NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF ARTS AND SOCIAL SCIENCES

COURSE CODE: GST105

COURSE TITLE: HISTORY AND PHILOSOPHY OF SCIENCE

COURSE GUIDE

GST 105
HISTORY AND PHILOSOPHY OF SCIENCE

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INTRODUCTION

GST 105 'History and Philosophy of Science' is a one semester, two-unit, foundation (100) level course. Students of Science and non-science programmes are expected to take this course. It is a prerequisite to your obtaining your B.A. or B.Sc. degree. The course will consist of eighteen units. The material has been developed to suit Nigerian students by using more practical examples from the local environment. There are no compulsory prerequisites for the course.

This course guide tells you briefly what the course is about, what course materials you will be using and how you are to use them. It provides some general guidelines for the amount of time you might be spending in order to successfully complete each unit of the course. It also gives you some guidance on your tutor-marked assignments, details of which are to be found in a separate 'Assignment File'. The course involves regular tutorials and you are advised to attend the sessions. Dates and locations of tutorials are included in the 'Assignment File'.

WHAT YOU WILL LEARN IN THIS COURSE

The general aim of GST 105 'History and Philosophy of Science' is to:

1. Stimulate your interest in science by encouraging you to think critically.
2. Help you attain a personal philosophy of life - that is to develop some set of principles that will guide your actions in relation to other people.

While going through this course, you will learn about how science and its branches originated, the contributions of ancient Africans to science, and how the use of scientific knowledge has helped to improve or mar our lives.

The study of the history of science and its philosophy is very important. This is because the knowledge of today incorporates the discoveries of the past and the method through which those discoveries were made. Thus if you are to appreciate pogramme and the level of advance it has attained, you must know something of how and where it originated and how it has evolved to its present state. Towards the end of this course, you will be exposed to the contributions of some great Nigerian scientists. This will motivate you to make your own contributions to society in whatever programme you may be running.

COURSE AIMS

The general aim of the course discussed in the last section will be achieved by trying to:

1. Establish the interrelationship between all disciplines.
2. Show the extent of ancient African contributions to modern technology.
3. Create an awareness of the services of science to man and the effects of science on human society.
4. Introduce you to the two schools of thought on the origin of man.
5. Explain to you the nature of man, components of the universe in which he lives, and how he obtains energy for his activities.
6. Awaken in you the sense of being a Nigerian in such a way as to inspire and motivate you to think scientifically.

COURSE OBJECTIVES

In order to achieve the aims listed above, the course sets overall objectives. Each unit also has specific objectives which are always outlined at the beginning of that unit. You should read them before you start working through the unit. It is necessary to refer to them during your study of the unit to check on your progress. Also, after completing a unit, you should glance through the unit objectives. This will enable you to be sure that you have done what was required of you by the unit.

Listed below are the wider objectives of the course as a whole. By meeting these objectives, you will have achieved the aims of the course as a whole. On successful completion of the course, you should be able to:

- Analyse accurately the nature of science.
- Describe sequentially the processes of scientific research.
- Recognise and relate the laws of nature to everyday life.
- Define and discuss some of the known scientific theories.
- Discuss vividly the origin of science in ancient times.
- Evaluate the state of science in the Middle Ages of Europe.
- Specify the events that gave impetus to the rise of modern science.
- Identify the advances obtained in science in the twentieth century.
- Outline and write an overview of the lost sciences of Africa in areas outside of Egypt.
- Identify the relationship between science and technology and recognise and show their various uses.
- Discuss intelligently the gains and negative effects of technological development on society.

- Analyse the fundamental principles and methods of science.
- Discuss the various viewpoints on the origin of man.
- Explain the nature of man.
- Identify the various components of the universe in which man lives, especially those parts that are connected with human life, survival and interest.
- Outline and evaluate the natural resources for man.
- Recognize the great scientists of Nigerian origin and appreciate their contributions to societal welfare.

COURSE REQUIREMENTS

To complete this course you are required to read the study units, read suggested books and other materials that will help you achieve the objectives. Each unit contains self assessment exercises, and at intervals in the course you are required to asignments for assessment purposes. There will be a final examination at the end of the course. The course should take you a total of about 34 weeks to complete. Listed below are the major components of the course.

COURSE MATERIALS

Major components of the course are:

1. Course guide
2. 4 modules of content of 5 units each
3. Recommended textbooks
4. Assignment file

STUDY UNITS

There are eighteen study units in this course. Each unit should take you 2-3 hours to work through. The eighteen units are divided into four modules. Three modules contain 5 units each while the last module contains 3 units in addition to two weeks of revision. This is arranged as follows:

Module 1

Unit 1 The nature of science
Unit 2 The scientific method
Unit 3 Basic scientific theories
Unit 4 Laws of nature
Unit 5 History of Western science — 1 (Origin of Western science in ancient times)

Module 2

Unit 1 History of science — 2 (Science in the Middle Ages of Europe)
Unit 2 History of science — 3 (Rise of modern science)
Unit 3 History of science — 4 (The twentieth century scientific revolution)
Unit 4 The lost sciences of Africa — 1: An overview
Unit 5 The lost sciences of Africa — 2: An overview

Module 3
Unit 1 Science, technology and inventions
Unit 2 Social implications of technological advancement
Unit 3 The nature and scope of philosophy of science
Unit 4 Man and his origin
Unit 5 The nature of man

Module 4
Unit 1 Man and his cosmic environment
Unit 2 Man and his natural resources
Unit 3 Great scientists of Nigerian origin
Unit 4 Revision
Unit 5 Revision

Each unit includes a table of contents, introduction, specific objectives, recommended textbooks and summaries of key issues and ideas. At intervals in each unit, you will be provided with a number of exercises or self-assessment questions. These are to help you test yourself on the material you have just covered or to apply it in some way. The value of these self-tests is to help you gauge your progress and to reinforce your understanding of the material. At least one tutor-marked assignment will be provided at the end of each unit. The exercises and the tutor- marked assignments will help you in achieving the stated learning objectives of the individual units and of the course.

RECOMMENDED TEXTBOOKS

Ezekwesili, N. O., P. O. Ubachukwu and C. R. Nwagbo (2001) (eds), Introduction *to Natural Sciences — 2, Newcrest Publishers, Onitsha.*

Nwala, T. U (1997) (ed.), History and philosophy of Science, Niger Books & Publishing Co. Ltd, Nsukka.

Onyewuenyi, I. C. (1993), The African Origin of Greek Philosophy - An Exercise in *Afrocentrism, University of Nigeria Press, Nsukka.*

ASSIGNMENT FILE

All the details of the assignments you must submit to your tutor for marking will be found in this file. You must get a passing grade in these assignments in order to pass this course. In the assignment file itself and in the section on assessment within this Course Guide, additional information will be found.

There are 9 assignments in this course. They will cover:

1. The nature of science, the scientific method and basic scientific theories (Module 1, Units 1 and 2).
2. Basic scientific theories and the laws of nature (Module 1, Units 3 & 4)
3. History of science 1 and 2 (Module1, Unit 5 & Module 2, Unit 1)
4. History of science 3 and 4 (Module 2, Units 2 & 3)
5. The lost sciences of Africa 1 and 2 (Module 2, Units 4 & 5)
6. Science, technology and inventions: social implications of technological development (Module 3, Units 1 & 2)
7. The nature and scope of the philosophy of science, and man and his origin (Module 3, Units 3 & 4)
8. The nature of man, and man and his cosmic environment (Module 3, Unit 5, Module 4, Unit 1 respectively)
9. Man and his natural resources, and great scientists of Nigerian origin (Module 4, Units 2 & 3)

The dates for the completion and submission of tutor-marked assignments and attending tutorials will be found in this file. Do not forget to submit all your assignments by the due dates.

ASSESSMENT

The course will be assessed in two aspects. These are:

1. Tutor-marked assignments
2. Written examination

For you to do the assignments very well, it is expected of you to apply information, knowledge and techniques obtained from the course. You must endeavour to submit the assignments to your tutor for marking before the deadlines given in the Assignment file.

The assignments will count for 50% of your total course mark. The final examination, which you will sit for at the end of the course, will also count for 50% of your total course work. The examination will be of three hours duration.

TUTOR MARKED ASSIGNMENTS

This course consists of 9 tutor-marked assignments. The four assignments with the highest marks will be counted for you. In other words, you need not submit all the assignments, but you are encouraged to do so. Each assignment counts 12.5% towards your total course mark.

In the Assignment file, you will find all the assignment questions for all the units. To demonstrate your understanding of the course, do not depend only on obtained from the units to answer the questions. Go to the library, read and research very well to obtain more information on the course. After completing each assignment, send it to your tutor. Try your best to get each assignment across to your tutor on or before the due dates given in the Assignment file. However, if it becomes impossible for you to submit any of the assignments on time, please let your tutor know before the due date. After due consideration, you might be given an extension.

FINAL EXAMINATION AND GRADING

To prepare for this examination, revise all the areas covered in the course. Revision of all the exercises and the tutor-marked assignments before the examination will also be of help to you. The revision should start after you have finished studying the last unit. This final examination will be of three hours' duration. It has a value of 50% of the total course grade.

COURSE OVERVIEW

The units, the number of weeks it would take you to complete them, and the assignments that follow them are outlined in the table below:
Table 1: Course organizer

Unit Title of work	*Duration (weeks)*	*Assessment (end of unit)*

Course Guide	1	
1 The nature of science	1	
2 The scientific method	2	Assignment 1
3 Basic scientific theories	2	
4 Laws of nature	1	Assignment 2
5 History of science- (Origin of 1 science in ancient times)	2	
6 History of science -(science in the Middle Ages of Europe)	2 2	Assignment 3
7 History of science – (Rise of modern science)	3 2	
8 History of science - The twentieth century scientific revolution)	4 2	Assignment 4
9 The lost sciences of Africa -1: An overview	2	
10 The lost sciences of Africa - 2: An overview	2	Assignment 5
11 Science, technology and inventions	2	
12 Social implications of technological development	2	Assignment 6
13 The nature and scope of the philosophy of science	2	
14 Man and his origin	2	Assignment 7
15 The nature of man	2	
16 Man and his cosmic environment	1	Assignment 8
17 Man and his natural resources	3	
18 Great scientists of Nigerian origin	1	Assignment 9
Total	42	

STRATEGIES FOR STUDYING COURSE

In distance learning, the study units replace the university lecturer. Thus one of the advantages of distance learning is that you can read the course materials at your own pace, at any time and anywhere. Exercises to test your understanding of the materials are provided in each unit. There is a common format for all the units. The first item is the introduction to what the unit will be introducing you to. The introduction also shows you how a particular unit is related with other units and to the course as a whole. After the introduction, you will see the objectives. The objectives indicate what you are expected to achieve after studying the unit. So you should keep it handy so as constantly check or monitor yourself in terms of achieving those objectives. The main body of the unit guides you through the required readings from other sources. Exercises, as was mentioned before, are provided at intervals throughout the reading materials. Answers to those exercises are provided at the end of each unit. Don't try to skip any of the exercises. Try to do them as you meet them while reading. This will help to do your tutor-marked assignments and also to prepare you for examinations. The following is a practical strategy for studying the reading materials. If you encounter any problem, don't worry. Contact your tutor and he/she will happily help you out.

1. Read this Course Guide thoroughly
2. Provide a timetable for yourself, and take note of the time you are required to spend on each unit and always stick to the timetable.

TUTORS AND TUTORIALS

There are 20 hours of tutorials (ten 2 hours) provided to support this course. The dates, times and locations of these tutorials will be made available to you, together with the name and address of your tutor.

The assignments will be marked by your tutor. Take note of the comments he might make and remember to send in your assignments before the deadline. In case you will not meet the deadline, don't forget to notify your tutor. The tutor will return your assignments to you after he must have marked them. Try your best not to skip any of the tutorials. This is because that's the only chance you have of meeting your tutor and your fellow students. And problems encountered while reading the course materials will be more easily solved by your tutor.

SUMMARY

GST 105 intends to introduce you to the History and Philosophy of Science. Upon completing this course, you will have been introduced to general education, which will help you have a coherent view of the world. You will know that all knowledge is interrelated. You will be able to answer these kinds of questions:

The questions are inexhaustible. There are many more you can answer. We wish you luck and success with the course and hope that you will find it both helpful and interesting. In the longer term, we hope you will enjoy your acquaintance with NOUN, and we wish you every success in your future.

MAIN COURSE

CONTENTS **PAGE**

MODULE 1

UNIT 1 THE NATURE OF SCIENCE

CONTENTS

1.0 INTRODUCTION

I believe you read the course guide? If so, it means you now have a general understanding of what this unit is about and how it fits into the course as a whole.

The unit will make you aware of the various definitions of science, branches of science, aims of science and the differences between science and non-science disciplines. It is also important to you because it will help you to understand the subsequent units. The objectives below specify what you are expected to learn after going through this unit.

2.0 OBJECTIVES

At the end of the unit, you should be able to:

1. outline the three ways of defining science
2. identify carefully the areas of knowledge which qualify to be science
3. state briefly the purpose of science.

3.0 MAIN CONTENT

3.1 Definitions of Science

What comes to your mind when the word ‘science’ is mentioned? Is it chemistry, physics, biology or mathematics? The word ‘science’ is derived from the Latin word, ‘scientia’ which means ‘Knowledge’ (Eneh: 2000). On the simplest level, science has been defined as the knowledge of the world of nature (The New *Encyclopaedia Britannica:1995). The above definition however does not exhaust* the full meaning of science. So it is difficult to define it. However, science generally is regarded in three main ways as (Nwala: 1997):

1. A body of knowledge.
2. A method for acquiring knowledge or studying and understanding the world.
3. An institution.

Science as a body of knowledge

What does the word ‘body’ tell you? The bodies of knowledge generally regarded as science include, chemistry, biology, physics, mathematics, microbiology, pharmacy and medicine. These bodies of knowledge differ from other forms of knowledge such as religion and art in both content and form. You will study about these differences in a subsequent section.

Science as a method for acquiring knowledge

Science has well-known procedures for obtaining knowledge. The two branches of science, which are empirical and formal sciences, use what is called the scientific method. The 2 steps of that method include observation, problem hypothesis formulation, experimentation, conclusion and theory formulation.

Formal science utilises concepts, rules and theories, and expresses them in quantitative and statistical manner. You will understand the meanings of empirical, *concepts, rules and theories in the subsequent section and units. Anybody that uses* the scientific method or the method of formal sciences to obtain knowledge is said to be involved in science.

Science as an institution

Science can be viewed as an institution which comprises millions of experts. These experts engage in the study and development of human knowledge. The experts or scientists can be found in various research and educational institutions, industries, hospitals, companies, etc. The cooperation and interaction among them make the development of science possible and reliable.

Exercise 1.1 (Answers on page 7)

Fill in the blanks by choosing the correct word or phrase:

1. List the three main ways in which science is viewed.

(a)- --
(b)--

(c)- --

2. Formal science utilises (a) ---------------------- (b)------------------- and (c) --------------------------------- to gain knowledge of nature.

3.2 Branches of science

In the last section you learnt the various meanings of the word 'science'. In this section, you will be exposed to the two ways of grouping scientific disciplines or bodies of knowledge. This will enable you to identify, any time, the areas knowledge which qualify to be called science.

The first way is to group the scientific disciplines into:

1. Formal sciences
2. Empirical sciences

Formal sciences include mathematics (which comprise geometry, algebra, trigonometry, arithmetic), logic, theoretical physics, and statistics. Formal sciences have a formal and deductive character. Science is said to be formal if its contents, arguments and procedures obey certain rules. The result and conclusions of such sciences are valid and authentic only if they conform to those rules (Nwala: 1997). For example, in mathematics there are rules of addition, subtraction, multiplication and division. There are also rules for solving certain equations and problems, theorems, etc. Let's take for instance that you are given the following problems to solve:

3/4 of (5/6 + 1/4) | 7/3 x 4 + 1/2 - 3

How would you go about it? The rule says that 'bracket' is solved first, followed by 'of ', then division, multiplication, addition and subtraction in that order. The mnemonic device for remembering this rule is BODMAS where:

B stands for bracket. The symbol is ( )
O stands for of. The symbol is still 'of '
D stands for division. The symbol is /
M stands for multiplication. The symbol is 'x'
A stands for addition. The symbol is +
S stands for subtraction. The symbol is -

The result and conclusion of the problem above will be valid and a authentic only if the rule of BODMAS is followed. Thus a body of formal systematic and deductive in character.

Empirical sciences, on the other hand, include physics, chemistry, biology, psychology, botany, zoology, biochemistr y, microbiology, geology, medical sciences, etc. These study objects and phenomena which can be observed through any of the senses and which can be tested with instruments such as the telescope, microscope, ruler, tapes and scales. In other words, anything that cannot observed with the senses of sight, touch, hearing, taste and smell or with instruments such as ruler, telescope, etc. is outside science. Can you think of examples of sense perception and non-sense perception objects? Sense perception objects, which are the subject of empirical sciences, include the human body, bodies of other animals such as goats, cows and dogs; as well as natural objects such as the weather, diseases, plants and insects. These can be observed with the senses or measured with instruments because they are material things. For instance, we can see a cow walking on the road, perceive the odour of its droppings, touch its hairy body or taste its flesh (Nwabuisi).

Thus, empirical scientists observe and experiment in order to find out how things originate, grow or develop, function and relate to each other. They also try to find out the laws which govern their behaviour. They are interested in regularities or laws, which enable them to understand or explain the objects or phenomena under study. The knowledge derived in empirical sciences includes inductive generalisations, laws and theories. You will study about these concepts in units 2 to 4. The concepts are formulated in clearly defined statements, propositions or in statistical equations or formulae. Objects which cannot be perceived by the senses include values such as the goodness or badness of a thing, rightness, virtue, beauty, holiness and truth. If the following statement is made, 'Ada is a good girl', do you think you can observe 'goodness' with your senses or measure it with an instrument? It is not possible, and so the study of 'goodness' is outside empirical science.

The second way of grouping scientific disciplines is according to the class of objects or phenomena they deal with (Nwala: 1997). For example,

1. Natural sciences deal with all natural objects. Under it are sub-branches such as:

(a) Physical sciences, which include disciplines like physics, chemistry, geology, applied mathematics, astronomy, etc. These deal with physical and inanimate objects such as rocks, rivers, and mountains.

(b) Biological sciences. Disciplines under it include biology, zoology, botany, microbiology. These deal with living bodies such as human beings, animals, insects and plants.

(c) Medical sciences. They include general medicine, anatomy, surgery, physiology, and veterinary medicine. These disciplines deal with objects and problems that affect human and animal health.

(d) Pharmaceutical sciences, which include pharmaceutics, pharmaceutical chemistry, pharmacognosy and pharmacology. These disciplines are concerned with drugs and drug contents of plants and other objects.

2. Social sciences. Disciplines under it are

(a) Economics
(b) Social psychology
(c) Geography
(d) Sociology and anthropology
(e) Social philosophy, etc.

These deal with society and social institutions.

In spite of all these classifications of science, there is a point that is worth noting. The differences between the disciplines are not absolute (Taylor: 1979). The disciplines began to be systematically arranged in the late nineteenth century so as to avoid inconsistency and overlap. You will understand this point clearer when you study units 5 to 8. The differences between the disciplines arise as differences of viewpoint between the scientists. In other words, the significant thing is not that chemistry differs from physics, but that the chemist's view of the world differs from that of the physicist. It is good that you accept all disciplines as part of life and of living and of our curiosity about the world around us. But to be realistic, most university departments or programmes and professional bodies are based on well-defined and separated subjects. Presently, however, some integration of the sciences is making a comeback. For instance, we now have fields of study such as physical chemistry, biochemistry and biophysics.

The figure below illustrates a theme approach to integration of science and other subjects in the Israeli curriculum (D'Ambrosio:1979). The theme orphenomenon under study is 'light and shadow'. The figure shows how the theme 'light and shadow' is viewed or studied by disciplines such as art, physics and botany.

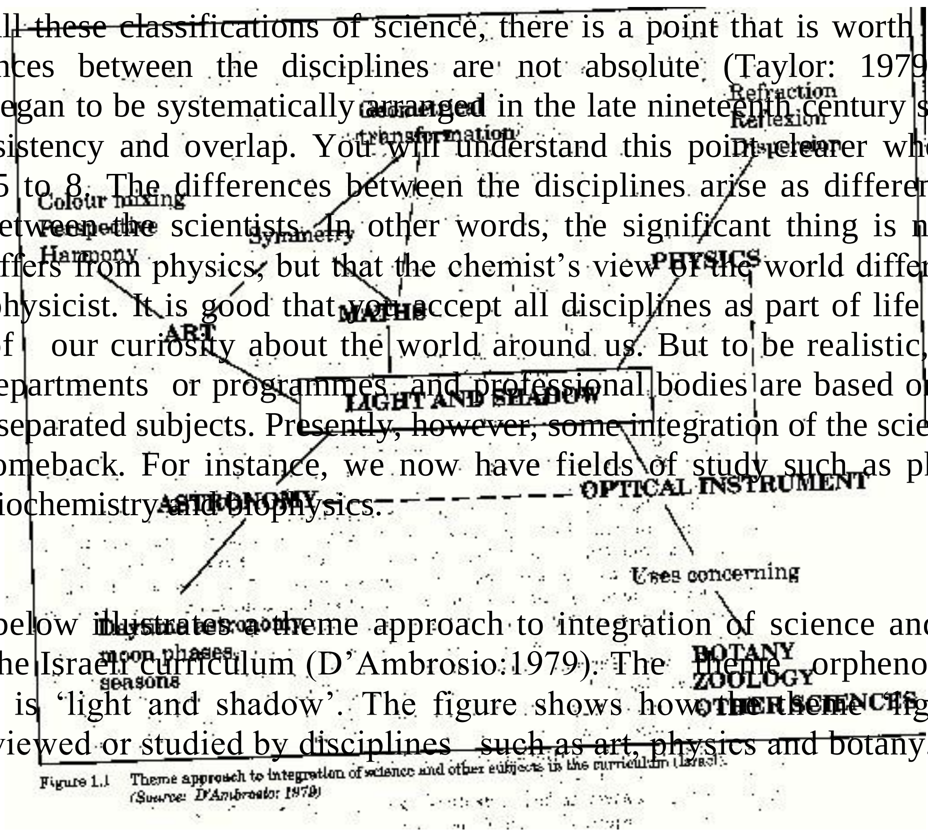

Figure 1.1 Theme approach to integration of science and other subjects in the curriculum (Israel)
(Source: D'Ambrosio: 1979)

Exercise 1.2 (Answers on page 7)

A. Multiple choice

Encircle the letter of the correct alternative:

1. An example of a formal science is

(a) Medicine.
(b) Economics.
(c) Biology.
(d) Mathematics.

2. Objects which can be perceived by the senses include:

(a) Human body.
(b) Goats
(b) Weather
(d) All of the above

B. Matching

3. Match the items in 'A' with those in 'B' by filling in the correct letter in the space provided.

A	**B**	
Virtue	a.	Deductive science
Physiology	b.	Measuring instrument
Scales	c.	Empirical science
Biochemistry	d.	Mathematical rule
BODMAS	e.	Non-sense perception object
Geometry	f.	Medical science

3.3 Aims of science

The last section described the two ways of grouping scientific disciplines. Before examining the steps involved in the process of obtaining knowledge, let us turn to the aims or purposes of science.

Why do you think people involve themselves in scientific activities? Right from the dawn of history, man has tried to understand himself and the nature surrounds him. He has seen the world around him, which evidently has remained the same world, and yet is full of change, motion and of variety. There are dawns and sunsets, births and deaths, the solid earth and the ever-restless seas. There are various kinds of things in the world — minerals, plants, and men. Thus, we can say that science aims at enabling man to explain how the world, events and objects around him originate, develop, operate or function. It also helps him to predict how they will behave in future and thus enables him to control the behaviour of the things around him, once he is able to develop the appropriate instruments for such control (Nwala: 1997).

Thus, science is theoretical. It equips us with theoretical knowledge about the world. Such knowledge is usually summarised using concepts, laws and theories.

These help us to express and systematise our understanding of objects phenomena. Science also equips us with practical knowledge in terms of the various ways, mechanisms and instruments which enable us to control objects and phenomena. Science is, therefore, not only a source of knowledge; it is also a source of power.

3.4 Differences between science and non-science disciplines

You may be able to identify areas of non-science if you have understood sections 3.1 and 3.2. Why do you think they are called non-science? Among those things called nonscience are religion, art, metaphysics (a branch of philosophy), mysticism, common sense, imagination, etc.

Religion, for instance, is concerned with worship of the supernatural; science is concerned with nature and natural phenomena and objects. In particular, religion is speculative. It is based on faith or dogma. The basic religious beliefs are questionable. In the field of study called rational religion or theology, the aim is to make religious beliefs reasonable without rejecting them. In other words, theology tries to confirm religious beliefs (Nwala: 1997).

Religion relies on the principle that the universe is governed by spiritual laws.

All the other non-sciences exhibit some of these attributes. Thus non-sciences are said to be subjective, unverifiable, non-factual, not objective, not systematic and not quantifiable (that is measurable). Their study is often a matter of involving trial and error. Consequently, knowledge based on them does not enable us to explain, predict and control phenomena in the way scientific knowledge can (Nwala: 1997).

Science, on the other hand, is not dogmatic. It is based on reason and does not accept any idea or belief on faith. It subjects everything under its study to critical examination. It does not accept anything as sacred and unquestionable. It relies on the principle that the universe is governed by material law which may meechanical, electrical, chemical, biological, etc.

Science seeks knowledge that is objective, certain, systematic, provable and supported by evidence. This is done through a systematic method of observation, formulation of hypothesis, experimentation, organised theory construction, etc. It further overcomes the limitations of the senses through the use of instruments, diagrams, equations and formal symbols (Nwala: 1997).

However, some have argued that science differs from non-science only in degree. It is pointed out, for example, that common sense has a certain scientific character. It recognises certain basic laws of nature and acts on their basis. For example, traditional agriculture, which is based mainly on common sense experience, recognises the laws governing soil fertility. On the other hand, science involves a certain degree of speculation and imagination especially at the level of formulating hypotheses (Nwala: 1997). You will discover this when you study the next unit, which is unit 2.

In general, science is said to be objective, systematic, reliable, etc. Being objective means that all those who adopt the same method or procedure can prove or verify the claims or statements, which the body of scientific knowledge contains. Being systematic means that all the various elements in a body of knowledge are locally related and each can be inferred from the other. For instance, go to the library, and get hold of any science textbook. If you turn to the table of contents, you will observe that topics are arranged sequentially. Basic topics in biology such as 'the cell — its structure and functions' are discussed before topics like the structure of the kidney, liver, brain, etc. These latter organs are made up of cells. So you need to understand what the cell is before you can understand the structure of the kidney or the liver. Science being reliable means that it can enable us to adequately and correctly explain, predict and control any phenomenon in question. Thus science differs from non-science in method and in the systematic character of its knowledge.

After all's said and done, the next unit will show us that science has some limitations. And these limitations are defined by the very method science uses to obtain knowledge — that is the scientific method.

Exercise 1.3 (Answers on page 7)

1. Non-science disciplines include (a)-----------------------(b)------------------------and (c) -------------------------------

2. List three characteristics of non-science disciplines.

4.0 CONCLUSION

In this unit, you have learnt what the nature (that is, characteristics) of science is. The definitions, branches, and aims of science were discussed. The final discussion was on 7 the differences between science and non-science disciplines. From these discussions you would now be able to tell which disciplines qualify to be sciences and what the overall purposes of sciences are.

5.0 SUMMARY

A summary of the major points in this Unit is that:

- Science was defined in terms of
  (a) a body of knowledge;
  (b) a method for acquiring knowledge, and
  (c) an institution.
- Science disciplines can be grouped in two main ways, viz:
  (a) Formal sciences such as mathematics and logic; and empirical sciences comprising physics, chemistry, biology, psychology, etc.
  (b) Natural sciences and social sciences, according to the class of objects or phenomena they deal with. Natural sciences deal with natural objects while social sciences deal with society and social institutions. Sub-branches of natural sciences are physical sciences such as physics and chemistry; biological sciences such as biology, and microbiology; medical sciences like anatomy and surgery, and finally pharmaceutical sciences such as pharmaceutics and pharmacology. Social science disciplines include economics and geography.
- The purpose of science is to enable human beings to explain, predict and to control nature.
- Non-science disciplines are said to be subjective, unverifiable, non-factual, not systematic and not quantifiable.

Answers to the exercises

Exercise 1.1

1. Science is viewed as

(a) A body of knowledge
(b) A method for acquiring knowledge

(c) An institution

2. (a) concepts, (b) rules, (c) theories

Exercise 1.2

1. (d) 2.(d) 3.e, f, b, c, d, a

Exercise 1.3

1(a) Religion, (b) Metaphysics, (c) Art
2. Non-science disciplines are subjective, unverifiable, non-factual, etc.

6.0 TUTOR-MARKED ASSIGNMENT

1. With examples, differentiate between formal and empirical sciences.
2. What do you consider to be the aims of science? Justify your decision as fully as you can.

7.0 REFERENCES/FURTHER READING

D'Ambrosio, U. (1979) 'The relationship of integrated science to other subjects in the curriculum' in: J. Reay (ed.) New Trends in Integrated Science Teaching, *Vol. V,* UNESCO Press, Paris.

Eneh, J. O. (2000) History and Philosophy of Science — An Outline, Magnet Business Enterprises, Publishing Division, Enugu.

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UNIT 2 THE SCIENTIFIC METHOD

CONTENT

1.0 INTRODUCTION

In the last Unit, science was defined in three main ways as:

(a) a body of knowledge, (b) a method for acquiring knowledge and (c) an institution. In this unit, that method of acquiring scientific knowledge called the scientific method will be discussed in detail. The emphasis will be on how it works in real life and how it has worked in science. This Unit promises to be very exciting because you will learn the method of effective thinking. It will be of great value to you if you apply it to solving life problems. Thus after studying this unit certain things will be required of you. They are listed in the objectives below.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. list sequentially the steps of the scientific method
2. explain vividly with one example how the method can be used to solve a named life problem
3. explain briefly with one example how the method can be used to solve a hypothetical scientific problem
4. assess clearly the use of the steps of creative and critical thinking when given a hypothetical case story.

3.0 MAIN CONTENT

3.1 Scientific Method of Acquiring Knowledge

Superficially, science is a collection of 'facts' (body of knowledge) that describe and explain the workings of nature. Although these facts are interesting - even fascinating - they are not the essence of science. Rather, the excitement of science lies in the intriguing observation and the carefully designed experiments that scientists have devised to help us learn about nature. The important thing here is the process of science — not just knowing the facts, but appreciating *how scientists discovered (and continue to discover) those facts. The process is* characterised by a sequence of steps, which enable scientists to approach objective truth asclosely as possible (Moore, McCann and McCann:1974).

Taken singly, most of the steps are commonplace procedures carried out by people on a daily basis. Taken together, they amount to one of the Powerful tools man has devised to know and to control nature ['The nature of science' (see 'References and further reading')].

The steps of science include the following:

1. Observation

Knowledge comes from noticing resemblances and recurrences in the events that happen around us — Wilfred Trotter (Source: Beveridge: 1970)

Observation is the first step of the scientific method. Thus anything that cannot be observed cannot be investigated by science. For example, a young student *observes that maize grains, which were placed in a wet container inside a dark* cupboard, germinated, but that the leaves were pale yellow instead of the normal *green colour of leaves (Olorode and Kloh: 2000). Scientific observation can be* both direct and indirect. Direct observations are made with the aid of the senses just as our hypothetical student observed the maize grains with his eyes. Indirect observations are performed with the aid of instruments. Atomic nuclei and magnetism, for example, cannot be perceived directly through our sense organs, but their effects can be observed with instruments. What other things do you think can be observed indirectly?

Observations can also be classified into:

1. Spontaneous or passive observations which are unexpected
2. Induced or active observations, which are deliberately looked out for (Beveridge, 1970).

Effective spontaneous observation involves firstly noticing some object or event. The thing noticed will only have meaning if the mind of the observer either consciously or unconsciously relates it to some relevant knowledge or past experience. It can also be important if the observer in the process of thinking over it arrives at some hypothesis.

From our hypothetical example, the student noticed that the pale yellow colour of the leaves of the maize grains was different from the normal green colour of maize grains. He thus related what he observed with his previous knowledge.

Powers of observation can be developed by cultivating the habit of watching things with an active enquiring mind. It is no exaggeration to say that well developed habits of observation are more important in scientific research or even in daily living than a large accumulation of academic learning (Beveridge: 1970).

Correct observation is a most difficult art acquired only after long experience and many errors. The difficulty lies largely in unsuspected bias. People forever see what they want to see or what they think they ought to see. It is extremely hard to rid oneself of such unconscious prejudice and to see just what is actually there, no more and no less. This is the reason why a scientific observation must be repeatable. Science does not take any observation at face value. Several scientists must be able to repeat that observation independently and report the same thing for that observation to be of value to science ('The nature of science').

After an observation has been made, the second step of the scientific method is to define the problem.

2. Problem definition

In this step, questions are asked about the observation. If our hypothetical student in (1) above shows further curiosity, he will decide to find out why those seedlings had pale yellow leaves instead of green. This is the definition of the problem. He asks himself, 'Why are the leaves pale yellow instead of green?' This is the kind of causal question that the scientific method deals with. Science is fundamentally about finding answers to questions.

Significantly, not everyone sees that there may actually be a connected with an observation. For thousands of years, even curious people simply took it for granted that any unsupported object that is thrown up in the air must fall to the ground. It took a genius (Isaac Newton) to ask, 'How come? ('The nature of science'), and few questions have ever contributed more to science as this. Good questioning, like good observing, is a high art. To be of value to science, a question must be relevant and it must be testable. Experience helps in deciding if a question is relevant or not. To find answers to scientific questions, scientists use past experiences, ideas and observations.

Exercise 2.1

1. Observation can be classified into (a) ——————— or passive observation, and (b)———————————or active observation.

2. To be of value to science, a question must be (a)————————— or (b) ————————— .

3. Hypothesis formulation

This is the third step of the scientific method. Do you know that this involves the seemingly quite unscientific procedure of guessing? One guesses what the answer to the question might be. Scientists call this assumed answer hypothesis. A given question, as you might be aware, may have thousands of *possible answers but only one right answer. Thus, there are excellent chances* that a random guess will be wrong. The scientist will only know if his guess was correct after he must have completed the fourth step of the scientific method, which is experimentation ('The nature of science'). The main function of a hypothesis is to predict new experiments or new observations.

Thus our hypothetical student in (2) above will try to state all the possible explanations of his observation, or all the possible solutions to the problem he defined. One possible explanation he might give is that the pale yellow colour referred to is the characteristic of the particular variety of maize that was germinating in the dark cupboard. Another explanation he might give is that the pale yellow colouration resulted from the exclusion of light.

As we said before, all the hypotheses relating to a problem cannot be valid, and the only way to decide which hypothesis is valid is to test each of the hypotheses. If experimentation shows that the first guess was wrong, scientist then must formulate a new hypothesis and once more test for validity by performing new experiments. Clearly, the guessing and guess testing might go on for years and a right answer might never be found.

Obviously, much faster progress would be made if the number of hypotheses were few. The amount of previous knowledge or experience a scientist has enables him to achieve this. This shows us the importance of knowledge for scientific progress and the truly social character of knowledge
(Olorode and Kloh: 2000).

If you may recall from section 3.4 of unit 1, it is while hypothesising that common sense, intuitions and lucky accidents help science enormously. The story has it that in one famous case, the German chemist, Kekulé went to bed one night after a fairly alcoholic party (Olorode and Kloh: 2000). In his sleep, he dreamt of six monkeys chasing one another in a circle, the tail of one held in the teeth of the other. Practically, our whole chemical industry is based on that dream because it told the sleeping scientist what the structure of benzene was. Scientists at that time had been trying to figure out the structure of benzene.

Kekulé then concluded that benzene has six carbon atoms 'chasing' one another in a circle, and that's exactly the present structure of benzene. And it is good to know that benzene is the fundamental parent substance for thousands chemical products.

Since it is the function of every experiment to test the validity of a scientific guess, the fourth step of the scientific method is experimentation.

4. Experimentation

You might be aware by now that answers without evidence are really unsupported opinions. Experimentation can provide the necessary evidence and anyone who experiments after guessing at answers becomes truly 'scientific' in his approach.

Experimentation is by far the hardest part of the scientific method. There are no rules to follow; each experiment is a case unto itself. Technically, knowledge and experience usually help. Making a correct decision on the means by which a hypothesis might best be tested shows the difference between a genius and an amateur ('The nature of science').

Can you think of how the young student in our hypothetical example would gather evidence in order to refute or confirm his hypotheses? Let us examine the two hypotheses regarding the young man's observation of pale yellowing leaves of maize seedlings. The first hypothesis to explain the observation was that the yellowing was due to the variety of maize germinating. A simple way to test that hypothesis is to collect various varieties of maize, put them in the dark cupboard and observe the results. All the varieties will be found to have produced the same pale yellow leaves. The other hypothesis, which states that the exclusion of light produced the pale yellow leaves effect, can also be easily tested. This is done by germinating a batch of seeds in the dark and another batch in a well-lit condition. The well-lit condition serves as the control. It provides a standard of reference for assessing the results of the experimental series. It would be found that the seedlings in the dark would be pale yellow while those in a well-lit condition would have the normal green colour (Olorode and Kloh: 2000). What do you think gives the green colour in plants?

Exercise 2.2

1. The main function of a hypothesis is to predict (a)—————or (b) ——————

2. The German chemist called ——————————— discovered the structure of benzene.

3. A scientific approach to explain various aspects of the natural world includes all of the following except

(a) hypothesis.
(b) testing.
(c) faith and simple consensus.
(d) systematic observation.

The next step after experimentation is the conclusion.

5. Conclusion

We shall again illustrate this step with our hypothetical example above. The test of the first hypothesis leads us to reject that hypothesis while our test of the second hypothesis leads us to accept the second (alternative) hypothesis. Thus our respective conclusions are:

(1) Yellowing of the leaves was not due to the variety of maize germinating. (2) Exclusion of light caused the yellowing of the leaves. Scientific conclusions can be redefined, modified and clarified when the situation arises. Some other conclusions may even be overthrown and discarded. For instance, the young man who observed the pale yellow leaves of maize seedlings may want to find out if the same result will be obtained with seedlings of other plants. He may also observe that in a large maize farm, some rare seedlings which lack green pigments completely, may exist. This will lead him to modify his original conclusion. He may add that 'other factors besides lack of light may cause yellowing of leaves'.

The final step of the scientific method is theory formulation.

6. Theory formulation

What is a theory? Would you be able to attempt an answer? If you cannot, here is the definition: A scientific theory is an explanation about the cause or causes of a broad range of related phenomena. It differs from a scientific hypothesis in its breadth of application (Starr and Taggart: 1992).

A theory is usually proposed when a hypothesis has been supported by really convincing evidence. This evidence must be obtainable in many different laboratories and by many independent researchers.

Theories are open to tests, revisions, and tentative acceptance or rejection. As soon as new information is observed in the course of applying the theory, such existing or established theory is revised. Thus, a new theory emerges to replace the existing one. This is a guarantee for the development of science and human knowledge. But you must note that old theories do not become incorrect but merely become obsolete ('The nature of science').

The figure below illustrates the process of the scientific method:

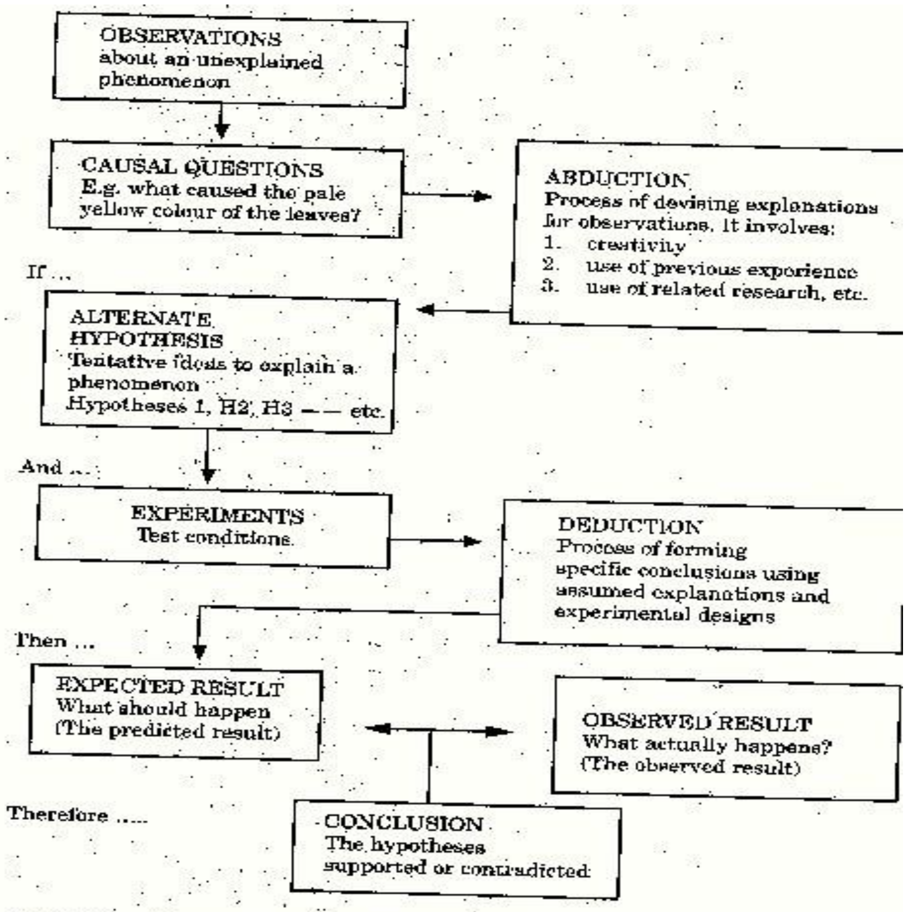

Figure 1.2 The process of the scientific method
(*Source:* Moore et al, 1995)

There is something very important which you have to know concerning figure 1.2. In real life situations, the scientific method does not really work as structured in that figure. In other words, you don't have to complete one step before beginning the next one. In practice, you may go back to an earlier step or work on several steps simultaneously. But for you to be sure that your final conclusion is right, all steps must be completed.

Exercise 2.3

1. ———————————— is an explanation about the cause or causes of a broad range of related phenomena.

2. When does a new theory emerge to replace an existing one?

3.2 How it works in real life

We have just gone through the process of the scientific method. How do you think it can work in real life? Let's suppose that you wake up one night with a skin rash (observation) (Moore, McCann and McCann: 1974). You want to know what caused this rash (causal question). You first try to figure out how this situation is similar to other known situations. Perhaps a classmate of yours had a similar rash that was caused by an allergy to the grass at a close by football field. You realise that your rash has appeared after all the football games that you have played on that field. The similarity (analogy) between your friend's allergy and your rash leads to the explanation *(hypothesis) that your rash is caused by an allergy to the grass, too.*

If your hypothesis is correct, you would not expect to get a rash from other kinds of grass (prediction). When you play football on several other fields, all with a different kind of grass than your nearby football field (experiment), you do not get a rash (results). Your results match the prediction of the grass-allergy hypothesis from which you decide that your rash is caused by the grass at a nearby football field (conclusion).

However, if this was your only hypothesis, you have not actually identified the cause. Perhaps your rash was caused by fertilizers, pesticides, bacteria, fungi or other agents associated with the grass or soil at one football field and not another. By testing a single hypothesis, you have not ruled out any of these other possibilities. To do so, you would have to devise alternative hypotheses, make predictions from them and obtain experimental results to compare with the predictions. By this process, you may be able to reject some but not all of the alternatives, or you may be able to hypotheses, even the grass-allergy hypothesis. Either way, you make progress by testing several hypotheses, not just one.

If you can reject all with the exception of the grass-allergy hypothesis, you can more confidently conclude that the grass caused your rash. Furthermore, you may decide not to play in that particular field again so that you can avoid the irritating plant (use of new knowledge).

You may agree with me that all of this seems like common sense, which it is. The use of the scientific method is not restricted to scientists. For example in 1820 at New Jersey, U.S.A. a colonel named Robert Johnson used the scientific method to disprove the belief that tomatoes were poisonous (Moore, McCann and McCann: 1974). He bravely climbed the steps of a city courthouse and ate a basketful of tomatoes. This action greatly amazed the 2000 townspeople who thought that tomatoes were poisonous. His bold experiment and its result (his survival) proved the townspeople wrong.

A principle characteristic of scientific thinking is that the sequence of observing, hypothesising, experimenting, concluding and interpreting is a cycle, with new ideas produced at every step. To the curious scientific person, a conclusion or a theory is never the final answer. There is always something more to study, something new to learn. Can you be such a person?

Exercise 2.4

Try using the scientific method to solve a hypothetical life problem.

3.3 How it has worked in science

You have seen in section 3.2 how the scientific method works in a real life situation. In this section, one example will be used to illustrate how a real scientist made an important discovery by using the method. In the Beveridge: 1970), it was reported that in certain parts of Great Britain and Western Australia there used to occur a nervous disease of sheep known as 'swayback'(observation). The cause of this disease baffled investigators for years (causal question). In estern Australia, a scientist known as H. W. Bennetts for certain reasons suspected that the cause of the disease might be lead poisoning (hypothesis formulation). To test this hypothesis he treated some afflicted sheep with ammonium chloride, which is the antidote to lead *(experiment). The first trial with this chemical gave promising results that* enabled the sheep to recover a little. However, subsequent trials or tests did not confirm this first result (observation and non-confirmation of Hypothesis 1). A question then arose, 'Why did the initial treatment with ammonium chloride give some relief to the sheep?' (causal question).

This suggested to Bennetts that the cause of the disease might be deficiency of some mineral which was present in small quantities in the first batch of ammonium chloride (Hypothesis 2). Bennetts went ahead to find out the constituents of the ammonium chloride (experiment). He found out that 'copper' was present in the ammonium chloride in small amounts as an impurity. When afflicted sheep were given pure copper mineral they recovered from the disease.

He then concluded that the disease was due to deficiency of copper (conclusion - *confirmation of Hypothesis 2). A deficiency of copper was never previously* known to produce disease in any animal. So by using the scientific method, Bennetts contributed to science the information that a deficiency of copper can cause disease in an animal.
According to the report, Bennetts stated that 'the solution of this problem came in Western Australia from an accidental "lead" (clue) resulting from the testing of a false hypothesis'. In other words, by testing a false hypothesis, which stated that 'the cause of swayback disease was lead poisoning', the true hypothesis came to limelight and the right answer was found. In the next section, creative and critical thinking will be discussed briefly. Read that section very well and if you are interested in knowing more about the topic the following reading may be of assistance to you:

Moore, W. E., H. McCann and J. McCann (1974) reative and *Critical thinking, Houghton Mifflin Co., Boston.*

3.4 Creative and Critical thinking

We live in a complex but rapidly changing society, in which we have to make simple or difficult decisions every minute of our lives. Such decisions might be vital to both our own and other people's health, success and happiness. How well the decisions turn out to be will depend in part on the procedures hinking we use (Moore, McCann and McCann: 1974).

The importance of the scientific method of thinking is richly illustrated by the history of science. You will learn about this in units 5-8. Until seventeenth century, science progressed quite slowly. In the last three centuries, procedures of thinking, the scientific method which we have just discussed, evolved. Its use has been responsible to a large extent for the impressive success of modern science in discovering the secrets of the universe, as well as in developing solutions to echnological problems. Many of our most serious problems can be lessened or even solved by the application of these techniques.

Progress in solving most human problems has lagged far behind progress in science. Most human problems cannot, of course, be taken to the laboratory to be worked on, and some aspects of the scientific method may not apply to these problems. However, a large body of evidence confirms that effective methods of thinking can be of great value in solving everyday human problems (Moore, McCann and McCann: 1974).

The procedures of science (the scientific method), which you have just learnt, require two distinctly different kinds of thinking, creative thinking and *critical thinking. Creative thinking may be defined as the formation of possible* solutions to a problem or possible explanations of a phenomenon. Critical thinking, on the other hand is the testing and evaluation of these proposed solutions.

Effective thinking is both creative and critical. Indeed, both kinds thin king are essential in all areas of human activity. In diagnosing an illness for example, a physician first develops possible diagnoses that seem to fit the symptoms. He then evaluates them by further examination of the patient or by laboratory tests. The final diagnoses cannot be right unless the possible diagnoses include the right one. Even when the possible diagnoses do include the right one, the physician may still make a mistake by being careless in criticising them and settling on the wrong one.

If you have understood the scientific method discussed in section 3.1, you would agree that it is both creative and critical. Outside the laboratory, however, both scientists and laypersons tend to be careless about both creative and critical aspects of thinking. When our feelings are aroused, we are likely to act first and think only after it is too late. Thus to 'create' and 'criticise' are the twin watchwords of the effective thinker.

The general process for applying creative and critical thinking to problem can be described as a cycle of six phases. You have already studied these phases in section 3.1. This cycle should not be treated as a rigid procedure in which each phase must be completed before the next is begun. In practice, you may go back to an earlier phase or work on several phases at the same time. But if you are to have any real assurance that your final decision is sound, all phases must be completed. Why don't you begin now to practise using this cycle (that is, the scientific method)?

You should know that every phase of decision-making is strongly affected by the fact that each one of us sees both the world and ourselves from our own personal point of view. This can interfere with objectivity, which is Important to effective thinking. How effective our thinking is depends partly on how objective we are in viewing ourselves and the world without bias. However, absolute objectivity is impossible because we observe the world only through the lens of our own point of view.

You should keep in mind two essential things for objectivity. The first is to concentrate on the pursuit of truth in all the problems you take up, no matter how unpleasant or threatening it may be. Science has a system of punishing failures of objectivity, but in human setting, you must develop your own sense of discipline. The second element in objectivity is to be open to your feelings. Exclude them when they are not relevant and include them when they are, and you must be able to discern the difference.

It should now be clear to you that perfection in thinking cannot be attained. Effectiveness is the important thing. Also a satisfactory solution to every problem is too much to expect. The person who expects to solve every problem and make the right decisions every time is unrealistic. Effective thinking, like laying a musical instrument, requires practice. This is important both for understanding the techniques fully and for developing skill in applying them. What stops you from practicing now?

4.0 CONCLUSION

This unit has introduced you to the scientific method of acquiring knowledge. You must have also learnt how it can be applied to solve real life problems and scientific problems. Thus the method is useful to every human being, whether a scientist or a non-scientist.

5.0 SUMMARY

The main points in this unit are:

1. The steps of the scientific method are:

(a) Observation. It can be direct or indirect, spontaneous or induced. Scientific observation must be repeatable.

(b) Problem definition. This involves question asking about the observation made. Scientific questions must be relevant and testable.

(c) Hypothesis formulation. It involves guessing or proposing answers to the questions posed.

(d) Experimentation. Answers without evidence are unsupported opinions.

Thus experimentation provides the necessary evidence for accepting or rejecting the proposed answer.

(e) Conclusion. It can be redefined, modified and clarified when the situation arises.

(f) Theory formulation. This will be the main topic of discussion in the next unit.

2. The scientific method is both creative and critical. Thus it can be used to develop effective thinking, which is very necessary for solving both scientific and real life problems.

6.0 TUTOR-MARKED ASSIGNMENT

1. List sequentially the steps of the scientific method.
2. Discuss briefly what each step involves.

7.0 REFERENCES/ FURTHER READING

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UNIT 3 BASIC SCIENTIFIC THEORIES

CONTENTS

1.0 INTRODUCTION

In unit 2, the scientific method — a process of acquiring knowledge about nature — was discussed. If you will recall, the process involves a sequence of steps, which are: observation, problem definition, hypothesis formulation, experimentation, conclusions and theory formulation. The material in this unit will explain to you in detail what a scientific theory means and also list some of the basic scientific theories. Emphasis in this unit will be on the theories of evolution. This topic is important because it will expose you to the different views people, right from the beginning of recorded history, have held about how life began and how the great variety of earth' sorganisms came to be. It is expected of you that at the end of the unit, you will have achieved the objectives listed below.

2.0 OBJECTIVES

After studying this unit you should be able to:

1. Define clearly a scientific theory.
2. List clearly three characteristics of a scientific theory.
3. Identify three events that led to the revival of discussion on evolution
4. Describe briefly evolution by natural selection.
5. Explain concisely how other fields of inquiry have led to a better understanding of the mechanism of evolution.

3.1 What is a scientif ic theory?

Would you be able to recall the definition given in unit 2? If so, well done! As was stated in that unit, a scientific theory is an explanation about the cause or causes of a broad range of related phenomena (Starr and Taggart: 1992).

A theory explains how things are related or their common properties. Scientific research (using the scientific method) leads to the accumulation of facts about nature. As the facts accumulate, organizing them into higher knowledge becomes imperative. This is because our minds require a rationalised, logically consistent body of knowledge to help retain and use information (Beveridge: 1970).

To help in the organisation, a working hypothesis is usually required. Thus, theories start as hypotheses or tentative formulations meant to explain the phenomenon under investigation. When hypothesis is confirmed through experimentation, it becomes a theory. Theories take various forms, which may be as diagrams, equations, statistical and propositional formulations.

A theory is formulated in such a way that its range of application is indicated (Nwala: 1997).It says, 'given such and such conditions', any phenomena, which satisfy those conditions, are subject to the theory under reference. Let's take for instance that a new drug called 'Relief tablets' against bacterial disease 'X' is manufactured in Nigeria ['The nature of science' (see p. 29)]. To test the effectiveness of that drug, Nigerian patients of different ages, sex, eating habits, hereditary background, etc, are used. Additionally, the experiment is carried out under specified hospital conditions with proper allowance for unspotted errors and with different doses of the drug. At the end of the experiment the drug might be found to have an effectiveness of 60% against the bacteria. If this result is confirmed by many independent researchers in different localities, a theory may be proposed.

The theory might state that 'in bacterial disease X, "Relief tablets" are effective in 60 per cent of the cases'.

This statement is very much broader than the experiment on which it is based, and theories are always like that. The statement has not given any limitations in terms of who manufactures the drug, where it is manufactured, where it can be used and whom it can be used on. Therefore that statement implies, for example, that 'Relief tablets', no matter who manufactures it, will be 60% effective anywhere in the world, under any conditions and can be used for both man and other animals.

You can understand that direct evidence for the added implications does not exist. But so far as 'Relief tablets' is already known to work within certain limits, the theory expresses the belief, the probability that it may also work within certain wider limits.

Every good theory therefore has a predictive value. It prophesies certain results. Scientific prophecies always have a considerate amount of evidence to back them up. Additionally, a scientific prophecy does not say that something will certainly happen, it only says that something is likely to happen and with a stated degree of probability. Theories that have proved to be universally valid and have a high degree of probability are called natural laws. You will learn about these in unit 4. Laws also do not pronounce certainties.

In conclusion, theories enable us to explain, predict and control phenomena. They also provide us with a new way of looking at a familiar object or phenomenon. The theory of optics, for instance, provides us with a new way of looking at the phenomenon of light (Nwala: 1997). Before this theory was discovered, people thought of light in the form of patches, shades of colour, etc. With the theory of optics, people's way of looking at light changed. Light is now viewed as travelling (propagation) and this gives room for explaining a wider range of phenomena than the old way of looking at light.

Since the advent of modern science in the sixteenth and seventeenth centuries AD, many scientific theories have been proposed. These include the theory of universal gravitation, the theory of evolution by natural selection, atomic theory, genetic theory, relativity theory, quantum theory, etc. The theories of evolution will be discussed in the next section.

Exercise 3.1

Test yourself with the following questions:

1. What is a scientific theory?
2. Theories enable us to (a) ——————, (b) ———————— and (c) phenomena.
3. Examples of scientific theories include (a)———————, (b)—————— (c) ————and(d)————————.

3.2 Theories of evolution

3.1.1 Evolution before Darwin

Ever since the beginning of recorded history, man has speculated on the origin of life. In ancient times, it was generally believed that organisms originatedspontaneously from non-living matter. Thus, the ancient Egyptians believed that rats came from garbage. Renaissance scientists knew better than this, but in the seventeenth and eighteenth centuries AD, it was widely believed that acteria (microorganisms discovered in 1676) originated spontaneously. It was only in 1862 that Louis Pasteur disproved, once and for all, the theory of spontaneous generation (Roberts: 1971).

Have you ever wondered how the earth came to be populated by a great variety of organisms? The search for explanations has proved to be challenging. The answers have been found to point to one direction — to evolution, which means the progressive change of living things through time.

The idea of evolution was not originated by Darwin in the nineteenth century as some people think (Raven and Johnson: 1986). Some ancient philosophers observed that organisms ranged from very simple to relatively complex ones.

Each group of organisms, according to them, was created by God. Modern individuals of each group trace their ancestry to the individual created by God. The Judeo-Christian culture also promoted such thinking.

Most early scientists believed fully that each kind of organism with all of its individual adaptations was created by God. They studied these organisms, their structures, and the relationships between them as a way of learning more about the creator. In the seventeenth century, for example, the English scientist-clergyman, John Ray (1627-1705) clearly declared his belief that each kind of animal and plant had remained unchanged from the day it was created (Raven and Johnson: 1986). All these views are collectively known as the doctrine of fixed species or creationism. It was never convincingly challenged before Darwin (Moore et al: 1995).

During Darwin's time, biology was dominated by natural theology. The natural theologians believed that the variations and adaptations of organisms proved that each species was fashioned by God for a particular purpose. Besides they believed that the earth was only a few thousand years old. For them, this was not long enough for significant evolutionary change. What is your own view? Do you believe in the theory of spontaneous generation or in the doctrine of fixed species? What are your reasons?

Gradually, some discoveries led to the revival of discussions on evolution. These include:

1. The discovery of many more kinds of organisms by the first part of the eighteenth century (Raven and Johnson: 1986).
2. The study of fossils which was begun in the eighteenth century by Georges

Cuvier (Moore et al:1995). Fossils as you might be aware are remains or body impressions of dead organisms that lived in the past. They are usually found within sedimentary rocks, which occur in layers. Cuvier, from his studies, found that different layers of the rocks held different kinds of fossils. Also the fossils appeared in chronological order that is the deeper the layer, the older the fossil it contains. To him, these observations seemed to be boundaries for dramatic change in ancient environments.

His attempt to explain these changes came to be known as catastrophism (Starr and Taggart: 1992).

Exercise 3.2

1. The belief that rats originated from garbage is an example of (a) ——— theory, and (b)——————— people held such a belief.
2. The view that each kind of animal and plant has remained unchanged from the day it was created is known as (a)—————————— or (b)————————————
3. Examples of proponents of such a view are (a) —————————— (b) —————————

I hope you have understood the narration so far. Let us continue with the events that led to the revival of discussions on evolution:

1. From 1707-1788, a French biologist named Georges-Louis Comte de Buffon studied many mammals and observed that all of them common features. He then suggested that these could be explained in terms of their evolution from a common ancestor.
2. In 1795, a geologist, James Hutton argued that the earth was older than a few thousand years (Moore et al: 1995). His hypothesis was based on the fact that he believed that sedimentary rocks that encased fossils were formed by the gradual accumulation of sediments in lakes, rivers and oceans. This idea is known as gradualism. His explanation indicated that the earth was millions rather than thousands of years old.

Catastrophists such as Cuvier and gradualists like Hutton and Lyell (1797-1895) were good geologists (Moore et al: 1995). They were convinced of an ancient earthbut they found it difficult to explain the appearance and disappearance of species in the fossil record. They were all creationists. Lyell, in particular attributed the gradual addition of new species to the earth's flora and fauna to an unspecified creator.

3. In 1809, the year Charles Darwin was born, Jean Baptiste de Lamarck (1744-1829) proposed that all species, including human beings were descended from other species (Moore et al: 1995; Raven and Johnson: 1986). He believed that life changed progressively from the simple to the more complex. He was the first naturalist to present a unified theory that attempted to explain the changes in organisms from one generation to the next.

Lamarck's explanations were based on the theory of inheritance of acquired characteristics, which he propounded. The theory states that 'changes acquired during an individual's life are brought about by environmental pressure and internal "desires" and that offspring inherit the desired changes' (Starr and Taggart: 1992).

Have you heard of an animal called giraffe? If your answer is yes, do you know why it has a long neck? Lamarck's theory explained it as suppose the ancestor of the modern giraffe was a short-necked animal. Pressed by the need to find food, this animal constantly stretched its neck to feed on the leaves on high tree branches. According to Lamarck, stretching increased the length of the neck and this acquired characteristic was passed to its offspring. These offspring in turn stretched their necks to reach higher leaves. Thus generations of animals desiring to reach higher leaves led to the modern giraffe.

Using similar reasoning, he also proposed that the use and disuse of a feature governed the fate of that feature in successive generations (Moore et al: 1995).

According to him organs of the body that were used extensively to cope with the environment became larger and stronger, while organs that were not used deteriorated.

Presently, scientists know that the mechanism he proposed for changes was wrong. Acquired characteristics cannot be inherited. His theories, however, stimulated people's interest in evolution. As a result of this, the stage was then set for the acceptance of the much simpler explanation that was developed by Darwin half a century later (Raven and Johnson: 1989).

Darwin's greatest contribution was the laying of the foundation for an evolutionary theory by noting that species change over time and the *environment is a factor in that change (Starr and Taggart: 1992).*

Exercise 3.3

You should be able to answer the following questions, to test your progress in studying this material:

1. The observation that distinct layers of rocks reveal sequences of ————— showing gradual changes in structure supports the hypothesis that species evolve.
2. Match the following individuals and ideas by filling in the correct letter in the space provided.

Individuals Ideas
————————Judeo-Christians (a) Gradualism
————————Cuvier(b) All mammals have common features
———————— Lamarck (c) Catastrophism
———————— Buffon (d) Doctrine of fixed species
———————— Hutton (e) Inheritance of acquired traits

3.2.2 Darwin and modern evolutionary thought

In this section, you will learn about Darwin's ideas on evolution. His ideas have had a great impact on a wide array of human endeavours than any scientific advancement of the past 150 years (Moore et al: 1995). His research work on evolution provided the first scientific explanation for the diversity of life. His explanation of how evolution works has attracted more controversy than most scientific ideas. This is because it has affected not only science but also philosophy, religion and human attitudes.

Charles Robert Darwin (1809-18882) was an English naturalist. At the age of eight, his interest in observing the natural world was manifested. At that age, he was an enthusiastic but haphazard collector of shells. At ten, his interest shifted to the habits of insects and birds (Starr and Taggart:1992). At fifteen, he preferred hunting, fishing and observing the natural world to doing his schoolwork. At the university, he could not complete his study of medicine, because that was not his area of interest. He later graduated from Cambridge University as a clergyman but was still interested in natural history.

At the age of 22, one of his professors at Cambridge University, John Henslow arranged for him to take part in a training expedition led by an eminent geologist. Henslow had earlier noticed and respected Darwin's real interest in natural history. He therefore arranged that he be offered the position of naturalist in the ship they were about to sail in. Do you know that right from the 1770s naturalists had always been posted on all British voyages to distant lands? The aim was to gather more knowledge of nature to add to the store of human knowledge (Raven and Johnson: 1989; Starr and Taggart: 1992).

The ship they boarded was called H.M.S. Beagle the main aim of the voyage was to complete an earlier work of mapping the coastline of South

America. While on the expedition, Darwin had chances to study many diverse forms of life on the islands where they stopped, near mountain ranges and along rivers. He returned to England in 1836, after nearly five years at sea and he began a long life of study and contemplation.

Exercise 3.4

1. Charles Darwin was born in (a) —————————— and died in (b) ————————————.
2. At what age was he a collector of shells?
3. He graduated from (a) ————————— University as a
   (b) ————————————————
4. Who arranged for him to be a naturalist aboard H.M.S. Beagle? ——————————————————

5. (a) At what age did he leave for the voyage?
   (b) At what age did he return to England?

Let's continue from where we stopped. When Darwin came back to England, the question that disturbed him was, 'What could explain the remarkable diversity among organisms?' Luckily, field observations he had made during his voyage enabled him later to recognise two clues that pointed to the answer (Starr and Taggart: 1992).

First, while the coast of Argentina was being mapped, he repeatedly got off the ship for exploratory trips inland. On these trips, he made detailed field observations and collected fossils. He saw for the first time many unusual species, including an armadillo.

Among the fossils were remains of th[illegible]inct glyptodonts. Glyptodonts were very large animals th[illegible]embled the living armadillos. This is shown in figure 1.3.

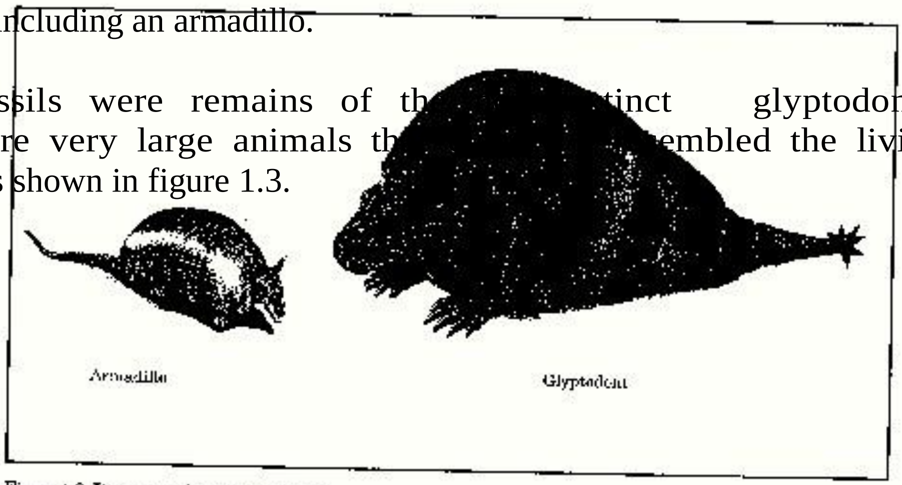

Figure 1.3 Reconstruction of a glyptodont
(Source: Raven and Johnson: 1989)

Darwin became puzzled and started wondering: If both kinds of animals had been created at the same time, if they lived in the same part of the world, and if they were so much alike, then why were armadillos still moving about while the glyptodonts were long gone and buried (Starr and Taggart: 1992)?

Nothing else in the world resembled either animal. Although nobody including Darwin had ever seen one species evolve into another, he later wondered whether armadillos were descendants of glyptodonts.

Second, he had observed that populations of similar kinds of organisms that lived in different geographic regions often showed remarkable differences in some of their traits (that is, characteristics). For instance, Darwin saw giant land tortoises on the Galapagos Islands which were off the coast of Ecuador. To his surprise, all the tortoises were not identical. It was recorded that even natives of those islands and the sailors could tell which island a particular animal had come from just by looking at it (Raven and Johnson: 1989). Darwin reasoned that perhaps all those species descended from the same ancestral form and had become slightly modified after they became isolated on different islands.

Darwin again wondered how such modification could occur. He got a clue from a book published by Thomas Malthus in 1798. The title of the book was 'Essay on the Armadillo Glyptodont principles of population'. According to Malthus, 'any population tends to outgrow its resources and its members must compete for what is available'. This statement struck Darwin and he thought about all the populations he had observed during his voyage. He thought about how the individual members of those populations had differences in body size, form, colouring and other traits. It then dawned on him that some traits could lead to differences in the ability to secure scarce resources (Starr and Taggart: 1992).

Exercise 3.5

1. Mention two pieces of evidence that suggested to Darwin that evolution occurs.
2. (a) Who wrote the book called 'Essay on the principles of population'? (b) In what year was it published?
3. State the main ideas in that essay.
4. How did that idea help Darwin in his study of the process of natural selection?

As we were discussing, Darwin got a clue of how modifications could occur from Thomas Malthus's 'Essay on the principles of population'. With that clue, Darwin declared that it was natural selection, that is nature selecting the 'fit' and rejecting the 'unfit' that led to modifications in members of a species. He described the process of natural selection as follows (Starr and Taggart:1992):

If there were struggles for existence (competition) within a population, then individuals that possess superior physical, behavioural or other attributes might have an edge in surviving and reproducing. In other words, Nature would select individuals with advantageous traits and *eliminate others — and so a population could change. Favoured* individuals would pass on the useful traits to offspring, their offspring would do the same and so on. Gradually, descendants of the favoured individuals would make up most of the population, and less favoured individuals might have no descendants at all.

Darwin published his work in 1859 and it caused an immediate sensation. Many people were very disturbed because the theory implied that humans probably evolved from apes, monkeys, etc, since all share similar characteristics. Surprisingly, in 1858, Darwin received an essay from a young English naturalist named Alfred Russel Wallace (1823-1913). The essay was on 'Theory of evolution by means of natural selection'! What a coincidence! Both of them had independently reached the same conclusion about evolution. However, Darwin was given the credit of propounding the theory because of the amount of evidence he marshaled out.

Thus, Darwin's theory of evolution is one of the main unifying themes of the biological sciences. It provides an explanation for three main sets of facts about life on earth, which we observe (Rutherford and Ahlgren: 1988). These are:

1. The incredible display of different types of living things we see about us.
2. The different degrees of likeness among the living things. The likeness could be anatomical or molecular.
3. The fossil record that shows a sequence in the kinds of organisms that have lived on earth over billions of years.

At the heart of the theory of evolution is the concept of natural selection. That means, natural selection is the mechanism that results in evolution. However, Darwin's theory still faced a crucial test which worried him. It did not explain the mechanism of heredity - that is the way desirable traits or characteristics were transmitted to offspring. You will read about the solution to this problem in the next section.

Exercise 3.6

1. Two keen observers of nature who outlined the theory of evolution by natural selection were
   (a) Cuvier and Lamarck.
   (b) Darwin and Wallace.
   (c) Buffon and Darwin.
   (d) Malthus and Lyell.
2. Natural selection may occur when there are
   (a) heritable traits.
   (b) variations in traits within a population.
   (c) adaptive traits.
   (d) differences in survival and reproduction among members of a population.
   (e) all of the above.

3.2.3 Evolution after Darwin

Before Darwin's death in 1882 and even after his death, many important discoveries have been made and these have led to a better understanding of the mechanism of evolution. These discoveries were made in other fields of inquiry such as paleontology, genetics, biochemistry, embryology, geology and ecology. You will learn about the contributions of the first three fields in this section.

Darwin before his death predicted that the fossil record should yield intermediate links between the great groups of organisms. I believe you know the great groups of organisms? They are fishes, amphibians, reptiles, birds and mammals. Paleontologists (those who study fossils) confirmed this prediction two years after Darwin's book was published. In 1861, an early bird-reptile called archaeopteryx was discovered. It resembled reptiles and birds. This is shown in figure 1.4. Like fossils of small two legged reptiles, it had teeth and a long bony tail. Like modern birds, its body was covered with feathers (Starr and Taggart: 1992).

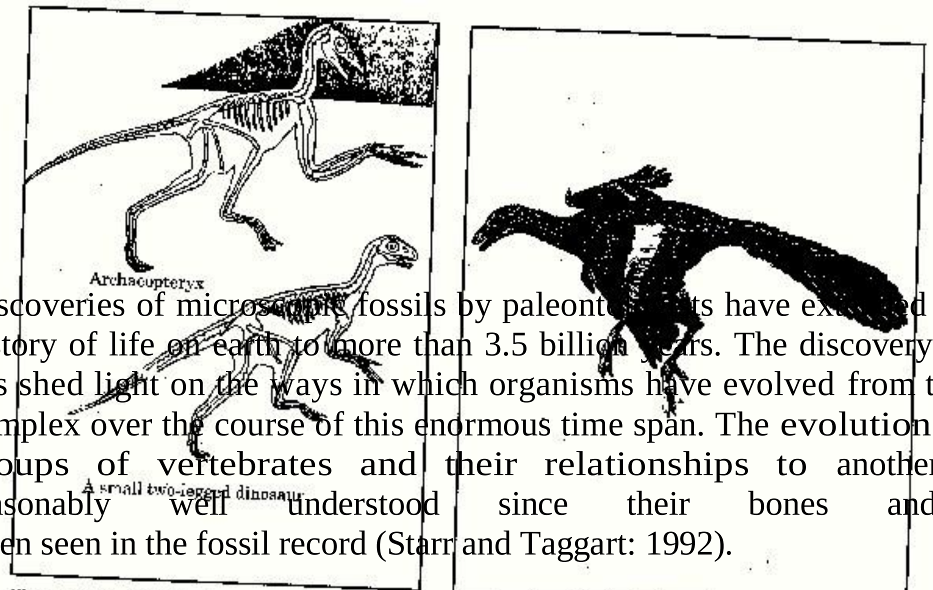

Figure 1.4(a) Archaeopteryx; a small two-legged dinosaur (*Source:* Starr & Taggart: 1992)

Figure 1.4(b) A reconstructed archaeopteryx (*Source:* Raven and Johnson: 1989)

Discoveries of microscopic fossils by paleontologists have extended back the known history of life on earth to more than 3.5 billion years. The discovery of other fossils has shed light on the ways in which organisms have evolved from the simple to the complex over the course of this enormous time span. The evolution of the major groups of vertebrates and their relationships to another have become reasonably well understood since their bones and teeth are often seen in the fossil record (Starr and Taggart: 1992).

Among the most important developments in evolutionary biology since Darwin is the application of genetics to the theory of evolution by natural selection. Genetics is the science of inheritance. If you would recall from section 3.2.2, Darwin was worried because his theory could not explain how parents pass on their characteristics to offspring. In the early part of the century, GregorMendel's laws of inheritance were rediscovered. Scientists found that those laws accounted for the origin of new variations in organisms and how these variations were passed on from parents to their offspring.

Biochemistry is the science that examines the chemical processes and

substances that occur in living things. Its techniques are being used understand evolution better (Raven and Johnson: 1989). Would you know how this is done? Samples of the same kind of protein are obtained from different organisms. Then biochemical tools are used to determine the sequences am into acids in those protein samples. Individuals, populations, species and even larger groups have sequences that are characteristic of them.
When sequences are compared for, let's say,10 different species, their degree of relationship can be specified precisely.

The following information might interest you very much (The Guardian: 2001): An international team of scientists from Australia, Great Britain and the United States found that human evolution is still operating according to the forces of natural selection which was first identified by Charles Darwin. The main findings of the study are that:

1. Natural selection is leading women to have the first child earlier in life.
2. This tendency is partly inherited.
3. As a result, evolution is leading to an increasing biological pressure on women to start families earlier than later.

In the study, Roman Catholic women are found to have a 20% higher 'reproductive fitness' than women of other religions. University educated women, on the other hand, had 35% lower fitness than those who left school early. The study, however, found that such cultural influences could not explain all reproductive differences between women. Dr Owens, a member of the research team from Imperial College, London said that it was surprising to find that genes played almost as much of a role in deciding these issues as religion or social class. Genes were found to explain about 43% of the differences in age of first child within the female population. Their next step according to Dr Owens is to try to discover what these genes are.

Exercise 3.7

1. Fields of inquiry which have contributed to a better understanding of the mechanism of evolution include:
   (a) ―――――――――――――――― (b) ――――――――――
   (c) ―――――――――――――――― and, (d) ――――――――

2. An intermediate link between bird-reptiles called (a) ―――――― ―――――― was discovered in the year (b)――――――
3. ―――――――――――――――― is the science which explains how characteristics are passed on from parents to offspring.

4.0 CONCLUSION

In this unit you have learnt what a scientific theory really means and its various characteristics. You have also been introduced to the various ideas on evolution before Darwin proposed his own theory. It is good to be aware that Darwin's theory of evolution by natural selection is one of the most comprehensive themes in biology. This is because it explains how life began and how diversified into the organisms of today. If you had thought that human evolution had stopped as a result of improvements in diets, housing and medicine, you would have been pleasantly surprised with the information in section 3.2.3. This shows that science is never finished. It is a dynamic activity.

5.0 SUMMARY

The main points in this unit include the following:

1. A scientific theory is an explanation about the cause or causes of a broad range of related phenomena. A theory explains how things are related or their common properties.
2. Theories take various forms, which may be as diagrams, equations, statistical and prepositional formulations.
3. A theory is formulated in such a way that its range of application is indicated.
4. Every good theory has a predictive value.
5. Theories enable us to explain, predict and control phenomenon.
6. They also provide us with a new way of looking at a familiar object or phenomena
7. Scientific theories include the theory of universal gravitation, the theory of evolution by natural selection, atomic theory, relativity theory, quantum theory, etc.
8. Theories of evolution propounded before Darwin include the theory of spontaneous generation and the doctrine of fixed species or creationism.
9. Events that led to the revival of discussions on evolution include:
   (a) The discovery of many more kinds of organisms by the first part of the eighteenth century.
   (b) The study of fossils which showed that layers of sedimentary rocks held different kinds of fossils. The fossils also appear in chronological order - the deeper the layer, the older the fossil it contains.
   (c) Comte de Buffon's observation that all mammals he studied had common features.
   (d) James Hutton's hypothesis that sedimentary rocks that encased fossils were formed by the gradual accumulation of sediments in lakes, rivers and oceans — thus indicating that the earth was millions rather than thousands of years old.
   (e) The proposition of de Lamarck's theory of inheritance of acquired characteristics.
10. Some of Darwin's pieces of evidence that evolution occurs include the following:
   (a) Extinct species, such as the glyptodonts shown in figure 1.3 most

closely resemble the living armadillos in the same area, suggesting that one had given rise to the other.

(b) Layers of sedimentary rock held different kinds of fossils and they appeared in chronological order.

(c) Populations of similar kinds of organisms that lived in different geographic regions often showed noticeable differences in some of their characteristics. For instance, the giant land tortoises on the Galapagos Islands were not identical; thus indicating to Darwin that all those species might have descended from the same ancestral form but had become slightly modified after they became isolated on different islands.

11. Darwin got a clue as to how those modifications could occur from Thomas Malthus's 'Essay on the principles of population'.
12. With the aid of those pieces of evidence and the clue from Malthus, Darwin declared that it was natural selection, that is, nature selecting the 'fit' and rejecting the 'unfit' that led to modifications in members of a species. That means that natural selection is the mechanism that leads to evolution. Thus Darwin's theory consists of two major parts (a) concept of evolutionary change, and (b) the concept of natural selection.
13. Darwin's theory, however could not explain how desirable characteristics or modifications were transmitted from parents to offspring.

14. After Darwin's death, fields of inquiry such as paleontology, genetics, biochemistry, embryology, geology, ecology, etc, have produced results that have led to a better understanding of the mechanism of evolution.
15. The field of genetics, particularly, through the laws of inheritance proposed by Gregor Mendel, has given evidence of how desirable characteristics are transmitted from parents to offspring.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is a scientific theory?
   (c) biochemistry (d) geology etc
2. List three characteristics of a scientific theory.
3. Identify three events that led to the revival of discussion on evolution.
4. Outline three of Darwin's pieces of evidence that evolution occurs.
5. Describe briefly evolution by natural selection.
6. How have the fields of paleontology and genetics led to a better understanding of the mechanism of evolution?

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UNIT 4 LAWS OF NATURE

CONTENTS

1.0 INTRODUCTION

Perhaps we should begin with some critical thinking…. Think of the sun and the moon, how they periodically repeat their movements. Think about when you wake up in the morning, you would first of all meet the dawn, that is when night (which is always dark) is gradually giving way to daytime (which is always light). Nighttime is always associated with some difficulties such as not seeing clearly the material things of nature, while daytime gives us light which enables us to see things very well. You know that this is what everyone of us experiences ever y time — nighttime giving way to daytime and daytime leading us into nighttime and vice versa. Do you know that these events are related to the daily 'movement' of the sun?
When the earth turns its face towards the sun, that region of the earth will have daylight, when it turns its back, the region will have nighttime. And you know that this is a continuous event which man has observed right from ancient times.

This daily motion of the sun is simple to observe while the annual motions are far more difficult to observe. Both motions are also related to other important events that occur on earth such as the seasons. In Nigeria, there are both the dry seasons and the rainy seasons while in European and American countries, they have winter, spring, summer, and autumn. These seasons as you know occur regularly, one changing into the other. Thus there are many regularities in nature which mankind has had to recognize for survival since human beings emerged as a species. These include births and deaths, storms and calms, the solid earth and the ever-restless seas, etc. The pattern and regularity of these changes can be expressed as rules or laws. These laws are called natural laws because they are derived from the natural properties of objects and phenomena. This topic — the laws of nature — is the topic of discussion for this unit.

You can see that it's going to be an interesting unit. If you study it very well, it will help you to understand a lot of natural events. And whenever such events are being discussed you would not be a novice there.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Outline briefly the components of the laws of nature.
2. Explain clearly the term ‘gravitation’.
3. Discuss, vividly, the law of uniformity of nature.

3.1 What is law of nature?

From the introduction, you now have an idea of what the law of nature is. Would you be able to define it when asked to do so? The discussion in this section will help you.

Some people believe that some regularities are figments of human imagination. They say that the human mind leaps to conclusions because it cannot tolerate disorder or chaos. Thus it constructs regularities even when none objectively exists (Encyclopaedia Britannica: 1995). These true regularities must be established by an impartial or unemotional examination of data. Science must, therefore, employ a certain degree of doubt criticism to prevent premature generalisations. Science also insists on getting explanations of the causes of these regularities. It, however, does not permit some kinds of causes. For instance, attributing some causes to spiritual and divine forces is not permissible in science.

Since scientists believe that the world is comprehensible, that is, understandable because there is order in the world, finding the causes of these regularities wouldn’t be problematic. If you can take your mind back to unit 3, you will remember that ‘an explanation about the cause or causes of a broad range of related phenomena’ was called a theory. A theory explains how things are related or their common properties.

In other words, when the properties and relationships between things are discovered, including their pattern and regularity of changes, they are then expressed as theories. A good theory, if you can remember from unit 3, has a predictive value. It prophesies certain results. But scientific prophecy does not say that something will certainly happen, but says only that something is likely to happen with a stated degree of probability. Thus theories that have proved to be so universally valid or true, that is, they are true anywhere in the world and have such a high degree of probability, are called natural laws. That means that not all theories are laws and laws also do not pronounce certainties. Based on this can you give an example of a natural law?

The idea of a law-governed universe assumes that the universe unifisorm.

Our ability to predict events and apply the fundamental laws of the sciences depends on this law of uniformity. That is why J.S. Mill cited in Nwala (1997) defined laws of nature as 'nothing but the uniformities, which exist among natural phenomena'. Thus, laws of nature refer to, that is, encompass the following:

1. Those uniformities found in nature (that is uniformities in behaviour, function, relations and properties of things).
2. Established connection of successive events which make up the order of the universe.
3. Established theories through scientific research (Nwala: 1997).

Examples of laws of nature are:

1. Law of the uniformity of nature
2. Law of causation
3. The law of gravitation
4. The law of natural selection

3.2 Belief in the uniformity of nature

There is a general belief that the universe and all aspects of it are law-governed and that the ordinary events or procedures of nature are uniform (Nwala:1997). This belief is found in primitive and traditional thought as well as in modern scientific thought. The birth of children, death, growth, normal and abnormal occurrences, lightning and thunder, the seasons, day and night, etc: these phenomena are usually explained in terms of general rules or causal laws. In traditional thought, these laws are believed to have a spiritual and teleological character. This means that in traditional thought, when these events occur, for instance, death, the traditionalist believes that it was the gods who caused the death to occur and also that the death occurred for a purpose. Teleology is a view that developments occur because of the purpose or design they serve. Therefore, traditional people look for the purpose for the occurrence of any event.

If a tree, for instance, breaks or a house suddenly collapses, traditional mind will seek to explain such a happening in terms of the purpose, interest and wishes of some spiritual forces. Thus, the principles, laws or factors, which the traditional mind uses to explain the work of nature is often speculative, that is, meditational in character. Therefore the laws or factors may be superstitious and unreliable (Nwala: 1997). The scientist, however, explains the work of nature in terms of material, causal and rational factors. That means that the scientist reasons through and tries to find the causes by means of some activity. We cannot knowledge of anything unless we are able to show why and how it occurs. This knowledge is expressed in terms of general rules or laws. Scientific laws are objective, factual and can be expressed in quantifiable (if you like mathematical) form. They are independent of our subjective wishes and interests.

Therefore according to J.S. Mill cited in Nwala (1997), it is the custom in science, wherever regularity of any kind can be traced, to call the general statement which reveals the nature of that regularity a law.
Science establishes such laws through the steps of the scientific method. You know that the steps include observation, problem definition, hypothesis formulation, experimentation, conclusion and, finally, an appropriate theory is formulated which embodies the law.
The entire universe is said to show uniform patterns and to form a united system.

This view is called the law of the uniformity of nature. You will learn more about this in the next section. The study of nature is the study of these laws and uniformities, which different natural phenomena show or exhibit. The regularities, which different phenomena exhibit, are sort of connected. They form something like a web but they can be studied separately.

Exercise 4.1

Check the rate of your understanding of the topic so far with the following questions:

1. Theories that have proved to be so universally valid and have such a high degree of probability are called——————————
2. Two examples of (1) above are (a)———————————and (b) ——————————————————
3. The laws which the traditional mind uses to explain the works of nature are ———————————in character.
4. ———————————— laws are objective, factual and can be expressed in quantifiable forms.

3.3 The law of uniformity of nature

Men generally believe in the coherence, consistency or common pattern in all phenomena, which can be observed and even in non-observable ones. Do you think that includes you? This natural sequence, regularity and pattern of behaviour of things is evidence that there is a causal order. Hence, men believe that every event has a cause, and that for anything that happens there must be a cause for it. It is said that like events behave alike and also have similar causes. Belief in the uniformity of nature enables us to explain, predict and reproduce these events, where we can (Nwala: 1997). Induction (a type of scientific reasoning where facts are produced to prove general statements), according to some scientists, is based on the general law of the uniformity of nature. You will learn more about induction in a subsequent unit. Since there is orderand regularity in the occurrence of events, if we observe certain characteristics in a certain number of members of a class, we can assume or conclude that all members of that class must have the same characteristics. For example, if we know from observation that all the men we have come across are mortal (that is, they die), we then conclude that 'All men are mortal'. This generalisation covers all men who have died, all those who are alive and all those who will be born in future.

From the point of view of logic (science of reasoning), the law of the uniformity of nature claims that nature is a system composed of many parts. Within this system, everything happens according to rule. The law assumes that the universe does not change and, therefore, the laws of the uniformity of nature governing its behaviour remains constant (Nwala: 1997).

David Hume cited in Nwala (1997) has criticised our concept of causation. He attributes the use of the idea 'cause' to the habit of anticipating one event after another because they have been associated in the past. His view is that we cannot demonstrate the idea of causation. And also that the necessary thing which links two events that are often associated together may not be there. What is there is the habit of seeing one following the other and thereby expecting that this will always be the case. For example, red and green lights may succeed each other without causing the other. That is, red light does not cause the green light to appear and vice versa, but they might succeed each other, that is, one appearing after the other.

It is good for you to know that causal notions or ideas are being replaced by statistical formulations in science.

3.4 The law of gravitation

In section 3.3 you were introduced to the law of uniformity of nature, which is one of the natural laws. The next natural law you will learn is the law of gravitation. What is gravitation? Gravitation is the force which pulls every object in the universe toward every other object in the universe (Arkady: 1997). It is the force that makes a body fall through space towards the earth. Thus the force exists between all bodies. For instance, two stones are not only attracted towards the earth but also attract each other (Abbot: 1973). Normally, we do not notice this force because of its smallness, although it can be measured with sensitive instruments.

The law of gravitation first started as a theory of universal gravitation. The theory was first postulated by Sir Isaac Newton (1642-1727) an English mathematician and physicist. He tried to explain the behaviour of falling objects. Before this theory, mysterious interpretations had been given as the reason why objects do fall downwards when suspended in space. The theory was the first scientific explanation of the behaviour of falling Newton noted that the earth possesses some force which attracts objects towards it. This force was recognised as gravitational force. Gravitation is the attraction between masses. This is what pulls objects around towards the surface of the earth. Hence, all objects within the earth's gravitational field fall towards the earth (Nwala: 1997). Why don't you experiment now? Throw up any object you can lay your hands on and see what happens.

Since the earth has a centre of gravity, all objects in the universe are attracted towards this centre. It was also noted that as objects move away from the earth, the gravitational force decreases, and their weight also decreases. If you can remember the definition of a theory given in section 3.1, you would agree that this theory of gravitation has turned the fictitious idea surrounding falling objects to science. It did this by explaining theoretically and empirically why objects behave the way they do.

Albert Einstein's theory of relativity, which was formulated in 1905, explained the Newtonian theory properly by asserting that gravitation is a property of space. The presence of any physical substance within space causes it to curve in such a manner that a field of gravitational force is created (Eneh: 2000). With this clarification by Einstein and others, the theory was elevated to the rank of a law.

Therefore, Newton's law of universal gravitation states that 'any two bodies attract each other with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them'. What this whole statement means is that if the mass (amount of matter) of one of the two attracting bodies is doubled, the gravitational attraction will also be doubled, but if their distance apart is doubled the force will be only one-fourth (1/4) as great (Arkady: 1977). Newton realized that gravitational attraction applies not only to bodies on the earth but is also responsible for holding the moon in its orbit round the sun. And it is also responsible for the movement of the earth and its fellow planets in their orbits round the sun.

Exercise 4.2

Test your understanding of the two laws discussed here with the following questions:

1. (a) ———————— (b) —————————— and
   (c) —————————————— of 'things' is evidence that there is a causal order.
2. Every ——————— has a cause.
3. The force which pulls every object in the universe towards every other object in the universe is called
   (a) centripetal force.
   (b) centrifugal force.
   (b) contact force.
   (d) gravitational force.
4. The first scientific explanation of the behaviour of falling bodies was given by—————

4.0 CONCLUSION

In this unit, you have learnt what natural laws are and how laws differ from theories.

And you should now be able to give examples of natural laws. Other topics discussed here include the law of uniformity of nature and the law of universal gravitation. From these discussions, you now know that these laws relate to events which we encounter everyday of our lives.

5.0 SUMMARY

The main points in this unit are

1. Theories that have proved to be so universally valid or true and have such a high degree of probability are called natural laws.
2. In general, law of nature refer to the following:
   (a) Those uniformities found in nature (behaviour, function, relations and properties of things).
   (b) Established connection of successive events which make up the order of the universe.
   (c) Theories established through scientific research.
3. Examples of laws of nature are the
   (a) law of the uniformity of nature.
   (b) law of causation.
   (c) law of gravitation.
   (d) law of natural selection.
4. Scientific laws are objective, factual and can be expressed in quantifiable form.
5. The entire universe is said to show uniform patterns and to form a united system.
   This view is called the law of the uniformity of nature.
6. Gravitation is the force which pulls every object in the universe towards every other object in the universe. It is the force that makes a body fall through space toward the earth.
7. The first scientific explanation (theory) of the behaviour of falling objects was given by Sir Isaac Newton (1642-1727).
8. Albert Einstein's theory of relativity which was formulated in 1905 explained the Newtonian theory further by asserting that gravitation is a property of space.
9. With this clarification by Einstein and others the theory of gravitation was elevated to the rank of a law.
10. The basic idea of the law is that if the mass (amount of matter) of one of the

two attracting bodies is doubled, the gravitational attraction will also be doubled; but if their distance apart is doubled, the force will be only one quarter as great.

11. Gravitational attraction explains the behaviour of falling objects and the motions of the moon and the planets and other motions we observe on earth.

6.0 TUTOR-MARKED ASSIGNMENT

1. What does the law of nature refer to?
2. Explain what is meant by the term ‘gravitation’
3. What is the basic idea of the law of universal gravitation.

7.0 REFERENCES AND FURTHER READING

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UNIT 5 HISTORY OF SCIENCE -1 (ORIGIN OF WESTERN SCIENCE IN THE ANCIENT TIMES)

CONTENTS

1.0 INTRODUCTION

In this unit you are going to learn how Western science originated in ancient times. In fact, the next four units will introduce you to how that science originated and how it evolved to its present state. Please bear in mind that when we talk about the origin of science, we are in essence talking about the origin of the scientific method. If you can recall from unit 1, science can be defined in terms of the method of acquiring knowledge of nature. From the time of recorded history to the early sixteenth century AD, Western science progressed very slowly. It was the emergence of this method of science in the seventeenth century that enabled the science to achieve the impressive success it has achieved today. This topic is important because it will help you to appreciate how logical thinking is of indispensable value to man. It is also important because it will expose the mistakes of the past and enable us to learn from them.

The history of Western science is going to be discussed in four phases namely:

1. Origin of Western science in ancient times beginning of recorded history to about AD 476).
2. Science in the middle ages of Europe (AD 476 -1400).
3. Rise of modern science (AD 1400 to the present time).(which dates from the
4. Twentieth century scientific revolution.

However, you should note that the division of history into these periods is only a guide to help historians. There was never any such clear-cut division of time in history. Rather, one period merged into the next. As was mentioned earlier, this unit will only treat the origin of science in the ancient times. The other phases will be discussed in subsequent units. The objectives below specify what you are expected to have learnt after studying this unit.

2.0 OBJECTIVES

After studying this unit you should be able to:

1. Write briefly on the contributions of ancient Egyptians and Babylonians to science
2. Discuss vividly how Thales of Miletus, Anaximander and Pythagoras explained the fundamental component of matter.
3. Identify the contributions of the Roman Empire to science.

3.1 Ancient science

The origin of science is often traced to the Egyptians and the Babylonians. They originated science during the Neolithic age when they settled down to an organized agricultural life and activity. It has been possible to infer what the content of science in these areas was from archaeological remains. This is because writing, as we know it today, hadn't been discovered:then (Dampier:1989; Nwala & Agbakogba:1997). It is important to note that the disciplines we call science today separated gradually from philosophy. Thus at the time of the Egyptians and Babylonians, people who studied plants, animals, stars and other heavenly bodies, rocks, soils, etc were all called philosophers. There was nothing like a botanist, zoologist, an astronomer, etc. It was in Alexandrian Academy in Egypt that specialisations started. You will read about this subsequently.

Please also note that the word 'philosophy' was taken from two Greek words, namely: 'philos' (which means love) and 'sophia' (which meanswisdom). Thus philosophy literally means 'love of wisdom'. Therefore to call a person a philosopher was to call him a lover of wisdom. This is because the reeks believed that whoever tried to study and understand nature was trying to be wise.

3.1.1 Egypt

The kingdom of Egypt was divided into three religious centres, which were Memphis, Heliopolis, Thebes or Hermopolis. These centres were administered by priest-scholars. They were called scholars because they were the intellectualclass of the ancientEgyptians.

Their power remendous and even the kings were subject to it (Onyewuenyi: 1993).

These priest—scholars established a kind of school system known as the Egyptian Mystery System schools. The schools were a kind of university where every known discipline was taught by the priests. Such disciplines were philosophy, comprising religion, medicine, law, mathematics, geometry, astronomy, etc. This group of disciplines was referred to as 'the Wisdom of the Egyptians'. Thus a lot of ancient Egyptian science studied as sacred knowledge. And such knowledge was possessed and disseminated by the priests. One of the main stimuli for the origin of ancient Egyptian science was their practical needs in agriculture (such as measuring, calculations, surveying and study of the weather and the heavens). Second is their understanding of the world they lived in through religion and philosophy (Nwala and Agbakoba: 1997).

Astronomy originated with the Egyptians through their study of the heavens, the stars and the weather. They knew that the best time to plant their crops was right after the Nile River overflowed its banks. Their priests noticed that between each overflow the moon rose 12 times. So they counted 12 moons or months and figured out when the Nile would rise again. Their accuracy in these predictions led to their invention of the lunar calendar. They divided the year into 12 'moons' or 'months' of 30 days each and added a space of 5 days to each year, thus bringing each year to a total of 365 days (Arkady: 1977).

Credit is also given to the Egyptians for the origination of mathematics. The evidence was the finding of the Rind Mathematical Papyrus, which was written during the reign of King A-User-Re (1650 B.C.). It contained arithmetical problems and solutions involving the use of fractions and decimals. Another ancient text which contains evidence of Egyptian origin of the sciences is the famous writings of Hermes Trismegistus which contain among other works, books on medicine, physics and chemistry (then called alchemy). The theory of transmutation of elements (the basis of modernchemistry) first appeared among ancient Egyptians.

The ancient Egyptians were also reputed highly in medicine. They are said to have performed caesarean operations and removed cataracts from the eyes. Evidence for these is contained in the Edwin Papyrus, which was excavated. Do you know that the first physician of the ancient world and the most famous was the Black Egyptian called Imhotep? He lived about 2980 BC. He was called 'the god of medicine' by the Greeks and he lived 2000 years before the Greek doctor, Hippocrates, who in modern times is called the father of medicine (Eneh: 2000; Onyewuenyi: 1993). The Egyptians also invented writing called Hieroglyphics and paper (papyr us) on which they recorded their ideas and culture.

3.1.2 Babylonia (present day Iraq)

The sciences of mathematics, astronomy and engineering (irrigation and canal construction) also developed in Babylonia about 1800-1600 BC. The Babylonians believed that the heavens were the abode of their gods. They also believed that terrestrial disasters such as floods, insect attacks and storms were caused by these gods. Thus, they studied heavenly events carefully in order to know when their gods were angry so as to pacify them. Out of these practices grew a descriptive astronomy that was the most sophisticated of the ancient world until the Greeks took it over and perfected it. The first accurate astronomical observation they recorded was the rising and setting of the planet Venus (The New Encyclopaedia Britannica: 1995).

The Babylonians also realised the importance of fixed units of physical measurement. Their unit of length was the finger; the foot contained twenty fingers; the cubit, thirty fingers. The measurements of weight were the grain, the shekel and the talent, while their medium of exchange was the barley (Dampier: 1989).

Their land was harsh and was made habitable by extensive damning and irrigation works from their two great rivers-Tigris and Euphrates. mathematics thrived under these conditions. For instance, they needed to calculate the volume of dirt to be removed from canals and the provision necessary for work parties. It might be interesting to you to know that they were the first to divide the day into hours, minutes and seconds, and also divided the circle into 360 degrees (The Encyclopaedia Britannica: 1995).

You will agree that the Egyptians and the Babylonians were *observers of nature and they gave precise descriptions. What was missing* was scientific explanations. To them, all knowledge was attributed to the revelations of their gods. They believed that it was the function of religion and magic to understand nature but that man could describe it and use it.

Exercise 5.1

Now test yourself with the following questions:

1. The religious centres in Egypt were (a) ——————— (b) ——————————— and (c) ————————— and they were administered by d) ———————————
2. Evidence for the Egyptian origin of mathematics and medicine can be found in a) —————— and (b) —————— papyri respectively.
3. The first physician of the ancient world was —————————
4. A day was divided into hours, minutes and seconds by the ————————

3.1.3 African philosophy

From the last two sections, you have learnt the contributions of Egyptians and Babylonians to the origin of various sciences. Before we discuss the contributions of ancient Greeks, your attention needs to be drawn to the influence of Egyptian philosophy on Greek philosophy. You should note again that in ancient times, philosophy embraced all the disciplines of study including natural science. But with the advancement and development of learning, specialised areas of study such as various sciences separated from their ancestor - philosophy, and became independent disciplines (Eneh: 2000).

The influence of colonial education has made it difficult for many to appreciate Africa's contribution to world civilisation. This is especially with regard to philosophy and science. European and Western civilisation and philosophy owe their origins to Egypt and Babylonia. Indeed Egyptian philosophy is the origin of Western philosophy but Greek philosophy itself owes its origin to Africa, particularly Egypt (Onyewuenyi: 1993). The evidence includes the following:

1. From the writings of the ancient Greeks themselves, such as Homer, Pythagoras, Socrates, Herodotus, Plutarch, Plato and Aristotle, etc, and modern historians such as William Stace, Edith Hamilton and James Henry Breasted, we learn
   (a) The fact that Egypt is said to have colonised Greece and dominated its culture.

The ancient Greeks also acknowledge the Egyptian origins of their language, identity, science, philosophy, names of their gods, their rituals, etc.

(b) The fact that many of the leading Greek intellectuals lived and studied in Egypt. Africa's major contributions to philosophy and philosophical foundations of the various sciences include the following (Eneh: 2000; Onyewuenyi: 1993):

1. The world's first philosopher in history Ptah-Hotep (c 2800 BC) was an African.
2. Another African, Ipuwar(c 2500 BC) was the world's first social philosopher.
3. The black Egyptian Imhotep who lived 2000 years before Hippocrates, was called by the Greeks 'the god of medicine'.
4. Hypathia - The world's first woman philosopher (360-415AD).
5. The Alexandrian Academy in Egypt, which flourished between 300 BC and AD 200, was the centre of the scientific world. It was also the first to establish the tradition of disciplinary scholarship and specialisation. Among its intellectual giants were:

(a) The great mathematician Euclid who synthesised geometry as a science in his book Elements of Geometry.
(b) Aristarchus, the great astronomer and 'Copernicus of Antiquity'.Human body.
(d) Archimedes, the great mathematician who laid the foundation for the science of mechanics. He founded the Archimedean screw for raising water and is attributed with the doctrine of levers.

(e) Eratosthenes, the librarian at Alexandria who was called ‘the most learned man of antiquity’. He also advanced the knowledge of prime numbers.
(f) Ptolemy of Alexandria, a geographer and an astronomer. His two greatest works were:

(i) Al magest, one of the most influential scientific works of all ages. It showed the paths in which the planets appear to move in
the heavens, a detailed star catalogues and, extensive description of astronomical instruments.
(ii) Geographical outline, which showed the map of the world representing the curved surface of the earth or a plane surface using latitude and longitude.

If you are interested in knowing more about the African origin of Greek philosophy, the following book will be of assistance to you:

Onyewuenyi, I.C. (1993) The African Origin of Greek Philosophy: An *Exercise in Afrocentrism, University of Nigeria Press, Nsukka.*

3.1.4 Ancient Greeks

Through the influence of Egypt and Babylonia, the Greeks acquired their knowledge of mathematics, astronomy and philosophy and developed these to an unprecedented degree (Nwala and Agbakoba: 1997). Science in ancient Greece will be treated under two headings:

1. Pre-socratic philosopher-scientists
2. Socratic philosopher-scientists

Pre-socratics

These people were known as natural philosophers because they engaged themselves with the study of nature and the origin of the world. They were ten in number and they included, Thales of Miletus, A Phoenician who migrated to Miletus in Ionia, Anaximander, Pythagoras, Heraclitus, Democritus, etc, who were Ionian philosophers. These men are usually called early Greek philosophers by some historians while some others are consistent in noting their non-Greek origin. They studied in Egypt erlsewhere under the same curriculum. After their studies, they went back to their respective countries to expand the teachings of the Egyptian Mystery System School (Eneh: 2000; Onyewuenyi: 1993).

They were more concerned with the phenomenon of change. They observed that physical substances (matter) change into one another but their main concern was to find out the original stuff from which all 0riginated and to which they return. Has such a thought ever come to your mind? They attempted to answer this question and named the 'world-stuff' each in his own way:

1. Thales of Miletus (620 -546 BC)

He is usually referred to as the father of Western philosophy. He taught that *water was the source of all things in the universe. According to Aristotle* (Dampier: 1989), Thales got this idea from seeing that the nutriment of all things is moisture and that water is the origin of the nature of moist things.

Things that exist in the world are solid, liquid or gaseous in form. Water, according to Thales, underlies these forms and change from one form to another. Thales also forecast the eclipse of 585BC, although knowledge about eclipses was far advanced in Egypt where he studied (Nwala and Agbakoba: 1997; The New Encyclopaedia Britannica: 1995).

2. Anaximander (611 -547 BC)

He was a pupil of Thales in the Milesian school. He was quick to argue that water could not be the basic substance, because water is essentially wet and nothing can be its own contradiction. According to him, if Thales were correct, the opposite of wet could not exist in a substance and that would preclude all the dry things in the world. Therefore Thales was wrong (The *New Encyclopaedia Britannica: 1995). Here was the birth of the critical* tradition that is fundamental to the advance of science. On his own part, he called the 'world-stuff 'the 'infinite something'. This expresses the idea that the original stuff had no beginning, was imperishable, inexhaustible and indestructible. He was also the first among the Greeks to represent the earth on a map, though the science of map making (cartography) was known in Egypt and Babylonia.

3. Pythagoras (582 -497 BC)

He spent 22 years in Egypt and received instruction in mathematics, physics, theology, music, philosophy and ethics from the priest-scholars of the Mystery System schools (Nwala and Agbakoba: 1997; The New *Encyclopaedia Britannica: 1995).*

The mathematical theory called Pythagorean theory is named after him. For him all things are numbers. He believed that the universe was composed of numbers in various shapes -squares, cubes, oblong, triangular, etc. To him all things in the universe were numerable and could be counted. Pythagoreans (his followers) believed that the unit 'one' is the source of all numbers and they divided it into odd and even numbers. The whole story is interesting, isn't it?

4. Heraclitus (535 - 475 BC)

For him the 'world-stuff' is divine fire. He was the first Greek to advance the principle of change as a universal law. Change, he said is the only reality and that there is nothing permanent in the world. According to him, 'From life comes death; from death comes life; sleep changes into wakefulness and wakefulness changes into sleep'. Everything in the universe, he says, has its own opposite (Dampier: 1989).

5. Democritus (460 BC - ?)

He was a disciple of Leucippus who is credited with the founding of the atomic theory or the doctrine of matter. He became the ablest and best known interpreter of the atomic theory (Dampier: 1989). He proposed that matter is made up of atoms and they are infinite in number and too small to be perceived by the senses. He said that atoms differ in size, some bigger, some smaller and that there is empty space between them. According to him, everything new is produced from a combination of atoms and that death or cessation takes place when atoms separate.

So you can see that even the atomic theory was known in the ancient times. This effort of the Greeks to explain the basic components of matter is important in the history of scientific thought. This is because they tried to reason and to explain it in seemingly simpler terms.

The Socratics

They included Socrates, Plato and Aristotle. Plato studied in Egypt, but history is silent on whether Socrates and Aristotle also studied in Egypt. We shall discuss them one after the other.

1. Socrates (469-399 BC)

He was the teacher of Plato and was born in Athens. He was a moral teacher and sought truth by asking questions. He enriched science with the tools of universal definitions and inductive reasoning. You will learn about inductive reasoning in a subsequent unit.

2. Plato (427-347 BC)

After Plato's studies in Egypt, he returned to Athens and opened a school called the 'Academy'. He taught that it was more noble and dignified to seek answers by reasoning rather than by experiments. He loved mathematics and he formulated the idea of negative numbers. His Academy also produced philosopher-scientists such as Heracleides of Pontus (388-315 BC). Heracleides suggested that the earth rotates on its own axis once in every 24 hours and that Mercury and Venus circle round the sun like satellites (Eneh: 2000; Nwala and Agbakoba: 1997).

3. Aristotle (384-322 BC)

He was the most accomplished of Plato's pupils. He was born at Stagira in

Macedonia. He was a tutor of Alexander the Great. He wrote books on almost all the areas of knowledge - biology, botany, anatomy, physics, metaphysics, astronomy, mathematics, logic, economics, politics, law, psychology, etc. His influence on subsequent development of science and philosophy was enormous. In particular, his views on physics and astronomy controlled the view most men had of the universe for two thousand years. However, to him, the proper means of investigation was observation. In conclusion, Greek science was said to be more of a speculative and theoretical activity rather than experimental and practical. In the next section, you will learn about the contributions of Rome to science. In the meantime, answer the following questions to check your understanding of the topic so far.

Exercise 5.2

1. Match the items in 'A' with those in 'B' by filling in the correct letter in the space provided:

A		B
——————— Imhotep	(a)	Wrote the book called 'Al magest'
——————— Hypathia	(b)	The first to dissect the human body
——————— Euclid	(c)	The first physician in the world
——————— Herophilus	(d)	The first woman philosopher
——————— Archimedes	(e)	Synthesised geometry as a science
——————— Ptolemy	(f)	Laid the foundation for the science of mechanics

2. Pre-socratics named the 'world-stuff' each in his own way. The following are what they named. Identify who named each:

(a) Water ——————————————
(b) Infinite something ————————
(c) Numbers ————————————
(d) Divine fire —————————————
(e) Atoms ——————————————

3.1.5 Science in the Roman period (50 BC-AD 400)

The last and the most important of ancient civilisations in Europe was the Roman Empire. People of many different races came under its rule - the English, the French, Arabians, Syrians, Greeks, etc.

The Roman Empire, however, did not have much influence in the development of science. It was more interested in conquests and maintenance of power through political and military administration. The spirit of independent research was quite foreign to the Roman mind, so scientific innovation was interrupted for awhile (The New Encyclopaedia *Britannica: 1995). However, some scientific works were produced during* this period, but none of them was revolutionary in nature. They were mainly a detailed explanation of scientific conceptions already developed in Alexandria or Greece. These include:

1. Geographical science

The wars and military expeditions of the Romans yielded much further geographical knowledge to mankind. Nations or countries, which were relatively unknown, entered the world map. Julius Caesar, one of e mperors gave the world its present calendar called the Julian calendar in 46 BC. In this calendar, the length of the year is fixed at 365 days and at 366 days at every fourth year. There were 12 calendar months of 30 and 31 days except for February, which has 28 days. However, February has 29 days at every fourth year or leap year. The month of July is also named after Julius Caesar (Nwala and Agbakoba: 1997).

Additionally, Pope Gregory III made a slight innovation to the Julian calendar. He made the leap year occur in any year whose number is exactly divisible by 4. The only exception is the centenary years whose numbers are not exactly divisible by 400, for instance, 1800, 1900. The revised calendar is called the Gregorian calendar.

2. Medical education and health care

The Romans of this period also established hospitals and paid physicians who worked there. They also promoted public health, hygiene and sanitation.

3. Pliny's natural History

Pliny (AD 23-79) promoted the development of natural history. He wrote a book on natural history and the topics of discussion in it were on animals and plants, especially medicinal plants and their uses. However, the book was a compilation of 2000 works by 146 Roman and 326 Greek authors.

In conclusion, both scientific research and theoretical science were in decline under the Roman Empire. The advances they made were more of a practical nature.

4.0 CONCLUSION

This unit has introduced you to how science originated in Egypt Babylonia and how the sciences were advanced further in Greece and in the Roman Empire. You have also been informed that Western philosophy and science owe their origins to Egypt.

5.0 SUMMARY

The main points in this unit include the following:

1. Science originated in Egypt and Babylonia (which is present-day Iraq).
2. Egyptian priest-scholars established a kind of school known as the Egyptian Mystery System Schools where every known discipline was taught by the priests.
3. Evidence for the Egyptian origins of mathematics and medicine can be found in the Rind Mathematical Papyrus and the Edwin Papyrus respectively.
4. Babylonians developed the most descriptive astronomy of the ancient world.
5. They were the first to divide the day into hours, minutes and seconds and also divided the circle into 360 degrees.
6. Egyptian philosophy is the origin of Western philosophy. Evidence can be found in the writings of ancient Greeks themselves such as Homer and Pythagoras, and from modern historians such as William Stace and James Henr y Breasted.
7. Pre-socratics named the original stuff from which all things originated and to which they return. The names given were:
   (a) Water by Thales of Miletus
   (b) Infinite something by Anaximander
   (c) Number by Pythagoras
   (d) Divine fire by Heraclitus
   (e) Atoms by Democritus
8. Socrates enriched science with universal definitions and inductive reasoning.
9. Plato formulated the idea of negative numbers
10. Aristotle wrote books on almost all the areas of knowledge - biology, zoology, physics, astronomy, etc.
11. Scientific innovation began to decline in the Roman Empire.
12. The calendar invented by the Egyptians was modified further by Julius Caesar and Pope Gregory III.

6.0 TUTOR-MARKED ASSIGNMENT

1. Write briefly on the contributions of ancient Egyptians and Babylonians to science.
2. How did Thales of Miletus, Anaximander and Pythagoras explain the fundamental component of matter?

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MAIN COURSE

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MODULE 1

UNIT 1 THE NATURE OF SCIENCE

CONTENTS

1.0 INTRODUCTION

I believe you read the course guide? If so, it means you now have a general understanding of what this unit is about and how it fits into the course as a whole.

The unit will make you aware of the various definitions of science, branches of science, aims of science and the differences between science and non-science disciplines. It is also important to you because it will help you to understand the subsequent units. The objectives below specify what you are expected to learn after going through this unit.

2.0 OBJECTIVES

At the end of the unit, you should be able to:

1. Outline the three ways of defining science.
2. Identify carefully the areas of knowledge which qualify to be science.
3. State briefly the purpose of science.

3.0 MAIN CONTENT

3.1 Definitions of Science

What comes to your mind when the word ‘science’ is mentioned? Is it chemistry, physics, biology or mathematics? The word ‘science’ is derived from the Latin word, ‘scientia’ which means ‘Knowledge’ (Eneh: 2000). On the simplest level, science has been defined as the knowledge of the world of nature (The New *Encyclopaedia Britannica:1995). The above definition however does not exhaust* the full meaning of science. So it is difficult to define it. However, science generally is regarded in three main ways as (Nwala: 1997):

1. A body of knowledge.
2. A method for acquiring knowledge or studying and understanding the world.
3. An institution.

Science as a body of knowledge

What does the word ‘body’ tell you? The bodies of knowledge generally regarded as science include, chemistry, biology, physics, mathematics, microbiology, pharmacy and medicine. These bodies of knowledge differ from other forms of knowledge such as religion and art in both content and form. You will study about these differences in a subsequent section.

Science as a method for acquiring knowledge

Science has well-known procedures for obtaining knowledge. The two branches of science, which are empirical and formal sciences, use what is called the scientific method. The 2 steps of that method include observation, problem hypothesis formulation, experimentation, conclusion and theory formulation. Formal science utilises concepts, rules and theories, and expresses them in quantitative and statistical manner. You will understand the meanings of empirical, *concepts, rules and theories in the subsequent section and units. Anybody that uses* the scientific method or the method of formal sciences to obtain knowledge is said to be involved in science.

Science as an institution

Science can be viewed as an institution which comprises millions of experts. These experts engage in the study and development of human knowledge. The experts or scientists can be found in various research and educational institutions, industries, hospitals, companies, etc. The cooperation and interaction among them make the development of science possible and reliable.

Exercise 1.1 (Answers on page 7)

Fill in the blanks by choosing the correct word or phrase:

1. List the three main ways in which science is viewed.

(a)- ---

(b)---

(c)- ---

2. Formal science utilises (a) -------------------------------- (b) ---------------------------

-- and (c) --------------------------------- to gain knowledge of nature.

3.2 Branches of science

In the last section you learnt the various meanings of the word 'science'. In this section, you will be exposed to the two ways of grouping scientific disciplines or bodies of knowledge. This will enable you to identify, any time, the areas kno wledge which qualify to be called science.

The first way is to group the scientific disciplines into:
1. Formal sciences
2. Empirical sciences

Formal sciences include mathematics (which comprise geometry, algebra, trigonometry, arithmetic), logic, theoretical physics, and statistics. Formal sciences have a formal and deductive character. Science is said to be formal if its contents, arguments and procedures obey certain rules. The result and conclusions of such sciences are valid and authentic only if they conform to those rules (Nwala: 1997). For example, in mathematics there are rules of addition, subtraction, multiplication and division. There are also rules for solving certain equations and problems, theorems, etc. Let's take for instance that you are given the following problems to solve:

3/4 of (5/6 + 1/4) | 7/3 x 4 + 1/2 - 3
How would you go about it? The rule says that 'bracket' is solved first, followed by 'of ', then division, multiplication, addition and subtraction in that order. The mnemonic device for remembering this rule is BODMAS where:
B stands for bracket. The symbol is ( )
O stands for of. The symbol is still 'of '
D stands for division. The symbol is /
M stands for multiplication. The symbol is 'x'
A stands for addition. The symbol is +
S stands for subtraction. The symbol is -

The result and conclusion of the problem above will be valid and a authentic only if the rule of BODMAS is followed. Thus a body of formal systematic and deductive in character.

Empirical sciences, on the other hand, include physics, chemistry, biology, psychology, botany, zoology, biochemistr y, microbiology, geology, medical sciences, etc. These study objects and phenomena which can be observed through any of the senses and which can be tested with instruments such as the telescope, microscope, ruler, tapes and scales. In other words, anything that cannot observed with the senses of sight, touch, hearing, taste and smell or with instruments such as ruler, telescope, etc. is outside science. Can you think of examples of sense perception and non-sense perception objects? Sense perception objects, which are the subject of empirical sciences, include the human body, bodies of other animals such as goats, cows and dogs; as well as natural objects such as the weather, diseases, plants and insects. These can be observed with the senses or measured with instruments because they are material things. For instance, we can see a cow walking on the road, perceive the odour of its droppings, touch its hairy body or taste its flesh (Nwabuisi).

Thus, empirical scientists observe and experiment in order to find out how things originate, grow or develop, function and relate to each other. They also try to find out the laws which govern their behaviour. They are interested in regularities or laws, which enable them to understand or explain the objects or phenomena under study. The knowledge derived in empirical sciences includes inductive generalisations, laws and theories. You will study about these concepts in units 2 to 4. The concepts are formulated in clearly defined statements, propositions or in statistical equations or formulae. Objects which cannot be perceived by the senses include values such as the goodness or badness of a thing, rightness, virtue, beauty, holiness and truth. If the following statement is made, 'Ada is a good girl', do you think you can observe 'goodness' with your senses or measure it with an instrument? It is not possible, and so the study of 'goodness' is outside empirical science.

The second way of grouping scientific disciplines is according to the class of objects or phenomena they deal with (Nwala: 1997). For example,

1. Natural sciences deal with all natural objects. Under it are sub-branches such as:
(a) Physical sciences, which include disciplines like physics, chemistry, geology, applied mathematics, astronomy, etc. These deal with physical and inanimate objects such as rocks, rivers, and mountains.
(b) Biological sciences. Disciplines under it include biology, zoology, botany, microbiology. These deal with living bodies such as human beings, animals, insects and plants.
(c) Medical sciences. They include general medicine, anatomy, surgery, physiology, and veterinary medicine. These disciplines deal with objects and problems that affect human and animal health.
(d) Pharmaceutical sciences, which include pharmaceutics, pharmaceutical chemistry, pharmacognosy and pharmacology. These disciplines are concerned with drugs and drug contents of plants and other objects.

2. Social sciences. Disciplines under it are
(a) Economics
(b) Social psychology
(c) Geography
(d) Sociology and anthropology
(e) Social philosophy, etc.

These deal with society and social institutions.

In spite of all these classifications of science, there is a point that is worth noting. The differences between the disciplines are not absolute (Taylor: 1979). The disciplines began to be systematically arranged in the late nineteenth century so as to avoid inconsistency and overlap. You will understand this point clearer when you study units 5 to 8. The differences between the disciplines arise as differences of viewpoint between the scientists. In other words, the significant thing is not that chemistry differs from physics, but that the chemist's view of the world differs from that of the physicist. It is good that you accept all disciplines as part of life and of living and of our curiosity about the world around us. But to be realistic, most university departments or programmes and professional bodies are based on well-defined and separated subjects. Presently, however, some integration of the sciences is making a comeback. For instance, we now have fields of study such as physical chemistry, biochemistry and biophysics.

The figure below illustrates a theme approach to integration of science and other subjects in the Israeli curriculum (D'Ambrosio: 1979). The theme or phenomenon under study is 'light and shadow'. The figure shows how the theme 'light and shadow' is viewed or studied by disciplines such as art, physics and botany.

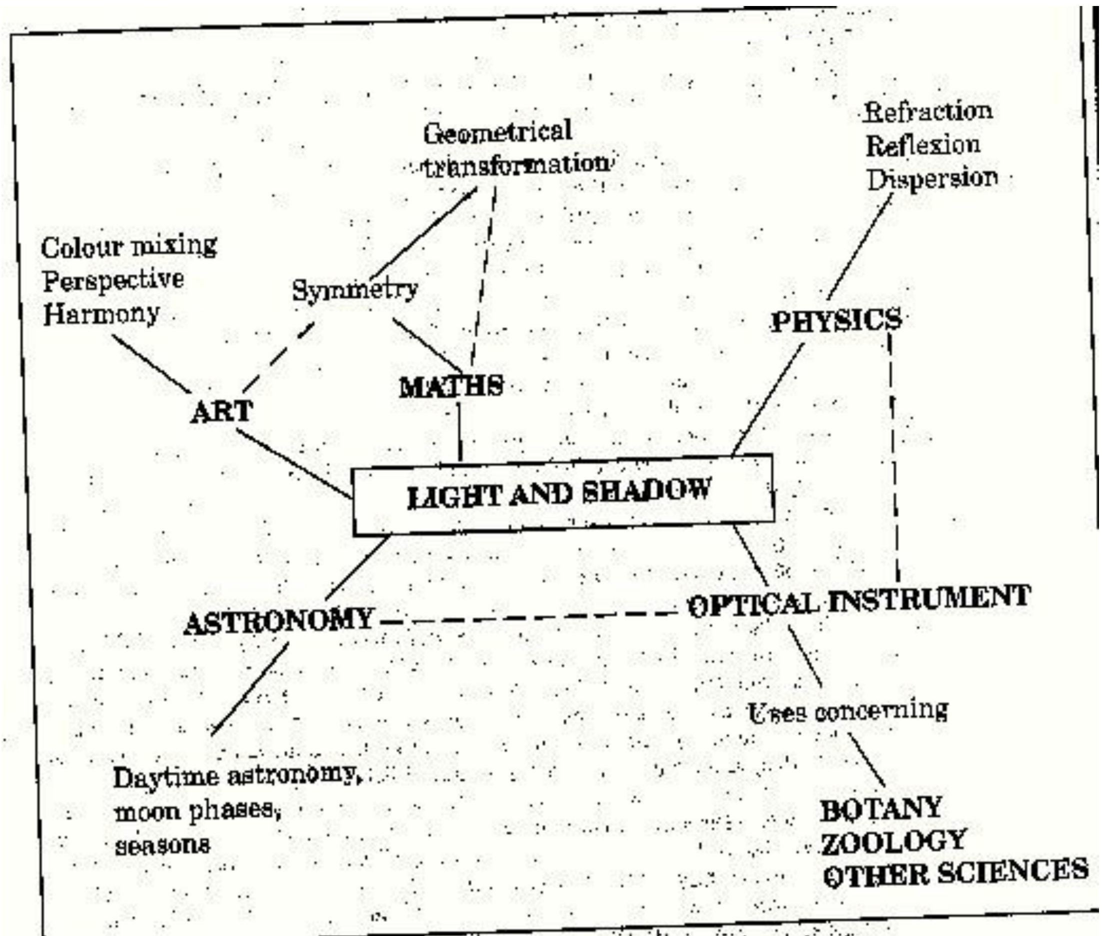

Figure 1.1 Theme approach to integration of science and other subjects in the curriculum (Israel)
(Source: D'Ambrosio: 1979)

Exercise 1.2 (Answers on page 7)

A. Multiple choice

Encircle the letter of the correct alternative:

1. An example of a formal science is
(a) Medicine.
(b) Economics.
(c) Biology.
(d) Mathematics.

2. Objects which can be perceived by the senses include:
(a) Human body.
(b) Goats
(b) Weather
(d) All of the above

B. Matching

3. Match the items in 'A' with those in 'B' by filling in the correct letter in the space provided.

A	**B**	
Virtue	a.	Deductive science
Physiology	b.	Measuring instrument
Scales	c.	Empirical science
Biochemistry	d.	Mathematical rule
BODMAS	e.	Non-sense perception object
Geometry	f.	Medical science

3.3 Aims of science

The last section described the two ways of grouping scientific disciplines. Before examining the steps involved in the process of obtaining knowledge, let us turn to the aims or purposes of science.

Why do you think people involve themselves in scientific activities? Right from the dawn of history, man has tried to understand himself and the nature surrounds him. He has seen the world around him, which evidently has remained the same world, and yet is full of change, motion and of variety. There are dawns and sunsets, births and deaths, the solid earth and the ever-restless seas. There are various kinds of things in the world — minerals, plants, and men. Thus, we can say that science aims at enabling man to explain how the world, events and objects around him originate, develop, operate or function. It also helps him to predict how they will behave in future and thus enables him to control the behaviour of the things around him, once he is able to develop the appropriate instruments for such control (Nwala: 1997).

Thus, science is theoretical. It equips us with theoretical knowledge about the world. Such knowledge is usually summar ised using concepts, laws and theories.

These help us to express and systematise our understanding of objects phenomena. Science also equips us with practical knowledge in terms of the various ways, mechanisms and instruments which enable us to control objects and phenomena. Science is, therefore, not only a source of knowledge; it is also a source of power.

3.4 Differences between science and non-science disciplines

You may be able to identify areas of non-science if you have understood sections 3.1 and 3.2. Why do you think they are called non-science? Among those things called nonscience are religion, art, metaphysics (a branch of philosophy), mysticism, common sense, imagination, etc.

Religion, for instance, is concerned with worship of the supernatural; science is concerned with nature and natural phenomena and objects. In particular, religion is speculative. It is based on faith or dogma. The basic religious beliefs are ques tionable. In the field of study called rational religion or theology, the aim is to make religious beliefs reasonable without rejecting them. In other words, theology tries to confirm religious beliefs (Nwala: 1997).

Religion relies on the principle that the universe is governed by spiritual laws.

All the other non-sciences exhibit some of these attributes. Thus non-sciences are said to be subjective, unverifiable, non-factual, not objective, not systematic and not quantifiable (that is measurable). Their study is often a matter of involving trial and error. Consequently, knowledge based on them does not enable us to explain, predict and control phenomena in the way scientific knowledge can (Nwala: 1997).
Science, on the other hand, is not dogmatic. It is based on reason and does not accept any idea or belief on faith. It subjects everything under its study to critical examination. It does not accept anything as sacred and unquestionable. It relies on the principle that the universe is governed by material law which may meechanical, electrical, chemical, biological, etc.

Science seeks knowledge that is objective, certain, systematic, provable and supported by evidence. This is done through a systematic method of observation, formulation of hypothesis, experimentation, organised theory construction, etc. It further overcomes the limitations of the senses through the use of instruments, diagrams, equations and formal symbols (Nwala: 1997).

However, some have argued that science differs from non-science only in degree. It is pointed out, for example, that common sense has a certain scientific character. It recognises certain basic laws of nature and acts on their basis. For example, traditional agriculture, which is based mainly on common sense experience, recognises the laws governing soil fertility. On the other hand, science involves a certain degree of speculation and imagination especially at the level of formulating hypotheses (Nwala: 1997). You will discover this when you study the next unit, which is unit 2.

In general, science is said to be objective, systematic, reliable, etc. Being objective means that all those who adopt the same method or procedure can prove or verify the claims or statements, which the body of scientific knowledge contains. Being systematic means that all the various elements in a body of knowledge are locally related and each can be inferred from the other. For instance, go to the library, and get hold of any science textbook. If you turn to the table of contents, you will observe that topics are arranged sequentially. Basic topics in biology such as 'the cell — its structure and functions' are discussed before topics like the structure of the kidney, liver, brain, etc. These latter organs are made up of cells. So you need to understand what the cell is before you can understand the structure of the kidney or the liver. Science being reliable means that it can enable us to adequately and correctly explain, predict and control any phenomenon in question. Thus science differs from non-science in method and in the systematic character of its knowledge.

After all's said and done, the next unit will show us that science has some limitations. And these limitations are defined by the very method science uses to obtain knowledge — that is the scientific method.

Exercise 1.3 (Answers on page 7)
1. Non-science disciplines include (a) ------------------------------- (b) -------------------------and (c) ------------------------------------
2. List three characteristics of non-science disciplines.

4.0 CONCLUSION

In this unit, you have learnt what the nature (that is, characteristics) of science is. The definitions, branches, and aims of science were discussed. The final discussion was on 7 the differences between science and non-science disciplines. From these discussions you would now be able to tell which disciplines qualify to be sciences and what the overall purposes of sciences are.

5.0 SUMMARY

A summary of the major points in this Unit is that:

- Science was defined in terms of
  - (a) a body of knowledge;
  - (b) a method for acquiring knowledge, and
  - (c) an institution.
- Science disciplines can be grouped in two main ways, viz:
  - (a) Formal sciences such as mathematics and logic; and empirical sciences comprising physics, chemistry, biology, psychology, etc.
  - (b) Natural sciences and social sciences, according to the class of objects or phenomena they deal with. Natural sciences deal with natural

objects
while social sciences deal with society and social institutions. Sub-branches of natural sciences are physical sciences such as physics and chemistry; biological sciences such as biology, and microbiology; medical sciences like anatomy and surgery, and finally pharmaceutical sciences such as pharmaceutics and pharmacology. Social science disciplines include economics and geography.

- The purpose of science is to enable human beings to explain, predict and to control nature.
- Non-science disciplines are said to be subjective, unverifiable, non-factual, not systematic and not quantifiable.

Answers to the exercises

Exercise 1.1

1. Science is viewed as
(a) a body of knowledge
(b) a method for acquiring knowledge
(c) an institution
2. (a) concepts, (b) rules, (c) theories

Exercise 1.2

1. (d) 2.(d) 3.e, f, b, c, d, a

Exercise 1.3

1 (a) Religion, (b) Metaphysics, (c) Art
2. Non-science disciplines are subjective, unverifiable, non-factual, etc.

6.0 TUTOR-MARKED ASSIGNMENT

1. With examples, differentiate between formal and empirical sciences.
2. What do you consider to be the aims of science? Justify your decision as fully as you can.

7.0 REFERENCES/ FURTHER READING

D'Ambrosio, U. (1979) 'The relationship of integrated science to other subjects in the curriculum' in: J. Reay (ed.) New Trends in Integrated Science Teaching, *Vol. V,* UNESCO Press, Paris.

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Taylor, C . (1979) 'A scientist's view of the Nijmegen conference' in: J. Reay (ed.) New Trends in Integrated Science Teaching, (Vol. V), UNESCO Press, Paris, pp. 9-12.

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UNIT 2 THE SCIENTIFIC METHOD

CONTENT

1.0 INTRODUCTION

In the last Unit, science was defined in three main ways as: (a) a body of knowledge, (b) a method for acquiring knowledge and (c) an institution. In this unit, that method of acquiring scientific knowledge called the scientific method will be discussed in detail. The emphasis will be on how it works in real life and how it has worked in science. This Unit promises to be very exciting because you will learn the method of effective thinking. It will be of great value to you if you apply it to solving life problems. Thus after studying this unit certain things will be required of you. They are listed in the objectives below.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. List sequentially the steps of the scientific method.
2. Explain vividly with one example how the method can be used to solve a named life problem.
3. Explain briefly with one example how the method can be used to solve a hypothetical scientific problem.
4. Assess clearly the use of the steps of creative and critical thinking when given a hypothetical case story.

3.0 MAIN CONTENT

3.1 Scientific Method of Acquiring Knowledge

Superficially, science is a collection of ‘facts’ (body of knowledge) that describe and explain the workings of nature. Although these facts are interesting - even fascinating - they are not the essence of science. Rather, the excitement of science lies in the intriguing observation and the carefully designed experiments that scientists have devised to help us learn about nature. The important thing here is the process of science — not just knowing the facts, but appreciating *how scientists discovered (and continue to discover) those facts. The process is* characterised by a sequence of steps, which enable scientists to approach objective truth as closely as possible (Moore, McCann and McCann: 1974).

Taken singly, most of the steps are commonplace procedures carried out by people on a daily basis. Taken together, they amount to one of the owerful tools man has devised to know and to control nature [‘The nature of science’ (see ‘References and further reading’)].

The steps of science include the following:
1. Observation
Knowledge comes from noticing resemblances and recurrences in the events that happen around us — Wilfred Trotter (Source: Beveridge: 1970)

Observation is the first step of the scientific method. Thus anything that cannot be observed cannot be investigated by science. For example, a young student *observes that maize grains, which were placed in a wet container inside a dark* cupboard, germinated, but that the leaves were pale yellow instead of the normal *green colour of leaves (Olorode and Kloh: 2000). Scientific observation can be* both direct and indirect. Direct observations are made with the aid of the senses just as our hypothetical student observed the maize grains with his eyes. Indirect observations are performed with the aid of instruments. Atomic nuclei and magnetism, for example, cannot be perceived directly through our sense organs, but their effects can be observed with instruments. What other things do you think can be observed indirectly?

Observations can also be classified into:
1. Spontaneous or passive observations which are unexpected
2. Induced or active observations, which are deliberately looked out for (Beveridge, 1970).

Effective spontaneous observation involves firstly noticing some object or event. The thing noticed will only have meaning if the mind of the observer either consciously or unconsciously relates it to some relevant knowledge or past experience. It can also be important if the observer in the process of thinking over it arrives at some hypothesis.

From our hypothetical example, the student noticed that the pale yellow colour of the leaves of the maize grains was different from the normal green colour of maize grains. He thus related what he observed with his previous knowledge.

Powers of observation can be developed by cultivating the habit of watching things with an active enquiring mind. It is no exaggeration to say that well developed habits of observation are more important in scientific research or even in daily living than a large accumulation of academic learning (Beveridge: 1970).

Correct observation is a most difficult art acquired only after long experience and many errors. The difficulty lies largely in unsuspected bias. People forever see what they want to see or what they think they ought to see. It is extremely hard to rid oneself of such unconscious prejudice and to see just what is actually there, no more and no less. This is the reason why a scientific observation must be repeatable. Science does not take any observation at face value. Several scientists must be able to repeat that observation independently and report the same thing for that observation to be of value to science ('The nature of science').

After an observation has been made, the second step of the scientific method is to define the problem.

2. Problem definition

In this step, questions are asked about the observation. If our hypothetical student in (1) above shows further curiosity, he will decide to find out why those seedlings had pale yellow leaves instead of green. This is the definition of the problem. He asks himself, 'Why are the leaves pale yellow instead of green?' This is the kind of causal question that the scientific method deals with. Science is fundamentally about finding answers to questions.

Significantly, not everyone sees that there may actually be a connected with an observation. For thousands of years, even curious people simply took it for granted that any unsupported object that is thrown up in the air must fall to the ground. It took a genius (Isaac Newton) to ask, 'How come? ('The nature of science'), and few questions have ever contributed more to science as this. Good questioning, like good observing, is a high art. To be of value to science, a question must be relevant and it must be testable. Experience helps in deciding if a question is relevant or not. To find answers to scientific questions, scientists use past experiences, ideas and observations.

Exercise 2.1

1. Observation can be classified into (a) ———————————— or passive observation, and (b) ——————————————or active observation. 2. To be of value to science, a question must be (a) —————————— or (b) —————————— .

3. Hypothesis formulation

This is the third step of the scientific method. Do you know that this involves the seemingly quite unscientific procedure of guessing? One guesses what the answer to the question might be. Scientists call this assumed answer hy pothesis. A given question, as you might be aware, may have thousands of *possible answers but only one right answer. Thus, there are excellent chances* that a random guess will be wrong. The scientist will only know if his guess was correct after he must have completed the fourth step of the scientific method, which is experimentation ('The nature of science'). The main function of a hypothesis is to predict new experiments or new observations.

Thus our hypothetical student in (2) above will try to state all the possible explanations of his observation, or all the possible solutions to the problem he defined. One possible explanation he might give is that the pale yellow colour referred to is the characteristic of the particular variety of maize that was germinating in the dark cupboard. Another explanation he might give is that the pale yellow colouration resulted from the exclusion of light.

As we said before, all the hypotheses relating to a problem cannot be valid, and the only way to decide which hypothesis is valid is to test each of the hypotheses. If experimentation shows that the first guess was wrong, s cientist then must formulate a new hypothesis and once more test for validity by performing new experiments. Clearly, the guessing and guess testing might go on for years and a right answer might never be found.

Obviously, much faster progress would be made if the number of hypotheses were few. The amount of previous knowledge or experience a scientist has enables him to achieve this. This shows us the importance of knowledge for scientific progress and the truly social character of knowledge (Olorode and Kloh: 2000).

If you may recall from section 3.4 of unit 1, it is while hypothesising that common sense, intuitions and lucky accidents help science enormously. The story has it that in one famous case, the German chemist, Kekulé went to bed one night after a fairly alcoholic party (Olorode and Kloh: 2000). In his sleep, he dreamt of six monkeys chasing one another in a circle, the tail of one held in the teeth of the other. Practically, our whole chemical industry is based on that dream because it told the sleeping scientist what the structure of benzene was. Scientists at that time had been trying to figure out the structure of benzene.

Kekulé then concluded that benzene has six carbon atoms 'chasing' one another in a circle, and that's exactly the present structure of benzene. And it is good to know that benzene is the fundamental parent substance for thousands chemical products.

Since it is the function of every experiment to test the validity of a scientific guess, the fourth step of the scientific method is experimentation.

4. Experimentation

You might be aware by now that answers without evidence are really unsupported opinions. Experimentation can provide the necessary evidence and anyone who experiments after guessing at answers becomes truly 'scientific' in his approach.

Experimentation is by far the hardest part of the scientific method. There are no rules to follow; each experiment is a case unto itself. Technically, knowledge and experience usually help. Making a correct decision on the means by which a hypothesis might best be tested shows the difference between a genius and an amateur ('The nature of science'). Can you think of how the young student in our hypothetical example would gather evidence in order to refute or confirm his hypotheses? Let us examine the two hypotheses regarding the young man's observation of pale yellowing leaves of maize seedlings. The first hypothesis to explain the observation was that the yellowing was due to the variety of maize germinating. A simple way to test that hypothesis is to collect various varieties of maize, put them in the dark cupboard and observe the results. All the varieties will be found to have produced the same pale yellow leaves. The other hypothesis, which states that the exclusion of light produced the pale yellow leaves effect, can also be easily tested. This is done by germinating a batch of seeds in the dark and another batch in a well-lit condition. The well-lit condition serves as the control. It provides a standard of reference for assessing the results of the experimental series. It would be found that the seedlings in the dark would be pale yellow while those in a well-lit condition would have the normal green colour (Olorode and Kloh: 2000). What do you think gives the green colour in plants?

Exercise 2.2

1. The main function of a hypothesis is to predict (a) ———————or (b) ————————

2. The German chemist called ———————— discovered the structure of benzene.

3. A scientific approach to explain various aspects of the natural world includes all of the following except

(a) hypothesis.
(b) testing.
(c) faith and simple consensus.
(d) systematic observation.

The next step after experimentation is the conclusion.

5. Conclusion

We shall again illustrate this step with our hypothetical example above. The test of the first hypothesis leads us to reject that hypothesis while our test of the second hypothesis leads us to accept the second (alternative) hypothesis. Thus our respective conclusions are: (1) Yellowing of the leaves was not due to the variety of maize germinating. (2) Exclusion of light caused the yellowing of the leaves. Scientific conclusions can be redefined, modified and clarified when the situation arises. Some other conclusions may even be overthrown and discarded. For instance, the young man who observed the pale yellow leaves of maize seedlings may want to find out if the same result will be obtained with seedlings of other plants. He may also observe that in a large maize farm, some rare seedlings which lack green pigments completely, may exist. This will lead him to modify his original conclusion. He may add that ‘other factors besides lack of light may cause yellowing of leaves’.

The final step of the scientific method is theory formulation.

6. Theory formulation

What is a theory? Would you be able to attempt an answer? If you cannot, here is the definition: A scientific theory is an explanation about the cause or causes of a broad range of related phenomena. It differs from a scientific hypothesis in its breadth of application (Starr and Taggart: 1992).

A theor y is usually proposed when a hypothesis has been supported by really convincing evidence. This evidence must be obtainable in many different laboratories and by many independent researchers.

Theories are open to tests, revisions, and tentative acceptance or rejection. As soon as new information is observed in the course of applying the theory, such existing or established theory is revised. Thus, a new theory emerges to
replace the existing one. This is a guarantee for the development of science and human knowledge. But you must note that old theories do not become incorrect but merely become obsolete ('The nature of science').
The figure below illustrates the process of the scientific method:

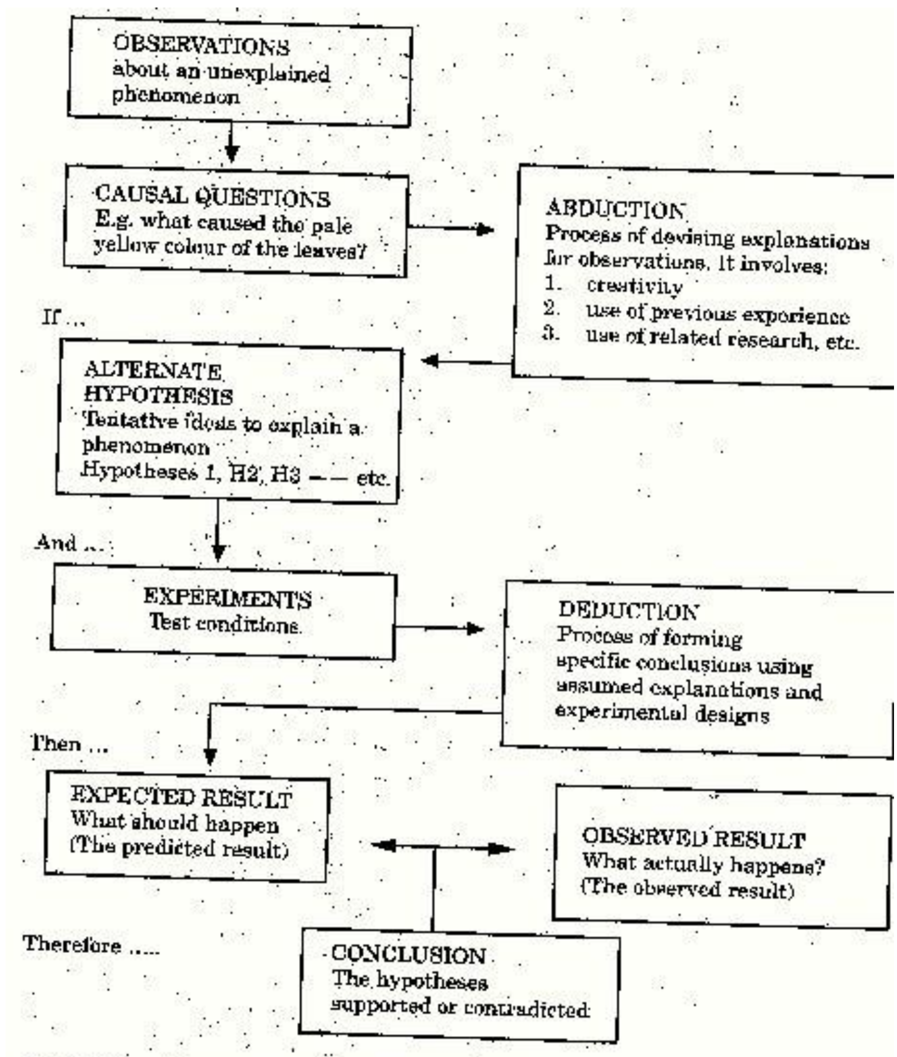

Figure 1.2 The process of the scientific method
(*Source:* Moore *et al*, 1995)

There is something very important which you have to know concerning figure 1.2. In real life situations, the scientific method does not really work as structured in that figure. In other words, you don't have to complete one step before beginning the next one. In practice, you may go back to an earlier step or work on several steps simultaneously. But for you to be sure that your final conclusion is right, all steps must be completed.

Exercise 2.3

1. ———————————— is an explanation about the cause or causes of a broad range of related phenomena.
2. When does a new theory emerge to replace an existing one?

3.2 How it works in real life

We have just gone through the process of the scientific method. How do you think it can work in real life? Let's suppose that you wake up one night with a skin rash (observation) (Moore, McCann and McCann: 1974). You want to know what caused this rash (causal question). You first try to figure out how this situation is similar to other known situations. Perhaps a classmate of yours had a similar rash that was caused by an allergy to the grass at a close by football field. You realise that your rash has appeared after all the football games that you have played on that field. The similarity (analogy) between your friend's allergy and your rash leads to the explanation *(hypothesis) that your rash is caused by an allergy to the grass, too.*

If your hypothesis is correct, you would not expect to get a rash from other kinds of grass (prediction). When you play football on several other fields, all with a different kind of grass than your nearby football field (experiment), you do not get a rash (results). Your results match the prediction of the grass-allergy hypothesis from which you decide that your rash is caused by the grass at a nearby football field (conclusion). However, if this was your only hypothesis, you have not actually identified the cause. Perhaps your rash was caused by fertilizers, pesticides, bacteria, fungi or other agents associated with the grass or soil at one football field and not another. By testing a single hypothesis, you have not ruled out any of these other possibilities. To do so, you would have to devise alternative hypotheses, make predictions from them and obtain experimental results to compare with the predictions. By this process, you may be able to reject some but not all of the alternatives, or you may be able to hypotheses, even the grass-allergy hypothesis. Either way, you make progress by testing several hypotheses, not just one.

If you can reject all with the exception of the grass-allergy hypothesis, you can more confidently conclude that the grass caused your rash. Furthermore, you may decide not to play in that particular field again so that you can avoid the irritating plant (use of new knowledge).

You may agree with me that all of this seems like common sense, which it is. The use of the scientific method is not restricted to scientists. For example in 1820 at New Jersey, U.S.A. a colonel named Robert Johnson used the scientific method to disprove the belief that tomatoes were poisonous (Moore, McCann and McCann: 1974). He bravely climbed the steps of a city courthouse and ate a basketful of tomatoes. This action greatly amazed the 2000 townspeople who thought that tomatoes were poisonous. His bold experiment and its result (his survival) proved the townspeople wrong.

A principle characteristic of scientific thinking is that the sequence of observing, hypothesising, experimenting, concluding and interpreting is a cycle, with new ideas produced at every step. To the curious scientific person, a conclusion or a theory is never the final answer. There is always something more to study, something new to learn. Can you be such a person?

Exercise 2.4

Tr y using the scientific method to solve a hypothetical life problem.

3.3 How it has worked in science

You have seen in section 3.2 how the scientific method works in a real life situation. In this section, one example will be used to illustrate how a real scientist made an important discovery by using the method. In the Beveridge: 1970), it was reported that in certain parts of Great Britain and Western Australia there used to occur a nervous disease of sheep known as 'swayback'(observation) . The cause of this disease baffled investigators for years (causal question). In Western Australia, a scientist known as H. W. Bennetts for certain reasons suspected that the cause of the disease might be lead poisoning (hypothesis formulation). To test this hypothesis he treated some afflicted sheep with ammonium chloride, which is the antidote to lead *(experiment). The first trial with this chemical gave promising results that* enabled the sheep to recover a little. However, subsequent trials or tests did not confirm this first result (observation and non-confirmation of Hypothesis 1). A question then arose, 'Why did the initial treatment with ammonium chloride give some relief to the sheep?' (causal question).

This suggested to Bennetts that the cause of the disease might be defi ciency of some mineral which was present in small quantities in the first batch of ammonium chloride (Hypothesis 2). Bennetts went ahead to find out the constituents of the ammonium chloride (experiment). He found out that 'copper' was present in the ammonium chloride in small amounts as an impurity. When afflicted sheep were given pure copper mineral they recovered from the disease. He then concluded that the disease was due to deficiency of copper (conclusion - *confirmation of Hypothesis 2). A deficiency of copper was never previously* known to produce disease in any animal. So by using the scientific method, Bennetts contributed to science the information that a deficiency of copper can cause disease in an animal.
According to the report, Bennetts stated that 'the solution of this problem came in Western Australia from an accidental "lead" (clue) resulting from the testing of a false hypothesis'. In other words, by testing a false hypothesis, which stated that 'the cause of swayback disease was lead poisoning', the true hypothesis

came to limelight and the right answer was found. In the next section, creative and critical thinking will be discussed briefly. Read that section very well and if you are interested in knowing more about the topic the following reading may be of assistance to you:

Moore, W. E., H. McCann and J. McCann (1974) Creative and *Critical thinking, Houghton Mifflin Co., Boston.*

3.4 Creative and Critical thinking

We live in a complex but rapidly changing society, in which we have to make simple or difficult decisions every minute of our lives. Such decisions might be vital to both our own and other people's health, success and happiness. How well the decisions turn out to be will depend in part on the procedures hinking we use (Moore, McCann and McCann: 1974).

The importance of the scientific method of thinking is richly illustrated by the history of science. You will learn about this in units 5-8. Until seventeenth century, science progressed quite slowly. In the last three centuries, procedures of thinking, the scientific method which we have just discussed, evolved. Its use has been responsible to a large extent for the impressive success of modern science in discovering the secrets of the universe, as well as in developing solutions to technological problems. Many of our most serious problems can be lessened or even solved by the application of these techniques.
Progress in solving most human problems has lagged far behind progress in science. Most human problems cannot, of course, be taken to the laboratory to be worked on, and some aspects of the scientific method may not apply to these problems. However, a large body of evidence confirms that effective methods of thinking can be of great value in solving everyday human problems (Moore, McCann and McCann: 1974).

The procedures of science (the scientific method), which you have just learnt, require two distinctly different kinds of thinking, creative thinking and *critical thinking. Creative thinking may be defined as the formation of possible* solutions to a problem or possible explanations of a phenomenon. Critical thinking, on the other hand is the testing and evaluation of these proposed solutions.

Effective thinking is both creative and critical. Indeed, both kinds thin king are essential in all areas of human activity. In diagnosing an illness for example, a physician first develops possible diagnoses that seem to fit the symptoms. He then evaluates them by further examination of the patient or by laboratory tests. The final diagnoses cannot be right unless the possible diagnoses include the right one. Even when the possible diagnoses do include the right one, the physician may still make a mistake by being careless in criticising them and settling on the wrong one.

If you have understood the scientific method discussed in section 3.1, you would agree that it is both creative and critical. Outside the laboratory, however, both scientists and laypersons tend to be careless about both creative and critical aspects of thinking. When our feelings are aroused, we are likely to act first and think only after it is too late. Thus to 'create' and 'criticise' are the twin watchwords of the effective thinker.

The general process for applying creative and critical thinking to problem can be described as a cycle of six phases. You have already studied these phases in section 3.1. This cycle should not be treated as a rigid procedure in which each phase must be completed before the next is begun. In practice, you may go back to an earlier phase or work on several phases at the same time. But if you are to have any real assurance that your final decision is sound, all phases must be completed. Why don't you begin now to practise using this cycle (that is, the scientific method)?

You should know that every phase of decision-making is strongly affected by the fact that each one of us sees both the world and ourselves from our own personal point of view. This can interfere with objectivity, which is mportant to effective thinking. How effective our thinking is depends partly on how objective we are in viewing ourselves and the world without bias. However, absolute objectivity is impossible because we observe the world only through the lens of our own point of view.

You should keep in mind two essential things for objectivity. The first is to concentrate on the pursuit of truth in all the problems you take up, no matter how unpleasant or threatening it may be. Science has a system of punishing failures of objectivity, but in human setting, you must develop your own sense of discipline. The second element in objectivity is to be open to your feelings. Exclude them when they are not relevant and include them when they are, and you must be able to discern the difference.

It should now be clear to you that perfection in thinking cannot be attained. Effectiveness is the important thing. Also a satisfactory solution to every problem is too much to expect. The person who expects to solve every problem and make the right decisions every time is unrealistic. Effective thinking, like laying a musical instrument, requires practice. This is important both for understanding the techniques fully and for developing skill in applying them. What stops you from practicing now?

4.0 CONCLUSION

This unit has introduced you to the scientific method of acquiring knowledge. You must have also learnt how it can be applied to solve real life problems and scientific problems. Thus the method is useful to every human being, whether a scientist or a non-scientist.

5.0 SUMMARY

The main points in this unit are:

1. The steps of the scientific method are:
(a) Observation. It can be direct or indirect, spontaneous or induced. Scientific observation must be repeatable.
(b) Problem definition. This involves question asking about the observation made. Scientific questions must be relevant and testable.
(c) Hypothesis formulation. It involves guessing or proposing answers to the questions posed.
(d) Experimentation. Answers without evidence are unsupported opinions.

Thus experimentation provides the necessary evidence for accepting or rejecting the proposed answer.
(e) Conclusion. It can be redefined, modified and clarified when the situation arises.
(f) Theory formulation. This will be the main topic of discussion in the next unit.

2. The scientific method is both creative and critical. Thus it can be used to develop effective thinking, which is ver y necessary for solving both scientific and real life problems.

6.0 TUTOR-MARKED ASSIGNMENT

1. List sequentially the steps of the scientific method.
2. Discuss briefly what each step involves.

7.0 REFERENCES/ FURTHER READING

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UNIT 3 BASIC SCIENTIFIC THEORIES

CONTENTS

1.0 INTRODUCTION

In unit 2, the scientific method — a process of acquiring knowledge about nature — was discussed. If you will recall, the process involves a sequence of steps, which are: observation, problem definition, hypothesis formulation, experimentation, conclusions and theory formulation. The material in this unit will explain to you in detail what a scientific theor y means and also list some of the basic scientific theories. Emphasis in this unit will be on the theories of evolution. This topic is important because it will expose you to the different views people, right from the beginning of recorded history, have held about how life began and how the great variety of earth's organisms came to be. It is expected of you that at the end of the unit, you will have achieved the objectives listed below.

2.0 OBJECTIVES

After studying this unit you should be able to:

1. Define clearly a scientific theory.
2. List clearly three characteristics of a scientific theory.
3. Identify three events that led to the revival of discussion on evolution
4. Describe briefly evolution by natural selection.
5. Explain concisely how other fields of inquiry have led to a better understanding of the mechanism of evolution.

3.1 What is a scientif ic theory?

Would you be able to recall the definition given in unit 2? If so, well done! As was stated in that unit, a scientific theory is an explanation about the cause or causes of a broad range of related phenomena (Starr and Taggart: 1992).

A theor y explains how things are related or their common properties. Scientific research (using the scientific method) leads to the accumulation of facts about nature. As the facts accumulate, organizing them into higher knowledge becomes imperative. This is because our minds require a rationalised, logically consistent body of knowledge to help retain and use information (Beveridge: 1970).

To help in the organisation, a working hypothesis is usually required. Thus, theories start as hypotheses or tentative formulations meant to explain the phenomenon under investigation. When a hypothesis is confirmed through experimentation, it becomes a theory. Theories take various forms, which may be as diagrams, equations, statistical and propositional formulations.

A theory is formulated in such a way that its range of application is indicated(Nwala: 1997). It says, 'given such and such conditions', any phenomena, which satisfy those conditions, are subject to the theory under reference. Let's take for instance that a new drug called 'Relief tablets' against bacterial disease 'X' is manuf actur ed in Nigeria ['The nature of science' (see p. 29)]. To test the effectiveness of that drug, Nigerian patients of different ages, sex, eating habits, hereditary background, etc, are used. Additionally, the experiment is carried out under specified hospital conditions with proper allowance for unspotted errors and with different doses of the drug. At the end of the experiment the drug might be found to have an effectiveness of 60% against the bacteria. If this result is confirmed by many independent researchers in different localities, a theory may be proposed.

The theory might state that 'in bacterial disease X, "Relief tablets" are effective in 60 per cent of the cases'.

This statement is very much broader than the experiment on which it is based, and theories are always like that. The statement has not given any limitations in terms of who manufactures the drug, where it is manufactured, where it can be used and whom it can be used on. Therefore that statement implies, for example, that 'Relief tablets', no matter who manufactures it, will be 60% effective anywhere in the world, under any conditions and can be used for both man and other animals.

You can understand that direct evidence for the added implications does not exist. But so far as 'Relief tablets' is already known to work within certain limits, the theory expresses the belief, the probability that it may also work within certain wider limits. Every good theory therefore has a predictive value. It prophesies certain results. Scientific prophecies always have a considerate amount of evidence to back them up. Additionally, a scientific prophecy does not say that something will certainly happen, it only says that something is likely to happen and with a stated degree of probability. Theories that have proved to be universally valid and have a high degree of probability are called natural laws. You will learn about these in unit 4. Laws also do not pronounce certainties.

In conclusion, theories enable us to explain, predict and control phenomena. They also provide us with a new way of looking at a familiar object or phenomenon. The theory of optics, for instance, provides us with a new way of looking at the phenomenon of light (Nwala: 1997). Before this theory was discovered, people thought of light in the form of patches, shades of colour, etc. With the theory of optics, people's way of looking at light changed. Light is now viewed as travelling (propagation) and this gives room for explaining a wider range of phenomena than the old way of looking at light.

Since the advent of modern science in the sixteenth and seventeenth centuries AD, many scientific theories have been proposed. These include the theory of universal gravitation, the theory of evolution by natural selection, atomic theor y, genetic theory, relativity theory, quantum theory, etc. The theories of evolution will be discussed in the next section.

Exercise 3.1
Test yourself with the following questions:
1. What is a scientific theory?
2. Theories enable us to (a) ——————————, (b) ————————— and (c) phenomena.
3. Examples of scientific theories include (a) ——————————————, (b) —————————— (c) —————————and (d) ——————————————.

3.2 Theories of evolution

3.1.1 Evolution before Darwin

Ever since the beginning of recorded history, man has speculated on the origin of life. In ancient times, it was generally believed that organisms originated spontaneously from non-living matter. Thus, the ancient Egyptians believed that rats came from garbage. Renaissance scientists knew better than this, but in the seventeenth and eighteenth centuries AD, it was widely believed that bacteria (microorganisms discovered in 1676) originated spontaneously. It was only in 1862 that Louis Pasteur disproved, once and for all, the theory of spontaneous generation (Roberts: 1971).

Have you ever wondered how the earth came to be populated by a great variety of organisms? The search for explanations has proved to be challenging. The answers have been found to point to one direction — to evolution, which means the progressive change of living things through time.

The idea of evolution was not originated by Darwin in the nineteenth century as some people think (Raven and Johnson: 1986). Some ancient philosophers observed that organisms ranged from very simple to relatively complex ones.

Each group of organisms, according to them, was created by God. Modern individuals of each group trace their ancestry to the individual created by God. The Judeo-Christian culture also promoted such thinking.

Most early scientists believed fully that each kind of organism with all of its individual adaptations was created by God. They studied these organisms, their structures, and the relationships between them as a way of learning more about the creator. In the seventeenth century, for example, the English scientist-clergyman, John Ray (1627-1705) clearly declared his belief that each kind of animal and plant had remained unchanged from the day it was created (Raven and Johnson: 1986). All these views are collectively known as the doctrine of fixed species or creationism. It was never convincingly challenged before Darwin (Moore et al: 1995).

During Darwin's time, biology was dominated by natural theology. The natural theologians believed that the variations and adaptations of organisms proved that each species was fashioned by God for a particular purpose. Besides they believed that the earth was only a few thousand years old. For them, this was not long enough for significant evolutionary change. What is your own view? Do you believe in the theory of spontaneous generation or in the doctrine of fixed species? What are your reasons?

Gradually, some discoveries led to the revival of discussions on evolution. These include:

1. The discovery of many more kinds of organisms by the first part of the eighteenth century (Raven and Johnson: 1986).
2. The study of fossils which was begun in the eighteenth century by Georges

Cuvier(Moore et al: 1995). Fossils as you might be aware are remains or body impressions of dead organisms that lived in the past. They are usually found within sedimentary rocks, which occur in layers. Cuvier, from his studies, found that different layers of the rocks held different kinds of fossils. Also the fossils appeared in chronological order that is the deeper the layer, the older the fossil it contains. To him, these observations seemed to be boundaries for dramatic change in ancient environments. His attempt to explain these changes came to be known as catastrophism (Starr and Taggart: 1992).

Exercise 3.2

1. The belief that rats originated from garbage is an example of (a) ——————————————— theory, and (b) ——————————————— people held such a belief.
2. The view that each kind of animal and plant has remained unchanged from the day it was created is known as (a) ——————————————————— or (b) ———————————————————
3. Examples of proponents of such a view are (a) ———————————————— (b) ———————————

I hope you have understood the narration so far. Let us continue with the events that led to the revival of discussions on evolution:

1. From 1707-1788, a French biologist named Georges-Louis Comte de Buffon studied many mammals and observed that all of them common features. He then suggested that these could be explained in terms of their evolution from a common ancestor.

2. In 1795, a geologist, James Hutton argued that the earth was older than a few t housand years (Moore et al: 1995). His hypothesis was based on the fact that he believed that sedimentary rocks that encased fossils were formed by the gradual accumulation of sediments in lakes, rivers and oceans. This idea is known as gradualism. His explanation indicated that the earth was millions rather than thousands of years old.

Catastrophists such as Cuvier and gradualists like Hutton and Lyell (1797-1895) were good geologists (Moore et al: 1995). They were convinced of an ancient earthbut they found it difficult to explain the appearance and disappearance of species in the fossil record. They were all creationists. Lyell, in particular attributed the gradual addition of new species to the earth's flora and fauna to an unspecified creator.

3. In 1809, the year Charles Darwin was born, Jean Baptiste de Lamarck (1744-1829) proposed that all species, including human beings were descended from other species (Moore et al: 1995; Raven and Johnson: 1986). He believed that life changed progressively from the simple to the more complex. He was the first naturalist to present a unified theory that attempted to explain the changes in organisms from one generation to the next.

Lamarck's explanations were based on the theory of inheritance of acquired characteristics, which he propounded. The theory states that 'changes acquired during an individual's life are brought about by environmental pressure and internal "desires" and that offspring inherit the desired changes' (Starr and Taggart: 1992).

Have you heard of an animal called giraffe? If your answer is yes, do you know why it has a long neck? Lamarck's theory explained it as suppose the ancestor of the modern giraffe was a short-necked animal. Pressed by the need to find food, this animal constantly stretched its neck to feed on the leaves on high tree branches. According to Lamarck, stretching increased the length of the neck and this acquired characteristic was passed to its offspring. These offspring in turn stretched their necks to reach higher leaves. Thus generations of animals desiring to reach higher leaves led to the modern giraffe.
Using similar reasoning, he also proposed that the use and disuse of a feature governed the fate of that feature in successive generations (Moore et al: 1995).

According to him organs of the body that were used extensively to cope with the environment became larger and stronger, while organs that were not used deteriorated.

Presently, scientists know that the mechanism he proposed for changes was wrong. Acquired characteristics cannot be inherited. His theories, however, stimulated people's interest in evolution. As a result of this, the stage was then set for the acceptance of the much simpler explanation that was developed by Darwin half a century later (Raven and Johnson: 1989).

Darwin's greatest contribution was the laying of the foundation for an evolutionary theory by noting that species change over time and the *environment is a factor in that change (Starr and Taggart: 1992).*

Exercise 3.3

You should be able to answer the following questions, to test your progress in studying this material:

1. The observation that distinct layers of rocks reveal sequences of —————————————— showing gradual changes in structure supports the hypothesis that species evolve.
2. Match the following individuals and ideas by filling in the correct letter in the space provided.

Individuals Ideas

———————Judeo-Christians (a) Gradualism
———————Cuvier (b)All mammals have common features
——————— Lamarck (c) Catastrophism
——————— Buffon (d) Doctrine of fixed species
——————— Hutton (e) Inheritance of acquired traits

3.2.2 Darwin and modern evolutionary thought

In this section, you will learn about Darwin's ideas on evolution. His ideas have had a great impact on a wide array of human endeavours than any cientific advancement of the past 150 years (Moore et al: 1995). His research work on evolution provided the first scientific explanation for the diversity of life. His explanation of how evolution works has attracted more controversy than most scientific ideas. This is because it has affected not only science but also philosophy, religion and human attitudes.

Charles Robert Darwin (1809-18882) was an English naturalist. At the age of eight, his interest in observing the natural world was manifested. At that age, he was an enthusiastic but haphazard collector of shells. At ten, his interest shifted to the habits of insects and birds (Starr and Taggart: 1992). At fifteen, he preferred hunting, fishing and observing the natural world to doing his schoolwork. At the university, he could not complete his study of medicine, because that was not his area of interest. He later graduated from Cambridge University as a clergyman but was still interested in natural history.

At the age of 22, one of his professors at Cambridge University, John Henslow arranged for him to take part in a training expedition led by an eminent geologist. Henslow had earlier noticed and respected Darwin's real interest in natural history. He therefore arranged that he be offered the position of naturalist in the ship they were about to sail in. Do you know that right from the 1770s naturalists had always been posted on all British voyages to distant lands? The aim was to gather more knowledge of nature to add to the store of human knowledge (Raven and Johnson: 1989; Starr and Taggart: 1992).

The ship they boarded was called H.M.S. Beagle. The main aim of the voyage was to complete an earlier work of mapping the coastline of South

America. While on the expedition, Darwin had chances to study many diverse forms of life on the islands where they stopped, near mountain ranges and along rivers. He returned to England in 1836, after nearly five years at sea and he began a long life of study and contemplation.

Exercise 3.4

1. Charles Darwin was born in (a) ——————————— and died in
(b) ——————————.
2. At what age was he a collector of shells?
3. He graduated from (a) ————————————— University as a
(b) ——————————————
4. Who arranged for him to be a naturalist aboard H.M.S. Beagle? ——————————————
5. (a) At what age did he leave for the voyage?
(b) At what age did he return to England?

Let’s continue from where we stopped. When Darwin came back to England, the question that disturbed him was, ‘What could explain the remarkable diversity among organisms?’ Luckily, field observations he had made during his voyage enabled him later to recognise two clues that pointed to the answer (Starr and Taggart: 1992).

First, while the coast of Argentina was being mapped, he repeatedly got off the ship for exploratory trips inland. On these trips, he made detailed field observations and collected fossils. He saw for the first time many unusual species, including an armadillo.

Among the fossils were remains of the now extinct glyptodonts. Glyptodonts were very large animals that closely resembled the living armadillos. This is shown in figure 1.3.

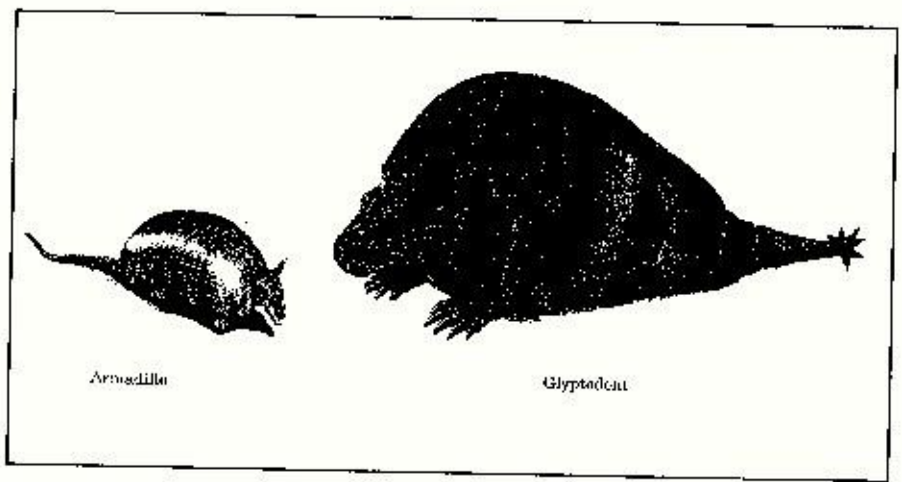

Figure 1.3 Reconstruction of a glyptodont
(Source: Raven and Johnson: 1989)

Darwin became puzzled and started wondering: If both kinds of animals had been created at the same time, if they lived in the same part of the world, and if they were so much alike, then why were armadillos still moving about while the glyptodonts were long gone and buried (Starr and Taggart: 1992)?

Nothing else in the world resembled either animal. Although nobody including Darwin had ever seen one species evolve into another, he later wondered whether armadillos were descendants of glyptodonts.

Second, he had observed that populations of similar kinds of organisms that lived in different geographic regions often showed remarkable differences in some of their traits (that is, characteristics). For instance, Darwin saw giant land tortoises on the Galapagos Islands which were off the coast of Ecuador. To his surprise, all the tortoises were not identical. It was recorded that even natives of those islands and the sailors could tell which island a particular animal had come from just by looking at it (Raven and Johnson: 1989). Darwin reasoned that perhaps all those species descended from the same ancestral form and had become slightly modified after they became isolated on different islands.

Darwin again wondered how such modification could occur. He got a clue from a book published by Thomas Malthus in 1798. The title of the book was 'Essay on the Armadillo Glyptodont principles of population'. According to Malthus, 'any population tends to outgrow its resources and its members must compete for what is available'. This statement struck Darwin and he thought about all the populations he had observed during his voyage. He thought about how the individual members of those populations had differences in body size, form, colouring and other traits. It then dawned on him that some traits could lead to differences in the ability to secure scarce resources (Starr and Taggart: 1992).

Exercise 3.5

1. Mention two pieces of evidence that suggested to Darwin that evolution occurs.
2. (a) Who wrote the book called 'Essay on the principles of population'?
(b) In what year was it published?
3. State the main ideas in that essay.
4. How did that idea help Darwin in his study of the process of natural selection?

As we were discussing, Darwin got a clue of how modifications could occur from Thomas Malthus's 'Essay on the principles of population'. With that clue, Darwin declared that it was natural selection, that is nature selecting the 'fit' and rejecting the 'unfit' that led to modifications in members of a species. He described the process of natural selection as follows (Starr and Taggart: 1992):

If there were struggles for existence (competition) within a population, then individuals that possess superior physical, behavioural or other attributes might have an edge in surviving and reproducing. In other words, Nature would select individuals with advantageous traits and *eliminate* *others — and so a population could change. Favoured* individuals would pass on the useful traits to offspring, their offspring would do the same and so on. Gradually, descendants of the favoured individuals would make up most of the population, and less favoured individuals might have no descendants at all.

Darwin published his work in 1859 and it caused an immediate sensation. Many people were very disturbed because the theor y implied that humans probably evolved from apes, monkeys, etc, since all share similar characteristics. Surprisingly, in 1858, Darwin received an essay from a young English naturalist named Alfred Russel Wallace (1823-1913). The essay was on 'Theory of evolution by means of natural selection'! What a coincidence! Both of them had independently reached the same conclusion about evolution. However, Darwin was given the credit of propounding the theory because of the amount of evidence he marshaled out.

Thus, Darwin's theory of evolution is one of the main unifying themes of the biological sciences. It provides an explanation for three main sets of facts about life on earth, which we observe (Rutherford and Ahlgren: 1988). These are:

1. The incredible display of different types of living things we see about us.
2. The different degrees of likeness among the living things. The likeness could be anatomical or molecular.
3. The fossil record that shows a sequence in the kinds of organisms that have lived on earth over billions of years.

At the heart of the theory of evolution is the concept of natural selection. That means, natural selection is the mechanism that results in evolution. However, Darwin's theory still faced a crucial test which worried him. It did not explain the mechanism of heredity - that is the way desirable traits or characteristics were transmitted to offspring. You will read about the solution to this problem in the next section.

Exercise 3.6

1. Two keen observers of nature who outlined the theory of evolution by natural selection were
(a) Cuvier and Lamarck.
(b) Darwin and Wallace.
(c) Buffon and Darwin.
(d) Malthus and Lyell.

2. Natural selection may occur when there are
(a) heritable traits.
(b) variations in traits within a population.
(c) adaptive traits.
(d) differences in survival and reproduction among members of a population.
(e) all of the above.

3. 2. 3 Evolution after Darwin

Before Darwin's death in 1882 and even after his death, many important discoveries have been made and these have led to a better understanding of the mechanism of evolution. These discoveries were made in other fields of inquiry such as paleontology, genetics, biochemistry, embryology, geology and ecology. You will learn about the contributions of the first three fields in this section.

Darwin before his death predicted that the fossil record should yield intermediate links between the great groups of organisms. I believe you know the great groups of organisms? They are fishes, amphibians, reptiles, birds and mammals. Paleontologists (those who study fossils) confirmed this prediction two years after Darwin's book was published. In 1861, an early bird-reptile called archaeopteryx was discovered. It resembled reptiles and birds. This is shown in figure 1.4. Like fossils of small two legged reptiles, it had teeth and a long bony tail. Like modern birds, its body was covered with feathers (Starr and Taggart: 1992).

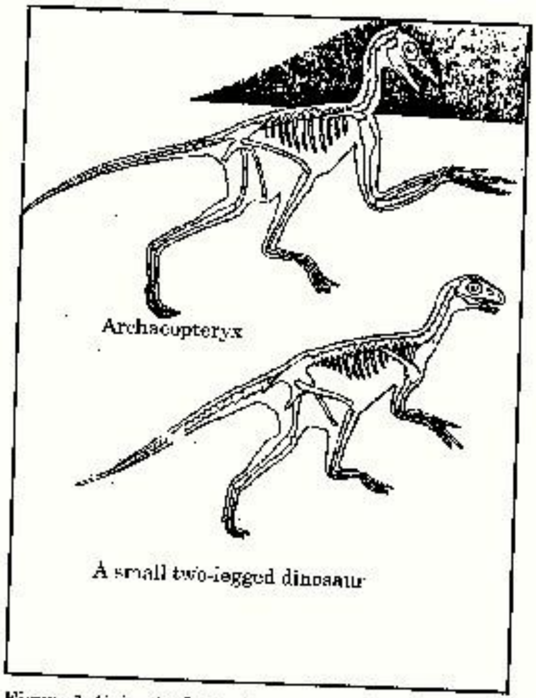

Figure 1.4(a) Archaeopteryx; a small two-legged dinosaur
(*Source:* Starr & Taggart: 1992)

Figure 1.4(b) A reconstructed archaeopteryx
(*Source:* Raven and Johnson: 1989)

Discoveries of microscopic fossils by paleontologists have extended back the known history of life on earth to more than 3.5 billion years. The discovery of other fossils has shed light on the ways in which organisms have evolved from the simple to the complex over the course of this enormous time span. The evolution of the major groups of vertebrates and their relationships to another have become reasonably well understood since their bones and teeth are often seen in the fossil record (Starr and Taggart: 1992).

Among the most important developments in evolutionary biology since Darwin is the application of genetics to the theory of evolution by natural selection. Genetics is the science of inheritance. If you would recall from section 3.2.2, Darwin was worried because his theory could not explain how parents pass on their characteristics to offspring. In the early part of the century, Gregor Mendel's laws of inheritance were rediscovered. Scientists found that those laws accounted for the origin of new variations in organisms and how these variations were passed on from parents to their offspring.

Biochemistry is the science that examines the chemical processes and substances that occur in living things. Its techniques are being used understand evolution better (Raven and Johnson: 1989). Would you know how this is done? Samples of the same kind of protein are obtained from different organisms. Then biochemical tools are used to determine the sequences am into acids in those protein samples. Individuals, populations, species and even larger groups have sequences that are characteristic of them. When sequences are compared for, let's say, 10 different species, their degree of relationship can be specified precisely.

The following information might interest you very much (The Guardian: 2001): An international team of scientists from Australia, Great Britain and the United States found that human evolution is still operating according to the forces of natural selection which was first identified by Charles Darwin. The main findings of the study are that:

1. Natural selection is leading women to have the first child earlier in life.
2. This tendency is partly inherited.
3. As a result, evolution is leading to an increasing biological pressure on women to start families earlier than later.

In the study, Roman Catholic women are found to have a 20% higher 'reproductive fitness' than women of other religions. University educated women, on the other hand, had 35% lower fitness than those who left school early. The study, however, found that such cultural influences could not explain all reproductive differences between women. Dr Owens, a member of the research team from Imperial College, London said that it was surprising to find that genes played almost as much of a role in deciding these issues as religion or social class. Genes were found to explain about 43% of the differences in age of first child within the female population. Their next step according to Dr Owens is to try to discover what these genes are.

Exercise 3.7

1. Fields of inquiry which have contributed to a better understanding of the mechanism of evolution include:

(a) ________________________________ (b) ____________________

(c) ———————————————————— and (d) ——————————————————————————

2. An intermediate link between bird-reptiles called (a) ———————————————— was discovered in the year (b) ————————————————

3. ————————————————— is the science which explains how characteristics are passed on from parents to offspring.

4.0 CONCLUSION

In this unit you have learnt what a scientific theory really means and its various characteristics. You have also been introduced to the various ideas on evolution before Darwin proposed his own theory. It is good to be aware that Darwin's theory of evolution by natural selection is one of the most comprehensive themes in biology. This is because it explains how life began and howdtiversified into the organisms of today. If you had thought that human evolution had stopped as a result of improvements in diets, housing and medicine, you would have been pleasantly surprised with the information in section 3.2.3. This shows that science is never finished. It is a dynamic activity.

5.0 SUMMARY

The main points in this unit include the following:

1. A scientific theory is an explanation about the cause or causes of a broad range of related phenomena. A theory explains how things are related or their common properties.
2. Theories take various forms, which may be as diagrams, equations, statistical and prepositional formulations.
3. A theor y is formulated in such a way that its range of application is indicated.
4. Every good theory has a predictive value.
5. Theories enable us to explain, predict and control phenomenon.
6. They also provide us with a new way of looking at a familiar object or phenomena
7. Scientific theories include the theory of universal gravitation, the theory of evolution by natural selection, atomic theory, relativity theory, quantum theory, etc.
8. Theories of evolution propounded before Darwin include the theory of spontaneous generation and the doctrine of fixed species or creationism.
9. Events that led to the revival of discussions on evolution include:

(a) The discovery of many more kinds of organisms by the first part of the eighteenth century.

(b) The study of fossils which showed that layers of sedimentary rocks held different kinds of fossils. The fossils also appear in chronological order - the deeper the layer, the older the fossil it contains.

(c) Comte de Buffon's observation that all mammals he studied had common features.

(d) James Hutton's hypothesis that sedimentary rocks that encased fossils were formed by the gradual accumulation of sediments in lakes, rivers and oceans — thus indicating that the earth was millions rather than thousands of years old.

(e) The proposition of de Lamarck's theory of inheritance of acquired characteristics.

10. Some of Darwin's pieces of evidence that evolution occurs include the following:

(a) Extinct species, such as the glyptodonts shown in figure 1.3 most closely resemble the living armadillos in the same area, suggesting that one had given rise to the other.

(b) Layers of sedimentary rock held different kinds of fossils and they appeared in chronological order.

(c) Populations of similar kinds of organisms that lived in different geographic regions often showed noticeable differences in some of their characteristics. For instance, the giant land tortoises on the Galapagos Islands were not identical; thus indicating to Darwin that all those species might have descended from the same ancestral form but had become slightly modified after they became isolated on different islands.

11. Darwin got a clue as to how those modifications could occur from

Thomas Malthus's 'Essay on the principles of population'.

12. With the aid of those pieces of evidence and the clue from Malthus, Darwin declared that it was natural selection, that is, nature selecting the 'fit' and rejecting the 'unfit' that led to modifications in members of a species. That means that natural selection is the mechanism that leads to evolution. Thus Darwin's theory consists of two major parts (a) concept of evolutionary change, and (b) the concept of natural selection.

13. Darwin's theory, however could not explain how desirable characteristics or modifications were transmitted from parents to offspring.

14. After Darwin's death, fields of inquiry such as paleontology, genetics, biochemistry, embryology, geology, ecology, etc, have produced results that have led to a better understanding of the mechanism of evolution.

15. The field of genetics, particularly, through the laws of inheritance proposed by Gregor Mendel, has given evidence of how desirable characteristics are transmitted from parents to offspring.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is a scientific theory?
(c) biochemistry (d) geology etc
2. List three characteristics of a scientific theory.
3. Identify three events that led to the revival of discussion on evolution.
4. Outline three of Darwin's pieces of evidence that evolution occurs.
5. Describe briefly evolution by natural selection.
6. How have the fields of paleontology and genetics led to a better understanding of the mechanism of evolution?

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UNIT 4 LAWS OF NATURE

CONTENTS

1.0 Introduction

Perhaps we should begin with some critical thinking…. Think of the sun and the moon, how they periodically repeat their movements. Think about when you wake up in the morning, you would first of all meet the dawn, that is when night (which is always dark) is gradually giving way to daytime (which is always light). Nighttime is always associated with some difficulties such as not seeing clearly the mater ial things of nature, while daytime gives us light which enables us to see things very well. You know that this is what everyone of us experiences ever y time — nighttime giving way to daytime and daytime leading us into nighttime and vice versa. Do you know that these events are related to the daily 'movement' of the sun? When the earth turns its face towards the sun, that region of the earth will have daylight, when it turns its back, the region will have nighttime. And you know that this is a continuous event which man has observed right from ancient times.

This daily motion of the sun is simple to observe while the annual motions are far more difficult to observe. Both motions are also related to other important events that occur on earth such as the seasons. In Nigeria, there are both the dry seasons and the rainy seasons while in European and American countries, they have winter, spring, summer, and autumn. These seasons as you know occur regularly, one changing into the other. Thus there are many regularities in nature which mankind has had to recognize for survival since human beings emerged as a species. These include births and deaths, storms and calms, the solid earth and the ever-restless seas, etc. The pattern and regularity of these changes can be expressed as rules or laws. These laws are called natural laws because they are derived from the natural properties of objects and phenomena. This topic — the laws of nature — is the topic of discussion for this unit.

You can see that it's going to be an interesting unit. If you study it very well, it will help you to understand a lot of natural events. And whenever such events are being discussed you would not be a novice there.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Outline briefly the components of the laws of nature.
2. Explain clearly the term 'gravitation'.
3. Discuss, vividly, the law of uniformity of nature.

3.1 What is law of nature?

From the introduction, you now have an idea of what the law of nature is. Would you be able to define it when asked to do so? The discussion in this section will help you. Some people believe that some regularities are figments of human imagination. They say that the human mind leaps to conclusions because it cannot tolerate disorder or chaos. Thus it constructs regularities even when none objectively exists (Encyclopaedia Britannica: 1995). These true regularities must be established by an impartial or unemotional examination of data. Science must, therefore, employ a certain degree of doubt criticism to prevent premature generalisations. Science also insists on getting explanations of the causes of these regularities. It, however, does not permit some kinds of causes. For instance, attributing some causes to spiritual and divine forces is not permissible in science.

Since scientists believe that the world is comprehensible, that is, understandable because there is order in the world, finding the causes of these regularities wouldn't be problematic. If you can take your mind back to unit 3, you will remember that 'an explanation about the cause or causes of a broad range of related phenomena' was called a theory. A theory explains how things are related or their common properties.

In other words, when the properties and relationships between things are discovered, including their pattern and regularity of changes, they are then expressed as theories. A good theory, if you can remember from unit 3, has a predictive value. It prophesies certain results. But scientific prophecy does not say that something will certainly happen, but says only that something is likely to happen with a stated degree of probability. Thus theories that have proved to be so universally valid or true, that is, they are true anywhere in the world and have such a high degree of probability, are called natural laws. That means that not all theories are laws and laws also do not pronounce certainties. B ased on this can you give an example of a natural law?

The idea of a law-governed universe assumes that the universe unifisorm. Our ability to predict events and apply the fundamental laws of the sciences depends on this law of uniformity. That is why J.S. Mill cited in Nwala (1997) defined laws of nature as 'nothing but the uniformities, which exist among natural phenomena'. Thus, laws of nature refer to, that is, encompass the following:

1. Those uniformities found in nature (that is uniformities in behaviour, function, relations and properties of things).

2. Established connection of successive events which make up the order of the universe.
3. Established theories through scientific research (Nwala: 1997).

Examples of laws of nature are:

1. Law of the uniformity of nature
2. Law of causation
3. The law of gravitation
4. The law of natural selection

3.2 Belief in the uniformity of nature

There is a general belief that the universe and all aspects of it are law-governed and that the ordinary events or procedures of nature are uniform (Nwala: 1997). This belief is found in primitive and traditional thought as well as in modern scientific thought. The birth of children, death, growth, normal and abnormal occurrences, lightning and thunder, the seasons, day and night, etc: these phenomena are usually explained in terms of general rules or causal laws. In traditional thought, these laws are believed to have a spiritual and teleological character. This means that in traditional thought, when these events occur, for instance, death, the traditionalist believes that it was the gods who caused the death to occur and also that the death occurred for a purpose. Teleology is a view that developments occur because of the purpose or design they serve. Therefore, traditional people look for the purpose for the occurrence of any event.

If a tree, for instance, breaks or a house suddenly collapses, traditional mind will seek to explain such a happening in terms of the purpose, interest and wishes of some spiritual forces. Thus, the principles, laws or factors, which the traditional mind uses to explain the work of nature is often speculative, that is, meditational in character. Therefore the laws or factors may be superstitious and unreliable (Nwala: 1997). The scientist, however, explains the work of nature in terms of material, causal and rational factors. That means that the scientist reasons through and tries to find the causes by means of some activity. We cannot kn owledge of anything unless we are able to show why and how it occurs. This knowledge is expressed in terms of general rules or laws. Scientific laws are objective, factual and can be expressed in quantifiable (if you like mathematical) form. They are independent of our subjective wishes and interests.

Therefore according to J.S. Mill cited in Nwala (1997), it is the custom in science, wherever regularity of any kind can be traced, to call the general statement which reveals the nature of that regularity a law.

Science establishes such laws through the steps of the scientific method. You know that the steps include observation, problem definition, hypothesis formulation, experimentation, conclusion and, finally, an appropriate theory is formulated which embodies the law.

The entire universe is said to show uniform patterns and to form a united system.

This view is called the law of the uniformity of nature. You will learn more about this in the next section. The study of nature is the study of these laws and uniformities, which different natural phenomena show or exhibit. The regularities, which different phenomena exhibit, are sort of connected. They form something like a web but they can be studied separately.

Exercise 4.1

Check the rate of your understanding of the topic so far with the following questions:

1. Theories that have proved to be so universally valid and have such a high degree of probability are called ————————————
2. Two examples of (1) above are (a) —————————————— and (b) ——————————————
3. The laws which the traditional mind uses to explain the works of nature are ———————in character.
4. —————————————— laws are objective, factual and can be expressed in quantifiable forms.

3.3 The law of uniformity of nature

Men generally believe in the coherence, consistency or common pattern in all phenomena, which can be observed and even in non-observable ones. Do you think that includes you? This natural sequence, regularity and pattern of behaviour of things is evidence that there is a causal order. Hence, men believe that every event has a cause, and that for anything that happens there must be a cause for it. It is said that like events behave alike and also have similar causes. Belief in the uniformity of nature enables us to explain, predict and reproduce these events, where we can (Nwala: 1997). Induction (a type of scientific reasoning where facts are produced to prove general statements), according to some scientists, is based on the general law of the uniformity of nature. You will learn more about induction in a subsequent unit. Since there is orderand regularity in the occurrence of events, if we observe certain characteristics in a certain number of members of a class, we can assume or conclude that all members of that class must have the same characteristics. For example, if we know from observation that all the men we have come across are mortal (that is, they die), we then conclude that 'All men are mortal'. This generalisation covers all men who have died, all those who are alive and all those who will be born in future.

From the point of view of logic (science of reasoning), the law of the uniformity of nature claims that nature is a system composed of many parts. Within this system, everything happens according to rule. The law assumes that the universe does not change and, therefore, the laws of the uniformity of nature governing its behaviour remains constant (Nwala: 1997).

David Hume cited in Nwala (1997) has criticised our concept of causation. He attributes the use of the idea 'cause' to the habit of anticipating one event after another because they have been associated in the past. His view is that we cannot demonstrate the idea of causation. And also that the necessary thing which links two events that are often associated together may not be there. What is there is the habit of seeing one following the other and thereby expecting that this will always be the case. For example, red and green lights may succeed each other without causing the other. That is, red light does not cause the green light to appear and vice versa, but they might succeed each other, that is, one appearing after the other.

It is good for you to know that causal notions or ideas are being replaced by statistical formulations in science.

3.4 The law of gravitation

In section 3.3 you were introduced to the law of uniformity of nature, which is one of the natural laws. The next natural law you will learn is the law of gravitation. What is gravitation? Gravitation is the force which pulls every object in the universe toward every other object in the universe (Arkady: 1997). It is the force that makes a body fall through space towards the earth. Thus the force exists between all bodies. For instance, two stones are not only attracted towards the earth but also attract each other (Abbot: 1973). Normally, we do not notice this force because of its smallness, although it can be measured with sensitive instruments.

The law of gravitation first started as a theory of universal gravitation. The theory was first postulated by Sir Isaac Newton (1642-1727) an English mathematician and physicist. He tried to explain the behaviour of falling objects. Before this theory, mysterious interpretations had been given as the reason why objects do fall downwards when suspended in space. The theory was the first scientific explanation of the behaviour of falling Newton noted that the earth possesses some force which attracts objects towards it. This force was recognised as gravitational force. Gravitation is the attraction between masses. This is what pulls objects around towards the surface of the earth. Hence, all objects within the earth's gravitational field fall towards the earth (Nwala: 1997). Why don't you experiment now? Throw up any object you can lay your hands on and see what happens.

Since the earth has a centre of gravity, all objects in the universe are attracted towards this centre. It was also noted that as objects move away from the earth, the gravitational force decreases, and their weight also decreases. If you can remember the definition of a theory given in section 3.1, you would agree that this theor y of gravitation has turned the fictitious idea surrounding falling objects to science. It did this by explaining theoretically and empirically why objects behave the way they do.

Albert Einstein's theory of relativity, which was formulated in 1905, explained the Newtonian theory properly by asserting that gravitation is a property of space. The presence of any physical substance within space causes it to curve in such a manner that a field of gravitational force is created (Eneh: 2000). With this clarification by Einstein and others, the theory was elevated to the rank of a law.

Therefore, Newton's law of universal gravitation states that 'any two bodies attract each other with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them'. What this whole statement means is that if the mass (amount of matter) of one of the two attracting bodies is doubled, the gravitational attraction will also be doubled, but if their distance apart is doubled the force will be only one-fourth (1/4) as great (Arkady: 1977). Newton realized that gravitational attraction applies not only to bodies on the earth but is also responsible for holding the moon in its orbit round the sun. And it is also responsible for the movement of the earth and its fellow planets in their orbits round the sun.

Exercise 4.2

Test your understanding of the two laws discussed here with the following questions:

1. (a) ———————————— (b) —————————— and (c) —————————— of 'things' is evidence that there is a causal order.
2. Every —————— has a cause.
3. The force which pulls every object in the universe towards every other object in the universe is called

(a) centripetal force.
(b) centrifugal force.
(b) contact force.
(d) gravitational force.

4. The first scientific explanation of the behaviour of falling bodies was given by ————

4.0 CONCLUSION

In this unit, you have learnt what natural laws are and how laws differ from theories.

And you should now be able to give examples of natural laws. Other topics discussed here include the law of uniformity of nature and the law of universal gravitation. From these discussions, you now know that these laws relate to events which we encounter everyday of our lives.

5.0 SUMMARY

The main points in this unit are

1. Theories that have proved to be so universally valid or true and have such a high degree of probability are called natural laws.
2. In general, law of nature refer to the following:

(a) Those uniformities found in nature (behaviour, function, relations and properties of things).

(b) Established connection of successive events which make up the order of the universe.
(c) Theories established through scientific research.
3. Examples of laws of nature are the
(a) law of the uniformity of nature.
(b) law of causation.
(c) law of gravitation.
(d) law of natural selection.
4. Scientific laws are objective, factual and can be expressed in quantifiable form.
5. The entire universe is said to show uniform patterns and to form a united system.
This view is called the law of the uniformity of nature.
6. Gravitation is the force which pulls ever y object in the universe towards every other object in the universe. It is the force that makes a body fall through space toward the earth.
7. The first scientific explanation (theory) of the behaviour of falling objects was given by Sir Isaac Newton (1642-1727).
8. Albert Einstein's theory of relativity which was formulated in 1905
explained the Newtonian theory further by asserting that gravitation is a property of space.
9. With this clarification by Einstein and others the theory of gravitation was elevated to the rank of a law.
10. The basic idea of the law is that if the mass (amount of matter) of one
of the two attracting bodies is doubled, the gravitational attraction will also be doubled; but if their distance apart is doubled, the force will be only one quarter as great.
11. Gravitational attraction explains the behaviour of falling objects and the motions of the moon and the planets and other motions we observe on earth.

6.0 TUTOR-MARKED ASSIGNMENT

1. What does the law of nature refer to?
2. Explain what is meant by the term 'gravitation'
3. What is the basic idea of the law of universal gravitation.

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UNIT 5 HISTORY OF SCIENCE -1 (ORIGIN OF WESTERN SCIENCE IN THE ANCIENT TIMES)

CONTENTS

1.0 INTRODUCTION

In this unit you are going to learn how Western science originated in ancient times. In fact, the next four units will introduce you to how that science originated and how it evolved to its present state. Please bear in mind that when we talk about the origin of science, we are in essence talking about the origin of the scientific method. If you can recall from unit 1, science can be defined in terms of the method of acquiring knowledge of nature. From the time of recorded history to the early sixteenth century AD, Western science progressed very slowly. It was the emergence of this method of science in the seventeenth centur y that enabled the science to achieve the impressive success it has achieved today. This topic is important because it will help you to appreciate how logical thinking is of indispensable value to man. It is also important because it will expose the mistakes of the past and enable us to learn from them.

The histor y of Western science is going to be discussed in four phases namely:

1. Origin of Western science in ancient times beginning of recorded history to about AD 476).
2. Science in the middle ages of Europe (AD 476 -1400).
3. Rise of modern science (AD 1400 to the present time).(which dates from the
4. Twentieth century scientific revolution.

However, you should note that the division of history into these periods is only a guide to help historians. There was never any such clear-cut division of time in history. Rather, one period merged into the next. As was mentioned earlier, this unit will only treat the origin of science in the ancient times. The other phases will be discussed in subsequent units. The objectives below specify what you are expected to have learnt after studying this unit.

2.0 OBJECTIVES

After studying this unit you should be able to:

1. Write briefly on the contributions of ancient Egyptians and Babylonians to science
2. Discuss vividly how Thales of Miletus, Anaximander and Pythagoras explained the fundamental component of matter.
3. Identify the contributions of the Roman Empire to science.

3.1 Ancient science

The origin of science is often traced to the Egyptians and the Babylonians. They originated science during the Neolithic age when they settled down to an organized agricultural life and activity. It has been possible to infer what the content of science in these areas was from archaeological remains. This is because writing, as we know it today, hadn't been discovered: then (Dampier: 1989; Nwala & Agbakogba: 1997). It is important to note that the disciplines we call science today separated gradually from philosophy. Thus at the time of the Egyptians and Babylonians, people who studied plants, animals, stars and other heavenly bodies, rocks, soils, etc were all called philosophers. There was nothing like a botanist, zoologist, an astronomer, etc. It was in Alexandrian Academy in Egypt that specialisations started. You will read about this subsequently.

Please also note that the word 'philosophy' was taken from two Greek words, namely: 'philos' (which means love) and 'sophia' (which meanswisdom). Thus philosophy literally means 'love of wisdom'. Therefore to call a person a philosopher was to call him a lover of wisdom. This is because the reeks believed that whoever tried to study and understand nature was trying to be wise.

3.1.1 Egypt

The kingdom of Egypt was divided into three religious centres, which were Memphis, Heliopolis, Thebes or Hermopolis. These centres were administered by priest-scholars. They were called scholars because they were the intellectualclass of the ancient Egyptians. Their power remendous and even the kings were subject to it (Onyewuenyi: 1993).

These priest—scholars established a kind of school system known as the Egyptian Mystery System schools. The schools were a kind of university where every known discipline was taught by the priests. Such disciplines were philosophy, comprising religion, medicine, law, mathematics, geometry, astronomy, etc. This group of disciplines was referred to as 'the Wisdom of the Egyptians'. Thus a lot of ancient Egyptian science tudied as sacred knowledge. And such knowledge was possessed and disseminated by the priests. One of the main stimuli for the origin of ancient Egyptian science was their practical needs in agriculture (such as measuring, calculations, surveying and study of the weather and the heavens). Second is their understanding of the world they lived in through religion and philosophy (Nwala and Agbakoba: 1997).

Astronomy originated with the Egyptians through their study of the heavens, the stars and the weather. They knew that the best time to plant their crops was right after the Nile River overflowed its banks. Their priests noticed that between each overflow the moon rose 12 times. So they counted 12 moons or months and figured out when the Nile would rise again. Their accuracy in these predictions led to their invention of the lunar calendar. They divided the year into 12 'moons' or 'months' of 30 days each and added a space of 5 days to each year, thus bringing each year to a total of 365 days (Arkady: 1977).

Credit is also given to the Egyptians for the origination of mathematics. The evidence was the finding of the Rind Mathematical Papyrus, which was written during the reign of King A-User-Re (1650 B.C.). It contained arithmetical problems and solutions involving the use of fractions and decimals. Another ancient text which contains evidence of Egyptian origin of the sciences is the famous writings of Hermes Trismegistus which contain among other works, books on medicine, physics and chemistry (then called alchemy). The theory of transmutation of elements (the basis of modern chemistry) first appeared among ancient Egyptians.

The ancient Egyptians were also reputed highly in medicine. They are said to have performed caesarean operations and removed cataracts from the eyes. Evidence for these is contained in the Edwin Papyrus, which was excavated. Do you know that the first physician of the ancient world and the most famous was the Black Egyptian called Imhotep? He lived about 2980 BC. He was called 'the god of medicine' by the Greeks and he lived 2000 years before the Greek doctor, Hippocrates, who in modern times is called the father of medicine (Eneh: 2000; Onyewuenyi: 1993). The Egyptians also invented writing called Hieroglyphics and paper (papyr us) on which they recorded their ideas and culture.

3.1.2 Babylonia (present day Iraq)

The sciences of mathematics, astronomy and engineering (irrigation and canal construction) also developed in Babylonia about 1800-1600 BC. The Babylonians believed that the heavens were the abode of their gods. They also believed that terrestrial disasters such as floods, insect attacks and storms were caused by these gods. Thus, they studied heavenly events carefully in order to know when their gods were angry so as to pacify them. Out of these practices grew a descriptive astronomy that was the most sophisticated of the ancient world until the Greeks took it over and perfected it. The first accurate astronomical observation they recorded was the rising and setting of the planet Venus (The New Encyclopaedia Britannica: 1995).

The Babylonians also realised the importance of fixed units of physical measurement. Their unit of length was the finger; the foot contained twenty fingers; the cubit, thirty fingers. The measurements of weight were the grain, the shekel and the talent, while their medium of exchange was the barley (Dampier: 1989).

Their land was harsh and was made habitable by extensive damning and irrigation works from their two great rivers - Tigris and Euphrates. mathematics thrived under these conditions. For instance, they needed to calculate the volume of dirt to be removed from canals and the provision necessary for work parties. It might be interesting to you to know that they were the first to divide the day into hours, minutes and seconds, and also divided the circle into 360 degrees (The Encyclopaedia Britannica: 1995).

You will agree that the Egyptians and the Babylonians were *obs rvers of nature and they gave precise descriptions. What was missing* was scientific explanations. To them, all knowledge was attributed to the revelations of their gods. They believed that it was the function of religion and magic to understand nature but that man could describe it and use it.

Exercise 5.1

Now test yourself with the following questions:
1. The religious centres in Egypt were (a) —————————— (b) ——————————— and (c) ———————————— and they were administered by d) ———————————
2. Evidence for the Egyptian origin of mathematics and medicine can be found in a) ——————————————— and (b) ——————— ——————— papyri respectively.
3. The first physician of the ancient world was ———————————
4. A day was divided into hours, minutes and seconds by the —————— ——————

3.1.3 African philosophy

From the last two sections, you have learnt the contributions of Egyptians

and Babylonians to the origin of various sciences. Before we discuss the contributions of ancient Greeks, your attention needs to be drawn to the influence of Egyptian philosophy on Greek philosophy. You should note again that in ancient times, philosophy embraced all the disciplines of study including natural science. But with the advancement and development of learning, specialised areas of study such as various sciences separated from their ancestor - philosophy, and became independent disciplines (Eneh: 2000).

The influence of colonial education has made it difficult for many to appreciate Africa's contribution to world civilisation. This is especially with regard to philosophy and science. European and Western civilisation and philosophy owe their origins to Egypt and Babylonia. Indeed Egyptian philosophy is the origin of Western philosophy but Greek philosophy itself owes its origin to Africa, particularly Egypt (Onyewuenyi: 1993). The evidence includes the following:

1. From the writings of the ancient Greeks themselves, such as Homer, Pythagoras, Socrates, Herodotus, Plutarch, Plato and Aristotle, etc, and modern historians such as William Stace, Edith Hamilton and James Henry Breasted, we learn

(a) the fact that Egypt is said to have colonised Greece and dominated its culture.

The ancient Greeks also acknowledge the Egyptian origins of their language, identity, science, philosophy, names of their gods, their rituals, etc.

(b) the fact that many of the leading Greek intellectuals lived and studied in Egypt. Africa's major contributions to philosophy and philosophical foundations of the various sciences include the following (Eneh: 2000; Onyewuenyi: 1993):

1. The world's first philosopher in history Ptah-Hotep (c 2800 BC) was an African.
2. Another African, Ipuwar (c 2500 BC) was the world's first social philosopher.
3. The black Egyptian Imhotep who lived 2000 years before Hippocrates, was called by the Greeks 'the god of medicine'.
4. Hypathia - The world's first woman philosopher (360-415AD).
5. The Alexandrian Academy in Egypt, which flourished between 300 BC and AD 200, was the centre of the scientific world. It was also the first to establish the tradition of disciplinary scholarship and specialisation. Among its intellectual giants were:

(a) The great mathematician Euclid who synthesised geometry as a science in his book Elements of Geometry.

(b) Aristarchus, the great astronomer and'Copernicus of Antiquity'.

Human body.

(d) Archimedes, the great mathematician who laid the foundation for the science of mechanics. He founded the Archimedean screw for raising water and is attributed with the doctrine of levers.

(e) Eratosthenes, the librarian at Alexandria who was called 'the most learned man of antiquity'. He also advanced the knowledge of prime numbers.

(f) Ptolemy of Alexandria, a geographer and an astronomer. His two greatest works were:

(i) Al magest, one of the most influential scientific works of all ages. It showed the paths in which the planets appear to move in the heavens, a detailed star catalogues and, extensive description ofastronomical instruments.

(ii) Geographical outline, which showed the map of the world representing the curved surface of the earth or a plane surface using latitude and longitude.

If you are interested in knowing more about the African origin of Greek philosophy, the following book will be of assistance to you:

Onyewuenyi, I.C. (1993) The African Origin of Greek Philosophy: An *Exercise inAfrocentrism, University of Nigeria Press, Nsukka.*

3.1.4 Ancient Greeks

Through the influence of Egypt and Babylonia, the Greeks acquired their knowledge of mathematics, astronomy and philosophy and developed these to an unprecedented degree (Nwala and Agbakoba: 1997). Science in ancient Greece will be treated under two headings:

1. Pre-socratic philosopher-scientists
2. Socratic philosopher-scientists

Pre-socratics

These people were known as natural philosophers because they engaged themselves with the study of nature and the origin of the world. They were ten in number and they included, Thales of Miletus, A Phoenician who migrated to Miletus in Ionia, Anaximander, Pythagoras, Heraclitus, Democritus, etc, who were Ionian philosophers. These men are usually called early Greek philosophers by some historians while some others are consistent in noting their non-Greek origin. They studied in Egypt erlsewhere under the same curriculum. After their studies, they went back to their respective countries to expand the teachings of the Egyptian Myster y System School (Eneh: 2000; Onyewuenyi: 1993).

They were more concerned with the phenomenon of change. They observed that physical substances (matter) change into one another but their main concern was to find out the original stuff from which all originated and to which they return. Has such a thought ever come to your mind? They attempted to answer this question and named the 'world-stuff' each in his own way:

1. Thales of Miletus (620 -546 BC)

He is usually referred to as the father of Western philosophy. He taught that *water was the source of all things in the universe. According to Aristotle* (Dampier: 1989), Thales got this idea from seeing that the nutriment of all things is moisture and that water is the origin of the nature of moist things.

Things that exist in the world are solid, liquid or gaseous in form. Water, according to Thales, underlies these forms and change from one form to another. Thales also forecast the eclipse of 585BC, although knowledge about eclipses was far advanced in Egypt where he studied (Nwala and Agbakoba: 1997; The New Encyclopaedia Britannica: 1995).

2. Anaximander (611 -547 BC)

He was a pupil of Thales in the Milesian school. He was quick to argue that water could not be the basic substance, because water is essentially wet and nothing can be its own contradiction. According to him, if Thales were correct, the opposite of wet could not exist in a substance and that would preclude all the dry things in the world. Therefore Thales was wrong (The *New Encyclopaedia Britannica: 1995). Here was the birth of the critical* tradition that is fundamental to the advance of science. On his own part, he called the 'world-stuff ' the 'infinite something'. This expresses the idea that the original stuff had no beginning, was imperishable, inexhaustible and indestructible. He was also the first among the Greeks to represent the earth on a map, though the science of map making (cartography) was known in Egypt and Babylonia.

3. Pythagoras (582 -497 BC)

He spent 22 years in Egypt and received instruction in mathematics, physics, theology, music, philosophy and ethics from the priest-scholars of the Mystery System schools (Nwala and Agbakoba: 1997; The New *Encyclopaedia Britannica: 1995). The mathematical theor y called* Pythagorean theory is named after him. For him all things are numbers. He believed that the universe was composed of numbers in various shapes -squares, cubes, oblong, triangular, etc. To him all things in the universe were numerable and could be counted. Pythagoreans (his followers) believed that the unit 'one' is the source of all numbers and they divided it into odd and even numbers. The whole story is interesting, isn't it?

4. Heraclitus (535 - 475 BC)

For him the 'world-stuff' is divine fire. He was the first Greek to advance the principle of change as a universal law. Change, he said is the only reality and that there is nothing permanent in the world. According to him, 'From life comes death; from death comes life; sleep changes into wakefulness and wakefulness changes into sleep'. Everything in the universe, he says, has its own opposite (Dampier: 1989).

5. Democritus (460 BC - ?)

He was a disciple of Leucippus who is credited with the founding of the atomic theory or the doctrine of matter. He became the ablest and bestknown interpreter of the atomic theory (Dampier: 1989). He proposed that matter is made up of atoms and they are infinite in number and too small to be perceived by the senses. He said that atoms differ in size, some bigger, some smaller and that there is empty space between them. According to him, everything new is produced from a combination of atoms and that death or cessation takes place when atoms separate.

So you can see that even the atomic theory was known in the ancient times. This effort of the Greeks to explain the basic components of matter is important in the histor y of scientific thought. This is because they tried to reason and to explain it in seemingly simpler terms.

The Socratics

They included Socrates, Plato and Aristotle. Plato studied in Egypt, but history is silent on whether Socrates and Aristotle also studied in Egypt. We shall discuss them one after the other.

1. Socrates (469-399 BC)
He was the teacher of Plato and was born in Athens. He was a moral teacher and sought truth by asking questions. He enriched science with the tools of universal definitions and inductive reasoning. You will learn about inductive reasoning in a subsequent unit.

2. Plato (427-347 BC)
After Plato's studies in Egypt, he returned to Athens and opened a school called the 'Academy'. He taught that it was more noble and dignified to seek answers by reasoning rather than by experiments. He loved mathematics and he formulated the idea of negative numbers. His Academy also produced philosopher-scientists such as Heracleides of Pontus (388-315 BC). Heracleides suggested that the earth rotates on its own axis once in every 24 hours and that Mercury and Venus circle round the sun like satellites (Eneh: 2000; Nwala and Agbakoba: 1997).

3. Aristotle (384-322 BC)
He was the most accomplished of Plato's pupils. He was born at Stagira in Macedonia. He was a tutor of Alexander the Great. He wrote books on almost all the areas of knowledge - biology, botany, anatomy, physics, metaphysics, astronomy, mathematics, logic, economics, politics, law, psychology, etc. His influence on subsequent development of science and philosophy was enormous. In particular, his views on physics and astronomy controlled the view most men had of the universe for two thousand years. However, to him, the proper means of investigation was observation. In conclusion, Greek science was said to be more of a speculative and theoretical activity rather than experimental and practical. In the next section, you will learn about the contributions of Rome to science. In the meantime, answer the following questions to check your understanding of the topic so far.

Exercise 5.2
1. Match the items in 'A' with those in 'B' by filling in the correct letter in the space provided:
A B
———————— Imhotep (a) Wrote the book called 'Al magest'
———————— Hypathia (b) The first to dissect the human body
———————— Euclid (c) The first physician in the world
———————— Herophilus (d) The first woman philosopher
———————— Archimedes (e) Synthesised geometry as a science
———————— Ptolemy (f) Laid the foundation for the science of mechanics
2. Pre-socratics named the 'world-stuff ' each in his own way. The following are what they named. Identify who named each:
(a)Water ————————————————
(b) Infinite something ——————————
(c) Numbers ——————————————
(d) Divine fire ———————————————
(e) Atoms ————————————————

3.1.5 Science in the R oman period (50 BC-AD 400)

The last and the most important of ancient civilisations in Europe was the Roman Empire. People of many different races came under its rule - the English, the French, Arabians, Syrians, Greeks, etc.

The Roman Empire, however, did not have much influence in the development of science. It was more interested in conquests and maintenance of power through political and military administration. The spirit of independent research was quite foreign to the Roman mind, so scientific innovation was interrupted for awhile (The New Encyclopaedia *Britannica: 1995). However, some scientific works were produced during* this period, but none of them was revolutionar y in nature. They were mainly a detailed explanation of scientific conceptions already developed in Alexandria or Greece. These include:

1. Geographical science

The wars and military expeditions of the Romans yielded much further geographical knowledge to mankind. Nations or countries, which were relatively unknown, entered the world map. Julius Caesar, one of e mperors gave the world its present calendar called the Julian calendar in 46 BC. In this calendar, the length of the year is fixed at 365 days and at 366 days at every fourth year. There were 12 calendar months of 30 and 31 days except for February, which has 28 days. However, February has 29 days at every fourth year or leap year. The month of July is also named after Julius Caesar (Nwala and Agbakoba: 1997).

Additionally, Pope Gregory III made a slight innovation to the Julian calendar. He made the leap year occur in any year whose number is exactly divisible by 4. The only exception is the centenary years whose numbers are not exactly divisible by 400, for instance, 1800, 1900. The revised calendar is called the Gregorian calendar.

2. Medical education and health care

The Romans of this period also established hospitals and paid physicians who worked there. They also promoted public health, hygiene and sanitation.

3. Pliny's natural History

Pliny (AD 23-79) promoted the development of natural history. He wrote a book on natural history and the topics of discussion in it were on animals and plants, especially medicinal plants and their uses. However, the book was a compilation of 2000 works by 146 Roman and 326 Greek authors.

In conclusion, both scientific research and theoretical science were in decline under the Roman Empire. The advances they made were more of a practical nature.

4.0 CONCLUSION

This unit has introduced you to how science originated in Egypt Babylonia and how the sciences were advanced further in Greece and in the Roman Empire. You have also been informed that Western philosophy and science owe their origins to Egypt.

5.0 SUMMARY

The main points in this unit include the following:

1. Science originated in Egypt and Babylonia (which is present-day Iraq).
2. Egyptian priest-scholars established a kind of school known as the Egyptian Mystery System Schools where every known discipline was taught by the priests.
3. Evidence for the Egyptian origins of mathematics and medicine can be found in the Rind Mathematical Papyrus and the Edwin Papyrus respectively.
4. Babylonians developed the most descriptive astronomy of the ancient world.
5. They were the first to divide the day into hours, minutes and seconds and also divided the circle into 360 degrees.
6. Egyptian philosophy is the origin of Western philosophy. Evidence can be found in the writings of ancient Greeks themselves such as Homer and Pythagoras, and from modern historians such as William Stace and James Henr y Breasted.
7. Pre-socratics named the original stuff from which all things originated and to which they return. The names given were:

(a) Water by Thales of Miletus
(b) Infinite something by Anaximander
(c) Number by Pythagoras
(d) Divine fire by Heraclitus
(e) Atoms by Democritus

8. Socrates enriched science with universal definitions and inductive reasoning.
9. Plato formulated the idea of negative numbers
10. Aristotle wrote books on almost all the areas of knowledge - biology, zoology, physics, astronomy, etc.
11. Scientific innovation began to decline in the Roman Empire.
12. The calendar invented by the Egyptians was modified further by Julius Caesar and Pope Gregory III.

6.0 TUTOR-MARKED ASSIGNMENT

1. Write briefly on the contributions of ancient Egyptians and Babylonians to science.
2. How did Thales of Miletus, Anaximander and Pythagoras explain the fundamentalcomponent of matter?

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MODULE 2

UNIT 1 HISTORY OF SCIENCE-2 (SCIENCE IN THE MIDDLE AGES OF EUROPE)

CONTENTS

1.0 INTRODUCTION

We studied the origin of western science in the ancient times in unit 5. This unit is a continuation of that unit. Here, we shall learn about how science progressed in the Middle Ages of Europe. Middle Ages as we learnt in unit 5, is a period in European history between about 476 and 1400.

Please remember that history has no clear-cut divisions. Rather, one period merges into the next. The history of science, which you will study from units 5 to 8, is essentially about European science. You will also learn about Africa's contributions to the advancement of modern science in module 3unit 3.

2.0 OBJECTIVES

After studying this unit, you should be able to do the following things:

1. Discuss vividly the state of science during the Dark Ages of Western Europes;
2. Outline the contributions of Arab scholars to science;
3. Write short notes on Robert Grossetesste, Rogar Bacon and Leonardo de Vinci.

3.1 Science in the Middle Ages of Europe (476 - 1400 AD)

The Middle Ages are also known as the medieval period. The period was dominated by Christian Theology and characterised by initial decline of science and its rise again much later (Nwala and Agbakoba: 1997). There are two phases within this period and they are:

1. The Dark Ages (450 to 800 AD)
2. The Renaissance (9th to 15th century AD)

3.1.1 Science in the Dark Ages

This is the first part of the Middle Ages in Europe. As a result of constant invasions by barbarian tribes (the tribes outside the Roman Empire), civilisation which had flourished under the rule of the Roman Empire, came to a standstill. Development in learning, architecture, science and art slowed down or stopped altogether. Life also became unsafe as a result of the many wars among the petty kingdoms within the Empire. A kind of 'darkness' covered life in Europe. For this reason, the period from about AD 450 to 800 is sometimes called the 'Dark Ages'. (You might be interested to know that this was the period when the old kingdom of Ghana reached the peak of its civilisation).

All through the Middle Ages, there was only one Christian church (Roman Catholic) in Western Europe. It became a symbol of unity, such that the united Christian world was called 'Christendom'. During the Dark Ages, the fathers of the church showed little interest in knowledge of nature for its own sake. They believed that holding discussion on the nature and position of the earth would not help them in their hope of life to come (Damper: 1989). Therefore, the desire and the power to study nature with an open mind gradually passed away. From the Christian perspective knowledge of nature was valued only as a means of edification, or as an illustration of the passage of scripture. People soon lost the ability to criticise and believe anything particularly if it was in accordance with the scriptures.

Example, a dictum of Aristotle, says, 'everything that moves is moved by something else'. Thomas Aquinas, one of the fathers of the church, used the statement as evidence that God must exist since he is an unmoved mover. Aristotle's cosmology was the dominant basis of science in the Dark Ages and the scholastic period—the period of Arab influence (The New Encyclopaedia Britannica:1995).He believed that heavenly bodies influenced human destinies.

However, some advances were made during this period. However, their fundamental nature, really made people not to notice them. These included the inventions of the rigid horse collar and the iron horse shoe. While the rigid horse collar helped to shift the weight of a load to a horse's shoulder, the horseshoe protected a horse's hoof from damage and so enabled the animal to travel farther and faster than it could without them. These were important inventions, since the use of horses were their means of land transportation (The New Encyclopaedia B ritannica: 1995). What do you think were the means of land transportation in Africa at that time?

In addition, the monks in monasteries ensured that some amount of learning was kept alive. During that period, they translated ancient knowledge and works of the Egyptians, Babylonians and Greeks into Latin. They also kept alive some knowledge of the art of agriculture, since they were practical farmers.

While Europe was in the Dark Ages, Islamic learning started to flourish in the East. To the Arabs, ancient science was a precious treasure. They eagerly searched for the writings of the Greeks and translated them into their language. In this way, much of the ancient science passed into Islamic culture. Greek medicine, astronomy and astrology, mathematics, philosophical works of Plato and particularly, Aristotle were assimilated in Islam, by the end of the 9th century. The Arabs, however, did not stop with assimilation (The New Encyclopaedia Britannica: 1995).

They criticised and tried to make their own innovations. Don't you think that should be the attitude of we Africans towards scientific advancements?

Don't you think that Africans should not just use foreign-made goods, for example, without some healthy criticisms? You may recall from unit 2 that critical thinking was defined as the testing and evaluation of proposed solutions to a problem. In unit 5 also, it was mentioned that 'critical tradition is fundamental to the advance of science'. You might be aware that some of the foreign-made goods don't function properly in Africa because of the weather, even though they help to solve some of our problems. Would you be able to give some examples of the foreign-made goods?

As we already mentioned in the foregoing, the Arabs criticised and innovated. Their major interest was in Astronomy and Astrology. They constructed great astronomical observatories, which they used in checking Ptolemaic predictions. (You may read about Ptolemy's work in unit 5, section 3.1.3 of module 1). The Arabs further made many improvements in medicine. In their hands, the primitive chemistry of the Greeks known as alchemy developed into modern chemistry. Rhazes (865 -925) was the greatest of the Arabic alchemist. His works were based on experience and experiment. The most eminent Muslim physicist was Ibn-al Haitham (965 - 1020 AD). His chief work was done in optics and showed a great advance in experimental method (Damper: 1989; Nwala and Agbakoba: 1997).

Islamic thinkers were fascinated with numbers. This fascination thus served as the motivation for the creation of algebra (from Arabic: al-Jabr) and the study of algebraic functions (The New Encyclopaedia Britannica: 1995). They also borrowed the idea of zero from the Hindu mathematicians and invented the Arabic numerals. Is this not interesting? Do you know what the Arabic numerals are? You might know but may not have known who invented them and how they were invented. The Arabic numerals are:
1,2,3,4,5, etc. Are you surprised? You would now know the importance of this invention. Just imagine how our everyday would have been like without these numerals? We wouldn't be able to do formal mathematics, various businesses would not have been able to keep records, and governments would have found it difficult to take census and so on and so forth.

Towards the end of the medieval period, it was widely recognised that the East held the secret of ancient wisdom in learning and science. Thus, the Europeans (west) developed interest in Arabic language and commenced translations of books from Arabic to Latin. You can observe the influence of Arabic learning of this period from several basic scientific terms that have their origins in Arabic or Persian language (Nwala and Agbakoba: 1997). Examples include the following:

1. Pharmaceutical terms: alcohol, camphor, and syrup. (These are of Persian origin
2. Technical/astronomical: Zenith, azimuth, azure, etc. (These are of Arabic origin).
3. Mathematical terms: zero, cipher, sine, root, algebra, algorism, etc
4. Music terms: lute, guitar, rebeck, etc.
5. Other words of Arabic origin include: almanac, mattress, take, tartarm astronomy, etc.

However, the Arabic or Muslim science was very speculative. making little or no experiments. It was not empirical. By the close of 11th century, the decline of Arabic learning had set in, and from then, science was chiefly a European activity.

Exercise 6.1

1. List two characteristics of the Dark Ages of Europe.
2. How did ancient science pass into Islamic culture?
3. Identify what you think are the contributions of Islamic scholars to science and society.

3.1.2 Science in the Renaissance Period

This period is the second half of the Middle Ages of Western Europe and it started from the 9th to 15th century. During this period, men began to be dissatisfied with a way of life, which made progress very slow. People felt that changes in ideas, in beliefs and in ways of thought were necessary. The ancient Greeks and the peoples of other ancient civilisations had written many books on mathematics, astronomy, geography etc., and learned men of this period began to study these ancient writings. This increasing desire for knowledge was satisfied by translation of the Greek books into Latin. This was done in two ways: firstly by retranslation from the Arabic and later by direct translation from the Greek (Damper: 1989).

The learned men of this period saw that the ancient scholars had a lot to offer them. But they were not satisfied to learn simply what those before them had written or taught. They tried to find out new things for themselves. (This should exactly be the attitude of Africans and Nigerians in particular towards scientific development. Don't you think so?) You would observe that this attitude of renaissance men was different from that of the men of the Dark ages. Men of the Dark Ages were often satisfied with whatever they learnt, without any form of questioning.

This spirit of questioning old beliefs and forming new opinions generally came to be described as the 'Renaissance', which means rebirth or revival of learning. The revival was started in Italy by three famous scholars: Dante (1265 -1321 AD), Petrarch (1304 -1374 AD) and Boccaccio (1313 -1321 AD). These artists tried to show how superior the learning, art and culture of the ancient Greeks were, and this led to a revival of interest in the Greek language.

In the field of science were two very influential theologians and philosophers: Albert 'the Great'(1193 -1280 AD), a Bavarian Dominican priest, and Thomas Aquinas (1225 - 1274 AD), an Italian monk. Both of them taught at the University of Paris. They were the first to accept the idea of a distinction between knowledge of nature and revealed knowledge. But they also pointed out that God was the author of both. This rationalistic approach separating large segments of human knowledge from theology, prepared the way for a relatively independent development of science.
(Damper: 1989; Ene: 2000; The New Encyclopedia Britannica: 1995).

Some scientists of this period with experimental and practical bent of mind include the following:
Robert Grosseteste (1175 -1253). He was an English philosopher science. He determined the main direction of the physical science in the 13th and 14th centuries. He had knowledge of the workings of mirrors and of the nature of lenses (Nwala and Agbakoba: 1997).

Roger Bacon (1214 - 1294 AD). He was an English, Franciscan Monk.

He was the first man in Europe, during the renaissance period, approached in scientific spirit, the great Arabians who preceded him (Damper: 1989). This was because of his clear understanding that experimental methods alone give certainty in science. This was a revolutionary change in mental attitude. He read all the authors he could reach. This included those of the Arabic and Greek authors. Instead of accepting the facts and inferences of natural knowledge from the scriptures, the fathers, the Arabians or Aristotle, he told the world that the only way to verify their statements was to observe and experiment. But in spite of his writing, he did not appear to have done much experimenting himself, except in optics.

In addition, for all his comparatively advanced outlook, accepted most of the medieval attitude of mind. This was with regards to the fact that the end of science and philosophy was to explain and adorn their queen - theology.

Leonardo da Vinci (1452 - 1519). He was an Italian and he could stand as the incarnation of the true spirit of scientific thought of the renaissance. He was a painter, a sculptor, an engineer, an architect, a physicist, a biologist and a philosopher. He was indeed supreme in each role. To him, 0 bservation of nature and experimentation were the only true methods of science. He also believed that knowledge of the ancient writers could be useful as a starting point, but could never be conclusive. He opined that mathematics, arithmetic and geometry gave knowledge that was certain within their domain, and therefore had something to do with reasoning. But true science, he said began with observation to obtain certainty of knowledge. According to him again, 'those sciences which do not begin with experiments, the mother of all certainties and which do not end with one clear experiment are vain and full of errors'. Science to him Give certainty and power (Damper: 1989).

Leonardo might have been great, but it is to be noted that he did not solely originate the scientific spirit he displayed. Alberti (1404 -1472) had studied mathematics and did physical experiments before him. While he was helped in his anatomical researches by Antonio della Torre, Amerigo Vespucci gave him a book on geometry.

What do you think we can learn from the men of Renaissance? If your answer includes the following, then you are on the right track:

1. They truly founded modern science. They emphasised observation, hypothesizing and experimentation, which are the core elements of the scientific method.
2. In spite of the above statement, science at the Renaissance period was still a branch of philosophy. This is because renaissance men were still philosophers in spite of their advanced scientific outlook.

3. Africans, especially Nigerians of all works of life should cultivate the habit of using the scientific method of reasoning. It was the emergence of this method and its use that led to the advancement of countries of Western Europe and other advanced countries.

Exercise 6.2

1. What is 'Renaissance'?
2. Where did it start and who started it?
3. Mention the two people who started the Renaissance in science.

4.0 CONCLUSION

In this unit, we have discussed how Western science, which originated in the ancient times, progressed through the Dark Ages and Renaissance period. As you are now aware, the Dark Ages and Renaissance period constitute the two parts of the time called the Middle Ages of Europe. Within these periods, Western science was still trying not only to find its feet, but also to free itself from the clutches of philosophy and religion. The next unit will focus on how science finally found its feet.

5.0 SUMMARY

The main points in this unit are as follows:

1. The Middle Ages of Western Europe comprise two phases which are: the Dark Ages (450 to 800 AD) and the Renaissance (9th to 15th century AD).
2. In the Dark Ages, knowledge of nature was valued only as a means of edification or as an illustration of the passages of scripture.
3. In that period also, people lost the ability to criticise and believed anything that was in accordance with the scriptures. Thus, science and earning declined rapidly.
4. In that same period, the monks in monasteries translated ancient works into Latin and thus kept alive some amount of learning.
5. While Europe was in the Dark Ages, Islamic learning started to flourish.
6. Islamic scholars translated Greek writings into their language because they treasured ancient science.
7. In this way, ancient science passed into Islamic culture.
8. The Arabs did not stop with assimilation. They also criticised and innovated.
9. In their hands, the primitive chemistry of the Greeks known as alchemy developed into modern chemistry.
10. Islamic thinkers also created the science of algebra and the study of algebraic functions.
11. They also borrowed the idea of zero from the Hindu mathematicians and

invented the Arabic numerals.

12 Many scientific terms such as alcohol, syrup, zenith, algebra, zero, sine etc. are legacies which Arabic science left to mankind.

13. The Renaissance period was characterised by an increasing desire for knowledge such that critical power resurfaced.

14. The Renaissance in science was started by two theologians: Albert the Great (1193 -1280 AD) and Thomas Aquinas (1225 - 1274 AD).

15. They were the first to accept the idea of a distinction between knowledge of nature and revealed knowledge. They also pointed out that God was the author of both.

16. This attitude of theirs prepared the way for a relatively independent development of science.

17. Some scientists of this period who emphasised the methods of observation and experimentation were: Robert Grossetesste (1175 - 1253 AD), Roger Bacon (1214 -1294 AD) and Leonardo da Vinci (1452 - 1519 AD).

6.0 TUTOR-MARKED ASSIGNMENT

1. During the Dark Ages of Western Europe, the desire and the power to study nature with an open mind gradually passed away. State the reason for this.
2. What were the contributions of the Arabs towards the development of science?
3. Write short notes on Roger Bacon and Leonardo da Vinci.

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UNIT 2 HISTORY OF WESTERN SCIENCE-3 (RISE OF MODERN SCIENCE)

CONTENTS

1.0 INTRODUCTION

This unit is the continuation of the History of Western science. The last unit described the state of science in the Middle Ages of Europe. In that unit, we learnt how Western science was still trying to find its feet, and to free itself from the clutches of philosophy and religion. This unit will introduce you to how that science finally became independent. The objectives below specify what you are expected to have learnt after studying this unit.

2.0 OBJECTIVES

After studying this unit, you should be able to do the following:

1. Compare accurately the Geocentric and Heliocentric theories of heavenly motion;
2. Write concisely on the contributions of Galileo, Kepler and Newton towards the change in scientific outlook of the 16th and 17thcenturies;
3. Explain briefly why the 19th century is regarded as the beginning of the scientific age.

3.1 Rise of modern science

This topic will be discussed under the following two sub-headings:
1. the scientific revolution;
2. the classic ages of science.

3.1.1 The scientific revolution

This was a period that witnessed a complex change in scientific outlook. It started in the late 15th century, and reached its highest point in the 16th and 17th centuries. True experimental science, free from philosophy and religion, emerged

in the 16th and 17th centuries.
The first great change in scientific outlook after the renaissance was made by a polish mathematician and an astronomer called Nicolaus Copernicus (1473 - 1543) (Damper: 1989). You will recall that in unit 5 of module 1, we came across a man called Ptolemy of Alexandria. He was a geographer and an astronomer. He wrote a book called Al Magest. In that book, he showed how the heavenly bodies such as the moon, the stars, the sun and all the planets move. According to him, the earth is located at the centre of the universe, and all other heavenly bodies move round it in circles. This view of his, can be called the Ptolemaic system or Geocentric system or Geocentric Theory.

Figure 2.1 below illustrates it.

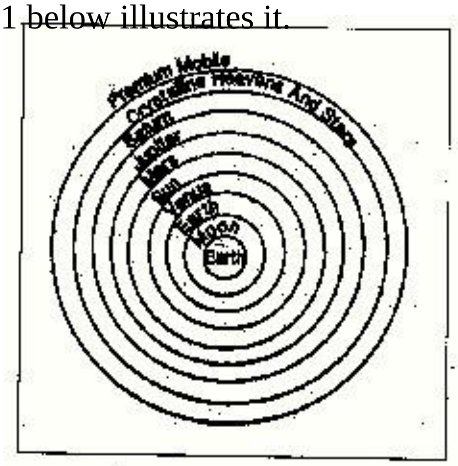

Fig. 2.1 The Ptolemaic world system

By now you might be asking, ‘How does Copernicus come into all these’?
Ptolemaic system was the view which people of that time had of mhov ement of heavenly bodies, until Copernicus came along and challenged it. To Copernicus, the sun is at the centre of the universe while the earth and other heavenly bodies move round it in a uniform, circular motion. This view is known as Copernican world system or Heliocentric theory (Nwala and Agbakoba: 1997). Figure 2.2 below illustrates it.

It is important to note that the Copernican theory was not based on experimentation. He based his theory on logical assumptions or hypotheses and his taste for aesthetic symmetry (Nwala and Agbakoba: 1997). He considered theory as a serious work in astronomy rather than in philosophy. So he set out to justify it observationally and mathematically. As a result, he had a lot of conflicts with the church authorities. The implication of his theory is that humanity no longer stands at the centre of creation, since the earth is no longer at the centre of the universe (Damper: 1989; The New Encyclopaedia Britannica: 1995). It is not surprising to know that the people of that time and their authorities felt bad over the affront to them and their earth, not being the centre of attraction in the universe.

Galileo (1564 - 1642), an Italian, provided a most beautiful evidence, to justify that ancient authorities should no longer be accepted without criticisms. He invented a telescope and used it to view the heavens and thus confirmed the Copernican theory that the sun was at the centre of the universe. Galileo also got into trouble with the church authorities for his audacity to be on the side of Copernicus.

Credit is usually given to Galileo for discovering and establishing the true method of physical sciences. This is because he combined experimental and inductive methods with mathematical deductions to obtain his results.

You will learn the meanings of induction and deduction in a subsequent unit. The experiment he carried out was to use the telescope to view the heavens. You will recall that it was said in unit 2 of module I, that whosoever 'experiments' after observations and hypothesis formulation are carried out becomes truly 'scientific' in his approach. Experimentation is the very essence of the scientific method. Thus, we can safely say that one of the greatest scientific discoveries of Galileo was the invention of the scientific instrument of observation called the telescope. With the aid of this telescope, he saw countless stars, whose existence no one had suspected.

At the same time Galileo was searching the heavens with his telescope, in Germany, Johannes Kepler (1571 - 1630) was searching them with his mind (The New Encyclopaedia Britannica: 1995). He was the first to apply mathematics as an empirical instrument in searching for the laws of heavenly motions. He was an advocate of the heliocentric theory. Greatest achievement as an astronomer was the discovery of the three laws of planetary motion. The laws are as follows:

i. All planets travel about the sun in an elliptical (oval) path, ii. A planet moves faster in its orbit as it nears the sun,

iii. There is a relation between its distance from the sun and the time it takes to make an orbit (that is one movement round the sun).

What Galileo and Kepler could not provide, although they tried quite hard, were answers to these questions:

i. If the earth revolves on its axis round the sun, then why do objects not fly off it?

ii. How is it possible for the earth suspended in empty space to go round the sun - whether in circles or ellipses - without anything pushing it? The answers were long in coming (The New Encyclopaedia Britannica: 1995).

The year 1660 seems to be the most important time in early development of modern science. It was in that year that Isaac Newton (1642-1727 AD) achieved one of the greatest successes of all times. In other words, through his work, he confirmed the results of Copernicus, Kepler and Galileo. Thus all the results (of Copernicus, Kepler, Galileo and Newton) formed the first great synthesis of physical knowledge, which is the primary aim of science.

This means that science aims to be able to combine many unrelated facts, so as to be able to explain, predict and control nature.
Newton proposed a principle of gravitational attraction, and used it to answer the questions posed by the works of Galileo and Kepler. The basic ideas in the principle are 'each object in the universe attracts all other bodies to the centre of its form, and that if the mass of one of the two attracting bodies is doubled, the gravitational attraction will also be doubled; but if their distance apart is doubled, the force will be only one-quarter (1/4) as great' (Arkady: 1977).

By using this theory, Newton was able to explain the motion of the planets round the sun, the familiar fall to the ground of fruit from trees, and all other motions which we see on earth. The accuracy of Newton's theory or law proved to be amazing. With the help of this theory, generations of astronomers have been able to explain and predict astronomical events (Dampier: 1989). Do the words - theory and predict ring a bell in your mind? As we mentioned in unit 2 of module I, 'every good theory has a predictive value'. Thus, Newton's theory is a good one.

Francis Bacon (1561 - 1626 AD) is regarded as the first person to attempt to arrange the steps of the scientific method in a logical manner. He emphasised the role of scientific discoveries and inventions in giving man mastery over the forces of nature.

At last, we have seen the true beginning of modern science. At rena issance, science was still a branch of philosophy, but after that period, it succeeded in finding its own method of observation and experiment. Where it is necessary, mathematical analysis is also used.

Exercise 2.1

1. State the Geocentric and Heliocentr ic theories. Name the people who proposed them.
2. What would you call the observation made by Copernicus and Galileo? What are the reasons for your answer?
3. ——————————— confirmed the Heliocentric theory.
4. ——————————— discovered the laws of planetary motion.
5. The results of a) ——————————— b) ——————————— c) ——————————— and d) ——————————— formed the first great synthesis of physical knowledge.

3.1.2 The classic ages of science (18th and 19th centuries)

At the time of the scientific revolution, scientific advances were restricted largely to physics, Astronomy and Chemistry (that is to the say, physical sciences). In the 18th and 19th centuries, further advances were made in Mathematics and Astronomy. One of the major advancements in Chemistry in the 18th century was the discovery of the role of air and gases generally in chemical reactions. Such chemical reactions include combustion (burning) and respiration in organisms.
The person that can be called the 'Newton of Chemistry' was a man named Antoine

Laurent L avoisier (1743 - 1794 AD) . He discovered that it was a gas, which he named oxygen that enables combustion (burning) and respiration to take place (Dampier: 1989; The New Encyclopaedia Britannica: 1995).

As you might be aware, people of nowadays now take it for granted that we need 'air' in order to breathe well. Try to imagine what people that lived before Lavoisier thought of an activity like burning of things. They were not able to explain why burning takes place in certain situations and not others. So you can appreciate the beauty of discoveries and inventions.

The revolution in chemistry was both a revolution in method as well as in ideas. Lavoisier insisted that the central concern of the new chemistry was the use of gravimetric method. This involves paying particular attention to the weight of the ingredients involved in chemical reactions and of the products that result. He found from his experiments that the weight of the products of combustion (burning), for instance, equals that of the original ingredients. His discovery became known as the law of the conservation of mass (or matter).

The 19th century has been regarded as the beginning of the scientific age because of many reasons. They include the following (Dampier: 1989):

1. There was very rapid growth of knowledge of nature during the period.
2. It was during this period that the view or idea people had of the natural universe changed, by recognising that 'man' was also subject to the same physical laws and processes as the world around him. Therefore 'man' should also be studied.
3. It was also realised that all the field of knowledge could use the scientific method and not just pure science alone.
4. Again, within this century, people started carrying out scientific investigations, with the sole objective of gaining more knowledge. It was understood that such investigators were moved by their insatiable curiosity concerning the unknown.
5. The knowledge obtained by investigators above was used by applied researchers to produce and invent things. For example, in 1864, James Clerk Maxwell, a British Physicist conducted research to determine the relationship between heat and other forms of energy. He expressed his

findings in mathematical formulas to design cars and even rocket engine that use fuel more efficiently.

6. Thus within this period, scientific research and industrial development went hand in hand. This was unlike in former ages when the need to solve a problem led to inventions unless those inventions were produced by accident.

You may have observed that the study of living things (Biology) had lagged far behind chemistry and physics. This was because people at that time believed that organisms were too complex for them to study. However, in the 19th century, researchers interest shifted from astronomy to geology and from physics to biology. The major discoveries of the 19th century include the following:

1. The understanding that atoms and molecules are the basic building blocks of matter.

Does this statement remind you of anything? If it does, it means you have been understanding the materials presented for the previous units. In module I, unit 5, we learnt that, the early Greeks tried to find out what matter was made of. Various answers were given such as water, divine fire and atoms. It was Democritus that mentioned atoms. It was only in the 19th century that John Dalton confirmed that Democritus was right.

Let's use water to illustrate. It is now known that water can be produced by combining hydrogen atoms and oxygen atoms. Once you combine two atoms of hydrogen with one atom of oxygen, water is produced!

2. The understanding that cells are the basic building blocks of living things. Although in 1665, R obert Hooke used his primitive microscope to observe that plant materials have a cellular structure (Dampier: 1989). He only saw the outline of the cells and not what was inside. To say that cells are the basic building blocks of living things means that every human being, other animals and plants are built up from cells. It is just like building houses with blocks. Living things are built with cells.

3. In human beings also, the cells which aid reproduction are called gametes. The gametes from fathers are called sperms, while those from mothers are called eggs or ova. The combination of the sperm of a man and the egg from his wife brings pregnancy, which ultimately results in bringing baby or babies into the world after nine months of pregnancy. This is what happens in all living things - whether plants or animals. That is why it is said that 'cells are the building blocks of living things'.

4 The statement that 'cells are the building blocks of living things' is called the cell theory. In unit 2 of module 1, it was defined as an phenomena. Scientists observed from experiments that all living things were composed of cells. They also observed that each living thing was built up by combining cells. So in 1839, two scientists, Theodor Schwann and Matthias Schleiden made this general statement or proposed a theory that 'cells are of universal occurrence and are the basic

building blocks of an organism and that cells come from pre-existing cells' (Roberts: 1971). This theory is one of the fundamental theories of Biology.

5. Another fundamental theory of Biology proposed in the 19th century was the theory of Evolution. You can now observe that topics that make up this course are interconnected. You will recall that in unit 3 of module 1, this Evolution was discussed.

Although there are many theories of evolution, the one which the scientific circle accepts is the theory of evolution by natural selection, which was proposed by Charles Darwin in 1859. Charles Darwin is also called the 'Newton of Biology'. This is because the publication of his theory led to an explosive growth of biological sciences - just as Newton's work stimulated in the physical sciences.

People started carrying out experiments here and there, either to confirm Darwin's theory or to prove him wrong. Some people were not prepared to accept the ultimate indignity of having descended from a bacterium, and of sharing common ancestors with monkeys, apes and even worms. The theory ignited an excitement in the scientific community that has not yet fully died.

People were then willing to research on plants and animals, which they thought were too complex to study.

Exercise 2.2

1. The Newton of Chemistry and Biology were
a) —————————— and b) —————————— respectively.
2. The basic building blocks of matter and living things are
a) ————————————— and b) —————————— respectively.
3. In year a) ————————, two scientists b) —————————— and
c) —————————— proposed the cell theory.
4. State the cell theory.

4.0 CONCLUSION

In this unit, you have learnt how there was a complete revolution sncientific outlook from the late 15th century onwards. Experimental science
became independent of philosophy and religion. You have also learnt that the 18th and 19th centuries are called the classic ages of science because of the explosion in knowledge of nature that occurred at that time. You will also note that the explosion is still continuing, if you think about all those stories about genetic engineering, chemical engineering, cloning of animals, etc. These will form part of our discussion in the next unit.

5.0 SUMMARY

The main points in this unit include the following:

1. There was a complete change in scientific outlook from late 15th century up to 17th century. True experimental science, free from philosophy and religion emerged in the 16th and 17th centuries.
2. The first great change in scientific outlook was made by Nicolaus Copernicus (1473 -1543). He disproved the Ptolemaic system or Geocentric theory, which stated that 'the earth was the centre of the universe and all other heavenly bodies move round it in circles'. To Copernicus, the sun was the centre of the universe while the earth and other heavenly bodies move round it, in a uniform circular motion. This view is called the Copernican world system or Heliocentric theory.
3. Copernicus got into trouble with the church authorities who believed the Geocentric theory. But it did not make him give up his theory.
4 The next person that brought this change in scientific outlook was Galileo (1564 -1642). While Copernicus obtained his result by using simple observations and mathematics, Galileo added experiments to those two. He invented a scientific instrument of observation called the telescope. This instrument enabled him to extend his sense of sight and he saw clearly that the sun was at the centre of the universe. Thus confirming the theory of Copernicus. Galileo is thus called the discoverer of the true research method of the physical sciences.
5. Johannes Kepler (1571 -1630) discovered the laws that govern movements of the heavenly bodies. He was the first person to apply mathematics as an empirical instrument to discover these laws.
6. However, in spite of their results, Galileo and Kepler could not answer why objects do not fly off the earth, considering their submissions that the earth revolves or moves round the sun. Another question they couldn't answer was how it was possible for the earth, which was suspended in empty space to go round the sun without anything pushing it.
7. It was in the year 1660 that these questions were answered by Isaac Newton (1642 - 1727 AD. He proposed a theory of gravitational attraction to answer these questions.
Gravitation is the force that pulls every object in the universe towards ever y other object in the universe. Therefore, the earth pulls every object within it towards its centre so that's the reason they don't fly off the earth when it moves round the sun. The sun also has a centre of gravitation, which pulls the earth, and all other heavenly bodies round it.
8. Francis Bacon (1561 - 1626) was the first person who attempted to arrange the steps of the scientific method in a logical manner.
9. The classic ages of science were the 18th and 19th centuries. An explosion in growth of knowledge of nature occurred at this time, especially in the 19th century.

10 The explosion in Chemistr y was started by Antoine Laurent Lavoisier (1743 - 1794).
He discovered that it was a gas, which he called oxygen that enables combustion and
respiration to take place. He also introduced the gravimetric method of carrying out research in Chemistry.
11. In the 19th centur y, there was a common understanding that atoms and molecules
were the basic building blocks of matter, and that cells are the basic building blocks of
living things. This statement led to the formulation of the cell theory by Shwann and Matthias Schleiden in 1839.The cell theory is one of the fundamentaltheories of Biology.
12. Another fundamental theory of Biology is the theory of evolution by natural selection. It was proposed by Charles Darwin in 1859.

6.0 TUTOR-MARKED ASSIGNMENT

1. With the aid of illustrations, compare the Geocentric and Heliocentric theories of heavenly motion.
2. What are the contributions of Galileo, Kepler and Newton towards the change in scientific outlook of the 16th and 17th centuries?
3. Why is the 19th century regarded as the beginning of the scientific age?

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UNIT 3 HISTORY OF SCIENCE-4 (THE 20TH CENTURY SCIENTIFIC REVOLUTION)

CONTENTS

1.0 INTRODUCTION

In unit 2, we discussed how Western science became independent of Philosophy and Religion, and thus progressed to an unprecedented degree. The 20th century scientific revolution will be discussed in this unit. It is in this century that science reached its zenith. Here, you will read about the ingenuity of man - modern Homo sapiens - in using scientific knowledge to produce products that are both useful and harmful to him.

After studying this unit, you are expected to have achieved the objectives listed below.

2.0 OBJECTIVES

After studying this unit, you should be able to do the following:

1. Discuss briefly how the discovery of x-ray and the formulation of theory of relativity redefined physics of the 20th century;
2. Write a short note on the term ‘Biotechnology’;
3. Outline vividly with an illustration, the basic idea in genetic engineering, and
4. Write short notes on at least three electronic communication devices.

3.1 20th century scientific revolution

Since the end of the 19th century, great advances have been made in our
knowledge of life and its manifestations. But the chief ideas by which those

advances have been guided were formulated before 1901. Mathematics and Physics of the 20th century were characterised by a true revolution in thought.
While 20th century biology still followed the main lines laid down before the century began (Damper: 1989).

Sir Francis Bacon (1561 - 1626) expressed his belief that with the increase in knowledge of nature, man would soon be a master to nature. Thus, with the explosion of knowledge in the 18th and 19th centuries, it seemed as if Bacon's dream would soon be realised. Science was moving ahead on all fronts, reducing ignorance and producing new tools to make the condition of human beings better (The New Encyclopaedia Britannica: 1995). But this good news did not last long in physics, especially at the beginning of the 20th century. You will read about this in the next section.

3.1.1 Physical sciences

Some discoveries in physics, which really led to a true revolution are worthy considering here. In December 1895, the German Physicist, Wilhelm Röntgen discovered the xrays. X-rays, as you know are used in hospitals to destroy cancerous cells, to look at bones, to check if they are broken or dislocated, especially after an accident. In industries, x-ray photographs are used to reveal hidden cracks in metal castings and welded joints. X-rays are also used to detect alterations, which have been made to art works.

The discover y of x-rays and radioactivity revealed to the physicists that the structure of the atom was not as simple as they thought (The ncyclopaedia Britannica: 1995). There were other components of the atom, which they didn't know about such as electrons and protons. Thus, definition of the atom 'as the indivisible particle of matter' had to change.

The most disturbing of all the upsetting results of early 20th century physics was the formulation of Theory of Relativity by Albert Einstein in 1905 (Dampier: 1989). When this theory was first published, it was said that only 12 or so scientists could understand it! (Arkady: 1977). The theory redefined physics, thus making classical Newtonian physics obsolete. According to Newtonian physics, time, space, motion, etc were objective properties; that is to say, they exist on their own. But Einstein noted that the existence of motion, for instance, could have meaning only when it is considered relative something which is fixed. If you are sitting in a moving train and look out through the window, you will see things moving by quickly. That will make you know you are in motion. But there's a man sitting opposite you, and relative to him, you are not moving at all.

That is the first basic part of Einstein's theory. The second basic part of his theory said that the only absolute unchanging quantity in the universe was the speed of light (Arkady: 1977). Because of this theory, the very foundations of physics threatened to crumble.

In spite of all these, it may interest you to know that science in the 20th century worked wonders. The new physics - relativity, quantum mechanics, particle physics - may insult our common sense but it enables physicists to examine closely the minutest part of matter (The New Encyclopaedia *Britannica:1995).*

It may specially interest chemistry students to know that chemists of the 20th century used the new information about atoms reported by the physicists to improve their idea about chemical bonds. This led to their production of many new compounds.

They also developed a variety of plastics, synthetic fibres such as nylon and polyesters and synthetic rubber. It is good for you to know that all the plastic cups, plates basins, slippers etc which were use in our homes, were prloduced by using the new information about atoms. Polyester nylon stockings, shirts and dresses are practical things made from the new information about atoms. The chemists also developed drugs, food preservatives and synthetic chemicals for use in agriculture.

It may also interest you to know that astronomy and cosmology have been transformed almost beyond recognition. This is because of the invention of new instruments like radio telescopes, orbiting laboratories, a lunar and planetary probe. In 1969, men walked on the moon and unmanned landings have been made on the planets - Mars and Venus, in the 1970s. As a matter of fact, the first men to walk on the moon were American Astronauts called Neil Armstrong and Edwin Aldrin. The first woman in space is Velentina Tereshkova, and that was in 1963.

Exercise 3.1

1. The x-ray was discovered by (a) ——————— in the year (b) ——————————
2. What did its discovery reveal to the physicists?
3. Albert Einstein formulated (a) —————————— theory in the year (b) ————————————
4. Improved knowledge of the chemical bonds enabled chemists to produce (a) —————————— (b) —————————— and (c) ——————————————

3.1.2 Biotechnology

Modern biotechnology is now recognised as one of the most developments of the 20th century. Of the many uses of biotechnology are test tube babies, artificial insemination (in man and other animals), gene cloning, animal cloning etc. Biotechnology is not an academic discipline like Biology or Chemistry. It is nota product, but a process (Iwu: 1996). Biotechnology is multidisciplinary. This means that many disciplines are involved in any biotechnological activity. They include microbiology, biochemistry, genetics, plant and animal biology, chemical and process engineering.

Biotechnology is therefore defined as the techniques that make use of living organisms or parts of organisms such as cells, to make or roducts, to improve plants and animals, or to develop microorganisms for specific applications (Okonkwo: 1996). The aim of using these techniques is to increase the production of goods and services for the benefit of mankind.

Some of the techniques of biotechnology are as follows:
1. cell and tissue culture technique;
2. fermentation technology;
3. cell fusion;
4. embryo transfer;
5. recombinant DNA (r DNA) technology (or genetic engineering).

Genetic engineering is the hard core of biotechnology. That is the reason why many people mistakenly assume that biotechnology means genetic engineering (Okonkwo: 1996). Our emphasis in this section will be on genetic engineering.

3.1.2.1 Genetic engineering

Can you imagine a potato plant that makes plastic, a tobacco plant that glows in the dark or a truly tasty tomato from the market (Moore et al: 1995)? All these products have already been made by genetic engineering.

What is genetic engineering? It is the transfer of genes from one organism to another. A gene is the basic unit of heredity. Heredity is also t ansmission of characteristics from parents to offspring through the gametes. Does this remind you of anything? You would recall that in unit 3 of module 1, we discussed Darwin's theory of evolution by natural selection. Darwin was worried that his theor y could not explain how favourable characteristics are passed on to the offspring from the parents.

Let's retrace our steps a little. You might want to know the exact function of a gene. Genes are responsible for all the characteristics of living things. This means that there are genes responsible for the colour of the skin, the shape of the nose, height, flower colour in plants and so on. So when it is said that genes are the basic units of heredity, it means that the genes for different character istics are what are transferred from parents to offspring. If I tell you that I resemble my mother in height and if my mother is tall, it means that my mother transferred her gene for tallness to me through her gamete called the egg or ova. The male gamete in the father is called sperm. Every human being is built up through the fusion of a sperm and an egg. Whatever characteristics parents pass on to their children are contained in the genes found in both the sperm and the eggs.

What happens in genetic engineering is this: If you have a chicken which lays only small eggs, but you will want it to start laying big eggs, what you will do is this. Find a chicken that lays big eggs, collect the gene responsible for those big eggs (there are techniques used for this) and transfer them into your own chicken. Your chicken will start laying big eggs. An interesting fact here is that no matter where you put a gene, it will still perform that function assigned to it.
Genetic engineering was born in the 1980's. Since then, the technique has been applied in pharmacy, medicine, agriculture, industry, etc. In the examples that began this section, the potato plant has bacterial genes that make polymers, which can be used to make biodegradable plastics. In other words, there are some bacteria that are difficult to grow but they make small amounts of polymers (which can be used to make plastics). The polymer genes were obtained from that bacteria and put into another bacteria that grows fast, while the second bacteria called E. coli started producing polymers.

However, polymer production is still low. Scientists are working hard to see how to increase the quantity of polymer production (Raven et al: 1986). Would you be able to tell the advantage of this? If the polymer production is increased, it means that biodegradable plastics will now be produced. They will therefore replace the petroleum - based plastics which remain in the environment for too long, thereby causing pollution. The implication is that the old plastic cups, buckets, basins will not be lying around the compound. They will be decomposed by decomposing organisms.

Exercise 3.2

1. The disciplines involved in biotechnological activity include
a) ——————————— b) ————————— c) ——————————
d) ——————————
2. Some of the techniques of biotechnology are
a) ——————————— b) ——————————— c) ——
————————— d) ———————————
3. What is genetic engineering and in what year did it begin?

Let's continue from where we stopped. We were discussing the application of genetic engineering technique to solving practical human problems. In pharmaceuticals, some of the medically important proteins now being produced include the following:
1. human insulin for the treatment of diabetes;
2. human interferon, a rare protein that increases human resistance to

viral infection;

3. tissue plasminogen activator, a protein produced by the body in minute amounts that causes blood clots to dissolve. Its effectiveness in preventing heart attacks and strokes is being studied;

4. atrial peptides, small proteins produced in the hearts of mammals that regulate blood pressure and kidney function; genetically engineered versions are being tested as possible new ways to treat high blood pressure and kidney failure (Raven et al: 1989).

In agriculture, applications of genetic engineering include the following:
Herbicide resistance: soyabean, maize and cotton plants resistant hoerbicides have been produced. The presence of weeds in any form is a source of concern to any farmer. In traditional agriculture, weeding of the farm is done at intervals, and it is a tiresome activity. In griculture, herbicides, which are chemicals, are sprayed on the farm. The disadvantage is that some times both the plant you are trying to protect and the weeds destroyed. Through genetic engineering of specific crops, the crops are now resistant to the herbicides. So herbicides can now be sprayed on fields harbouring such crops without any fears.

Insect resistance: There is a bacterium called bacillus thuringiesis. It produces a toxin that kills insects fast. Through genetic engineering, the gene responsible for producing that toxin was extracted from the bacterium. It was then cloned into tomatoes, potatoes, and tobacco and some other plants. This resulted in the production of the toxin by the plants. Thus, whenever any insect larvae eat, for instance, the leaves of any of the plants, the digestive process of the insect is interrupted and the insect dies (Arntzen: 2000). The only problem here is that these results of genetic engineering are being enjoyed mostly by farmers in Europe and America.

There are other applications of genetic engineering. An example is in human cloning. This means producing offspring that are genetically identical to the individual from whom a cell nucleus has been obtained. There are various reasons people give for wanting to do this. It involves getting a cell from say 'Mr John'. The cell is manipulated in certain ways in the laboratory. After some time, an embryo will start developing from that cell. The embryo is transferred back into, let's say 'Mr John's wife'. After nine months, another 'Mr John', but now in a baby form of him will be born. This is because the adult Mr John and the baby Mr John will have the same genes in their bodies. It is important that you take note of one fact in this process. The new baby originated from a body cell of Mr John and not from the fusion of the sperm from Mr John and the egg from his wife. Presently, there are laws, in the United Kingdom and some other countries, against human cloning. Bills have been passed in the US congress to protect the cloning of humans.

Exercise 3.3

1. Match the items in ‘A’ with those in ‘B’ by filling in the blank space provided.

A B

———————— human insulin (i) confers insect resistance
———————— human interferon (ii) causes blood clots to dissolve
———————— tissue plasminogen activator (iii) diabetes
———————— atrial peptides (iv) resistance to viral infections
———————— Bacillus thuringensis (v)regulates blood pressure and kidney function

3.1.3 Transport and communication

The 20th century has witnessed dramatic changes and improvements in the areas of transport and communication. Do you know that the aeroplane is an invention of the 20th century? Imagine how people who lived before that century coped without this fastest means of transportation. It was in 1903, that two American bicycle makers called Orville and Wilbur Wright built the first petrol-engine aeroplane (Arkady: 1977). It became the first aeroplane not only to lift a person into the air, but also to fly successfully. Since some other people before these Wright brothers had tried to build a flight machine but they were not successful, the two brothers got the credit for building the first aeroplane.

Aeroplanes with jet engines were built during the late 1930’s by German engineers. The first supersonic passenger airliner, called the Concorde, began flight services between Europe and the United States in 1976. These are called supersonic jets because they travel at about 2,400kph, which means that they exceed the speed of sound. Normal aeroplanes, on the other hand, travel at 800 to 1000 kilometre per hour.

Do you know why the 20th century is called the space age? Although men of the previous centuries studied the planets and other heavenly bodies from the earth with the aid of instruments, it is the men of the 20th century that actually decided to go to some of those planets and heavenly bodies to see what they looked like. A 27-year- old Russian called Yuri Gagarin was the first person to be in space. He orbited the earth for the first time on 12th April 1961. He stayed in orbit for 108 minutes. He was called the Columbus of the interplanetary age. The first American in space is called Allan Shepard. These days, men and women enter the space and return to earth like any normal journey. It will not be out of place to also call the 20th century the age of communication. The world is now a global village as a result of development in the transport and communication industr y. The traditional electronic means of communication such as the fax, the telephone, the radio, and television are now commonplace devices, despite the improvements made in some of them. For instance, cellular telephones were introduced in 1979. They have made it possible for people to communicate without the restriction of telephone lines and geographical locations.

What about the telephone? Do you know anything about its development? It is one of the additional developments of the 20th centur y that made it possible to use single telephone lines for several simultaneous transmissions. This line, for example, may transmit cable TV broadcasts and phone calls simultaneously. Many TV stations in Nigeria both government-owned and privately-owned now use the device. The single telephone line can also serve as a picture phone or video conferencing device (kellerman: 1993). Picture phone or videophone is where the callers pictures are transmitted along with their voices. It was first introduced in 1964. CNN and BBC often use this technology for their broadcasts.

The first communication satellite called Echo I, was launched by the United States in 1960. A communication satellite is a transportation vehicle launched into space to transport existing forms of communication devices, such as camer as, radios, television Etc. The satellite enables the communication devices to operate at a far greater distance and add vast amounts of information to man's knowledge (The World Book Encyclopedia: 1992). Therefore, communication satellites serve as relay stations. They can relay several television programmes or many thousands of telephone calls at once. Thus, if you install the necessary equipments, you can turn your TV on and watch programmes from any TV station of your choice. You can watch programmes from BBC, CNN, Hallmark, etc, by just sitting in your house. The TV stations are changed with the aid of a remote control.

There is hardly any sector of human endeavour that is unaffected by computer technology - homes, schools, universities, military, police, banks, medicine, agriculture, etc. Indeed, the computer revolution is total and has completely replaced the industrial revolution of the last 150 years or so (Okwuosa: 1997). The first electronic digital computer was built in 1946, and was called ENIAC (Electronic Numerical Integrator and Computer). It was built by two US engineers called J. Presper Eckert, Jr. and John William Mauchly. In a subsequent unit, you will read about the contributions of two great Nigerians to the computer industry.

Exercise 3.4

1. The first aeroplane to lift a person into the air and fly successfully was built by a) —————————— and b) ———————————— in the year c) ——————————————— . The aeroplane had d) ————————————————— engine.

2. a) ——————— jets exceeds the speed of sound and it travels at b) ——
————— kilometres per hour (kph).
3. The first American and the first Russian in space are a) —————————
——— and b) ——————— respectively.
4. Cellular phones were introduced in a) ————————— year. b) What is the advantage of using them?
5. Picture phone otherwise called a) ————————— or b) ——————————— was introduced in c) ——————————— year. d) What is the characteristic feature of picture phone?

The Internet is another invention of the 20th century. It began in the early 1970's as a US Defense department network called ARPAnet. What then is an Internet? What is a network? A network is a group of connected computers that allow people to share information and equipment. The Internet is a collection of various computer networks, linked together and communicating by a common protocol known as TCP/IP (Transmission Control Protocol/Internet Protocol. In order for your PC (personal computer) to communicate with other computers using TCP/IP, you must have the appropriate TCP/IP software installed and properly configured. When someone talks about being 'on' the Internet, it means that his/her computer is connected to one of the interconnected networks that make up the Internet (Adibe: 2000).

Some of the facilities and services which Internet can provide to subscribers are as follows:

Electronic mail (E-mail). The e-mail works just like a post office. Your e-mail address provides all of the information required to get an electronic message to you from anywhere in the world. The e-mail has two distinct advantages over regular mail. The first obvious advantage is speed. Instead of several days or even weeks, your message can reach the other side of the world in hours or even minutes. The other advantage is that you can use your e-mail address to access databases and file libraries.

File Transfer Protocol (ftp). By using this, one can copy a file from a computer in New York to one in South Africa at a very fast speed.

Telnet. Many institutions of higher learning in advanced countries have made their library catalogues available for searching by anyone on the Internet, through the telnet. Library catalogues give information on the books, journals, and periodicals, etc, that are available in a particular library. Most universities in Nigeria still use the manual, that is, card catalogue (Okoye: 1994).

In Nigeria, as you might be aware, oil companies, banks, tertiary institutions of learning, many government bodies, have acquired mainframe computers. Many individuals, businesses (small and medium), homes, now have computers. Computer science is now taught in primar y, secondary and tertiary institutions of learning (Okoye: 1994).

Satellite dishes can be found in a number of homes, hotels, offices, etc for the reception of broadcasts from foreign states. NITEL in conjunction with SIEMENS, the German contracting firm to NITEL is trying doigitalise many of the telephone exchanges in Nigeria. Mobile telephone services have been established in major cities in the country.

You can see that some building blocks that will enable Nigeria join the information super highway are already in place. What the country needs is a well thought-out and integrated master plan for a National Information Infrastructure (NII). This will try to provide solutions for current needs and problems, but will be flexible enough to accommodate future changes (Okoye: 1994).

Exercise 3.5

1. What is the Internet?
2. When someone talks about being "on" the Internet, what does it mean?
3. Some of the facilities and services provided by the Internet include

a) ——————— b) ——————— and c) ———————

4. The atomic bomb was dropped in two Japanese cities

a) ——————— b) ——————— and by the

c) ———————, in the year d) ———————

3.1.4 War

Science in the 20th century has also been a key to victory in wars (negative contributions). That is why many nations have now entered into the race of who will be the first with radar, with an atomic bomb or with a nuclear submarine. The greatest problem facing man and his ecosystem today is the possibility of a nuclear war. The nuclear weapons of destruction such as the atomic, hydrogen and neutron bombs have been stockpiled by both developed and developing nations. Nuclear weapons are real, and could put the human race out of existence within a twinkle of an eye. These bombs derive their energy from the nucleus of atoms.

Can you give an example of the use of atomic bomb in the 20th century? You might have heard of Hiroshima and Nagasaki. These were the two Japanese cities leveled with atomic bomb during the Second World War in 1945. The bombing was done by the Americans. They did this in retaliation of the Japanese surprise attack on the American fleet at the pearl

Harbour in 1941. As a result of this, the American Arizona ship was sunk with a loss of about 1000 navy (Ene: 2000).

The effect of atomic bomb is also devastating. When an atomic bomb is released, the radioactive fallout or dusts have radioactive particles or iodines, chemical element of carbon, hydrogen, strontium etc. These are dangerous to health since they contaminate the soil, water, air and all living things. They damage the Central Nervous System, cells of the intestine lining and bone marrow. Anaemia, leukaemia, cancers of the breast and stomach are some of the results of damage to the bone marrow.

4.0 CONCLUSION

There has indeed been a scientific revolution in the 20th century. This revolution has touched all aspects of life such as industries of all types - pharmaceuticals, chemical, clothing, wood, medicine, etc. Transportation and communication have already shrunk the world into a global village. Even in wars, science has also been a key factor - hence the race to be the first with radar, with an atomic bomb or with a nuclear submarine. So in the 20th century, we have seen both the ingenuity and stupidity of man.

That is why philosophy of science is very important. Scientists do not worry about planning, direction and guidance in their activities. This is why there is overpopulation, nuclear proliferation, environmental abuses, etc. Philosophers of the sciences pay close attention to all these. They try to rationalise most scientific inventions, and try to give directions to scientific activities. Philosophy of science will be discussed in detail in a subsequent unit.

5.0 SUMMARY

The main points in this unit are as follows:

1. The chief idea that guided the advances of the 20th century was formulated before 1901.
2. Physics of the 20th century was characterised by a true revolution in thought.

Discoveries that led to this revolution include:

(a) the discovery of x-rays by Wilhem Röntgen in 1895.

(b) The formulation of theory of Relativity by Albert Einstein in 1905.

3. Chemists of the 20th century used the new information on the structure of the atom reported by physicists to improve their ideas about chemical bonds. This led to their production of many new compounds and products such as plastics, synthetic fibres like nylon and polyester.
4. Astronomy and Cosmology were transformed almost beyond recognition due to the inventions of new instruments such as radio telescopes, orbiting laboratories etc.

5. The first men to walk on the moon were Neil Armstrong and Edwin Aldrin, while Velena Teres Kova in 1963 became the first woman in space.
6. Modern Biotechnology is now recognised as one of the most important developments of the 20th century.
7. Biotechnology is not an academic discipline like Biology or Chemistry. It is not a product, but a process. Modern Biotechnology is multidisciplinary. The disciplines include microbiology, biochemistry, genetics, etc.
8. Techniques of Biotechnology include the following:
(a) cell and tissue culture technique
(b) fermentation technology
(c) cell fusion
(d) embryo transfer
(e) recombinant DNA (or r DNA) technology (or genetic engineering)
9. Genetic Engineering, which is the hard core of Biotechnology, started in 1980.
10. It is the transfer of genes from one organism to another and the technique has applications in pharmacy, medicine, agriculture, industr y, etc.
11. In pharmaceuticals, genetically- engineered proteins include, human insulin human interferon, tissue plasminogen activator and atrial peptides.
12. In Agriculture, genetic engineering is used to confer herbicide resistance to plants, such as soyabean and cotton plants.
13. Genetic engineering is also used in human cloning.
14. The 20th century also witnessed dramatic changes and improvements in the areas of transport and communication.
15. The first petrol-engined aeroplane was built in 1903 by Orville and Wilbur Wright.
The plane became the first to lift a person into the air and successfully.
16. The supersonic jet began service between Europe and United States in 1976. It exceeds the speed of sound since it travels at about 2,400 kph.
17. The 20th century is also called the space age.
18. A 27-year -old Russian called Yuri Gagarin was the first person to be in space. He orbited the earth for the first time on 12th April 1961. He stayed in orbit for 108 minutes. He was called the Columbus of the interplanetary age.
19. The first American in space is Allan Shepard.
20. Cellular phones were introduced in 1979.
21. New developments in the telephone industry have led to the use of single telephone lines for several simultaneous transmissions.
(a) It may transmit cable TV broadcasts and phone calls simultaneously.

(b) It may also serve as a picture phone or videoconferencing device.

22. Communication satellite is a transportation vehicle launched into space to transport existing forms of communication devices, such as cameras, radio, television etc. It enables the device to operate at a far greater distance and add a vast amount of information to man's knowledge.

23.The Internet began in the early 1970's. It is a collection of various computer networks, linked together and communicating by a common protocol known as TCP/IP (that is Transmission Control Protocol/Internet Protocol). Some of the facilities and services which the Internet can provide include

(a) E-mail
(b) File Transfer Protocol (ftp)
(c) Telnet

24. Science in the 20th century has also been a key to victory in wars (negative contribution), hence the race to be the first with radar, with an atomic bomb or with a nuclear submarine.

6.0 TUTOR-MARKED ASSIGNMENTS

1. a) Mention two of the discoveries that led to true revolution in thought of the 20th century physics.
b) How did the discoveries influence physics of the 20th century?
2. a) Define Biotechnology.
b) List 5 techniques of Biotechnology.
3. a) What is genetic engineering and in what year did it begin?
b) How would you go about it to make your chicken, which lays small eggs, to start laying big ones?
4. Write short notes on the following items:
a) Communication satellites;
b) The Internet;
c) E- mail.

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UNIT 4 THE LOST SCIENCES OF AFRICA-I: AN OVERVIEW

CONTENTS

1.0 INTRODUCTION

In unit 3, we discussed about the 20th century scientific revolution. Without doubt, science reached its zenith at that century. However, most of the advancements we discussed about had their origins in the European countries and America. It is then pertinent to ask where is Africa in the scheme of events? What have we contributed to knowledge? Have we ever invented anything or explored something? If you would remember, these questions were partly answered unit 5 of module 1, where we discussed the origin of Western science in ancient times. There, some evidence was given to show that Western science owe a lot to Egypt, a North African country.

However, European and American historians deprived blacks of the knowledge of their early contributions to science by ignoring or subtly misrepresenting the black identity of the ancient Egyptians. However the discovery of a seminal black kingdom in the Nile valley, which predates the Egyptian dynasties, has settled the question, once and for all, of the roots of classical Egyptian culture and technology. In other words, Egypt even owes their culture and technology to a black kingdom, which flourished before it came into existence.

While going through these materials, a question you are likely to ask is 'How come Africa is in shambles if science and technology really started with it? You will find the answers as you read along. As the topic of this unit is the lost sciences of Africa, emphasis will be on the lost sciences in areas outside of Egypt. Just an overview will be given. If you are interested in getting more details, you can consult the book on the reference page of this unit.

2.0 OBJECTIVES

At the end of this unit, you should be able to do the following:

(a) Describe briefly, the process of smelting in your area and compare it with that of the Haya people of Lake Victoria.
(b) Write a short note on Sirrius B.

3.1 The lost sciences of Africa

3.1.1 Introduction

Recently, archaeology has revealed the distinctive features of a lost African science, at least, in areas outside Egypt. It is also only within recent years that the discovery of a rudimentary black kingdom in the Nile valley, predating the Egyptian dynasties, has settled the question, once and for all, of all roots of classical Egyptian culture and technology. Right from early 1980's some evidence have been obtained in the field of agricultural and pastoral science, architecture, aeronautics, engineering, mathematics, mining, metallurgy, medicine, navigation and physics. These astonishing discoveries have shaken the whole world, including some Africans, who were not aware of the major contributions of blacks to modern technology.

Africans, just like the Europeans, or Asians, or Americans were characterised by the slow spread of new techniques or technologies from the centres to the edges, or peripheries of their civilisations. Thus, a skilled African surgeon could for example, be performing delicate eye operation in the city of Jenne in middle age Mali, while certain villagers in a village would be going blind with cataracts, a few hundred miles away, on the edge of the same empire. This happens as a result of lack of the surgeon's expertise.

It is necessary that you understand that this phenomenon of concentration of high technology in a centre (such as a scholar or priest caste, trading post or royal capital) and its absence or slow spread to the periphery (village or desert outposts or forest) was the same all over the world, before the industrial revolution. The fact that the world is now a global village does not change this fact. If you use this statement to compare the present countries of the world, you would agree that the centres of high technology (with their complex information network) are concentrated in powerful industrial countries (cities of the super-powers). While at the edges would be found whole countries or continents with just fragments of that technology.

It is important to understand the above paragraph, if we are to understand how science or technology may rise and fall with civilisation. The destruction of a centre could lead to the almost instant evaporation or disappearance of centuries of knowledge and technical skills. For instance, a nuclear war could destroy the primary centres of twentieth century technology in a matter of days. The survivors on the periphery, although, they would remember the aeroplanes, the television sets etc, they would not be able for centuries to reproduce that technology.

What do you think would follow? A dark age would certainly follow. Centuries afterwards, the technological brilliance of the 20th century would seem dream-like and unreal. The saving grace would be if archaeology would begin to pick up the pieces. It is believed that this is what happened to Africa, although not in the same way. The catastrophic effect has been the low technological know-how of Africans of today. Another traumatic effect visited on Africa was the slave trade, which lasted for centuries. Vast populations were uprooted and displaced, whole generations disappeared, family network disintegrated, the threads of cultural and historical continuity were severed. Therefore, one would have to think of two 'continents' Africa: the one before and the one after the Holocaust. Five centuries later, archaeologists, digging among the ruins, began to pick up some of the pieces.

3.1.2 Metallurgy

In 1978, an anthropology professor called Peter Schmidt and a professor of engineering called Donald Avery, both of them lecturers at Brown University, in USA, announced that between 1,500 and 2,000 years ago, Africans who lived on the western shores of Lake Victoria, in Tanzania, had produced carbon steel. What is steel? It is a malleable mixture of iron and carbon elements. It is used in producing tools, weapons, etc. For example, the Ajaokuta steel complex in Kogi State of Nigeria is being built with the aim of supplying raw materials to the tool industries.

According to Prof. Schmidt, the method the Africans used was 'pre-heated forced draft furnaces'. He said that the method was technologically more sophisticated than any developed in Europe until the midc ntury. He went on further to say that 'To be able to say techn ologically superior culture developed in Africa more that 1,500 years ago overthrows popular and scholarly ideas that technological sophistication developed in Europe but not in Africa'.

How did he obtain this information? Peter Schmidt was an historical anthropologist.

He was studying the history of the Haya people who now live on the shores of Lake Victoria. In the course of his work, the Haya people told him that one of their ancient kings had climbed a pillar of iron to ascend to the

heavens. He was shown the site of this 'shrine tree'. He carried
archeological investigations there and confirmed what the elders had told him, that this was a site on which steel had been produced as long as
2,000years ago.

Schmidt, who saw some similarities between the stories he was told and his archaeological findings, did not understand exactly how they fit. He therefore enlisted the help of a metallurgist, Donald Avery. They decided to find out if these descendents of the ancient iron smelters would be able to construct a traditional iron furnace and produce iron fragments. Their main aim was to compare the iron they would produce with the ones excavated. Their criteria for comparison were temperature in the furnace and structure of iron fragments (in the form of crystals).

In 1976 again, Schmidt was able to discover a group of blacksmiths and other old men who had smelted iron in the traditional way during their youth, some fifty to sixty years ago. He persuaded them to construct a traditional furnace. This is shown in figures 2.3 and 2.4.

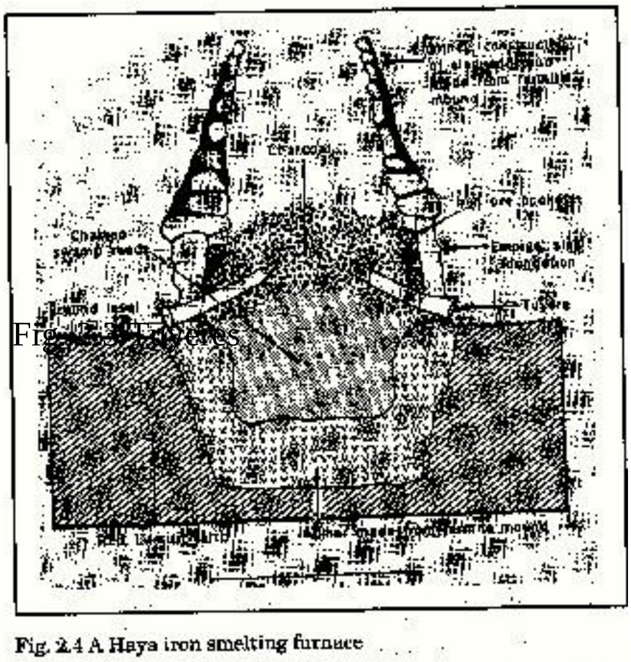


Fig. 2.3 Tuyeres

Fig. 2.4 A Haya iron smelting furnace

The results of the experiment showed that temperatures in the blast zone of the furnace exceeded 1800o C (3,275o F). This was 200-400o C higher than temperatures observed during smelting experiments based on European archaeological evidence. They also observed that the Haya people introduced a process in their smelting that was very original and in advance of their time. They made the steel through the formation of iron crystals rather than by 'the sintering of solid particles as found in European melting'. Avery commented that 'this is really semi-conductor technology -the growing of crystals - not iron-smelting technology.

Thus they concluded that two characteristics of the Haya smelting process were unique: the preheating of the air draft through blowpipes so as to increase the temperature, and the formation of iron crystals rather than by 'the sintering of fine, solid particles as done in European smelting'.

You can now see how archaeological evidence correlated with the oral history of the Haya and the oral history had been passed down without major alterations for 2000 years. This technology was not confined to Victoria. Further investigations showed that there was a widespread distribution of early Iron Age industrial sites in West Lake and neighbouring areas, such as Rwanda and Uganda. The nature of the industry also indicates that these Africans lived in densely populated centres, with an organised, highly cooperative labour force.

Exercise 4.1

1. In 1978, a) ———————————— and b) —————————————— announced that between c) ———————————— to d) ——————————— years ago, Africans who lived on the Western shores of Lake Victoria in e) ———————————————— had produced carbon steel.
2. Two characteristics of the Haya smelting process are a) ——————————————————— b) ——————————

3.1.3 Astronomy

In units 4 and 5 of module1, we discussed about some regularities in nature such as the rising and setting of the sun, which coincide with day and night, seasonal cycles, planting cycles etc. From unit 5 in particular, we learnt that the ancient Egyptians used the cyclic appearance of the moon to invent the calendar. Their initial aim was to know when to plant their crops. This correlation of the cyclic movement of the sun with certain festivals and planting seasons is also common in today's Africa. (Could you think of some examples of festivals, which take place in your area with appearance of some heavenly bodies? In igboland, new yam festival is one of such. Find out other examples from your area).

It has been reported that in an attempt to fix dates for their festivals, rituals, optimum planting and harvest times, the Dogon people of Mali in West Africa acquired an extremely complex knowledge of Astronomy. Their knowledge of the heavenly bodies, when it was revealed, sent shock waves throughout the scientific world.In order to make their calendar more accurate, the astronomer priests of many African families, such as the Dogon of Mali incorporated the rising and setting of certain stars or groups of stars into their various calendars. One of the stars important to them was 'Sirius', the brightest star in the sky. Many temples and even streets throughout Mexico and in Egypt are aligned to the rising of Sirius.

But for the Dogon, the most sacred of their 700-year old tradition do not revolve around Sirius, but to its small and incredibly dense companion star called 'Sirius B'. Sirius B (see fig. 4) cannot be seen with the naked eye.

Therefore, the Dogon's extensive knowledge of heavenly bodies, particularly this invisible star, is a mystery that has sent shock waves around the scientific world.

It will interest you to know that this information was revealed by two French anthropologists called Marcel Griaule and Germaine Dieterlen. They studied the Dogon very closely and over a considerable period of time -from 1931 to 1956. For a whole generation, they lived and worked with these people, looked at and listened to everything and wrote down all they could find out. The Dogon loved them so much that they initiated them into the tribe. Despite the intimacy, Griaule and Dieterlen had to go through the Dogon's system of education in order to learn the secrets of the universe
from them. At first, Griaule and Dieterlen received the 'words at value' (simple knowledge), then the 'word on the side', then the 'word from behind'. It was only in 1947, sixteen years later that the elders decided that they were ready to receive 'the clear word' which was the abstract and esoteric knowledge. It was at this time that they could learn the Dogon's

most sacred knowledge, which consisted of: the realisation of the nature of creation, the creation of stars and spiraling galaxies, the creation of plants, and the purpose of human existence.

Yet according to these French anthropologists, they had only reached 'the slight acquaintance' level, which was one of the levels of the eight level, 'clear word' phase of knowledge. The summary of know what they learnt are as follows:

1. Although Sirius B is invisible, it's the most important star in the sky. It is the egg of the world.
2. It has an elliptical orbit around Sirius A that takes 50 years to complete. Modern science confirms this orbit.
3. The Dogon drew a diagram showing the course and trajectory of this star up to the year 1990. Modern astronomical projections are identical with this. The diagrams are shown below.
4. The Dogon stated that this tiny star was composed of a metal, which was brighter than iron, and that if all men on earth were a single lifting force, they could not move it. Modern science confirms that this is the nature of that type of star usually called 'a white dwarf'. This type of according to modern science is so compacted that its mass may be many times greater than a star, which appears many times bigger.
5. But the Dogon went even farther than that in their observation about this star, beyond what modern science knows. They say it has an orbit of one year around its own axis. They were so certain of this that they held a special celebration called the bado celebration to honour that orbit.

Modern science has not yet been able to confirm or deny this observation.

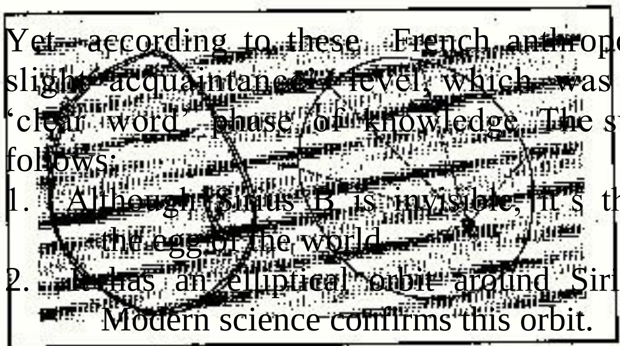
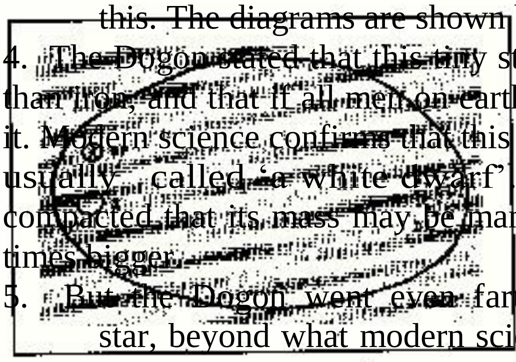


Fig. 2.5 A Dogon sand drawing of the orbit of Sirius B (Po Tolo) around Sirius



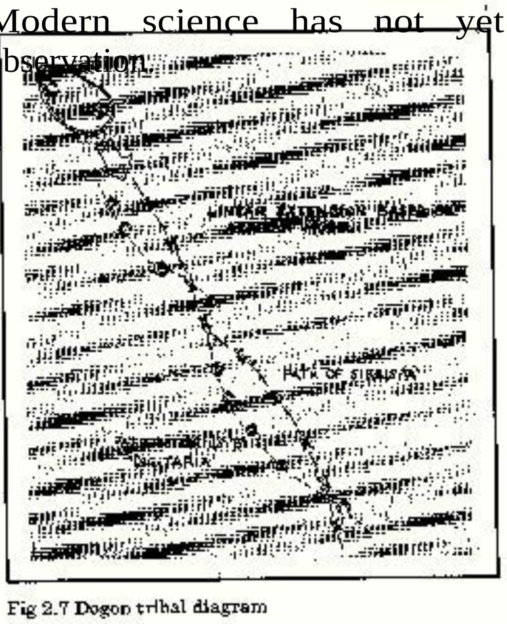


Fig 2.7 Dogon tribal diagram

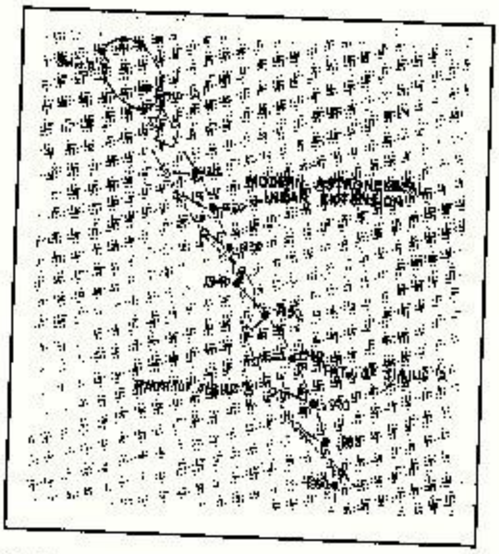


Fig. 2.8 Modern astronomical diagram

To provide such details about something that only the most advanced observatories can detect today, and to have done it ahead of them, is what sent shock waves throughout the scientific world.

To show the profound contempt for African scientific capabilities, which still dominates world scholarship, European or (Eurocentric) scientists believed the Dogon obtained this knowledge from either spacemen, Jesuit priests or European travellers. However, Hunter Adams III of the Argonne National Laboratory believes the Dogon people, since the Sirius traditions among them had been on for up to 700 years. He observed that other black people also have the Sirius traditions in their culture.

Archaeologists have excavated a wooden mask called the Kanaga. It is used by the Dogon to celebrate their Sirius-related Sigui ceremonies. Archaeological methods of giving dates to objects show that the mask dates back to the 13th century, which indicates the Dogon's preoccupation with this star for at least 700 years.

A source of concern to Eurocentric scientists is that the Dogon apparently did not use either Western technology or its scientific methodology to obtain their results. It has been reported that cience is a research without illumination. That eastern societies such as those of India and Africa do not have this problem. This is because there are no distinct separations between science and religion, philosophy and psychology, history and mythology. All of these are viewed as one reality and are closely blended into the structure of daily life. You will recall that in unit 1 of module 1, we discussed how the various scientific disciplines are now trying to unite. Examples given include physical chemistry, biophysics, biochemistry etc.

Thus, Hunter Adams III believed that early African science used both intuitive and empirical methods to make their discoveries. He therefore emphasised that modern science should be revolutionised by combining both methods in scientific research.

Exercise 4.2

1. The brightest star in the sky is called a) ——————————. The Dogon's 700-yearold traditions centre on a star called b) ————————————————————

2. Where can the Dogon people be found?
3. a) ———————————— and b) ———————————— studied the Dogon people over a considerable period of time from c) ——————————— to d) ————————————
4. The Dogon's system of education comprises of 8 levels, the first four of which are a) ———————————— b) ————————————

c) ______________________ d) ______________

5. Mention two astronomical observations, which the Dogon made and which science has confirmed.

Griaule and Dieterlen learned much more from the Dogon people. They were told that [illegible] is dry and dead, like dried blood and that it turns like a helical spiral around the earth. Modern science confirms that the moon revolves around the earth. Their chief instructor called Ongnonlou, [illegible] in the sand a picture of the planet, Saturn showing its rings and to[illegible] those rings are permanent. A fact which modern science confirms. They were further informed that the earth is in the Milky Way Galaxy and that the Milky Way has a spiral structure. Modern science confirms this. They were also told that there are an infinite number of stars and spiralling worlds. Modern science also confirms this.

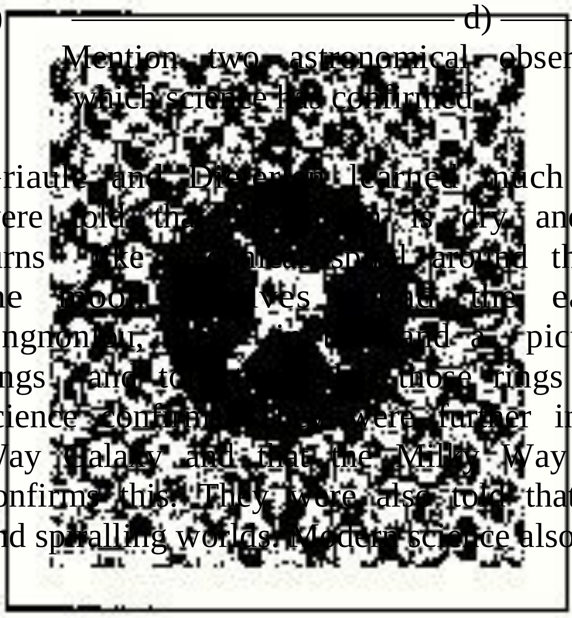


Fig 2.10 The heliacal rising of Sirius

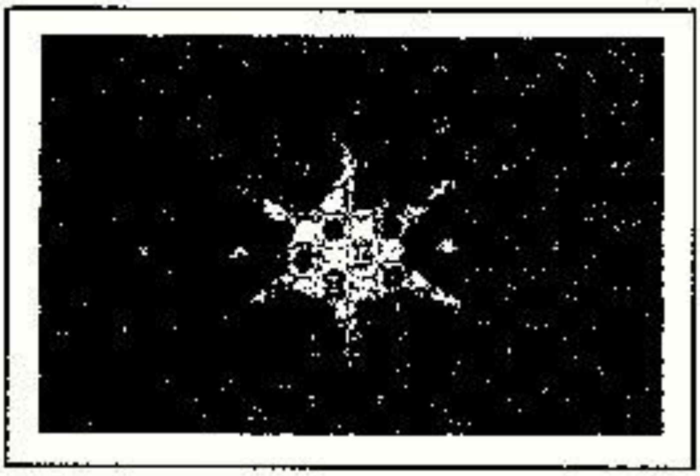


Fig. 2.9 A photograph of Sirius B taken in 1970

4.0 CONCLUSION

This unit has given incontrovertible evidence that Africans outside Egypt also originated the sciences of Metallurgy and Astronomy. So it can be concluded that civilisation really started in Africa.

5.0 SUMMARY

The main points in this unit are as follows:

1. In 1978, Peter Schmidt and Donald Avery both of Brown University, USA, announced that between 1,500 - 2,000 years ago, Africans who lived on the western shores of Lake Victoria in Tanzania had produced carbon steel.
2. The Haya people are the present occupants of the western shores of Lake Victoria.
3. Peter Schmidt excavated iron crystals from the site where the Haya people said that one of their ancient kings had climbed a pillar of iron to ascend to the heavens.
4. He persuaded some Haya blacksmiths to carry out a smelting experiment.

The results showed that temperatures in the blast zone of the furnace exceeded 1800 oC (3,275 o

F). Thus was 200-400° C higher than temperatures observed during smelting experiments based on European archeological evidence. The Haya people achieved this by preheating of the air draft through blowpipes.

5. The Haya people introduced a process in their smelting that was very original and in advance of their time. They made the steel through the formation of iron crystals rather than by ‘sintering of solid particles’ as found in European smelting.

6. The Dogon people of Mali incorporated the rising and setting of certain

stars or groups of stars into their various calendar. One of the stars of importance was the star called ‘Sirius’. It is the brightest star in the sky.

7. But for the Dogon, the most sacred of their 700-year-old traditions do not revolve around Sirius but to its companion known as ‘Sirius B’. This star is not visible to the naked eye.
8. The Dogon’s extensive knowledge of the heavenly bodies, especially ‘Sirius B’ sent shock waves around the scientific world.
9. Two French anthropologists called Marcel Griaule and Germaine Dieterlen were the people that revealed this information on the Dogon people.
10. They studied the Dogon people form 1931 to 956. Their ambition was to fully understand the Dogon especially their religion.

11. They had to pass through the Dogon system of education before they could learn anything from them. Their education lasted for 16 years.
12. From the Dogon, they learnt that although 'Sirius B' is invisible, it's the most important star in the sky, and that it has an elliptical orbit around Sirius A, which takes 50 years to complete.
13. They drew a diagram showing the course and trajectory of this star up into the year 1990; they say that this tiny star is composed of a metal brighter than iron and that if all men on earth were a single lifting force they could not move it. Modern scientists have confirmed all these observations.
14. They also made an observation which modern science has not been able to confirm, that 'Sirius B' has an orbit of one year around its own axis.

6.0 TUTOR-MARKED ASSIGNMENT

1. Visit local blacksmith in your area. With the aid of a diagram, describe briefly their process of smelting. Compar e it with that of the Haya people of Lake Victoria.
2. Write a short note on 'Sirius B'

7.0 REFERENCES/FURTHER READING

The materials in this unit were adopted from:

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UNIT 5 THE LOST SCIENCES OF AFRICA-- 2: AN OVERVIEW

CONTENTS

1.0 INTRODUCTION

In unit 4, we discussed about the first part of the lost science of Africa. Some evidence were given to show that Metallurgy and Astronomy also originated in Africa in areas outside Egypt. This unit is a continuation of unit 4. The materials in this unit will give evidence that mathematics also originated in Africa, in areas outside of Egypt. Special emphasis will be on the Yoruba number system. We shall also consider the evidence given for Africa's claims to the origination of medicine. After studying this unit, you exepected to have achieved the objectives listed below.

2.0 OBJECTIVES

After studying this unit, you should be able to: write, in not more than 2 pages, short notes on pieces of evidence of the use of numbers in Africa, and show with examples, that the African traditional doctor had much knowledge of anatomy and physiology and also fundamental public health principles.

3.1 Mathematics

The tendency to deny an African astronomical science is because such accurate observations over long periods involve the most precise record keeping. That means a capacity to measure complex distances and times, to calculate orbits, azimuths and convergences. That calls for mathematics and not just the simple hand count of one, two, three, etc.

Among the earliest evidence of the use of numbers in Africa, is a carved bone discoveredat the fishing site of Ishango on Lake Edward. Lake Edward is in Zaire, Democratic Republic of the Congo. It dates back to the period between 9000BC and 6500BC. The discoverer of the artifact called Dr Jean de Heinzelin, suggested it may have been used for engraving or writing. He was particularly intrigued by the markings on the bone. This is illustrated by the diagram below:

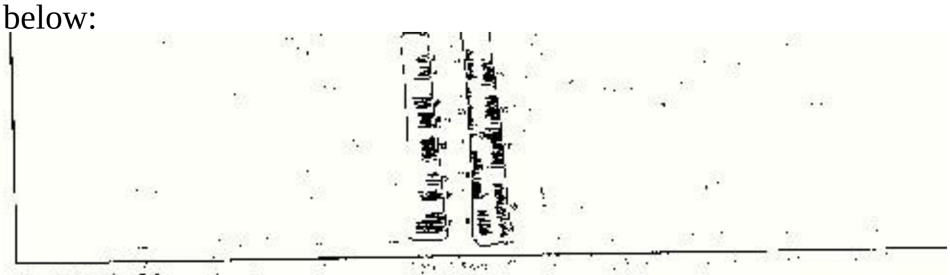


Fig. 2.1.1 The Ishango bone

From Dr Heinzelin's observations, there are three separate columns in the bone, with each consisting of sets of V-shaped identifications (or notches) arranged in distinct patterns. One column has four groups composed of eleven, thirteen, seventeen and nineteen notches. From the knowledge of mathematics, these are the prime numbers between ten and twenty. What do we mean by prime numbers? They are numbers, which cannot be divided, by any other number except by themselves and one (1).

In another column, the groups consist of eleven, twenty-one, nineteen and nine notches in that order. The pattern here maybe 10 + 1, 20 + 1, 20 - 1, and 10 - 1. The third column has the notches arranged in eight groups in the following order: 3, 6, 4, 8, 10, 5, 5, 7. The '3' and '6' are close together, followed by a space, then the '4' and '8', also close together, then another space, followed by 10 and two 5's. To Dr Heinzelin, this arrangement seems to be related to the operation of doubling. He concluded that the bone may have been the artifact of a people who used a number system based on ten and who were also familiar with prime numbers and the operation dup lication. However, to Dr Marshack, who also examined the notches, it was used as a lunar calendar.

Mathematics develops according to a need. If a situation calls for a simple count of objects, a people will develop a simple set of numbers. If their cultural demands are more complex, a more complex mathematics system will evolve. The Yoruba people of Nigeria belong to the latter group.

3.1.1 The Yoruba number system

The Yoruba people are one of the tribes in Nigeria, and can be found in the Western part of the country. The map of Nigeria below shows where they can be found.

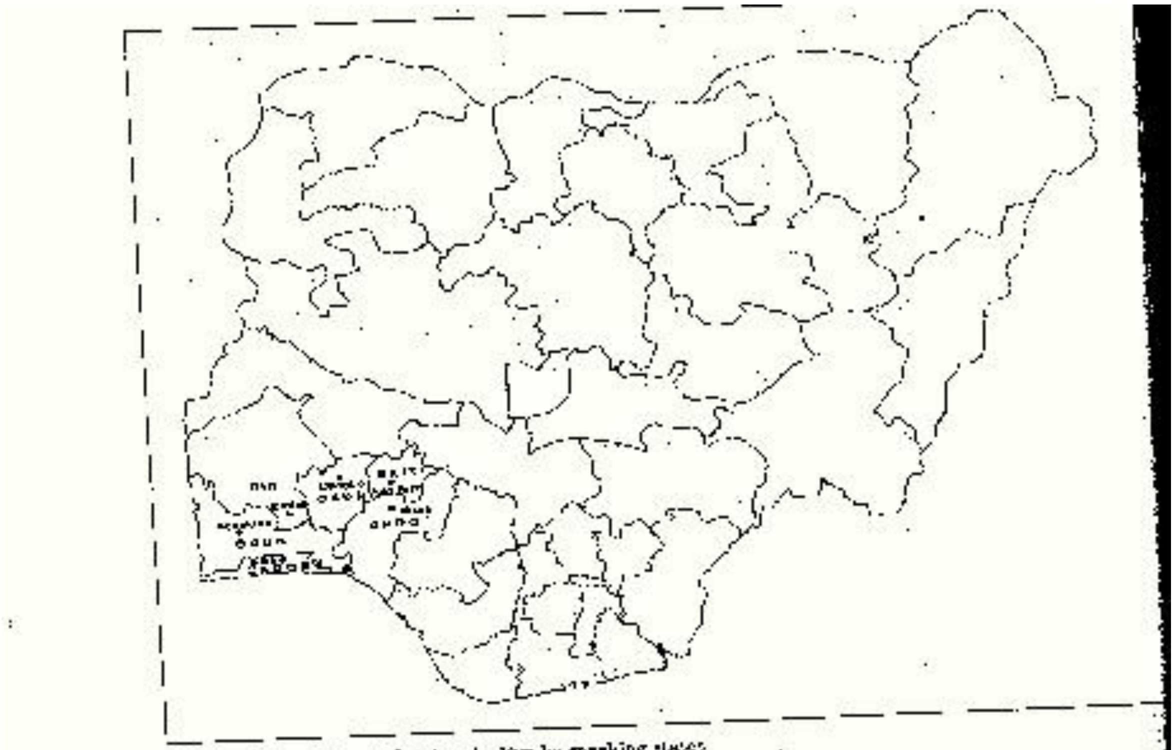


Fig. 2.12 Map of Nigeria showing the Yoruba speaking states

They have been urbanised farmers and traders for centuries. They have a complex number system. The mathematician named Conant calls it 'the most peculiar number scales in existence'. He said that one has to be really bright at mathematics to handle the Yoruba one. It is a system based on *twenty, of which there are many examples in western Africa.*

The unusual feature of the system is that it relies on subtraction to a very high degree. To the Yoruba person, it seems perfectly natural and he uses it with the same ease with which a European writes IX (ten minus one) for nine in Roman numerals. In a study of the Yoruba numerals, it has been stated that the numerals give evidence that the Yoruba have the capacity for abstract reasoning. This is the reason why they could have developed and learned such a system. The Yoruba express forty- five, for example, as 'five from ten from three twenties'. In symbolic form it is written as: 45 = (20 x 3) -10 -5
One hundred and s ix is expressed as 'four from ten from six twenties. Symbolically, it is written as 106= (20 x 6) -10-4. This is quite a feat of arithmetic involving addition, subtraction and multiplication to express just one number. A summary of the system is as follows:

1. From one to ten, different terms are used. For example the numbers:
1 = ookan 6= eefa

2= eeji 7=eeje
3 =eeta 8=eejo
4= eerin 9=eesan
5= aarun-un 10=eewa
2. Different terms are also used for 20, 30, 200 and 400. For example,
20 = ogun, 30 = ogbon, 200 = igba, 400 = irinwo
3. The rest of the numbers are multiples and compounds. For example,
11= ookan laa (laa from le ewa meaning in addition to ten) 12= eeji laa
13= eeta laa
14= eerin laa
4. 15 to 20 are ascertained as follows:
15= eedogun (from arun din ogun meaning 20 less five)
16= eerin din logun (meaning 20 less four) (20 - 4)
17= eeta din logun (meaning 20 less three) (20 - 3)
18= eeji din logun (meaning 20 less two) (20 - 2)
19= ookan din logun (meaning 20 less one) (20 - 1)
20=ogun

Exercise 5.1

1. Among the earliest evidence of the use of numbers in Africa is a a) ———————— discovered at the fishing site of b) —————————— on Lake Edward. It was discovered by c) ——————————
2. The Yoruba have a a) —————————— number system. Its peculiar feature is that it relies on b) —————————— to a very high degree. If you didn't get all the answers correctly, do not be disturbed. With practice, you will understand the system. Now let's continue.

3. From 21 to 24 are ascertained as follows:
21= ookan le logun (meaning one on twenty = 20 + 1)
22= eeji le logun (meaning two on twenty = 20 + 2)
23= eeta le logun (meaning three on twenty = 20 + 3)
24= eerin le logun (meaning four on twenty = 20 + 4) 4. 25 to 30 are ascertained as follows:
25= eedogbon (or arun din ogbon meaning (30 - 5) thirty less five) 26= eerin din logbon (meaning 30 less four (30 - 4))
27= eeta din logbon (meaning 30 less three (30 - 3)
28= eeji din logbon (meaning 30 less two, (30 - 2)
29= ookan din logbon (meaning 30 less one, (30 - 1)
Then 30 = ogbon. This is the procedure for obtaining all figures that are in tens.
5. The multiples of 20 are obtained as follows:
40 = ogoji (a shortened form of ogun meji, meaning two twenties or twenty in two ways)
60=ogota (a shortened form of ogun meta, meaning three twenties or twenty in three ways, that is 3 x 20)
80= ogorin (a shortened form of ogun merin, meaning four twenties or twenty in four ways, that is 4 x 20)

100= ogorun-un (a shortened form of ogun marun-un meaning five twenties or twenty in five ways , that is 20 x 5)
This is continued up to ten twenties, that is 200, when the new word igba is used.

6. The intermediate numbers such as '50' are obtained as follows:
50= aadota [(20 x 3) - 10] this is expressed as sixty less ten. 70= aadorin [(20 x 4) -10] This is expressed as eighty less ten.
Let us summarise what we have discussed so far.

Sum mary: We have seen that with numbers that go by tens, five is used as the intermediate figure, that is five less than the next higher stage. In those by 20, ten is used as the intermediate.

The constructions for unit fractions are:
ebu = fraction
idaji = one half (divide into two)
idameta = one-third (divide into three) idamerin = one-fourth
idamarun-un = one-fifth, etc
Doublings are constructed as follows:,
ilopomeji = two time or doubling
The constructions for powers of a base are:
Erin lona meji = 42
Erin lona meta = 43
Erin lona merin = 44
The following tables summarise what we have been discussing:
Table 1 shows the words for the first ten numbers in the four principal applications, that is, in the four ways they are used:
Table 1: Yoruba numerals from one to ten
Table 2: Names of the numbers for the counting series and their derivations

Cardinal Counting Adjectival Ordinal
1. ookan ookan = eni kan ekini ni = ikin ni = akoko
2. eji eeji meji ekeji = ikeji
3. eta eeta meta eketa = iketa
4. erin eerin merin ekerin = ikerin
5. arun aarun-un marun- un ekarun = ikarun-un
6. efa mefa mefa ekefa = ikefa
7. eje eeje meje ekeje = ikeje
8. ejo eejo mejo ekejo = ikejo
9. esan eesan mesan ekesan = ikesan
10. ewa eewa mewaa elewaa - ikewa

Table 2 shows the names of the numbers for the counting series, as well as derivations.

Table 2 - Y	
1	ookan
2	eeji

3	eeta
4	eerin
5	aarun
6	eefa
7	eeje
8	eejo
9	eesan
10	eewaa
11	ookan laa (laa from le ewasi = in addition to ten)
12	eeji laa
13	eeta laa
14	eerin laa
15	eedogun (from arun din ogun = five reduces twenty)
16	eerin din logun (20 - 4)
17	eeta din logun (20 - 3)
35	aarun din logoji (five less than two twenties = 20 x 2) - 5)
40	ogoji (twenty in two ways)
50	aadota (20 x 3) - 10)
60	ogota
(3 x 20, or more literally, ‘twenty in three ways’)	
100	ogorun = orun
(20 x 5)	
105	aarun din laaadofa
(20 x 6) - 10 - 5)	
200	igba
300	oodunrun = oodun
(30 x (20 - 5)	
315	orin din nirinwo odin marun-un (400 - (20 x 4) - 5)
400	irinwo
2000	egbewa (200 x 10)
4000	egbaaji (2 x 2000)
20,000	egbaawaa (2000 x 10)
40,000	egbaawaa lona meji (ten 2000s in two ways)
1,000,000	egbeegberun (idiomatically 1000 x 1000)

Table 3 - Analysis of Yoruba Numerals 35 - 54

Twenty		ten	unit
35	2	0	-5
36	2	0	-4
37	2	0	-3
38	2	0	-1
39	2	0	0
40	2	0	0
41	2	0	1
42	2	0	2
43	2	0	3

44	2	0	4
45	3	-1	-5
46	3	-1	-4
47	3	-1	-3
48	3	-1	-2
49	3	-1	-1
50	3	-1	0
51	3	-1	1
52	3	-1	2
53	3	-1	3
54	3	-1	4

only five do not involve subtraction at all, and five numerals involve subtraction in two columns.

The idea of infinity is expressed in the following Yoruba proverb 'There is nothing as numerous as the locusts; they are found at home and in the farm'. Although, some farms were as much as twenty miles from the towns in which the farmers lived, the locusts covered every bit of foliage on the route.

3.1.1.1 Origin of the subtractive system

Early investigations concluded that the origin of this complex system for large numbers could be due to cowrie counting. Cowries are shells (shells are hard outer case covering eggs, seeds or animals) obtained from small snail - like animals found in Indian Ocean.

They were used as money in Africa and South Asia in olden days.

Cowrie counting was the earliest occasion that required the Yoruba to count in such large denominations. The procedure for cowrie counting among the Yoruba was as follows:

a. First, the bag of 20,000 shells, for example, is emptied on the floor.
b. The cowrie counter kneels or sits beside the heap and rapidly draws four groups, each group containing five shells. This will make a small pile of twenty.
c. Five twenties, that is twenty into five places, are combined to make a pile of one hundred; then two hundreds, that is a hundred into 2 places, are combined to form the important unit of two hundred.

Thus, the subtractive principle in the numeration system originated because of the practice of counting cowries by fives. Although this method of cowrie counting was widely used, only the Yoruba and a few others formalised the procedure in this unique subtractive system of counting. It is important for you to know that mathematical system is not always recoverable. It is also not always blessed with historical continuity like that found among the Yoruba and a number of large African communities.

Other ways of knowing that a certain ancient group of people had mathematical knowledge include the following:

a. It may be hidden in architectural design for example, as found in the Granary of the Master of Pure Earth (among the Dogon).

b. It may be in abstract patterns like that obtained from the combination of two geometric operations such as translation and reflection on an axis. This can be seen in decorations on bowls and cloth of the Kuba of the Congo.

c. It may be in measuring systems such as the beautiful brass weights for measuring gold dust currency among the Ashante of Ghana.

d. It may also be in the complex network games, the Shongo children play or in mathematical recreations, which are the delight of many Africans.

An example is the traditional game called Ayo. It is also known a the 'Warri Game' and it often sharpens one's mental capacity for calculations. The Ayo game is very common in many Nigerian villages. You may wish to find out how it is played in your village.

Exercise 5.2

1. Give the Yoruba terms for the following numbers
(a) 1 = (b) 2 =(c) 3= (d) 21= (e) 22=
(f) 23=
2. (a) ——————— was the earliest occasion that required the Yoruba to count in large denominations.
3. When a mathematical system is not recoverable, other ways of knowing that certain group of people had mathematical knowledge include:
(a) —————————— (b) ——————————— (c) ————————————

3.1.2 Medicine

The numbering system is not the only thing that originated from Africa. Medicine has its roots in the continent. It is important for us to remember that Africa has been subjected to centuries of almost continuous political, social and cultural disruption. Since many of our cultures rely heavily on oral transmission of knowledge, a lot of knowledge has been lost. Therefore, the state of traditional medicine today does not reflect the best of what the traditional doctors knew. Surviving fragments of eyewitness reports of what we see in some of our villages indicate that they knew quite a lot. There is an element of ritual and magic in some African healing practices. This has been highlighted so often to cause sensational effect in films and books, and has resulted in hiding the serious scientific superstructure of the African medicine. You also may be aware that traditional medical practice is intimately familiar with the psychic, social and cultural inclinations of the patients. The traditional African doctor is, therefore, often an expert psychotherapist, achieving results with his patients that conventional western psychotherapy cannot.

Western medicine is, however, gradually appreciation the use of suggestion, hypnosis and the placebo, in addition to internal and external treatment, as the case may warrant. It is obvious that every profession has its quacks, but western-trained doctors who have studied the traditional medicine man agree that African doctors have much knowledge of human body and anatomy. For example, an African doctor usually gives a careful diagnosis, beginning with a history of the disease, followed by a thorough physical examination.

Africans are known to have many plant medicines, including those for abortion, for retarded labour, malaria fever, rheumatism, neurotoxic venoms, snakebite, intestinal parasites, skin ulcers, tumours, catarrh, convulsion, veneral disease, bronchitis, etc.

Most of the treatments for these are as effective as those being used in western medicine.
Though there is no single pattern of medical practice that applies to all of Africa, many of the essential features of the various traditional systems are comparable and even identical. Among the Mano of Liberia, for example, all children's diseases, all obstetrics, all of the 'everyday' complaints are handled by women, particularly the elderly women; surgery, bone setting and special diagnostic and therapeutic problems are handled almost exclusively by men. This is the pattern that repeats itself throughout Africa.

Most commentators have discredited the traditional doctor's knowledge of anatomy and physiology. The Mano, however, have names for most major organs and know the difference between normal and abnormal anatomy. A Hausa manoeuver test for impotence has been described:

An individual is stripped and placed on a mat lying on his back. A pin or thorn is lightly rubbed over the inside of his thigh. If the scrotum or testicles do not move, the individual is considered impotent. There is a physiological basis for this procedure.

The manoeuver in effect, tests the cremasteric reflex. The cremaster muscle contracts and pulls the testicles upward on stimulation of the inside of the thigh. This passage counters the notion that African doctors do not have a knowledge of some of the body's physiological processes. However, these interesting fragments do not prove thatAfrican doctors have a sophisticated anatomical or physiological knowledge. They show that they have a greater degree of knowledge, perhaps in past ages, than has yet been recognised.

In some parts of Africa, traditional doctors are known to understand some fundamental public health principles. In Liberia, the Mano developed an admirable quarantine system for smallpox. They were very well aware that it was contagious and set aside a 'sick bush' for affected patients. This was situated far from the village and the patient was attended to by only one person; no one else was allowed to approach the area. The patient was put on a careful diet. He was rubbed with topical anaesthetic medications to prevent scratching which could lead to super infection. When the patient go well, the area was burned. The 'sick bush' approach would do a modern epidemiologist proud.

Another interesting fact is the practice of smallpox variolatin (that is smallpox markings), which is carried out all over Africa. The practice is centuries old. What is involved here is that, during an epidemic, material from the pustule of a sick person is scratched into the skin of uninfected persons with thorn. In some other cases, there was no reaction and the persons inoculated were protected against smallpox.

In some other cases, the inoculation would produce a mild, non-fatal form of the disease. This would also confer permanent immunity on the individual It is a noteworthy achievement that Africans had devised an effective vaccination method against smallpox, centuries before Jenner, who first devised a vaccination against smallpox in the western countries.

Exercise 5.3

1. Traditional medical practice is intimately familiar with the a) ———— ————— (b) ——————— and (c) ————————— inclinations of the patient.
2. A quarantine system for smallpox was developed by the ——————— —— people of Liberia.
3. A smallpox patient was rubbed with (a) ————————— to prevent scratching, which could lead to (b) —————————
4. Smallpox vaccination involved (a) —————————— It was an effective (b) ————— method against smallpox.

In the area of surger y, the best evidence indicates that some African surgeons attained a level of skill comparable, and in some respects superior, to that of Western surgeons up to the 20th century. Just as in ancient Egypt, the bonesetter guilds or associations were separate from those of traditional doctors, and were well known for their skill. In many places in Nigeria, you would find that these guilds are very much in operation. Many accident victims for example, have more faith in them than in orthopedic hospitals. Mano bonesetters treated a patient with a thigh fracture by placing him in the loft of a house. They allowed the affected leg to dangle free with a heavy stone attached. This was a very effective traction method. Once the fracture was reduced, the leg was immobilised with a tight splint. anddition, the patient was encouraged to exercise a fractured leg. It is widely known today that a new bone is laid down more rapidly over the fractured site, when there is some exercise of the limb.

The following is an interesting story from Nigeria. It was reported that a man who had his abdomen cut open by an elephant was treated by a traditional doctor in the following way. He replaced the intestines in the abdominal cavity, secured them in place with a calabash covering, and finally sutured together the overlying abdominal wall and skin. The man soon recovered and went back to work.

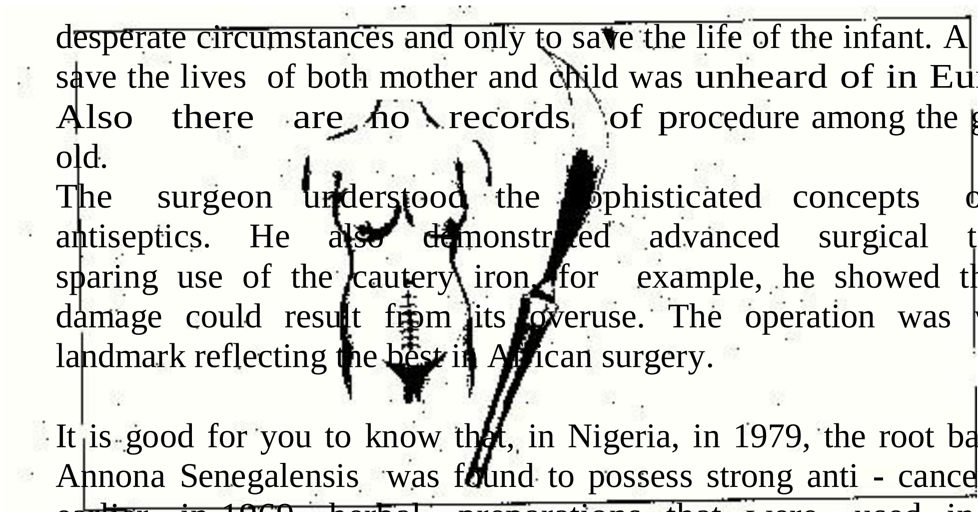
A caesarean section (figs 2.13 & 2.14) performed by a Banyoro surgeon in Uganda in 1879 is one of the most remarkable examples of African surgery ever documented. It is an eyewitness account by a missionary doctor called Felkin. Quoting him:

The patient was a healthy looking primipara (first pregnancy) of about twenty years of age. She lay on an inclined bed, with its head rested against the side of the hut. She was half intoxicated with banana wine, was quite naked and was tied down to the bed by bands of bark cloth over the thorax and thighs. Her ankles were held by a man …. While another man stood on her right steadying her abdomen….the surgeon was standing on her left side holding the knife upwards and muttering an incantation. He then washed his hands and the patient's abdomen first with banana wine and then water. The surgeon made a quick cut upwards from just above the pubis to just below the umbilicus severing the whole abdominal wall and uterus so that amniotic fluid escaped. Some bleeding points in the abdominal wall were touched with red-hot irons. The surgeon completed the uterine incision, the assistant helping by holding up the sides of the abdominal wall with his hand and hooking two fingers into the uterus. The child was removed and the cord was cut. The child was handed to an assistant.

The report went on to say that the surgeon squeezed the uterus until it contracted. He dilated the cervix from inside with his fingers (to allow postpartum blood to escape)- He removed clots and the placenta from the uterus and then sparingly used red-hot irons to seal the bleeding points. A porous mat was tightly secured over the wound and the patient turned over to the edge of the bed to permit drainage of any remaining fluid.

The peritoneum, the abdominal wall and the skin were approximated back together and secured with seven sharp spikes. A root paste was applied over the wound and a bandage of cloth was tightly wrapped around it. Within six days, all the spikes were removed. Felkin observed the patient for 11 days and when he left, mother and child were alive and well.

In Scotland, Lister had developed antiseptic surgery just two years before the event described above. But universal application of his methods in the operating rooms of Europe took many years to be realised. You will be interested to know that caesarean sections in Europe then were performed only under the most



desperate circumstances and only to save the life of the infant. A caesarean section to save the lives of both mother and child was unheard of in Europe at that time. Also there are no records of procedure among the great civilisations of old.
The surgeon understood the sophisticated concepts of anaesthesia and antiseptics. He also demonstrated advanced surgical technique. In his sparing use of the cautery iron, for example, he showed that he knew tissue damage could result from its overuse. The operation was without question a landmark reflecting the best in African surgery.

It is good for you to know that, in Nigeria, in 1979, the root bark of a plant called Annona Senegalensis was found to possess strong anti - cancer properties. Even earlier, in 1969, herbal preparations that were used in Nigeria to treat skin infections were found to have definite bactericidal activity. This was against gram- positive bacteria, the very organisms that cause skin infections.

This section of the unit has attempted to show that the traditional doctors of Africa had a high level of medical and surgical skills from the earliest times. They had much more than they have been given credit for.

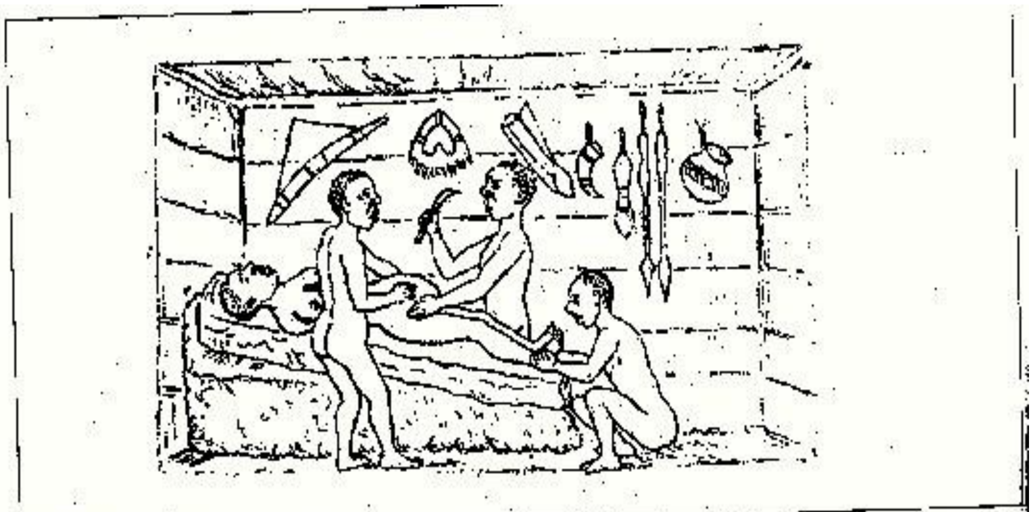


Fig. 2.13 Illustration from Dr R.W. Felkin's description of the caesarean section.

Exercise 5.4

1. One of the most remarkable examples of African surgery ever documented was (a) ———— performed by a (b) ———— surgeon in Uganda in the year (c)———— It is an eyewitness account by a missionary doctor called (d) ————————
2. The surgeon that performed the surgery understood the sophisticated concepts of (a) ———————— and (b) ————————

4.0 CONCLUSION

In this unit, pieces of evidence to support the fact that the sciences of mathematics and medicine also originated in Africa in areas outside Egypt were given. Thus, Africa's claims have been vindicated.

5.0 SUMMARY

The main points in this unit includes the following:

1. Among the earliest evidence of the use of numbers in Africa is a carved bone. It was discovered by Dr Jean de Heinzelin at the fishing site of Ishango on Lake Edward, Democratic Republic of Congo.
2. The Yorubas have a complex number system, which is based on twenty, and the unusual feature of the system is that it relies on subtraction to a ver y high degree.
3. In the system, in numbers that go by tens, five is used as the intermediate figure, that is, five less than the next higher stage. In those that go by twenty, ten is used as the intermediate.
4. The subtractive principle in the Yoruba number system originated because of the practice of counting cowries by fives.
5. When a mathematical system is not recoverable, other ways of knowing that a people had mathematical knowledge include the following: it may be hidden architectural design; it may be in abstract patterns; it may be in measuring systems and it may also be in complex network games children play or in mathematical recreations such as the Ayo game.
6. The state of traditional African medicine today does not reflect the best of what the traditional doctors knew. This is because of the fact that a tremendous amount of knowledge has been lost due to various disruptions of its culture
7. There is an element of ritualand magic in some African heapi actices. This has been highlighted so often for sensational effect in films and books with the result that it has hidden the serious scientific superstructure to African medicine.

8. Africans have various plant medicines for many diseases and conditions such as abortion, retarded labour, snakebite etc.
9. Traditional doctors had much knowledge of anatomy and physiology, and understood some fundamental public health principles, for example the use of the quarantine system for smallpox.
10. They also developed a vaccination method against smallpox long before Edward Jenner's vaccination method became widely used, and also had ver y early knowledge of psychotherapy, anaesthesia, antiseptics and surgical techniques.

6.0 TUTOR-MARKED ASSIGNMENT

1. Write short notes on
(a) the Ishango bone (b) the Yoruba number system
2. With examples, show that the African traditional doctors had much knowledge of
(a) anatomy and physiology (b) fundamental public health principles.

7.0 REFERENCES AND FURTHER READING

The contents of this unit were adapted from: Sertima, I.V. (1992) (ed.) lacks *in Science: Ancient and Modern, Transaction Books, New Brunswick.*

MODULE 3

UNIT 1 SCIENCE AND TECHNOLOGY AND INVENTIONS

CONTENTS

1.0 INTRODUCTION

We have entered a new module - module 3. The first unit of our discussion will be on science, technology and inventions. In the last unit of module 2, we discussed about the lost sciences of Africa. Evidence was given to show that whatever we know today to be science, originated in Africa. Since science and technology can be likened to a pair of identical twins, it means that technology also originated in Africa. You will read about this as we go along. This unit will also introduce you to the differences between science and technology, their subdivisions and how a technology can be acquired.

After studying this unit, you are expected to have achieved the objectives listed below.

2.0 OBJECTIVES

At the end of this unit, you should be able to do the following:

1. Mention at least five areas where science and technology have had impacts on the society,
2. Distinguish clearly between science and technology,
3. Describe briefly the development of technology,
4. Outline vividly the importance of science, technology and inventions to the nations of the world,
5. Classif y accurately science and technology,
6. List and briefly describe the methods of acquiring technological advancement,
7. Name and discuss some early modern contributions to science and technology.

3.1 The impact of science and technology on society

Where do you live? In a village or in a town? Wherever you may be living, you are likely to see, hear, and touch or use various objects in the course of a single day. Such objects include soap, toothpaste, broom, knife, safety razors, hot water, telephones, cars, buses, trains, objects in offices, factories, homes, schools, restaurants and theatres. In addition to all these, you are likely to touch and use such devices designed to save physical labour such as tractors, those designed to help in communication, entertainment, transportation, high-speed computers and medicines. All these and many more are called products of technology.

It is interesting to note that before each of these products developed, a significant scientific discovery had been made. Each of these examples demonstrates a symbolic relationship between science and technology. For example, knowledge obtained fromthe scientific disciplines of mathematics and electronics were used to produce highspeed computers. What other connections can you make between science and technology?

Has technology had any effect on your lifestyle? Consider how it has affected the way you eat, drink, travel, work, play and sleep. Think about technology and environmental implications - how some of the products such as cars can cause air pollution with the exhaust fumes. Also think about technology and life and death - about how babies are born today and how old people live before they die, as compared to a hundred years ago. You might now be aware that key influences in all these are science technology. These have been the most potent forces for social change in the history of man.

3.2 Definitions/distinctions between science and technology

In unit1 of module 1, various definitions of science were given. There, science was defined as:

a. a body of knowledge such as chemistry, physics, biology, etc,
b. a method or process of acquiring knowledge;
c. an institution.

Thus, science is both the process and the product of investigation and research. The process involves research and the product is a set of ideas, theories and principles, which make up the various body of knowledge.

Technology is therefore defined as the application of scientific knowledge and research, with the aim of developing products or processes for the use of man. It consists of the practical knowledge of what can be done and how. It is not a body of theoretically related laws and principles. It is character ised by techniques, devices, procedures, processes and materials.

It is more of a collection of practical information that can be used to do something.
Let's consider an example from agriculture. A large crop of vegetables is in danger of destruction by insects. Agricultural scientists have already developed insecticides to be used to fight the insects. If a decision is taken to spray the crops with the insecticide from an aeroplane, that decision is made by an agricultural engineer. He will take health, economic and environmental factors into consideration in making the decision. The actual spraying is carried out by a technician. The technician is a specialist who knows how to load the insecticide, fly the plane and spray the crops. All the techniques, procedures and materials used make up the technology of insecticide spraying from an aeroplane.

It is important for you to know that in spite of the seeming differences between science and technology, they are intimately linked or symbiotic. This is because technology will be crippled and blinded, if not for the new knowledge which science provides it.

Science, on the other hand, will not progress much, if technology does not supply it with new instruments, new techniques and new powers. Let's illustrate with the following examples. The practice of photography (technology) originated before the theor y of photographic process was formulated (science). Photographic mater ials were made by trial and error. Up till about 1950's, the methods used in manufacturing photographic materials were a little advanced than the basic science of the photographic process. A point was reached however, when progress in photography became slow. Progress was only accelerated when the physical chemistry
underlying the photography process was understood.

X-rays were discovered through scientific research. The knowledge of these x-rays enabled the technologists to develop x-ray machines. These x-ray machines, in turn, now help scientific researchers to examine, example, the arrangement of atoms in crystals. So both science and technology go hand in hand. Do you still remember who discovered x-rays? Remember we discussed about it in module unit 3 of module 2.

Now let us consider what motivates scientists and technologists. What drives the scientist when he is acting as a scientist is the longing to know and understand. The key word here is curiosity. The scientist is curious to know and understand nature. He is not bothered about application of his knowledge. Other haracteristics of the spirit of inquiry include:

a. a questioning of all things;
b. a search for data and for relations that give them meaning;
c. a demand for verification;
d. a respect for logic.

In other words, the principal activity of a scientist is research.

What drives the technologist, on the other hand, is the desire to translate ideas and plans into concrete products or processes. The key word is know-*how. His aim is to produce things and not to formulate theories about the* devices and techniques used in the process. It is important for you to know that the ideas implemented by technologists are derived both from science and non-science areas.

The corresponding plans are often developed by engineers.

Exercise 1.0

1. Science is both the (a) ——————— and (b) ——————— of investigation and research.
2. Technology is characterised by (a) ——————— (b) ———————— (c) —————— and (d) ——————
3. Scientists are motivated by (a) ——————————— while technologists are motivated by (b) ————————.

3.3 The beginning and importance of technology in human affairs

Technology is as old as man himself. In his desire to provide for his basic needs of food, clothing and shelter, he made and used tools (origin of technology). With time, man not only sought to satisfy his needs but also his wants. Technology also helped man to get what he wanted. These include play, leisure, houses, exotic foods, travelling, faster communication with others etc. Do you know that man's earliest natural tools were his hands and teeth? He graduated to stones, and then to sticks shaped to be used as tools. As time went on, he developed tools of special types to be used for hunting, fishing and the making of clothes and shelters.

Man's technical progress is believed to be governed by two elements, which are discover y and invention. A discovery is a new way of looking at an old phenomenon.
Invention, however, is defined as a mental process in which various discoveries and observations are combined and guided by experience into some new tool or operation. In other words, experience guides somebody to make use of his various discoveries and observation to produce new tools or operation. It is important for you to know that much experience is needed to lead to truly important inventions. This may be the reason why the material progress of ancient man was very slow.

The next stage in the evolution of technology is the discovery of fire. It is the most important discovery of Stone Age man. He used the fire to warm himself and to prepare tastier food. Fire then led to the birth of cooking and subsequently to the invention of suitable kitchen utensils and cooking methods such as baking, frying, steaming etc.

Can you imagine what it's like to eat uncooked food? The discovery of fire was therefore a very important event.

Man later began to cultivate his own crops and rear animals for a more regular supply of food. This led to the establishment of communities. He domesticated animals and developed agricultural tools. He made textiles, produced pottery, invented the wheel and the sail to improve his transportation. Man also learned to mine and utilise metals such as copper and iron. Technology thus made possible the beginning of civilisation in Egypt and Babylonia.

3.4 The importance of science, technology and inventions today

It may interest you to know that the factors that distinguish our age (20th century upwards) from the past are: the recognition of the importance of science and technology in human affairs, the increased pace of scientific and technological development, which makes it part and parcel of our daily living, and the realisation that science and technology are not simply a limited or local factor. It encompasses all men everywhere, and is interrelated with nearly all-human endeavour.

The 20th century as we discussed in unit 3 of module 2 has cha acterised by rapid advances in science, technology and inventions (S T & I). We all feel the impact of them (S T& I) in our daily lives as well as in our social and political institutions. For instance, modern man has replaced the heavenly implements and tools of primitive man with tractors and ploughs for tilling the soil. This represents a higher level of technology. The hydrogen bomb, nuclear weapons/missiles have replaced the bow and arrow technologies of the old eras. Even on the home front, housekeeping has been happily made a lot easier for the housewives with the introduction of labour saving machines such as microwave and electric ovens, vacuum cleaners etc.

Without doubt, the standard of living of a nation depends on S T and I! Developing nations such as Nigeria and other African countries, are
beginning to realise one essential difference between them and the so-called developed nations. This is the fact that these (developed) nations have been able to create, master and use, modern S and T. This means that S, T and I form the foundations of modern existence.

A highly developed education and research programme in the basic sciences is needed by any country (including Nigeria) that would want a secure and stable society.

Knowledge of the basic sciences such as physics, biology and chemistry are of indispensable value because it is through their research efforts technological growth can take place. The stable society should be one where industrialisation, public health care, advanced agriculture etc can flourish. Long- term progress is only possible if a percentage of government funds are used for teaching and research.

In the past, especially during the colonial era, S & T did not feature in the policy of the colonialists, and generally not seen as an mechanism that could contribute to the development of the African continent. Its recognition in today's Africa is a significant step forward, even though much still remains to be done to make S and T an integral part of national development strategy of African countries.

Exercise 1.1

1. Man's earliest natural tools were (a) —————————— and (b) ——————————.
2. Two elements that govern man's technical progress are (a) —————————— and (b) ——————————
3. Mention three factors that distinguish the 20th century from the previous centuries.
4. A stable society is characterised by many things among which are (a) —————————— (b) —————————— and (c) ——————————

3.5 Subdivisions of science and technology

While science is usually subdivided into basic sciences and sciences and sciences in application, technology is subdivided into classical low technology and science-based high technology. We shall discuss them one after the other.

3.5.1 Science

(i) Basic sciences

These can also be called pure or fundamental sciences. They can be defined as man's systematic effort to understand natural phenomena. The investigator's primary aim here is to have fuller knowledge or understanding of the subject under study. They are not bothered about practical application of the results obtained. These basic sciences play a fundamental role in modern society. It is through deeper understanding of nature that mankind has learnt how to derive the greatest benefit from it whether for good or bad. Basic sciences comprises of five sub-disciplines which are: physics, chemistry, mathematics, biology and basic medical sciences. This is why research and training for basic sciences are conducted in the Universities or in the research centres specially created for this purpose.

(ii) Sciences in application

These are concerned primarily with applying the results of basic sciences to practical uses. There are five areas of sciences in application. They are: medicines, health and population, energy policies, environment and pollution, as well as the earth sciences (including irrigation and meteorology, oceanography and seismology).

However, it is important for you to note that research and development in applied sciences are carried out under the supervision of research councils or by private industries. It is also worth noting that today, especially in industries, basic and applied sciences work hand in hand. Many conclusions arising from basic sciences cannot be tested unless the applied scientist discovers the means of testing. Conversely, before the applied scientist can produce desirable new products, years of basic research may first required. Thus, basic science is dependent on applied science, as much as applied science is also dependent on basic science.

Another important thing for you to take note of is that despite the large technological contents of some of these areas of applied science, they are not areas of manufacturing technology but of applied science.

3.5.2 Technology

As we have mentioned before, technology may be sub-divided into two groups, which are: classical low technology and science based high technology. The generic word 'technology' is used here to refer to the whole area of manufacturing technology. High technology differs from low technology because high expertise in the relevant basic sciences (like physics, chemistry, biology, mathematics, etc) is crucial. The materials used in high technology are minimal in bulk. Just like basic versus science, the distinction between the two areas of technology that is low versus high is often not clear. This is noticed particularly when methods and tools of high technology such as microprocessors are used in industrial products of low technology.

Exercise 1.2

1. What is the primary aim of a basic scientist?
2. Four areas of sciences in application are (a) ——————————
(b) ————— (c) ——————— (d) ——————————
3. Research and training for basic sciences are conducted in the
(a) —————————— or (b) ——————————:

(i) Classical low technology

There are five sub-areas here and they are: bulk chemicals, fabrication of iron, steel and other metals, design and fabrication in (indigenous) industries(for example, cotton, leather, wood, food products, tobacco, construction materials), petroleum technologies, as well as power generation and transmission (including heavy electrical industry).
In these areas there are no new scientific principles to be discovered.

However, designs, adaptation and modification of products need to be developed from time to time. These areas are the traditional areas craftsmanship and skills. Thoroughness (in all aspects of manufacture and after service), beauty of design, the quality of workmanship, cost manufacturing competitiveness are all-important. Do you think Nigeria belongs to this area of technology? If you do try to categorise the kinds of industries in Nigeria, do they fit into the five sub-areas of classical low technology?

While the basic processes of classical low technology remain unchanged as stated above, new high technologies such as microelectronics, robotics and new materials are being introduced. These have helped to modify some processes, management and control of existing ones. When people talk about transfer of technology from abroad, they are referring to this area of classical low technology. A country that wishes to industrialise will have to develop one or more of the technologies listed above. Japan, the former Russian Federation and South Korea became industrialised through that method. The same is true with regards to other developing countries such as Nigeria. As it was in the case of those countries imported, low technology is now playing a big role in building up of our technological base.

(ii) Science-based high technology

You may have observed that the last two decades of the 20th century has been characterised by an unprecedented pace of development of new technologies and rapid change in their adaptations and utilisations. The highest achievement in this ultramodern technology may be divided into six areas, which are: communication, informatics and other sciences. These consist of two sub-disciplines

(a) Microelectronics. It includes development of software, microprocessors, computer - aided design, eventual fabrication of microchips. All these are in use in industries such as the automobile industry.

(b) Microphotonics. It includes the development of lasers and fiber optics.

Of these two, Microphotonics is the less developed and it requires greater research effort to bring it to fruition.

Others here include space technologies such as the manufacturing of rockets for space travel, composite materials and high temperature superconductors, nuclear energy, pharmaceuticals and fine chemicals, as well as biotechnology and gene splicing.

Do you think Nigeria belongs to this group? I don't think so. Very few of the developing countries with the exception of the Confucian belt countries (such as Singapore, South Korea, China, Malaysia, India and Brazil) are conscious of the need for or have made progress in high technologies. The general feeling in many developing countries is that these new areas are beyond them. You may agree with me that it is this feeling of lack of faith in their own scientists and technologists that one must fight against. This is because the future of these countries undoubtedly lies in making effective use of these specialists.

Exercise 1.3

1. Five areas of classical low technology include (a)—————————— b)——————————(c)———————————(d)————————— and e)———————————

2. What 3 aspect of new high technology can be introduced into classical low technology to help improve process and management?
3. Two sub-disciplines of communication/informatics are (a)——————————— and (b)——————————— what does each consist of?
4. Which countries make up the Confucian Belt?

3.6 Methods of acquiring technological advancement

Technological advancement can be achieved in the following ways: *Technology transfer: This is a situation where the productive sectors of the* economy (that is the manufacturing industries in a country) import from another country, both the productive machinery and equipment and the experts that will organise the systematic transfer of the required technology.

Acquisition technology: This is an advanced form of technology transfer. Unpackaged technology: This refers to technology obtained through relevant software and during the repairs/maintenance of the item. Through such exposure, a local replication of the technology is made possible.

Adaptation technology: Here, the technological product is first obtained. It is then dismantled and reproduced with infused local input, based on useful indigenous technology.

Poached technology: This is the covert taking away of technology without the consent of its originator or producer. This may be achieved through the help of spies or unscrupulous private entrepreneurs, with occasional support of their governments. Occasionally, key scientists behind important innovations are kidnapped or attracted to the seeking country by monetary inducements. Such activities infringe on the patent law and the international property rights.

3.7 Some early contributions to science and technology

Some scientists who have contributed monumentally to scientific knowledge by their pure or basic research include:

a. Robert Boyle (1627 - 1691). He is regarded as the Father of Chemistr y. He is famous for his discoveries on the physics of gases.

b. Marcello Malppghian (1628 - 1694). He has been referred to as the 'Father of Microscopy'. This is because of his numerous anatomical and botanical investigations with the newly invented microscope. The malppghian layer in leaves of plants is named after him.

c. Christian Huygens (1629 - 1695). He was a reputed mathematician and an astronomer. He built the first accurate pendulum clock.

d. Robert Hooke (1635 - 1703). He made his living as a surveyor and an architect. He was a research assistant to Boyle. He carried out various researches in biology and physics. He is most remembered for his microscopic discovery of the cells of plants.

e. Isaac Newton (1642 - 1727). He was a brilliant mathematician and physicist. He is remembered mainly for his laws of motion, and the discovery of the composite nature of white light using a sunbeam and a prism.

f. Michael Faraday (1741 - 1867). He was a brilliant physicist. He is remembered for his discovery of electricity in 1813 during a series of deliberate researches with very simple apparatus.

On the other hand, the production of steam power, a technical development is the most important in the whole history of modern industrial civilisation. This technical production proceeded without any help from pure or basic science. The original incentive forthis invention was cormcmlyercial and industrial. That is how to solve the problem of pumping water from a mine. The only significant contribution form theory was the invention of separated condenser in 1764 by James Watt (1736 -1819). Apart from this the steam engine was invented and improved by a succession of practical inventors without any training in mathematics or physics.

3.8 Some modern contributions to science and technology

It is important to know some modern contributions to science and technology. Invention is an outstanding feat emanating from science and technology. The claim is often made that modern industry depends on basic science for its supply of innovations. It is also said that the support of pure science is justifiable because it would lead, eventually to economic benefits through improved industrial products or processes.

For instance, the zip used to fasten a piece of clothing, especially women's dresses was invented by W. L. Judson. He was an American mechanical engineer. He applied for the first patent of his invention in 1891. (The patent is an open letter from the government of a country, conferring the sole right for a period of time to make, use or sell some invention.) Judson's invention was a unique one. He formed a company to try to make and market a saleable product. But the company failed after a period of twenty years. It took another company called the Automatic Hook and Eye Company and a Swedish electric engineer called G. Sundback (1913) to improve and finally come up with the essential design we know today. But public acceptance of this new product only came in 1918.

Another notable invention was that of antibiotics. The invention was a technical innovation that sprang directly from pure or basic scientific research. In 1928, Alexander Fleming accidentally observed the effects of microorganisms (fungi) named Penicillium on a bacterial culture. He was deeply interested in natural products that could kill bacteria. He immediately started research on the penicillium phenomena. Over a period of three to four years, he extracted the active agent in the fungi, tested its action on animals and humans. He found out that it was not toxic to animals and humans. He published his results in a journal. But because Fleming was a man who didn't like publicity, his discovery was almost completely ignored. Again, he didn't have the money to isolate and purify the active agent for commercial purposes. Additionally, he didn't seek publicity because commercial pharmacists of that time generally considered the concept of a non-toxic bactericide, a contradiction.

Ten years later in 1939, a group under Howard Florey and Ernest Chain began work on natural antibiotics. They came across Fleming's paper in the literature and soon confir med Fleming's work that penicillin was highly effective and could be concentrated and purified. Florey went to the United Statesin 1941.

Since that was wartime and many people were wounded, he was able to convince the pharmaceutical industry to commit some amount of money to develop and produce penicillin. In eighteen months, they had enough active penicillin to treat 200 cases. After thirty months, processes for large-scale industrial production became available. For all these, Fleming, Florey and Chain were awarded the Nobel Prize for hysiology and Medicine in 1945 and also received knighthoods. Being basic scientists, they were well satisfied with the honour and glory. The industrialists had to comfort themselves with the financial profits of the operation.

Exercise 1.4

1. Where the productive sectors of an economy, imports productive machinery and equipment and also experts, that technology is called ——————————————.
2. A technology that is acquired through the repairs/maintenance of an item s called ————————.
3. What is poached technology?
4. Match the items in A with those in B by filling in the blank spaces provided.

A **B**

——————————Robert Boyle a. Zip fastener
——————————Marcello Malpighi b. Laws of motion
——————————Christian Huygens c. Father of Chemistry
——————————Robert Hooke d. Discovery of electricity
——————————Isaac Newton e. Father of microscopy
——————————Michael Faraday f. First accurate pendulum clock ——————————Judson g. Discovery of plant cells

4.0 CONCLUSION

This unit is a very interesting unit, particularly as it has exposed us to the distinctions between science and technology, the importance of science, technology and inventions (popularly called S, T & I) to the standard of living of any country of the world today. We have also learnt some of the methods of acquiring technological advancement. So if you are interested in helping your country to be more technologically developed, you can choose any method of your choice with the exceptions of Poached technology. Examples of some early and modern contributors to science and technology ended the unit.

5.0 SUMMARY

The main points in this unit are as follows:

1. Science and technology have affected our lifestyles. This is

more
obvious when lifestyles of today and that of 100 years ago are compared. So they have been the most potent forces for social change in the history of man.

2. Science is both the process and product of investigation and research, while technology consists of what can be done with the products of investigation and how they can be used.
3. Curiosity motivates scientists to carry out investigations and research, while the desire to know how to translate ideas and plans into concrete products or processes, is what motivates technologists.
4. Technology began when man-made and used tools, in his desire to provide for his basic needs of food, clothing and shelter. Man's earliest natural tools were his hands and feet. He later graduated to stones, to sticks shaped to be used as tools, and then he developed tools of special types to be used for hunting, fishing etc.
5. Man's technical progress is believed to be governed by two elements, which are discovery and invention.
6. The discovery of fire is the most important discovery of the Stone Age man. With it he learnt how to cook, which then led to the invention of cooking methods and kitchen utensils.
7. Man later domesticated plants and animals, and thus invented Agriculture. This led to the establishment of communities. Technology thus made possible the beginnings of civilisations in Egypt and Babylonia. The 20th century can be distinguished from the previous centuries by the following:
   a. the recognition of the importance of science and technology in human affairs;
   b. the increased pace of scientific and technological development, and by
   c. The realisation that science and technology are not simply a limited or local factor.
8. The standard of living of any nation is dependent on science, technology and inventions.
9. Science can be subdivided into basic and applied sciences. Basic sciences include physics, biology etc, while applied sciences include agriculture, medicine etc.
10. Technology can be subdivided into classical - low technology such as fabrication of iron, steel etc, and science - based high technology such as space technologies, Nuclear energy etc.
11. Methods of acquiring technological advancement include: technology transfer, acquisition technology, unpackaged technology, adaptation technology, and Poached technology.
12. Some early contributors to science and technology include Robert Boyle, Marcello Malpighi, Christian Huygens etc.
13. Some modern contributors to science and technology include W. L. Judson, Alexander Fleming, Howard Florey and Ernest Chain.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the differences between science, technology and inventions?
2. Write short notes on the following:

a) Basic sciences
b) Applied sciences
c) Classical low technology
d) Science based high technology

7.0 REFERENCES/FURTHER READING

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UNIT 2 SOCIAL IMPLICATIONS OF TECHNOLOGICAL DEVELOPMENT

CONTENTS

1.0 INTRODUCTION

From the discussions in the last unit, that is unit 1, you may now be aware of the relationship between science and technology. You may also be able to identify several situations in life where science and technology have enriched men's lives. The topic of discussion in this unit will help to refresh your memory of some of the gains of science and technology. specifically, the unit will acquaint you with some of the negative or adverse effects of technological development on society. It is important to know these because a. they will enable you to develop an awareness of problems which confront human beings everywhere.

b. they will also help you to be aware of the fact that the solution to social problems depends on every human being and on bringing together knowledge and understanderived from every known discipline.

Since we have discussed the relationship between science and technology and their uses in the previous units (module 2, unit 3 and module 3, unit 1), you will not find this unit too difficult to understand.

2.0 OBJECTIVES

After studying this unit, you should be able to:

a. outline some of the gains of technological development.
b. discuss vividly, how technological development has affected society in terms of

(i) increase in population
(ii) environmental pollution (iii) poverty
(iv) pursuit of peace

3.1 Gains of technological development

Can you remember the meaning of technology? Don't worry if you cannot! Let us try to understand it. The widespread meaning is 'the application of scientific knowledge and research with the aim of developing products or processes for the use of man.' These products and processes can be found in the areas of agriculture and food production,
medicine, architecture, engineering, transport and communication, space exploration, pharmaceutical industries and so on.

In the field of agriculture, for example, technological equipment comprising ploughing machines, tractors, harvesters, has tremendously increased production. Agricultural raw materials have also been turned into various forms of manufactur ed goods. An example is the use of animal skins in the production of leather for manufacturing handbags, wristwatch handles and so on. Can you think of other examples?

In the field of medicine, new drugs and new techniques for curing diseases have been discovered. These have helped to improve the life of individuals in society. Better surgical techniques and better understanding of the body's immune system have led to increase in organ and tissue transplant (such as lung, liver, kidney etc). Do you know that through ultra sound techniques, the condition of a developing baby in the womb can be known clearly and quickly?

In the areas of architecture and engineering, incredible structures such as dams, pyramids, artificial lakes, canals, houses and so on have been built. Biotechnology has helped to improve agriculture and food production by increasing yields of plants and animals. It has also helped to medicine by the development of drugs such as the human insulin used for the treatment of diabetes.

We have now outlined some of the gains of technological development. Let us now turn to the negative or adverse effects of development.

3.2 Adverse effects of technological development on society

You may be aware that some of the worst problems of humanity have either been brought about or increased by science and technology. This is in spite of the many in which ways they have enriched men's lives. Can you mention some of the problems? You are on the right track if you say technological development has:

a. caused an increase in world population
b. caused pollution of air, land and water
c. caused poverty or
d. threatened the pursuit of peace in the world.

The mnemonics device for remembering these are the four P's: Population, pollution, poverty and pursuit of peace. They are intimately interrelated with one another and with science and technology.

We shall discuss them one after the other.

3.2.1 Population

You probably may not know that one of the most serious adverse effects of science and technology is overpopulation. The world's population is doubling approximately every thirty-five years. The global population in 1974 was approximately 4.0 billion. By the year 2006, it is expected to have increased to 6.8 billion.

Seventy - five per cent of the world's inhabitants live in the developing countries and the highest immediate increments are bound to take place there. The population of Africa, for example, was 275 million in 1960 and it was projected to be 853 million by the year 2000. Nigeria alone has over 100 million people already.

What do you think has caused these spectacular increases in recent years? Well, you will be correct to say advances in agricultural and health technologies have brought death rates below birth rates.

During the 10,000 year-phase of agriculture, minor improvements in agriculture made it possible to obtain a slow but distinctive growth in the world population. This was at a rate of somewhat less than 0.1 % per year. Then around 1750 AD, the agricultural revolution was in full swing. It brought about three areas of development:

1. Improved crop growing methods such as in crop rotation, which eliminated land fallow method.
2. Advances in livestock breeding.
3. The invention of new farm equipment such as machines for planting, cultivating and harvesting crops.

The effect of these was 'increase in food production'. This effect when added to that of industrial revolution, which is, increase in standard of living resulted in increased birth rate and decreased death rate. This trend has continued till today in spite of that fact that some countries are trying to curtail birth rate through various means, such as natural family planning or the use of condoms.

You will agree that the links between these population increases and technology are obvious. For instance, adverse seasons could no longer cause famine because of improved food production and distribution. Epidemic diseases no longer reduced population because standard of feeding had risen and advances in environmental sanitation and increasing sophistication of medical treatment had decreased death rates. Is it not both interesting and terrifying to consider the fact that what was apparently a beneficial aspect of technology -the reduction of death rate due to the effective control of disease and famine - has generated the problem of overpopulation?

3.2.2 Pollution

It may interest you to note that too many people can cause depletion of natural resources, and energy; It also gives rise to poverty and pollution. They are all interlinked and are aggravated by overpopulation. The deterioration of the human environment, in particular, is a problem that arises as a result of industrialisation brought about by science and technology.

When man was using his hands as his only tool (that is in the ancient times), his impact on the environment was small. But as soon as he had power tools and machines to extract coal, oil, and other fossil fuels from the earth in large quantities, he began to generate power (such a electricity, gas, kerosene, etc). He also began to deplete the natural resources at unp recedented rate. Power, however, is absolutely necessary to run an industrialized society but power also pollutes.

Let's take a break and do this exercise.

Exercise 2.0

Complete the following sentences:

1. ———————— techniques can be used to clearly see a developing baby's condition in the womb.
2. In 1974, the global population was —————— while it is expected to be ——————— by 2006.
3. The increase in population was brought about by ————————— and ————

That was a nice break. We were discussing about pollution - that power pollutes. Power includes the use of petroleum, gas, kerosene and other aspects of crude oil.

If you can get some copies of Nigerian dailies or magazines, you can read stories on the pollution of the land, water and air of the states of the south-south and other oil- producing states of the country.

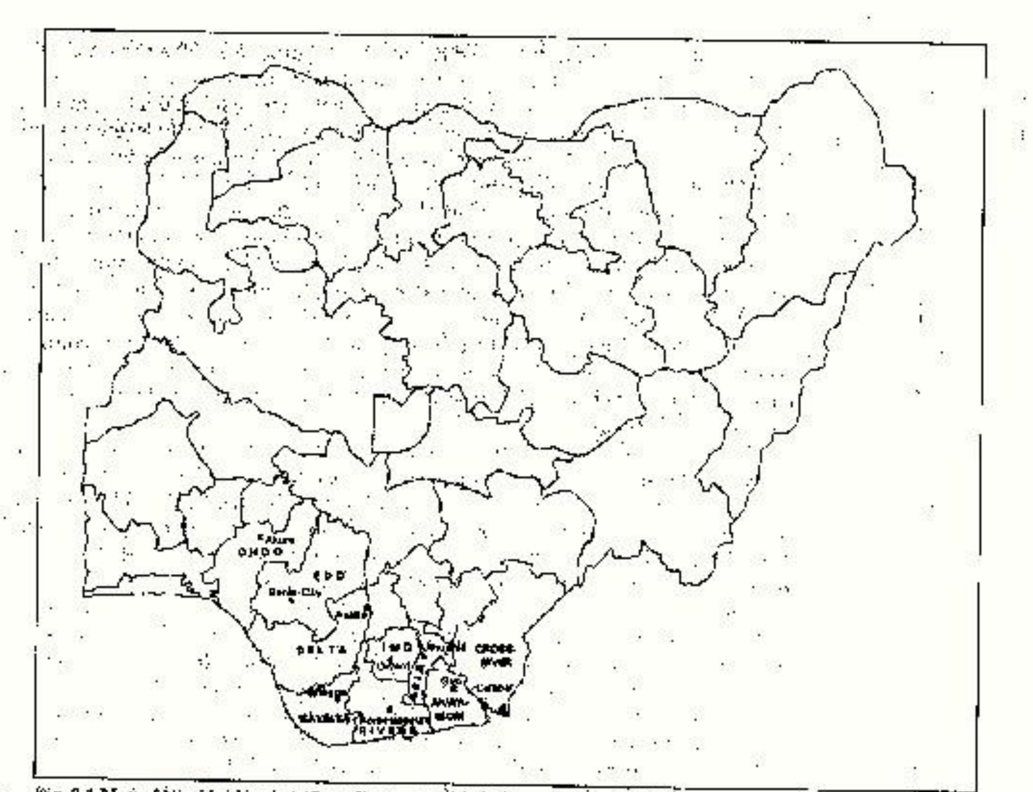

Fig. 3.1 Map of Nigeria showing oil producing states

From the map of Nigeria above, you can observe that the oil producing states are Delta, Edo, Rivers, Bayelsa, Imo, etc. The natives of these states are not particularly happy about the activities of the oil companies located there. Such oil companies include the Royal Dutch/Shell Group, Chevron, Exxon -Mobil, Texaco, Agip (Italian) and Elf (French). The unhappiness of these people can be gleaned from the following statement:

Since Shell began drilling oil in Ogoni land in 1958, the people Ofgoniland have had pipelines built across their farmlands and in front of their homes, suffered endemic oil leaks from these very pipelines, been forced to live with the constant flaring of gas. This environmental assault has smothered land with oil, killed masses of fish and other aquatic life and introduced devastating acid rain to the land of the Ogoni. For the Ogoni, a people dependent upon farming and fishing, the poisoning of the land and water has had devastating economic and health consequences.

The above passage has said almost everything about pollution. If you are now asked to define pollution, can you do so? I believe you can. You are right if you say that pollution is the release of substances or energy into the environment in quantities which are harmful to man or other living things. A pollutant therefore is a substance whose presence in the environment is harmful. Examples are chemicals, garbage, noise, heat, acids, etc. It is necessary to know that although some pollutants occur naturally (like oil seepage from undersea deposits and from volcanoes), most of them are produced by human activities. They can affect air, water and land. Can you list air pollutants? You are right if you list things like exhaust fumes, domestic and factory smoke, poisonous gases like carbon- monoxide,
ozone, etc. Air pollution affects human beings directly by causing smearting of the eyes, coughing and respiratory distress.

Air pollution can alter the earth's climate significantly. The threat to climate arises from the retention of a high level of carbon dioxide in the atmosphere, which gives rise to a green house effect. Human activities such as combustion, deforestation and release gases such as carbon dioxide, methane, chlorofluorocarbons (CFCs) etc in high quantities into the atmosphere. These gases are called greenhouse gases because they change the flow of light and heat energy through the atmosphere. Together, they act as an insulating blanket covering the planet. They do this by absorbing and returning to the earth's surface much of its outgoing heat (that is infra-red energy radiations). They trap this heat within the lower atmosphere thus warming it. This is known as global warming.

You might also have heard of global warming in the news. It is a natural or human induced increase in the average temper ature of the atmosphere near the earth's surface.
Various studies have provided sufficient evidence to indicate that this
change in climate would have important effects on life. For instance, it can affect agricultural livestock, increase rise in sea level, modify ocean
circulation, cause regional famine, desertification, forest fires and flood.

Water pollution as you might be aware of it includes industrial wastes, oil spillage from oil refineries, leakages from petroleum tankers etc. These are washed into rivers/ streams after rain. All these render the water unfit for drinking. Oil pollutants constitute danger also to aquatic life through
suffocation. This is what happens in the Niger - Delta region of Nigeria,

where the oil companies operate. Other water pollutants include human faeces, fertilizers, soap, detergents and so on.

Rainwater ordinarily is slightly acidic because it dissolves atmospheric carbon - dioxide to form carbonic acid. Scientists in 1970 discovered that some countries like Scandinavia, North - East USA, southern Canada, Northern Europe and Japan experience rains that were becoming more acidic and more devastating. This is as a result of accumulation of nitrous oxides (from power plants and automobile emissions) and sulphuric oxides (mainly from power plants and smelters) in the atmosphere.

These dissolve in rain water to form nitric acid and sulphuric acid. These acids in the rainwater fall on earth to bathe forests and cities and fill the lakes with corrosive mix. The rains cause reduction or elimination of fish in many lakes.

You may be aware that land pollution is caused mainly by industrial wastes such as 'tarlings' from steel plant (it can cause the land to be rock - like and deprive it of its nitrogen). Other industrial wastes from tanning, textile and iron industries; refuse from the cities, metal scraps as well as abandoned garbage cause land pollution.

Do you know that noise is a form of land pollution? It constitutes a social problem in many developed and developing countries. Very often noise in excess of 90 decibels (when noise can cause permanent loss of hearing) exists in technologically advanced societies. Such noise often comes from jet airplanes, jackhammers and very loud music.

In addition, such noise could be damaging to human health.

Let's take a break.

Exercise 2.1

1. Oil- producing states in Nigeria include ——————,————— and —————
2. What is a pollutant? Give 2 examples.
3. What is green house effect? Give 3 examples of green house gases?
4. What do you understand by global warming?

Pollution, as we have already said, can affect the land, water and air. It is important to know that pollution crisis goes hand in hand with the energy crisis. In advanced countries, the so many amenities, which make life so convenient, are often responsible for an insatiable energy demand. Homes are heated and air - conditioned by energy consuming devices and many of them use electricity. The affluent countries are the worst offenders. It has been estimated that the US alone, whose population is only 6% of the world's population, consumes

40% of the earth's natural resources output.

The rich invariably pollute more than the poor. The poor people in rich countries suffer the effects of pollution more than the rich. This inequality can give rise to social and economic tensions.

3.2.3 Poverty

Do you know what it means in human terms to be poor? It mal utrition, protein deficiency with possible brain damage in children,
corrosive hunger, famine, lack of medical care, poor health, diseases, suffering, illiteracy, unemployment, apathy and despair.

Even in the richest of countries there are pockets of poverty. The majority of people in the world, however, are poor and further more, although the rich consume the world's resources at a much greater rate than the poor, they are getting richer faster than the poor.

The continent of Africa has the lowest Gross National Product (GNP) per capital in the world. GNP is a measure of national wealth. There is obviously a strong link between overpopulation and poverty. It is due to the fact that food and other resources are not increasing at the same rate as population that there is poverty. Although there have been very significant improvements in world food production, it is still far below population growth despite all current national, bilateral and international efforts to reverse this trend.

3.2.4 Pursuit of peace

It is an irony that man throughout his long and tortured history has pursued peace mostly by waging war, and when an interval of peace is achieved it is often utilised to prepare for war. 'In time of peace', they say, 'prepare for war'.

The pursuit of peace arises simply as an indication of the kinds pro bflems that pose a major threat to mankind. An example is the case of possible extinction. This is because of its interactions with science, technology and education.

The founders of UNESCO considered peace important enough to cite it in the very first sentence of the constitution, which reads:

Since wars began in the minds of men, it is in the minds of men that the defences of peace must be established.

This suggests at once that UNESCO, the international organisation devoted to education, science and culture, considers the pursuit of peace its longrange target. Let us briefly review some of the most recent examples of the impact of science and technology on warfare.

Since the days of the bow and arrow, the skill of technologists and the ingenuity of engineers have been utilized in the design and production of weapons. Modern industrialised society is characterised by mass production of goods, thus mass production of weapons and their use were felt for the first time in the First World War. The war led to inventions that rapidly improved methods of communication (radio), transportation (the aeroplane) and reconnaissance (aerial photography) to cite just three examples. It also generated the development of huge cannons and chemical agents, which were used for the first time in the most widespread, lethal and destructive war, which had ever taken place. Science and technology thus made devastation possible on an unprecedented scale.

Only twenty years later, however, the Second World War produced developments that dwarfed those of the First World War. The participation of scientists in warfare, which had paid off during the First World War, was increased and magnified during the Second World War. But a new dimension was added and that was the use of scientific knowledge, which had just barely been discovered in the laboratory. The commonest example of this was, of course, the development of the atomic bomb.

The financial, scientific, industrial and technological efforts that were required to produce the first bomb exceeded any previous similar effort in histor y. It required a two-year crash programme that brought together the leading scientists of the world and it cost $2billion.

The bomb was dropped by the Americans on two Japanese cities of Hiroshima and Nagasaki in 1945. A total of 152,000 people were killed within a few minutes of dropping the bomb. The scientists who participated in the Second World War were not after scientific pursuits, that is they were not primarily motivated by a desire to understand phenomena in the natural or man-made worlds.

The period of uneasy peace, called the cold war, that followed the Second World War was character ised by suspicion among former war-time allies. It was also characterized by a furious and extremely costly technological race that led to the development by the super powers of the fusion or Hydrogen (H) - bomb. This bomb is at least fifty times more powerful than the atomic bomb.

Later, these super powers felt there was the need for sophisticated methods of delivering nuclear weapons. This led to another spectacular

development that is the orbiting earth satellite. The Russians were the
pioneers and many nations then joined the mad race for supremacy of outer space. To illustrate this, in 1974 alone, there were 500 earth satellites orbiting the earth at the same time. They were clearly used for scientific investigation, but it was obvious to the whole world that the technology can also be used for reconnaissance and rapid delivery of nuclear weapons since it takes less than 90 minutes for a low-altitude satellite to orbit the earth.

3.3 The social responsibility of scientists and the reciprocal responsibility of society

One interesting thing to note is that having seen the havoc wrought by the misuse of science and technology and other threats posed to mankind by it, some scientists have begun to re-address the issue in respect of what can be done in order that mankind and our planet may survive. How can we, they ask, put science and technology to work for the benefit of mankind? The events of the Second World War awakened many scientists to this responsibility. Some of them joined existing organisations or formed new ones for the purpose of giving expression to this concern.
The physicists who had worked on the bomb and other defence projects were among the most active. Einstein, a pacifist, regretted the disaster caused by his brainchild, the atomic bomb. Before his death on 18th April, 1955, he urged scientists worldwide to realize that it was their duty to prevent the annihilating weapons from being used.

Some of the groups that were formed include:

1. Scientists and Engineers for Social and Political Action (SESPA). It was formed in 1969 by a group of US scientists and engineers who pledged not to participate in war research or weapons production but to counsel their students and urge their colleagues to follow their example.
2. British Society for Social Responsibility in Science (BSSRS). It was formed at about the same time as SESPA. This organisation was signed to make scientists aware of the social significance of science, and of their social responsibility as individuals, and to assist scientists in creating an informed public that can exercise a choice in scientific matters.

Exercise 2.2

1. What kind of bomb was used in Second World War?
2. (a) Where was the bomb dropped during the war?
(b) Who dropped the bomb?
3. How many people were killed by the bomb?

4.0 CONCLUSION

This unit has revealed to us the adverse effects of science and technology. It is because the scientists and the technologists do not pay much attention to planning, direction and guidance that these adverse effects - over population, nuclear proliferation, environmental abuses, depletion of natural resources - manifest. This suggests that new and improved ways of teaching and learning science must be devised. Science education must be closely linked with social responsibility.

5.0 SUMMARY

The main points in this unit are:

1. Technological development has improved every aspect of man's life - agriculture, medicine, architecture, engineering, transport and communication.
2. Some of the worst problems of humanity have either been brought about or aggravated by science and technology.
3. Some of these problems include:

(a) population increase,
(b) pollution of air, land and water,
(c) poverty,
(d) threat to the pursuit of peace.

4. Some scientists joined existing organizations or formed new ones in order help both scientists, technologists and other laymen to be aware of the social responsibility of science.

6.0 TUTOR-MARKED ASSIGNMENT

1. Technological development has resulted in increase in population. Discuss.
2. Write short notes on

(a) air pollution
(b) water pollution

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UNIT 3 THE NATURE AND SCOPE OF PHILOSOPHY OF SCIENCE

CONTENTS

1.0 INTRODUCTION

In the previous unit - unit 2, we discussed the social implications echnological development. There we were made to understand that some of the worst problems of humanity have either been brought about or aggravated by science and technology.

This is in spite of the many ways they have enriched men's lives. Thus, these problems and others will require more and wiser use of the scientific and technological ways of thinking to solve. And it is our belief that science and technology will continue to improve the lot of mankind if they are guided by properly motivated men. This is the reason why philosophy of science is very important. It will enable science to be man-centred in terms producing products that would really be useful to man without side effects. Thus in this unit, we shall be discussing the nature and scope philofsophy of science.

After studying the unit, you are expected to have achieved the objectives listed below.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Explain vividly the meaning of philosophy of science
2. Outline the common characteristics of philosophy and science.
3. Recognise the scope of the philosophy of science
4. Explain the nature of scientific method.

3.1 Meaning of philosophy of science

It may interest you to know that philosophy of science is a branch philosophy. As we said in module 1, unit 5, philosophy initially embraced all the various disciplines. In other words, knowledge about the world gneneral was called philosophy. But with specialisation of knowledge, various disciplines such as the sciences were separated from philosophy. To get back to what we were saying, philosophy of science is the systematic study of the nature of science especially its methods, its concepts and its presuppositions. It attempts to answer such questions as:

1. What is science?
2. What is the nature of scientific knowledge?
3. How does it differ from other forms of knowledge?
4. How do we arrive at a scientific truth?
5. What are the aims and objectives of science? By that, it is meant what is the goal, end or purpose of science?

If you have read the previous modules very well, you will see that we have tried to answer these questions in module 1. There we discussed definitions, branches and aims of science. We tried to show the differences between science and non-science disciplines. We have also examined the historical development of science in a general outline.

In this unit, we shall examine the nature of science in a philosophical manner.

Scientists work on the assumptions of some facts and on general principles.

For example, one fundamental notion in science is the idea of law of nature.

And the idea of law - governed universe assumes that the universe usniform. So the assumption of the uniformity of nature poses a problem which philosophy tries to explore. According to some philosophers, the laws of nature are not the same in the planets, yet the scientists use the same law of gravitation for them because of the scientific faith in the uniformity of nature. Philosophy questions the empirical generalizations, which the scientists feel are unquestionable.

Before we go on, let's discuss the common characteristics of philosophy and science.

3.2 Common characteristics of philosophy and science

It is important for you to know that though philosophy and its offshoots - the small sciences, are not identical yet they share a lot in common in their systematic pursuit of knowledge. Their common characteristics include:

1. They are both critical, skeptical and non - dogmatic in character or attitude. In module 1, unit 2, we explained what a critical attitude means.
2. They both show the curiosity to know and the courage to explore every question within no-go areas and heresy.
3. They both search for knowledge which is rational, systematic, universal, objective, certain and verifiable (that is provable or demonstr able). The demands for evidence or grounds of belief are also very important. Logic is central to both philosophy and science. The principles of valid or true reasoning are important for both philosophy and scientific inquiry.
4. They both lay emphasis on method. The deductive method is important for philosophy while both the deductive and inductive methods are important for the sciences. We shall discuss about this in a later section. Analytic method is also very important in philosophy.
5. They both search for general laws or principles and theories for explaining the nature, character and functioning of the universe or any of its parts.
6. Whereas philosophy focuses on the general principles and fundamental assumptions of the sciences such as the law of uniformity of nature, the sciences focuses on both the general laws and particular laws such as the law of inheritance.
7. Philosophy is ver y reflective in that it meditates or reflects on the nature, methods and concepts of the sciences. That is why we have philosophy of science.

Exercise 3.0

1. Define philosophy of science.
2. List 3 characteristics common to both philosophy and science.

3.3 Scope of philosophy of science

From what we have discussed so far, philosophy of science embraces the following:

1. Definition of science.

Here, such questions as the nature, branches and meaning of science are explored.
We discussed this in module 1, unit 1.

2. The aims, end or purpose of science.

That means that philosophy tries to understand the objectives of engaging in scientific activities, this was discussed in module 1, unit 1. It also inquires into the utility or uses of science. Scientific knowledge as we now know leads the world to attaining progress and better

conditions.
Therefore modern science has contributed to improving the lots of man with regards to food/plant production, housing, health, clothing, communication, etc. Science has also influenced other disciplines of man's engagement. This is with regards to the skill or art of doing things. And we now know that the skill or art of producing and application of science starts with the art of correct observation and experience.

3. The methods of science.
Philosophers examine the experimental method. The practice of a scientists as we saw in module 1, unit 2 is done in the following steps. The scientist works with some data to solve a particular problem. He formulates various hypotheses which if true would solve that particular problem. He expseriments to discriminate among the competing hypotheses. The performed experiment selects and adopts the hypothesis that verifies the problem.

4. The above practice for the philosophy of science filled up with problems because it is just like the activity of every person. For instance, a female cook can adopt this procedure to establish that she is an excellent home-economic woman. The philosopher tries to find out how true the result obtained through this method is.

To the philosopher, scientific opinions, belief, facts and results are not the only criteria of knowledge. Some scientific beliefs often conflict with each other, therefore they are sometimes unstable even with the experimental data, while a sound philosophical knowledge is always permanent. With the established results of empirical sciences, it is difficult for the scientist to change his opinions. For instance, the early scientists viewed the world as being flat. Later when it was proposed that the earth was spherical, it took the scientists some time to change their view. Philosophy as a reflective discipline sometimes rethinks it own views.

A hasty implementation of some scientific discoveries like the atomic bomb explosion in Hiroshima and Nagasaki in the Second World War (1939 -1945) does not improve human life. A sound philosophy must encourage the examination of scientific inventions. This is why philosophy of science criticizes scientific opinions and practice. (or method). When the scientific method is properly analyzed by philosophy, it describes or presents an ideal situation which every scientific activity or practice tries to satisfy. You will learn more of this in the next point to be explained.

5. Analysis of scientific concepts and theories. Do you know what a concept is? It is an 'idea of a class of objects' or a 'general notion'. Many concepts are encountered in science. Some of them are listed below:
a. There are general concepts which apply to science in general such as, science, facts, theory, law, motion etc.

b. There are concepts which apply to scientific methods in general such as observation, experiment, hypothesis, theory, induction, deduction, etc.
c. There are those concepts that are basic to various branches of science such as time, atom, electron, proton (in the physical sciences) and gene, cell, etc (in the biological sciences).

You may not be aware of it that philosophy tries to analyse these concepts.

One of the chief tasks of philosophy is the analysis of the language of science or semeiotic.

Semeiotic is also called the theory of signs and the signification of terms or semantics. Semantics means the science of the meaning of words. Semantics as a department of semiotics is the study of the relation of signs to the objects to which the signs refer to or designate or are applicable. For instance, if one uses the word 'cell', philosophers try to study the relationship of that word 'cell' to the object to which it refers.

Philosophers also analyse theories. Apart from studying the relationship of this word theory to what it refers to, philosophers also present some constraints or limitations, which are used in establishing the quality and nature of theories for good scientific practice. These limitations are the criteria for determining the practicability of a hypothesis. One of these criteria is falsifiability. This principle was introduced by Karl Popper. It is meant to take care of those statements which cannot be verified now and which may be verified in future. Such statements have to be accepted in principle until experience or test falsifies or verifies them. For example, a theory about the origin of the universe may not be verifiable in the meantime but it can be falsified. The falsifiability principle advocates that a theory be treated as a possible scientific one if there are reasonable grounds to believe it until it has been shown to be false.

Let's take a break.

Exercise 3.1

1. Mention 4 aspects of science which philosophy studies.
2. List 4 concepts in science.
3. What is semantics?
4. (a) The falsifiability principle was introduced by ————————

(b) What is the principle all about?

Let us go on with the discussion on the criteria for determining how practicable a hypothesis is. The next criterion is significance. Significance is what something means. We have earlier discussed this in connection with analysis of concepts. The final criterion is called paradigm conservation. It is a device against impractical proposal. It suggests that insistence on the past model or theory is preferable when a new model conflicts with the past one. It is used especially if a reliable datum has been previously established by hypothesis and laws. Thus conflicting explanations of data can be offered on the basis of paradigm conservation.

Please remember we are still discussing the scope of philosophy of science. The last but not the least is:

6. The nature and character of scientific knowledge and its relation to other branches of knowledge.

If you would recall from module 1, unit 1, we discussed the characteristics of the scientific knowledge and also the differences between science and non-science. But we can still summarize the characteristics here. A genuine scientific knowledge according to philosophy is characterised by:

(a) Systematicness: The propositions of any scientific knowledge must be logically related. They must exhibit a deductive character such that no proposition which is true could relate logically to a false one. Scientific knowledge must be pursued in a systematic manner. The steps leading to results or conclusions must be repeatable or be capable of being repeated. This makes it possible for a true scientific statement, proposition or theory to guarantee certainty.

(b) Universality: Every true scientific statement must show a universal character. This means that it must be true in all cases under the same conditions. If an exception occurs, the proposition must be so qualified and the limit to its applicability must be indicated.

(c) Objectivity: This refers to the absence of personal bias to recognise that there is a fixed external reality which refuses to quit whether we accept it, know it or not. Thus a scientific proposition or statement must be true irrespective of the interest of the scientist. It must be factual and nonsubjective.

All experts in the area must be able to confirm, through logical or experimental demonstration, the truth of the statement.

3.4 Nature of the scientific method

Do you still remember what is meant by the scientific method? You will recall that it was the topic of discussion in module 1, unit 2. In that unit we discussed the steps of the scientific method. In this section, we shall discuss the philosophy behind the method.

A brief introduction will help you understand this topic. Philosophy has many branches and they include, metaphysics, epistemology, logic, ethics and aesthetics. But only epistemology and logic are relevant to the discussion on the philosophy of science.

Epistemology and logic are branches of methodology. Methodology is one of the divisions of philosophy. Methodology deals with ways afttaining knowledge, that is the process of intellectual inquiry, research and reasoning. In philosophy, epistemology is the branch that deals with how we discover true knowledge from a direct process of investigation while logic enables us to arrive at new knowledge from existing knowledge.

This then means that the process of discovering new knowledge is not the same as the process of inferring or deducing knowledge from implications of what we already know. Thus the differences between the two are as follows:
1. While logic is concerned with validity or 'soundness', epistemology
is concerned with the truth of our assertions or propositions. 2. Epistemology is important in the process of discovery and research while logic is important for the systematization of knowledge and also in deducing new knowledge from what we have already discovered.

These two aspects of methodology can be found within the scientific method and they are essential for all branches of knowledge. We shall discuss logic then show where it can be found within the scientific method.

3.4.1 Logic

Logic as you may already know is concerned with human reasoning or thought. It studies the structure of human thought as well as the principles or laws of valid reasoning. It is concerned with the validity or soundness of the inferences and conclusions, which we make in our arguments. To reason is to infer, to judge or to argue. To infer or argue is to move from certain premises to other premises or conclusions. That which is inferred from another premise(s) is the conclusion. In an argument or reasoning we move from knowledge to new knowledge or from a supposition (premise) to that which validly follow from it.

Before we proceed any further, we need to explain certain terms. These are *premise and conclusion.*

When we have a sequence (a number) of statements in addition to a claim, then we have an argument. Sequence itself is made up of two or more statements while the claiming is one of the statements called the conclusion. Other statements in an argument are called premises. The following is an example of an argument:
All dogs are mammals.
All mammals are animals.

Therefore, all dogs are animals.
The first two statements are called premises while the last statement is the conclusion.
Thus conclusions are always derived from premises.

Exercise 3.2

1. Genuine scientific knowledge is characterised by (a) ——————
(b) —————— and (c) ————————.
2. Methodology is a sub-division of (a) ————————. Its two aspects are (a) ——————— and (b) —————————
3. The following is an example of an argument. Identify the premise(s) and conclusion
• All men are mortal.
• Peter is a man.
• Therefore Peter is mortal.

We are still discussing logic and now, we shall look at the two types of logic, which are relevant to the scientific method. The two types deeductive logic and inductive logic

1. Deductive logic (or method of reasoning)
Here we move from a set of premises, which we assume to be true to a conclusion. If we reason correctly according to the rules of deductive logic, then the conclusion will be valid. And if the premises are true, then the conclusion will be necessarily true.

For example, the following argument is a deductive one:
All men are mortal.
John is man.
Therefore, John is mortal.

The conclusion 'John is mortal' is a deductive knowledge. Its truth is derived from logical implications that it follows which happen to be true at the same time. Therefore in deductive method, we move from a general principle or law to particular instances, which fall under such a deductive reasoning is applied mainly in formal logic, mathematics and philosophy. But science also applies the method especially with regard to the organisation and systematisation of knowledge, as well as in making inferences from what we already know. Deductive method is also called platonic method. It gives knowledge that is certain.

2. Inductive logic (or method of reasoning)
This is the type of reasoning in which we go from some particular statements to a general conclusion. It is used in empir ical (scientific)

generalisations. For example:

Many Africans are black.

Therefore all Africans are black.

The inductive method is also called the Baconian method because Francis Bacon founded it. The inductive method is the method of discovery which emphasizes observation, experimentation, verification and theory construction. The problem with induction is that it is possible for a member of the class to turn out to be different from what we have generalised for all the members of the class. For instance, some Africans are white (such as in South Africa). Therefore induction gives us probable knowledge.

Probability shows the degree of reliance to which we can place on the inductive generalization. To say that an event is probable is to say that it is likely to occur. When the scientists talk of probability they must indicate the degree of probability of the occurrence of the event in question.

In summary, therefore, the scientific method has two phases, which are:

1. The method of discovery which is inductive - it emphasises observation, experimentation, verification and theory construction.
2. The method of organization of scientific knowledge, which is deductive and systematic.

Thus logical reasoning runs through the scientific method. It is the main tool in

1. formulating hypotheses;
2. judging the correctness of ideas conjured up by imagination and intuition;
3. planning experiments and deciding what observations to make;
4. assessing evidence and interpreting new facts
5. making generalization and
6. finding extensions and applications of a discovery.

You will recall that we discussed all this in module 1 unit 2

Exercise 3.3

1. (a) Mention the two types of logic and (b) define them.
2. Give examples of each.

4.0 CONCLUSION

In this unit, we discussed the meaning of the philosophy of science, the common characteristics of philosophy of science, scope of the philosophy of science and the nature of the scientific method. From all this you would have learnt that philosophy of science is a sort of a guard that guides science through the way it chooses to gain knowledge of nature.

5.0 SUMMARY

The main points in this unit are:

1 Philosophy of science is the systematic study of the nature of science especially its methods, its concepts and its presuppositions.

2 Common characteristics of philosophy of science include the fact that it is critical in nature, it show curiosity, it lays emphasis on methods etc.

3. Definition of science, aims, end or purpose of science, analysis of scientific concepts and theories and finally the nature and character of scientific knowledge and its relation to other branches of knowledge were treated under philosophy of science.

4. A genuine scientific knowledge is characterised by systematicness, universality and objectivity among others.

5. The scientific method makes use of both inductive and deductive methods of reasoning.

6.0 TUTOR-MARKED ASSIGNMENT

1. Outline 5 characteristics common to philosophy and science.
2. Write short notes on
(a) falsifiability principle
(b)paradigm conservation
(c) Inductive reasoning

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UNIT 4 MAN AND HIS ORIGIN

Thus Please note: This unit has been adapted from:

Nwagbo, C. R. (2000) 'The origin and Nature of man' in: Ezekwesili, N. O., P.O. Ubachukwu and C. R. Nwagbo (ed.) Introduction to natural sciences, Newcrest publishers, Onitsha.

CONTENTS

1.0 INTRODUCTION

In the last unit, unit 3, we discussed the nature and scope of philosophy of science. In unit 2, we discussed the social implications of technological development. From that discussion, we found out that some of the inventions of man are harmful to him and to his environment. This fact gave rise to the need to guide and direct scientists in their activities. Thus, in unit 3, we discovered that philosophy tries to provide that guidance and direction needed by scientists. It does this through the systematic study of scientific methods, concepts and presuppositions. It identifies where there may be pitfalls and enables science to sidetrack those pitfalls. Philosophy does all this for the good of man and that is why science is said to be homocentric or man-centered.

In this unit, we are going to discuss the origin of man. We said that philosophy and science are working for the good of mankind. The next question to ask is, 'How did this man originate'? How did he come into this world? These are the kinds of question this unit will try to answer.

After studying this unit, it is expected that you would have achieved the objectives listed below.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. Discuss the various views on the origin of man.
2. Describe how hominids originated.
3. Write short notes on the factors of human evolution.
4. Discuss briefly the diversification of recent humans.

3.1 Various views on the origin of man

You may be aware that there are two main views about the origin of man. They are the religious view and the scientific view. These two will be discussed one after the other.

3.1.1 The religious view

The religious view is upheld by the creationists. Man, according to them, is created by God and in God's image. This view is also upheld by the African traditionalists.

God is variously called Allah, Chukwu, Olodumar e, etc. The most popular accounts of the origin of man are found in the doctrines of various religions. For instance, the Christian account of man's origin can be found in chapters 1 and 2 of the Book of Genesis in the Holy Bible.
We shall now discuss the scientific view.

3.1.2 The scientific view

It may interest you to know that this view is held by the evolutionists - people who believe in the theory of evolution. You may recall that we discussed this theory in module 1, unit 3.

The theory of evolution developed from the perspective of science states that man, like all other living things (animals and plants) have evolved from simpler forms of life by a process of slow and gradual change (evolution).

Scientists in the field of paleontology, comparative anatomy, embryology, natural history, etc have provided evidence for this evolutionary account of the origin of man and other creatures from the study of fossils. Ancient animals' remains and skeletons and various plant forms spread over large areas, over a long period of time have provided evidence to support the view that all forms of life have a common origin and that each form of life has developed at certain periods in the evolution of the entirety of life forms.

Charles Darwin, as we read in module 1, unit 3, gave explicit formulation of the theory of evolution. According to the theory, all living things (animals and plants) have evolved from simpler forms through a gradual process of change. Every living thing struggles to exist. To exist, both food and favourable environment are essential. Only living things with those characteristics that enable them to feed on available food and sourvive the effects of the environment can continue its line of development or evolution to a higher form.

In the struggle for existence, no two living things (e.g. animals) are exactly alike. As a result, we find that some are better suited to e nvironment than others. If the adaptable variations, traits or characteristics are inherited, then evolution will proceed through their natural selection and the fittest will survive. That is to say, evolution involves struggle for survival and in that struggle only the fittest survives.

In the struggle for survival, man is aided by his inherent capacity for physics - psychological change, through various forms of physical, intellectual and spiritual nourishment and the transformations of his environment.

Darwin's wealth of information also made him put forward evidence that man and higher primates originated from Africa. Before then, former evolutionists believed that man originated from central Asia. At about 85 years after Darwin's proposal, ossil evidence was found to show that he was right, and that it was in the continent of Africa that the basic stock which eventually gave rise to apes as well as man as we have known
e merged.

According to evolution, man evolved from apes, consisting of the monkeys, gibbons, gorillas and chimpanzee. Among the apes, the pre-human that had tools were the Australopithecus africanus and Arubustus discovered by Raymond Dart near Kimberly in South Africa. The main ancestors of man are the Homo habilis which had small hairs with small supra orbital ridge developed neck and forehead but with jaws. Language and rudimentary culture started with them and they also introduced the use of tools.

From the Homo habilis evolved the Homo erectus discovered first in Java in 1893 and later in Perking in 1970. Its neck was more developed and this made its head not to look hanging. It had a more elongated forehead, a more developed nose than that of the Homo habilis and it fashioned dvanced tools and also controlled fire.

From the Homo erectus evolved the Homo sapiens (Neanderthal), which looked very much like the modern man. The supra orbital ridge and jawbone is much smaller than others but bigger than that of man. From the Homo *sapiens evolved the Homo sapiens sapien (modern man), The brain and* other organs were more developed because of more extensive usage. Details of these groups will be discussed subsequently, but first let's take a break.

Exercise 4.1

1. People that uphold the religious view of the origin of man and the scientific view are called (a) -------------- and b) ---------------- respectively.
2. The pre-humans that had tools were the (a) --------------------- and (b) --------------- and were discovered by (c) -------------------
3. Homo erectus was discovered first in (a) ------------------- in 1893 and later in (b) ----------- in 1970.

3.2 Origin of hominids

You may not be aware of what hominids are. Hominids constitute the zoological family to which human beings belong. The family has only a single surviving specie Homo sapiens. The first hominids emerged 5 million to 10 million years ago. That was during the Miocene period. Fossils of human-like forms discovered in Africa were about 4 million years old. Varieties of hominids were found but many had three features in common namely:

1. pedalism - ability to stand on two legs;
2. omnivorous feeding behaviour;
3. brain expansion and elaboration.

These hominids possessed the ability to be flexible and had a wide range of demands.

For instance, the first hominids that appeared were able to use the hands, survive on more than one type of food and had brains that enabled them learn how to adapt to the changing environment.

The earliest known hominids were members of the genus *Australopithecus (meaning southern ape) and they survived for 3 million* years. At least four distinct species were distinguishable: Australopithecus *afarensis, A. africanus, A. boisei and A. robustus.*

These early humans were found only in Eastern and Southern Africa. Each of these is briefly described below.

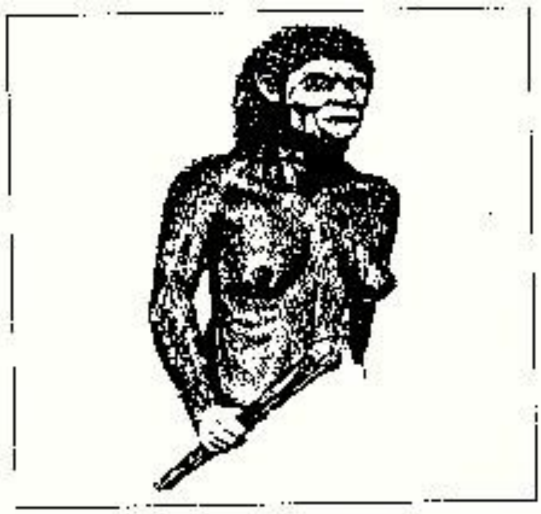

Fig. 3.2 Reconstruction of an adult female Australopithecus, a member of the genus that gave rise to our own, Homo.
Source: Raven & Johnson (1986)

Australopithecus aferensis

This genus was found in 1978 at Hader in Ethiopia by Johanson, Yves Coppers and co. They were regarded by paleontologists as the stem stock leading to later Australopithecus and Homo sapiens. Their fossils exhibited a mixture of human and ape characteristics.

The skulls were ape-like -- small with large projecting faces. ommon features included the teeth and the jaw, the skeleton, arms and legs.

A . aferensis individuals stood only 1 - 4 m tall and must have weighed only 18 - 23kg.

They were probably tree dwellers. The brain size and surface-folding pattern were each a little larger than that of a chimpanzee; hence their intelligence was a little higher.

There is no evidence to show that this group made use of tools (stones or bone) nor was there any to show group hunting or butchering of prey.

Australopithecus africanus
This was discovered in 1924 in South Africa by Raymond Dart. This fossil shared

many anatomical features with those of A. aferensis. A. africanus individuals were relatively small bipedal humans with protruding face, a slightly larger brain than that of A. aferensis. The body differed a little from that of the earliest hominids. Analysis of the hand and foot structure showed that these hominids spent time on trees probably while sleeping or feeding or perhaps for safety. The teeth looked more like those of human than ape in their sizes and shapes. The cheek teeth (molars and premolars) were flat for grinding and crushing and were set on heavily built jaws. These were probably for processing coarse abrasive food such as tubers.

Australopithecus boisei and Australopithecus robustus. These last two appeared in East Africa about 2.5-3 million years ago. Fossils of pecimens showed large flat teeth and jaws. The limb skeleton was like those of the early Australopithecus but their brains and bodies were slightly bigger. There is evidence to show that a form of A. robustus had stone tools and fingers and thumbs to use them.

Fig 3.3 Comparison of size and stature of australopiths with modern humans *Source: Starr & Taggart (1992).*

Succeeding these groups of hominids is a new type of hominid whose first member is the genus Homo to which man belongs. There are four species in this genus namely: Homo habilis, H. erectus, H. sapiens (archaic) and H. *sapiens (modern).*

1. Homo habilis (meaning handy man)

These are the earliest humans. Homo habilis superficially resembles its forebear - Australopithecus but was different in several aspects. For instance, the brain is more than half of humans' unlike that of Australopithecus that was about one-third that of humans'. The increase in brain size of H. habilis implies that they have higher intelligence than the Australopithecus. There is controversy amongst anthropologists as to the real origin of H. habilis. Some claim that they originated from A. africanus. However, this is yet to be resolved.

The trunk and limbs of H. habilis were fully adapted for upright bipedal locomotion, but the hands showed features of human hands like thumbs and finger tip bones. This suggested improved manipulative skills, yet the bones of its digits were heavy and somewhat curved permitting powerful grasping as seen in chimpanzee and gorillas. These character istics were taken by researchers to mean that H. habilis lived on the ground during the day, but retired to the trees at night to sleep.

H. habilis exhibited two characteristics of human activities: tool making and butchering of large animals. They may have butchered both large and small games, as cut marks on the bones that were excavated long time ago indicated. The use of tools and animal carcasses may have started the shift in animal adaptive patterns that were to dominate subsequent human evolution.

I hope you are not finding all this difficult to understand. But if you do, don't worry. Your tutor will further explain it to you.

Exercise 4.2

1. Hominids differ from all other mammals because their normal posture while walking is erect. True or False?
2. The two critical steps in the evolution of human beings were the evolution of bipedalism and the enlargement of the brain. True or false?
3. The first Hominids appeared about 5 million years ago in Africa. They belong to the genus ------------------.

Let's continue with our discussion. We were discussing about the four species in the genus Homo. We have talked about Homo habilis. The next one we shall discuss is Homo erectus.

2. Homo eretus

This appeared in the fossil record around 1.5 million years ago. They also had the capacity to make tools and there was evidence to show that they were more skillful than the H. habilis. They were much larger than the Australopithecus. H. *erectus underwent evolutionary change during their tenure. The face and* teeth decreased in size and massiveness and the brain increased in size. The larger brain correlated with the wide travel of H. erectus and also with refined tool making. Among the tools were carefully fashioned hand axes and scrapers. These tools were used for food preparation, including clearing of bush and cutting of meat, scrapping hides, digging and cutting wood. The first evidence of the use of fire by humans occurred at the campsite of this species in the Rift Valley of Kenya at about 1.4 million years ago. The species were replaced by our own species Homo sapiens in Africa 500,000 years ago and in Asia about 250,000 years ago.

3. Modern human beings (Homo sapiens)

There are two groups of the species:

(a) An early group known as achaic Homo sapiens consisting of the well known Neandertals (Neanderthals) among others.

(b) A later group - Homo sapiens which were physically indistinguishable from modern humans.

Neanderthals: The Neanderthals lived in Europe and Western Asia from 70,000 to about 32,000 years ago. When compared with modern people, they were powerfully built, short and stocky. Their skulls were massive with protruding faces, projecting noses and rather heavy bony ridges over the brows. They had larger brain than modern human beings probably as a result of their massive bodies. The distinctive physical features of the Neanderthals became apparent in Europe about 200,000 years ago. Similar populations of *H. sapiens were also widespread in Africa at that time.*

The tool making ability of the Neanderthals was quite high. Tools like scrappers, borers, spear points and hand axes were made. They lived in hut-like structures or in caves; took care of their injured or sick and buried their dead. They often placed food and weapons and perhaps flowers beside the dead bodies thus indicating their strong belief in life after death. They also made simple body ornaments. Both the burial of the dead and the making of ornaments indicated growing consciousness, socialization and even spirituality. These acts went further to indicate thought processes that are characteristics of modern H. sapiens - Cro-Magnons.

4. Cro-Magnons (modern Homo sapiens)
These were a more modern set of people that replaced the Neanderthals about 34,000 years ago. This replacement was sudden and took place all over Europe.
Some evidence pointed to the fact that the Cro-Magnons came from Africa where fossils of essentially modern aspects were found in southern Africa and Ethiopia.

The Cro-Magnons made and used sophisticated tools. A wide variety of tools were made from bones, ivory, and antler — materials that had not been used earlier.

They were hunters who killed game with complex evidence from their social organization showed that they might have been the first to have had full modern language capabilities. They showed creative abilities and made ritual paintings in caves. The period then was cooler than the present and thus favoured the growth of grasslands, tundra and
coniferous forests that inhibited larger herds of grazing animals across
Europe.

Human beings of modern appearance later spread across Siberia to the New World, which they reached at least 12,000 to 13,000 years ago. The period was warmer and as people spread throughout the world, a large number of animals and plants became extinct due to hunting activities - a process that has been accelerated only recently. By the end of the Pleistocene Epoch, about 10,000 years ago, there were only about 10 million people in the entire world. When this is compared with the world population today, one would understand more clearly the reason for the increased human pressure on world ecosystem.

Let's take another break.

Exercise 4.3

1. The first evidence of the use of fire by humans occurred at the campsite of (a) -------- species in the Rift Valley of Kenya at about (b) ---------------- years ago.
2. Which species started indicating a strong belief in life after death? -----------------
3. Which species were the first to fully have modern language capabilities? --------------

That was a nice break. Our next discussion will be on the factors of human evolution.

3.3 Factors of human evolution

There are speculations that man arose from the australopithecine-like ancestors.

The origin of the human stock from progressive dryopithecene apes probably occurred in late tertiary times, for man is essentially a pleistocene animal. Man evolved during the pleistocene period and was differentiated from his primate relatives through perfection of details.

The evolutionary development of man from an ape-like primate was marked by four important factors, namely:
1. the growth and elaboration of the brain;
2. the perfection of erect posture;
3. a slowing down of postnatal development; and
4. the growth in human population.

These four factors of human evolution will be considered.
1. The growth and elaboration of the brain

Man has been a thinking animal in the course of his evolution. Structurally and physically, man is inferior to many of the larger animals that share his environment but has distinguished himself from them because of his superior intelligence. Man has achieved great success in adjusting himself to changes in the environment and in overcoming his enemies as a result of this superior intelligence. This is attributed to the size of the brain in relation to other primates. For instance, the largest of modern apes, the gorilla, has a brain case with a capacity of about 500 to 600 cubic centimeters. In the most primitive man, of Pleistocene age, the cranial capacity was about 900 cubic centimeters whereas in late Pleistocene and recent man, the figure

has
ranged from a minimum of about 1,200 to a maximum of over 2000 cubic centimeters. The size of the brain is a rough index to mental development. Thus as the brain gets larger over time, the intelligence of man increased. As evolutionary trend progresses, the braincase gets increasingly larger when compared with other parts of the skull. It was also noted that evelopment of the human brain manifested in growth in the frontal region. Thus the cranium has bulged in front to give men of Pleistocene and recent times a high, broad forehead. Consequently, the face has become increasingly vertical and the jaws proportionately short and small. These features led to changes in the shape of the bones containing the teeth from a long U-shaped arch in the ancestral type to a short parabolic curve in the more modern man.

Fig 3.4 Reconstruction of the skull of Homo erectus and Homo sapiens showing comparative features

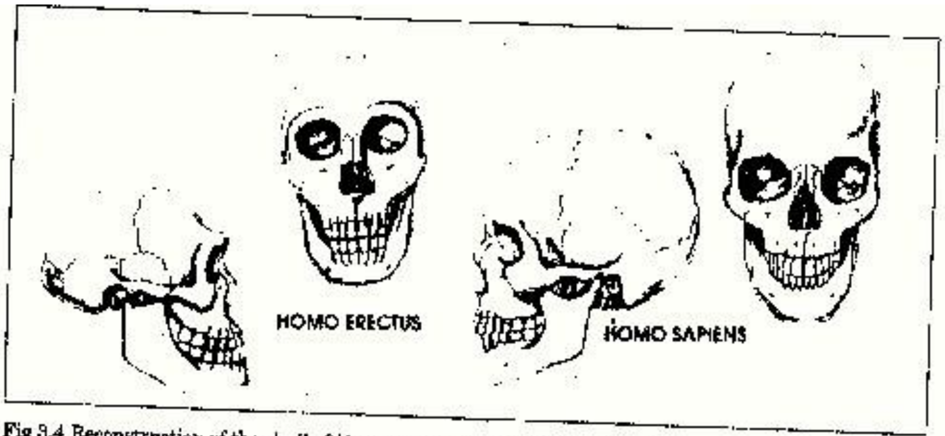

Fig 3.4 Reconstruction of the skull of Homo erectus and Homo sapiens showing comparative features
Sources: Raven and Johnson (1986)

Apart from the physical changes brought about in the skull and jaws as a result of the increase in the size of the brain, other less tangible changes occurred as a result of the growing intelligence of man. For instance, growth in the intellect has resulted in the ability to communicate ideas by facial gestures and especially by speech. It also made man to become a tool-making animal at an early stage in his history. The manufacture and use of tools like speech has helped man to progress beyond the status of a mere forest-living animal that competed with other animals in making a living from the environment.

2. The development of the upright posture
Man has, by this development, distinguished himself from most other
primates which are either tree or ground living animals that walk and run on all fours as baboons and gorillas do. By this upright posture, the hands have been freed from being used for locomotion and have been made available for handling things, for defence and for manufacturing tools. The ability to pick

up things and examine them has made all higher primates especially man to be curious. This curiosity leads to experimentation through which more knowledge is acquired.

Do you know that the upright posture of man also led to changes in the shape of the spinal column? In the ancestors of man eg. ape, the backbone between the skull and the pelvis formed a simple curve, so that the body leaned forward from the hips, and the head was thrust forward from the shoulders. In man, the vertebrae are aligned in a complex, S-shaped flexure that throws the body and the neck into an upright position, with the head balanced on top of the neck. This posture is possible because the forelimbs are freed from locomotive function and the entire body from head to heels is aligned along a vertical axis in line with the force of gravity. Furthermore, the upright posture and the development of bipedal locomotion led to the development of long legs for fast running on the ground and arms that are shorter than those of other higher primates that walk on four legs.

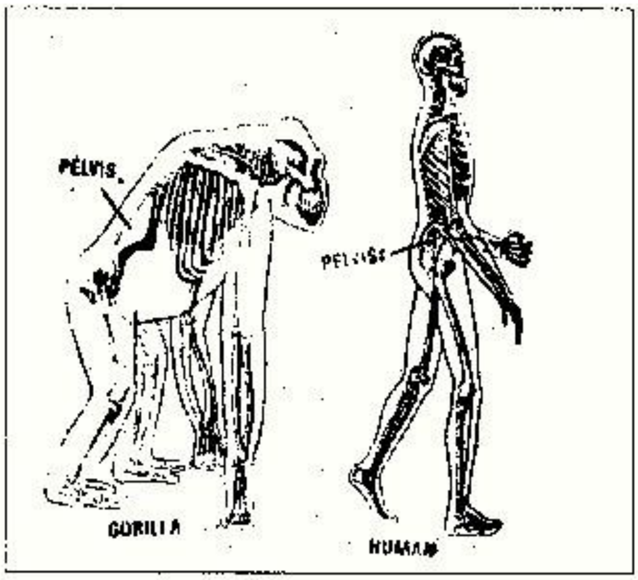

Fig 3.5 Comparison between the skeleton of an ape and that of a human being, showing details of the pelvis and other important structures
Source: Raven and Johnson (1986)

Exercise 4.4

1. The evolutionary development of man from an ape like primate is marked by four important factors. These are (a) ----------------, (b) -------- ----------, (c) ------------------ and (d) ---------------.
2. As the evolutionary trend progresses, the ------------------- gets increasingly larger when compared with other parts of the skull.
3. In man, (a) -------------- and (b) ------------ led to the development of long

legs for fast running on the ground and arms that are shorter than those of other higher primates that walk on four legs.

We have taken a good break and we shall continue with the factors of human evolution.
The next factor to be considered is the slowing down of postnatal development.

3. The slowing down of postnatal development
The increase in the process of growing up is another factor in the evolution of man. A gorilla matures at age 10 whereas it takes a man twice that age to reach his full stature and powers. The long period of maturity implies that young human beings spend longer time under the care of their parents than other primates. This in turn leads to perfection of family life. As man grows up within this period, his intelligence increases and his ability for moaking also develops. All this puts man in a better stead than other animals.

4. The growth of human population
Within the last few thousand years, man has increased tremendously population wise.

The progression from family to clan to tribe to nation and continents was in quick succession as the years rolled by. This trend of human evolution has depended on the social behaviour of man first developed within the family group. It has been made possible by man's capacity for co-operation and by his realisation of the necessity for restraint in his behaviour. Knowledge of the growth in human population is important for modern world as well as world of the future. Man's social relationship together with other intangible physical aspects of evolution has made him unique among the other primates, has made him a being with a culture.

3.4 A recap of the evolution of man

The nature of man makes the study of its evolution controversial. A number of studies have been carried out on the evolution of man but there is still a lot to learn. Because most of these studies had to be carried out on fossils and fossils are not common, great care had been taken to examine the fossil man. Although there are imperfections and disagreements among different authorities that worked on that field of knowledge, the general outline of the evolution of man is fairly well defined.

Man, as stated earlier, arose from australopithecine-like ancestors. The first true man, the pithecanthropids evolved by early to middle Pleistocene period. These men were known from fossils found in Java and in China near Peking. The Javanese fossils were designated as Sinanthropus. Because these early men were essentially the same, they were placed within a single genus Homo and belonged to the species erectus (Homo erectus).

The early men were definitely more primitive than modern men. Their cranial capacity was smaller (900 to 1000 cubic centimeters as opposed to an average of 1,500 for the modern man). Other differentiating features include low cranium, heavy eyebrows, strong and large jaws that projected farther forward than the jaws of modern man and a receding chin. The teeth were like those of humans but heavier with the canine longer than the other teeth. These early men through their skeletal evidence were ground-living and erect-walking primates.

The pithecanthropoids were probably forest men that traveled in small family groups and sought shelter in caves. They knew how to use fire and utilise simple tools and weapons of stone and wood. They had a lot of advantages over other animals around them and had made great strides along the path leading to modern men. The pithecanthropoids were not known in Europe but some fossil fragments were seen in the region during the first half of the Pleistocene period.

In the late Pleistocene times, the Neanderthal men appeared. A considerable number of their skulls and skeletons were found in Europe, Asia and Africa as earlier stated.

They were of the Stone Age - the period in the development of human culture. One of the last of the Old Stone Age men was Cro-Magnon man of Europe. He was a modern man belonging to the species Homo sapiens. The essential features of this species have previously been discussed. The Cro-Magnon man has displaced and finally exterminated the Neanderthal man in the old world.

At the close of the Pleistocene period and during the sub-recent times, various men spread over most of the earth's surface. They spread to North and South America from Asia, others spread from Asia to East Indies and Pacific Islands. As men became proficient with tools, they learnt to make clothes and dwelling places. They were able to spread out to other places and learned to live comfortably even in Polar Regions.

Man is a very restless being and the perfection in rapid and easy methods of transportation and communication has made him even more restless. Consequently the races of men have been mixing with each other thou sands of years and this is further accelerated in modern times. Thus,
although the racial stock remains distinct, the integration among the different races increases as the years progress.

Exercise 4.5

1. A gorilla matures at the age of -------------
2. The cranial capacity of early men were (a) ----------------- to
--)----------- as opposed to an average of (c) ---------- for the modern man.

The last topic we shall be discussing is the diversification of recent humans.

3.5 Diversification of recent humans

The earliest humans of modern appearance, the Cro-Magnons, unlike their predecessors have developed greater ability to adapt to various environmental conditions.

Anatomically, they differed from the Neanderthal because they have higher and rounder braincase, no brow ridge, athletic body (particularly the limbs). As people gradually became less nomadic, adopted agriculture and became urbanised during the past 10,000 to 15,000 years, physical changes continue.

With the appearance of modern humans, elaborate technology emerged based primarily on fabrication of tools from varied materials and through more sophisticated techniques. Arts appeared in the form of sculpture, painting and engraving and this suggested a major development in symbolic communication through the use of art (a form of abstraction). People lived and associated more, and human burials became more common and often included elaborate offerings.

These cultural manifestations led to massive migration and general population explosion. Before then, people were nomadic hunters and gatherers who followed games and collected diverse seasonally available plants. Further cultural evolution of humans was marked by the transition from hunters and gatherers to agriculturalists. Agricultural revolution took place about 10,000 years ago. People began planting seeds, harvesting crops and domesticating animals. These agricultur al practices improved with time and more varieties of crops and animals were planted and reared respectively. The agricultural revolution greatly modified the environment and had far reaching consequences, including stable communities at specific sites, career specialization, writing, written number and population expansion.

It is however expected that a species as numerous and widely dispersed as H. sapiens should have genetic differences among the various populations and the product of different environmental pressures must have led to the formation of such species - races. Linnaeus recognised long ago the basic unity of living humanity when he placed all people in our single species - H. *sapiens. We now understand better that this biological unity came about as a* result of common evolutionary origin.

4.0 CONCLUSION

In this unit we have discussed the origin of man. Two popular accounts of the origin of man were discussed and these were the creationist and the evolutionist accounts. The evolutionist view or account was then discussed in details.

5.0 SUMMARY

The main points in this unit are:

1. Two views on the origin of man are the religious or creationist view and the scientific or the evolutionist view.
2. The first Hominids emerged 5 to 10 million years ago.
3. The earliest known hominids were the members of the genus *Australopithecus*
4. They were succeeded by the early Homo - H. habilis. These were omnivorous and had larger brain. These were the first known representative of the human lineage.
They used simple tools and showed some social development.
5. Later on came the Homo erectus, which had larger brain than their predecessors.
They lived by gathering, scavenging and sometimes hunting. They were the first humans to use fire and to live at times in caves.
6. These were replaced by our species, Homo sapiens about 500,000 years ago in Africa and about 250,000 years ago in Asia. Full human forms that is Homo sapien sapiens evolved about 40,000 years ago and formed societies that increased greatly in complexity especially with the development of agriculture.

6.0 TUTOR—MARKED ASSIGNMENT

1. Write short notes on (a) Homo Habilis (b) Cro-Magnons
2. Discuss the growth and elaboration of the brain as a factor in human evolution.

7.0 REFERENCES AND FURTHER READING

This unit has been adapted from

Nwagbo, C.R (2001) 'The Origin and Nature of Man' n: Ezekwesili, N.O,

P.O. Ubachukwu and C. R. Nwagbo (ed.) Introduction to natural sciences, Newcrest Publishers, Onitsha.

UNIT 5 THE NATURE OF MAN

Please note: The materials in this unit have been adapted from; Nwala, T. U. (1997) 'Man: His Origin and Nature' in: Nwala, T. U. (ed.) *History and Philosophy of Science, Niger Books and Publishing Co. Ltd,* Nsukka.

CONTENTS

1.0 INTRODUCTION

In this unit, we are going to discuss the nature of man- his cha acteristics and innate qualities. In the last unit, unit 4, we discussed the origin of man. There you were taught that there were two views on the origin of man. These are the religious and the scientific views. Deciding which view to believe is a matter of personal conviction.

Having discussed origination, we will now, in this unit, study the nature of man. This unit will help answer the question, 'What are the characteristics and innate qualities of man?' After studying this unit, you are expected to have achieved the objectives listed below.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. Describe man's nature vividly.
2. Explain what chromosomes are.
3. Indicate with an example how sex is determined.
4. Discuss how twins are produced and how the environment modifies inherited traits.

3.0 MAN'S NATURE

You are aware that man is a living being. i.e. he has life (just like plants and other animals). He grows and dies and has the principles of growth and death (or the things that make one grow and die) inbuilt in him.

Man eats, breathes, moves, etc. These characteristics he has in common with other animals. In addition, man reasons, communicates with his fellow men through speech and other forms of communication and produces the means of his subsistence in a manner far beyond what any other animal can do. Man has attained the highest level of cultural and intellectual development unthinkable for any other living being. These have enabled man to become master of the created beings in the universe.

Thus, what distinguishes man and places him high above all other earthly and visible creatures is his infinite capacity to create. The abundance of his creative capacity is seen in the massive and profound systems of thought art, technology, morals, religion, law, society, etc, which he has created. It is also seen in the wonders of the interplanetary intercourse he has initiated, the invisible forms of communication of the computer age, his destructive capacity, i.e., ability to destroy himself, all forms of life and all that man has created, within a split second.

All living beings, including man, are composed of cells, i.e., the basic unit of life. Man is made up of the most complex type of cell structure. There are six kinds of specialized cells in man. These are:

(a) Skin cells called epithelium tissues

These tissues cover the outside of the body and cover those parts that communicate with the outside. These are the mouth, throat, stomach, the rest of the digestive canal, the nose, windpipe, the lungs. Epithelium tissues are also found in the liver and the kidney. The liver is the great factory of the body, where dissolved substances from the food are prepared for ‘burning’ to produce energy or for building new cells.

The kidney, on its part, is a filtering plant where waste substances are filtered out of the blood.

(b) Bone or connective tissues cells

These include all supportive structures of the body including the bones and cartilages.

(c) Muscle cells

These are the fleshy parts of the body which expand and contract and thereby enable other parts of the body to function or move.

(d) Blood cells.

(e) Nervous tissue cells.

(f) Reproductive cells.

The nerves are like the telephone wires of the body, carrying messages from one part to another. One group of nerves carries messages from the brain to the muscles. Another carries messages from the other parts of the body to the brain. The brain, together with the spinal cord, form teelephone exchange. Each nerve cell has a central body with very long filaments reaching out from it, some to the particular area it serves and some to meet the filaments of neighbouring nerve cells.

Let's take a break.

Exercise 5.1

1. Outline four characteristics which man has in common with other animals.
2. Mention the six kinds of specialized cells in man.

The next topic we shall discuss is the reproductive cell.

3.1 Reproductive cell

This is the cell responsible for the birth of new organisms. It is called the seed or egg of reproduction. The father's cell is called the spermatozoa (or sperm) which fuses with the mother's cell called the egg, to produce a new organism or life.

It was Dr William Harvey who showed that every living thing comes from the union of the sperm and egg. The truth about whether human beings and other creatures were created as they are today and whether man has a special place in the scheme of things depends on the truth of the theory of evolution. It was Anton Van Leeuwenhoe (1632 - 1723), a Dutch naturalist, who made 'a detailed study of the spermatozoa and showed that at the meeting of the male sperm and the female egg, if fertilisation takes place, then a new life starts'. The hitting of the 'spot' or nucleus of the ovum of the mother by the nucleus of the father is the vital stage in the starting of a new life.

Embryologists are the scientists who study the development of life from the point of fertilization. They have shown that from the point of fertilization, the development of the individual creature appears to resemble that of its ancestors in the long course of evolution.

The embryo of man is first a single cell, like a protozon, then a cluster of cells together, like some of the little water creatures, then a folded-in ball, like a jelly - fish, and so on, until a backbone appears and four limbs borne out well- developed tail. It never looks like an actual fish, but goes through a stage of looking like the embryo of a fish, and another stage of looking like the embryo of a quadriped.

3.2 Chromosomes (carriers of hereditary materials)

There is a group of 46 chromosomes within the nucleus of each reproductive cell.

Each chromosome contains several genes. Genes are the determinants of heredity - the process by which mental or physical qualities, abilities, or illnesses pass from parents to children in the cells of the body.

The genes are composed of what is called deoxyribonucleic acid or DNA. DNA is the protein substance, which controls the form and function of the cells and tissues of each particular individual so that they harmonize with his hereditary pattern. DNA has giant molecules with characteristics, which enable them to perform their functions.

DNA is thus responsible for transmitting hereditary characteristics and for the building of proteins.

DNA molecules in the chromosomes function like a blueprint with every cell in the body having a copy. This enables the regulation of the function of cells so that each performs its function in co-operation with the rest. At conception, the father's sex cell is united with the mother's sex cell to form one single cell.

Cells multiply into two in a continuous pattern. Thus, one multiplies intotwo, two into four and so on. This makes growth possible. Each group cell makes possible the correct development of each part of the body.

In order for the chromosomes to control the form and function of the body, every cell formed must have an exact copy of the chromosomes contained in the original cell. The 46 chromosomes are arranged in pairs of 23. Each pair contains one chromosome from the father and one from the mother, each being identical with its original. Thus, every cell in the body contains 23 chromosomes, which carry over the hereditary influence of the father and which are paired with 23 chromosomes, which carry the hereditary influence of the mother. Consequently, one's father and mother are of equal importance in their influence on what kind of person a man is.

The other major influence on a person's character is the society and its culture.

Since each cell contains 46 chromosomes, it is expected that the union of the father's sex cell and the mother's sex cell would yield one cell with 46 x 2, i.e. 92 chromosomes. But this is never the case. Before the cells are available for initiating a new life, one member of each pair is eliminated from the cell. The elimination is random. It could be the chromosome that came from the parent's father or mother many years ago when the parent was conceived.

Owing to this chance eliminationn, no two cells produced by indi vidual would be identical and have the same composition of chromosomes when they become mature. This chance selection operates in preparing both the male and female sex cells for conception.

It is estimated that there are 281 billion different combinations chromosomes possible when the sex cells from husband and wife unite at the time of conception.

Thus, no two brothers and sisters in the same family are exactly alike with the exception of identical twins.

I hope the material is not too difficult to understand. You may test yourself by doing the following exercise.

Exercise 5.2

1. The cell responsible for the birth of new organisms is called (a) -----------
--- and it has (b) --------------------- number of chromosomes.
2. The father's reproductive or sex cell is called (a) ------------ while the
mother's cell is called (b) -------------.
3. Why are brothers and sisters from the same family never exactly alike?

We have discussed the reproductive cell and the chromosomes. Let's now go to sex determination.

3.3 Sex determination

Are you a male or female? How do you think your sex was determined? Read on and you will get the answer.

One chromosome in each pair of chromosomes is sex chromosome while the rest of the 22 cells are autosomes. In a female, this pair chromosomes are alike and may be designed as x and x chromosomes (i.e, xx). In the case of male they are different, designed as x and y (i.e.-y). At conception one pair is eliminated. In the case of the female, the one that - is retained will always be x while in the case of the male it could be x y. If X female unites with X male (xx) then a girl results. If x female unites with male (x y) then a boy results. So the sex of a child from this union is a matter of chance, ut it is the father's sex cell, which determines the sex of the child. This is illustrated in figure 3.6.

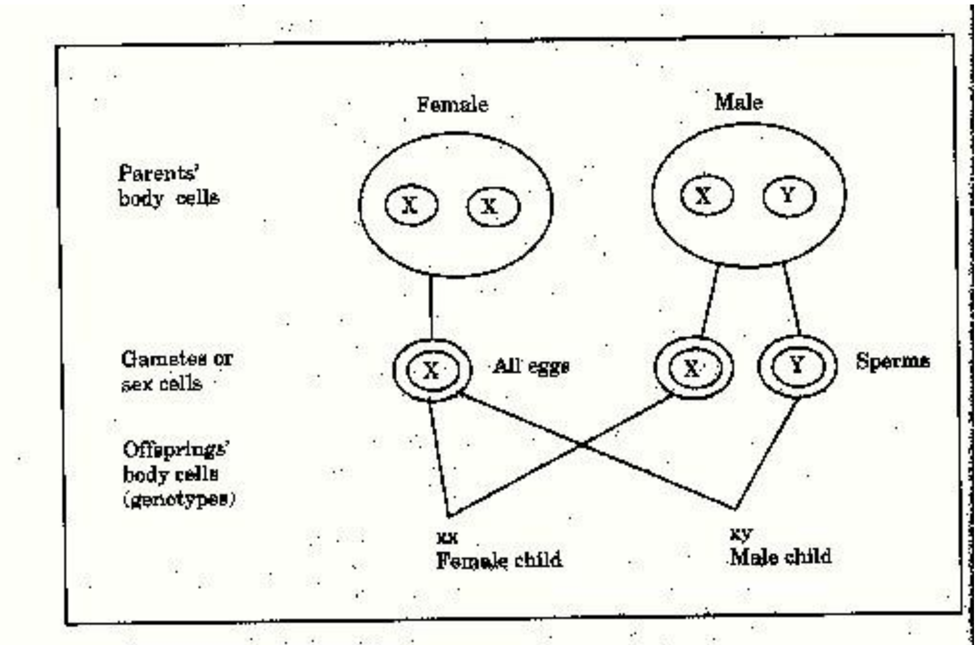

Fig. 3.6 Source: Roberts (1971)

This shows that it is the man who determines the sex of the child. The woman always produces x - type gametes whereas the man produces the equal numbers of x- and y- type gametes. If an x-type sperm fuses with the egg, the child is female xx whereas if y- type sperm fuses with the egg, the child is male xy. Our culture tends to criticize a woman who produces no sons. It is clear this criticism I totally unjustified as it is the man who in the main determines the sex of the child.

3.4 Twins

Twins? Do you know how they are determined? This material will show you. Twins may be fraternal or identical. In the case of fraternal twins, it means that the mother released two female sex cells at one time for the particular month in which conception occurred, each being joined or fertilized by separate male sex cell. And so two lives were initiated at the same time, both each having a single placenta. Fraternal twins are no closer to each other than any two brothers or sisters. In the case of identical twins, the single fertilized egg divided at the stage of the blastocyst and then two individuals developed in a single placenta. Identical twins are mirror images of each other. Hereditary characteristics of fraternal offspring's are different; they may be both boys or both girls or one boy, one girl. But hereditary characteristics of identical twins are similar. They are always the same sex,

both boys or both girls. Fraternal twins make up 75% of all twin pregnancies while identical ones constitute 25%.

3.5 Heredity and environment

Most of a child's basic physical features are inherited. These include colour of hair, shape of the face, general body build, colour of the eyes including certain preferences and abilities.

However, environment and societal culture do modify these traits. Before birth, the environment and home surroundings have the influence. And from childhood, the home, the school, parents, peers, church, etc, continue to modify the character and personality of the developing child. Thus, heredity merely provides the foundation on which environment;
society, culture and the mature decisions and choice of the offspring finally determine his personality.

Exercise 5.3

1. The female and male sex chromosomes can be designated as (a) ----------- and (b) ------------ respectively.
2. Which sex cell determines the sex of the child?
3. Two types of twins are (a) ------------ and (b) --------------
4. Characteristics which a child may inherit from the parents include (a) --------------- (b) -------------------- and (c) ---------------------.

4.0 CONCLUSION

In this unit we have discussed the general characteristic of man. The unit has given us information on the cell responsible for the birth of new organisms, the material responsible for whatever we inherit from our parents. It has also given us information on how sex is determined, how twins are produced and finally the interrelationship between the environment and the characters we inherit from our parents.

5.0 SUMMARY

The main points in this unit are:

1. What distinguishes man and places him high above all other earthly and visible creatures is his infinite capacity to create.
2. Six kinds of specialised cells in man which are
(a) skin cells called epithelium tissues
(b) bone or connective tissue cells
(c) muscle cells
(d) blood cells
(d) nervous tissue cells
(f) reproductive cells
3. Reproductive cell which is responsible for the birth of new organisms and it has 46 chromosomes.
4. The chromosomes which are the carriers of the hereditary materials. The

hereditary materials or determinants of heredity are called the genes.
5. The father's sex cell as it determines the sex of the child
6. Twins that may be fraternal or identical
7. Inherited traits that may be modified by the environment and societal culture.

6.0 TUTOR-MARKED ASSIGNMENT

1. Write short notes on the following
(a) Reproductive cell (b) Chromosomes (c) Sex determination

7.0 REFERENCES AND FURTHER READING

The materials in this unit have been adapted from:

Nwala, T. U. (1997) 'Man: His origin and Nature' in: Nwala, T. U. (ed.) *History and philosophy of science, Niger Books and Publishing Co. Ltd,* Nsukka.

Roberts, M.B. V. (1971) Biology - A Functional Approach. Thomas Nelson and Sons Ltd, Middlesex.

MODULE 4

UNIT 1 MAN AND HIS COSMIC ENVIRONMENT

Please note: The materials in this unit have been adapted from Nwala, T. U. (1997) 'Man and his cosmic environment' in: Nwala, T. U. (ed.) *History and Philosophy of Science, Niger Books and Publishing Co. Ltd, Nsukka*

CONTENTS

1.0 INTRODUCTION

In module 3, unit 5, where we discussed the nature of man, we mentioned that man reasons, and that what distinguishes him and places him high above all other earthly and visible creatures is his infinite capacity to create. This creative ability is seen in the massive and profound systems of thought, art, technology etc. which he has created. It can also be seen in the wonders of interplanetary intercourse he has initiated. This last fact is what this unit will explain fully among other things. It will explain to us the between man and the entire universe surrounding him. After studying this unit, you are expected to have achieved the objectives listed below.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Explain the cosmos and the cosmic environment

2. Discuss about the rotation and revolution of the earth
3. Identify the components of the solar system and its relations to Galaxies.
4. Discuss measurement of distance in space.

3.0 Man and his cosmic environment

3.1 The cosmos

It may interest you to know that the cosmos is the world or the universe, regarded as one orderly system with a structure, whose parts are linked together in an orderly manner. Both philosophy and astronomy study the structure of the universe.

Cosmology is the area of study (in both disciplines) concerned with the structure of the universe.

Cosmology therefore is,

1. The branch of philosophy, which studies the structure of the universe. It deals with its origin and general structure, its parts, elements, laws. It focuses on such characteristics of the universe as space, time, causality and freedom.
2. Also the branch of astronomy, which deals with the general structure and evolution of the universe. It studies the composition extent and origins of the universe and its various components.

The branch of philosophy which deals with the evolution and origin of the universe is called cosmogony.

3.2 The cosmic environment

It may also interest you to know that the cosmic environment is the entire universe in which we live, especially those of its aspects or parts that are connected with human life, survival and interests. The structure of the cosmos as revealed by astronomy includes the earth (and other planets), their satellites, the sun and other stars, the groups of stars called Galaxies, etc. Man depends on air, heat, water and other natural resources from the entire cosmos, particularly his own earth and the sun for survival.

Let's take a break. You may wish to test yourself with the following exercise.

Exercise 1.0

1. Differentiate between cosmology and cosmogony.
2. The structure of the cosmos as revealed by astronomy includes

(a) -------------, (b) ---------------------, (c) -----------------and (d)-------------

The topic of our next discussion is the earth. We will try to find out what the nature of the earth is.

3.3 The earth

The earth on which man lives is a planet or satellite of the sun. We do not as yet have evidence of human habitation in any other celestial body. The earth is one of the nine planets, which rotate on their axis and revolve around the sun. The earth is spherical in shape and moves around the sun in space.

1. Rotation of the earth

It takes the earth approximately 24 hours (around the equator) to rotate or turn on its axis. This rotation gives rise to day and night as the earth faces or turns away from the sun. The earth derives its light from the sun. When it faces the sun it is day for that part of the earth, when it turns away, it is night for that part so affected. Does this remind you of anything? You may recall that we discussed about this in module 1, unit 4. From the explanation above, it is easy to deduce that when it is day in one part of the earth, it will be night in another part.

2. Revolution of the earth

It takes the earth about 365 days (i.e. one year) to complete one revolution around the sun. The sun is at the centre around which the earth and all the other planets (or satellitesof the sun) revolve. You may recall that iscussed about this in module 2, unit 2 The earth is 93 million miles away from the sun. It is 4,000 iles in radius. Because of its spherical shape and its flattered shape around the poles, its diameter is 13 miles shorter at the poles than the equatorial radius.
The equatorial diameter is 7,9261/2 miles, while the polar diameter is 7,900 miles.

The earth has a surface area of 196,550,000 square miles. Of 55,500,000 sq. mile surface is land, the rest is water. Do you know that the greatest known height is Mount Everest, which is 29,028 feet high? While the greatest known oceanic depth is the swire deep, which is 34,430 ft below sea level. Mount Everest is in South Asia between Nepal and Tibet.

3. Spheres of the earth

The most important spheres of the earth are the following:

(a) The biosphere: This is the part of the earth's crust, water and atmosphere where living organisms can subsist.

(b) The atmosphere: This is the gaseous envelope (or air) surrounding the earth. It is of mixed gases consisting of: Nitrogen (75,54.9) Oxygen (23
-14 %) Argon (1.2%) and Carbon Dioxide (0.05%).

The three sub-layers of the atmosphere are:

(i) The troposphere - the layer from the sea level to about 5 miles high at the North Pole and 11 miles at the equator.

(ii) The stratosphere - up to 50 miles. Within the stratosphere is the region of gas called ozone (a special form of oxygen). The ozone gas is being continually formed and destroyed due to radiation from the sun.

Ozone is a powerful oxidising agent used in water purification. The ozone in the upper atmosphere absorbs the most energetic ultra-violet radiation from the sun.

Radiation is dangerous to life, so the ozone layer in the atmosphere is a protective layer important for the sustenance of life on earth.

(iii) The ionosphere - from 50 miles t0 300 miles. Above this, the gases become very rare. The ionosphere has two sub-layers - the mesosphere and the thermosphere.

The various layers of the atmosphere differ mainly in their temperature. For the troposphere, temperature drops to about 30F for every 100 feet height. For strato sphere, it rises to 900 F in the ozone layer and falls to about 1000 F at the top of the layer. For the ionosphere, it rises to about 4,0000 F at the 300 miles up.

You may wish to test yourself with the following exercise.

Exercise 1.1

1. The earth is a satellite of (a) --------------------. It takes it approximately (b) ------------ hours to rotate on its axis while it takes it about (c) -------- ---- days to complete one revolution around the sun.
2. The three sub-layers of the atmosphere are (a) ------------- (b) ------------ (c) -----------

3.4 The solar system

You may have learnt about the composition of the solar system elsewhere, but read on.

The sun and the nine planets that revolve around it and their satellites, plus the minor planes called asteriods make up the solar system. The system is held together by the gravitational force of the sun. Can you remember the unit where we came across gravitational force before? You are correct if your answer is module 1, unit 4. The sun is a star; one of the innumerable stars in the universe. The nine planets which revolve around the sun in different orbits are (according to their proximity to the sun):

1. Mercur y (no satellite) — smallest planet.
2. Venus (no satellite) — most brilliant planet in the solar system.
3. Earth (one satellite or moon)
4. Mars (2 satellites)

5. Jupiter (12 satellites) — largest planet in the solar system.
6. Saturn (10 satellites) — second largest planet
7. Uranus (5 satellites)
8. Neptune (2 satellites)
9. Pluto — the outermost planet in the entire solar system.

In addition, there are 2,000 minor planets called asteroids. Each planet has its own moon(s) or satellite(s) which rotate(s) around it. The earth has one. Mars has two moons (phobos and deimos). Neptune has two. The planets with large numbers of satellites are Saturn and Jupiter. Saturn has 10 while Jupiter has 12. Uranus has 5.
It is believed that the planets were formed from the sun, from which they broke off as gaseous elements and gradually became solid bodies in space. The sun itself is in motion in space and at the same time the planets rotate around it. The planets and their satellites are held in their relative positions around the sun by the gravitational power of the sun. This magnetic power holds them together as a common system. The powerful energy from the sun, called solar energy is responsible for all the energy and the light in the whole solar system.

3.5 Galaxies

The sun, plus its nine planets and their satellites form the solar system. The solar system along with other stars and their satellites form a collection or group called the Galaxy. Galaxies are a large system of stars held together by mutual gravitation and isolated by similar systems by vast regions of space. Precisely, our Galaxy is called the Milky Way Galaxy. The Milky Way Galaxy contains about 100,000 million stars. There are several other galaxies (or nebulae) with different shapes in the universe. The origin of the universe and it galaxies is unknown.

3.6 Measurement of distance in space

It may interest you to know that the distances between celestial objects, especially stars and galaxies, are so great that we can't express them with ordinary numerical notation. The unit of measurement which is used to measure such astronomical distances is called a light year. A light year is therefore, a unit of measurement of distant objects such as stellar (i.e. star) distances. A light year is the distance traversed by light in one mean solar year. One light year is about 5,880,000,000,000 miles (abbreviated Ityr). So some distances are so great that they look clumsy when written in plain figures.

Hence, the use of lt -year (or light year) a unit. One set of such stellar objects is Quasirs or Black Holes which are powerful sources of radio energy. Hence, they are called Quasir-Stellar Radio Source. Some are as far as 14 billion light years.

It's time to do some exercises. Try your best to get all the answers correct.

Exercise 1.2

1. The nine planets according to their proximity to the sun are (a) ----------- (b) ---------- (c) ------------- (d) ------------ (e) ------------- (f) ----------- (g) ----------- (h) -------------- (i) ----------------
2. The energy from the sun is called ---------------
3. (a) Define Galaxies (b) Name our own Galaxy (c) How many stars does it contain?
4. The unit of measurement, which is used to measure astronomical distances, is called ---------

4.0 CONCLUSION

This unit has presumably been really instructive. It has given us information on the composition of the universe, the characteristics of the earth on which we live, the solar system and its components. It has also given us an idea on how distant celestial objects are to each other and why there are day and night on earth.

5.0 SUMMARY

The main points in this unit are:

1. The cosmos is the world or the entire universe regarded as one orderly system with a structure, whose parts are linked together in an orderly manner.
2. Cosmology is the area of study concerned with the structure of the universe while cosmogony deals with the evolution and origin of the universe.
3. The structure of the cosmos is made up of (a) the earth (and other planets) (b) their satellites (c) the sun and other stars (d) the groups of stars called galaxies.
4. Man depends, for his survival, on air, heat, water and other natural resources from the entire cosmos, particularly his own earth and the sun.
5. The earth takes approximately 24 hours to rotate on its axis and 365 days to complete one revolution around the sun.
6. Spheres of the earth are (a) the biosphere (b) the atmosphere The 3 sub-layers of the atmosphere are

(i) the troposphere
(ii) the stratosphere and
(iii) the thermosphere.

7. The solar system is composed of the sun and the 9 planets. Each of some of the planets have its own moon(s) or satellite(s) which rotate round it.
8. Galaxies are a large system of stars held together by mutual gravitation

and isolated by similar systems by vast regions of space.

9. Our solar system belongs to the Milky Way Galaxy, which contains 100,000 million stars.

10. The unit of measurement which is used to measure astronomical distances is called light year.

6.0 TUTOR-MARKED ASSIGNMENT

1. Write short notes on
(a) Measurement of distances in space (b) Galaxies
2. When the earth faces the sun it is day for that part of the earth, but when it turns away, it is night for the part so affected. Comment and give reasons.

7.0 REFERENCES AND FURTHER READING

Nwala, T. U. (1997) 'Man and His Cosmic Environment' in: Nwala, T. U. (ed.) History and philosophy of science, Niger Books and Publishing Co. Ltd, Nsukka.

UNIT 2 MAN AND HIS NATURAL RESOURCES

Please note: The materials in this unit have been adapted from Nwala, T. U. (1997) 'Man and his natural resources' in Nwala, T. U. (ed), *History and philosophy of science, Niger Books and Publishing Co. Ltd,* Nsukka.

CONTENTS

1.0 INTRODUCTION

This unit is a continuation of unit 1. We shall discuss the relationship between man and his environment. But emphasis here will be on how

man
utilises the material resources from his natural environment for his sustenance on earth. After studying this unit, you are expected to have achieved the objectives listed below.

2.0 OBJECTIVES

After studying this unit, you are expected to be able to:

1. Describe the types of food man needs.
2. Discuss how man produces food through agriculture, and the influence of climate, soil and vegetation.
3. Define and classify natural resources.
4. Assess the various conservation methods.

3.0 Man and his natural resources

In this unit, you will learn about the things which nature supplies man, how these things help to sustain him and how he tries to conserve them. Man's existence is sustained not only through the process of biological reproduction of his existence and his offspring, but through the utilization of the material resources from his natural environment. These include air (especially oxygen), water, food, economic resources (such as agricultural, fishing water, animal foods, etc), mineral resources (such as metal, gold, silver, iron, ore, etc), fuels (such as coal, gas, wood, etc).

The sun supplies him solar energy and light as we saw in unit 1. The plants provide him oxygen and energy through foods of various kinds. From the foods, he derives energy which enables him function physically and biologically to reproduce the cells and all the basic organs of the body. From natural resources, he gets energy and other economic resources including the things he needs for technological construction — shelter, road, bridges, electrical installations, communication and all types of industrial plants, equipment, spare parts, transportation equipment, etc, It is important to know that the process of interaction and the necessity of survival has forced man to learn to manipulate natural factors and forces to his benefit.

Man has thus learnt the science and practice of agriculture and industry, and created massive cultural, social economic, military and political structures and institutions. He has, thus, created the modern complex society. In addition, he now reaches to other distant planets and maintains non-
visible communication across continents, lands, oceans and space. In section 3.4 we shall discuss the nature of these natural resources and their various uses.

3.1 Man and his food

You may be aware that man sustains himself through food and essentials of life such as air and water. The food he eats derives from plants and animals. Some types are eaten just as they are derived from nature, for example, fruits, vegetables, and roots. Some are cooked or prepared in
different ways, for example fruits, seeds, vegetables, roots, animals etc. Some are manufactured in different sophisticated ways, e.g. cereals, sugar, oil, flour, meat, etc which are canned or turned into other forms.

Agriculture and industry have therefore become the major institutions through which man feeds himself.

3.1.1 Types of food

There are three different types of food. Generally, plants are responsible for the production of the basic food needed by both plants and animals through a process called photosynthesis which is made possible by the energy from sunlight and water (through their roots) and air (carbon dioxide) through the stomata in its leaves. Plants first convert water and air into glucose — a simpler form of sugar. This gives it potential energy.

In the process of producing glucose, plants release oxygen, which essential for man. Animals use oxygen while plants need carbon dioxide. When plants take in carbon dioxide, it releases oxygen. This interdependence between man and plants in their air consumption is called symbiosis. The earth is the only celestial body presently known to contain enough oxygen, the all-important element for the sustenance and nourishing of life.

Basic foods needed by man
It is important to know the basic types of food man needs. They include:

(a) Carbohydrates: It is the main source of energy needed by plants and animals. The three main types of carbohydrates are sugar, starch and cellulose.
(b) Fats and oil: Plants produce fats from carbohydrates.
(c) Proteins: Like carbohydrates and fats, protein contains oxygen, hydrogen and carbon.
(d) Mineral and vitamins: Minerals are important to both animals and plants. They are important constituents to human bones, teeth and body cells needed for the formation of blood, liver, muscles, etc. Three types of mineral are iron, calcium and phosphorous. Calcium is derived from cheese and milk, phosphorous from cheese and liver, iron from liver, bread, peas and cabbage.

Vitamins are essential to the enzyme system of all organisms, which enhance chemical reactions necessary for converting food into energy. Man needs an adequate and balanced proportion of these types of food for his normal growth. Hence, he needs what is called a balanced diet.

It's time to take a break. You may wish to test yourself with this exercise.

Exercise 2.0

1. Material resources from man's natural environment include (a) ----------- - (b) ---------- (c) ------------------- (d) -----------------
2. Basic types of food needed by man include (a) ----------- (b) --------------- (c) --------------- (d) ------------------. Examples of each are (e) ------------ (f) -------------------- (g) ----------- (h) --------------- respectively.

Since we have discussed the basic types of food needed by man, it is important that we also study, how he produces this food and the environmental factors which affect his food production. Thus, the topic of our next discussion is agriculture.

3.2 Agriculture

Through the ages, man has learnt to sow and produce the wide variety of plants and animals he needs to use and eat for his survival. From s implest process of fruits and roots gathering and hunting, he has developed a complicated system of planting and rearing animals. He has progressed from using simple instruments and implements to large-scale scientific and technologically dependent agriculture. He has also progressed from raw consumption of food to cooking, drying and manufacturing it into a wide variety.

3.2.1 Agriculture, climate and soil

You may be aware that man's ability to produce his food and agricultural needs depends on the type of climate, weather, and soil of the region in which he lives. From ancient times, man has known these secrets about nature. Hence, the areas that first saw the earliest human settlements and the emergence of ancient civilization were areas favourable for agriculture and general human settlements. Such areas include the Nile valley, the valleys of Tigris and Euphrates in Babylonia, the Yangtse river of China and the Indus river in India. You may recall that we discussed this in module 1, unit 5. In these areas, the valleys were found fertile and very conducive for agriculture and secure settlements. The rivers in these areas often over flowed and spread silt, rich with mineral deposits and nutrients which helps crops to grow abundantly. In this way man was able to produce enough food to support a large population all year round.

It is important to know the meaning of climate, weather and soil.

1. Climate is the generally prevailing weather conditions of a region. It is determined by the temperature, barometr ic pressure, humidity, precipitation, sunshine, cloudiness and winds, throughout the year. It is the average condition over a period of years. Precipitation is the falling down of products of condensation in the atmosphere.

Such products include rain, snow, and hail.
2. Weather is the prevailing state of the atmosphere as regards wind, rain, temperature, moisture, cloudiness, pressure, etc.
3. Soil is the portion of the earth's surface consisting of disintegrated rocks and humus.

Humus is the dark organic material in soils produced by the decomposition of vegetable or animal matter, which is essential for the fertility of the earth or ground. Disintegration or breakdown of rocks, which produces soil, is accomplished by a process called weathering. It is done by ice and frost naturally occurring chemicals and lowly plant organisms such as algae or lichens. Soil has inorganic components such as clay, soils and sand. These are mixed with the organic portion called humus.

The totality of these factors determines the state of the vegetation which is the plants and plant life of a region.
Let's take a break. You may wish to test yourself with the following exercise.

Exercise 2.1

1. List 5 parameters for determining climate.
2. Define weathering.

Did you get all the answers correct? If so, well done! You can proceed to the next section. If you failed one question, don't worry; with time you will understand the topic very well. The next sub topic to be discussed vsegetation.

3.3 Vegetation

Depends on the type of vegetation there. The major vegetational regions Vegetation means the plant life of a region. The type of farming done in an area on the earth's surface are:
1. Tundra, mountain Flora, ice cap, eg. Antarctic Zone.
2. Coniferous forest (Northern region and Russia).
3. Deciduous forest North-Eastern Canada, Russia.

4. Temperate rain forest, USA, China.
5. Tropical rain forest, Africa, S. America, India.
6. Grassland and savannah, USA, Africa.
7. Thuru forest and shrubs, Australia.
8. Scrub and semi-desert, Africa, Australia middle East, etc.
9. Desert, Africa, Australia, Middle East.

References to the continents above are in respect of the relevant parts of those continents and regions. These zones correspond to the climatic zones of the cold temperate, tropical and desert zones.

Large-scale farming is possible mainly in the grasslands and in those areas of the coniferous, deciduous and tropical rain forests that have been cleared by man for cultivation.

Farming is very difficult in desert, semi-desert, tundra, mountain flora and ice cap vegetations. Altitude, or height of an area from the sea level, affects the vegetation of several areas of the wood. So do intensive and active human settlements. Technology has enabled man to influence the vegetation as well as agricultural potential of several areas of the world. Through the use of manure, fertilizer and irrigation (from artificial lakes, dams, canals, etc) and the introduction of special breeds of crops, man has been able to engage in agriculture and, hence, produce foods in regions hitherto unsuitable for such purposes. This has happened in Israel, for example.

3.4 Natural resources

You will recall that we mentioned the natural resources man needs for his sustenance in section 3. In this section, we shall discuss them in details. But first we shall define the term.

3.4.1 Definition of natural resources

The term natural resources is used to signify those things (raw materials) man uses to satisfy his needs. Natural resources in this sense means such things as minerals, fuels, forest, grazing lands, wild-life, etc. However, with the development of ecology (the science that explores the relationship between life and the environment in which it occurs), the term natural *resource(s) was introduced to include all the things that could be found on* the surface layer of our planet earth, namely, the earth's crust which is about 33 km deep at most of the oceans and seas, and the atmosphere which is made up of three layers - troposphere, the stratosphere and the ionosphere.

The reason for this is that it has been recognized that the earth takes its life supporting form from the continuous interaction of the various elements within it. Thus, the earth's surface forms an integrated life-supporting unit, which is called the biosphere. The biosphere as we saw in unit 1, includes part of the earth's crust, water and the atmosphere where living organisms including man can subsist.

Man derives his sustenance from the biosphere just as he makes some input towards the maintenance of the equilibrium of the biosphere. However, man's contribution towards the maintenance of the life sustaining equilibrium of the biosphere is now in doubt, hence, the present drive to curb the ecological damages perpetrated by man. You may recall that in module 3, unit 2, we talked about the social implications of man's technological development.

3.4.2 Classification of man's needs for natural resources

Man's needs for natural resources can be classified into primary secondary needs.

1. Man's primary needs are those he requires for existence. For example, internal energy in the form of food, external energy in the form of adequate clothing, heat for cooking, warming of homes, etc, good water for drinking and cooking, general hygiene and at least, marginally polluted air with the required degree of oxygen.
2. Secondary needs of man are those needs that have arisen due to man's desires to subdue nature to his satisfaction as well as aesthetically and emotionally enjoy it.

These needs include the higher energy forms required for an urban civilization, the materials required to maintain the modern industrial society, as well as the parks, open spaces, experiences and materials needed for recreation, etc.

Exercise 2.2

1. Man's need for natural resources can be classified into (a) -------------
(b) ---------------
2. Ecology means ---

3.4.3 Classification of Natural Resources

You may be aware that natural resources could be classified in two ways, which are:

1. Living resources. Living resources include all forms of plants and animal life as well as micro-organisms.
2. Non living resources are those without life, for example, minerals. They could also be classified into;

1. Renewable and
2. Non-renewable resources.

Renewable resources

These are resources that can reproduce or renew themselves, for example, plants and animal resources. Resources are also classified as renewable when they are maintained, rejuvenated or improved upon by a naturally occurring process. An example is soil formation. The natural process of soil formation goes on at all times, building up of soil and restoring of destroyed soil. In addition, seemingly inexhaustible resources such as solar energy, air and water are regarded as renewable resources.

Non- renewable resources

These are those resources (mostly non living resources such as fuels and minerals), which do not usually replace themselves once they are used.

However, the classification of resources as renewable and non renewable is not so satisfactory, given the fact that it is known that all forms of natural resources are integrated in a continuum, consisting of those that are renewable over a short time and those that are renewable over a very long period of time. It is, therefore, necessary to see all forms of natural resources in terms of their cycling time. The cycling time of a resource is the period it takes to replace a particular quantity of such a resource that has been used with an equivalent quantity in the same useful form. Thus, the difference in terms of renewability between the tropical trees we lumber for timber (for instance, iroko, obeche) and petroleum (a fossil fuel) will be the 400 - 1000 years it takes the tropical trees to mature and the hundreds of thousands of years it takes the fossil to get renewed. A resource is non-renewable if the rate of its consumption or utilization surpasses its cycling capacity. When an easily renewable resource (e.g. fish) is consumed at a rate that would render it non-renewable, such a resource is said to be ‘mined’.

The next sub-topic we shall discuss is conservation of natural resources.

3.4.4 Conservation of Natural Resources

The danger presented by non-renewability of resources on a large scale has created the need for the conservation of natural resources. The term conservation as presented in world conservation strategy by the international union for conservation of nature and natural resources means the management of human use of the biosphere so that it may yield the greatest sustainable benefit while maintaining its potential to meet the needs and aspirations of future generations.

Conservation is carried on for other reasons apart from making resources available on a long-term basis. These other purposes are scientific, recreational and aesthetic.

Conservation activities serve science because through conservation, species of life and biological communities are preserved for scientific study. The disappearance of such species of life and biological communities when they have not been adequately studied or studied at all is a great loss to science and scientific understanding of the biosphere.

Aesthetically and recreationally, conservation is required to preserve some of nature for people living in the urban areas who yearn to come in contact with nature. For instance, people living in the urban areas usually like to see animals such as lion s and elephants in their natural habitats. It also provides camping sites as well as recreational facilities. An example is the Yankari game reserve in Bauchi state.

We shall discuss the conservation or management of non-living and living resources separately.

Management of non living resources

The ways and objectives of managing and conserving resources are different from those concerning the management of living resources. Non-living resources are managed by:

1. Beneficiation: This is the process of care whereby a resource that occurs in an uneconomical formation is upgraded or improved, i.e. rendered economically viable.

   Beneficiation usually depends on technological improvements, for instance, manganese, cobalt, nickle and copper that are relatively scarce on dry ground are continuously formed as nodules on the ocean floor. These nodules await the technology that would enable human beings collect them.
2. Maximisation: This is the sum of those measures that make for the avoidance of waste and which also increase the production of a resource.
3. Substitution: This is the utilisation of readily available resources in place of a rare one. For instance, the use of plastics in place of metals for packaging and other purposes and the use of aluminum in place of copper for certain purposes.
4. Allocation: This involves the determination of the best use of a particular resource and the scheduling of such a resource for that use.

   mechanism for allocation in the market (capitalist) economics is the pricing system. It depends on demand, which, once high, is likely to lead to a high price. High price for a particular resource will more or less ensure its utilization for the expected purpose. This mechanism is not very reliable because it is not quite amenable to long-term conservation purposes.

   For instance, petroleum goes into all sorts of products, whereas one may wish to conserve it for energy purposes only.
5. Recycling: This is the gathering of waste or used materials, reprocessing

them, and using them again in place of fresh materials. The effectiveness of recycling depends on its being organized and sustained on a large scale. Living resources could also be recycled, for instance wood and paper could be reused.

Take a break and do this exercise.

Exercise 2.3

1. Classif y natural resources and give examples.
2. Outline 4 ways of managing non-living resources.

We shall now discuss the management of living resources.

Management of living resources

The aims or purposes of managing living resources include:

1. To maintain very important ecological processes and life support systems.
2. To preserve the diverse and various life forms (i.e. plants and animals)
3. To establish a sustainable pattern of how to use species and ecosystems.

The conservation of living resources involves;

1. The protection and restoration of endangered species through the development of parks, game reserves, etc.
2. The sustainable or wise use of resources by ensuring that resources are not 'mined' through, for instance, fishing laws that aim at restricting harvest of fish.
3. Recycling which involves the processing of already used materials for re- use.
4. Specie substitution, this is the use of readily cultivatable species in place of species with long periods of cycling. For instance, the use of the Kenaf trees for pulp in place of certain kinds of timber.

Management for the purposes of conservation could involve more that one goal. For instance, wild life park could be open to scientific ecreational purposes. And a protected man-made water reservoir, such as is developed from the damming of river, could be used for scientific, fishing and recreational purposes. The management of any particular areas for the achievement of more than one purpose of conservation is known as multiple use management.

Awareness about conservation has grown from the concern of a few intellectuals and intellectually inclined artists in the early 19th century to become the concern of many people including politicians. There is now a growing concern about conservations, mainly connected to the increased rate of the deterioration of the biosphere, especially after World War II, by all sorts of pollutants. The 20th century has witnessed industrialization and urbanisation, which have generated by-products that pollute the environment making it uncomfortable or at times fatal to life. You may recall that we discussed this in module 3, unit 2.

4.0 CONCLUSION

This unit has really been instructive. We have talked about man and his food, types of food man needs for sustenance, how he produces the food through agriculture and the effects of climate on food production. We also discussed the various vegetational zones of the world and how they influence the type of crops that cab be planted there. The term natural *resources was discussed in details in terms of its classifications and* conservation.

5.0 SUMMARY

The main points in this unit are:

1. Man sustains himself through food and other essentials of life such as air and water.
2. Basic types of food needed by man include carbohydrates, fats and oils, proteins, minerals and vitamins.
3. Man's ability to produce his food and other agricultural needs depends on the type of climate, weather and soil of the region in which he lives.
4. Vegetation means the plant life of a region. It influences the type of farming done in an area.
5. Natural resources can be classified into two:
(a) living and non-living resources
(b) renewable and non-renewable resources.
6. Man's needs for natural resources can be classified into primary and secondary needs.
7. Non living resources are managed by:
(a) Beneficiation.
(b) Maximisation.
(c) Substitution.
(d) Allocation.
(e) Recycling.
8. Living resources can be managed through means such as:
(a) the protection and restoration of endangered species through the development of parks, game reserves, etc.
(b) recycling.

6.0 TUTOR-MARKED ASSIGNMENT

1. Write short notes on (a) Management of living resources (b) Vegetation

7.0 REFERENCES/FURTHER READING

Nwala, T. U. (1997) 'Man and his natural resources' in: Nwala, T. U. (ed.) *History and Philosophy of Science, Niger Books and Publishing Co.* Ltd, Nsukka.

UNIT 3 GREAT SCIENTISTS OF NIGERIAN ORIGIN

CONTENTS

1.0 INTRODUCTION

This unit will bring us to the end of this course - History and philosophy of science. Here, brief biographies of worthy Nigerians who have contributed to science will be presented. The aim is to awaken in you the consciousness of being a Nigerian, to inspire you, no matter what people think of Nigeria, to contribute to her upliftment just as Marie Curie did for her fatherland Poland. She married a French man Pierre Curie. Both of them discovered an element which Marie named after her country Poland. She called the element Polonium.

After studying this unit you should be able to achieve the objective stated below.

2.0 OBJECTIVE

Discuss the contributions of Philip Emeagwali, Bart Nnaji, Col. Ovadje and Henrietta Ukwu among others to science.

3.1 Philip Emeagwali

He was born on August 23, 1954 in Akure, Nigeria. His father was James Emeagwali while his mother was Agatha. He dropped out of school many times because his parents could not afford to pay his school fees.

He earned his first diploma from the University of London (through self-study) in 1973, and subsequently won a scholarship to Oregon State University. From 1977-93, he did graduate study, professional practice and academic research in Civil Engineering at Howard University and Transportation Engineering at Maryland State Highway Administration.

For six years, he served as a distinguished lecturer at both the Institute of Electrical and Electronic Engineers (the world's largest technical organisation) and the Association for Computing Machinery (the oldest computer society). He has delivered many major lectureships all over the world, including the Massachusetts Institute of Technology, the United Nations Educational, Scientific, cultural Organisation (UNESCO, Paris) and the International Congress on Industries and Applied Mathematics.

In 1974, Emeagwali read a 1922 science fiction article on how to use 64,000 mathematicians to forecast the weather for the whole earth. Inspired by that article, he worked out a theoretical scheme for using 64,000 far-flung processors that will be evenly distributed around the Earth, to forecast the weather. He called it a Hyper Ball International Network of computers.

Today, an International Network of Computers is called the Internet.

Initially, his proposal to use 64,000 computers to form an International Network was rejected by his peers on the ground that it would be impossible.

Since he was denied funding and employment for a decade, he quietly developed and wrote down his calculations in a thousand page monograph which described the hypothetical use of 64 binary thousand — the equivalent of 65,536 processors to perform the world's fastest computation.

In 1987, an experimental hypercube computer with 65,536 processors became available at the Los Alamos National Laboratory, the United States government's prime nuclear weapons research centre. Frustrated by their inability to programme 65,536 processors to simulate nuclear blasts, the Los Alamos officials had a hunch to allow physicists simulate problems similar to theirs. Fearing that the lab officials would not accept him if it was known that he was black, Emeagwali decided to submit his proposal remotely. The lab officials approved his usage of its computers and he remotely programmed 65,536 processors in Los Alamos (New Mexico) while living in Michigan.

His success in using 64 binary - thousand processors gave credibility and renewed interest in his formerly rejected proposal to use 64 thousand far- flung computers to forecast the weather for the whole earth. Because the topology of his rejected international network of computers was similar to, but predated that, of the Internet, it was rediscovered. The book, History of *the Internet called him an Internet pioneer. He was voted one of the twenty* innovators of the Internet and CNN called him 'A father of the Internet'.

He was awarded the 1989 Cordon Bell prize (supercomputing Nobel prize) for his contributions, which in part inspired the petroleum industry to purchase one in ten supercomputers.

Emeagwali considers himself to be 'a black scientist with a responsibility to communicate science to the black in diaspora'. In other words, he has a dual sensibility of being deeply rooted in science while using it as a tool to remind his people in the Diaspora of where they have been and who they are. During his career, he has received more than 100 prizes, awards and honours.

3.2 Col. Dr Oviemo O. Ovadje

He is a chief consultant Anesthesiologist. He has been recognised worldwide due to his contribution to product development in medicine. He invented an Emergency Auto- Transfusion set (EATSET) which has been acclaimed internationally as Nigeria's contribution to Global Blood Safety. He has received many awards among which are:

1. Best African Inventor/Scientist Award, 1995
2. First African winner, World Health organisation Sasakawa Award, UN Hall, Genera Switzerland, 18 may 2000.
3. Winner ARCO Excellence in Science and Technology Award, Dorchester, London England, April 26, 2001.

3.3 Prof. Henrietta Ukwu

She also received the ARCO Award on 26 April 2001 for the production of a potent chicken pox vaccine (varivax) and an HIV-protease inhibitor (crixiran) for managing AIDS patients.

3.4 Prof. Njoku Obi

In the early 1970s, Prof. Njoku Obi of the University of Nigeria, Nsukka made a vaccine which was recognised, accepted and adopted for use by the World Health Organization (WHO).

3.5 Prof. Mobison Oliver Udemmadu

He hails from Awo-Idemili in Orlu Local government area of Imo State, Nigeria. He left Nigeria in 1965 after his secondary school at Christ The King College, Onitsha. For the Massachusetts Institute of Technology (M.I.T) Cambridge, Mass, USA (1965 - 1970) where he obtained degrees in mechanical and Electrical Engineering, Computer science, Aeronautics and Astronautics, while working in the District Equipment Corporation, he developed a computer machine for industrial use and became an indispensable consultant in the American Scientific outfit, called the National Aeronautics and Space Administration (NASA). He is a director of Ruben Engineering Corporation. In 1980, he embarked on the building of computers — ASUTECH 800 series and ASUTECH 800 super personal computers and super personal systems.

3.6 Prof. Bartholomew Nnaji

He is from Umuode in Nkanu East Local Government Area of Enugu State, Nigeria. He was born in July 1956. He studied at St. John's University, New York, Virginia Polytechnic and Massachusetts Institute of Technology (MIT). He became a professor and founder of the Automation and Robotic Laboratory at the University of Massachusetts at Amherst.

He is the founder of the Geometric Machine Corporation to affirm that everything in use has a geometric approach. He founded the National Centre for Computer-Aided Medical Devices for Visualisation Diagnosis and Surgical Intervention Systems. He is the first man to be named a distinguished professor of engineering in American history.

He consults for Digital Equipment Corporation, the North Atlantic Treaty Organization (NATO), the American Army, United Nations Development Programme and other leading international bodies.

3.7 Some home based computer experts

1. Prof. Olayide Abass (UNILAG)
2. Dr Gabriel Atah Olayi (UNCIAL)
3. Prof. Simeon Fatula (UNIBEN)
4. Prof. Yayo Akinde (FUTA)
5. Dr Chris Okeke (formerly of UNN)

These are some of the experts teaching computer science in Nigerian Universities and researching into different aspects of technology. The list presented here is not exhaustive. There are many other Nigerian scientists in other fields. Unfortunately, these are the only ones I could get hold of.

4.0 CONCLUSION

Yes, it's true all these superstars are foreign-based. They are not fully appreciated at home and so cannot abandon their jobs to come and languish in Nigeria. One doesn't know how long this situation will last. Nigeria needs her superstars in all fields to be at home in this technological age.

5.0 REFERENCES

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