori* statement – one which is true by virtue of its definition, and without observational experience – have a role to play in an empirically grounded scientific theory?

Two possibilities can be considered:

- An analytic statement is either a logical-mathematical theorem (thus it has no empirical significance); OR
- it is a convention that defines the meaning of theoretical terms.

The solution to the problem proposed by Carnap was based on the analytic-synthetic distinction. His method explains the meaning of theoretical terms and their relationships with observational concepts, and provides ways of separating synthetic and analytic statements and of dividing theoretical axioms from rules of correspondence.

Logical positivism deems scientific theory deductive. Hence, pragmatic aspects are not considered.[5] Neo-positivism was also not concerned with the real process of discovery, but with the rational reconstruction of scientific knowledge, that is, with logical relationships between statements in a given theory. According to positivism, there is no discovery method, and therefore a scientist can propose any hypothesis, but only logical relationships between the hypothesis and the given empirical evidence are relevant.

Nevertheless, there is a problem with this conception of science: the relation between empirical experience and theoretical principles is not a deductive one. Observational statements do not imply theory.

Theory is relevant to science, however, as the point of science is to describe, explain, and predict the way the world is. To this end, science utilises hypotheses. Recognition of significant connections or correlations among hypotheses may lead to the formulation of scientific laws that express regularities under specific conditions.

Theories, in turn, consist of a number of laws and their application to concrete instances. In the development of theories, theoretical postulates such as electrons, mass, gravity, etc., are proposed and are related to phenomena. In considering gravity, for

5 "A **pragmatic** approach to dealing with something is concerned with what is sensible and realistic in the actual circumstances rather than with following a principle or theory" (*South African student's dictionary* 1996:751–752).

instance, the relationship between the weight and volume of an object is emphasised. This is a theoretical construction. Because the specific gravity of various substances can be determined using instruments that give precise readings of the weight and volume in the applicable instances (observed), there is a connection between theoretical terms and observable terms (as gravity is theoretical).

Point to ponder

Are theoretical terms an indirect way of describing "what is really there" or are theoretical terms merely convenient descriptive and explanatory tools?

3.7 REALISM AND INSTRUMENTALISM

Consider the appearance and the reality of water (as an example of any phenomenon that can be analysed, explored and explained scientifically) (Hung 1997:212–213):

> *"*Water is (a collection of) H_2O." What can this mean? Water, as we know it, is a homogenous fluid, continuous, transparent, smooth, and usually cool to the touch. It is drinkable and thirst-quenching. Above all it is substantial, weighty, and bulky. On the other hand, H_2O is a molecule too small to be perceived and is composed of three atoms – two hydrogen and one oxygen atom. A bucket of water is said to consist of billions and trillions of these molecules all buzzing around incessantly at exceedingly high speeds. The most amazing thing, however, is that the distances between the molecules are so enormous when compared to the actual sizes of the molecules (and the distances between the nuclei and the electrons of the individual atoms are also so enormous) that most of what we call water is in fact empty space.

Water can, as this excerpt demonstrates, be conceived of on at least two planes: the experiential and the theoretical. We begin by considering the latter, for it is the concern of realism.

In its broadest definition, *"realism"* refers to any theory which proposes that entities exist objectively and independently from human minds (Psillos 2007:211). An understanding of reality that is contrary to realism, in other words, "which dispenses with the things in question", can be broadly considered *"anti-realist"* (Lacey 1996:286).

Because it has that which exists as its object of study, realism is a metaphysical theory (Psillos 2007:211). It is also epistemological in that it purports to make statements about what it is possible to know (Bortolotti 2008:96).[6]

In the view of scientific realists, then, scientific theories seek to describe beyond the observed or the experienced, such that "truth values" can be ascribed to particular theoretical statements. Hence realists attempt to transcend the perceiver's experience in the development of scientific theories (Bortolotti 2008:96):

> According to the ontological thesis of a typical realist, there are mind-independent objects and properties in the world, objects and properties that would be there even if there were no mind to think about them. According to the

6 The term "epistemological" refers to that which is of or pertains to "epistemology", which is rooted in the Greek word *episteme* (Merriam-Webster 2013a). "Epistemology" is defined as "the study or a theory of the nature and grounds of knowledge" (Merriam-Webster 2013a).

> epistemological thesis, we can have access to these objects and properties, and our representations of them, though fallible, are not systematically misleading.

Realists base their theory on the physical reality: there is, according to their thesis, sufficient reason based on experience of phenomena in physical reality to assert that these objects actually do exist (Bortolotti 2008:96). The task facing the scientific realist, then, is to make an attempt at explaining and describing this experienced reality without remaining in the subjective experience (Bortolotti 2008:97).

For a scientific realist, a theory can be deemed likely to be true if it has *"*both high explanatory power and high predictive power*",* which implies that there is a causal connection between the theory and the particular entity to which the theory refers. Some "radical" realists have taken this thesis to yet a further level in proposing that the observed take on reality is not at all true, as it is a distortion of what is real (Hung 1997:213). These realists might argue that, while I may experience my pen as an object, it is nothing more than atoms, their constitutive subatomic particles, and empty space! According to them, there is no object.

Points to ponder

What is real, according to scientific realism? Do you agree with this characterisation?

In your view, to what extent is a pen a unified entity with which one can write?

Indeed, if we take the radical realists seriously, whilst phenomena are sensorily observed, they could be nothing more than fiction created by our minds! This is part of the problem faced by extreme realists. To develop greater nuances in realism, other forms of realism have been developed. Among these is "critical realism", which takes into account the subjective experience of the perceiver, who is also the developer of a scientific theory.

"Instrumentalism" takes a contrary view to realism. It is grounded in the notion that the common-sense understanding of reality as founded in human, sensory observation is the "way things are". This emphasis leads instrumentalists to assert that the world of sensory observation *"*is the correct and true picture of reality" (Hung 1997:213).

Point to ponder

In your view, to what extent are atoms or subatomic particles (declared by realists to be real entities) discountable as "non-real" or fiction because they are not experienced through observation?

For instrumentalists, scientific theories are no more than *"*mental constructs" (Hung 1997:213). According to Psillos (2007:123), they are *"*view[s] about science according to which theories should be seen as (useful) instruments for the organisation, classification and prediction of observable phenomena.*"*

Instrumentalism conceives of reality as that perceived in everyday life by human beings through the five senses, rather than as the unperceived, unobserved reality realists emphasise as illustrated in their theoretical portrait of reality. Instrumentalists can be said to have a powerful argument in their arsenal.

Point to ponder

Can anything not perceived by means of the senses be known? Does something we cannot perceive exist? Explain.

Instrumentalists rely on "our senses in the presentation of the world. Our senses are likened to a camera … which yields in the exact likeness of reality" (Hung 1997:214).

Point to ponder

How do instrumentalists view scientific theories? Explain in detail.

Pierre Duhem and his followers in instrumentalism simply view theories as tools for dealing with statements of observation. Science, from the instrumentalist perspective, serves as a means to explain, with the aid of theories, what is observed by the senses. The content of science, however, remains at the level of sensory observation. Instrumentalism therefore tries "to 'save the phenomena'… [to make it] compatible with the available data as received by the senses" (Bortolotti 2008:105). A scientific theory becomes an instrument to explain what is observed through the senses. Hence, extreme instrumentalists can argue (Psillos 2007:123–124):

> "[O]ne need not assume the existence of an unobservable reality behind the phenomena, nor that science aims to describe it, in order to do science and to do it successfully."

According to instrumentalism, the task of science is not to explain the phenomena experienced (for instance, by making a statement regarding how things are themselves), but to provide for the development of theories that conveniently explain the observed. A "convenient" theory is one that fits whatever is observed (Bortolotti 2008:105).

Therefore, a "good" theory for an instrumentalist is useful rather than true (Lacey 1996:163). An instrumentalist could thus embrace the H_2O model of water (as a useful theory), but still argue the experience of the phenomenon of water to be that of "a homogenous and continuous substance", according to the way in which the phenomena is observed (Hung 2007:214).

A principle issue realism points to, is the problem regarding the certainty of whether or not reality actually exists (Bortolotti 2008:97):

> "[N]othing would justify the step from accepting a scientific theory that can efficiently predict the phenomena within a given domain to believing that the entities and relations posited by that theory actually exist".

This problem, which can be traced back to Descartes, may well apply to us all: we could all be nothing but brains in vats controlled by a mad scientist! How could we ever know anything more? Everything around us could be fiction: we take a leap of faith in believing that anything is real. Thus, the instrumentalists' critique of realism applies (Bortolotti 2008:97):

> "No amount of confirmatory evidence we gather for any specific theory can tell us whether the theory is more than just a useful tool for the prediction of events that we want to be able to control".

Points to ponder

How can the imperceptible be known as existing?
Can any sensory information be deemed an illusion?
Explain your thoughts on the two questions posed above

Humanity in general, and science in particular, continue to live as if what is perceived as real, is indeed, truly there. A quantum physicist deals with his/her research in the belief that what he/she is exploring, is in fact an extant reality, rather than just a theory that would appear to work.

But what of the instrumentalist stance? According to their take on reality, which emphasises phenomena as common-sensically perceived, problems arise. Hung (1997:214), for instance, uses the example of people reflected in a mirror to point this out: "The instrumentalist would have to say that, in reality there are people-in-mirror because that is what her eyes suggest."

Following the perception of phenomena, a theory could be developed to explain it. But even this seems to be counterintuitive. Logically a reflection of people in the mirror does not mean that there are actually people in the mirror. Instrumentalism has now been transcended, however, for it argues that scientific theories should never "attempt to describe a reality 'underlying' the phenomena, but instead merely … codify those phenomena in a coherent, efficient, and 'simple' way … to enable their prediction" (Worrall 2002:32).

Point to ponder

Are realism and instrumentalism integrateable? Explain

When examining the aforementioned critique, it seems tenable that both realism and instrumentalism have a strong case. In fact, an approach to scientific theory according to which both instrumentalism and realism are acknowledged "has been made respectable" (Hung 1997:216). But given the existence of such an integration, are we compelled to question whether or not realism and instrumentalism are contrary approaches to scientific theory? Michael Gardiner (1998:410) poses this dichotomy:

> There is supposed to be a problem in the philosophy of science called "realism versus instrumentalism"… this supposed problem is whether scientific theories in general are put forward as true, or whether they are put forward as untrue, but nonetheless convenient devices for the prediction (and retrodiction) of observable phenomena.

Taking an historical approach to science, Gardiner (1998:410) uses the example of the development of atomic theory (in the 19th century). He shows that, while initial theories concerning the atom were "regarded by most of the scientific community as a set of false statements useful for the deduction and systematization of the various laws regarding chemical combination, thermal phenomena, etc.", they gradually came to be accepted. This was due to improvements in the theory's predictive power, empirical investigation, and so forth. They came to be statements of how reality is. Thus, Gardiner (1998:411) proposes that this example may be indicative of how science progresses.

This theory conceives of both instrumentalism and realism on a continuum of the development of scientific theories rather than allowing itself to be forced to "embrace" the one or the other. Thus, according to this theory, one does not have to choose between the "scientific" (realist) view or the "common-sense" (instrumentalist) view of reality, but can simply see these as two levels of perception of the same phenomena, albeit at different evolutionary stages.

If scientists need to express their theories in terms that are theoretical – in order to represent perceived and cognate dimensions of that which has been investigated – they need to employ theoretical (as opposed to observational) language. Theoretical language is used regardless of whether realism or instrumentalism is embraced. Whilst this may appear to be a circular argument, how could science be expected to explain phenomena unless it implicitly draws upon a large body of theory that, though unfamiliar, can be tested intersubjectively? There is no way in which observable phenomena can be "explained" by simply drawing attention to other observable phenomena without appealing to the mediation of theoretical terms. In fact, the process does not proceed in that manner at all. The observable is explained by means of unobservable – theoretical terms, the "existence" of which may or may not be confirmed by means of further occurrences (that are usually indirectly observable), on the basis of which the policy of adopting theoretical terms is justified. That is as far as a direct answer to the question could be given.

In our daily experiences, we are not often specifically aware of using theoretical terms, nor do we use them in the strict sense in which scientists need to use them by precisely defining terms in order to avoid vagueness and ambiguity. Nevertheless, to the extent that terms originate from science and refer to that which cannot be observed straightforwardly, they are theoretical terms. Among these are terms such as "temperature", "acidic", etc. There is a continuity between everyday life and science. When we speak of the temperature of a body, for instance, we do not necessarily refer to the phenomenon in the way in which a scientist would do so. Instead, we speak of an indirectly observable entity, about which we have no other way of talking besides by implicitly appealing to a theory or utilising that part of the theory that has become part of our everyday knowledge.

REFLECTION

(1) What is the difference between scientific laws (such as PV = RT) and principles (such as the principle of the conservation of energy)?
(2) Large molecules may be observed by means of an electron microscope. Does this mean that molecules are no longer theoretical entities?
(3) Suppose a friend informs you that he can make plants grow faster by playing music to them. Is this statement verifiable?
(4) Is the proposition "The increase in glubbification of glycerine is proportional to the increase in temperature" verifiable?
(5) Are theoretical terms applicable only to nonobservable objects? Are observational terms applicable only to observable objects?

FEEDBACK ON REFLECTION

(1) There is no real difference between laws and principles apart from the assumption that principles are more inviolable than laws. The more laws and hypotheses a principle supports, the more difficult it is to reject that principle.

(2) An electron microscope, or for that matter an ordinary one, is itself based on theory. Hence molecules are not directly observable (without making theoretical assumptions).

(3) Yes, because it refers to observable events.

(4) That would depend on what "glubbification" means. If it is a property associated exclusively with a rise in temperature, it cannot be tested independently. But if it expresses, say, fluidity – which may be measured independently – such a statement is verifiable. Hence we cannot say whether or not an isolated proposition is verifiable unless we assume some context.

(5) Instances of theoretical terms being applied to observable objects include "soluble" with reference to sugar, or "electrical charge" in relation to lightning. Observational terms such as "spherical" or "moving" are applied to objects that are not directly observable, such as viruses or bacteria.

PART C

PHILOSOPHY OF SCIENCE IN THE LATE 20TH CENTURY

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STUDY UNIT 4

Induction, Popper and falsificationism

> **"[T]he criterion of the scientific status of a theory is its falsifiability, or refutability, or testability."**
>
> – Karl Popper (2009:474)

OUTCOMES

After completing this study unit, you should be able to

- define and place induction in scientific theory development
- explain and evaluate arguments in favour of induction
- critically discuss David Hume's identification of the "problem of induction"
- appreciate and appraise Popper's problem of demarcation and his theory of falsificationism
- relate the epistemological approach of realism to the problem of induction

4.1 INDUCTION

When we seek an explanation for a phenomenon, we put forward a tentative[7] proposition that serves as a point of departure for research. A tentative statement of this variety is called an "hypothesis". Hypotheses are used in daily life.

For example, when Kgalakgadi does not arrive at work, her friend Fatima reasons: "She must be sick, because she was not feeling too well yesterday." Fatima proposes the hypothesis, "She (Kgalakgadi) is ill," with supportive evidence that Kgalakgadi was well the previous day.

In the sciences, hypotheses are formulated, enabling a better understanding of phenomena through theory development. This is illustrated in the following example:

> "There is a general attraction between physical objects."

Scientific hypotheses are not always self-evident, however. Why did Newton conceive of general gravitational force? Where do hypotheses in the natural sciences come from?

Simply put, *observations* (as we have already touched on) are made through the sensory system. For instance, iron, copper, zinc, silver and gold all expand when heated. All of these are metals, and each metal expands when heated. The conjecture that all metals expand when heated is thus offered. Therefore, a general rule that summarises all these observations is tentatively proposed. What has occurred, is that a number of specific observations have been collected, and a general proposition has been derived from them.

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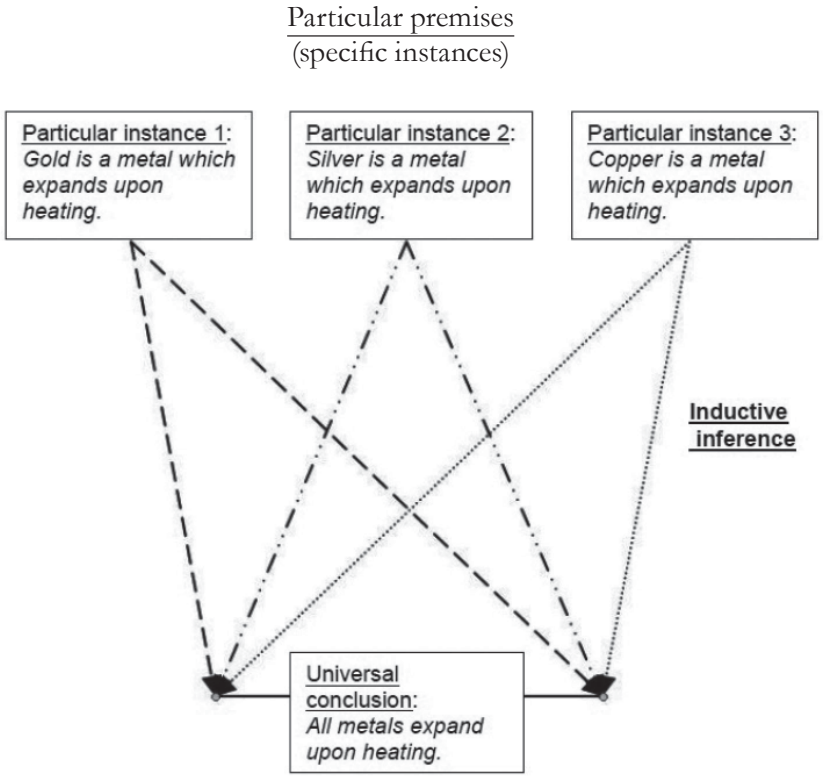
7 The term "tentative" in this context refers to a conclusion which "is not finally agreed on or decided" (*South African student's dictionary* 1996:1019).

In logical terms, such an observation statement may be symbolised by saying that object *a* has the quality or feature *F* which may be described as "*Fa*"; object *b* also has quality *F*, therefore "*Fb*", and so on. Hence the conclusion follows that all objects possess quality *F*: *Fa, Fb, Fc, … Fn*. Conclusion: hypothesis: All objects possess quality *F*.

In this process of reasoning, particular observed instances are extended to a generalisation. This is known as an "inductive generalisation" or an "inductive inference". Graphically, induction can be illustrated as proceeding as follows (using the above example of the metals):

Induction

Arguments structured in an inductive manner proceed form particular premises (statements in support of a conclusion) to a universal/generalised conclusion:



Induction: from particular premises to universal conclusions

There are, however, different forms of induction among these, *from simple statement to simple statement*. Consider the following:

> The 11:20 Gautrain is two minutes late, as is the 11:30 Gautrain, therefore the 11:40 Gautrain will also be late. In such cases the derivation (to the second statement) proceeds via an inductive generalisation.

This can be logically illustrated as follows:

> Train *a* (the 11:20 Gautrain) is late, train *b* (the 11:30 Gautrain) is late …

> From the evidence it can be implied that:
> All trains are late.
> Therefore the 11:40 Gautrain will be late.

Statistical generalisation is another form of induction often used in the social sciences.

Suppose we test a number of South African citizens and find that 10% of the tested population belongs to blood group *A*. We now generalise to arrive at the conclusion that 10% of the population – whether tested or not – belongs to blood group *A*.

Although this type of induction is usually valid – unless the original random sample was too small – we cannot generalise from "10% of the population of South Africa" to "10% of the population of the world", as the distribution of blood groups is not the same in all countries.

Hence we have one of the problems associated with induction: we should be very careful which and how many individuals are selected for a random sample. Moreover, we may not generalise indiscriminately, for it is always possible that we will find exceptions.

A further type of induction is *analogy*, according to which a number of cases with certain features in common are compared and the researcher assumes that these cases will also have further features in common. For example:

> The planet Mars corresponds to the earth in many ways. Although it is a smaller planet, its distance from the sun and the duration of its days are similar to those of the earth. It has two moons. We observe colour changes on Mars that could be interpreted as seasonal changes (summer and winter). The equatorial temperature rises to about 278 °C. *Because there are so many similarities between Mars and our own planet, there is probably life on Mars as well, because there* are living beings on earth.

Finally, there are *statistical analogies*:

> Twenty per cent of a test sample of women who smoke during pregnancy have babies with a low birth weight. Therefore, 20% of all women who smoke during pregnancy have babies with a low birth weight.

Point to ponder

Briefly define "induction" using examples to substantiate your explanation.

4.2 ARGUING FOR INDUCTION: FRANCIS BACON (1561–1626)

"Induction" is defined as (Bortolotti 2008:170):

> [A p]icture of scientific reasoning and practice according to which scientists arrive at explanatory theories by making observations and formulating generalizations on the basis of their specific observations.

That scientific theories are founded on the methodology of inductivism was argued for by Francis Bacon, an English philosopher who lived in the 16th century (Bortolotti 2008:45). Of Bacon, the Scottish philosopher Thomas Reid (in Broadie 2004:41) noted:

> Did not his [Bacon's] Novum Organum give birth to the Art of Induction? Was there ever a Book in the World that delineated so important an Art so justly, & so minutely before that Art had an Existence? Has not Newton in his Opticks and in his Astronomy followed his precepts, step by step?

Perhaps Reid's praise of Bacon was a little extreme. Still, not only did an eminent scientist like Newton embrace the method of induction, but almost all scientists in the practise of scientific experiment and theory development continue to employ it!

There are, however, two qualifications regarding Bacon's approach to induction that should be noted: firstly, his particular form of inductivism refers to scientific discoveries in particular (*not* to the entire scientific project – although by inductive inference it could be extrapolated to this level). And, Bacon's inductive methodology is at its essence a "careful articulation of piecemeal generalization" (Ducheyne 2005:116).

While much philosophy from the time of the Ancient Greeks had employed Aristotelian syllogistic argumentation, Bacon wanted to begin with the observation of particular instances of a phenomenon in order to draw generalised conclusions. Bacon saw syllogisms as mixing "words with the order of things and corrupted natural philosophy". He thus sought a return to the phenomenon itself through the experience of the perceiver, that is, the one who comes to have knowledge. For Bacon, the person who has knowledge is one who has created that knowledge, in that if we have knowledge of something we should be able to create that knowledge again (Ducheyne 2005:117). Bacon (2009:190) states it thus:

> Man is Nature's agent and interpreter; he does and understands only as much as he has observed of the order of nature in fact or by inference; he does not know and cannot do more.

Through the observation of the perceiver – the creator of scientific knowledge – scientific methodology moves from particular instances to universal/generalised conclusions. Perhaps rather tongue-in-cheek, Bacon (2009:191) proposes: "The mind loves to leap to generalities, so that it can rest."

Nevertheless, because knowledge of particular natural phenomena was replicable, the scientist was assured that the information that arose in a theory was a reflection of the way the world is (Ducheyne 2005:118). Moreover, replicability of findings became – because of Bacon's approach – one of the hallmarks of scientific reasoning.

For Bacon (2005:118), science should proceed from the perceiver's observation of particular phenomenon in the world as they present themselves to the perceiver. A generalisation can then be drawn, first at a "low level", and then to the extent that laws of nature can be induced following many low-level inferences. Scientific theories, therefore emerge "from sense and particulars, rising in a gradual and unbroken ascent to arise at last at the most general axioms" (Bacon 2009:191).

Science thus begins in the observation of particular instances, from whence a universal conclusion is inferred. In this inductive process, scientific reasoning goes beyond the evidence available, because it is impossible to evaluate every instance of any particular phenomena.

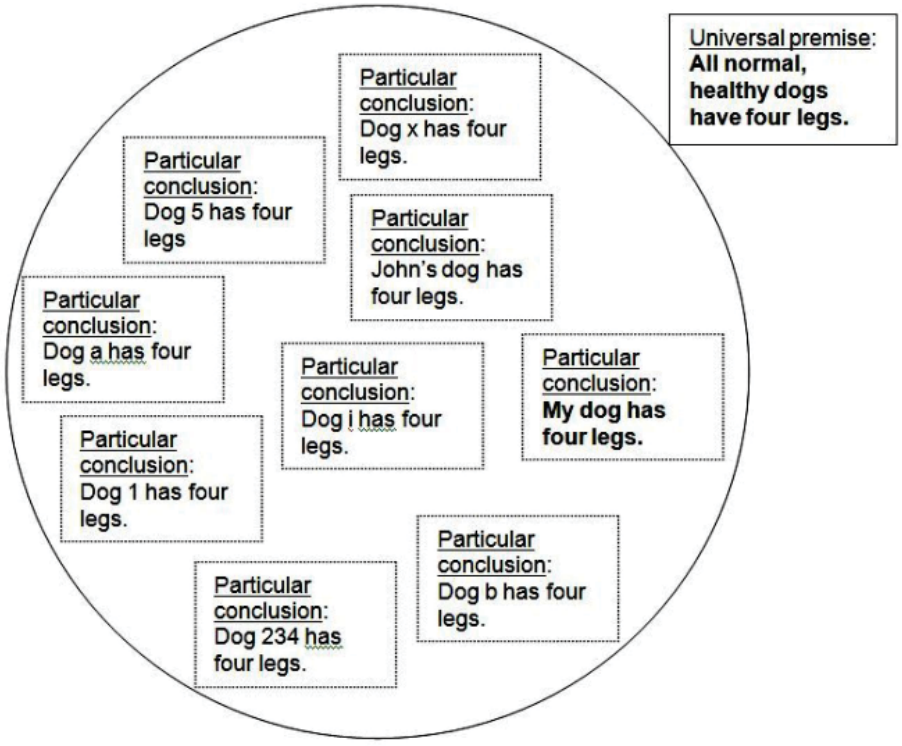
Point to ponder

If the evidence for premises is transcended in inductive arguments, how can the content of inductive conclusions be assured? Motivate by means of sound reasoning.

As in deductive reasoning more information than that which is contained in the premises can never be provided, science cannot make new discoveries (generate new knowledge) relying on deduction alone.[8] The following argument is deductive:

- Universal premise 1: *All normal, healthy dogs have four legs.*
- Premise 2: *My pet is a healthy dog.*
- Particular conclusion: *Therefore, my dog has four legs.*

Deductive reasoning (wherein the particular conclusion is contained within the universal premise) can be illustrated as follows:



Deduction: from universal premises to particular conclusions

Since deduction does not produce knowledge outside of the evidence available (that is, outside of the universal premise), scientists must apply induction to aspire to new knowledge.

Because induction generates hypotheses in science, we call this approach "inductivism". The basic idea underlying inductivism is that reality should be approached without preconceptions, and that scientific hypotheses and theories should be rationally built up on this random sample of basic material. Obviously it is not possible

8 The conclusions of deductive arguments are contained within their premises.

to take a sample of every entity that exists. Therefore, taking a random sample and formulating a generalisation based on it, is the best that can be done.

Point to ponder

Differentiate between induction and deduction, and cite examples were possible.

4.3 THE "PROBLEM" OF INDUCTION: DAVID HUME (1711–1776)

Bacon (2009:193) was aware of the flaws of induction, for he offered the following caveat:

> [I]nduction which proceeds by simple enumeration is a childish thing, its conclusions are precarious, and it is exposed to the danger of the contrary instance; it normally bases its judgment on fewer instances than is appropriate, and merely on available instances.

Bacon's critique is valid. He did not attempt naive induction, however, for Bacon, generalised conclusions could not be rushed. Rather, they should always be tempered by varied experiences of dimensions of reality. Sophisticated induction should necessarily include "appropriate rejections and exclusions; and then, after as many negatives as are required, conclude on the affirmatives" (2009:193).

David Hume (2009:224), a Scottish philosopher, argued critically against induction as a valid form of argumentation:

> [A]ll arguments from experience are founded on the similarity which we discover among natural objects, and by which we are induced to expect effects similar to those which we have found to follow from such objects. And though none but a fool or madman will ever pretend to dispute the authority of experience, or to reject that great guide of human life, it may surely be allowed a philosopher to have so much curiosity at least as to examine the principle of human nature which gives this mighty authority to experience, and makes us draw advantage from that similarity which nature has placed among different objects.

The "problem of induction" is an ancient and current problem, both for philosophy and for the practise of the scientific method. If induction really is problematic, the implication is that the basis for the scientific claim to have knowledge of the way material reality is, is flawed (Howson 2000:181). David Hume's (2009:224) "curiosity" led him to take issue with induction.

Let us consider induction in terms of the following example:

> Millions of swans have been observed and all of them were white, therefore by induction the statement "all swans are white" is true.

Points to ponder

Based upon a limited number of examples of a particular phenomenon, can it be argued that all instances conform to those observed? Explain.

To what extent can a universal conclusion be drawn from particular instances? (Remember, this is what induction is.)

In these questions we have Hume's problem with induction in a nutshell (Prevos 2005):

> Hume comes to the conclusion that there is no rational justification for inductive references and that Bacon was wrong in assuming that we can derive universal principles from observation of the particular.

Upon analysis, Hume's critique of induction is three-fold, and refers to, firstly, the problem of assuming that nature is uniform, secondly the problem of cause-and-effect reasoning, and thirdly the problem of past experience. We shall explore these in more detail.

4.3.1 The problem of the uniformity of nature

Hume (2009:220) states:

> That the sun will not rise to-morrow, is no less intelligible a proposition, and implies no more contradiction, than the affirmation, that it will rise.

While humans assume that consistency in natural events is the norm, certain knowledge regarding a future event cannot be held without actually having experienced that future event. It is thus impossible to know definitively whether or not the sun will rise tomorrow. When the statement "The sun will rise tomorrow" is made, an inductive inference based upon the assumption that nature is uniform is made. It is therefore questionable.

4.3.2 The problem of cause-and-effect reasoning

In this regard, Hume (2009:220) states:

> All reasonings concerning matter of fact seem to be founded on the relation of Cause and Effect. By means of that relation alone we can go beyond the evidence of our memory and senses … [for instance a] man finding a watch or any other machine in a desert island, would conclude that there had once been men in that island … here it is constantly supposed, that there is a connection between the present fact and that which is inferred from it.

A person arriving on a desert island and finding a watch or any other supposedly human remnant, makes (the reasonable) assumption that another human must have been on that particular island and left that particular item. The *effect* (the watch left on the island) is assumed to have been *caused* by the presence of another person.

However, in making the assumption that there was a cause for the perceived effect, we transcend the observable knowledge available to us. No observation has in fact been made of someone having been on the island and having left the watch there. Indeed, the watch could have been washed up on the beach after falling off the wrist of someone at sea. We simply do not know.

Point to ponder

To what degree is there a necessary connection between the cause and the effect that remains unobserved or that could be ascribed to a myriad of different causes?

In developing the explanation, reason rather than experience is relied upon to infer the conclusion. A cause is thus imagined by the perceiver of a cause-and-effect "relationship" to be the cause of the particular effect (in this case the presence of the watch). Thus, Hume (2009:221) states categorically in this regard: "The mind can never possibly find the effect in the supposed cause."

It is useful to consider another example specifically employed by Hume (2009:221) in his critique, namely concerning a game of billiards:[9]

> When I see, for instance, a billiard-ball moving in a straight line towards another; even suppose motion in the second ball should by accident be suggested to me, as the result of their contact or impulse; may I not conceive that a hundred different events might as well follow from the cause?

From the Humean viewpoint, reality is composed of causes and effects that should be conceived of as unrelated events because it is impossible to discern the effect from the myriad of potential effects possible by a particular cause (which remain unobserved) (Hume 2009:221). The relationship between cause and effect, Hume (2009:221) clarifies, must be inferred employing not reason alone, but with "the assistance of observation and experience".

4.3.3 The problem of reliance upon past experience

Hume's (2009:223) last consideration refers to the reliance upon past experience in drawing inductive inferences:

> [W]hy this experience should be extended to future times, and to other objects, which, for aught we know, may be only in appearance similar, this is the main question on which I would insist.

Here lies the issue of extrapolating knowledge based on the experience of particular events in the past and applying them to possible future events. Hence, knowledge founded upon past experience that is applied to similar events in the future will be – at most – probable. No projection can be absolute fact.

Hume (2009:224) attacks the assumptions employed in the development of a theory employing the inductive mode of reasoning:

> We have said [when employing inductivism] that all arguments concerning existence are founded on the relation of cause and effect; that our knowledge of that relation is derived entirely from experience; and that all our experimental conclusions proceed upon the supposition that the future will be conformable to the past.

4.3.4 Are all swans white?

Let us have another look at the infamous example of the swans: for the Europeans of the early 17th century, all observed swans had been white. The conclusion drawn was that "all swans are white", since the effect that only white swans were observed, was reasoned to be the result of the observation of the cause that there were only white swans!

9 "Billiards" refers to a game similar to snooker and pool.

However, in 1697, Willem de Vlamingh ventured to Australia and became the first European to lay eyes upon a black swan. What had previously been considered a European "universal", that is that "all swans are white", was proved false (and this could have been by the observation of one counterexample of a black swan), for some swans are in fact black!

From such examples, Hume drew the conclusion that inductive reasoning cannot lead to universal conclusions, despite some of the premises being true. While it is true that the premise regarding the observed swans being white was true, the observation was incomplete, as there were unobserved instances of black swans. Rather than declaring that all swans are white, it would have been more accurate – although not true – for people before De Vlamingh to declare that there is a probability that all swans are white! Only when all instances of the phenomenon have been observed, can a true universal be declared.

Point to ponder

Given the vastness of the cosmos, are true universals possible? Explain.

4.4 ATTEMPTING TO COUNTER HUME

4.4.1 Countering the problem of past experience

Intuitively, Hume may perhaps be countered by appealing to past experience. For example, if a particular phenomenon has always been observed, and the same phenomenon has also always been observed by many other people, it appears reasonable that that phenomenon has a strong chance of always remaining as it is. This is, of course, one of the assumptions behind induction.

Consider the following chemical reaction: the test for the presence of carbon dioxide involves the use of limewater. When in the presence of carbon dioxide, a drop of limewater will change from transparent to milky white. Once this experiment has occurred, and has been repeatedly verified, the hypothesis that limewater (a calcium hydroxide saturated solution) changes colour in the presence of carbon dioxide becomes an accepted scientific theory. Regardless of how many times the experiment is performed, the outcome is the same. This repetition of outcomes is one of the hallmarks of science.

Yet, Hume's counter-argument regarding the applicability of past experience to future instances remains valid (Hume 2009:223). All that can be ascertained from observation, is how a particular entity is observed in a particular space and at a certain moment through the use of the senses, which provide a limited perspective on the event or object. The maximal information that is available to us, is that based on past experience we can declare what knowledge we had of an object, and we can infer about the probability of how it may be in the future. Neither, however, guarantees how things will be in the future.

Point to ponder

In the light of Hume's critique, could the moment arise when limewater does not turn milky white in the presence of carbon dioxide?

4.4.2 Countering the problem of the uniformity of nature

Consider the following example:

Premise 1: Every day in the past, the sun has risen.

Premise 2: Nature is uniform. (The future will be like the past.)

Conclusion: Therefore, tomorrow the sun will rise.

The principle of the uniformity of nature is justifiable: from experience we know that the sun rises each morning, or that the moon is present at night, etc. These are events we observe and experience daily. But, Hume counters: how are we justified in assuming that the past will repeat itself in the future? "We cannot know it directly by experience, since we cannot observe the future" (Speaks 2006).

Howson (2000:181) formulates it thus:

> However extensive the observational evidence, there is, according to Hume, no legitimate inference to the truth or even the probability of any hypothesis whose logical content transcends that evidence; what today we call ampliative, or inductive, inference is for Hume no species of reasoning at all, merely a psychological propensity.

Hence the scientific enterprise is in an awkward position: while science has been successful following the inductive method, the method itself is not free from problems.

Point to ponder

Are there any possible ways to "save" induction for science? Explain your reasoning.

4.5 REICHENBACH'S VINDICATION OF INDUCTION

Hans Reichenbach (1891–1953) became the founder of the second wave of positivism, the *Berlin Circle*, in Berlin, Germany. Based on the needs of the positivist approach to science, Reichenbach attempted to justify induction in the light of the critique by Hume (2009:368).

Rather than conceiving of induction as a route to absolute, certain knowledge, Reichenbach defined induction in a more speculative manner. According to him, "[t]he inductive inference is a procedure which is to furnish us the best assumption concerning the future" (Reichenbach 2009:368).

Reichenbach thus proposes that, in the absence of certain knowledge of the future, when there is a need for such knowledge, reliance upon an assumption about the future may be helpful. Such an assumption must, however, always be related directly to knowledge already held, in other words it must not be an assumption sourced from the imagination or from a whim. Reichenbach (2009:368) is of the opinion that, if it could be proved that induction gives rise to informed assumptions regarding the future, then inductive inferences would be justified.

Point to ponder

Explain whether or not scientific theories should be founded upon assumption.

Consider the following example (Reichenbach 2009:368):

> A man may be suffering from a grave disease; the physician tells us: "I do not know whether an operation will save the man, but if there is any remedy, it is an operation." In such a case, the operation would be justified. Of course, it would be better to know that the operation will save the man; but, if we do not know this, the knowledge formulated in the statement of the physician is a sufficient justification.

Certainly Reichenbach's appeal to a medical condition could be an emotion-based fallacy. Nevertheless, if the inductive inference (i.e. that an operation would be useful) could be justified, then for Reichenbach, induction would be legitimated.

Problematic still, however, is that we simply do not know the future, and therefore we do not know if an operation is necessarily the best course of treatment for the sick man. Of the medical practitioner, Reichenbach (2009:268) warns:

> [H]is knowledge about an operation as the only possible means of saving a life is based on inductive generalizations, just as all other statements of empirical character.

Reichenbach cautions, however, that a proof for induction cannot itself rely upon induction. In order to prove that induction is justified, Reichenbach sought to define the aim of induction, which in terms of common-sense explanation could be conceived of as predicting future events based upon past realities. However, Reichenbach sought to clarify this more precisely: "The aim of induction is to find series of events whose frequency of occurrence converges toward a limit" (2009:368).

If induction attempts to ascertain the likelihood of particular occurrences in the future (i.e. the probability of their happening), it is directly related to the frequency of similar phenomena having happened in the past. Reichenbach (2009:368) therefore defines probability as "the limit of frequency" of any particular event occurring. With knowledge of the limits of the frequency of a phenomenon, Reichenbach (2009:369) argues, the universal laws of nature themselves are unearthed. If a law of nature is thus known, it would be possible to project a series of events, founded in past frequency, upon the future.

A Humean problem is, though, that material reality may itself be disordered, such that a discernible limit in a series of phenomena cannot be found. Therefore, "the world" may not be predictable (Reichenbach 2009:369).

Point to ponder

Are the future assumptions of Reichenbach's inductive method assured? Explain, citing examples where possible to substantiate your answer.

To save his theory, Reichenbach (2009:371) once more turns to the frequency of limits of phenomena in order to inform the inductive extrapolation into the future. However, an "informed" (experience-based) inference is not what Hume sought (Reichenbach 2009:371):

> Hume demanded too much when he wanted for a justification of the inductive inference a proof that its conclusion is true ... We do not perform, however, an inductive inference with the pretension of obtaining a true statement.

> What we obtain is a wager; and it is the best wager we can lay because it corresponds to a procedure the applicability of which is the necessary condition of the possibility of predictions.

Induction is thus not concerned with postulating generalised conclusions that are true, but rather conclusions that are best approximations of the likelihood of phenomena occurring.

Point to ponder

Is a "wager" (or a bet) sufficient a foundation in which to locate the scientific method? Explain.

4.6 MID-20TH CENTURY CRITIQUE OF INDUCTION

The influence of the logical positivists on the common understanding of science was immense. Science was held to simply record the observed, without interpretation or consideration of the influence of subjective factors (such as culture or worldview). Whatever science produced, was deemed to be true, since the scientific method captured the way that things are. This stance towards science has come to be known as that of "naive inductivism".

In the second half of the 20th century, the inductivist approach to research was subjected to criticism, including its very first stage, that of the selection of facts.

Points to ponder

How do we know which facts to select?

Should we include information on the date, temperature, venue, atmospheric pressure, people present, dimensions of rooms, fabric of the furniture, the weather, the type of plants in the garden, the cars passing by in the street, and the like? Explain.

Should we describe everything within a radius of 500 metres, a kilometre or 10 kilometres? Motivate your answer.

What does the idea "everything" include?

A certain degree of selection is necessary, but on what basis is this selection to take place? Suppose we want to know why some chemical compounds are soluble in water. Which observations are relevant to our problem? We cannot answer this question unless we already have a hypothesis on factors that affect solubility. We may believe, for example, that the temperature of the water is significant, in which case we shall see to it that water temperature is measured and that solubility is tested at different temperatures. Or we may believe that the colour of the compound is important, which means that we should pay attention to variations in colour. Or perhaps we attach significance to the crystalline form or the origin of the compound.

The second stage of induction is the generalisation obtained by means of analysis, and classification of the information collected during the first stage.

Point to ponder

Analyse how we know when and where to classify and generalise.

We can classify the collected data in various ways. Do we regard colour as important? Or taste? Gravity? Toxicity? Thus, any analysis or classification is based on certain tentative hypotheses.

In the third stage of induction, scientific hypotheses do not consist of mere generalisations. We do not know which factors are to be generalised. Actually, a hypothesis often represents a new insight rather than merely a factor already present in our descriptions. For example, we might describe the movements of celestial bodies – the sun, moon, stars and planets – and attempt to find a common denominator. But seeing and describing the sun, moon and stars rising in the east and setting in the west and noting how their positions differ from month to month is very different from coming to the daring conclusion that the celestial bodies are relatively stationary while the earth is rotating. Indeed, the acquisition of scientific knowledge is not simply a matter of deriving generalisations from facts. The real pattern is different and more complicated.

4.7 FALSIFICATIONISM

Particularly problematic for induction is observation as a basis for generalised conclusion in any statement. For example, there is always the question of how many cases should be observed; for induction on the basis of an analogy, we need to know which analogies are relevant and which are not, and so forth.

Certain plants – living organisms – grow towards the sun. Should we therefore conclude that they have organs with which to perceive the sun, just as other living organisms – human beings and animals – have eyes with which they can see its light? This analogy is invalid.

In 1934, Karl Popper published a work entitled *The logic of scientific discovery*, which has been influential in philosophy of science. Herein, Popper critiques and rejects inductivism and attempts to replace it with what he calls deductivism.[10]

Popper's (1963:47) critique of inductivism finds its origin in a problem concerning observations of particular phenomena:

> [I]t is quite true that any particular hypothesis we choose will have been preceded by observations – the observations, for example, which it is designed to explain. But these observations, in their turn, presupposed the adoption of a frame of theories.

Popper contends that regardless of how many repeated observations of an observable phenomena are made, no two repetitions are identical. Rather, Popper argues that observations perceived as identical are in fact only similar (Jones 1982:335). Popper (2009:477) states:

> [S]imilarity-for-us is the product of a response involving interpretations (which may be inadequate) and anticipations or expectations (which may never be fulfilled) ... For even the first repetition-for-us must be based upon similarity-

10 Hume, I felt was perfectly right in pointing out that induction cannot be logically justified ... [A]n attempt to justify the practice of induction by an appeal to experience must lead to an infinite regress. As a result we can say that theories can never be inferred from observation statements, or rationally justified by them" (Popper 2009:476–477).

> for-us, and therefore upon expectations – precisely the kind of things we wished to explain.

While observations may have similarities, they also have dissimilarities. These are noticeable when we consider different people and how "some similarities will strike us if we are interested in one problem, and others if we are interested in another" (Jones 1982:335).

Hence it can be seen that Popper understands observation as connected to pre-existing knowledge and theories, which aid the theorist in inducing further knowledge. The induction of further knowledge, you will recall, is core to the method of inductivism, in which the content of the conclusion is not contained in the content of the premises. Popper attaches greater importance to the role of prior knowledge in "filtering" the observed, rather than to induction itself, which is a later process, for from observation a scientific theory is induced: "[T]he belief that we can start with pure observations alone, without anything in the nature of a theory, is absurd" (Popper 2009:478).

Elsewhere he states (Popper 1963:44–45):

> [T]here must always be a point of view – such as a system of expectations, assumptions, or interests – before there can be any repetition; which point of view, consequently, cannot be merely the result of repetition.

Popper's view on observation and the resulting induction is that, to observe and to repeat observations, a theory system has to be in place to categorise observations as similar (Jones 1982:336). This contention is also supported by Barrow (2007:192):

> No science can be founded upon observation alone. We would know neither what we were observing nor how our observations are biased by a propensity to gather some types of evidence more readily than others. As any good cross-examiner knows, certain types of evidence are more readily abandoned than others.

Consider Popper's (2009: 478) own practical example of the matter:

> "I tried to bring home the same point to a group of physics students in Vienna by beginning a lecture with the following instructions: "Take pencil and paper, carefully observe, and write down what you have observed." They asked, of course, what I wanted them to observe. Clearly the instruction, "Observe!" is absurd ... Observation is always selective. It needs a chosen object, a definite task, an interest, a point of view, a problem. And its description presupposes a descriptive language, with property words; it presupposes similarity and classification, which in its turn presupposes interests, points of view, and problems. "A hungry animal," writes Katz, "divides the environment into edible and inedible things. An animal in flight sees roads to escape and hiding places ... Generally speaking, objects change ... according to the needs of the animal." We may add that objects can be classified, and can become similar or dissimilar, only in this way – by being related to needs and interests. This rule applies not only to animals but also to scientists. For the animal a point of view is provided by its needs, the task of the moment, and its expectations; for the scientist by his theoretical interests, the special problem under investigation, his conjectures and anticipations, and the theories which he accepts as a kind of background: his frame of reference, his "horizon of expectations".

The above discussion reminds us that theory cannot be value-free.

Point to ponder

What is the role of "theory-laden" observations in the establishment of scientific theories? Explain fully.

From the Popperian (2009:484) perspective, the scientific enterprise has its origin in problems that arise rather than solely in observations of phenomena. Theories must always allow the perceiver to account of observations, for observation still has a role in the development of scientific theory, albeit a secondary one (Popper 2009:478):

> [A]ny particular hypothesis we choose will have been preceded by observations – the observations, for example, which it is designed to explain. But these observations, in their turn, presupposed the adoption of a frame of reference: a frame of expectations: a frame of theories.

Point to ponder

Why should we rely upon induction if it is so heavily theory-laden? Motivate your answer.

Science is not left without method in the critique of induction, however. For Popper, the process of science is conceived of not as "a process of observation and inductive reasoning, but as a process of conjectures and refutations" (Prevos 2005). In the light of his theory of falsification (which you will shortly be introduced to), this fits perfectly. Popper understood that scientific theories should be exposed to the kind of rigorous testing that is intended to falsify any theory not worthy of acceptance.

This critical rationalism – Popper's philosophy of science – is the cornerstone to his solution to the problem of induction. Popper's solution is simple: rather than attempting to find a solution to the problem, he removes the problem altogether, because in his view science progresses through the process of falsification rather than through induction.

In Popper's theorising, science proceeds only by falsifying theories by means of the identification of instances countering the theory itself. If we consider the earlier example of de Vlamingh's swans, "The acceptance of one counterinstance (the discovery of a black swan) immediately falsifies the law (all swans are white)" (Prevos 2005).

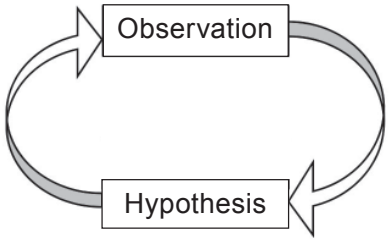
According to Popper, the problem of induction is not a problem at all, as induction is not relevant to the scientific method (Howson 2000:182). Popper considers inductive inference a complete misconstrual of the facts. He argues that scientists sometimes jump to conclusions, often after a single observation. Therefore, repeated observations and experiments serve as *tests* of scientific hypotheses and not as justification of theories or hypotheses. For Popper, induction has no role to play in science; instead *deduction* is of major importance. So Popper's solution to the problem of induction is to sidestep it entirely and to offer an alternative criterion whereby science can be sufficiently characterised, namely, deduction.

The error of the inductivist is to consider that observations and experiments give rise to theory when they are partially derived from theory and are designed to test it. For Popper, scientific theories are not the outcome of observations, but are conjectures

that can be eliminated if they clash with observations that are not accidental but the result of an intention to test a theory by obtaining a decisive refutation. Popper's argument is that observation cannot be prior to theory as such, because some theory is presupposed by any observation: all observations are theory-laden, and none can be regarded as determined in advance of theoretical considerations (Popper 1972:107):

> [O]bservations, and even more so observation statements … are always interpretations of the facts observed … they are interpretations in the light of theories.

Popper claims that hypotheses determine observation, although particular hypotheses arise in attempts to explain certain observed phenomena. Observation is therefore informed by theory, as theory is developed partly by means of observations. Observations in turn presuppose frames of reference (or of expectations).



For instance, for scientists a point of view is determined by theoretical interests, the special problem under investigation, conjecture and anticipation, as well as by the theories accepted as background: the scientist's expectations. If the frame of expectations is significant, it would give rise to the invention of new hypotheses, since the existing theoretical framework would be inadequate.

Point to ponder

Could it be argued that Popper's view leads to an "infinite regress" of theory and observation?

Popper is faced with the problem that, if we constantly push back to more and more primitive theories, we shall be engaged in an infinite regress. He tries to avoid this by his theory of "evolutionism": "Going back to more and more primitive theories and myths we shall in the end find unconscious inborn expectations" (Popper 1969:47).

For Popper, every organism has inborn reactions or responses, and amongst these are responses adapted to impending events. These are unconscious "expectations". For instance, a new-born baby "expects" to be fed, loved, protected, etc., but this does not mean that this inborn expectation is valid *a priori* (without experience), since the new-born baby could be abandoned and could starve. Popper believes, however, that the expectation is psychologically – or genetically – *a priori*, that is, prior to all observational experience. He argues that one of these "expectations" is that of finding regularities. So, according to Popper, people have an inborn tendency to find regularities. Thus Popper's theory of knowledge shares a boundary with a theory of evolution.

Popper claims that science begins not with observations but with problems. Problems crop up especially when we are disappointed in our expectations or when our

theories involve us in difficulties that may arise within a theory, between two different theories, or as a result of a clash between our theories and our observations.

It is only when we experience a problem that we become conscious of actually having a theory. It is the problem that challenges us to learn, to experiment and to observe. It is the conscious task of the scientist to find the solution to a problem through the construction of a theory, for example, by explaining unexpected and unexplained observations.

However, every worthwhile new theory raises new problems regarding how to conduct new observational tests that had not previously been thought of. Hence, Popper's view of science is of a constant preoccupation with problems – problems of increasing depth and ever-increasing fertility in suggesting new problems. Problem-solving is the fundamental activity and the essential problem of survival. Popper's theory of knowledge is therefore intertwined with a theory of evolution.

Popper distinguishes between the psychology of the sciences and their logical structure. He argues that the first stage of our scheme – collection of facts and formulation of a hypothesis – belongs to the psychology, not the logic, of science. There can be no logic of scientific discovery. Discovery is a process. Questions regarding what it is like, and what circumstances favour scientific creativity (e.g. whether certain personal characteristics are advantageous, or whether practice, support or criticism play a positive role) are matters for a psychologist. Discovery cannot be justified logically. We do not know in advance what scientists will discover, nor can we predict it by reason and logic alone. Even after a scientist has formulated a new hypothesis, we cannot explain logically how he or she arrived at the hypothesis via the facts: "[T]here is no such thing as a logical method of having new ideas, or a logical reconstruction of this process … every discovery contains 'an irrational element', or 'a creative intuition' " (Popper 1972:32).

Instead, Popper argues that the deductive verification of theories and hypotheses should be the focus of attention, for these permit logical structure.

Popper's views may be summarised by distinguishing between the *context of discovery* and the *context of justification*. It is the scientists' business how a specific step is arrived at and "discovered" – the possibilities considered and the time taken. However, once it has been seen that, for argument's sake, step four may be derived from the preceding steps, this needs to be justified by examining the logical structure of the derivation and writing it down: the number of the premises and the name of the rule applied in the step need to be provided. Such justification is logical and has no reference to any personal thought processes. Popper held that scientists likewise do not justify a new hypothesis by revealing step by step the thought processes whereby they discovered it, but by subjecting it to logical tests. Popper therefore stresses the deductive derivation of conclusions and their verification.

According to Popper, deduction is more reliable than induction, such that scientific testing can occur in the following manner: an hypothesis *deduces* an implication. The implication is proven false. Hence, the hypothesis is false. An argument of this variety is that of the *modus tollens* (the denial of the consequent), which has the following structure in formal logic:

If P then Q
<u>Not Q</u>
∴ Not P

But, can the truth of an hypothesis ever be proven? Popper (2009:483) argues that a conclusion may *never be induced* empirically from experience of phenomena. For, if it were to be attempted, the pattern of argumentation would have the following logical structure:

If P then Q
Q
∴ P

This, however, is an invalid form of the *modus ponens* argument; it is the fallacy of affirming the consequent. Thus, according to Popper's approach, *we can prove beyond doubt that an hypothesis is false*, but we can never definitely prove it to be true: the verification of any theory is impossible. The most that is possible, is to test hypotheses thoroughly and, if they withstand stringent tests, the hypotheses are corroborated and accepted as provisionally true. However, a new test that will prove an hypothesis false may be discovered and performed at any moment. Popper (1972:18) clarifies the meaning of "corroboration" as follows:

> By degree of corroboration of a theory I mean a concise report evaluating the state (at a certain time t) of the critical discussion of a theory, with respect to: the way it solves its problems; its degree of testability; the severity of the tests it has undergone; and the way it has stood up to these tests. Corroboration (or degree of corroboration) is thus an evaluating report of past performance … But it says nothing whatever about future performance, or about the "reliability" of a theory … Like preference, it is essentially comparative: In general, one can say that the theory A has a higher (or lower) degree of corroboration than a competing theory B, in the light of the critical discussion, which includes testing, up to some time t.

Because Popper rejects induction, he cannot employ probability in relation to theory selection, as probability implies induction due to assessment being based on observation claims. Thus, he must explain why he chooses one theory over another using other means.

Popper's analysis of the nature of scientific knowledge is based on an attempt to reconcile the empirical or informative content of a theory or statement with its truth value. The higher the empirical (measurable) content of a theory or statement, the lower the logical probability. This is because the more information a statement contains, the greater the number of ways in which it may be proven false (hence, the lower the probability of the theory).

Highly falsifiable theories are highly testable, because they make predictions that can be examined and compared with observable facts. The true statement with the highest possible empirical (or informative) content is an accurate description of reality, and every possible observation would constitute a test – and potential falsification. Thus the probability of its truth is close to zero.

In any problem regarding a phenomenon, more than a single theory may be advanced to describe or explain it (bearing in mind Popper's inability to use inductive probability selection). That each theory is different, suggests that it may be possible to deduce testable statements that are not deducible from other theories. For Popper, the theory with the higher empirical (or informative) content should be preferred, because it will be more testable (i.e. there will be more ways in which to test it). At any given time, it is the most corroborated theory with the highest empirical (or

informative) content that gives the best results, therefore this theory should prevail. For Popper, the rationality of science lies in the reasoned choice of a new theory rather than in the deductive development of theories.

Point to ponder

What differences are there between corroboration and confirmation (verification) of scientific theories?

A difference between corroboration and confirmation is that a hypothesis is corroborated when it survives a test considered crucial to the theory before it was formulated. A further difference is that, whereas confirmation is an inductive inference, corroboration is not an inference because it allows scientists to explore differing, highly corroborated hypotheses. Corroboration is a reflection of a scientist's decision to promote critical discussion of highly corroborated theories.

Perhaps the most crucial difference, however, between corroboration and confirmation, is that for Popper it is the quality rather than quantity of supporting evidence that counts most. A theory is given a high degree of corroboration not by surviving a large number of tests, but only by surviving the most severe tests devised to refute a theory. The severity of the tests depends on the degree of testability of the hypothesis or theory and upon the simplicity of the hypothesis or theory. The theory that is falsifiable to a higher degree (or the simpler theory) is also the one that is corroborative to a higher degree. Thus the degree of falsifiability of a theory enters into the appraisal of its corroboration.

Popper mentions some factors that may be used to justify the preference of one theory over another. He believed that theories that best hold their own in competition with other theories are selected. The chosen theory has stood up to the tests and is testable in the most rigorous way. The testing procedure may be severe in various ways. For a theory to be accepted, it must survive tests under which its predecessors broke down – sometimes even more severe tests. Popper speaks of the degree of testability of a theory. A theory that is more precise and more easily refutable than another, would be more testable. Popper speaks of hardly testable, well-testable and non-testable theories. The latter, of course, are not viewed as scientific theories by Popper (and are defined as non-science or pseudo-science).

Popper has demonstrated that scientists who wish to construct theories with a high degree of probability must choose theories that go as little beyond evidence as possible. Popper claims that scientists dislike ad hoc theories (theories which are able to explain specific phenomena but cannot explain a wide range of phenomena). Science prefers bold theories that can be more severely tested. So, according to Popper, since the degree of testability of a theory increases with its empirical content, science aims at higher testability content and lower probability. Hence Popper's concept of corroboration is a measure of the acceptability of theories among scientists. Those theories with higher falsifiability are more likely to be quickly falsified and disposed of. However, theories that go beyond what we already know, give us greater opportunities for extending our knowledge in as yet unknown areas. In Popper's problem-solving method, if a theory is testable it is scientific, and it is testable if some imaginable observation could prove it false.

Popper is critical of the practice of modifying theories by attaching ad hoc hypotheses to them because this protects them from falsification; he suggests that unexpected

findings need not necessarily lead to the falsification of a theory. A theory may be assisted by means of an auxiliary (ad hoc) hypothesis to account for such data.

An example is the observed motion of the planet Uranus, which was inconsistent with the Newtonian theory of the solar system, but Newton's theory was saved by postulating a planet lying beyond Uranus in a particular orbit. Its gravitational attraction was held to be responsible for the observed irregularity of Uranus' orbit. The later discovery of Neptune by Adams and Leverrier confirmed Newton's theory.

Points to ponder

Do auxiliary hypotheses merely serve as a means to "save" a theory from falsification? Explain.

Is falsification falsified by the introduction of auxiliary hypotheses? Explain the extent to which you agree or disagree.

By accepting auxiliary hypotheses, Popper weakened his concept of falsifiability as a criterion for the empirical character of scientific theories. He therefore laid down the methodological rule that only those auxiliary hypotheses that do not diminish the degree of falsifiability or testability of the theory in question are scientifically acceptable. Thus, the theory together with the augmented hypothesis increase empirical content and as such renders greater testability, or opportunities for falsification.

In Popper's theory, the problematic concept of induction is rejected and a purely logical deductive testing pattern is instead argued for.

Points to ponder

Deduction presupposes that conclusions are contained in arguments' premises. Can it therefore be implied that science makes no new discoveries? Explain your response.

Can induction be completely abandoned in science, as Popper desires? Motivate your answer.

4.8 THE DEMARCATION PROBLEM

The problem of induction is intimately related to the problem of demarcation that Popper (2009:476) proposes. The former problem concerning what can be considered scientific, thus forms part of the latter problem of induction. Indeed, Popper (2009:483) argued that solving the demarcation problem would provide a solution to that of induction. He states further (2009:471–472):

> "When should a theory be ranked as scientific?" or "Is there a criterion for the scientific character or status of a theory?" ... I wished to distinguish between science and pseudo-science; knowing very well that science often errs, and that pseudo-science may happen to stumble on the truth.

Point to ponder

In terms of Popper's dismissal of induction as irrelevant to science, what criterion can be given to categorise the "scientific"?

For Popper (2009:472), the "traditional" feature used to demarcate science from that which is not science, in other words inductive, empirical methodology (as espoused by the positivists), was not adequate. His demarcation search led him to question why Marxism, psychoanalysis and individual psychology as "scientific" theories differ so much from other scientific theories like Einstein's relativity theory (Popper 2009:472):

> I felt that these other three theories, though posing as sciences, had in fact more in common with primitive myths than with science; that they resembled astrology rather than astronomy.

The principle reason for Popper's rather harsh assertion was the verifications that abounded in support of these theories, rather than the falsifications (Popper 2009:472):

> [T]he world was full of *verifications* of the theory. Whatever happened always confirmed it. Thus its truth appeared manifest; and believers were clearly people who did not want to see the manifest truth; who refused to see it, either because it was against their class interest [as in the case of Marxism], or because of their repressions which were still "un-analysed" and crying aloud for treatment [in the case of Psychoanalysis].

For Marxists and Freudians, it is the constant confirmatory nature of reality always "fitting" their theories that provided them with verification and confirmation of the veracity of these theories. Of course, these "discoveries" were always rooted in prior experience of similar phenomena (2009:473). This strength, however, Popper deemed as weakness upon consideration of his newly developed criteria for what could be delimited as "science" (Popper 2009:473–474):

(1) If confirmations of theories are sought, then these will be found (remember, observations are theory-laden).
(2) "Risky predictions" should be the criteria for the confirmation of theories, where the results of testing are counterintuitive or not in line with the expected outcome.
(3) Stronger theories prohibit more than they allow, thus giving them less porous boundaries.
(4) Scientific theories must be refutable, not impenetrably unfalsifiable.
(5) All scientific theories are testable; this determines their scientific nature.
(6) Evidence that corroborates a theory must be the product of an "unsuccessful attempt to falsify the theory".
(7) "Saving" a theory through the addition of ad hoc auxiliary hypotheses lowers the theory's scientific nature.

A scientific theory would thus fulfil these criteria, whereas a pseudo[11]-scientific theory would masquerade around as science, while not being testable! Popper (2009:474) compares Einstein's gravitational theory with astrology to illustrate the difference between science and pseudo-science, where the former is falsifiable (the major criterion for a scientific theory) and the latter not:

Einstein's theory of gravitation clearly satisfied the criterion of falsifiability. Even if our measuring instruments at the time did not allow us to pronounce on the results of the tests with complete assurance, there was clearly a possibility of refuting the theory.

11 "Fake", "pretend", "artificial", etc.

Astrology did not pass the test. Astrologers were greatly impressed, and misled, by what they believed to be confirming evidence – so much so that they were quite unimpressed by any unfavourable evidence. Moreover, by making their interpretations and prophecies sufficiently vague they were able to explain away anything that might have been a refutation of the theory had the theory and the prophecies been more precise. In order to escape falsification they destroyed the testability of their theory.

The same could be said for both Marxism and psychoanalysis: there was no action that would *not* fit the theories; hence they were not falsifiable at all despite their pretending to be so (2009:474). These are all examples of "pseudo-science".

On the other hand, a theory that does not attempt the deception to prove that it is scientific (that is, a theory that is not falsifiable at all, and that does not claim to be), is not "pseudo-scientific". Instead, like metaphysics, ethics, aesthetics, and the like, it is "non-scientific". Such theories do not have a scientific character. But, Popper (2009:475) insists:

[A non-scientific theory] is not thereby found to be unimportant, or insignificant, or "meaningless", or "nonsensical". But it cannot claim to be backed by empirical evidence in the scientific sense – although it may easily be ... the "result of observation".

Whilst the positivists thus declared considerations regarding metaphysics, ethics, etc., "meaningless", Popper retains room for them in the human experience and understanding of the world.

In providing clear criteria to distinguish between the scientific, that which pretends to be scientific, and the non-scientific, Popper provides a method through which hypotheses can be tested for belonging to the realm of science, wherein theory-construction and phenomena meet one another.

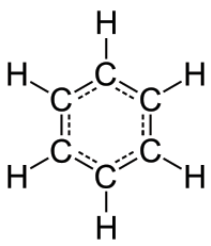
4.9 TESTING AND ACCEPTING HYPOTHESES

It is not how a hypothesis originates but *what the scientist does with it* that is important. Hypotheses may arise from a non-rational, creative, or dream-like mental state. It never emerges from nowhere, but from a theory-laden perspective.

> **Point to ponder**
>
> Once the scientist has formulated an hypothesis, what should he or she do next?

First, deductive implications should be derived from every hypothesis, on the basis of which the hypothesis can then be tested.

Consider the organic chemical compound, benzene (C_6H_6), a molecule that can be imaged as follows:



The benzene molecule has a cyclical structure with no atoms at the end of a chain. We would therefore expect all six of the carbon atoms (C) in benzene to be equivalent and to display the same chemical behaviour. If we replace the hydrogen atoms (H) in the benzene molecule, there would be fewer different compounds than if there had been an open chain in which the carbon atoms were not chemically equivalent. Therefore if benzene has a ring structure, potential substitution products will be equivalent. This is a *deductive implication*.

We shall now examine the relation between an hypothesis, deductively derived test implications, and empirical testing.

Point to ponder

In what sense can we regard test implications as actual implications?

Test implications are derived from or implied by hypotheses and they have certain implications because they are formulated as conditional ("if … then" type) propositions, containing both an antecedent ("if ..."), and a consequent ("then ...").

For example:

Hypothesis: The earth takes a year to revolve around the sun.

Test implication: If we make careful observations, we shall notice an annual difference in the relative positions of the stars (annual parallax). This can be illustrated as follows:

We can now introduce the antecedent of the test implication (the "if" in a conditional statement) and see whether the consequent (the "then" in a conditional statement) occurs as well. We should therefore have a certain degree of control over the test conditions.

Point to ponder

What about experimental control in sciences like astronomy, where human beings have no control over the objects concerned (the stars, planets, etc.): are these scientific?

Test implications in astronomy do not necessarily require the manipulation of the observed objects. They could simply involve directing instruments at certain parts of the sky at certain times and predicting what will be observed.

Consider the hypothesis: *There will be a lunar eclipse tonight.*

A test implication will be: *If we look at the moon at 10 pm tonight, we shall see it eclipsed.*

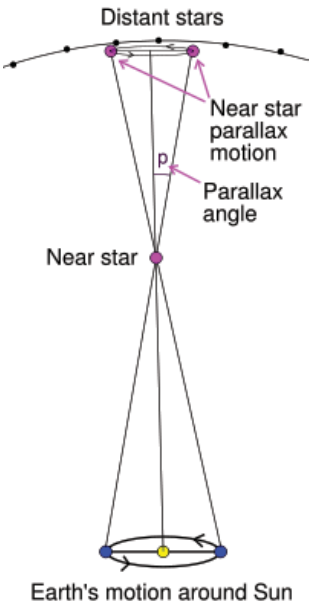
We have seen that the testing of a hypothesis takes the general form of the *modus tollens* (denial of the consequent):

If P then Q

Not Q

∴ Not P

However, scientists always make a number of additional assumptions or auxiliary hypotheses that are not stated explicitly.



Stellar parallax

(**Source:** http://upload.wikimedia.org/wikipedia/commons/e/e3/Stellarparallax2.svg)

For instance, in the example of the parallax of the stars, the parallax is visible only when the stars are close enough to the earth. If they are far away, the differences in their individual positions are too small to be observed.

Hence, we do not know whether the hypothesis is false or whether only the additional assumptions are false. In the case of the parallax, which could not initially be observed, only the assumption that the stars are close enough to the earth to show a clear parallax was false. Assumptions and auxiliary hypotheses may therefore require further testing. Scientists may even make an assumption of which they themselves are unaware, but which is false (an unknown assumption).

Point to ponder

Is it possible to devise an experiment to determine which one among a number of alternative hypotheses is correct?

No, because an experiment can at best serve to indicate the untenability of a hypothesis: we can only falsify but never verify an hypothesis. Even if we should find that one is not correct, it still does not mean that the other hypothesis can be accepted automatically, since both may be false and any number of others correct. Once more, the tentative nature of scientific hypotheses is apparent.

Crucial experiments, in other words experiments designed to enable a definite decision about the acceptability of an hypothesis, should be approached critically and with caution. Apart from the impossibility of establishing that a given hypothesis is correct (given that alternative findings may always arise), a theory or hypothesis that is apparently disproved by the facts may be salvaged by means of an ad hoc (auxiliary) hypothesis.

Consider an hypothesis that seeds planted at full moon germinate more rapidly than seeds planted at new moon. A test is conducted and the difference predicted by the hypothesis does not materialise. An ad hoc hypothesis is now presented that the test conditions were not identical: for example, the person who planted the seeds was biased and planted the seeds deeper at full moon, so that the seedlings took longer to emerge. Ad hoc hypotheses, as can be seen in this example, make theories or hypotheses unfalsifiable.

Point to ponder

Specify whether you think all ad hoc (auxiliary/additional) hypotheses should be accepted or rejected?

Ad hoc hypotheses cannot be rejected. For example, calculations regarding the radioactive disintegration of atoms indicated at a certain stage that energy was being lost somewhere. This result conflicted with one of the basic principles of physics, namely the law of energy conservation (which states that energy cannot be lost or created). Rather than regard this principle as falsified, two natural scientists (Pauli and Fermi) suggested that the missing energy was represented by a new particle with a velocity equal to that of light, zero mass and a zero charge. Since this particle has no mass and no electric charge, its existence was difficult to detect by experiment. This hypothesis operated in the same way as an ad hoc hypothesis, serving to protect the original theory. Only 30 years later, in the 1950s, experimental proof was found for the existence of neutrinos. In rare cases, therefore, ad hoc hypotheses may be useful. We therefore cannot risk discarding them. Nevertheless, *all hypotheses must undergo stringent testing,* as Popper (2009:484) so emphatically proposes:

> [F]alsified theories are known or believed to be false, while the non-falsified theories are known or believed to be true ... [W]e do not prefer every non-falsified theory – only one which, in the light of criticism, appears to be better than its competitors: which solves our problems, which is well tested, and of which we think, or rather conjecture or hope ... that it will stand up to further tests.

Point to ponder

Can all scientific hypotheses be tested empirically?

Empirical testability depends on how "science" is defined. For Popper, "science" (per his definition) requires empirical testability: "[I]t must be possible for an empirical scientific system to be refuted by experience" (1972:4).

As we have realised, he was opposed to the introduction of ad hoc hypotheses to protect a system against refutation. However, there are certain scientific principles (such as the law of energy conservation) that scientists wish to protect at all costs. In this process, such principles lose their status as hypothetical assumptions: they become definitions, considered true because of the meaning scientists have come to give to the terms involved. However, they could still be rejected at a later stage following testing.

The question of the testability of every individual hypothesis is also the problem of the verification theory of meaning.

Point to ponder

Do you see the parallel between the testability of hypotheses and the verification of meanings?

A problem associated with the verification theory is that it requires every proposition to be verifiable; it is not sufficient if propositions are indirectly verifiable.

For example, if propositions are implications of verifiable propositions, we talk of "verifiability in principle", because verification is possible if the circumstances are right. Here we have the weak form of verification, because we only verify an implication and not the original statement itself.

The same applies to scientific hypotheses: some have no direct empirical implications. An example is the original hypothesis regarding the existence of the neutrino: this could not be tested at that time in history. Yet hypotheses without direct test implications are accepted, as they form part of a comprehensive theoretical framework. Hence, although not all propositions in a scientific system are always directly – or indirectly – verifiable, they are nevertheless accepted as components of the system, provided most of the propositions in the system are verifiable.

It is imperative that scientists know that not all observations and tests regarding an hypothesis are equivalent. As Popper advised, we should always carry out the observations and tests that are *most likely* to falsify an hypothesis. Some of these would enable falsification of a theory, whilst others would not.

On the other hand, this is a typical philosophical problem, and the result of generalising without considering multifarious specific situations. The philosopher seeks an answer to all possible instances. Scientists who set up and test specific hypotheses have no difficulty in determining which observations are relevant to their hypotheses, and interestingly their task is, in effect, related only to a particular instance.

Point to ponder

What criteria could be employed to evaluate (and later accept) hypotheses?

Hempel (1966:33–46) lists a number of *non-formal criteria* for evaluation:

- the volume and nature of positive evidence
- the variety of positive evidence
- the precision of positive evidence
- the confirmation of the hypothesis by new evidence, that is, facts not taken into account in the formulation of the original hypothesis
- the compatibility of the hypothesis with the rest of the scientific system
- the principle of simplicity (This means that the simplest hypothesis will always have preference, or that, if there is only one hypothesis, the simpler it is the more satisfactory it will be.)

The same philosopher also considered similar criteria for the acceptance of theories. Theories are more complex hypotheses or systems of hypotheses. Hence the correspondence between the criteria for the testing of hypotheses and of theories is not surprising (Hempel 1966:70–82). Theories should

- be testable
- be explanatory
- agree with known scientific facts
- provide a systematically unified account of diverse phenomena
- be simple and precise
- lead to new predictions

Point to ponder

How does Newton's theory of gravity comply with Hempel's theory-determining criteria?

Newton's theory is quantitative and testable, applies to objects falling on earth and to the orbits of heavenly bodies, and permits predictions based on calculations in astronomy and physics. Additionally, Newton's basic laws, such as the law of the attraction between two masses, are simple.

4.10 CRITIQUE OF POPPERIAN FALSIFICATIONISM

Point to ponder

What objections have you developed against Popper's falsificationism (hypothetico-deductivism) from your reading?

Popper's view has provoked considerable criticism over the years. We now consider some of these (although you are encouraged to develop and add your own).

4.10.1 Only sets of propositions can be tested

Every test is based on a number of assumptions and explicit auxiliary hypotheses. We assume, for instance, that instruments employed are reliable. A single hypothesis is not tested. Rather, a set of hypotheses are tested, which always includes a series of additional assumptions. A negative result in a test may mean that part of a set of hypotheses is false, rather than all of it.

Consider this example: A car engine cuts out and the driver proposes the hypothesis, "There is no fuel left". He derives the test implication: "The fuel gauge must be showing zero", but this, upon observation, is false. Does this mean that there is no fuel? No, as this would imply an additional assumption, namely that the fuel gauge is working as it should! Indeed, the fuel gauge itself may be faulty.

In the example above we can discern that people impose conceptions and ideas upon the world that give a better explanation of states of affairs. Specifically, scientists decide whether their instruments and perceptions are scientifically accurate by determining whether the measurements and observations from the real world conform to the science-world picture of their theories. This approach is called "conventionalism". For conventionalists, acceptable observations are only those observations that conform to their theories (of course, this position is itself theory-laden).

Theories are logical constructions that define a scientific "world" with reference to the system of theories chosen. The world of science is not the "real" world but the

constructed world of concepts. The meanings of these concepts have to be determined by means of agreement, and represent the real world through the contained constructs (concepts) and ideas. The conventionalist believes that scientists decide whether instruments or perceptions are scientifically accurate by reconciling the measurements and observations of instruments with theories. The theories chosen need to explain a range of natural phenomena, and to do so as economically and coherently as possible. However, in conventionalism particular laws or theories can be retained in science, even when explanations involving them are found to be false. Thus, laws of nature are not falsifiable by observation. This is because laws of nature are required to determine what an observation is or what a scientific measurement is constituted by.

For conventionalists, then, a set of prior conditions must be correlated with the hypothesis. If this is performed correctly, and the predicted phenomenon does not materialise, such failure does not prove the falsity of any hypothesis. Rather, it is only the combination of hypotheses that has been shown to be faulty. To restore agreement with observation, the scientist can change any hypothesis. A particular hypothesis may thus be kept unchanged while others are changed. The unchanged hypothesis, therefore, is a convention, for which the question of truth or falsity does not arise. Conventions are subject to neither confirmation nor refutation. A scientist may use a law as a convention to specify the meaning of a scientific concept. If a law is true without experience, it is stated as such to avoid falsification. If it proves fruitful in subsequent scientific explanations or predictions, it will probably be retained. The more diverse the phenomena that can be included within a theory or law, the greater the likelihood that it will be used as a convention.

Point to ponder

How could the falsificationist respond to the conventionalist?

Falsificationists could say that, if we can devise crucial experiments to decide between theories, then such tests discriminate between the two theories. However, we cannot decide whether a given statement in a scientific explanation has been falsified unless the statement is independent of other statements. The argument is made that a previously well-corroborated theory has been falsified because it has been extended to cover more phenomena through the addition of a new hypothesis. Nevertheless, an attempt should still be made to test this hypothesis by uncovering some of the consequences that have not yet been tested. This is a form of induction. If these tests show the new hypothesis to be false, this does not prove the previously well-corroborated theory false. Hence a method is proposed to weed out false hypotheses and statements in order to preserve well-corroborated ones.

Point to ponder

How might the conventionalist respond to the falsificationist?

Popper's willingness to admit auxiliary hypotheses is a concession to conventionalism. The conventionalist may argue that the idea of greater or lesser testability of a theory is vague and prevents discrimination between auxiliary hypotheses that increase the "testability" of a theory and those that merely preserve the theory by being ad hoc hypotheses.

4.10.2 The observation statements underlying falsification may be false

Observations are not merely given data, but are based partly on prior experiences and expectations. If a potentially refutable theory predicts something, observations may unconsciously be interpreted in a way that refutes it. Because scientists are fallible[12] humans, they too perceive what their theories lead them to. In other words, we humans often see what we want to see.

For instance, the medical theories of the Greek Galen (who lived in the 2nd century) proposed that blood flows from the right side of the heart to the left through holes in the wall between the heart chambers. However, the 16th century anatomist Vesalius could not find these holes. Vesalius assumed that they must be imperceptibly small. For Vesalius, the holes definitely existed, because this was what the influential Galen's theory maintained. The function of the heart as a circulatory pump was only discovered by Harvey in the 17th century. As this example illustrates, the facts by which a theory should be tested are not always independent of the theory, which is itself conceived and developed in accordance with prior theoretical constructions. Thus, the instruments available to measure certain phenomena often influence/affect the outcomes of tests or experiments.

4.10.3 Science is not practised in a falsificationist manner

Another commonly raised objection is that scientists do not actually try to falsify theories and hypotheses. Instead, scientists seek to verify their theories! Popper, however, ruled out this possibility. Still, Popper's refutation may be nothing more than an ad hoc auxiliary hypothesis employed in an attempt to save his own theory from falsification!

4.10.4 Lack of Popperian criteria for theory choice

Points to ponder

How could a choice be made between two incompatible hypotheses when neither has been falsified and both agree with the available facts?

How does one evaluate an hypothesis when there is no case for straightforward rejection?

Think about the following example: A person has been told that he is HIV-positive. The medical professionals have informed him that he should proceed with anti-retroviral treatment (ARVs) as soon as possible. However, this person is deeply spiritual. A faith healer has told him that there are other means through which to be treated for the condition. The newly HIV-positive person does not have the background knowledge to make an informed decision. Moreover, there is no evidence apparent to this person that would enable him to falsify either the explanation of the medical professional nor that of the faith healer.

12 Fallible people are those who "are likely to make mistakes, because their knowledge is incomplete, or their judgment faulty" (*South African student's dictionary* 1996:340).

Point to ponder

What grounds could be given to the patient on which to reasonably select between the two theories proposed?

Perhaps the medical professional could produce evidence of his/her academic and professional training, the success of ARVs in the treatment of the symptoms of HIV, and so on. On the other hand, there might be many people who could report to the HIV-positive person on the efficacy of faith healing through what appears to be miracle treatments.

Because of presuppositions (including individual beliefs), those inclined to a more scientific approach would favour the medical professional's theory over that of the faith healer: reason would prevent belief in superstition. That said, in groupings where faith healers are honoured and regarded highly, the underlying assumptions may reject scientific methods and findings.

Regardless of a particular position, the ultimate reason for choosing between theories will always be based on inductive reasoning. A universal conclusion will be made based on multiple particular instances of success.

In science the situation is similar. We may state our assumption that no conclusion on inductive grounds can ever be definite and that no hypothesis can ever be corroborated. But, in practice, scientists are forced to prefer certain hypotheses as a result of induction, based on past experience. If scientists should refuse to do so, science would not proceed, as even basic assumptions (e.g. that medical doctors are trained to deal with ailments of the body) are induced knowledge.

Thus, even Popper's theory of science contains induction, for instance in the assumption that falsification brings science closer to truth than uncorroborated theories could (Lakatos 1978b:158). Given an unknowable future, induction cannot be avoided, for even the use of terms such as "day" and "night" implies presupposed regularities of each day (and night) that give the words their meaning founded in prior knowledge. Popper's point that an hypothesis can never be finally verified, carries weight, however.

4.11 A REALIST SOLUTION TO THE PROBLEM OF INDUCTION

Roy Bhaskar (2008:215), an influential critical realist, proposes that many "traditional" solutions to the problem of induction in fact do not succeed, as becomes evident when we carefully examine the points of critique brought against Popper's hypothetico-deductivism. As a realist solution, Bhaskar's approach is directly related to the issue of universals, and bears in mind that the inductive process induces from particular instances towards generalisations (2008:216).

Bhaskar's proposal is that, if induction is at times successful, it could only be successful if the inductive method reveals something about the way the world is, as demonstrated in scientific theories which expose this reality. Thus, for Bhaskar, among the tasks of philosophy of science is the unearthing of the requirements needed to make induction a possibility (2008:218). Hence, certain regularities within physical reality need to be discerned in order to make reliable inductive inferences possible. Induction is therefore, hypothetically, limited only to universals that are

laws of nature (2008:219). An example could be the law of gravity: Objects are always "pulled" towards the earth's core, and thus it could be reasonably induced that, if an object is released, it will "fall" towards the earth's surface. "It is the possibility of an adequate explanation ... that must justify any piece of inductive reasoning in science" (Bhaskar 2008:220).

It is for this reason that realist interpretations of scientific theories are fundamentally important: they provide rationale, independent of particular observation, as to why a certain phenomenon rather than any other should occur (although, as Bhaskar [2009:220] notes, within a contained system). Bhaskar's form of realism, transcendental (critical) realism, seeks to study laws as patterns, as they could exist outside human perception (2009:222).

Point to ponder

Is it possible for a theory to be generated without the input of human, subjective factors?

Nevertheless, Bhaskar proposes that if one *explores the being* (thus generating an ontology – a theory of being) of any particular entity, the problem of induction is removed. Consider the following example given by Bhaskar (2008:223):

> It is physically impossible for a cabinet minister to bear figs; that is, nothing which bore figs could properly be said to be a cabinet minister at all. Desk lamps cannot fly or walk about the room.

Whilst the example may appear ridiculous, a cabinet minister – as a human being – does not grow fruit on his/her body. If this happened, the humanity of the entity would have to be questioned! Similarly, a lamp does not have legs or wings, and hence cannot walk or fly. If that could happen, the being of the lamp would have changed into something that is not a lamp any longer.

That a human does not produce figs is a law of nature. That gravity is present, is too. Stating, though, that a human being cannot grow figs, is in fact delineating what it is possible for that being to be and to possess in the future (2008:224). Indeed, to make an inductive inference such as, "[a]s a human being, Nonhlanhla will never be able to fly as a bird using its wings", is to induce knowledge that "has a basis in the enduring nature of the thing" (2008:225). What such common-sensical and daily experiences reveal, are the "enduring mechanisms" that are present in the cosmos, existent apart from the whims, opinions, and presuppositions of human beings in the creation of their scientific theories (2008:228). Such mechanisms are knowable via inductive processes because these are real, as the success of inductive science demonstrates.

REFLECTION

(1) Carefully read the following quotation and then answer the questions below. "But then, and then only, may we hope well of the science, when in a just scale of ascent, and by successive steps not interrupted or broken, we rise from particulars to lesser axioms; and then to middle axioms, one above the other; and last of all to the most general" (Francis Bacon 2011:290).

   (a) Which theory of scientific practice is involved here? Why do you say that?

(b) What would you say are Bacon's grounds for optimism regarding this method?
(c) What objections can you raise against this view of scientific practice?
(d) Why do you think Bacon (2011:290) sees fit to give the following warning? "The understanding must not therefore be supplied with wings, but rather hung with weights, to keep it from leaping and flying – when it is done, we may entertain better hopes of the sciences."

(2) A method that is often recommended to school teachers is that of active learner participation. The learners are provided with a set of facts and must derive their own hypotheses. The purpose is to actively involve them in the lesson and stimulate interest. Is this basic principle of knowledge acquisition deductive or inductive?
(3) Is the scientific nature of research guaranteed by the application of the inductivist or the deductivist method?
(4) Popper believes that his method of "conjecture and refutation", that is, of proposing hypotheses and then trying to refute them, can also be applied to philosophy. What do you think?

FEEDBACK ON REFLECTION

(1) Note how Bacon spells out the inductivist method, and in the process exposes some of the method's strengths and weaknesses.
(2) This method is inductivist. One difficulty it presents, is that it can be very time-consuming. Unless the kind of inference the student has to make is clearly indicated, it may lead to something like a repetition of the original discovery situation. Not every student is a Galileo or a Newton. Also, bear in mind the problems we raised with regard to "all swans are black". Nonetheless, learners may find this method interesting if it is used cautiously.
(3) A method cannot by itself guarantee that something is scientific. Remember that we cannot furnish rules for discovery (because if we could, science would already have discovered everything and no secrets would be left), but at best rules for justification.
(4) This is a difficult question. The answer would depend on how you regard philosophy. Should philosophy construct theories, and if so, how can philosophical theories be tested? It has been suggested that a conceptual analysis is in fact a hypothesis that can be tested by means of counterexamples. This is based partly on the assumption that Popper's underlying logical pattern (the *modus tollens* rule) constitutes a universal pattern and therefore applies in every field.

STUDY UNIT 5

Kuhn, scientific revolutions and paradigms

> **"The net result of a sequence of ... revolutionary selections, separated by periods of normal research, is the wonderfully adapted set of instruments we call modern scientific knowledge. Successive stages in that developmental process are marked by an increase in articulation and specialization. And the entire process may have occurred, as we now suppose biological evolution did, without benefit of a set goal, a permanent fixed scientific truth, of which each stage in the development of scientific knowledge is a better exemplar."**
>
> – Thomas Kuhn (2009:509)

OUTCOMES

After completing this study unit, you should be able to

- theorise over and problematise the role of history in scientific theory development
- critically gauge Kuhn's paradigmatic conceptualisation of scientific theories
- develop a nuanced understanding of Kuhn through consideration of his critics and his self-defence

5.1 THE IMPORTANCE OF THE HISTORY OF SCIENCE

Practitioners of both induction and deduction assume that objective facts exist independently of theory and guarantee the truth of theories. This is apparent in the emphasis placed on testing theories against observations. The evolution of science is thus imaged to consist in the accumulation of a developing set of true propositions (statements) that enable us to describe reality with emerging accuracy.

Point to ponder

To what extent can observations and theory construction be theory-independent and objective?

Thomas Kuhn challenged this view, arguing instead that new theories result in new ways of conceptualising. These, however, do not necessarily relate to "the world": "[T]he notion of a match between the ontology of a theory and its 'real' counterpart in nature ... seems to me illusive in principle" (Kuhn 2009:512).

As will be demonstrated, Kuhn (2009:508) argued that, whilst theories evolve from pre-science through to normal functioning science and crisis, they do not evolve toward any point. This is counterintuitive to the "traditional" way in which scientific theories have been conceptualised as developing towards ever greater knowledge of "the world".

In 1962, Kuhn published *The structure of scientific revolutions*, which influenced both theory of science and actual scientific practise. He proposed that the history of sci-

ence was important, but in need of reinterpretation. Science does not have a history of steady expansion towards greater truth, but is rather a series of periodic reappraisals of existing knowledge. As a result, new insights replace earlier interpretations.[13]

In Kuhn's historical reading of science, theories are replaced by others as a consequence of the changing standards, problems, and problem-solving tactics of particular scientific communities at certain historical moments. As such, scientific knowledge is not cumulative, but forms discrete "pockets" of knowledge that are readily identifiable as unique.

Point to ponder

Compare this basic explanation of Kuhn's theory of science with what you know of scientific theory development.

5.2 THE STAGES OF THE SCIENTIFIC PROCESS: FROM PRE-SCIENCE TO REVOLUTION

From his analysis of the history of science, Kuhn realised that neither the inductivist approach of the logical positivists nor the deductivist (falsificationist) approach of Popper adequately explained the development of scientific theories, and more broadly, the development of the scientific project (Chalmers 2009:104). Like the logical positivists and Popper, however, Kuhn attempted to articulate the scientific endeavour in the context of "theoretical frameworks" that would illustrate both how science is done and how it progresses (Chalmers 2009:107).

In addition to the historical situation that he observed, Kuhn proposed that the development of the scientific community also needed consideration: that there are historical, sociological, political, and other factors that have an impact on the scientific community's work (Bortolotti 2008:114).

Point to ponder

Identify some of the historical, sociological or political factors that could influence the research of scientists.

To ground his approach in a practical instance from the history of science, Kuhn explored the "chemical revolution", which was principally concerned with "a new theoretical account of combustion, the rejection of the phlogiston theory and the discovery of oxygen" (Bortolotti 2008:118).

The 18th century scientist Antoine-Laurent Lavoisier developed a theory that the element oxygen was involved in the process of combustion, rather than the then dominant idea that it was "phlogiston" (Bortolotti 2008:18). Lavoisier's innovation was the product of his experimental findings.

Before the development of the theory of the existence of oxygen, phlogiston was regarded as the "inflammable principle" that any combustible substance released upon combustion, and was understood as "inflammable earth". It was argued that

13 Kuhn saw his work as being clearly founded in "the historical record of the research activity itself". Moreover, it is through the study of the historical record of scientific activity that the advancement and the regression of scientific theory is to be found (2009:490).

if phlogiston was released from a burned product, it could be added back to the burned product to restore the product by bringing it into contact with another substance containing phlogiston (in an uncombusted state), for example oil or wax. For instance: "If phosphorous is burnt, it produces acid matter (Phosphorous + Acid = Phlogiston). If acid is heated with charcoal, Phlogiston is absorbed and phosphorous is reproduced" (Bortolotti 2008:119).

A number of anomalies were present in the theory of phlogiston, however, among which that the calx (that remained after combustion) was heavier than the originally combusted metal, even though phlogiston had been released (2008:119). Thus, in 1772, Lavoisier re-performed experiments, and found that (Bortolotti 2008:120)

> sulphur and phosphorous gain weight when they burn and that at the same time the volume of air is reduced … [Lavoisier supposed] that during combustion air is absorbed by them … He did not [at this juncture] have any particular conjecture on oxygen, but presumably he became persuaded that effervescing calces contain air, because in calcinations metals gain weight as well.

Lavoisier was, however, unsure about whether or not it was parts of the air or all of the air that was released during combustion (2008:120). However, as he developed his theory, Lavoisier was able to refine it, particularly through his later isolation of the oxygen gas, which he labelled as the element that combusts. What was particularly novel in Lavoisier's theory, was that, instead of seeing the "inflammable principle" within the body to be burnt, he conjectured that combustion was only possible when the body to be burnt came into contact with oxygen. The process of the development of this theory, which started in 1772, ended in 1789 with Lavoisier's inclusion of oxygen in his table of elements (Bortolotti 2008:121).

The theory of phlogiston was thus discounted, as Lavoisier's theory of combustion better explained how it was that combustion occurred: Lavoisier had removed some of the anomalies identified in the theory of phlogiston (Bortolotti 2008:122).

Point to ponder

When you have read the next section, return to the oxygen/phlogiston narrative, and consider how this example illustrates Kuhn's induction of the manner in which scientific theories evolve through a continuous stage-like process of paradigm emergence and change as a result of anomalies.[14]

5.2.1 Pre-science

The first stage Kuhn identified in his model is "pre-science", within which the earliest examinations and investigations of phenomena or events occur. In this stage, there is no dominant paradigm, thus "all of the facts that could possibly pertain to the

14 According to Kuhn, a "paradigm" in terms of scientific theory refers to "the general theoretical assumptions and laws and the techniques for their application that the members of a particular scientific community adopt" (Chalmers 2009:108). This is the product of the process you will shortly discover, which begins in pre-science and then moves through to the practice of normal science in the development of particular ways of doing science and the emergence of different lenses through which phenomena are viewed. Practitioners of normal science constantly work towards stengthening the paradigm within which they work by making their arguments sounder, especially when it comes to the explication of phenomena they perceive and which are relevant to their field of study (Chalmers 2009:108).

development of a given science are likely to seem equally relevant" (Kuhn 2009:491). As there is no direction to the research, the phenomena observed (which may not necessarily actually be the identical phenomena at all) are most often interpreted differently (2009:491). It should also be noted that within pre-science there are no commonly agreed standards, theories, or procedures. Indeed, there is no "community" of scientists, for at this stage, research is usually done in isolation.

5.2.2 Paradigm emergence

Over time some theory or group of theories emerges as more acceptable or successful than others. Hence, Kuhn provides grounds for the emergence of a particular paradigm: " [A] theory must seem better than its competitors, but it need not, and in fact never does, explain all the facts with which it can be confronted" (Kuhn 2009:491).

In the midst of paradigm emergence, however, some scientists will hold fast to their own paradigm (2009:492).

Point to ponder

In your view, why would scientists retain their dominant paradigm?

The newly emerging paradigm attracts scientists to it. Certain sets of problems remain unsolved, however. Within these events, a "research tradition" emerges in the provision of an image or model of doing science. Here is reference to a "paradigm" that refers to such research traditions together with the accepted theory (Kuhn 1970:175):

> On the one hand, it [the paradigm] stands for the entire constellation of beliefs, values, techniques, and so on shared by the members of a given [scientific] community. On the other, it denotes one sort of element in that constellation, the concrete puzzle-solutions which, employed as models or examples, can replace explicit rules as a basis for the solution of remaining puzzles of normal science.

Kuhn (1975:182) referred to the first kind of paradigm as structural systems in a "sociological" (1975:175) sense; and to the second as "exemplary past achievements" (1975:175) or "shared examples" (1975:187):

> A paradigm is what members of a scientific community, and they alone, share. Conversely, it is their possession of a common paradigm that constitutes a scientific community of a group of otherwise disparate men [people]. As empirical generalisations, both those statements can be defended. But in the book they function at least partly as definitions, and the result is a circularity with at least a few vicious consequences. If the term "paradigm" is to be successfully explicated, scientific communities must first be recognised as having an independent existence.

5.2.3 Normal science

The third stage of science is called "normal science". It is practised within a dominant theory/paradigm, and has as its aim the continuation and extension of that paradigm. The research done within the newly dominant paradigm is more often than not of a

conservative nature, not venturing much outside of the theoretical framework (i.e. paradigm) (Bortolotti 2008:118).

Point to ponder

Consider why "normal scientists" do not expand their work outside the dominant paradigm. Explain your answer with reference to some examples.

Remember, a paradigm comprises an entire worldview. It includes the metaphysical and ideological assumptions made by the particular scientific community, as well as the criterion used by scientists to assess their theories, approaches to the creation of new theories, and so on (Bortolotti 2008:118). A "paradigm" is an entire scientific enterprise in which individual scientists and entire scientific communities have deeply vested interests. Movement outside a paradigm is therefore inconceivable!

A paradigm is akin to a Wittgensteinian "game", which entails very particular rules and modes of playing.[15] Kuhn (2009:496) explains this comparison:

> [C]onfronted with a previously unobserved activity, we apply the term "game" because what we are seeing bears a close "family resemblance" to a number of the activities that we have previously learned to call by that name. For Wittgenstein, in short, games, and chairs, and leaves, are natural families, each constituted by a network of overlapping and crisscross resemblances ...

Something of the same sort may very well hold for the various research problems and techniques that arise within a normal-scientific tradition. What these have in common is not that they satisfy some explicit or even some fully discoverable set of rules and assumptions that gives the tradition its character and its hold upon the scientific mind. Instead, they may relate by resemblance and by modelling to one or another part of the scientific corpus which the community in question already recognizes as among its established achievements.

As the "game" of "normal science" is "played" from within a dominant paradigm, it is this paradigm that demarcates science from non-science (or pre-science): non-science would not have a dominant paradigm supportive of the diversity of theories developed in, for instance, a pre-scientific phase (Chalmers 2009:109). A paradigm is empowered to continue functioning by scientists continuously attempting to seek alignment between the paradigm's theories and the observed data (2009:110). Implicit within this process is the assumption that the dominant paradigm is composed of the tools necessary for further explanation and alignment between theory and observation (2009:109).

The role of the subject (the scientist) is paramount for Kuhn (2009:492) in the adoption of a paradigm: "Paradigms gain their status because they are more successful than their competitors in solving a few problems that the group of practitioners has come to recognise as acute."

But the task of the "normal scientist" is not to generate novel science. Instead, the scientist is tasked solely with solving puzzles (as articulated by that particular science's practitioners) (Kuhn 2009:494–495). Kuhn (2009:495) explains the activity of the "normal scientist":

15 Ludwig Wittgenstein (1889–1951), who was Austrian born, was a British philosopher of the analytic tradition.

> The scientific enterprise as a whole does from time to time prove useful, open up new territory, display order, and test long-accepted belief. Nevertheless, the individual engaged on a normal research problem, is almost never doing any one of these things. Once engaged, his [or her] motivation is of a rather different sort. What then challenges him is the conviction that, if only he is skilful enough, he will succeed in solving a puzzle that no one before has solved or solved so well ...

Anomalies observed do not necessarily discount or falsify the dominant paradigm. They serve rather as moments when the paradigm's explanatory power (i.e. its alignment of theory with observation) can be strengthened (Kuhn 2009:109). However, at times this is impossible, as can be seen in Kuhn's example of phlogiston and oxygen. Hence, whilst some anomalies are "puzzles" that can be solved within a paradigm, there are instances when paradigms are struck down by particular anomalies.

During the stage of "normal science", clear articulation and acceptance of the standards, procedures, and meaning of terms are established. This enables the "game" of normal science to be played. A narrowed down, in-depth study of relevant systems therefore occurs. Problematic, however, is that only facts significant within the limits of the accepted paradigm are noticed. For example, if the assumption of the relevant paradigm is that electrons are particles, then the wave-like properties of electrons will be ignored.

Point to ponder

Why is it problematic that only dimensions of the "world" relevant to a paradigm are "picked up" by theorists from within that particular paradigm?

5.2.4 Crisis

From time to time, it does happen that within a paradigm, novelties emerge in scientific theories "with the recognition that nature has somehow violated the paradigm-induced expectations that govern normal science" (Kuhn 2009:497).

Thus a crisis emerges within the dominant paradigm, resulting in "a psychological effect" on the practitioners of that paradigm. Scientists are thus obliged to seriously consider whether or not their particular paradigm fits the anomalous observations made, and if not, the explanatory power of the paradigm needs to be questioned (Bartolotti 2008:122). This is the fourth stage in the Kuhnian model, namely "crisis".

Kuhn (2009:499) explains the difference between normal science and the period of crisis:

> For what is it that differentiates normal science from science in a crisis state? Not, surely, that the former confronts no counterinstances. On the contrary, what we previously called the puzzles that constitute normal science exist only because no paradigm that provides a basis for scientific research ever completely resolves all its problems.

But for an anomaly to cause a crisis, it must be stronger than a perceived abnormality or difference from the dominant paradigm (Kuhn 2009:499–500). An anomaly must challenge underlying foundations of a paradigm to such a degree that a crisis can be evoked. Indeed, a paradigm may have sufficient explanatory power to dis-

sipate the cause of a crisis (2009:500). In such instances, scientists first check the experimental data, and then start making minor changes to the paradigm itself. On the other hand, anomalies can continue to defeat attempts to be resolved from within the dominant paradigm. At such moments, a crisis can only be resolved by a new paradigm (Chalmers 2009:108):

> A crisis is resolved when an entirely new paradigm emerges and attracts the allegiance of more and more scientists until eventually the original, problem-ridden paradigm is abandoned.

Closely resembling the pre-scientific stage, the crisis stage is a time of extraordinary science. Competing theories challenge one another, and there is no consensus on standards or procedures. Hence difficulties arise in the occurrence of meaningful debate between scientists, as they disagree in terms of concepts, approaches, and meanings of terms.

Point to ponder

Kuhn acknowledges that anomalies always tend to arise, and that a single anomaly cannot discount an entire paradigm. When should a paradigm realistically be replaced with another paradigm?

Once a number of anomalies have presented themselves, making the match between observation and theory (in the dominant paradigm) increasingly harder, scientists should consider changing views (Bortolotti 2008:123). For Kuhn, though, scientists will not "swap" paradigms until one has emerged that is able to explain anomalies (Bortolotti 2008:124). Thus, the urgency of a crisis is determined by how seriously a newly formed paradigm can be taken by the practitioners of "normal science".

5.2.5 Revolution

"Normal science" progresses to enable science to develop and to "enflesh the skeleton". However, scientists who become "revolutionary" – those who challenge the status quo by bringing anomalies to the fore – keep the scientific activity at the cutting edge and try to narrow the gap between scientific theory and observed data (Chalmers 2009:118).

The last stage of the Kuhnian model of science is that of "revolution". Kuhn (in Chalmers 2009:114) argues that the emergence of a new paradigm is a sudden, revolutionary moment:

> [T]he new paradigm, or a sufficient hint to permit later articulation, emerges all at once, sometimes in the middle of the night, in the mind of a man [person] deeply immersed in crisis.

In Kuhn's estimation, a revolutionary moment in terms of a paradigm shift does not occur progressively as the result of the evolution of theory (Kuhn 2009:501). Revolution is sudden, swift and drastic.

Points to ponder

If history demonstrates that scientific theories emerge over prolonged periods of time, how can the revolutions alluded to by Kuhn be so rapid and non-cumulative?

Differentiate between the concepts of "evolution" and "revolution".

The answer lies in the fact that the crisis within the dominant paradigm occurs, is not timeously short. Crisis is the fruit of panic, defence, rethinking, etc., which is a rather time-consuming process. Hence, whilst the revolution may be "instant", the process of arriving at the revolution is not.

The new paradigm that emerges in reaction to the anomalies of the prior paradigm will be vastly different from the former paradigm. So great is this difference that "[e]ach paradigm will regard the world as being made up of different kinds of things" (Chalmers 2009:114). To some degree the rival paradigms may not be able "to speak" to one another. What will be considered relevant, will depend on a paradigm's view of reality, as was illustrated by the phlogiston/oxygen debate: either phlogiston or oxygen existed (2009:114). The phlogiston theorists and the oxygen theorists perceived the particular aspect of the world they investigated differently. Kuhn's scientific paradigms result in supporters of rival paradigms disagreeing with one another. Each remains in their own paradigm, construing the world differently, which makes the paradigms incommensurable (Kuhn 2009:503; Chalmers 2009:116–117). Competing theorists from different paradigms do not function in the same world (Kuhn 2009:504).

Points to ponder

What does "incommensurable" mean?

Define "mutually exclusive".

What informs the choice between competing paradigms?

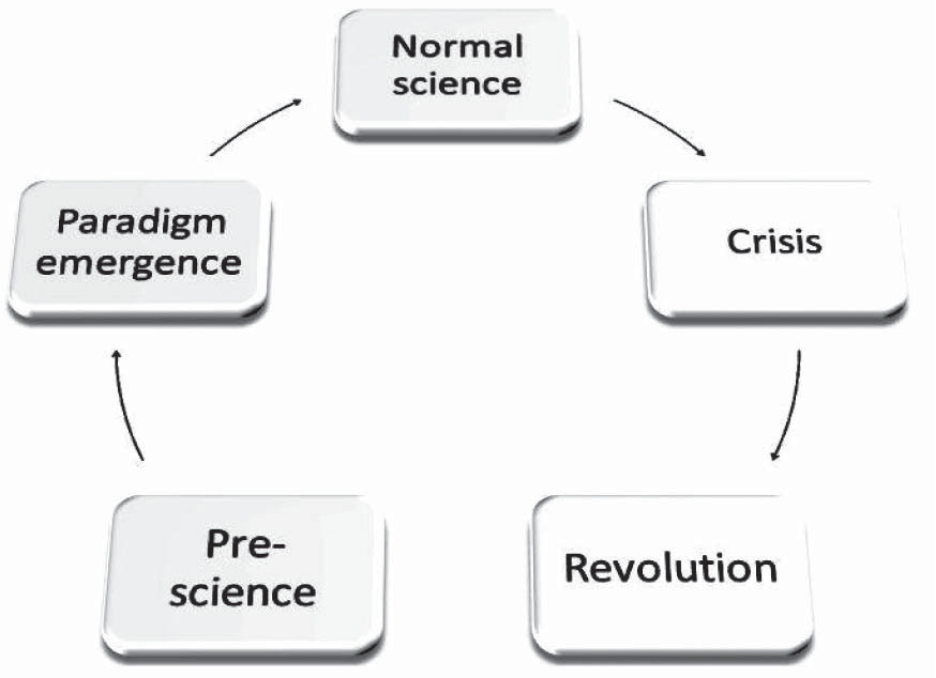
In the Kuhnian understanding, the choice between competing paradigms is not the result of a rational decision, but is "a choice between incompatible modes of community life" (Kuhn 2009:501). Because it is a paradigm that is under scrutiny, and paradigms inform entire schools of thought, members of a scientific community cannot rely on a dominant paradigm to aid them in choosing one paradigm over another. While proponents of a particular paradigm may state that their choice for one paradigm over another is based on the one having better problem-solving ability than the other, for Kuhn, this is simply a way in which paradigm choice is articulated. The reality is often quite different, and very subjective (Kuhn 2009:507):

> The man [person] who embraces a new paradigm at an early stage must often do so in defiance of the evidence provided by problem-solving. He [or she] must, that is, have faith that the new paradigm will succeed with the many large problems that confront it, knowing only that the older paradigm has failed with a few. A decision of that kind can only be made on faith ... .

Point to ponder

Kuhn's appeal to paradigm choice as a matter of faith appears counterintuitive to the way in which the choice of scientific theory operates. To what extent can reason be left out of the choice of paradigm?

Regardless of how new paradigms are chosen, the result of the revolutionary stage is the conquest and dominance of a particular paradigm (Kuhn 2009:508). In a similar evolutionary manner, a new paradigm will meet its own anomalies, resulting in a new crisis, a revolution, and the eventual emergence of another paradigm. The Kuhnian "process" of scientific paradigm emergence can be graphically represented in terms of an ongoing cycle:



The Kuhnian stages of scientific paradigms

5.3 SCIENTIFIC THEORY DEVELOPMENT AS PARADIGM CHANGES

Whilst Kuhn applies the concept of "paradigm" in several ways, it is sufficient that we regard a "paradigm" as a framework that determines which facts and problems, questions and tests are pertinent to a particular piece of research regarding phenomena.

For instance, Newton and Ptolemy's explanations of gravitational attraction and the motion of the planets can be compared. To many in the 17th century, Newton's account of gravitation seemed a poor account when compared to Ptolemy's explanation of the motion of the planets in terms of contiguous crystalline spheres. Because Newtonians and Ptolemaicans operate within different theoretical frameworks ("paradigms"), they do not consider the same facts! For Kuhn, the facts that form part of different frameworks or paradigms can never be "the same".

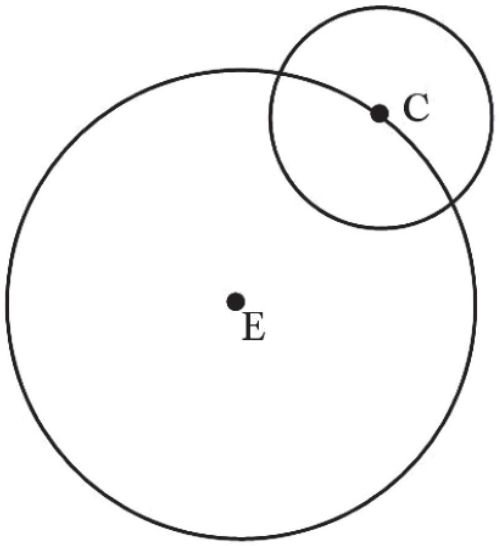
Nevertheless, as time passed and Newton's theory became accepted (and became the paradigm against which later theories would be judged), the lack of an underlying

mechanism for a fundamental force was not perceived as an objection. Anomalies were accommodated within Newtonian physics, until "normal" Newtonian science broke down towards the end of the 18th century.

This indicates that comparison between theories is not as clear-cut as the standard empiricist account desires, because the standards and instruments of evaluation are themselves subject to change, as are the facts relating to the particular theory.

Kuhn therefore conceives of the process as beginning in a pre-scientific context, developing a form of science until insoluble problems are encountered, at which point a scientific crisis occurs.

Let us consider a Ptolemaic astronomical theory. Ptolemy assumed the earth was the centre of the universe, and that celestial bodies were perfect spheres moving in circular orbits. Because it was soon apparent that the planets did not orbit the earth in perfect circles, allowances were made by assuming composite circular orbits, for instance an orbit round centre *C,* which in turn describes a circle round the earth, *E*.



Ptolemaic astronomical model

Point to ponder

At what stage of science – according to Kuhn's model – is Ptolemaic astronomy at this moment?

Eventually there were many deviations from the theory, the system becoming extraordinarily complicated because of the presence of many ad hoc hypotheses. Astronomy faced a crisis.

Point to ponder

How would the Kuhnian paradigmatic model of science solve the problem of an astronomical model with multiple ad hoc hypotheses?

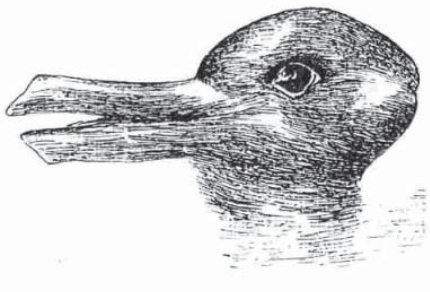
In Kuhn's view, such a scientific crisis is resolved by a revolution: a new interpretation develops and receives support. Here, the new interpretation was the Copernican model or framework, wherein the sun was located at the centre and the earth rotated on its own axis. This was not an adjustment of existing knowledge; it was a novel theoretical framework.

In turn, the Copernican model will be developed and refined for the duration of its own period of "normal science". During this period, the model serves as the framework within which scientists operate. In "normal science", a general paradigm dominates, and it is in terms of this dominance that research is conducted, even – as we have seen – in terms of what is classified as "fact". Theories and hypotheses are constructed and tested in light of the paradigm. If they conflict with the paradigmatic facts, they are adapted and revised within the framework of the paradigm.

Prior to Copernicus, the observation that certain celestial bodies did not orbit the earth in perfect circles was insufficient to falsify the Ptolemaic theory of the circular orbits of heavenly bodies. On the contrary, the paradigm was retained and the hypothesis adapted: "All heavenly bodies move in circles or in composite circles." Hence Ptolemaic astronomy continued to evolve within the old paradigm. A paradigm determines which facts are relevant, where possible empirical tests may be found, and where (and how) adjustments can be made.

A Kuhnian revolution in a new paradigm represents a break from previous paradigms. Each paradigm is a complete system of understanding in which a different picture of the world is represented.

These breaks in paradigm can be understood as "Gestalt switches", and at any particular moment only one particular system of understanding or another can be perceived. This is likened, analogously, to the image of *My Wife and my Mother-in-Law* (see study unit 3), or to either of the following images:



Is this an image of a duck or a rabbit? (Jastrow 1899)



The Rubin vase: A vase or two faces?[16]

No particular interpretation of any of these images is "true". And this was Kuhn's point in terms of the incommensurability of paradigms. One cannot uphold both interpretations of these images simultaneously, but at any particular moment, either interpretation is acceptable. Similarly, in terms of Kuhn's theory, we cannot mix propositions, laws or hypotheses (or concepts) from different paradigms. Each paradigm has its own facts, laws and concepts. Different paradigms are thus described as incommensurable or mutually exclusive.

16 Edgar Rubin (1886–1951) developed the vase image in 1915. He was a Danish psychologist and phenomenologist.

Points to ponder

In your opinion, can paradigms come into contact with one another?

Are paradigms discrete entities? In other words, can they overlap, or are they mutually exclusive?

5.4 CRITIQUE OF KUHN'S PARADIGMATIC VIEW OF SCIENCE

While Kuhn's historical approach to the development and change of paradigms of scientific theory has merit, this is his "reading" of scientific history. Sure enough, Kuhn's emphasis upon science occurring within particular structural frameworks cannot be disputed, but there are many dimensions of his work which can be called into question (Chalmers 2009:119).

5.4.1 Instantaneous nature of paradigm shifts in scientific revolutions

Among the principal points critiqued is Kuhn's theory that revolutions – the movement from the rejection of one paradigm to embracing another as a result of a crisis in the original dominant paradigm – occur instantaneously (Chalmers 2009:119–120):

> It is all very well painting a heroic picture of Einstein as making a major advance by having the originality and courage to challenge some of the fundamental principles of physics, but we should not lose sight of the fact that it took two hundred years of detailed work within the Newtonian paradigm and one hundred years of work within theories of electricity and magnetism to reveal the problems that Einstein was to recognize and solve with his theories of relativity.

Often scientific theories are the result of long periods of developing hypotheses from observations, testing these theories to confirm or deny them, and so forth. Thus, while it may happen that discoveries could cause swift paradigm changes, it is likely that a more nuanced approach – accommodating both rapid and slower changes in paradigms – would better account for the development of scientific theories. Indeed, the history of science illustrates this, both in the aforementioned case of Einstein – whose work was the result of the accumulation of many theories over a long period – and in the earlier example of phlogiston and oxygen.

5.4.2 Different worlds between paradigms

"Kuhn used the notion of revolution to stress the non-cumulative nature of the advance of science" (Chalmers 2009:120–121). There are moments of sudden "discovery", for it is not always the case that scientific paradigms take long periods of time to develop, nor that scientific paradigms necessarily build on past paradigms (2009:121).

We should bear in mind that, for Kuhn, a paradigm shift not only concerns a change in the laws evident in the particular theory, but a different way of perceiving reality and of evaluating the paradigm (2009:121).

Kuhn may be correct in stating that a different paradigm brings about a different approach to the world; phlogiston and oxygen is a case in point (2009:121–122).

Point to ponder

Do different paradigms refer to different worlds, rather than simply perceiving the same reality differently?

In the case of phylogiston and oxygen, could we argue that the paradigms do not speak to one another? No, since it was the phlogiston paradigm that led to the establishment of the oxygen paradigm due to the anomalies that arose. And these anomalies would not have arisen had the previously developed theory not existed.

A nuanced approach would postulate that as paradigm shifts develop scientific theories, the resultant knowledge about the entities explored from within the paradigms do change. In this way, for example, oxygen came to be seen as the element responsible for combustion, and Einstein's theory replaced previous ones.

5.4.3 Change in standards of evaluation across paradigms

If Kuhnian paradigms exist in different worlds, it is logical to assert that what is contained in a particular paradigm – for instance, the measuring criteria, standards for evaluation, etc. – are also relative to that particular paradigm, rather than to a previous one (Chalmers 2009:122).

Points to ponder

What standards can be applied across paradigms to judge which paradigm is stronger?

If there are no standards of judgment, can one paradigm ever be said to replace its predecessor more adequately?

It could be argued that every paradigm thus appears to be relative to itself only. Against this charge Kuhn (in Chalmers 2009:122) saves himself by rejecting relativism:

> [L]ater scientific theories are better than earlier ones for solving puzzles in the often quite different environments to which they are applied. That is not a relativist's position, and it displays the sense in which I am a convinced believer in scientific progress.

Nevertheless, as we shall see below, Kuhn maintains the importance of standardised criteria of evaluation across paradigms.

5.4.4 "Kuhn-loss"

A principle reason for rejecting one paradigm in favour of another is that the latter paradigm has the ability to explain anomalies which have arisen in the former. However, there have been some cases in the history of science where a scientific revolution has resulted in a new paradigm not being able to explain particular observations as adequately as the previous paradigm (anomalies). Kuhn made attempts to discount this phenomenon, but the history of science demonstrates evidence in support of a particular paradigm losing explanatory power due to its having been succeeded by another new, revolutionary paradigm. This has come to be known as "Kuhn-loss" (Worrall 2002:32).

Despite this criticism, we should take Kuhn's approach concerning the selection of one paradigm over another seriously (Chalmers 2009:116–117):

> [T]here is no logically compelling argument that dictates that a rational scientist should abandon one [paradigm] for the other. There is no single criterion by which a scientist must judge the merit or promise of a paradigm, and, further, proponents of competing programs will subscribe to different sets of standards and will even view the world in different ways and describe it in different languages.

If that is the case, a paradigm's explanatory power is not a real consideration. However, this is an anomaly in Kuhn's theory.

5.4.5 Lakatos's critique of Kuhn

While Imre Lakatos sees value in Kuhn's historical approach to the way in which science develops, and emphasises the importance of psychological, political and sociological factors in scientific development, he is less enthused with Kuhn's use of the term "paradigm". Lakatos accuses Kuhn of being both vague and having metaphysical undertones (Bortolotti 2008:126).

Perhaps Lakatos's greatest point of criticism against Kuhn is his use of the term "revolution" with regard to the rejection of an old paradigm and the adoption of another. Moreover, it is Kuhn's point that paradigm revolution is akin to religious conversion that prompts Lakatos to propose that Kuhn is really saying that science proceeds irrationally (2008:126).

Point to ponder

Does Lakatos assume that a religious conversion is necessarily irrational? Provide supportive evidence for your answer.

From the perspective of theology – in particular systematic theology – this is not the case, as sophisticated reasoning for religious belief is constantly being developed. This does not imply irrationality.

Moreover, if Kuhn simply uses the term "conversion" to describe the rejection of one paradigm and the adoption of another, he is not making an appeal to "religious conversion" in a literal sense, but is rather drawing an analogy. Thus, Kuhn does not propose an irrational account of science, nor does he then cloud "any demarcation criteria between science and non-science" (Bortolotti 2008:126).

Rather than focusing on "paradigms" in science, Lakatos emphasises "research programmes". He states that there are some dimensions of a particular scientific research programme that are "core" to that programme. These will not be changed particularly easily despite the presence of empirical evidence contradicting the core dimensions of the research programme. Lakatos also argues that there are other dimensions of the research programme that are not core to it, and that these can more readily be changed when counter-evidence is presented. For Lakatos, this account – according to which "anomalies" result in changes to aspects of the research programme but not to its core – ties in more closely with historical evidence of scientific development (Bortolotti 2008:127).

If we consider the aforementioned examples of Einstein or of the phlogiston-oxygen paradigm shift, Lakatos has a point. There is a link between the different paradigms, for the more "archaic" paradigm usually has – to a greater or lesser extent – some relationship to the "revised" paradigm, even if it is simply that the new paradigm stands in reaction to the old; that it is a reaction illustrates a connection.

Of course, problematic is Kuhn's insistence on the closed nature of paradigms: that the particular worldviews are so intimately tied to their paradigms that they cannot be "transferred" to another paradigm. This includes the evaluation tools, which according to Kuhn are paradigm-specific.

It is here that Lakatos proposes the main difference between Kuhnian "paradigms" and his "research programmes": "[T]he validity of the latter can be assessed objectively, from a point of view that need not be internal to the research program under consideration" (2008:127).

Lakatos has something to say, too, with regard to why one would change a paradigm, or in his case, why one would choose to accept or reject a theory functioning within a research programme (Bortolotti 2008:127–128):

> [F]or the shift to contribute to progress, the new theory needs to be more informative than the previous one; needs to be able to explain the success of the previous one and needs to receive independent corroboration.

Examining the history of science, Lakatos argues that there is insufficient evidence to propose, as Kuhn does, that there is no rational explanation for why one would choose one paradigm over another, and furthermore, that science progresses through a series of occasions of normal scientific practice and then of crisis and revolution (Bortolotti 2008:128). Rather, science is constantly in the process of choosing theory over theory, thus enabling the entire project to advance towards tying observation data to the correct theories (2008:127).

Lakatos's proposal entails that science is not bound by separate paradigms, each with its own research methodology, evaluative tools, and so on, arguing rather that "methodological strategies and criteria for theory-choice are not theory-dependent" (Bortolotti 2008:128). It would be akin to throwing the baby out with the proverbial bathwater, every time new water is found.

Point to ponder

Explain whether the methodologies and strategies behind theory choice are theory-dependent. (You may wish to refer back to study unit 2, where the problem of objectivity in scientific theory development is dealt with.)

5.5 KUHN'S SELF-DEFENCE

Let us now turn to Kuhn's response to criticisms levelled against his theory. In an article entitled *"Objectivity, value judgment, and theory choice"*, Kuhn does just this. He states that, in his earlier work, *The structure of scientific revolutions*, "I considered the ways scientists are brought to abandon one time-honoured theory or paradigm in favor of another" (Kuhn 1998:212).

He argues that a change in paradigm is for the better advancement of science, when that change is the product of the collective decision-making of the particular scientific community (1998:212). Problematic with this approach is that Kuhn could be seen as adopting a consensus approach to truth: a sort of mob-mentality, if you like.

Point to ponder

Is the ontology of something as it is simply because a majority of people have declared it as such? Explain your position.

Returning to his critics, Kuhn (1998:212–213) states in a rather sarcastic tone (referring to the take of critics on himself):

> Kuhn believes, I am told, that "the decision of a scientific group to adopt a new paradigm cannot be based on good reasons of any kind, factual or otherwise".

In response, he states unequivocally:

> Reports of this sort manifest total misunderstanding and I have occasionally said as much (1998:213).

Kuhn explains that he upholds five characteristics that make for a good scientific theory, namely "accuracy, consistency, scope, simplicity, and fruitfulness – all are standard criteria for evaluating the adequacy of a theory" (1998:213.). These are clear criteria by which to evaluate scientific theories, but says Kuhn (1998:214), even with these criteria in place, subjective issues arise in theory selection, or to be more specific, in choosing one paradigm over another:

> When scientists must choose between competing theories, two men [people] fully committed to the same list of criteria for choice may nevertheless reach different conclusions. Perhaps they interpret simplicity differently or have different convictions about the range of fields within which the consistency criterion must be met … With respect to divergences of this sort, no set of choice criteria yet proposed is of any use.

We could be flippant, accusing Kuhn of being unwilling to change paradigms! But, in more serious vein, we need to consider the possibility that he proposes. It could be that subjective factors (affecting the individual scientist) could result in her not agreeing with her colleague as to which paradigm to adopt: this could be the product of culture, intellectual background, etc. (1998:215).

Of course, the "objective" criteria accepted by Kuhn remain, and perhaps he "downgrades" them in overemphasising the subjective role of scientists' circumstances in theory selection: the shared criteria for theory selection – that is what determines a good theory – are guides that should serve both to direct scientists and to provide guidelines for dialogue when such difficulties arise.

While Kuhn's position may appear radical, he "tones it down" when he states his intention in emphasising the role of subjective factors in paradigm selection: "My point is, then, that every individual choice between competing theories depends on a mixture of objective and subjective factors, or of shared and individual criteria" (1998:215).

5.6 REVOLUTIONARY IMPLICATIONS FOR SCIENCE

The discussion has led us through Kuhn's theory and to some points of critique. Many implications for science and its progression have been touched on.

> **Point to ponder**
>
> In the light of the Kuhnian philosophy of science, where do we stand in relation to the history of science and its development of theories?

In this study unit, we've taken a balanced approach to the understanding of how science develops historically. We have made the choice to accept some of Kuhn's proposals while rejecting others. We've seen that paradigm shifts may occur suddenly and dramatically, and that yet, on other occasions, scientific theory development progresses in a slower, less dramatic manner, the result of long periods of "normal science". This seems to be a more truthful depiction of scientific history.

An implication is that most paradigms remain connected to one another, unless, on occasion, a new paradigm emerges that is unrelated to the original paradigm, although always remaining linked to the same reality. We cannot say, for example, that Einstein's theories are unrelated to Newton's; Einstein's formation in science was in the Newtonian paradigm, thus there remains some connection in the revised paradigm to what was before – even if only in the sense of being a reaction to the former paradigm.

It is important, however, that we should take Kuhn seriously, particularly his notion of paradigm and paradigm shift, and the acceptance of a paradigm shift being determined by a combination of subjective and objective factors rather than by science purporting to be either totally objective and absolutely true, or subjective and therefore only relatively true.

REFLECTION

(1) Consider the Kuhnian approach to understanding founded in paradigms as all-encompassing systems of understanding. In the light of this, compare the simple differences between the descriptions by a pedestrian and a motorist of the distance from your home to the nearest café. To which facts does each of them attach importance? Is it always quicker to drive? Suppose the café is next door and you first have to get the car out of the garage? Does the relation between the two descriptions (the motorist's and the pedestrian's) reflect the difference between paradigms that Kuhn had in mind?

(2) Can we, on the basis of historical evolution alone, decide on criteria for what constitutes science?

FEEDBACK ON REFLECTION

(1) The example is only a partial analogy: the two descriptions will still fit the same framework in that the facts (the location of your home in relation to the café, etc.) remain the same. This is what Kuhn denies. According to him, facts from different frameworks (paradigms) would not even be comparable.

(2) This question was answered in study unit 1. To determine what has constituted science throughout history, we have to start out with criteria to enable us to identify science. Hence such a study presupposes certain basic ideas.

STUDY UNIT 6

Scientific development and research programmes: Lakatos and Feyerabend

> **"The history of science refutes both Popper and Kuhn: on close inspection both Popperian crucial experiments and Kuhnian revolutions turn out to be myths: what normally happens is that progressive research programmes replace degenerating ones."**
>
> – Imre Lakatos (2009:518)

OUTCOMES

After completing this study unit, you should be able to

- grasp, appreciate and deconstruct the "problem of development" of scientific theories
- critically scrutinise the Lakatosian "middle path" between Popper's falsificationism and Kuhn's paradigms
- understand the historical context and provide a critique of the "postmodern" anarchism of Feyerabend in relation to philosophy of science

6.1 THE HISTORICAL EVOLUTION (DEVELOPMENT) OF SCIENTIFIC THEORIES

A leading figure among those who have challenged Kuhn's theory was Imre Lakatos.[17] Lakatos radically revised the theory of falsification, incorporating into it several Kuhnian elements without embracing Kuhn's principle of the non-rational transition of paradigms.

Before considering Lakatos's philosophy of science, we should pay some attention to the issue of theory development in science, as well as to the influence Popper and Kuhn had on Lakatos, by exploring their considerations of the idea of development in science.

6.1.1 What is "development"[18] in science?

Much of what is examined in this module is the theme of how science develops, if it does. The history of science and the evolution of scientific theories should enable us to take the stand that science does in fact develop.

17 Imre Lakatos (1922–1974) was an Hungarian mathematician-philosopher.

18 "Development" can be defined as "the progress of growing, changing and progressing ... Development is work done on studying and improving on previous or basic models, designs or techniques" (*South African student's dictionary* 1996:253).

The discoveries and theoretical innovations of Galileo Galilei, for example, were built on his exposure to those who had considered the movements of celestial bodies before him, for instance Nicolaus Copernicus, Giordano Bruno, and Tycho Brahe. In a similar vein, while Albert Einstein brought science far beyond what Isaac Newton could imagine, Einstein nevertheless "built upon" Newtonian physics to reach his "theory of relativity".

Reflecting on the progress and development of science in the sense of theories building upon one another, Chalmers (2009:142) notes:

> If someone wants to deny that Galileo's physics was an advance on Aristotle's or that Einstein's was an advance on Newton's then he or she is just not using the word science in the way that the rest of us are.

6.1.2 Popper and Kuhn on scientific development

In preceding study units, we have considered two of the most notable philosophers of science: Popper and Kuhn. Popper's work is a reaction to the logical positivists, while Kuhn has developed in contrast to Popper. These scholars explored the manner in which scientific theories developed: Popper viewed this development as occurring through the process of falsifying a theory, whereas Kuhn emphasised incommensurable paradigms and shifts between paradigms. For the latter, development is paradigm-specific, providing no reasonable grounds for choice between paradigms, but outlining a very clear development of science within a paradigm.

Popper deemed the aim of science to be intimately bound with its progress: theories develop through the falsification of theories through testing. This theory was the product of his seeking to demarcate the scientific from the non-scientific and pseudo-scientific. Thus Popper argued that, rather than science proceeding from theoretical proof to theoretical proof, it developed through the process of falsifying theories. By proving a theory false, another theory – more capable of making novel predictions and offering explanations – would arise to replace the preceding theory. For Popper, scientific development proceeds in a seemingly negative way, distinguishing science from other systems of understanding (McHenry 2009). Popper (1965:222) formulates it thus:

> [T]his picture of science – as a procedure whose rationality consists in the fact that we learn from our mistakes – is not quite good enough. It may still suggest that science progresses from theory to theory and that it consists of a sequence of better and better deductive systems. Yet what I really wish to suggest is that science should be visualized as progressing from problems to problems – to problems of ever increasing depth.

Scientific progress is, from the Popperian viewpoint, not fundamentally about one theory replacing another theory, although this is what also occurs. For Popper, science progresses from one problem to another problem, and the theory needs to meet the challenge of creating a novel explanation for the particular problem at hand: if it does not, it will be weakened and proved false.[19]

When a theory is assessed for its strength, it will be in terms of how well it responds to explaining a problem (Thornton 2009):

19 Recall that Popper also argued that in the development of a scientific theory, the beginning point is a problem rather than an observation (i.e. the theory-laden nature of scientific theories).

> If ... its explanatory success matches that of the existing theories, and additionally, it explains some hitherto anomalous phenomenon, or solves some hitherto unsolvable problems, it will be deemed to constitute an advance upon the existing theories, and will be adopted.

If not, the theory will continue to be assumed to be false until some corroborating evidence can be found to deem the theory "not false" at this particular moment (McHenry 2009). Progress in science, from Popper's perspective, is fundamentally proving that a particular theory is false as movement occurs from scientific problem to scientific problem, and the response to theories as they arise in an attempt to solve these problems.

Lakatos (2009:516) disagreed with Popper, however, for the process of falsifying theories may not be quite so simple:

> Popper's criterion ignores the remarkable tenacity of scientific theories. Scientists have thick skins. They do not abandon a theory merely because facts contradict it. They normally either invent some rescue hypothesis to explain what they then call a mere anomaly or, if they cannot explain the anomaly, they ignore it, and direct their attention to other problems.

Point to ponder

Was Lakatos's judgement of Popper's falsificationism accurate?

Thomas Kuhn differed from Popper in that he focused on the development of scientific paradigms rather than on the development of the entire scientific enterprise, which he believed the individual paradigms formed part of.[20] And Lakatos (2009:516) differed from Kuhn:

> [I]f Kuhn is right, then there is no explicit demarcation between science and pseudoscience, no distinction between scientific progress and intellectual decay, there is no objective standard of honesty. But what criteria can he then offer to demarcate scientific progress from intellectual degeneration?

Point to ponder

Look up the term "solipsism", and then explain whether or not solipsism is the end product of Kuhnian theory. Give reasons for your response.

6.2 THE METHODOLOGY OF SCIENTIFIC RESEARCH PROGRAMMES (MSRP)

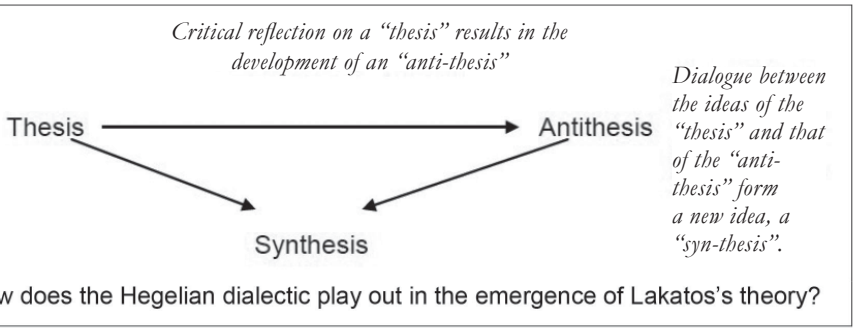
> In the last few years I have been advocating a methodology of scientific research programmes, which solves some of the problems which both Popper and Kuhn failed to solve (Lakatos 2009:516).

20 According to Kuhn, a scientific "paradigm" refers to "the general theoretical assumptions and laws and the techniques for their application that the members of a particular scientific community adopt" (Chalmers 2009:108).

Lakatos saw his theory (the Methodology of Scientific Research Programmes – also known as MSRP) as building upon the falsificationist work of Popper (Folse 2005). His theory was a response to that of Kuhn, but from the Popperian perspective.

Point to ponder

Consider the Hegelian dialectic as illustrated below:



How does the Hegelian dialectic play out in the emergence of Lakatos's theory?

Lakatos attempts in his theory to seek a middle ground between the theories of Popper and Kuhn. He is very critical of Kuhn's vagueness in defining "paradigm", his metaphysical implications, and his view of revolutions as conversions. In addition, Lakatos is critical of the idea of "revolution" in terms of paradigm shifts, which Kuhn proposed as the means through which one theoretical framework is replaced by another. However, Lakatos acknowledges the importance of history in the development of a philosophy of science that acknowledges historical events in science (Bortolotti 2008:126).

He observed that scientists do not reject a theory on the basis of one or even a series of falsifying experiments. He claimed that a distinction should be made between an anomaly (an item, e.g. an observation or an experiment that does not fit the framework of a theory) and a falsifying instance.

A theory is not rejected on the basis of a single experiment, although historians often depict it thus. For one thing, said Lakatos, propositions are never tested in isolation: a test always involves a set of propositions. Moreover, there is always a nucleus of assumptions that are not lightly rejected. If these are rejected, it happens because the falsifying evidence is overwhelming and derives from various quarters, and because an alternative theory is available. Scientists would rather use a theory they know to be imperfect than proceed without a theory. Hence a theory is rejected only in favour of a rival theory.

Regarding progress in science, Lakatos (1998:199) believed that scientific theories are progressive in their nature, as each theory is "a theoretically progressive problemshift" when a particular theory has greater "empirical content" than the theory it replaces. This higher empirical content specifically concerns the prediction of original facts. For Lakatos, a problem shift is both theoretically progressive and empirically progressive, while if no novel discoveries are made as a result of the theory, it may be deemed to be degenerative (1998:199).

The falsificationist theory emphasises progression to such an extent that Lakatos states that if a theory were not progressive ("at least theoretically"), it could not be considered scientific (1998:199). He explains:

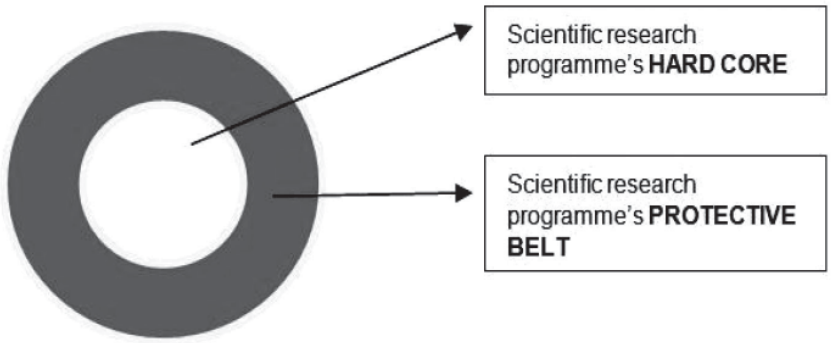
> Progress is measured by the degree to which a problemshift is progressive, by the degree to which the series of theories leads us to the discovery of novel facts. We regard a theory in the series as "falsified" when it is superseded by a theory with higher corroborated content (Lakatos 1998:199).

The continuity or coherence evident in the series of theories derives from the framework of the research programme in which it is constructed. For science to progress, a theory needs to be the product of the falsification of a preceding theory. Thus, theories are built upon the "bones" of older theories that are theoretically and empirically less capable. Science progresses, in the falsificationist understanding, in a great "series" of theories, and theories are not appraised singularly. "[O]nly a series of theories can be said to be scientific or unscientific: to apply the term 'scientific' to one single theory is a category mistake" (Lakatos 1998:199).

Lakatos's methodology emphasises that we should not analyse theories on their own, but rather whole research programmes, as he understands the development of science as a continuous progression – indeed, a process of theories, which differs from "Popper's herky-jerky multiplicity of conjectures and refutations" (Nickles 2001:208).

Science, for Lakatos, was conceived as a "huge research programme", which follows Popper's rule: "Devise conjectures which have more empirical content than their predecessors" (Lakatos 1998:205). Thus, in the development of his methodology of scientific research programmes, Lakatos saw science as cumulative. His focus, however, was not on this broader picture but on the "particular research programmes" that made up the greater endeavour (1998:205).

In analysing scientific research programmes, Lakatos (1998:205) theorised them as comprising a "hard core" as well as a "protective belt". This can be graphically illustrated as follows:



A graphic representation of the "hard core" and "protective belt" of Lakatos's scientific research programme[21]

21 Lakatos (2009:516) explains, using the example of Newtonian science:

> Science is not simply trial and error, a series of conjectures and refutations. "All swans are white" may be falsified by the discovery of one black swan. But such trivial trial and error does not rank as science. Newtonian science, for instance, is not simply a set of four conjectures – the three laws of mechanics and the law of gravitation. These four laws constitute only the "hard core" of the Newtonian programme. But this hard core is tenaciously protected from refutation by a vast "protective belt" of auxiliary hypotheses. And even more importantly, the research programme also has a "heuristic", that is, a powerful problem-solving machinery, which, with the help of sophisticated mathematical techniques, digests anomalies and even turns them into positive evidence.

At the centre of the diagram is the heart of the research programme. These are the elemental principles and laws that "are so fundamental as to come close to being the defining feature of a science" (Chalmers 1999:131). Thus, the "hard core" is what characterises any particular research programme; without that hard core, the character of the research programme would be altered (1999:131). According to Lakatos (1998:206), the core of a research programme is "irrefutable" because of a "methodological decision of its protagonists". The hard core determines both the direction of the research and the problem to which a solution is sought.

While the "hard core" remains unaltered as scientists are developing a particular research programme, what changes – and perhaps more greatly contributes to the development of any research programmes – are the auxiliary hypotheses (the additional reasons that help to tie the core of the research programme to evidence and rational explanation). These arise as a result of anomalies or other observations that demand explanation but may not fit with the hard core immediately.

There are numerous examples from the history of science that illustrate the need for auxiliary hypotheses. One such is the experience of Copernicus (Chalmers 1999:132):

> [T]he hard core of the Copernican program needed to be supplemented by adding numerous epicycles to the initially circular orbits and it was also necessary to alter previous estimates of the distance of the stars from earth.

The auxiliary or supplementary hypotheses were labelled by Lakatos (1998:205) as the "protective belt" that buffers the core of the research programme against any attack in the form of adjustment and testing. The "protective belt" is continuously subjected to tests and adjustments, and at times, the protective belt can be replaced altogether with a new protective belt which still serves to protect the "hard core" but does so better than its predecessor. In this way the research programme contributes to the advancement of science. According to Lakatos, a research programme is successful if it leads to development in the sense of a "progressive problem shift", while if it does not and the problem shift degenerates, the research programme could not be considered successful (1998:205). Revolutions in science, for Lakatos (2009:518), occur as a result of scientists tending to choose progressive research programmes over degenerating ones. It does happen, however, that scientists may choose to retain a degenerating programme.

Again, turning to the history of science, Lakatos (1998:205) uses the example of Isaac Newton's theory of gravity to drive home his point:

> The classical example of a successful research programme is Newton's gravitational theory, possibly the most successful research programme ever. When it was first produced, it was submerged in an ocean of "anomalies" (or, if you wish, "counterexamples"), and opposed by the observational theories supporting these anomalies. But Newtonians turned, with brilliant tenacity and ingenuity, one counter-instance after another into corroborating instances, primarily by overthrowing the original observational theories in the light of which this "contrary evidence" was established. In the process they themselves produced new counter-examples which they again resolved. They "turned each new difficulty into a new victory of their programme".

The Newtonian example emphasises progress in terms of problem shift: new problems are always sought and encountered and are employed to strengthen or change the protective belt. As it strengthens in facing new challenges, the belt better protects

the hard core of the research programme, and science progresses in a falsificationist manner.

Lakatos (1998:206) saw that research programmes should progress on two levels: theoretically and empirically, although he cautioned that, while theoretical progress can be discerned immediately, the same is not true for empirical progress. Indeed, for the latter, progress may be very slow before an auxiliary hypothesis comes to light that better corroborates the hard core of the research programme. For progress to be detected, the research programme must increase its content at every stage of its development: a "consistently progressive theoretical problemshift" is necessary, and from time to time there should also be an increase in empirical corroboration. This is, however, a vague criterion for the evaluation of the progress of science. Nevertheless, Lakatos continues to discern development towards better corroboration between the hard core of a research programme and the auxiliary hypotheses of that programme within science.

When a research programme is no longer anticipating novel facts, and when the corroboration is no longer occurring, it may be necessary to abandon not only the protective belt of a research programme, but the hard core too (1998:206). Lakatos (1998:208) goes on to say:

> It would be wrong to assume that one must stay with a research programme until it has exhausted all its heuristic power, that one must not introduce a rival programme before everybody agrees that the point of degeneration has probably been reached ... The history of science has been and should be a history of competing research programmes ... .

Science progresses not only in the development of auxiliary hypotheses that better protect the "hard core", but also in the abandonment of the hard cores of research programmes and their replacement with other research programmes.

Point to ponder

On what grounds should a research programme be terminated?

You may recall in your study of Kuhn that he did not provide any reasonable grounds for a choice between paradigms (which led to him being accused of relativism) (Chalmers 1999:137). On the contrary, Lakatos sought a standard from science for a "non-relativist sense in which science progresses", that is, an objective standard (1999:138).[22] He proposed:

> [S]uch an objective reason is provided by a rival research programme which explains the previous success of its rival and supersedes it by a further display of heuristic power" (Lakatos 1998:208).[23]

22 Lakatos (1998:208) asked: "Can there be any objective ... reason to reject a programme, that is, to eliminate its hard core and its programme for constructing protective belts?"

23 In his footnotes, Lakatos (1998:211) explains: "I use 'heuristic power' here as a technical term to characterize the power of a research programme to anticipate theoretically novel facts in its growth. I could of course use 'explanatory power'."

Reasonable grounds for the abandonment of a research programme arise from whether or not it progresses or degenerates in terms of novel predictions.[24] Science develops by replacing a research programme which is not progressive in terms of novel predictions and explanations with one that is (Chalmers 1999:138). The "better" research programme becomes the one that, in hindsight, was able to make novel predictions – indeed, one that was better able to corroborate by means of evidence. Hence, Lakatos (1998:208) emphasised that "instant rationality" is unsuccessful, as the development of science occurs over long periods of time, from problem shift to problem shift, which can very often be assessed for progress (especially empirically) only after the event.[25] Therefore, it is only when studying the history of science that Lakatos's Methodology of Scientific Research Programmes can truly be appreciated (Chalmers 1999:144).

Lakatos's theory represents a definite improvement on Popperian "naive falsificationism". Lakatos, like Popper, maintains that ad hoc hypotheses are unacceptable. Hence the need to modify the hypotheses of the protective belt in such a way that the modifications are in turn verifiable.

Point to ponder

Consider the following:

A new astronomical theory predicts a particular observation.

The observation requires instruments, be they optical or radio telescopes. Thus, the facts against which the theory has to be tested, are not given independently, but are based on a particular theory: the theory of light waves (for optical telescopes) or radio waves and electromagnetic phenomena (for radio telescopes).

These theories are, however, independent of the astronomical theory being tested. We accept that the facts used for verification are reliable.

In your view, how would Lakatos explain this scenario?

In contrast to naive falsificationists, Lakatos denies the existence of totally objective, independent facts. For him, a test can at best establish that there is an error somewhere, but we should not take it for granted that it lies in the theory that is being tested.

Another improvement on falsificationism in Lakatos's approach is his acknowledgment that scientists are reluctant to reject a theory whereas, according to naive falsificationism, such rejection should be their aim. Scientists will try to modify a theory to have it to conform to empirical facts rather than reject it. Popper does not consider this. Moreover, Lakatos provides an explanation for the transition from one theory to another. It may be the result of inadequate instruments.

6.3 CRITIQUE OF LAKATOS

There are problems in Lakatos's approach. We will briefly explore some of these.

24 What really count are dramatic, unexpected, stunning predictions: a few of them are enough to tilt the balance; where theory lags behind the facts, we are dealing with miserable degenerating research programmes" (Lakatos 2009:517–518).

25 "As opposed to Popper the methodology of scientific research programmes does not offer instant rationality. One must treat budding programmes leniently: programmes may take decades before they get off the ground and become empirically progressive" (Lakatos 2009:518).

While Lakatos did provide the occasion to replace a research programme with another, he was consistently vague in that, while he provided some criteria as to when to replace a research programme, he did not give clear rules which could assist scientists in making the hard decision as to when to replace a degenerative research programme with a more progressive research programme (Nickles 2001:209).

Lakatos argued that it is not irrational to hold on to a research programme that is degenerating in terms of problem shifts, even if you are aware that the research programme has no hope of becoming progressive again. Furthermore, he thought that there is no obligation to remain loyal to a research programme that you determined is degenerating (Nickles 2001:209).

The choice to abandon a research programme is the choice of the individual engaged in research within that research programme. It is a subjective choice (Folse 2005). This standpoint is interesting given Lakatos's seeking of objective criteria by means of which to choose between research programmes as a direct counter to the relativism of Kuhn's paradigms (his refusal to provide criteria based on which to choose between paradigms).

Still, Lakatos's consistent argument for the development and progression of science within and between research programmes towards better corroboration may subtly provide a rule for the choice between research programmes. As Nickles (2001:209) explains: "The stronger the heuristic, constructive resources – the forward drive – of a program, the better." Perhaps this then is the criterion for choice between research programmes: seek a research programme that best explains the evidence presented.

A further weakness is his contention that the choice of a research programme depends on expectations concerning a theory's future potential. He emphasises that, unless the choice of research programme is allowed to depend upon the theory's potential, every new theory would be stillborn. The best of theories (such as the early beginnings of Newton's theory) cannot, at their inception, account for all the facts, and they make use of simplified models that theorists themselves know to be, in a strict sense, "false".

Copernicus' theory presented scientists with more riddles than the Ptolemaic theory, for example if the earth revolves, why does a stone thrown into the air land at the exact spot from which it was thrown? We would have expected that the earth would have revolved further and that the stone would therefore fall slightly to the west of the original spot. If the earth revolves eastward, why is there not a constant strong wind from the east? To questions such as these, the Copernican theory at first had no answers.

Still, scientists continued to develop the new theory because they believed that in the *future* it would do more for science's progress. Such decisions are difficult, as they imply that we have to act before the information is available. Hence, Lakatos's research programmes cannot be rationally justified until after the event, which means that his proposal is actually no better than Kuhn's. Lakatos defended himself by distinguishing between the practical or psychological facts concerning the choice of a theory and the subsequent logical justification of such a choice.

Point to ponder

To what extent, if at all, is Lakatos's MSRP similar to Kuhnian paradigms?

Lakatos's research programmes are analogous to Kuhn's paradigms. For Kuhn, in times of normal science, the paradigm is inviolable, which also applies to Lakatos's core assumptions (the hard core). Lakatos's degenerating programme at the end of the development of a programme series is similar to Kuhn's crisis in paradigms.

Whilst Lakatos can account for the succession of theories within the framework of a research programme, in terms of the succession of entire programmes he is faced with the Kuhnian problem regarding different paradigms, namely: What determines the choice between frameworks?

Point to ponder

What are the differences between MSRP and paradigms?

For Lakatos, theories can be tested against facts that are independent of the theory tested. He does not accept that facts are completely objective and independent of all theories, but neither does he view them purely in terms of his research programme.

Like Popper, though, Lakatos can distinguish between sciences and pseudo-sciences because he is able to test, and because he makes a research programme a prerequisite. Thus Lakatos holds that sociology and psychoanalysis are not sciences, because sociology has no general framework (research programme) and psychoanalytic theory does not result in test implications.

Lakatos consciously sought a rational reconstruction of scientific research, whereas Kuhn was satisfied in describing scientific development as recorded in history as a *contingent* succession of theories. Kuhn likened scientific development to Darwinian evolution (development without purpose), while Lakatos, like Popper, believed that theories can be evaluated independently and that science is moving steadily closer to truth (Lakatos 1978b:101).

6.4 REALISM AND IDEALISM CONTINUED

Kuhn's paradigmatic theory of science results in relativism or scepticism. Indeed, scientific knowledge in different paradigms cannot be compared, as there are no standards for the selection of paradigms (or even evaluative criteria for the contents of paradigms). Because there are no standards of comparison, neither the transition from paradigm to paradigm nor the conflict between paradigms is based on reason, but on sociological, psychological, aesthetic and personal considerations.

Fundamentally, the issue at hand is the relation between knowledge and reality. Kuhn's position is idealistic, since the mind is conceived as primary: we know reality only as it is constituted by human minds. There are no objective facts and no general standards.

Point to ponder

If reality is a mere mental construct, why do people perceive the same reality about which they communicate through scientific theory?

In Kuhn's estimation, there are no objective standards outside a particular scientific community's paradigm. The paradigm determines the facts in such a manner that a

community's knowledge cannot be related to the knowledge of other communities or tested by standards valid for all communities.

Point to ponder

Consider the controversy between the evolutionists and the creationists.[26] Each side of the debate has its own facts and its own authorities; both are rational. Neither are circular or self-contradictory. The facts invoked are always reliable within its particular theoretical framework.

Would you agree that the members of these two communities are unable to communicate across their respective paradigms? Back your answer up with well-reasoned evidence.

Kuhnian paradigms demonstrate the inability of individual groups of scientists to appreciate the rationality and scientific status of other groups.

Lakatos, on the other hand, maintained that knowledge needs to meet consistent rational criteria. As these correspond with the way the world is, Lakatos's position is congruent with realism. To the realist the world is primary and influences us in such a way that we perceive it.

Point to ponder

How do we know that we perceive the world as it actually is?

The debate between the falsificationists (Popper and, to a lesser extent, Lakatos) and the idealists (e.g. Kuhn) is a continuation of a long-standing problem.

Points to ponder

Which is primary: reality, that is the world (facts, perceptions) or the mind (hypotheses, theories, paradigms)?

If reality is primary, how are theories generated?

If the mind is primary, how can theories be tested?

Whether scientific theories conform to reality, or whether there are no criteria based on which to choose between theories as reality is construed by the scientist, science aims to explain phenomena observed. It attempts to explain phenomena from the perspective of a scientist who brings baggage along to both her observations and her theory construction.

It appears that a more accurate conception of the realist/idealist debate is a position of "both/and" rather than "either/or". Scientific theories are constructed and construed in partially realist fashion because the scientist engaged with "the world". In this encounter, the phenomena and the subjective scientist interact with each other.

26 The "evolutionists" are followers of Darwin's evolutionary theory of natural selection, whereas the "creationists" believe that the Bible book of Genesis should be interpreted literally as scientific fact as to how the world and everything in it came to be.

6.5 FEYERABEND: A CRITIQUE OF METHOD IN SCIENCE

> A truth that reigns without checks and balances is a tyrant who must be overthrown and any falsehood that can aid us in the overthrow of this tyrant is to be welcomed (Feyerabend 1984:138).

6.5.1 Feyerabend against the Popperians and the Kuhnians

Feyerabend may be regarded as a critic of empiricism and of other philosophers such as Popper and Kuhn, due to their acceptance of some or other scientific methodology. For Feyerabend, historical investigation suggests that most successful scientific inquiries have not proceeded in accordance with a rational method.

Feyerabend points out that when a theory conflicts with the facts, the inference that it is the theory that is to blame, is not justified because facts are not somehow pure and uncontaminated by theories. Facts and ideas about them are constituted by older ideologies. The idea of pure observations and a language reflecting them, without any reference to human interests, prejudices and assumptions, is a delusion.

In response to Popper, Feyerabend argues that no non-arbitrary limits can be assigned within which a theory could be allowed to test itself against evidence. Hence he argues that the limits of the "evidence" brought against a theory are arbitrary. Once Popper permitted falsifiability to be modified by the addition of auxiliary hypotheses, he undermined his own theoretical framework, making falsification by evidence arbitrary: a theory can be saved by ad hoc hypotheses.

Feyerabend singles out another of Popper's pronouncements: his modification of the falsifiability criterion, and brings it to its logical conclusion. Thus, no definite frame of reference for criticism is required so that "we may revise even the most fundamental rules and drop the most fundamental demands if the need for a different measure of excellence should arise" (Popper 1962:390). In this understanding, no criterion exists at all. Feyerabend's *anarchistic epistemology* is hence established on the basis of Popper's ad hoc approach.

In his opposition to general criteria for theory selection – whether empiricist or falsificationist – Feyerabend is in agreement with Kuhn. But, Feyerabend cannot accept Kuhn's paradigms as overall theories that dominate branches of science. Feyerabend deems paradigms as constructions that "could only give rise to the most narrow-minded and most conceited kind of specialism" (Feyerabend 1970).

Science is conceptualised by Feyerabend as close to mythology in that it is one of the many forms of thought developed by humans. Standards for theory-choice are themselves abstracted from science. They hence cannot validly be used as neutral arbiters in the dispute between science, myth and religion.

All science is laden with supposition and subjective theory at every level. Feyerabend's criticism of unquestioned scientific method is founded in the inability of theories to be derived from facts because of the layer-upon-layer of theory behind theory-choice, observation, etc.

Point to ponder

What is depicted by a scientific theory?

For Feyerabend there are two disagreements between theory and fact:

(1) *Numerical disagreement*: Certain numerical predictions are made by a theory, but the value obtained may differ from the prediction made by more than the margin of error. For example, Bohr's atomic model was introduced and retained in the face of precise and unshakable evidence to the contrary.
(2) *Qualitative failure*: There are instances of qualitative difference between theory and fact. Newton's theory of colours is an example. According to this theory, light consists of rays of different refrangibility (that which is refractible) that can be separated, reunited and refracted but never change their internal constitution. If we consider that the surface of mirrors is much rougher than the "surface" of light rays, it is odd that mirror images should appear at all. If light consists of rays, a mirror should behave like a rough surface.

Nevertheless, Newton retained his theory by arguing that the reflection of rays is brought about by a power of the body which is evenly diffused all over its surface. Even such ad hoc hypotheses are rarely used according to Feyerabend; scientists usually retain their theories despite contrary evidence. Feyerabend ([1975]1993:50) states:

> Methodologists may point to the importance of falsifications – but they blindly use falsified theories; they may sermonise about how important it is to consider all the relevant evidence, but they never mention those big drastic facts which show that the theories which they admire and accept may be as badly off as the older theories which they reject. In practice they slavishly repeat the most recent pronouncements of the top dogs in physics, even though in doing so they must violate some very basic rules of their trade.

6.5.2 Feyerabend's "method"

> A straight forward and unqualified judgment of theories by "facts" is bound to eliminate ideas simply because they do not fit into the framework of some older cosmology [for example]. Taking experimental results and observations for granted and putting the burden of proof on the theory means taking the observational ideology for granted without having ever examined it (Feyerabend [1975]1993:52).

Evidence, for Feyerabend, does not determine theory validity. Feyerabend sought to establish criteria to evaluate customary concepts and customary reactions such as the aforementioned. This can be done through a new conceptual system. When a new theory clashes with established observational results, problematising the most plausible principles, counter-induction is necessary. The ideological ingredients of our knowledge and observations are discovered with the aid of theories that are refuted by them. Facts contain ideology, that is older views that are not visible or were never explicitly formulated or questioned. In the event of contradiction between an interesting new theory and a collection of firmly established facts, the best procedure is not to abandon the theory but to use it to discover the hidden principles responsible for the contradiction.

Feyerabend identifies two approaches to conceiving of science:

(1) *There are no objective facts.* All facts are viewed in a certain way, loaded with preconceived ideas, theories, etc. From this perspective, the history of science is

as "complex, chaotic, full of mistakes and entertaining as the ideas it contains" (Feyerabend [1975]1993:11).

(2) *Science admits to a logic of discovery*. Of this, Feyerabend ([1975]1993:11) notes:

> [A] little brainwashing will go a long way in making the history of science duller, simpler, more uniform, more "objective", and more easily accessible to treatment by strict and unchangeable rules.

The actions of scientists are accordingly interpreted by means of a "logic" of science, which deems scientists' actions more uniform. Thus, stable and impersonal facts (objective facts) are uncovered, which are assumed to be independent of opinion, belief and cultural background.

Feyerabend cannot support this exclusive scientific method, because:

(1) The world is largely unknown, thus potential findings should not be restricted in advance.
(2) Current scientific education is incompatible with a humanitarian approach in its stifling of individuality (human uniqueness).

Feyerabend criticises the imposition of universal standards and rigid traditions. From his perspective, developments like the rise of modern atomism occurred either because some thinkers decided to be bound by certain obvious methodological rules or because they unwittingly broke with methodological rules.

Scientific decision-making is a political and propagandistic process in which prestige, power, argument and controversy decisively determine the outcome of the struggle between competing theories and theorists.

Point to ponder

Consider the polemical processes that contributed to the emergence of Copernicanism, atomic theory, and quantum mechanics, and thereafter write a summary of your interpretations and understanding.

According to Feyerabend, choices between scientific theories are irrational, for in the emergence of these theories, scientists began to investigate problems before theories had given evidence of inductive support or problem-solving success, exhibited degrees of falsifiability, or yielded novel predictions. Hence there are seldom rational grounds for pursuing a theory that has not been confirmed. Here, then, is a similarity between Kuhn and Feyerabend.

Feyerabend believed that scientific theories are not open to comparison, being incommensurable. Thus it is impossible to prove that any theory, paradigm or research programme triumphs over another. Still, Feyerabend proposed that traditions of scientific research succeed one another, because the history of science is a succession of different worldviews. No worldview, however, is any more rational than another.

In the Feyerabendian approach, the only criterion for theory choice that is defensible, is that there are no criteria at all! Anything goes! The continued success of scientific discovery is the result of freedom from any dominant paradigm, coupled with an openness to use whatever procedure seems to fit best (Einstein in Feyerabend [1975]1993:10):

> The external conditions … which are set for [the scientist] by the facts of experience do not permit him to let himself be too much restricted, in the construction of his conceptual world, by the adherence to any epistemological system. He, therefore, must appear to the systematic epistemologist as a type of unscrupulous opportunist … .

Point to ponder

How is Feyerabend's anything-goes approach compatible with the rigorous, methodological natures of scientific traditions in practice?

"Counter-induction" for Feyerabend is the process adopted and employed by the anarchist epistemologist (one who has embraced opportunistic, anything-goes scientific "methodology"). By this Feyerabend meant the introduction and expansion of hypotheses that are inconsistent with established theories or facts, because the evidence that may refute a theory can often only be unearthed through incompatible alternatives. The same counter-induction is true for understanding, too (Feyerabend [1975]1993:21):

> A scientist who wishes to understand [the empirical content] of the views as clearly as he possibly can must introduce other views, i.e., he must introduce a pluralistic methodology. He must compare ideas with other ideas rather than with experience and he must try to improve rather than discard the views that have failed in the competition.

Knowledge, Feyerabend ([1975]1993:21) argues, is theorised as

> an ever increasing ocean of mutually incompatible alternatives, each single theory, each fairy-tale, each myth that is part of the collection forcing the others into greater articulation, and all of them contributing via this process of competition, to the development of our consciousness.

Point to ponder

Feyerabend has blurred the distinction between science and other belief systems. Is the approach of, for example, a traditional healer, therefore equally justified as the empirically founded approach of a medical doctor?

By comparing science and other belief systems, Feyerabend claims that neither is superior to the other. Science, too, is a belief system because people believe the claims made by science.

Feyerabend has indeed identified commonalities to all belief systems. However, this does not imply any equivalence among such systems. Science need not necessarily be any more objective in revealing facts about the world than systems of superstition. But scientific theories qualitatively explain and quantitatively predict phenomena with a very great degree of accuracy. A distinction can be made between science as a system of beliefs and other such systems on this very basis, as other belief systems cannot empirically explain or predict to this extent.

Still, for Feyerabend, as many alternative theories and worldviews should be entertained as possible. He claims that the invention of alternatives to the theory

examined is part of the empirical method. If empiricism requires empirical content to be increased, it is logical that this requires a theory to cover as wide a range of phenomena as possible. Feyerabend argues, however, that the relevance and the refuting character of decisive facts can be established only with the aid of factually adequate theories that do not agree with the theory being examined. The proposal is thus made that the generation of alternatives that are inconsistent with the theory being examined is essential for theory construction and scientific practise. He thereby rejects the consistency condition and the inductive process in theory development, demonstrating that they exclude valuable tests that could indicate the limitations of existing theories.

For Feyerabend, the apparent success of a theory as conforming to nature should not suggest that it actually does correspond with nature. Rather, its "success" suggests that the theory has been turned into rigid ideology. The "rigid" theory is successful because facts that may have constituted a test of that theory have been removed. Additionally, the facts that do "support" a theory are the facts that the theory has helped reveal.

Feyerabend concludes that the most adequate theoretical system consists of a set of partly overlapping, factually adequate but inconsistent theories. In his view, multifarious theories are beneficial to science, while uniformity impairs its critical power and endangers the free cognitive development of the scientist. The variety of opinion is necessary for knowledge, and the only method compatible with a humanitarian approach is one that encourages diversity.

Point to ponder

What is implied from Feyerabend's claim that variety is required in knowledge production, and hence that all methods work equally well?

That "anything goes" implies that there are no universal standards and no regularities about the scientific enterprise. There are, therefore, no facts about nature, despite the fact that nature itself exists in order for theories to exist. The assumption made is precisely the opposite: there are no regularities to be discovered in nature or in the modes of exploring the natural world, designing experiments, testing theories about nature, etc. When "anything goes", fundamentally everything is gone, and science ends in a relativistic quagmire of nothingness!

REFLECTION

(1) Why do Kuhn and Lakatos need the concepts of a paradigm and a research programme respectively to explain the thought and actions of scientific researchers? Do we need something of this nature to account for the behaviour of people in everyday life?
(2) Compare the theories of Lakatos and Kuhn. Could we apply their theories to their own views? Substantiate your answer.
(3) According to Feyerabend, value systems are embedded within claims to "fact". Do you agree with Feyerabend? Give an example in support of your answer.
(4) If Feyerabend's position is correct, namely that no fact is free of presupposition, is the scientific attempt to be objective nullified?

FEEDBACK ON REFLECTION

(1) Researchers work according to certain common (shared) criteria, which is partly what we mean when we call science "objective". Hence some stability is necessary to evaluate something in the light of received knowledge. When one explains behaviour in everyday life, such a paradigm is provided by the accepted pattern of customs and norms in a society.

(2) Attempts were made to apply the views of Lakatos and Kuhn to their own theories – in fact, if Kuhn was right in saying that Aristotle's world and ours are incommensurable, then Kuhn himself would be unable to make this point. As for Lakatos, his naive falsificationism and subsequent attempts to improve on it have collectively been described as a series of theories in the form of a research programme.

PART D

A NEW WAY FORWARD FOR PHILOSOPHY OF SCIENCE?

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STUDY UNIT 7

Socially relevant philosophy of science: feminist and African philosophy of science

> **"A scientist, an artist, a citizen is not like a child who needs papa methodology and mama rationality to give him [sic] security and direction; he can take care of himself, for he is the inventor not only of laws, theories, pictures, plays, forms of music, ways of dealing with his fellow man, institutions but also of entire world views, he is the inventor of entire forms of life."**
>
> – Paul Feyerabend (1978:38)

OUTCOMES

After completing this study unit, you should be able to

- identify the place and the relevance of philosophy of science in and to society
- appreciate and critically consider the presence and impact of power in knowledge systems
- indicate the importance of the feminist critique to the scientific project
- contextualise the study of science in the African reality and experience

7.1 INTRODUCTION

Feyerabend's ([1975]1993:21) appeal for a pluralistic methodology of science wherein contradicting theories are given space and honoured, directly supports liberationist intellectual movements apparent in discourse from the 1960s to the present.[27] Systems of knowledge have come to be highly contested areas wherein dominant paradigms are challenged, especially by those who propose that the dominant paradigms do not adequately reflect their theoretical frameworks. Moreover, in many cases dominant paradigms have become part of – and thus contribute towards – systems of power and oppression.

Science, and its philosophical counterpart, philosophy of science, have traditionally been imaged as not only disconnected from social realities but disinterested in them. As the progenitors of science, humans who are social animals, are also the creators of social realities in which they consistently find and define their being. Science should therefore relate to social realities and their associated problems.

This means that a socially more relevant philosophy of science should be articulated – one that better relates to the lived experience of science's human creators. This implies a direct challenge through multiple systems of knowledge to the positivist tradition, in which the empirically unquantifiable is disregarded, and is a direct response to Feyerabend's challenge posed in study unit 6.

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27 Here we think of African philosophy, Latin American liberation theology, Black theology, and so on.

A socially relevant philosophy of science attempts to resituate itself within human existence in all its fullness and variation, recognising formerly ignored ethical and political considerations (Fehr & Plaisance 2010:302). Rendering philosophy of science socially relevant would draw attention to three dimensions or themes of the scientific enterprise:

(1) The dimension or theme of *public welfare*, which would include biomedical ethics, race issues, genome research and the like (2010:302).
(2) The dimension or theme of *stakeholder groups* with an interest in science, especially the marginalised or underprivileged; for stakeholders and science have a mutual impact on one another (2010:303). Among such stakeholder groups could be included women and people of colour, both of whom have been subjugated by traditionally "male" and "white" scientific practices. Given our context, we will focus on philosophy of science becoming socially more relevant specifically in relation to women and Africa.
(3) A third theme concerns *making the work done by philosophy of science more widely known*, to the extent that it might have an impact on policy development and the practice of science (2010:304).

The process of developing a philosophy of science with a bearing upon society is not one that would entail adding anything to philosophy of science. Instead it would entail conducting a critique of philosophy of science, in such a way that particular epistemologies (e.g. feminism and African philosophy) would be given occasion to challenge the status quo as well as scientific practice.

Point to ponder

Can you identify any areas where dominant paradigms within science impede alternative systems of knowledge?

Lisa Gannett argues "that philosophers of science tend to approach questions of biology and race as a natural kinds problem" (Fehr & Plaisance 2010:306). As a result of this reductivism, social and political issues relevant to race and racism have come to be ignored due to the belief that all answers lie in biology (2010:306).[28]

Point to ponder

To what extent can race be reduced to either biology or social constructivism?

The problems of race and racism, so evident in South African society because of its colonial and apartheid history, reveal the complex societal factors that contribute especially to the identification of the "other" and of the emergence of racist ideology. Hence race can clearly not be reduced to biology alone.

Here we have only one example that illustrates the fundamental importance of employing differing epistemologies to challenge the conclusive worldviews influenced by the dominant, mostly Western and "white", scientific paradigms. It could be argued that philosophers of science, as both professionals and citizens, are compelled to use

28 "[T]hese approaches tend to dichotomize race as being either biologically real or socially constructed, which does not allow for interactions between biological and social factors" (Fehr & Plaisance 2010:306–307).

their philosophical expertise to transform science in becoming better connected to the human experience through critical analysis (Fehr & Plaisance 2010:312).

We now turn to two epistemologies that have confronted the dominant scientific paradigm, thereby adding to the disputed space of scientific practice.

7.2 FEMINIST PHILOSOPHY OF SCIENCE

> **"What we need are more feminist scientists, feminist historians, feminist philosophers and feminists in every discipline."**
>
> – Sue V Rosser (1987:13)

7.2.1 Feminism as socially relevant discipline

> **Point to ponder**
>
> From your past experience within different disciplines – and from your general knowledge – define "feminism".

"Feminism" is both a worldview informing perspectives and an interest group that insists "that women's rights and opportunities should be equal to those of men" (*South African student's dictionary* 1996:350).

Feminism is therefore more than just a group of individuals who hold opinions contrary to that of the dominant group; it is a movement geared towards lasting and real change to relieve the plight of women in society. Any feminist perspective is socially relevant, as it is aimed at the emancipation of a subjugated social category of people.

The following definition of feminism focuses on the content of the Feminist movement (Rich in Namenwirth 1986:18):

> Feminism means finally that we renounce our obedience to the fathers and recognize that the world they have described is not the whole world. Masculine ideologies are the creation of masculine subjectivity; they are neither objective, nor value-free, nor inclusively "human". Feminism implies that we recognize fully the inadequacy for us, the distortion, of male-created ideologies, and that we proceed to think, and act, out of that recognition.

> **Point to ponder**
>
> List some examples of general areas of human experience in which male dominance is heavily apparent.

In the context of the practice of the sciences it is clearly apparent that men dominate. A commonly provided (stereotypical) explanation for why there are so few women compared to men in the scientific professions argues that men are simply "better" at science and mathematics than women!

This, for some, is evident in the overwhelming male domination among the winners of the Nobel Prize, as well as in the majority of high achievers in science being male (Machin & Pekkarinen 2008:1331). In an analysis of boy-girl differences in the 2003

Programme for International Student Assessment of the Organization for Economic Co-operation and Development, which involved 15-year-old boys and girls engaged in full-time or part-time education in developed countries, Machin and Pekkarinen (2008:1331) found some rather politically incorrect results. When analysing reading scores, it was found that girls scored better than boys. However, in terms of mathematical performance, boys appeared to outperform girls (2008:1332). Inductively extrapolating these results, Machin and Pekkarinen (2008:1332) conclude: "These results imply that gender differences in the variance of test scores are an international phenomenon and that they emerge in different institutional settings."

Point to ponder

Can the generalisation validly be inferred that girls do better in reading and boys in mathematical/numerical tasks?

A recent research project entitled "Debunking myths about gender and mathematics performance" (by Jonathan M Kane and Janet E Mertz) does just that, thus flying in the face of the study by Machin and Pekkarinen (Kane & Mertz 2012:10–21). Kane and Mertz argue that, if differences in the mathematical abilities of male and female children are determined by biological variances, then – roughly speaking – these differences should be present across the world, regardless of cultural context (2012:10).

An analysis of the statistics of recipients of doctoral degrees in mathematics in the United States since the 1960s has shown an increase in female recipients from 6% to 30%, which provides clear evidence of women's mathematical abilities (2012:10).

Whilst there are researchers who propose that the difference in the mathematical ability of boys and girls narrows as a result of decreases in equity between the sexes, Kane and Mertz (1012:11; 18) found that, as equity increases, so do the mathematical abilities of both boys and girls. Of course the quality of education plays a role, but the disparity between the mathematical abilities of boys and girls in developed countries shows that "females have now largely reached if not exceeded parity with males" (2012:18).

Hence it is concluded in this study that mathematical differences between boys and girls are not the product of biology or even income, but rather of equity between the sexes (2012:19). Hence bringing about equity has become the feminist *raison d'etre*.

The masculinity of many worldviews – and of the assumptions and paradigms undergirding the Machin and Pekkarin study cited above – demonstrates the degree to which science is theory-laden and thus value subjective (Tuana 1996:17). It is important to draw attention to the fact that the scientist does not operate in isolation from cultural and societal norms (1996:17).

Within the context of science practice, which informs the philosophy of science, feminists in the field have attempted to demonstrate "the dynamics of gender and oppression in the theories and method of science" (Tuana 1996:17). Feminist philosophy of science therefore explores how pervasive gender prejudices are in science, favouring all things masculine and patriarchal. Richardson (2010:337) writes:

> Feminist philosophers of science have worked to advance the status of women in the science professions, to critique and correct sexist science, and to critically evaluate our models of scientific reason and practice in light of the findings of gender studies in science.

The relationship between gender and knowledge continually needs to be plumbed further, in order to ensure that gender inequality is countered in all spheres of human existence, including that of science (Grasswick 2011:xiii).

> **Point to ponder**
>
> What impact may the omission of women from science have had on the history and development of science?

7.2.2 Feminist science studies and feminist philosophy of science

Feminist philosophy of science was founded in the period of the 1960s to the 1970s, within the broader feminist movement of the time, particularly from the area of feminist science studies (Richardson 2010:338). Due to its male-dominated approach in the 1970s, science was an area of particular concern for feminist scholars (2010:341):

> In the 1970s, science was not only an institution that appeared hostile to women in its professional ranks and deeply implicated and entrenched in a history of providing ideologically-motivated support to sexist theories of gender difference. It was, more broadly, a generative locus of threats to the legitimacy of feminist work in the academy.

In its earliest forms, feminist science studies was critiqued by scientists on three grounds:

(1) *Feminism is only relevant to women*: Some scientists could not accept that the focal area of feminist science studies as a universal discourse was issues relating to women only. This reduced science, it was assumed, to focusing solely upon women (Richardson 2010:341).

> **Point to ponder**
>
> To what extent does the feminist critique as a liberation-inspired ideology impact on more than just women?

(2) *Feminism is ideologically motivated*: Because feminist science studies must be ideologically motivated, it does not approximate the objectivity required for science (Richardson 2010:341).

> **Point to ponder**
>
> Is ideological neutrality possible in any event?

(3) *Feminism has no methodology*: Feminism provides no epistemological methodology for its scholarly work, and is hence not scientific (Richardson 2010:341).

The levellers of this criticism fail to recognise the essence of the feminist engagement with science: that it is positioned as a critique of what is purported to be objective, value-neutral and white, male-dominated scientific practice (2010:342). Feminist appraisals of science do not end in critique, however, for they attempt to contribute to the generation of a more liberating science, by "refiguring the very terms we employ to speak of core epistemological concepts" (2010:343). This is achieved by beginning from the context of the marginalised, those who find themselves – in the context of

science – existing on the periphery, who can only be liberated from oppression by turning to the politics of emancipation of peoples who are suppressed (2010:346).

7.2.3 Science from a feminist perspective

It has been argued by Nancy Tuana and Sandra Harding that, from the perspective of feminist epistemology, a richer critique of science occurs from the particular perspective of women scientists. From this perspective, it may be possible for unique dimensions of science to be highlighted (Tuana 1996:18). Of course, from within the feminist viewpoint, the role of the social context of the scientist is to be given maximal attention, as its influence upon the scientist's work is paramount to the final product (1996:19).

From the beginnings of science, the social influences affecting it have been patriarchal, in other words male, such that it "became burdened and distorted by a pervasive male bias" (Namenwirth 1986:19).

Point to ponder

Make a list of stereotypical masculine traits that exclude women.

Traditional Western society expected boys to be clever, strong, autonomous leaders. Complex disciplines such as science, philosophy, law, etc. would be their domain, while women, who were expected to be softer, gentler, more caring and nurturing, would stay away from analytical pursuits (Namenwirth 1986:19; Fee 1986:44–45). McCormack (1981:2) lucidly describes this negative attitude towards women and science:

> In an earlier period when the essential quality of the scientific mind was defined as analytic ability, women were thought to be unintellectual, deficient in reasoning ability. Warm and sensual, they were damned with faint praise for their allegedly "natural" gift of intuitive insight, a desirable but clearly a lower level of skill ... .

Francis Bacon (1561–1626) considered science to be "masculine", and historically it was practised along the lines of "men's only" clubs (Richardson 2010:349). With dominant white, male ideological backing, science maintained the interests of this particular group in scientific experimentation and the interpretation of these findings (Namenwirth 1986:25). Nevertheless many scientists perceived their own practice as ideologically, politically, and gender neutral (Namenwirth 1986:29):

> Isolation from political and cultural influence is thought to be essential for achieving scientific objectivity. Scientists think of themselves as totally rational, neutral beings who have no political agenda and neither interest in, nor responsibility for, the ways in which their research is interpreted or utilized by society.

With its ideological overtones, many scientists have considered feminism a movement to steer clear of: it was thought that the value-ladenness of feminism could contaminate the neutrality and objectivity of science. In its actualisation, however, science is not neutral: when one considers the numerous occasions on which dominant political ideology has employed scientific practice, the opposite is true (Namenwirth 1986:29).

The history of science is an interesting domain in which to detect the interaction between "nature, culture, power, desire, and ideology" (Richardson 2010:349).

> **Point to ponder**
>
> The "race science" (also referred to as "eugenics") of pre-Germany and Nazi Germany was utilised to support the political agenda of Hitler and his party. Ponder the value-laden practices with which this "science" was imbued. Summarise your thoughts in 200 words.

From colonialism through Nazism and to apartheid, scientists were as much influenced by societal and cultural phenomena as all other people. This will surely also recur in other instances of oppression that are yet to come (Namenwirth 1986:29). Scientists exist within social settings and are formed and educated by those settings (1986:35).

A massive issue for many scientists in contemporary times is where funding for their research will come from. Of course, if research meets the expectations of funders and of society, funding becomes more readily available. While it may be a generalisation, scientific funding tends to come from the dominant wealthy, and the resultant research mostly aids that same group (1986:34). Funded research is hence plainly value-laden.

Arguing that women emerge from an existential experience quite different to that of men, the feminist critique of science demands that science itself should change (Fee 1986:46). Women conceive of reality in a unique way, they perceive themselves differently in relation to reality, and are more connected to emotions (1986:47):

> [W]hether consciously articulated or not, women carry the seeds of an alternative ontology, epistemology, and ethics. While Western culture legitimizes only masculine ontologies, epistemologies, and ethics, the alternative epistemological assumptions making up women's world view remain subversive possibilities.

> **Point to ponder**
>
> From the feminist perspective, can you think of some "alternative epistemological assumptions" that may inform and challenge science as it is "traditionally" done? (Fee 1986:47) Write these down in 200 words.

7.2.4 Themes of feminist philosophy of science

Against the background and basic positioning of feminist philosophy of science, we turn to a few central themes of this emerging branch of philosophy of science.

7.2.4.1 Gender bias

Feminist philosophy of science – originating in the female perspective – exposes the gender bias present in science (Richardson 2010:346). This may take the form of gender discrimination, dominant gendered assumptions, etc., which have resulted in scientific findings being interpreted in particular ways, for example being expressed in a gender-biased manner (Richardson 2010:346).

Point to ponder

In the works *Evolution's rainbow* (2004) and *The genial gene* (2009), Stanford Biology professor, Joan Roughgarden, explores evolutionary sexual selection (Richardson 2010:347):

> According to the theory of sexual selection, first proposed by Charles Darwin ... females choose mates among males who compete with one another for female attention. This model of mating behaviour is used to explain everything from why males in some species develop exuberant male ornamentation ... to the greater role of the female in rearing offspring, to the supposed female preference for monogamy and male instinct for promiscuity.

What gender biases do you detect in this "scientific" explanation?

In the view of Roughgarden as explained by Richardson, the theory of sexual selection is heavily weighted with gender bias. She reconfigures Darwinian "sexual selection" as "social selection", whereby reproduction not only entails mating, but also bonding and the rearing of young (2010:347). In this reinterpretation of observed behaviour, the masculine bias present in the Darwinian explanation of "sexual" selection is challenged in such a manner that the male is no longer at the centre of all action.

7.2.4.2 Feminist epistemology

A feminist epistemology involves the complexity and vastness of the entire person (Fee 1986:47). The emotions, reason, creativity, history, etc., all of which form the person, are engaged in science. In every sense, feminist epistemology is holistic, which is manifested in its removal of dichotomies and its localisation of the subject within its context, not as apart from the object of scientific investigation (Fee 1986:47):

> [N]o rigid boundary separates the subject of knowledge (the knower) and the natural object of that knowledge; where the subject/object split is not used to legitimize the domination of nature; where nature itself is conceptualized as active rather than passive, a dynamic and complex totality requiring human cooperation and understanding rather than a dead mechanism, requiring only manipulation and control.

Hence feminist-informed scientific knowledge in its holism serves to promote liberation, as opposed to the exclusionary, male dominated, "traditional" science, which has contributed to so much oppression, as we have already seen (1986:47). All of this is founded in the theory, which is supported by "post-Freudian psychoanalytic object relations theory", that women indeed view reality differently from the way in which men view it (1986:48).

Point to ponder

How does your gender shape the ways in which you acquire knowledge and know things?

7.2.4.3 *Knowledge and power*

As feminist epistemological accounts focus on developing a critique of dominant epistemologies and on supporting the proliferation of alternative epistemologies, the core issue concerns power relations in the production and dissemination of knowledge (Fee 1986:48). Power relations transcend gender, however, and feminist epistemologists must include "race, class and sexuality into their analyses" (Grasswick 2011:xv). Hence, feminist epistemology becomes fully liberatory in always having a preferential option for people at the periphery of society (2011:xv).

Indeed, moving beyond gender-based domination is a result of the realisation that gender does not exist alone, but forms part of an entire network of societal realities in which there are both dominant and marginalised groups (2011:xv):

> [T]he socially underprivileged need to understand the world from the perspective of the dominant class who has the power to set the rules of engagement in order to survive. But the socially underprivileged also understand the world from the perspective of their experience of oppression.

Knowledge is always produced from the context of the person who is engaged in its production, and that person's ideological position influences the knowledge that is produced. The knowledge produced by someone who is oppressed, will contain traces of oppression, often unknown to that person. At other times, knowledge produced by a member of an oppressive group will be oppressive in nature.

Point to ponder

Do power relations, manifest in interchanges between the oppressor and the oppressed, exist in your knowledge systems? Explain your answer in 150 words.

7.2.4.4 *Situated knowing*

A scientist is first a person, and the activity of science is a human one. There is thus no escaping the humanity of science, and all that comes along with that humanity – not only reason, but history, emotion, bias, etc. The contextualisation of knowledge ("situated knowing"), is – according to Grasswick (2011:xvi) – the most influential idea that has emerged from Feminism. This concept may be grasped in the simple maxim: "[O]ne's social location (gender being one such dimension) both shapes and limits one's knowing" (2011:xvi).

Point to ponder

Pinpoint some dimensions of "situated knowing". How do these aid or hinder your ability to know? Write them down in 100 words.

If knowledge production is value-laden, a problem arises for the traditional conception of science as value-free, objective, etc. (Grasswick 2011:xvi; Tuana 1996:22). Grasswick (2011:xvi) offers the dichotomous solution that either feminist philosophers of science should reject objectivity outright or reconceive objectivity in terms of scientific practise. Either way, science must change its conscious understanding of its situated producers!

An analysis of the positivist tradition, in which it was thought that scientific objectivity, unbiased empirical research and clear rationality was exemplified, reveals underlying normative positions (Tuana 1996:22–23). Indeed, the theory and value-ladenness of scientific theory and practice is apparent even in observation, the first step in the development of positivistic science, for "[f]ar from being the neutral receptor or static mirroring of the visual metaphors informing traditional accounts of knowledge, observation is a dynamic process of organization in which our bodily being plays a central role" (Tuana 1996:28).

Realistically science is merely partially objective, many subjective factors being involved in knowledge evolution (1996:30).

Point to ponder

How does your embodied being influence how and what you know? Explain.

7.2.4.5 Ethics and epistemology

As a result of human activity, situated knowing has important ethical considerations, and feminist philosophers have paid particular attention to the ethical implications of knowledge. Never neutral, knowledge is ethical in the ways in which it is obtained, produced and applied, and especially in its impact on other people and the environment (Grasswick 2011:xviii). Knowledge is not simply the result of observing and recording without distortion of sensory observation.

The feminist philosopher of science challenges scientists to generate "ethically sound knowledge" (2011:xix). Considering the often troubled history of scientists' involvement with political and economic systems of oppression, as discussed, ethics is a particularly relevant topic to be considered.

Point to ponder

In the light of the feminist critique of "traditional" science, define "ethically sound knowledge".

7.2.4.6 Novel questions

From the experience of marginalisation, women who engage in philosophy of science are able to uniquely question science (Richardson 2010:348). With the focus on gender issues in science, feminist philosophy of science can reformulate its central themes by asking new/novel questions (2010:349).

Whilst traditional philosophy of science has often been removed from the complexity of humanity, feminist philosophers can reconsider and question the embodied nature of science, the possibility of objectivity, the sociology and ethnography of science, etc. (2010:349). Within these novel sorts of questions, exploration can occur without fear of loss due to being too tightly bound to a particular conception of science.

Point to ponder

Explain how science is a social practice or endeavour.

7.2.5 Challenges for feminist philosophy of science

Feminist philosophy of science is confronted with several points of criticism and with certain challenges.

> **Point to ponder**
>
> From your reading and reflection on the issues brought to the fore by feminist philosophers of science, can you identify any challenges or points of critique?

7.2.5.1 Marginalisation of women

Feminist philosophy remains at the margins of many of the more "elite" areas of intellectual concern. This situation is compounded by the exclusion of some women from permanent academic posts, from some publications, and from the curricula of philosophy courses at universities (Richardson 2010:350–351). Gender issues are oftentimes considered intellectually not sufficiently stimulating, or are completely sidelined from consideration (Richardson 2010:351).

> **Point to ponder**
>
> Does the marginalisation of feminist philosophy of science mimic the continued marginalisation of women and other minorities in society in general?

7.2.5.2 Oversimplification

The critical stance of feminist philosophy of science towards the manner in which science is practised, particularly in terms of gender bias, tends to be oversimplified by those outside this specialised field of enquiry (2010:352). This oversimplification has been labelled a "problem of translation" (2010:353).

Scholars like Gross and Levitt, for instance, have translated or interpreted the feminist critique as being "anti-scientific", and as exhibiting a general "hostility to science" (Gross & Levitt in Richardson 2010:353). This attitude towards feminist philosophy of science has become manifest in three ways (Richardson 2010:353):

(1) Because feminist philosophers of science deem science discriminatory towards women, it is claimed that they seek to detract from science or to undermine it.
(2) It is pointed out that some scientific discoveries are denied by feminist scholars. (Richardson uses the example of differences between men and women identified by means of biological studies.)
(3) The traditional values of science, such as neutrality, objectivity, rationality, and the like, are disregarded by feminist science studies.

> **Point to ponder**
>
> In your study of the topics of feminist philosophy of science, have you perceived any evidence of any of the aforementioned points of critique? If you have, provide details.

7.2.5.3 Social context of science

Though gender bias is a central theme of feminist philosophy of science, it is not the sum of what this branch of philosophy of science is about (2010:354). The feminist conception of science should therefore not be reduced to this alone.

Richardson (2010:355) proposes that part of the problem of stereotyping feminist philosophy of science in this manner is that it implies "an idealized, progressive picture of science – in which unbiased, value-neutral science is the ideal". Hence, in overcoming gender bias, science would be imaged as becoming value-free, an end to which all scientific pursuits should be directed (2010:355).

Feminist philosophy of science does not, however, pursue such neutrality in the practice of science: it conceives of science as a value-laden social product (2010:355). The emphasis on the value-ladenness of science remains a core factor in feminist philosophy of science, since it believes that it is never possible for the scientist to escape from values in this human activity (Richardson 2010:355):

> [T]his model [of feminist philosophy of science] suggests that we ought to focus on understanding scientific practices in their full social dimensions, and conceiving and developing normative discursive and critical methods and approaches for the sciences.

7.2.6 Feminism as a radical epistemology

Feminist philosophy of science is not alone in critiquing dominant perspectives on science and its actualisation. So too do the epistemologies of former colonial countries (e.g. in Africa, Asia and Latin America), as well as those of marginalised groups (e.g. the proletariat). For the most part, the science that feminists identify as "masculine" is identified by the proponents of other epistemologies as "white", "colonial", and "Western" (Fee 1986:50).

Historically, "traditional" science has been the product of men in Europe (and North America) over the past four centuries (1986:52). "[I]t is [thus] European and also male, and white, and bourgeois: it is also a historical creation with boundaries in time" (1986:53). Logic dictates that critical discourses that resemble one another should touch on one another: both feminist and liberatory epistemologies of marginalised peoples/groups direct their critiques of the oppressive nature of science to the same reality (Fee 1986:53):

> Each of these critiques addresses one set of dominant/dominated power relations articulated and reproduced within scientific knowledge, reflecting the unequal power relations in the social world; the critiques thus undermine the scientific legitimation of those dominant/dominated relations.

Point to ponder

Explore how multiple power relations play out in the social practice of the production of scientific knowledge.

As a product of social beings, science is generated with the input of numerous value factors: masculine, white, European or, in neo-colonial countries, where new dominant groups have emerged or are emerging, their particular value factors. The complete story of dominant value systems within science is hence not covered by the feminist critique alone (Fee 1986:54). Given the colonial and apartheid history of Africa, and specifically of South Africa, it is essential that the African critique of "traditional" science be given space.

7.3 AFRICAN PHILOSOPHY OF SCIENCE

> **"Is there any common ground between African and Western science? ... Yes, there is a common ground ... the scientific method."**
>
> – Nwankwo Ezeabasili (1977:88–89)

7.3.1 The colonial legacy in science

The successes of science are oftentimes entirely attributed to "the West", creating "a false superiority over other forms of knowledge and a real power hegemony of the west over other peoples" (Okere 2005:20). With this hegemony[29] has also come a sense of inferiority among "non-Westerners". The fact that the term "science" has its etymological roots in the Latin word *scientia* contributes to science being understood as a peculiarly Western concept and practice (2005:22).[30]

In their ancient Greek meanderings into *scientia* (although, of course, their activities predated the advent of Latin, hence of the term *scientia*), Plato and Aristotle articulated that science, or "knowledge of the true", was knowledge of being, obtained by grasping the four causes of that entity's being (Okere 2005:23).[31]

The Western model of science was later delineated further, for in the 17th century Copernicus, Kepler and Galileo viewed science as concerning only matter or entities that could be explored mathematically. Hence, the only "truly" scientific disciplines came to be understood as astronomy, physics and chemistry, for these all deal with quantifiable entities, and only the quantifiable could be scientific (2005:23):

> Only elements that yield to measurements and give information on the quantitative aspects of material phenomena are concerned with the real world. Only they relate to the objective world and only they can yield science.

Point to ponder

You will recognise these 17th century attitudes as forerunners to the positivism of the 20th century. Whilst they did lead to extraordinary developments in the human understanding of reality, what has been the cost of this conceptualisation of science? Is the entirety of reality quantifiable? Put differently, can everything that is real be counted and/or measured? Explain in detail.

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29 The Merriam-Webster dictionary (2013b) defines "hegemony" as "the social, cultural, ideological, or economic influence exerted by a dominant group".

30 Okere (2005:22) explains that "scientia" can be defined as: "a special activity or mode of being of man by which man relates to reality from the perspective of the truth, truth here meaning somehow getting at reality as it is."

31 The "four causes" as identified by Aristotle (Physics, Book II, Part 3)** are:

(1) the "material cause": "that out of which a thing comes to be ... e.g. the bronze of the statue, the silver of the bowl ..."
(2) the "formal cause": "the form of the archetype, i.e. the statement of the essence ..."
(3) the "efficient cause": "the primary source of the change ... e.g. ... the father is cause of the child ..."
(4) the "final cause": "'that for the sake of which' a thing is done, e.g. health is the cause of walking about".

"Western"-dominated science originated in a time and environment that predated the practice of modern science. Its historical origins are to be found in the "East versus West" declaration of the Emperor Constantine (in the period 272–337), whereby Constantinople became the Eastern capital of the Roman Empire in the year 330 (Okere 2005:23). Rome remained the Western capital of the Roman Empire for many centuries.

The division between "East" and "West" deepened along religious rather than political lines with the extension of Islam to Western Europe, whereby countries as far west (geographically) as Spain and Portugal were Islamised (2005:23). During the Islamic conquest of the Iberian Peninsula in 711 CE under Tariq ibn-Ziyad, Islam spread throughout most of that Peninsula.[32] Together with Hinduism and Buddhism, Islam is labelled as "Eastern", whilst the Judaeo-Christian faith tradition (and worldview) is regarded as "Western" (2005:24).

Due to global colonisation and migration, what was previously geographically "Western" now covers Europe and North America, as well as geographically "Southern" nations such as Australia and New Zealand. "Western" has therefore become more of a cultural concept than a geographical one, where the common factors defining "Western" are "the old European, Western Christendom ... stretching backwards historically and spiritually to appropriate Greco-Roman civilization ..." (2005:24).

In the science of the "West" clearly limiting itself to the measurable, that is the quantifiable, it has progressively deemed a huge portion of knowledge outside of its field of relevance. Okere (2005:27) explains, rather succinctly, that Western science "has become more a science for the materially useful and less the science in quest of the true, a know-how rather than a knowledge". In its favouring of particular forms of knowledge inquiry, this "science" has in fact pitted itself against what it deems "unscientific", to the detriment of the complexity of the human experience (2005:27).[33] For, in its utility, "science" has been employed to enforce Western power over "non-Westerners", even to the extent of denigrating the knowledge systems of the latter, silencing them, declaring them "obsolete", or removing them completely (Okere 2005:28; Okere, Njoku & Devisch 2005:5).[34] These were the actions of both the colonial and the Christian missionary movements in all parts of the African continent, whereby the Enlightenment knowledge of the West was brought to "civilise" Africans (Okere et al 2005:5).

In an extraordinarily conciliatory tone, Okere, Njoku and Devisch (2005:5) argue that the educational systems of the colonial powers did have positive aspects too:

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32 Islamic Spain (711–1492).

33 A critique of "Western", modern science points out a number of flaws apparent in this dominant system. In the first instance, science alone as a knowledge system is not able to adequately grasp the complexity of reality or the diversity of humanity (Okere 2005:29). Its objectivity is challenged, even by the mere fact of its existence as a human, subjective enterprise (Ogunniyi 1988:4). This is exacerbated by disagreements and inconsistencies within Western science, for instance in both mathematics and physics (Okere 2005:29). The universality, objectivity, and all-encompassing ability of science are all challenged (2005:29; Ogunniyi 1988:4). Hence science needs to include other systems of knowledge that may facilitate our understanding (2005:29). This necessitates reclaiming previously marginalised intellectual traditions (2005:29).

34 "'Modern science' reinscribes the Eurocentric dichotomy between the dynamic, progressive sciences of the North and the static, historically unchanging traditional knowledge of other cultures. Only the North carries forward the trajectory of human history, for the cultures of the South have only static, unchanging tradition, this contrast implies" (Harding 1997:49).

> It indeed initiated young Africans into a groping dialogue with the West, its literature and technological development, by making the western texts, histories and world views and technical skills accessible to them primarily by the breaking down of the linguistic barrier.

The cost, however, was the elimination of alternative epistemologies to those propagated by colonial schools in guiding the minds of African children from their intellectual heritage (2005:5–6). In imposing new colonial languages upon these children, a severance occurred: elders and sages could no longer pass their age-old wisdom on to colonially "schooled" children. Moreover, the teaching of foreign disciplines in foreign languages had dire consequences for many local languages and local knowledge systems. The history of mad King George III of the United Kingdom (1738–1820), for example, or of Queen Victoria (1819–1901) (who was not only Queen of the United Kingdom and "Empress" of India, but "Queen" of many African countries despite never having set foot on African soil) was completely irrelevant to the people to whom it was being taught. Local history and systems of knowledge were ignored, for the focus was always on what was happening in the "mother" country . The belief was instilled in young Africans by colonial authorities through colonial educators that, prior to the arrival of the colonisers, "no valuable education had been taking place" in Africa (Okere et al 2005:6).

Whilst movements to "Africanise" post-colonial African countries proliferated in African countries, especially in the 1970s (one may think of Nyerere of Tanzania's policy of *ujamaa* [Ibhwawoh & Dibua 2003:62] or Mobuto of Zaire's *Zairianization* [Kabemba 2001:6]), local knowledge systems remain devalued (Okere et al 2005:8). The dominant knowledge systems for governments, international funding and aid agencies, and for institutions of research and higher learning, remain in the colonial mould of maligning indigenous systems of knowledge (2005:8). Sadder still is that liberated African leaders in all spheres continue to uphold the beliefs of their former colonial masters (2005:10).

Points to ponder

When thinking about "science", what are your ideas concerning its history?

Identify some areas of life, whether educational, economic, political, etc., where African worldviews dominate.

7.3.2 Scientific knowledge and Africa

So, while "modern" science is identified as Western and successful, traditional systems of thought are seen as alternative and unscientific (Ogunniyi 1988:1–2). In the historical development of this belief, however, lies the distortion of the integrity of traditional knowledge, for within its own context, African thought is a logical system (1988:3). It is therefore essential that perspectives not biased towards Western science should be given consideration!

A worldview is understood when the parts comprising that worldview and the manner in which it makes sense to those who hold it, show logic and consistency. When one considers a notion of causation in African thought, it is plainly obvious that it has been conceptualised according to a different logic to that of causality in Western science (1988:3). This does not necessarily imply, however, that the African conception is illogical or unscientific.

Point to ponder

Do any traditional African accounts of phenomena spring to mind that Western science would regard as superstitious falsehood?

Consider the following scenario. A man drowns after attending a party where he drank excessively. The scientific, specifically medical, explanation for his death is that he died as a result of suffocation due to his lungs filling with water. However, the traditional African explanation would be inclined to seek answers to the question regarding what blinded the man from seeing the danger of the swollen river. After all, he knew the river well and had crossed at that particular place many times.

There is nothing illogical about the traditional African response to the issue presented, in that, rather than simply identifying and possibly solving the problem through scientific means, broader causal and teleological issues are posed.[35] It could be argued, hence, that in the traditional African mindset, more philosophical questioning is in fact espoused than the mere identification of problems. In the given example, the paramount question is why this fate befell the individual involved. In fact, both the philosophical themes of chance and necessity are examined here; the African person would be interested in considering explanations regarding both chance and necessity, as opposed to the Western scientific explanation, which deals with only chance, and where events simply occur at random for no reason.

Point to ponder

How would you respond to the Western critique that the African argument for necessity is an oversimplification of complex realities?

For African ontologies, there is no separation between natural and supernatural explanations; indeed, they conceive only of a "homogeneous order of things" (Hallen & Wiredu [sa]:1). If reality is deemed to be homogenous, it should be emphasised that not only are there no supernatural explanations, but there are no solely natural explanations either ([sa]:2). In the aforementioned examples, accounts that are interpreted by Westerners as natural or supernatural are seen by African people as multiple explanations of singular phenomena.

This stance is clarified by Hallen and Wiredu in considering the etymology of the Akan word for "nature", namely abode ([sa]:2).[36] Abode, however, refers to "created things", and includes the spiritual realm. Hence nature includes that dimension of the real that Westerners would conceive of as supernatural ([sa]:2).[37] The supernatural is caught up in the natural, the natural in the supernatural.

This is further revealed in Akan cosmology, in which the Creator (Odomankoma) is conceptualised as having created order, knowledge, and death ([sa]:5). The Crea-

35 Refer to the glossary at the end of the study guide for the meaning of the term "teleological".

36 Speakers of the Akan language are to be found predominantly in Ghana, but also in the Ivory Coast. The example thus serves as an illustration of an African worldview.

37 In his famous work *African religions and philosophy*, John S Mbiti (1970:5) explains this by saying that "no line of distinction is drawn between the spiritual and the physical" in traditional African thinking.

tor brings order, which lays the foundation for the cosmos, about which knowledge is concerned: "With order comes knowable objects and knowing subjects" ([sa]:6).

Physical reality is imaged as a direct product of the action of the supernatural, which is seen as intertwined with the created order. An awareness of the role of the Creator does not preclude scientific or technological development, however, for Africans have developed tools, weapons, and accounts for their observations ([sa]:7).

Point to ponder

To what extent do Western worldviews include notions of the "supernatural"?

Western colonial powers employed their scientific advancements in the subjugation and oppression of African peoples, for instance, with the use of artillery and other weaponry. Since Africans historically had scientific and technological knowledge, it might be natural to pose the question: "[W]hy was science not developed to great heights at the time of the fateful encounters between Africa and her eventual colonizers?" (Hallen & Wiredu[sa]:8).

Some believe that the reason for this is that Africans were obsessed with spiritism, and attached great importance to the roles of the ancestors, who needed appeasement using witchcraft, etc. This does not adequately explain, however, why the West developed as it did scientifically, understood in the Western sense, since spiritism was and remains present in many Western countries. Consider the massive influence of the Judaeo-Christian faith tradition upon the worldview of Western Europeans, as well as that of the continued influence of superstition, fortune telling, astrology, witchcraft, and the like, among Westerners. In other words, the acknowledgement of a spiritual realm and its trappings does not exclude scientific activity ([sa]:8).

Hallen and Wiredu ([sa]:9), dissatisfied with the above explanation, propose a more plausible account – the mathematical nature of science:

> [I]f a culture does not … rely on writing, the chances of developing and sustaining the mathematization of knowledge are low. Although indigenous systems of writing are reported in various African cultures, writing does not seem to have become a way of life among a large enough proportion of their populations.

Point to ponder

In this argument, writing is equated with mathematical skill by the authors. Do you agree or disagree with this necessary correlation?

Developing mathematics, Hallen and Wiredu ([sa]:9) argue, and communicating it to other people, necessitates the abstraction and grouping of elements. For peoples with more artistic temperaments, "the direct avenue of an art motif" may be preferred for developing meaning, rather than the abstraction of mathematics required for a Western conception of scientific knowledge.

Point to ponder

Generalised to the whole African continent and its peoples, would you say that Hallen and Wiredu's proposal is somewhat unfair? Explain.

Our authors present a second argument which may explain Africa's lagging in terms of Western scientific development when compared with the West, namely that many African cultures reject reliance upon "second-hand" knowledge ([sa]:10). Propositional knowledge, that is information that individuals usually do not test themselves – such as knowledge obtained from the sciences – is proposed and accepted by other people, on the basis that the propositional knowledge is reasonable. In the Yoruba culture of Nigeria, however, knowledge may only be obtained first-hand, that is, by the subject himself or herself ([sa]:10).

Point to ponder

For the most part, scientific knowledge is assumed to be true because it is presented as truth by scientists to lay people who are not subject experts. Do you possess any scientific knowledge that is not second-hand?

Reliance on another's knowledge, for the Yoruba, is considered to be naive, for such knowledge has not been observed and reasoned over by the individual. The truth of second-hand knowledge claims would be considered possible at best, but never certain ([sa]:12)! It could thus be argued that part of the reason for science having developed at a slower rate in Africa is because people have been wary of relying on the "facts" discovered by others, tending to rely more on individual observation and experience.

The scientific knowledge of both the Akan and Yoruba peoples – as examples of African peoples – was evident in the use of specific terms and systematic modes of reasoning and argumentation. However, rather than being recorded in writing, as scientific knowledge was in the West, this knowledge was kept within the oral traditions of the peoples ([sa]:16). Another example of written scientific texts, however, would be those documents so recently under threat of destruction in the libraries of Timbuktu, Mali.

As Okere (2005:31) indicates, assuming that all science needs to be performed in the Western mode is a theory-laden value stance!

Point to ponder

Consider knowledge held by means of oral traditions. Some have proposed that this is not "scientific" knowledge, a position prejudiced by particular approaches to the definition of "science". Do you agree?

7.3.3 The false dichotomy between Western "science" and African thought

In his well-cited article, "African traditional thought and Western science", Robin Horton (1967:50) provides a critique of the Western presupposition that African thought precludes scientific activity. This assertion is founded in the frequent failure among Westerners to perceive science in African thinking. Horton hence proceeds to critique this position by identifying numerous overlaps and similarities between these two human endeavours, namely Western science and African indigenous knowledge systems. Let us take a closer look at these, with a view to investigate how "unscientific" African thought possibly is.

7.3.3.1 Theory construction is the systematic seeking of order in nature

In the development of theory, human beings innately seek order in the natural world in a systematic manner. Of course, this occurs in a world filled with complexity and a multiplicity of experiences, which means that order is not always readily perceptible (Horton 1967:51).

Amidst this complexity, Western scientists have developed theories of subatomic particles, atoms, waves, etc. – models that impose order on what would otherwise be extraordinarily complicated (1967:52).

Point to ponder

The chair you are sitting on is made up of innumerable subatomic particles, atoms, etc., which from the perspective of quantum mechanics are in a state of superposition that is neither wave nor particle, but both wave and particle, until the collapse of the wave/particle function. Consider the difficulty in grasping this reality without a representation of order through the use of scientific models. Explain.

In his research into African cosmologies, Horton (1967:52) has identified a similar form of modelling, whereby a systematic explanation (a "scheme") is developed as a result of the varied daily experiences of ordinary people. These are then reduced, as with atoms, molecules, etc., into "relatively few kinds of forces", which in the instance of the Nigerian Kalabari, are imaged as "ancestors, heroes, and water-spirits": "Like atoms, molecules, and waves, then, the gods serve to introduce unity into diversity, simplicity into complexity, order into disorder, regularity into anomaly" (1967:52).

Point to ponder

If science is a representational system, whereby terms are assigned to represent dimensions of reality to perceivers and then arranged logically and systematically, could the Kalabari cosmological system described above be regarded as "scientific"?

7.3.3.2 Theory places reality in a bigger context than common sense

Each day, an individual has many particular mundane experiences, and identifies reasons for them in a common-sensical fashion. However, in the process of theory construction, the common-sensical experience of the particular is transcended by extension into a broader context. Therefore, the physicist does not remain stuck in her ponderings alone, but places them, in the development of her theories, into the setting of nature more generally (Horton 1967:54).

In a similar way, the theoretical considerations of an African who conceives of her world in a traditional manner may be labelled by Westerners as "supernatural". However, what she in fact does, is to push out from the particular experience of the "supernatural cause" into the natural world itself by seeking explanations for natural occurrences (1967:54). The terminological approach employed by the thinker shapes the nature of the theory that will be construed (1967:54–55). Horton (1967:55) goes on to say:

> [M]ost traditional African cultures have adopted a personal idiom as the basis of their attempt to understand the world. And once one has adopted such an idiom, it is a natural step to suppose that personal beings [e.g. spirits, gods, forces, etc.] underpin, amongst other things, the life and strength of social groups.

Point to ponder

"Are these traditional notions of cause merely artefacts of the prevailing theoretical idiom, fantasies with no basis in reality? Or are they responses to features of people's experiences which in some sense are 'really there'?" (Horton 1967:55). Explain your views, interpretation and understanding.

While medical treatment of illness in the West took a particularly positivist approach, that is, one of precise empirical identification of illness of the body, more traditional approaches have always focused on holistic treatment. One could think in particular of Indian *ayurvedic* medicine or traditional African medicine. In both of these, the emotional situation of the person concerned is seen to impact upon the body, and vice versa. The human being is viewed as a whole rather than as separate and unrelated parts.

It is intriguing to note then that, since the 1960s, Western medical professionals have begun to acknowledge that a person's psychological state impacts on and even intensifies his or her physical illness (Horton 1967:55). Indeed, such traditional medical approaches can no longer clearly be categorised as "unscientific", in that the realities posited by traditional healers could very well be real, since they impact on an individual's health.

It can be concluded, therefore, that although traditional African thought is interested in natural causes, its articulation simply differs from that of Western science. Since it is therefore not possible to place African traditional thought in opposition to Western science, this should be declared a falsehood (1967:58):

> [T]he contrast [between Western science and traditional African thought] is misleading because traditional religious theory clearly does more than postulate causal connexions that bear no relation to experience. Some of the connexions it postulates are, by the standards of modern medical science [as illustrated in the example on p 167], almost certainly real ones. To some extent, then, it successfully grasps reality.

While Horton does not seek to replace Western science with African thought, he emphasises that the scientific approach is not the only means by which to obtain knowledge. African thought includes empirical and explanatory dimensions, which could aid better understanding when coupled with the dominant scientific tradition (1967:58).

7.3.3.3 Theory ties in with common sense

Science needs to make sense to those who believe in it. Horton proposes that the same relationship that exists between common sense and science in the West, exists in Africa too. In support of this contention, he uses the example of a person suffering from an illness, who is first treated by herbalists. Usually the traditional

medicine will help, for example, when a person suffers from a cold or some other common illness. To cure the problem, no appeal will be made to anything outside the "ordinary", such as spiritual forces (1967:60).

If the illness does not respond to herbal treatment, however, it could be that there is more to the illness than a mere physical malady. It would be at this point that the person would approach a "diviner": "Using ideas about various spiritual agencies, he will relate the sickness to a wider range of circumstances – often to disturbances in the sick man's social life" (1967:60).

If the common-sense treatment of the sick person does not result in healing, the reasonable action would be to look beyond the ineffective treatment (1967:60).

Point to ponder

Give an example of treatments for ailments in the West in which common-sense approaches are not effective and alternative treatments need to be considered.

Western belief systems are also not without appeal to the miraculous. In the Catholic Christian tradition, for example, miraculous cures are often sought at shrines such as Lourdes in France, Fatima in Portugal, and Ngome in KwaZulu-Natal. Such options tend to be explored when common-sense approaches are not effective. Exploring alternative means of healing cannot be regarded as irrational, however, as it makes logical, reasonable sense to pursue good health.

7.3.3.4 Theory employs analogical reasoning

Scientific methodology necessarily involves the use of analogy, that is, comparing the unknown with what has already been experienced: the known. Without this comparison, the unknown cannot be conceived of, since it has to be conceptualised in terms and concepts that are already known before anything new can be generated. In traditional theories of science, following the use of analogy, a model can be developed "in which something akin to the familiar is postulated as the reality underlying the unfamiliar" (1967:64).

Indeed, whenever scientific reasoning is employed, analogy is used. The observed is stated in terms of *what it is like*. Hence, the atom – as a model of something that is – is, in fact, an "it is like" type statement. The entity *is like an* atom. Later, it may indeed turn out to be like other entities that are deemed to be "atoms". But at the initial moment, the phenomenon must be conceived of as what it most resembles, in the light of the limited available knowledge.

Similarly, African traditional thought employs analogical reasoning in its scientific dimensions: perceived realities are conceptualised by means of analogy to what they most resemble, "homely everyday experiences", such as spiritual entities, gods, or whatever (1967:64). This is no different to imaging an atom analogically as a ball, for example. The realness of the entity postulated about in the scientific theory is not removed in the analogy; instead, the analogy is simply a means to conceptualise and speak about a dimension of reality.

Point to ponder

In his work, Ezeabasili (1977:48) explores many instances of African science. The following describes the Nigerian Ibo's understanding of the female gynaecological problem of uterine fibroids:

> There is a disease known in Ibo as *ajienyi* ... which is held responsible for a great majority of miscarriages and infertility in women. *Ajienyi* means literally "the elephant's loincloth". It is supposed to be a worm of some sort. This is how an expert traditional healer described it: "Inside the woman's belly (womb) the child is enclosed in a sac like the globe of a kerosene lantern. The child is in the middle and is surrounded by a liquid. A boy is shaped like a lizard, and a girl is like a frog. If a pregnant woman is suffering from *ajienyi* the worms go into the womb and pierce the sac, so that all the liquid gushes out and this results in miscarriage."

Identify the analogies used, whereby everyday items and occurrences are used to explain more complex phenomena.

Of course the use of analogy has its limits. Analogy does not explain the thing as it is, but only conceives of the thing as akin to something already known. Therefore, analogous reasoning in science does not entirely explain a particular phenomenon. We could also consider the example Horton provides – that of the molecular theory of gas. In this theory the model of gas is imaged as "fast moving, spherical balls in various kinds of space" (1967:65). The entity of the ball is not completely carried over analogically to that of the molecules that make up gas; their colours and the other attributes of the molecule are not exhausted by the image of the ball, for instance its size (1967:65).

The success of analogical reasoning in the development of scientific models is founded on the extension of certain overlapping characteristics of the two entities brought into an analogical relationship (1967:65). The limitations must always be borne in mind, however.

Once again, Horton (1967:66) argues that there is an overlap between the use of analogy and African thought (as we have already seen in the above example):

> [J]ust the same [analogical] process is at work in traditional African thought. Thus, when traditional thought draws upon people and their social relations as the raw material of its theoretical models, it makes use of some dimensions of human life and neglects others ... It is the result of the same process of abstraction as the one we see at work in Western theoretical models: the process whereby features of prototype phenomena which have explanatory relevance are incorporated into a theoretical schema [that is, into a scientific theory].

The commonalities between Western science and traditional African thought that we outlined above, appear to supersede two commonly held assumptions, namely that:

(1) science must be conceived of in a Western manner
(2) Africans have lagged behind in scientific theory development

Both these negative assumptions, the one regarding the limitation of science and the other regarding the capabilities of African people to think scientifically, can

therefore be challenged (1967:69). The form of reasoning labelled "scientific" in the West existed in Africa prior to the advent of colonialism. Indeed, it is from our study of the commonalities between the two that we can assert the existence of African scientific thought (Ezeabasili 1977:xi):

> By African science I mean an African account of nature and how it works. This account contains hypotheses, many of which are not acceptable to men [sic] of Western culture. The testing ground of all sciences (African and Western science) is utility. For example, without the discovery of antibiotics, the germ theory of disease is nothing but folklore of Western science. In the same way also, it would be idle of us, black Africans, to imagine that peoples of other cultures will easily accept our theories of matter if we cannot produce practical results to back up our theories.

7.3.4 All science is local knowledge

The knowledge generated by any group of people is unique, as it is influenced by many factors that inform and form that setting (Okere et al 2005:1). All knowledge production can thus be said to be local, and all knowledge as a result is necessarily the product of its locality (2005:3). In this sense, "local" includes the shared dimensions of culture, history, religion, language, economic situation, and the like, which links people in a shared experience of reality. Okere, Njoku and Devisch (2005:3) explain:

> The particular local ... indicates the active creative originality of vital contexts and networks, the originary well-springs of that given people's endogenous ability to shape and manage their world, generation after generation ... .

It is absolutely coherent, therefore, to assert that knowledge is forever a result of the context from which it is produced, from which the local people approach understanding the world within which they find themselves (2005:4). We may put forward that all science is in fact "ethnoscience", implying that the core values of "Western" science, namely objectivity, universality, etc., are fundamentally flawed assertions revealing the context out of which they are produced (Harding 1997:45).

Point to ponder

Consider to what extent science can be labelled objective, universally valid, impartial, etc., if all scientific activity is the outcome of contextualised scientists.

Given the contextualised nature of science, Harding even proposes that claims to universal validity, objectivity, etc., are localised claims of virtues held in high regard by particular cultural groupings (in Okere et al 2005:45).

Point to ponder

Identify some of the European/Western cultural trappings presenting in "Western" science.

The scientific culture within which Western science emerged, was a dominantly Western European one, in which scientists, for the most part, shared the same broad cultural vision. The dominant epistemology and theoretical tools, indeed the paradigm within which science was done, was imbued with this culture (2005:52). That

science was seen as the sole means to knowledge, could well have been a remnant of the conquering force and colonising power behind European expansion into Africa.

For example, the virtue of science being value-free, which was regarded so highly by Western science, was a manifestation of the European cultural milieu in which science was done (2005:56). Harding (in Okere et al 2005:56) readily identifies it as peculiarly European, indicating the link between Western science and European culture:

> [T]rying to maximize cultural neutrality, as well as claiming it, expresses a culturally specific value. Most cultures do not value neutrality; they value their own Confucian, or Indigenous American, or Islamic, or Maori, or, for that matter, Judaic or Christian values.

Point to ponder

How do dimensions of culture manifest themselves in scientific research?

The concerns and orientations of particular cultural groups are imbedded within the practices of the scientists in their midst. Hence, if a particular grouping finds itself in a desert location, the desert will impact on the sort of knowledge produced, and the key concern will be, for example, the finding, preserving and conserving of water, the scarcest resource. Other interests might be of a political or social, nature (Harding in Okere et al 2005:58). Another example was that of the Eugenics research undertaken by Nazi Germany scientists, which was directed by the racist ideology of the German state of the 1930s and 1940s.

While knowledge emerges out of a particular context, this does not mean, however, that it has no impact outside of its locality (2005:59). It is possible for science to transcend its locality and have relevance beyond it. Of course, the fact that science is produced by people of locally diverse contexts, such as Europeans, Asians, Africans, Jews, Muslims or Christians, implies that it can transcend locality (2005:61). That said, it should be emphasised that there has been wide agreement between these scientists, mostly because, despite their diversity, most of these scientists have been practising science in a European/Western manner. The influence of science among people belonging to different cultural groupings is a direct result of its effectivity in modelling and articulating natural laws (2005:62).

Point to ponder

Should science exclude alternate explanations of phenomena that could also be valid if the observed phenomena were conceived of in a different manner? Explain.

7.3.5 Compatibility of African and Western science

Within theoretical constructions of African traditional thought, which is conceptualised completely differently from Western "local knowledge", Western science may be pitted as opposing African knowledge systems (Ogunniyi 1988:5).

Points to ponder

Is African local knowledge compatible with Western local knowledge? Give reasons for your response.

Does embracing a scientific perspective mean that Africans must abandon their traditional worldviews? Substantiate.

Indeed, the conceptual framework of the African knowledge system – that is the manner in which its conceptualisation occurs – differs from that of the Western conceptual framework. "Science is based on a mechanistic explanatory model, while the traditional world view is based on an anthropomorphic explanatory model" (Ogunniyi 1988:6).

Where in Western models, forces, waves, etc. may be proposed as underlying particular phenomena, as we have seen, in the African conception the explanation may refer to spirits, non-mechanistic forces, etc. The two approaches may in fact not be as far removed from each other as is assumed, however. Ogunniyi (1988:6) argues that traditional accounts for phenomena do contain scientific explanations, and that among African peoples both scientific and traditional worldviews can be held simultaneously. Simply put, where one knowledge system fails or does not adequately explain, the other may come to the fore (1988:6–7). Coupled together, a more complete understanding of the human experience of the self and the natural reality becomes possible (1988:7).

As cultural beings contextualised within their environments, Africans should be cautious to abandon their cultural affiliations for the sake of what has been presented as incompatible with their own worldview, namely Western science. Hence, for Western science – a dominant dimension of daily reality – to have more impact, and indeed, to achieve success in Africa, a way needs to be found for these two worldviews to work in tandem (1988:8). If this does not happen, science – in its Western guise – may remain superficial to the lives of African people. Such a lack of consideration of the African context would be perceived as further contributing to the entrenchment of oppression in various forms in Africa, particularly through exclusion from certain knowledge systems.

If the challenges to "traditional" positivistic accounts of science – such as those proffered by what is deemed "the West" – by schools of thought such as feminism and African philosophy should be taken seriously, Feyerabend's call for alternative epistemologies would be heeded. In paying careful attention to these epistemologies, it will become apparent that an understanding of *the (singular) way* things are is always an understanding from the perspective of particular human beings. It reflects the worldview, culture and limitations of the theory constructors. Hence the absoluteness of any particular theory should always be called into question, as phenomena that are observed can always be accounted for in numerous, pluriform, and contested ways.

REFLECTION

(1) In what ways should philosophy of science become socially relevant? Why is this important?

(2) Feminism is a critique of the dominance of patriarchy, in this instance in the practice of science. Determine to what extent this discrimination is apparent in science.

(3) Describe the notion of "African science".
(4) The colonial impact on the practice and further development of science in Africa has been extreme. Explore the commonalities that exist between all local sciences.

CONCLUSION

> **"Multiple hypotheses should be proposed whenever possible. Proposing alternative explanations that can answer a question is good science. If we operate with a single hypothesis, especially one we favor, we may direct our investigation toward a hunt for evidence in support of this hypothesis."**
>
> – Campbell, Reece & Mitchell (1999:14)

In this module, you have been exposed to considerations about the history, development, purpose, problems, etc. of science in practice from the perspective of philosophy of science.

Having considered the themes of objectivity, the approaches to science of positivism, Popper, Kuhn, Lakatos, Feyerabend, as well as feminism and African philosophy of science, you should now be aware of the contested nature of claims to knowledge. In its functioning, data acquisition and interpretation and theory selection, science is not a smooth process that is unhampered by discord.

Most importantly, this philosophy of science module challenges you to be particularly aware of the many and varied human factors that play a role in the development of scientific theories, which are, after all, the activities of human beings. These include cultural, ideological, religious, linguistic and political influences, which reduce the possibility of a unified, objective, standardised science dealing uniformly with theoretical constructions about phenomena.

Any absolute claim to knowledge that rejects and negates counter-theories should be openly questioned and confronted. Philosophy of science *must oppose* theories that reject a plurality of accounts of phenomena. Indeed, the very nature of scientific theory development is tentative: as theories emerge that better explain certain phenomena, less effective theories are replaced. Science essentially would appear to be the historical process of the emergence of contested ideas. And so it should be, so that people may discover an ever better understanding of the reality in which they find themselves.

GLOSSARY

ad hoc hypothesis: An hypothesis constructed specifically to protect a theory, or another hypothesis, from rejection.

auxiliary hypothesis: An additional assumption to allow us to infer a test implication from a hypothesis.

cosmology: The philosophical and scientific study of the origins and destiny of the universe.

confirm: A general statement is confirmed every time it applies to a concrete empirical situation. For example, "All ravens are black" is confirmed every time a black raven is observed.

corroborate: A hypothesis or theory is considered to have been corroborated once it has survived stringent tests. Hence a well-corroborated theory is one that we have good reason to accept.

counterfactual statement: A conditional, subjunctive statement, the antecedent of which is pure supposition: "If p were the case, then q would follow."

crucial experiment: An experiment that determines conclusively whether a hypothesis is acceptable or not.

deductive argument: An argument in which the denial of the conclusion is contradictory to the affirmation of the premises.

deductive-nomological pattern of explanation: This amounts to Popper's and Hempel's conception of explanation, namely as a deductive argument, the premises of which contain one or more laws.

deductivism: Deductivism (or hypothetico-deductivism, or falsificationism) distinguishes between the *discovery* and *justification* of hypotheses and theories. The creation or discovery of a hypothesis is not a matter of methodology (logic). As for justification, according to deductivism a general hypothesis or theory can only be falsified, not verified.

epistemology: The philosophical study and development of theories pertaining to knowledge.

experimental law: A directly verifiable or falsifiable law of nature containing no theoretical terms.

explanans: That which is offered by way of explanation.

explanandum: That which has to be explained.

falsificationism: See "deductivism".

falsifying: Rejection of a hypothesis (more generally a proposition) on the grounds of unfavourable empirical evidence.

feminism: An ideological movement seeking to ensure that the rights and prospects of women are equivalent to those of their male counterparts in all dimensions of life.

functional explanation: An explanation referring to a function or operation to which the phenomenon to be explained contributes.

human sciences or humanities: Human sciences or humanities are concerned with the way in which people think and behave, for example literature, history, language and philosophy.

hypothesis: An assumption used as a basis for argument or research.

hypothetico-deductivism: See "deductivism".

idealism: The view that the mind is primary and that "external reality" is a mental construct.

incommensurable: Two items are incommensurable when they cannot be compared because they lack anything in common; they belong to different contexts. For example, "red" (a colour) and "square" (a shape) are incommensurable properties.

inductive argument: An argument with at least one contingent premise and a contingent conclusion, denial of which does not logically contradict acceptance of the premises.

inductive-probabilistic pattern of explanation: An explanation in the form of an inductive argument, the premises of which contain a statistical or probabilistic law.

inductivism: The view that we approach reality without preconceptions, observe this neutral reality and, through rational induction, build up scientific knowledge.

metaphysics: A discipline within philosophy that focuses on theories of reality.

methodology: The study of scientific methods and of the concepts and assumptions on which the sciences are based.

natural law (law of nature): A statement expressing a regularity in nature.

natural sciences: Sciences concerned with studying the physical world.

observational statement: A statement of which the truth or falsity may be determined by means of a limited number of direct observations.

observational term: An expression referring to directly observable objects, events or properties.

ontology: A subdiscipline of metaphysics wherein notions of being/existence are investigated.

operational definition: A specification of a procedure to decide whether a given expression is applicable to specific instances, or to determine the numerical value of a given quantity.

operationalism: The view that a scientific concept is synonymous with the corresponding operational definition, and hence that the meaning of a concept or a word consists in a particular verifying procedure.

paradigm: Generally "pattern" or "typical example"; in philosophy of science a way of looking at phenomena; the general framework within which a scientist operates.

philosophy of science: The study of the systems of concepts, the methods and explanations applicable in scientific practice. Also see "methodology".

prediction (scientific): A statement about future events or conditions that is corroborated in the same way as nomological explanations of past events.

rational reconstruction: A logical (re)interpretation of the history of science proposing a distinctive rational (logically acceptable) pattern for the growth of scientific knowledge. The expression originated from Lakatos.

realism: The assumption that theories can describe the world as it really is; that they refer to entities existing in reality. The world is assumed to exist independently of our perception.

reductionism: The contention that sophisticated, complex matters may be reduced to familiar, simple things. In the theory of science, the assumption that every theoretical term may be defined by means of observational terms.

relativism: Denial of the existence of absolute standards.

research programme: A structure acting as a guide to research, characterised by (1) a conventionally accepted and hence inviolable core of basic assumptions, (2) a protective belt of replaceable auxiliary hypotheses, and

	(3) rules or instructions for further development of the programme.
science:	A discipline that is aimed at the growth and systematisation of basic knowledge about the natural and physical world.
scientific explanation:	An explanation of why certain things occur, supported by theories and empirical facts. A scientific explanation must be testable.
scientific prediction:	See "prediction (scientific)".
technology:	The application of scientific knowledge to control nature.
teleological explanation:	An explanation that refers to the future purpose of an event or situation.
test implication:	A deductively inferred, implicative proposition used to test a hypothesis empirically.
theoretical entity:	An object or phenomenon that can only be observed indirectly. Information about its existence is derived theoretically.
theoretical law:	A law of nature with a theoretical background.
theoretical term:	An expression referring to indirectly observable entities, events or properties.
theory of science:	See "philosophy of science" and "methodology".
verification:	Definite confirmation of a hypothesis (more commonly a proposition) on the basis of observations.
verification theory of meaning:	The theory that a proposition is meaningful if it is verifiable.

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