A Textbook On

MAN, SCIENCE, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

Edited by

Prof. Sherifat A. Aboaba

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FOREWORD

It is my singular honour to write the foreword to this ingenious course material on *Man, Science, Environment and Sustainable Development*. Science is an interesting aspect of life which focuses on human and environmental growth. Its evolution accounts for changes in the genetic material of a population over time. This evolution reflects the continuous need for man to adapt at varying stages of life to new challenges posed by his environment in order to survive. Therefore, to acquire this knowledge for adaptation, and aid the teaching of science to students in different fields of the academia, the General Studies Unit of Chrisland University Abeokuta, Ogun State, developed this book to serve as a guide to the fundamental principles of basic scientific techniques and application.

The identification of the centrality of science to teaching and research in general, makes this book an essential asset. It widely discusses the relationship of science with the society in simple and clear terms which make it beneficial to everyone, including those with non-scientific background. Driven by expectation towards enhancing the stellar performances of our students in a dynamic world in the nearest future, the seasoned contributors to this book, explain the topical issues from definite angles of science to vital areas of discourse.

Chapter one starts with the definition of man, highlighting his features, tendencies and temperaments. Meanwhile, chapters two and three elaborate on ecological interaction, the symbiotic interrelationship of organisms, influences of man on his environment and man's constant strife for technological and sustainable development. Chapters four and five give an overview of chemistry, its role in social development, with emphasis on the definition of matter, its nature and spheres of influence within chemistry, and its modus operandi in the fields of medicine, pharmacy and agriculture. It gives further elaboration on the environment and chemical concerns, naming the component of the environment, giving a picture of environmental health and the dangers of ozone layer depletion.

Chapters six and seven examine the meaning of sustainable developmental goals, roles and implementation, alongside a general appraisal of microbiology and its roles in sustainable development. Chapters eight and nine present exploration and exploitation of space in physics, the synergy that physics shares with other fields and an overview of the study of geography, geology and their applicability. Besides, chapters ten and eleven shed light on the role of computer science in social development, application of computer in industrial institution, its implication on education and research organisations. It further makes an outline of its statistics and administration. Chapters twelve and thirteen focus on the categorisation of waste types and its effective management. The chapters equally discuss cell as the basic component of life and how it functions. The concluding chapter focuses on the world of biotechnology and the fields where it can be adopted. The authors are seasoned faculty members and authorities in their respective fields.

The book is highly recommended for use in any university or other tertiary institutions where man, science and social development are studied.

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CHAPTER 1
MAN AND HIS NATURE

A.S. Ayesa

Who is Man?

Man is a living organism. Man (male and female) is part of the living organism as stated in the definition of biology.

> "Biology is the scientific study of living organism (both plants and animals)"

Living organisms possess the following characteristics:

1. **Cell:** Living organisms arise from pre-existing cells. Cell is the basic, structural and functional unit of life; without cells, there is no life.
2. **Movement:** Movement is defined as the ability to move part/whole body from one location to another.
3. **Growth and Development:** Growth is an irreversible increase in size, and therefore, as they increase in size, the organs are also developing.
4. **Reproduction:** Is the ability to produce offspring/young ones either sexually or asexually. But man reproduces normally by sexual act.
5. **Nutrition:** It is the ability to feed, that is, eating a balanced-diet food.
6. **Excretion:** This is a way of removing harmful/toxic materials from the body. It could be via sweat, faeces, boil, urine, etc.
7. **Respiration:** Is the exchange of gases. Man breathes in oxygen and breathes out carbon dioxide.
8. **Irritability or Responsiveness:** It is the ability to respond to stimuli.
9. **Evolution:** This is the ability to change from one form to another.

Origin of Man

There are certain questions that should come to mind when talking about the origin of man; these questions include:

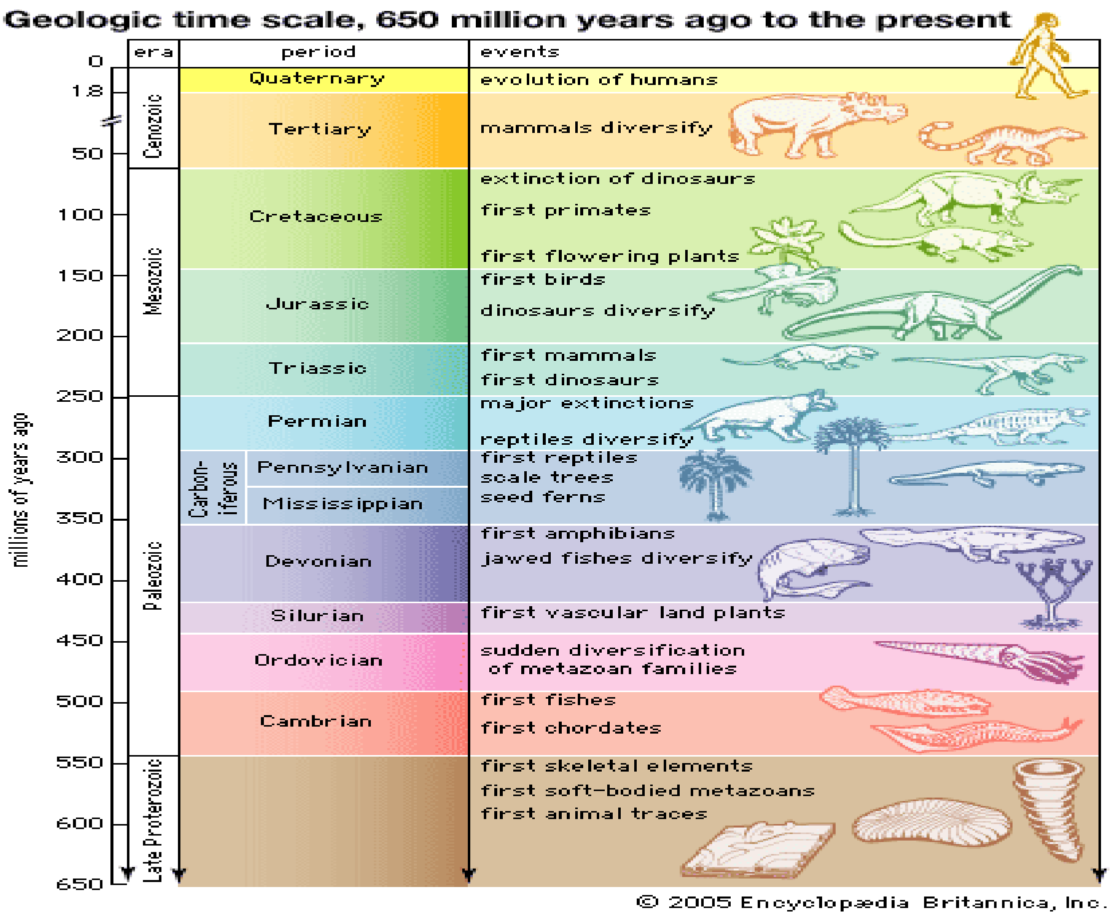
- Who am I? The prompt response will be that you are a living being either male or female while some may even give description of themselves.

➢ Who created me? It is assumed by all that God created everything (living and non-living)

➢ How did I come into existence? Biologically, we all came into existence through the fertilization of sperm and egg developing in the uterus of female reproductive system; and after 9 or 10 months, you are born ~~birth~~.

➢ Who is my ancestor? Some may say their forefathers, but in the real sense, somebody started the journey. Scientist believes that man hails from Apes owing to the fact that we have most features in common, while some believe that they are not descendant of apes but of Adam. This led to questions like, how did we *Homo sapiens* (man) transformed from *Homo erectus*(apes)? This and many questions led to the theory of Evolution.

EVOLUTION



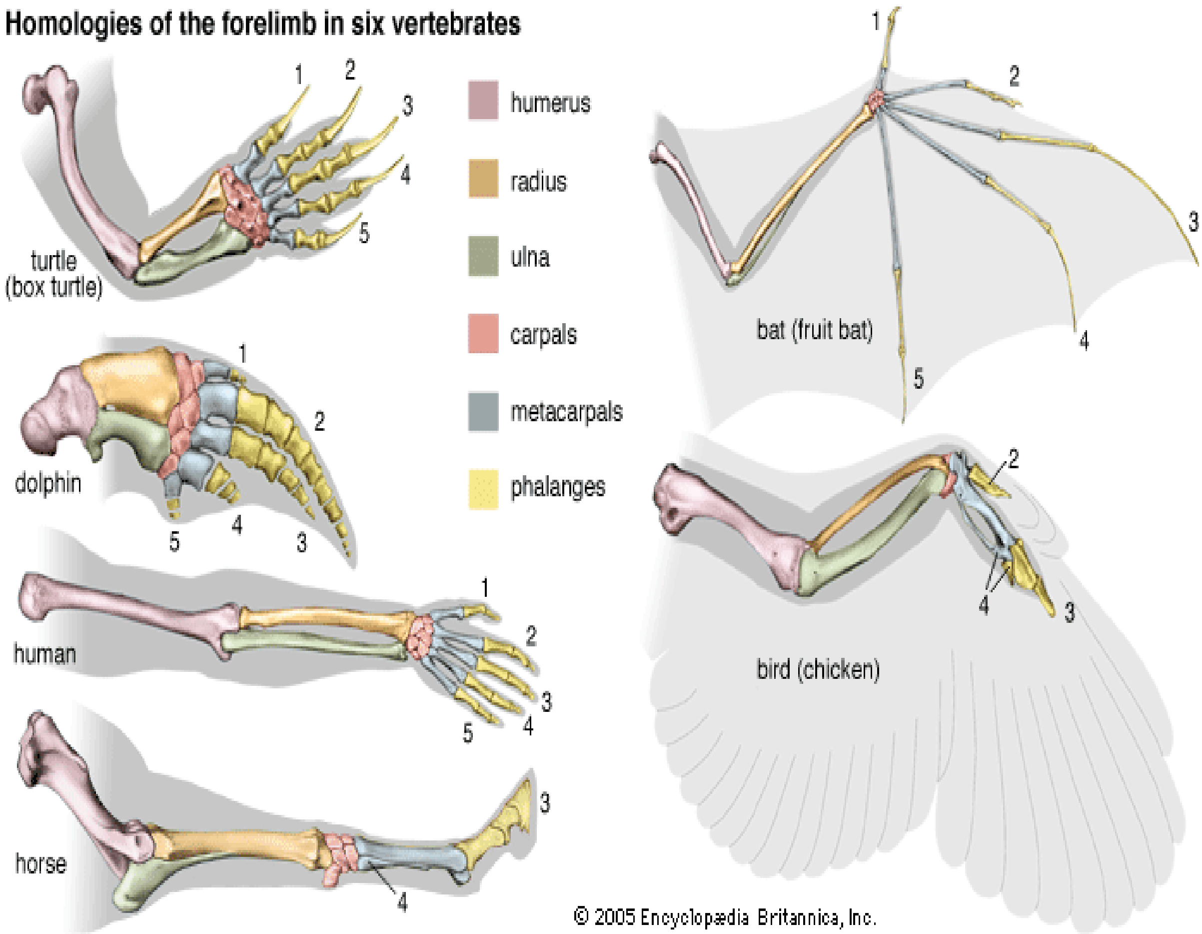
Evolution can be described as the theory of the development of more complicated forms of life in plants and animals from earlier and simpler forms. Evolutionists are of the opinion that all living organisms are of common ancestors, though, they may appear related or unrelated. Several attempts have been made to explain how life evolved into a variety of living organisms which presently inhabit the earth.

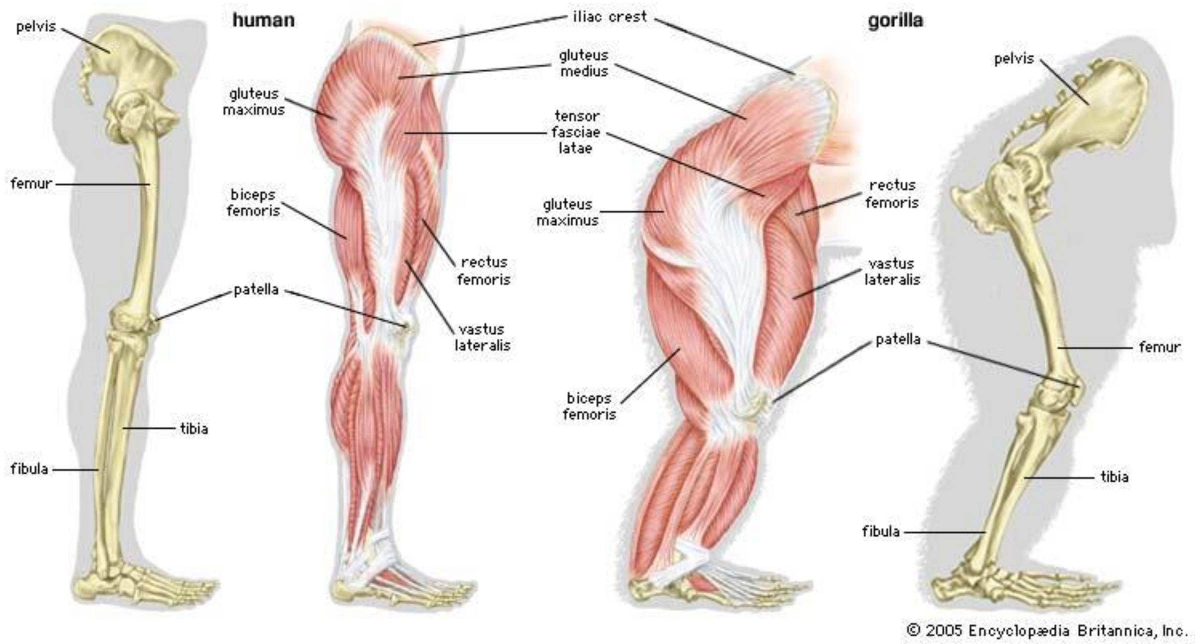
The most prominent attempts are however those of Lamark and Darwin.

Evidence shows that evolution has taken place. They are:

1. Fossil record: A fossil is a part or an impression of a plant or animal that has lived a very long time ago. Fossils are normally preserved in sedimentary rocks. Fossil records are also called geographical, paleontological, archeological or historical record.

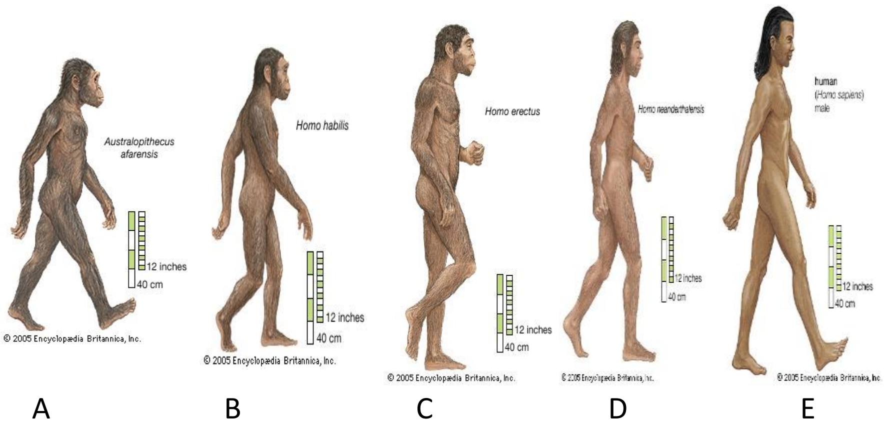
2. Comparative anatomy: It investigates the homologies, or inherited similarities, among organisms in bone structure and in other parts of the body. The correspondence of structures is typically very close among some organisms—the different varieties of songbirds, for instance—but becomes less so that the organisms being compared are less closely related in their evolutionary history. The similarities are less between mammals and birds than they are among mammals, and they are still less between mammals and fishes. Similarities in structure, therefore, not only manifest evolution but also help to reconstruct the phylogeny, or evolutionary history, of organisms.





1) Evidence of geographical distribution: It has been proven that living things tend to show some variation in forms, structures and functions in the same climatic condition producing same type of plants and animals that have some resemblance.

2) Evidence of Embryology (Human Evolution): Embryo is an organism that develops after fertilization of egg before birth or hatching. It is noticed that in embryology of vertebrates, for instance, there are stages which resemble the embryo of other vertebrates from which they are believed to have evolved.



A=*Australopithecus afarensis*, B= *Homo habilis*, C= *Homo erectus*, D= *Homo neanderthalensis*, E= *Homo sapiens*

Lamarck's Theory

Jean-Baptiste Lamarck (1774-1829) was a French naturalist and the first biologist to attempt explanation of the evolvement of the variety of living organisms. Lamarck’s theory was based on three premises:

- He believed environmental influences are the main cause of evolution.
- He believed that organs that are used extensively usually become enlarged and more efficient while the unused organs degenerate and become useless.
- He also believes that character acquired through routine activity can be inherited by the future generations.

Lamarck's Illustration

Lamarck illustrated his views by describing the evolution of giraffe. According to him, the ancestors of giraffes were short-necked and depended mostly on leaves. Due to decrease in the availability of leaves at lower height, the ancestors began to stretch their necks, and the neck became progressively longer. Their offsprings later inherited the longer neck to feed in the same way.

Conflict of Interest

Recent experience has however faulted this assertion that characters acquired through routine activities are inherited by the next generation. For example, the nature of work of the blacksmith had made many of them to acquire large biceps but most of their children who are not blacksmith have been found to have normal biceps.

Darwin's Theory

Charles Darwin (1809-1882) was a naturalist who made voyage around the world between 1831 and 1836. During this voyage, Darwin kept a careful record of the diversity and distribution of living organisms throughout the world. He also made an extensive collection of fossils from various parts of the world. In 1858, Darwin presented a paper titled "Origin of species by means of natural selection" which was based on the following observations:

1. Most organisms produce a larger number of progeny than those that survive and hence, the population size remain constant over an extended period.

2. Individuals in a population usually struggle i.e. compete among themselves to survive.

3. The offspring show variation (characters), some of which are heritable.

4. Some of the variations enable the individual organisms to survive the competition.

5. Organisms having the most advantageous variations have greater capacity to survive and produce offspring which may inherit the variations

Darwin's Illustration

Darwin illustrated his theory by describing what gave rise to long neck of giraffe. According to Darwin, the ancestors of the giraffe consisted of animals with a range of browsing the leaves of a tree and thus avoided competition with other herbivores which ate vegetable growing closer to the ground. Later, the short-necked ancestors succumbed to the competition and became extinct. The long-necked variety survived and thus constituted the ancestors of the modern-day giraffe.

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CHAPTER 2

MAN AND HIS ENVIRONMENT

A.S. Ayesa

Introduction

As earlier discussed, biology is defined as the scientific study of living organisms. Nevertheless, the environment not totally excluded. The environment falls under the sub-discipline “ecology” in biology. That is why death is not accepted as part of the characteristics of living organisms. The environment is the non-living part in which man inhabit. Interaction of organisms in relation to their environment will be studied under “ecology”.

Ecology

The term “ecolog’y was first used by a German biologist called Ernest Hackel in 1869. The term was coined from two Greeks words *Oikos* meaning home and *logos* means study. Thus, literarily, ecology could be described as the study of home or the management of homes of organisms. Hence, ecology has been described as the study of plants and animals in relation to their homes called habitats.

Basic Ecological Concepts

Habitat: Habitat is a Latin word which means ‘it dwells’; a place where organisms or group of organisms live. It could be micro-habitat or macro-habitat. There are two main types of habitats, these are, terrestrial and aquatic.

Niche: Ecological niche refers to the activities or role played by organism in its habitat.

The Environment: This is the total of all factors that affect organisms. These factors, which are also known as ecological factors, may be climatic, topographic, Edaphic and biotic.

Ecosystem: An ecosystem therefore is the unity of the organisms and their environments. Broadly speaking, the whole subjects of ecology study deals with ecosystems. Examples of ecosystems include ponds, forests, lake, lawn, river and even laboratory Microsystems.

The Individual: The individual is either a plant or an animal. No organisms can exist independently for a long time and when an individual is studied in relation to its physical and biotic environment, the study is called AUTECOLOGY.

Community: The community is the group or assemblage of populations of several species living together in a particular locality. When a community is studied, with its relationships with its physical and biotic environments, the study is called SYNECOLOGY.

Population: The composition of individual of several species in a particular area is called a population.

Characteristics of a Population

Birth Rate: The rate at which individuals is added to the population through birth. It is also called Natality.

Age distribution: The proportion of individuals of various ages in the population.

Sex ratio: The proportion of individuals of various series in the population.

Density: The number of individuals per units' area of space.

Dispersion rate: The way the individuals in the population are distributed.

Death rate: The rate at which individuals in a population are lost through death and it is also called Mortality.

Growth rate: The net result of birth rate, dispersion rate and death rate.

Factors and Components of the Ecosystem

Climatic factors: This includes rainfall, temperature, light, wind and humidity. All these parameters have impact on the environment. High or inadequate supply of these parameters could be injurious to biotic components

Topographic factors: It indicates the terrain of the environment whether plain or sloppy.

Edaphic factors: This basically the soil in the ecosystem. This encompasses the soil profile; soil type, texture, colour etc. For instance, the soil is used for different factors and there are specific soils for specific purpose, agricultural soil is known to be loamy soil while sandy soil for building.

Biotic factors: These are the living components of the ecosystem stabilizing it.

Nigerian Vegetation

The two vegetations in Nigeria are the Forest and savannah.

Forest is an area thickly populated with trees and over 90% of plant covering the surface are trees. We have rainforest, mangrove rain forest, swamp forest (southern hemisphere). The savannah is thickly populated with grasses and over 90% of the populations are grasses. There is Sahel savannah and Sudan savannah (northern hemisphere).

What contributes to the success of these vegetations is climatic condition of the areas. We have two major seasons viz: wet (rainy) season and dry (harmattan) season. In the northern hemisphere, they experience 4 months of wet season and 8 months of dry season. In southern hemisphere, reverse is the case. They experience 8 months of wet season and 4 months of dry season.

Climate and Weather

Climate is the average of the weather conditions of a place, or a region over a period of years. It is usual to assess the weather conditions for a period of between 20 and 25 years before taking the average to represent the climate of the place.

Weather on the other hand is the condition of the atmosphere at a given time, or over a short period of time. We can therefore talk of the weather of a given period of the day, the weather of the day, the weather of last week, the weather of a month and the weather of a year or the weather over the last few years.

Both the climate and the weather share a number of features which include the following:

i. Both are expressions of the conditions of the atmosphere of the environment of a place.

ii. Both are usually assessed through a number of meterological phenomena, which include atmospheric temperature, rainfall, pressure, light, humidity, wind speed and direction and a number of others such as evaporation, lightning and thunderstorm and visibility.

Table 2.1: Instruments used in measuring climatic factors and the unit in which they are recorded

Climatic factors	Instruments used in measuring them	Units in which they are recorded
(I) Temperature	Thermometer	Degree centigrade
(Ii) Rainfall	Rain guage	MM
(iii) Humidity	Hydrometer	%
(iv) Pressure	Barometer	Atmosphere
(v) Sunlight	Photometer	Lux
(vi) Wind speed Wind direction	Anenometer Wind vane	Meter/Hour NE/SW direction

Association between Organisms

Biotic Interaction

Whenever there is the presence of two or more individual organisms of the same or different species, certain forms of interactions usually exist between them. Some the various types of interactions recognisable among the biotic components of natural ecosystems are mutualism, commensalism, neutralism, parasitism, predation, ammensalism, and competition. These biotic interactions fall into three basic categories: symbiosis, antagonism and neutralism.

Symbiosis

This is the term used for any interrelationship which is beneficial to one or both species of organisms involved in the interaction, and in which none of the species of organism suffers any loss of any harmful effect as a result of the interaction. Only mutualism and commensalism fall into this category of interrelationship which is also termed symbiotic association.

<u>Mutualism</u><u>:</u> This is an association between organisms of different species in which both partners benefit. The association may be obligatory where the partners are so dependent on each other and that they are unable to live independently. e.g. Mycorrhizae, Lichen.

<u>Commensalisms</u><u>:</u> This is an association between organ of different species in which one species called the commercial benefits but does not harm the other called host which neither loses nor gains from the association.

Antagonism: This is a term which covers all forms of interactions between living things in which one species of organisms participating in the interaction suffers some harm from the interaction irrespective of whether or not the other party in the interaction benefits from such interaction. Examples of this category are **parasitism, ammensalism and competition**.

<u>Parasitism</u><u>:</u> This is a form of association between two individuals, where one individual known as parasite live and feed on another individual known as the lost. The activities of parasites are usually harmful and often results in the death of the lost.

Neutralism: In this interaction, the species of organism involved suffer no loss or harm from the interaction even though no benefit or gain of any type is derived by any of them from the interaction. The only example of this category of interaction is neutralism, also known as neutrality.

Predation: This is an interaction occurring between two species of organisms in which one species the ***prey*** is killed and fed upon another-the ***Predator***. Example of predatory interactions include that between some predatory bird (e.g. hawks) and the smaller animals on which they prey.

Ammensalism

This is a conflict type of interaction where one of the species participating loses and the other neither gains nor loses. An example of this is the interaction between some huge herbivores such as cattle, hippopotamus and elephant and the plant of the herb stratum over which they trample in the field. These animals walk through the vegetation and in the process, do a lot of damages to the small plant of the herb stratum.

Man and the Environment: Influences of Man in the Environment

Man is not just an animal; he is a special animal. Why? He is the king of all species of organisms (*Genesis 1:26-28*). The factor of man in the environment is described in ecology as Anthropogenic factor. Why is man so peculiar?

1. The large size of the brain
2. Man can stand erect-bipedal stance
3. Effective use of the hand
4. Powerful muscles attached to man
5. In the process of evolution, man evolved more biologically, culturally, spiritually, industrially, scientifically and technologically
6. undergone much development in his practice of agriculture

Positive Influences of Man on the Environment

1. Agricultural activities-crop production, animal husbandry, wildlife management etc.
2. Urbanization and industrialization
3. Control of diseases, pests and parasites of man
4. Control of diseases, pests and parasites of beneficial plants and animals
5. Family life education and control of human populations
6. Conservation of environment
7. Pollution control

Negative Influences of Man on the Environment

1. Adverse effects of man on the vegetation
2. Adverse effects of man on the atmosphere
3. Adverse effects of man on water and water resources

4. Adverse effects of man on other natural resources within the environment

5. Adverse effects of man on ecosystem functioning

Conservation

Conservation is the protection, preservation, management, or restoration of wildlife and natural resources such as forests and water. Through the conservation of biodiversity, the survival of many species and habitats which are threatened due to human activities can be ensured. Other reasons for conserving biodiversity include securing valuable Natural Resources for future generations and protecting the well-being of eco-system functions.

In-situ and Ex-situ Conservation

Conservation can broadly be divided into two types:

In-situ: This involves conservation of habitats, species and ecosystems where they naturally occur. In-situ conservation and the natural processes and interaction are conserved as well as the elements of biodiversity.

Ex-situ: The conservation of elements of biodiversity out of the context of their natural habitats is referred to as ex-situ conservation. Zoos, botanical gardens and seed banks are all example of ex-situ conservation.

In-situ conservation is not always possible as habitats may have been degraded and there may be competition for land which means species need to be removed from the area to save them.

It is the ability to sustain natural resources in the environment; be it renewable or non-renewable. The renewable natural resources are the resources that can replenish themselves even when tapped. Examples are water, soil, forest (trees), animal etc.

The non-renewable natural resources are the resources not capable of replenishing themselves when tapped. Examples are coal, crude oil, tin and columbite, gold etc.

There are so many measures or policies put in place by individual, private, government etc. to curb excessive or indiscriminate use of these natural resources.

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CHAPTER 3

SCIENCE, TECHNOLOGY AND SUSTAINABLE DEVELOPMENT

R.A. Adedokun

Introduction

From creation man has always sought for ways of improving his quality of life. To this end man has continued to seek for knowledge relevant in understanding and interpreting the world around him. The acquired knowledge has inspired man to develop ideas, skills, tools and machines that have influenced his fate in the universe. This search for knowledge and the practical application of the knowledge so acquired fall within the scope of **science and technology**. Today, through the practical application of science, scientist and researchers have made tremendous technological advancement in different spheres of life and there seems to be no limit to how far the application of science can go. However, all these would not have been possible without a practicable ***scientific method***. Unfortunately, in the bid for technological advancement, man through anthropogenic activities has also negatively affected his ecological, social and cultural environment. It is thus expedient that in the pursuit of technological advancement, man must put in place sustainable ways of effecting positive changes in the environment.

What is the Scientific Method?

The quest for knowledge is insatiable. To satisfy this quest man has continued to explore its environment in search of answers to observed natural and social phenomena. These answers can only be obtained through systematic steps of procedures known as the ***scientific method***. The scientific method involves the collection of relevant data to formulate, test or modify an explanation for an observed phenomenon. In other words, the scientific method is a standard method of investigation in which a problem is identified and then experiments are designed to formulate, test or modify an explanation that is relevant in solving the problem. The scientific process is thus aimed at investigating observable phenomenon for the purpose of acquiring new knowledge or correcting existing knowledge

Steps Involved in the Scientific Method

Although the scientific method used by different scientists may vary because of the different nature of the phenomena being investigated, it basically involves the following steps:

Observation: Man by nature is inquisitive. He asks questions based on observations from what he sees, feels and hears. This is the starting point of the scientific method. Data (information) is collected based on ***observations*** made from nature, experiments or literature. A scientific observation should be ***measurable*** and ***reproducible*** under the same conditions in which it was made. Science cannot measure values such as morality, beauty, evil goodness, and so on. When natural events and measured events are universally consistent, it can be stated as a ***law***; an example of this is the ***"law of gravity".*** Observations can occur over a short or long period. A good scientific observation should culminate in the identification of a problem or ask questions such as why does an object thrown up fall down?

Hypothesis: This is the second step of the scientific method. Once the research question is formulated, a scientist searches for existing answers and then through critical evaluations of the existing answers and measured events, he can put forward, an educated guess (logical conjecture) known as a ***hypothesis***. In other words, a scientific hypothesis is a proposed logical explanation for an observed phenomenon. A good hypothesis should be able to make predictions using the cause effect relationship. In other words, it should be able to make prediction using the '"if and then" statements such as:

- If natural immunity to smallpox can be acquired by exposure to cowpox, then a person who is exposed to cowpox will be immune to smallpox.

- If sunlight is necessary for photosynthesis, then in the absence of sunlight, photosynthesis cannot take place.

A hypothesis is highly uncertain, and experiments are carefully designed to test it. If the hypothesis is incorrect, a new hypothesis is formulated based on observations and findings from experiments. This new hypothesis is also subject to experimentations.

Experimentation: Experiments are carefully designed to test a given hypothesis. Identify the population of interest and how to select a sample that will be a good representative of the population for which the experiment is designed. The experiment should be a true test of your hypothesis and should be reproducible under the same experimental parameters and variables. There are two variables. These variables are the dependent variables and the independent variable. The dependent variable(s) is kept constant while the independent variable is allowed to change. The dependent variable is the variable being observed. In other words, it can be referred to as the data being collected. On the other hand, the independent variable can be controlled by the scientist and a control experiment is used as a check to correct errors. The control experiment is a group in which the independent variable is removed but the dependent variables are measured in the same way as when the experimental variable is inclusive. To obtain a non-biased data experiments are also done in replicates

Data Analysis and Conclusion: This is the next step after experimentation. Data obtained from experiment is statistically analysed to reach a conclusion that either supports or refutes a hypothesis. When a large body of facts and experiments by several scientist and researchers within experimental error supports a hypothesis, it becomes a ***scientific theory***. A theory is thus not based on logical conjecture but by evidence from careful experimentation. A theory is thus a well substantiated explanation for an observed phenomenon or law. Because theories are formed from a large body of facts and several repeated experiments by independent scientists, it is not likely to change and hence can also be used to predict natural events and occurrences.

There are however cases where further experiments conflict with existing theories. A **paradigm shift** is therefore sometimes inevitable in scientific discoveries. In such cases the theories must be discarded or modified so that it can become consistent with experimental observations. For instance, although experiments by other scientists disproved Dalton's theory of the indivisible atom, it is still useful in explaining how atoms of different elements combine to form compounds during ordinary chemical reactions. In this regard modern day chemists have modified the theory by stating that the atom is the smallest indivisible particle that can take part in ordinary chemical reactions. Another example is the discarded hypothetical theory of spontaneous generation

There are also cases in which the hypothesis is proved however with limited application. In such cases, the hypothesis becomes a **model** rather than a theory. For instance, Bohr's model of the atom works well for hydrogen-like atoms (atoms having one electron) however, it does not satisfactorily explains the spectra lines of atoms having more than one electron. On the other hand, when overwhelming evidence over a period of time supports a theory, it becomes a ***law***. A law is basic principle, rule, or natural phenomenon that always holds true under certain conditions.

Data can be represented using graphs, charts and tables. No experiment is completely devoid of error. These errors are classified as either systematic or random errors; systemic errors can be traced while random errors cannot. Random errors are a slight deviation in replicate measurements made by the same analyst under the same experimental parameters. It should be noted that a single measurement is not sufficient to make an analysis, but replicate measurements are needed to make a non-biased analysis. From the above-mentioned reasons, errors in an experiment must be quoted in terms of measures of precision such as standard deviation and mean deviation while in some cases, conclusions are drawn based on probability. In other words, the frequency of the individual occurrences within a known domain is used in reaching a conclusion.

Communicate findings: Every good scientific finding should be communicated to the outside world so as to add to the pool of knowledge. Such finding may serve as a reference for further research. These findings are made available to the larger body of knowledge work by publishing them in reputable journals, conference proceedings, seminars and workshop.

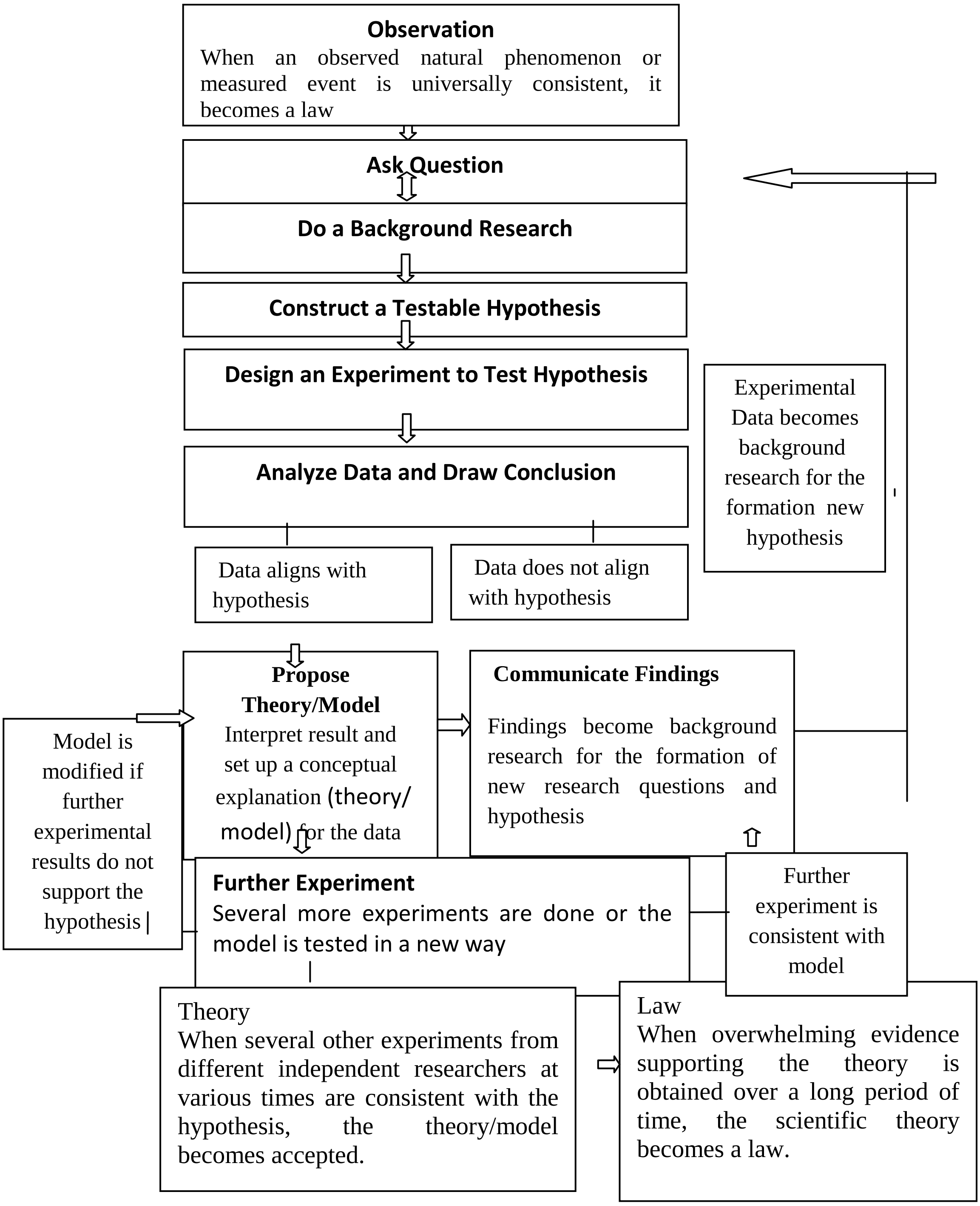


Fig. 3.1 Steps that may be involved in the scientific method: The basic steps are highlighted in bold. Scientific work rarely proceeds in a straightforward manner.

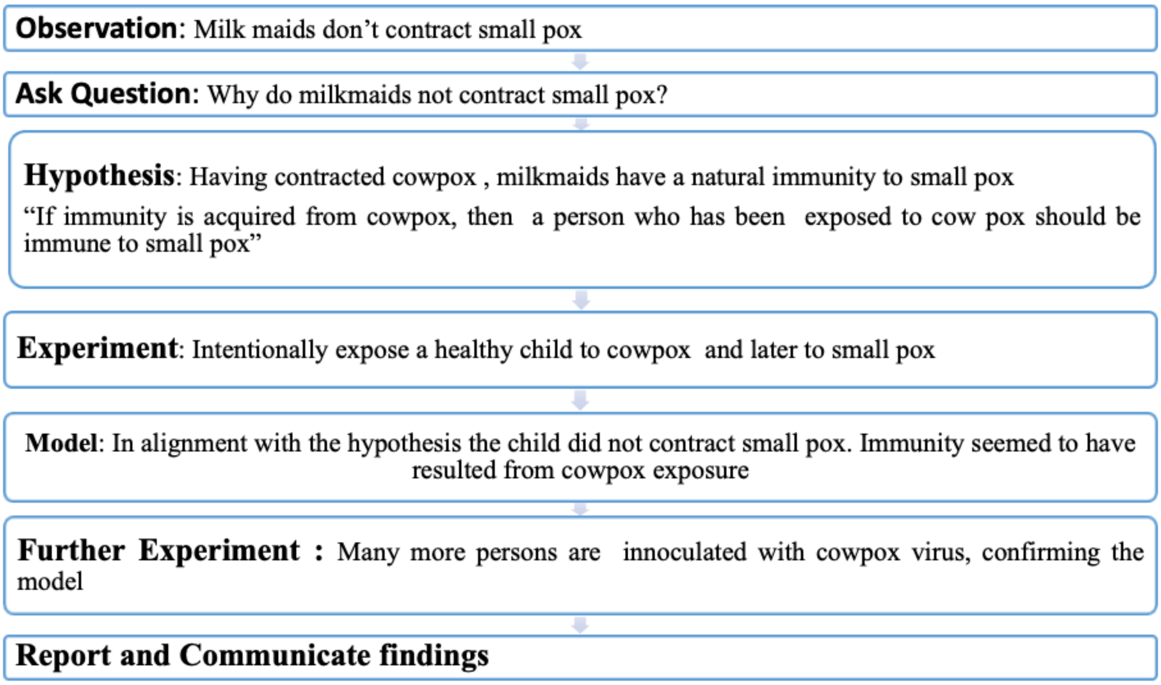


Fig 3.2 Simple illustration on how the scientific method is used in scientific discoveries

Basic Attributes of the Scientific Method

Although scientists do not follow the same approach in investigating a given phenomenon, as some areas of science are easier to measure than others, there are however some features or attributes that are consistent in the scientific method irrespective of the nature of the scientific investigation. These attributes include:

Orderliness (methodical): There are standard procedures of carrying out an experiment. It therefore not biased by personal, religious or cultural sentiments as logical conclusions are drawn from experiments.

Empiricism: It is not based on speculations, intuition, mirth and superstition but rather on observations from carefully designed experiments and thus results obtained can be replicated under the same experimental conditions.

Testable questions: Basic phenomena are uniform across time and space. Scientific observation should therefore be uniform across time and space. To this end, every scientific investigation requires the formulation of testable hypothesis

Continuous process: In science, there is no absolute certainty to knowledge. Scientists are always in search of alternative and better ways of doing things hence accepted data are constantly being re-evaluated. Therefore, proof is elusive and there is no such thing as a "final answer". It is often said that theories can never be fully proved but can be disproved. This however does not mean that scientific conclusions are invalid. A scientific finding may serve as the starting point of a fresh scientific investigation.

Cause and effect relationship: In respective of the nature of experiment, a general approach of predicting in the scientific method is to establish the cause-and-effect relationship. This is to say that for every action there is a cause. For instance, a body continues to remain in its stationary state accept when acted upon by an equal and opposite fall. This means that displacement (the displacement is the effect) of the body is caused by the opposite force. This cause-and-effect relationship can be tested using the "if and then statements". In the above illustration, the hypothesis is that the body remains in its stationary state except when acted upon by an equal and opposite force. To validate this hypothesis, the scientist will design his experiments on the premise that, "if I push a can at rest (in its stationary state) then I should be able to displace it."

Parsimony: When two or more plausible hypothesis satisfactorily explain an observable phenomenon, the simplest one is preferable.

Logical Reasoning: Science makes use of **inductive** and **deductive** reasoning in proposing hypotheses, designing experiments and drawing conclusions.

Inductive reasoning draws a general conclusion based on empirical premises and observations of samples (specific cases). In making use of inductive reasoning, the scientist collects data and then sees if there is a trend. A unifying explanation is then put forward for the observed trend.

Example:

Premise Spider is an insect with eight legs

Premise Cockroach is an insect with eight legs

Premise Mosquito is an insect with eight legs

Conclusion (New Generalisation): All insects have eight legs

New generalisations are made through inductive reasoning. The new generalisation may be true or false. More data may come up to invalidate the generalisation.

Deductive reasoning: In deductive reasoning, a pre-existing generalisation that is known to be true is used to make conclusions regarding a specific case. New generalisations are not made using deductive reasoning however it can be used to determine the type and nature of experiment that can be used to test a hypothesis.

Example:

General rule	All Insects have eight legs
Specific example	Flies are insects
Conclusion	All Flies have eight legs

Unscientific Methods of Acquiring Knowledge

There are some unscientific methods of acquiring knowledge. Although these methods are not scientific, they can be used in conjunction with the scientific method. The unscientific methods of acquiring knowledge are:

Intuition: it is a method of knowing that is based on individual hunch or feeling that something is correct. It is subjective and has no definitive or logical basis for the belief.

Authority: Is a method of acquiring knowledge based on instructions and statements from experts. These experts are known as authorities in the field. Authorities include parents, teachers, book of faith, doctors, and so on. It is the most common method of acquiring knowledge. There is always little effort to challenge authoritative knowledge thereby leaving authoritative knowledge unverified.

Empiricism: This is knowledge acquired through observation. Although making observation is a step in the scientific method, empiricism may be bias when solely used in absence of the scientific method. The way in which observations are made differ from person to person and such observations may not be void of bias and illusions.

Rationalism: This is knowledge acquired through reasoning and logic. It is also used in the scientific method. One disadvantage of knowing solely by reasoning is that it can lead to erroneous belief as even the most rational idea can be wrong.

Tenacity: it is a method of knowing based on superstition or habit. It is accepted because such beliefs have persisted over time**.** The disadvantage of tenacity is that knowledge acquired is assumed and has no basis of fact.

Science and Technology

Science is from the Latin word ***scientia*,** "to know" hence science can be referred to as a cumulative body of knowledge. Science and technology though closely related do not define the same concept. Science is a systematic process of pursing knowledge to gain understanding of the theories or laws governing verifiable and observable natural phenomena. The main goals of science are thus: to describe, explain, predict and control natural phenomenon.

Technology is the creation of products with use of craft, skills and tools with little or no understanding of the underlying theories governing its creation. Most of the early technology used by man predates science. In simple words, science seeks understanding on how things happen while technology makes things happen. For instance, a baker who uses sodium bicarbonate is not interested in understanding the chemical reactions that causes the dough to rise but rather concerned with making leavened dough. On the other hand, a scientist is rather concerned with understanding the chemical reaction that causes the dough to be leavened. Having understood that the leavening of bread is caused by the reaction of sodium bicarbonate with an acidic ingredient such as butter to produce bubbles of carbon (IV) oxide which expands the dough, the scientist may decide to try other reactions which can produce carbon (IV) oxide and consequently more leavening agents are discovered. Hence technology has been defined by some scientist as the application of science.

In recent times, it is becoming increasingly more difficult to classify science into different fields. There seems to be no defining boundary separating the different fields due to their interdependency. In the light of this, interdisciplinary research is gaining popularity as it is not biased towards any field and so reveals the unbiased truth concerning a subject area. Nonetheless, fields of science can be classified into two main groups: Natural and Social Sciences.

- Natural sciences: is the branch of science that studies natural phenomena. Some authors however make distinction between natural science and formal science.

Natural science is seen as the branch of science that studies materials and includes physical science (chemistry, physics and astronomy); biological sciences (microbiology, biology, botany, zoology) and earth science (geology, geography archaeology). Formal science is said to exist only in the mind and include mathematical sciences.

- Social sciences: is the branch of science that studies human behaviour and societies.

Science and Technology in Societal Development

Science and technology are pivotal in the socio-economic development of a nation. Rich nations of the world are known to be highly developed. Such nations include: The United States, Japan and most of Europe. The poor nations are moderately or poorly developed. These countries are often referred to as third world countries or developing countries. Unfortunately, 81% of the total human population lives in these poor nations. Countries in which the average per capital income is below $620 (US) per year are classed as poor countries. Most of these poor countries are found in sub –Saharan African and Asia with Sub- Saharan Africa (Most of these poor nations are found in sub–Saharan Africa).

Irrespective of whether a country is rich or poor, there will always be poor and homeless people who lack resources. However, the number of poor persons to rich persons is low in developed countries while the reverse is the case developing nations. Owing to their affluent lifestyles, people in developed countries consume a disproportionate share in the world's natural resources. More natural resources (energy and materials) are consumed to give them the desired comfort. The rich nations therefore contribute more to pollution and waste generation.

Table 3.1: comparison of developed and developing countries

Developed countries	Developing countries
Highly industrialised with high level of technological know how	Low levels of industrialization and technological backwardness
High per capital income	Low per capital income

Low rates of population growth	Population explosion and high level of dependency
Low mortality rate	High mortality rate
Low rates of unemployment	High rates of unemployment
High Adult literacy	Higher level of illiteracy relative to developed
Improved basic amenities and infrastructure such as water, health care,	Lack of basic amenities

Meaning of Development

Development as a concept has been associated with different meanings by different scholars. However, from the above context, development means the acceleration of economic growth through the creation of goods and services to eradicate poverty reduce inequality and improve the quality of life of a people. Sadly, the use of technology in the creation of goods and services has equally impacted negatively on our environment. Although difficult to assess, human impacts on the environment can be analysed using the **IPAT** model designed by Paul Ehrlich and John Holdren.

Environmental Impact (I) = P x A X T

P= population

A= affluence

T= Technology used to prepare goods and services

From the above formula, it is evident that population, affluence and Technology are three essential factors that affect our environment

Population: The number of persons consuming a given resource has an effect on the environment. Overpopulation often has a negative impact on the environment. Overpopulation can occur as either people overpopulation or consumption overpopulation.

- People overpopulation occurs when too many people consume a resource. Even when there are few resources per person, there is an adverse effect on the environment owing to the large number of persons who consume the resources are few resources per person. This type of overpopulation occurs in developing countries.

- Consumption overpopulation occurs because of affluent lifestyles of people. Consumption is not proportional to the number of persons. Resource consumption per person is high (few persons consume so many resources). Consumption overpopulation has the same effect as people overpopulation

Affluence: this is a measure of the number of resources consumed per person

Technology: The environmental effects of technologies used to obtain and consume the resources. Examples include the amount of waste generated from the consumption and use of resources, the amount of pollution arising from using a technology. The amount of carbon dioxide (a greenhouse gas) that would have been utilized by felled trees

Table 3.2: Illustration on the environmental impact of greenhouse gas CO_2 in people overpopulation and consumption overpopulation

	People Overpopulation	**Consumption Overpopulation**
Population	10000	1000
Affluence	10 persons own a car = 1000 cars	1personown a car = 1000 cars
Technological impact	4.6 metric tons of CO_2 per car/year	4.6 metric tons of CO_2 per car per year
I= PAT	I = 10000 x 1/10 x 4.6 = 4600 metric tons per year	1000 x 10 x 4.6 =4600 metric tons per year

Assuming that a typical vehicle emits 4.6 metric tons of CO_2 per year

Historical Background, Concept and Principles of Sustainable Development

Man in the bid for development has over exploited his environment and has altered the natural balance in the ecosystem. For many centuries, Man has lived with the erroneous impression that the earth has the capacity to accommodate all the waste generated from his activities. However, by the 18th century, concerns were being raised regarding the capacity of the earth's resources to support the needs of the increasing human population, this discourse gained more popularity with the advent of Malthusian population theory. By the 19th century, western societies came to the reality that their economic and social activities have significantly altered environmental and social balances. The followings are some of the major events which took place by the twentieth century:

Socio- economic

- 1907: the American banking crisis
- 1923: the crisis of American hyperinflation
- 1929: the financial crisis of the 1930s begins
- 1968: the worldwide protests against bureaucratic elites
- 1973 and 1979: oil shocks
- 1982: the debt shock of developing countries

Ecological:

- 1952: London smog disease
- 1954: Rongelap nuclear fallout
- 1956: Mercury crisis of Minamata
- 1957: Torrey Canyon oil spill
- 1976: Italian dioxin crisis (Seveso disaster)
- 1984: The union carbide gas link in Bhopal
- 1986: Chernobyl nuclear plant explosion

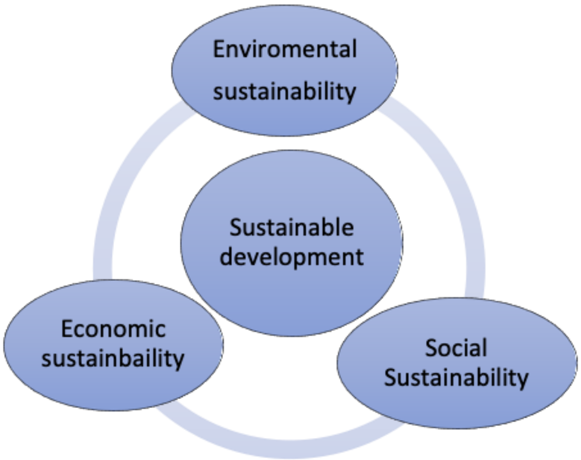
- 1989: Exxon Valdez oil spill
- 1999: Erika disaster

These events shook the world and by 1967 Prof Garrett Hardin released his classic essay on the "Tragedy of the commons".

Sustainability and The Tragedy of the Commons: Prof Garrett Hardin, a professor of human ecology at the University of California- Santa Babara argued that the many environmental problems arise due to the inability to meet short term individual welfare and long-term environmental sustainability and societal welfare. He illustrated using the destruction of the commons (pastureland) by overgrazing. His work and the works of others provoked a lot of scientific research and by 1987 Brundtland released a groundbreaking report on sustainable development. Sustainable development was defined by the Brundtland commission as:

- "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

In the light of the above, nations should not pursue economic growth and industrial development at the detriment of the natural environment. This is because the careless and uncontrolled use of technology and resources may lead to the extinction of the earth itself as evident in the rising number of environmental problems such as global warming and climate change, ozone depletion, deforestation. Developments should thus not be aimed solely at eradicating poverty and improving the quality-of-life people but should also be geared at preserving the natural environment for the continued existence of the earth while meeting the needs of the present. Sustainable developments should be encompassing and transcends beyond science and technology. For true sustainability, the benefits of developments should be available to all and not to a few privileged persons. This can only be achieved through political stability, democracy and equitable economic distribution. Based on the concerns of sustainable development, the three **pillars of sustainable development** are: economic sustainability, environmental sustainability and social



sustainability

Fig 3.3: Pillars of Sustainable Development

Goals of Sustainable Development: In September 2015 the General assembly, building on the principle of "leaving no one behind", adopted the 2030 agenda for sustainable development. The following are the seventeen (17) Sustainable development goals of the 2030 agenda.

Fig 3.4: Sustainable Development Goals for 2030 Agenda

Energy Resources and Sustainability: Energy is the driving force for all the processes that occur in the universe. Energy is needed in every sector of life, ranging from cellular processes such as photosynthesis to other areas such as transportation, agriculture, industry, domestic lighting and heating. It is thus a very crucial tool for development. Notwithstanding our energy consumption has a negative effect on our environment. For sustainability energy should be cheap, available, safe, versatile and environmentally friendly. Man's energy resources can be classified under two broad headings: Renewable and Non-Renewable energy resources.

(i) **Renewable energy resources** are those resources which can be renewed or replaced over time. Renewable energy resources are in continuous supplies and examples are wind, energy, biomass sunlight, tides and geothermal energy resources. Geothermal is the source of energy which is extracted from the heat which is stored under the surface of the Earth. This source is considered to be cost efficient. It is found in the form of inactive volcanic sites and hot springs. This form of energy may be utilised in heating, generating electricity, and heat pumps. Geothermal energy is a sustainable source as the hot water seeps down into the crust again. Plant or animal material used for energy production or various industrial processes as raw substance for a range of product is often referred to as biomass. Biomass is also considered a renewable resource if used properly

(ii) **Non-renewable Energy Resources:** are those natural resources which are slowly replenished or cannot be renewed once they are completely consumed. The best examples of non-renewable resources are fossil fuels such as coal, oil, and natural gases. Fossil fuels are produced by the decay of animal and plant matter. Their rate of production is very slow as compared to the rate of their extraction and consumption. Most of the world's energy consumption is from fossil fuel. Fossil fuel is very versatile; it can be used for diesel, jet fuel and gasoline. However, it is non-renewable and generates pollutants. Other examples of non-renewable resources are nuclear fuels, minerals, and shale. Water is a controversial resource which can be categorized as both a renewable and non-renewable resource. The cyclic change of water makes it a renewable resource while its unmanaged usage is makes it non-renewable.

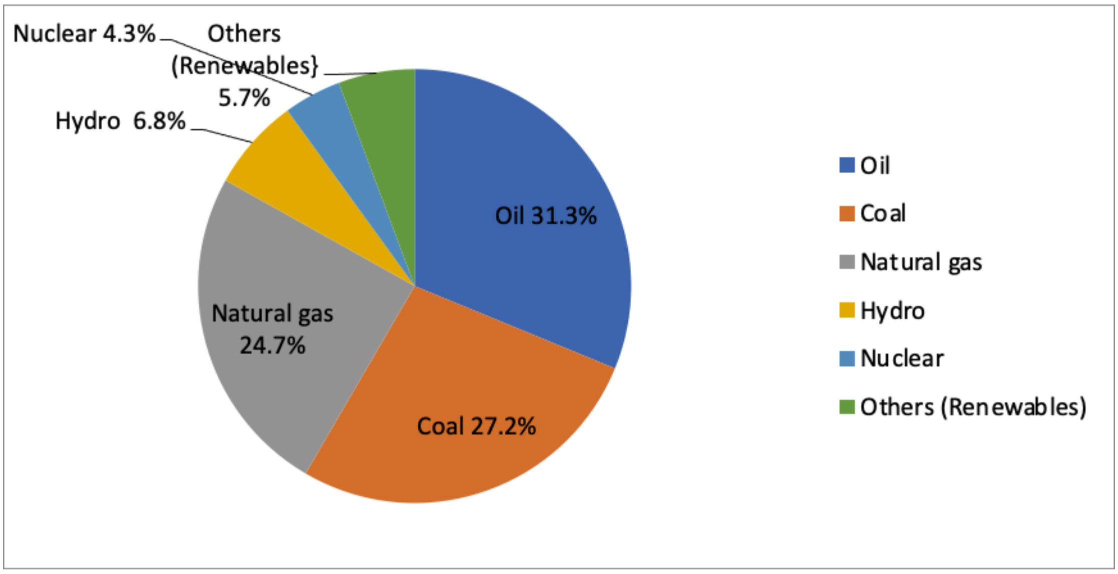


Fig 3.5: Worldwide primary energy consumption in 2020 (Source: Statistical Review of world Energy 2021)

World energy consumption is on the increase, and it will further rise as the human population continues to increase. The increase is however not uniform throughout the world. Similarly, the impact of our technology is not uniform throughout the world. China is known as the world's largest emitter of carbon dioxide (CO_2 a major pollutant and greenhouse gas). Once these pollutants are emitted, there is no boundary as the effects are felt globally.

Energy Efficiency and Conservation: One of the key approaches of achieving sustainable energy is to increase energy efficiency and conserve energy. Energy efficiency is a measure of the amount of available energy that is transformed into work while energy conservation is using lesser energy through changing our lifestyles. In other words, energy efficiency is getting the same energy service while using less energy. In achieving energy efficiency, there should be technological innovation. Machines should be designed to use lesser fuels but do the same amount of work it ordinarily would do if were originally designed to use more fuels. Conservation measures include walking rather than driving, opening windows and doors rather than air conditioners and fan, lesser lightings. The main goal of energy efficiency and conservation is to reduce energy consumption, reduce pollution, save money, reduce cost and reliance on foreign energy resources.

Future Energy: Currently, conventional fossil fuels (oil, coal and natural gas) are predominantly our major source of energy. Fossil fuel is however non-renewable, and the huge amount of fossil fuels being burnt is generating serious negative environmental impact. In addition, the geopolitical and economic problems arising from the use of fossil fuels makes fossil fuel an unsustainable source of energy. In this regards, renewable energy is beginning to gain popularity as an alternative to fossil fuels. Many developed countries are already developing this alternative energy. Currently, China is leading in renewable energy and China's successes will most likely impact positively on our global climate creating an inroad for cleaner energy technologies. Although many energy sources have been described as clean, no energy is sustainable rather each energy source varies in their advantages and disadvantages. Despite the challenges in the use of renewable energy, it has been suggested that renewable energy have the potential of providing all the needed energy. It is hoped that renewable energy will meet future needs more economically and safely than fossil fuels. To this end, research should be heightened in developing renewable energy. In addition, sound policies should be put in place by the government to promote renewable energy, energy efficiency and conservation.

Table 3.3: Some advantages and Disadvantages of the different Sources of Energy

Source	**Geographic Distribution**	**Application**	**Advantage**	**Disadvantage**
Oil	Found in limited number of countries	Highly versatile, can be used heating, cooking, transportation and industry.	Can be easily transported	Non- renewable. Releases pollutants during combustion. Refining can be cumbers ome. Accidental spills during transportation. Risk is high as it is Inflammable. Political conflicts over oil supply.
Natural gas	Found in limited number of countries	Versatile, can be used heating, cooking, transportation and industry.	Cleaner combustion. Can be transported	Explosive and constitute risk during handling. Non-renewable.

Coal	Found in limited number of countries	Versatile, can be used heating, cooking, transportation and industry.	Fuel can be transported. Coal resources are vast.	Non-renewable. Does not burn cleanly. Releases huge amounts of pollutants (sulphur, nitrogen soot). Contains toxic impuritie s such as heavy metals. Coal mining is dirty and dangerous, power plant failure can lead to death
Nuclear	Chief source is uranium. Found in limited number of places	Used to generate electricity	Can be moved but must be used in a fixed location. Release of Pollutants is low.	Contain radioactive materials and so is Hazardous to handle. Energy is difficult to store. Waste is difficult to manage. Rapidly increasing production cost. Susceptibility to terror attack.
Solar photovoltaic	Widely available	Used to generate electricity	Widely available. Renewable.	Seasonal and daily variability. Requires equipment that is expensive and environmentally harmful to produce. Low intensity.
Wind	Available in all countries	Mostly used to generate electricity. Can sometimes be used as mechanical energy to do	Low risk in handling Renewable.	Seasonal and unpredictable variability

		work		
Geothermal	Available in most countries	Used for generating electricity and heat	Renewable. Low risk	Cannot be moved
Hydro	Found in limited number of countries	Mostly for electricity but sometimes used as mechanical energy		Cannot be moved/ Dams destroy biodiversity and could cause permanent disruption of upstream and downstream ecosystem
Biomass	Widely available as woods, oil palm fruit, corn, soybean, algae, waste product of plant and animal tissues, saw dust, sewage treatment plant and landfills	Used to generate Heat, electricity, automobile fuels	Risk of handling is low. Renewable. Methane is a clean fuel	Deforestation, soil erosion and desertificati on . The burning of wood releases of oxides of carbon. Requires large amount of water. Competition between food and energy. Methane is a powerful agent of atmospheric warming

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CHAPTER 4
AN OVERVIEW OF CHEMISTRY AND ITS ROLE IN SOCIETAL DEVELOPMENT

R.A. Adedokun & S.O. Ogungbesan

Introduction

Chemistry is the study of matter and the changes it undergoes. It thus studies the composition, properties and interactions of matter within itself and other matter. Matter itself can be defined as; anything that has mass and occupies space. Matter includes both natural and man-made things (such as vegetation, automobiles, animals) that can be seen and touched as well as unseen things such as air. Therefore, it is indeed true that Chemistry studies everything in the universe and hence the knowledge of chemistry is thus essential in all scientific disciplines. Founded on the above premise, chemistry is referred to as a central science.

Based on the composition, properties and interaction of matter, chemists have been able to study and design materials with diverse applications across various disciplines. Indeed, Chemistry has contributed significantly to the rapid boom of modern-day technology and will continue to be relevant as new materials with superior properties and functionalities are being designed. These materials among others include drugs, pesticides, fertilizers, textiles, plastics and so on.

Matter and its Classification

What is Matter?

Matter as earlier defined is anything that has mass and occupies space. Matter can be described by its physical and chemical properties. A ***physical property*** is one which can be observed and measured without changing the composition of matter. Examples of physical properties are colour, taste, smell. A **chemical property** is observed when matter undergoes a change in its composition. For example, iron will react with moist air to form rust. This reaction describes a chemical property of iron. Based on the physical state in which matter exists, it can be basically classified as solid, liquid or gas. Other states of matter include the plasma and Bose-Einstein condensate. Matter can undergo a change in its physical or chemical properties. A change in which only alters the physical state of matter without changing its composition is known as a physical change. A ***physical change*** is reversible. For example, ice can melt into liquid water. Ice and water only differ in state but not composition and so the change can be reversed by freezing the water back to ice. A ***chemical change*** is one that causes a change in the composition of matter. A chemical change is irreversible. For example, iron rust cannot be converted back to iron by any physical change. Despite the changes matter undergoes, it cannot be created or destroyed in ordinary chemical reaction. This phenomenon is referred to as the ***law of conservation of matter***. In addition, matter can be classified into subcategories such as substance, elements, compound and mixtures.

Substance: a substance is a form of matter that has a definite composition and distinct property. A substance is homogenous and differs in composition from other substances. A substance and can be identified by its properties. A substance can either be an element or a compound. Substances are made up of elementary particles such as atoms, molecules, ions and photons. Chemists count number of substances using the ***mole*** just as we can count items using dozen, score, gross. There are 6.02×10^{23} elementary particles called in a mole.

Elements: An element is a substance that cannot be separated into simpler substances by any known chemical process. For example: oxygen, hydrogen and gold. Chemists use chemical symbols to identify the different elements. Chemical symbols consist of either one or two letters. When one letter is used it is in the upper case and when two letters are used, the first letter is in upper case and the second in lower case. For example, the symbol for oxygen is O and gold is Au (Au is from the Latin word Aurum). To date, chemists have identified 117 elements. Most of them occur naturally but some have been artificially created via nuclear reactions. The smallest unit of an element that can take part in chemical reaction is known as an ***atom***. Atoms of the same or different elements can combine to form ***molecules*** or c***ompounds*.** A molecule is two or more atoms held together by a chemical bond. The atoms can be atoms of the same or different element

Compound: A compound is made of two or more elements chemically combined. For instance, one atom of oxygen can combine with two atoms of hydrogen to form water. Regardless of where water is collected, provided it is pure, its constituent elements will always be oxygen and water combined in the ratio of 2 parts of hydrogen to a part of oxygen. This is phenomenon is known as the **law of constant (definite) composition**. Similarly, just like elements, compounds are written using the symbols of all the elements that constitute the compound. This is called the chemical formula of the compound. The formula for the molecular compound water is H_2O while the formula for Chlorine molecule is Cl_2). The numerals written as subscript indicate the number of atoms of each of the elements involved in the formation of the bond. (When one atom is involved, the numeral 1 is ignored in the formula). The elemental components of a compound can only be separated by chemical means.

Mixture: A mixture is the combination of two or more substances in which the substances retain their distinct identities. The different substances present in a mixture can be separated using physical means such as sieving, filtration, centrifugation, distillation, fractional distillation, crystallization, and evaporation. Examples of mixtures are air, sugar dissolved in water, starch and sand. Unlike compounds, mixtures do not have a constant composition and cannot be written with chemical formula but can however be homogenous or heterogeneous. For instance, there is no constant amount of sugar that can be in a mixture of sugar and water. Likewise, air samples collected in different places vary in composition. A homogeneous mixture is also called a solution. The composition of a homogenous mixture is uniform throughout the sample. An example of a ***homogenous mixture*** is a solution of sugar dissolved in water. In as much as the solution is properly mixed, the amount of sugar in every drop of the solution is the same. In a homogeneous mixture the substance that is present in larger amount is called the ***solvent*** while the substance(s) that is present in lesser amount and dissolves in the solvent is called the ***solute***. A ***heterogeneous mixture*** is one in which the composition is not uniform throughout the sample. An example of a heterogeneous mixture is a mixture of sand and flour.

Chemical equations: The chemical changes that substances undergo can be written using chemical equations. In a chemical equation the reactants and products are separated by an arrow. The reactants are the substances that are changed while the products are the substances that are formed. The reactants are written on the left and the products on the right.

Reactants $\longrightarrow$ Products

Below is the chemical equation to show the rusting of iron.

$$4Fe + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3 \qquad \textbf{Equation 4.1}$$

(Where Fe = iron, O_2 = molecular oxygen H_2O = water and Fe $(OH)_4$ is rust. The coefficients 4, 3 and 6 are the amounts of substances in moles**)**

Traditional Areas in Chemistry

Strictly separating chemistry into different areas is practically impossible because all the areas are interwoven. Nonetheless chemistry can be arbitrarily divided five traditional areas: organic chemistry, inorganic chemistry, physical chemistry, analytical chemistry and biochemistry. Other areas of chemistry include environmental chemistry, forensic chemistry, medicinal and pharmaceutical chemistry, food chemistry, industrial chemistry, chemical engineering and so many others.

Organic chemistry: This area of chemistry studies compounds of carbon, their synthesis, reactions and applications. Most of the compounds found in living cells are organic compounds. In the eighteenth –century, Chemists used the word “organic “to refer to substances obtained from living sources. Before 1828, it was believed that only living things possess the vital force to produce organic substances. However, in 1828, Fredrich Wohler, a German chemist synthesised urea, an organic compound from inorganic substances thereby disproving the hypothetical force. Today, over 14 million natural and synthesised organic compounds are known. The compounds of carbon are by far greater than the compounds formed by all the other elements put together.

Inorganic Chemistry: Except for carbon and its compounds, inorganic chemistry studies the composition, synthesis and application of other elements and their compounds. However, compounds of carbon such as calcium carbonate, carbon monoxide, carbon dioxide, cyanide ion, and carbides of carbon are studied in inorganic chemistry. Inorganic substances occur in nature and can also be synthesised in the laboratory. Inorganic substances are most found in rocks and minerals.

Physical Chemistry: This is the area of chemistry that studies the atomic, molecular and macroscopic properties of substances as well as phenomenon that occur in chemical systems be it organic or inorganic. Description of matter at the atomic and molecular levels cannot be perceived by human senses because there are far too small (microscopic) to be seen. Such descriptions are however possible using sophisticated instruments. When the number of atoms, ions and molecules is large enough to be seen by the naked eye, we can describe matter in terms of its macroscopic property such as density, volume, temperature, viscosity and pressure. The macroscopic property of matter is a consequence of its microscopic properties. A physical chemist can study the feasibility and rate of chemical reactions as well as the energy transfer involved in a reaction to design chemical reactors with optimum efficiency. Today, nanomaterials with novel applications are being fabricated by controlling and manipulating matter at atomic and molecular levels. These nanomaterials have novel properties and are being used for diverse application in the fields of medicine, agriculture, textile and consumer products.

Analytical Chemistry: Is the area of chemistry that characterises the composition of matter both qualitatively and quantitatively. In other words, it studies the chemical constituent of a substance and in what amount the constituents are present. Analytical chemistry is also that branch of chemistry that is concerned with discovering new methods of characterizing samples as well improving on existing methods of carrying out chemical analysis. An analytical chemist basically carries out chemical analysis to answers two pertinent questions.

What is the constituent of a sample of a substance? (Qualitative analysis)

How much of each of the constituent is present in the sample? (Quantitative analysis)

Biochemistry: Though sometimes considered as a distinct discipline on its own, biochemistry studies chemical processes that occur in living things both at the cellular and molecular processes. It explores the chemistry of living cells and uses the methods of chemistry to explain the structure, mechanism, function of biomolecules. It also explains the molecular basis of changes that occur in living cells. Biochemistry is fundamental to the understanding of all biological processes and so provides explanation for the causes of diseases and how such diseases can be treated.

Nanotechnology

Nanotechnology is a broad and interdisciplinary area in science and technology that has integrated several disciplines such as chemistry, physics, biology engineering and material science. It is an emerging field that is revolutionizing the fabrication of material substances. An example of this revolution is the size reduction of electronic devices. Nanotechnology can be defined as the synthesis, engineering and application of devices and materials whose particle sizes are in the nanoscale range. At the nanoscale range materials exhibit unique optical magnetic, electrical and chemical properties that make them superior to their bulk forms. Most authors limit this range to 1- 100 nm. This is because, for some materials, above these range some physical properties of nanoparticles approaches that of the bulk. A nanometre (nm) is one-billionth of a meter. 1 nm is approximately 100,000 times smaller than the diameter of human hair. Materials fabricated with at least one dimension less than 100 nanometres are known as nanomaterials.

Although nanotechnology is a relatively new field of research that has become increasingly relevant in the last few decades, nanomaterials are not present-day inventions. Nanoscale materials occur naturally in volcanic ash, seashells, nano-scopic wax in the epidermal cell of lotus leaf and others. Nanomaterials were produced and used by early humans particularly artisans. Examples include cementite nanowires observed in Damascus steel, silver and copper nanoparticles used in the Middle Ages and Renaissance for glazing. Much attention was however not given to the sizes of these nanoscale material until after the invention of sophisticated instruments such as scanning electron tunnelling microscope, the discovery of fullerene and the and the popularisation of conceptual frame works by notable scientists. One of such conceptual frameworks is that of Richard Feynman.

On December 29, 1959, Richard Feynman at the annual meeting of the American Physical Society held at the California Institute of Technology presented his famous lecture on “there’s plenty room at the bottom”. He suggested that in principle it was possible to manipulate and control things on a small scale by precisely manipulating atoms and molecules. He envisioned nanoscale machines that would arrange atoms down to the desired scale. It was not until after the invention of scanning tunnelling microscope and notable works from Eric Drexler and Norio Tanigushi that is speech began to gain popularity. Today he is arguable thought of to be the first scientist to conceptualise nanotechnology even though he did not explicitly used the term nanotechnology. The term nanotechnology was first used in 1924 by Norio Tanugushi to describe semi- conductor processes

Nanoscale materials are of interest because a wide variety of novel applications arises because of their unique properties. Their applications cut through diverse physical, chemical and biological processes hence there are becoming extremely versatile tools in the areas of medicine, energy storage, data storage catalysis electronics, environmental remediation and others. Nanomaterials have thus become commercially important and are found in cosmetics, sunscreen clothing, scratch resistant coating, self-cleaning glass, stain resistant clothing, and so on. They are equally extensively used in medicine for the purpose of diagnosis, drug delivery and imaging and wound dressing.

Synthesis of Nanoparticles

Although nanomaterials exist in nature and can be accidentally produced as by-products of some processes, engineered nanomaterials are mostly of interest in the fabrication of materials. Nanomaterials are developed from nanoparticles. Examples of some commonly synthesized nanoparticles are carbon nanotubes, metal and metal oxide nanotubes (some of which can be used as nanofertilizers and antimicrobial agents), ceramic nanoparticles polymeric and lipid –based nanoparticles. Nanoparticles can be synthesised using physical, chemical or biological methods. There are two approaches used in the fabrication of nanomaterials. The approaches are the top-down and bottom-up approaches. In general, compared, to the bottom-up, the top-down method has the advantage of having higher yield however the surface of the nanoparticles may have some imperfections. On the other hand, particles of uniform sizes and desired morphology can be prepared using the bottom-up approach; however, the yield is low. The method used is therefore basically determined by the property of the nanoparticle desired.

The physical method usually uses both approaches. In the top-down approach, bulk materials are disassembled through mechanical means into finer forms. The limitation with physical method is that it is difficult to control the particle size and morphology of the nanoparticles. The bottom-up method utilises the ability of atoms or simple molecules to self-assemble. Physical methods used in the bottom-up approach include laser ablation, inert gas condensation, vacuum sputtering, ultra sonification. Chemical methods include co-precipitation, chemical reduction, sol- gel process hydrothermal and pyrolysis. Chemical method of synthesis may involve the use of hazardous chemicals and reagents or may generate hazardous by-products during synthesis. This of course limits the use of chemical synthesis. In recent times for reasons for sustainability biological synthesis and biomolecule mediated fabrication of nanoparticles have gained considerable attention. Biological synthesis which is otherwise referred to as biogenic synthesis is a green chemistry approach of synthesis. Biological synthesis is a bottom- up approach to that employs various organisms such as fungi, yeast, bacteria, microalgae, actinomycetes and plants to synthesise nanoparticles. Biogenic synthesis is sustainable method because it has the advantage of being eco-friendly, cost effective and biocompatible. In addition, biogenic synthesis does not require the use of hazardous materials and high energy consumption. The size and morphology of nanoparticles can be controlled by optimizing abiotic factors such as temperature and pH. Despite the merits in the biological method of synthesis, challenges such as time intensive purification step, optimisation of experimental conditions and unclear mechanism of synthesis limits its applicability. Intensive research is therefore needed to expand its applicability.

Petroleum and Petrochemical Industry

Petroleum is a complex mixture of hydrocarbons formed from fossil remains. Although its composition varies, petroleum is predominantly composed of hydrocarbons (hydrocarbons are compounds consisting of hydrogen and carbon only) and variable amounts of oxygen and sulphur. In addition, it may also contain trace amount of other elements such as nitrogen and argon. Petroleum occurs deep underground or below seabed and exists in all three states of matter: oil shale (solid), crude oil (liquid) and natural gas (gas). However, most times crude oil is generally called petroleum. Crude oil is found in different parts of the world. The major producers include Nigeria, United State, Canada Mexico and the Middle East. Natural gas is predominantly methane and may occur in association with crude oil or separately. Other constituents of natural gas are ethane, propane and butane, iso-butane, nitrogen, carbon dioxide and hydrogen sulphide. Natural gas may also contain trace amounts of argon, hydrogen and helium. The basic types of gaseous fuel are oil gas, reformed propane or liquefied petroleum gas (LPG) and reformed natural gas.

The demand for useful commercial petroleum products which are obtained from the bulk fractions of petroleum is on the increase. Petroleum products are used as fuels (gasoline, aviation fuel, diesel and others), lubricants, asphalt and in the production of petrochemicals. It is estimated that one- third to one-half of worldwide energy consumption is based on petroleum. In the past, gaseous hydrocarbons obtained as by-products of petroleum refining were not considered very important and so were burnt off. However, these gaseous hydrocarbons are now being collected and used as important petrochemicals. In the strict sense, petrochemicals are chemicals derived from petroleum and natural gas. In this regard, a chemical having the same chemical composition with a petrochemical but from a nonpetroleum source is not considered a petrochemical. For instance, ethanol obtained from plant biomass is not a petrochemical. Petrochemicals are predominantly hydrocarbons such as the heavier hydrocarbons (for example: styrene, benzene and toluene) and the light/gaseous hydrocarbons (for example: methane, ethane, butane, iso- butane and pentane). Nonetheless other petroleum derivatives that are not hydrocarbons such as ammonia, sulphur and oxides of carbon are also referred to as petrochemicals. In contrast to petroleum products which contain bulk fractions derived from petroleum, petrochemicals are individual chemicals used as building or starting materials in other industries. The petrochemical industry provides raw materials to produce virtually all consumer products such as textile, plastic, paint, adhesives, packaging materials, pharmaceutical bulk drugs, industrial appliances, solvent and detergents. The starting material used to produce petrochemicals is called feed stock. Feedstock is a raw material that is obtained directly from petroleum either by distillation, thermal and catalytic processing of crude oil. Based on the raw materials and method of processing, petrochemicals can be classified as first, second and third generation petrochemicals.

First Generation Petrochemicals: petrochemicals obtained directly from feedstock are referred to as primary petrochemicals. Primary petrochemicals are used in the production of intermediate petrochemicals.

Second Generation (Intermediates) petrochemicals and derivatives: intermediates are obtained from further processing of primary petrochemicals. Intermediate petrochemicals can be further processed to useful end products which are referred to as **third generation petrochemicals**. The conversion of petroleum into daily consumer products can be summarized as illustrated in the figure below:

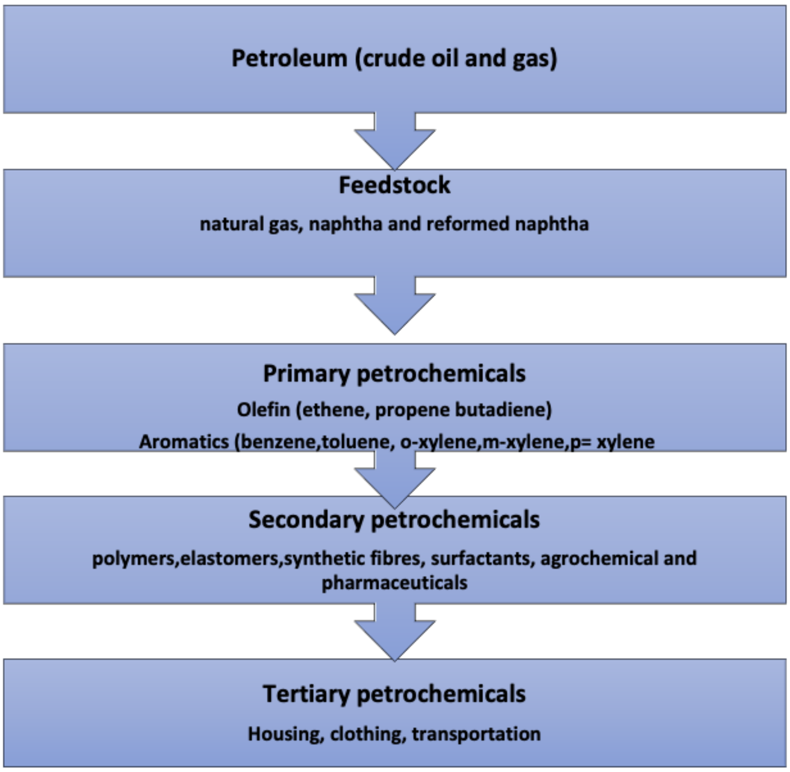


Fig. 4.1 Relationship between petroleum and the useful end products

Plastic Industry

Following the aftermath of the large-scale production of plastic in the 1950s, plastics have become an integral part of our society owing to their extensive applications in areas such as packaging, building and constructions, medical tools and devices, electrical wirings and insulations. Plastics are usually synthetic and made from petrochemicals. Synthetic plastics unlike conventional materials possess desirable properties such as strength, low cost, longevity and good barrier properties hence the commercial production of these plastic has continued to increase despite their disposal problems. These commercially important plastics include polyethylene (PE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), polypropylene (PP), polyurethane (PUR) and polyamide (PA). Although versatile, the usage and disposal of these synthetic plastics is not sustainable. This stems from the fact that these plastics are difficult to degrade and cause serious waste disposal problems. This property of plastics raises environmental and health concerns as harmful plastic chemicals may be released in soils and water. It is in this regard that biodegradable plastics such as polyhydroxyalkanoates (PHA), polycaprolactone (PCL) and polylactic acid (PLA) are arising as an emerging eco-friendly alternative, however these biodegradable plastics may take over thirty years to degrade. Biodegradable plastics are made from biomass such as cellulose, starch and chitosan. The term biomass refers to plant or animal (organic) materials that are used for energy production or various industrial processes as raw materials for a wide range of products. Plastic is made by a process known as polymerisation. Polymerisation is a process whereby small molecules (which are referred to as monomers) under suitable conditions join to form giant molecules (which are referred to as polymers).

Textile Industry: The textile industry is large and contributes substantially to the economy of many nations. It encompasses the production of natural and synthetic fibres. Natural fibres such as cotton, wool, linen, jute, and silk can be obtained from plant and animal sources while asbestos can be obtained from minerals. On the other hand, synthetic fibres are made from petrochemicals. The textile industry is diverse and uses materials such as polymers, dyes, Mordants, defoamers, Soaps and detergent during fibre, textile and clothing production. Owing to the nature of chemicals associated with the textile industry, the textile industry is a major contributor to soil, air and water pollution. The operations used in the production and usages of textiles require large volumes of water thus effluents generated from textile production constitute the major source of pollution as such effluents contain potentially harmful substances such as:

- Heavy metals from dyeing and printing processes
- Salts surfactants, metal ions and complexes, emulsifiers, organic chemicals, biocides and toxic anions during bleaching and laundry

It is therefore necessary to treat effluent from textile industries before discharge into the environment. The second most important source of pollution from textile production and application is the emission of hazardous air pollutants from boilers, storage tanks, ovens and spills. Other concerns bothering on the sustainability of the textile industry include:

- High energy consumption during processing of fibres
- Low biodegradation of fibres particularly the synthetic fibres
- The use of pesticides and herbicides during the cultivation of natural fibres

Paint Industry: Paint is a stable mixture of one or more suspended colouring material (pigment). The basic functions of paint are to impart colour and protective coating for the material to which it is applied. Paints are also used to improve the aesthetic property of a material. The main constituents of paint are the pigments (which is the colouring material and the solid portion) and the vehicle (liquid portion).

The pigment is the colouring material and constitutes the solid portion of the paint. Most pigments are inorganic and insoluble in the vehicle. Pigments can be obtained naturally or through synthesis. Below are some important pigments used in the production of paints.

Colour	**Example of pigment**
White	Titanium dioxide, zinc oxide, white lead zinc sulphide, antimony (III) oxide, calcium carbonate, barium sulphate, talc (hydrated magnesium silicate) , china clay (hydrated aluminium silicate), silica and basic lead carbonate
Red	Iron oxides, cadmium red and lead red
Blue	Cobalt blue, Prussian blue
Green	Chromium oxide and chrome green
Yellow	Lead chromate
Black	Carbon black, lamp black and furnace black
Metallic	Zinc dust, copper powder and powdered aluminium metal

Owing to their toxic nature, the heavy metal based inorganic pigments (such as lead, chromium and cadmium are being replaced by bismuth, vanadate and cerium sulphides and less toxic heavy metals such as zinc.

The vehicle constitutes the liquid portion of the paint and basically consists of binders and thinners. Binders fix the paints to the coated material and give the paint its adhesive, glossy, hardness and drying properties. Examples are drying and semi drying oils such as linseed oil, soybean oil and castor oil. The classification of oils into drying and semi drying oils is dependent on the siccative (drying) property of the oil which is in turn determined by the iodine value. Oils with iodine number greater than 130 are drying oils while those with iodine number within 115 to 130 are semi drying oils. Over the years, the need for drying oils have declined as alkyd, epoxy and acrylate resins have emerged as better alternatives. The thinner is the volatile portion of the vehicle and it allows for easier handling of the paint. Examples of thinners are mineral spirit and turpentine. For reasons of sustainability, it is required that organic solvents should be minimal in paint formulations to reduce the emission of volatile hydrocarbons. Other materials which can be added to achieve some other desirable properties in the paint mixture include fillers, dryers, plasticisers, anti-skinning agents and antifoaming agents. Paints are formulated according to the end use. Based on these formulations the different types of paints include primers, emulsions, gloss, enamel and lacquer.

Glass Industry

Glass is a non-crystalline amorphous solid that is transparent. The application of glass is diverse and varied. This ranges from simple (such as window panels, bottles) to technological applications such as optoelectronic and photosensitive glass. However, the oldest and commonest are the silicate glass. Silicate glass is made by using heat energy to melt sand, limestone and sodium soda ash in a furnace at temperatures over 1000^0C. The basic chemical constituent present in sand, limestone and soda ash which react to form glass are silica (SiO_2), calcium carbonate ($CaCO_3$) and sodium carbonate (Na_2CO_3) respectively. The heating is continued until the glass melt is free of gases such as carbon dioxide that evolved during the process.

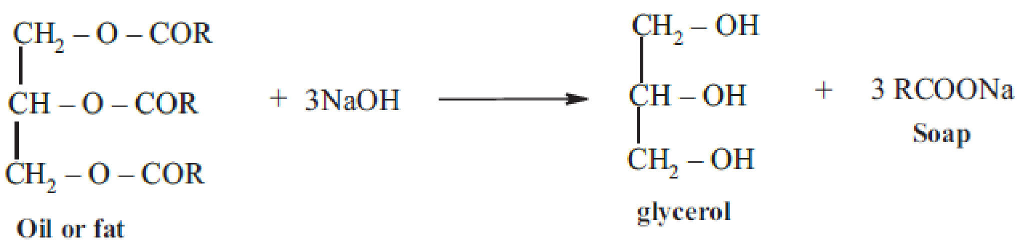
$$CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2$$

$$Na_2CO_3 + SiO_2 \longrightarrow NaSiO_3 + CO_2$$

The molten glass obtained is poured into moulds where there are shaped into sheets, rods, wires and tubes. After shaping the glass are slowly cooled as rapid cooling would make the glass crack easily. This process of gradual cooling down of the molten glass is known as *annealing* and it occurs in special chambers. After annealing the glass is subjected to finishing such as cleaning grinding and polishing. Decolorizing agents such as cerium oxide can be added to neutralize undesired colours. The physical and chemical properties of glass are dependent on type and proportion of materials used its production of glass. Examples of some silicate glass are soda-lime -silica glass, borosilicate (Pyrex) glass, armoured and fused quartz glass.

Soap and Detergent Industry

Soap and detergent are cleansing agents are used on daily basis by almost everyone whether rich or poor. It is thus a major chemical industry. Earliest evidence of soap making dates as early as 2800 BC in ancient Babylon. The Latin word Sapo is cognate for the Latin sebum tallow. Soaps are chemically sodium or potassium salts of long chain fatty acid made primarily made the hydrolysis of fatty by alkali. The emulsification of fatty acid and alkali results in the formation of soap and glycerol. The process described above is known as *saponification*. The period it takes for complete process of saponification to take place is known as the curing period. Fatty acids are obtained from fats and oils. The alkali (lye) used is usually caustic soda (sodium hydroxide) or caustic potash (potassium hydroxide). Harder soaps are made using caustic soda (NaOH) while caustic potash gives softer soaps. Essential oils and fragrance can be added to the oils just before it reacts with lye while other additives depending on how it affects the soap mixture can be added in trace amounts just as the soap begins to thicken. To have soaps of suitable pH, it is important to obtain the saponification value of any oil used from saponification charts. The right amounts of lye to add is then calculated based on the saponification value of the oil. This is because using lesser than required amount of oil will result in soaps with high pH as the oil will not be sufficient to react the alkali. This can lead to skin irritation and burns. Soap is usually formulated with 4-10 % less lye than the calculated value. This is done so that there will be little oil for skin conditioning.



Where R = alkyl group of 11-17 carbon atoms

Until the industrial revolution soap making was conducted on small scale but today soap making is done on large scale. However, the small-scale production is usually done in batches using either the cold, semi hot or hot processes. In the cold process, heating is not necessarily required. However little heating may be needed to melt the fat before it reacts with the acid. The hot process requires heating during the emulsification process. Heating speeds up the saponification process hence soaps prepared using the hot process takes lesser time to cure. Soap is precipitated (precipitation is a separation technique) from the mixture by adding salt while the excess liquid (spent hydroxide solution) together with the impurities is discarded. This process is known as *salting out*. The hot *neat soap* obtained is then poured into moulds and allowed to continue the process of saponification while glycerine can be recovered from the spent hydroxide. On industrial scale the hot process is used. However, the neat soap is further dried using spray driers and vacuum dryers and then compacted into pellets or noodles.

Detergents are synthetic cleansing agent consisting chemically of long – chain alkyl hydrogen sulphate or sodium salts of long –chain alkyl benzene sulphonic acid. The long chain alkyl sulphonated groups are obtained from petrochemicals unlike soaps in which the alkyl groups are obtained naturally from fats and oils. One advantage of detergents is that they lather in hard water better than soaps and as such are preferable during laundry.

Chemistry in Medicine and pharmacy: Living cells are formed by molecules and these cells themselves can be considered as metabolic factories in which complex biochemical reactions occur. Since chemists are interested in matter at atomic, molecular and bulk levels, they are also interested in the cellular reactions taking place in living cells to improve human well-being. Chemistry being a central science has contributed significantly to the development of medicine. Research in the various fields of chemistry such as Biochemistry, medicinal chemistry, polymer chemistry and nuclear has helped in the design of drugs, diagnostic kits, surgical materials and disinfectants. Chemists have over the years extracted and isolated active phytochemicals from medicinal plants which are now being synthesised by chemists in the laboratory. A good understanding of chemistry is needed to understand the chemical constituent of biomolecules including the reactions of this biomolecules in living cells. Chemists play a key role in clinical laboratory testing, employing techniques used in chemical analysis. Some specific applications of chemistry in the field of medicine are listed below:

- Cis- Diamminedichloroplatinum (II) (commonly called Cisplatin) is used as an anti-cancer drug to inhibit the growth of cancerous cells
- The dye fluorescein is used in fluorescein angiography. In fact, the medical term derives its name from the dye fluorescein.

- Barium meal which consists of barium sulphate is used in the diagnosis of ulcer
- Antacids such as magnesium trisilicate (mist mag), milk of magnesia (magnesium hydroxide; $Mg(OH)_2$), sodium bicarbonate is used to treat occasional constipation and acid imbalance in the stomach
- Iodine -131, a radioactive isotope of iodine is used in the treatment of goitre and thyroid cancer
- Quinine is used to treat malaria
- The knowledge of chemistry has been used in producing a biomolecule (insulin) which is used in the treatment of diabetes
- Luminescent pigments and florescent dyes are used in making tamper- proof seals and brand protection for pharmaceutical and other products.

Chemistry in Agriculture

Chemistry has been vital to most of the development made in agriculture. The process itself by which plants make their food is a photochemical reaction called *photosynthesis*. Photosynthesis is a chemical reaction in which plants use carbon dioxide and water to form glucose (food) and oxygen in the presence of sunlight. In other words, light energy is converted into chemical energy. Photosynthesis occurs in the chloroplast of plant cell which is concentrated particularly in the parenchyma cells of leaf mesophyll. The chloroplast contains a complex molecule called *chlorophyll*, which enables plants to trap sunlight energy. This reaction can be shown using the chemical equation below.

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$$

Several research on the above photochemical reaction have enabled the maximization of plant yield. Plants generally need mineral nutrients (elements obtained from soil) and non-mineral elements for their growth and development. Soil nutrients or mineral nutrients are essential elements which are present in soil solution for uptake by plants. Nutrients can be broadly classified as macro and micronutrients. Macro nutrients control cellular processes and are needed in relatively large amounts for building large molecules which play important roles in photosynthesis, respiration, transport and storage of food. The three primary macro nutrients are nitrogen (N), phosphorus (P) and potassium (K) while the secondary macro nutrients are calcium, sulphur and magnesium. Micronutrients that are needed in trace amounts to drive reactions in plant. The micronutrients are iron (Fe), molybdenum (Mo), boron (B), manganese (Mn), copper (Cu), zinc (Zn), nickel (Ni) and chlorine (Cl). A fertile soil should therefore have all these nutrients in the right proportion. Once any of these nutrients (either macro or micronutrient) is lost or insufficient, plant yield will be reduced. The soil is the major source of nutrients for plants but at times the fertility of the soil can be lost due to continuous farming and soil erosion. When this occurs, the soil will no longer sustain the growth of plants resulting in reduced crop yield. Thankfully researches in soil chemistry have made it possible for agriculturist to manipulate soil chemistry using fertilizers. Fertilizers are substances which contain plant nutrients that are usually added to soils to supplement its natural fertility. Organic and inorganic fertilisers have been prepared or synthesized through natural and synthetic routes to boost crop yield. Organic fertilisers are prepared from organic sources (organic substances are carbon containing matter formed by living organisms) such as compost, animal manure, domestic sewage, fish and bone meal. Once applied to the soil, soil microbes break down organic fertilisers into nutrients.

On the other hand, the most produced industrially produced inorganic fertiliser is the NPK fertilizer in which nitrogen (N), phosphorus (P) and potassium (K) are mixed in different proportion. The discovery of the Haber Bosch process has made fertiliser widely available thereby making food more readily available for the growing human population. The Haber Bosch process is therefore considered as one of the most important inventions of the 20th century. Haber process was first discovered by Haber in the early 1900s and later modified by Bosch for the industrial production of fertiliser. In the Haber Bosch process, ammonia is synthesised under high pressure from nitrogen (N) and hydrogen (H). Nitrogen is thus added in the form of ammonium nitrate (NH_4NO_3), ammonium sulphate ($(NH_4)_2SO_4$) and urea. Phosphorus and potassium are usually obtained from naturally from their ores and salts. Chemists have also been able to produce insecticides, herbicides which have been able to effectively kill crop-eating insects and weeds thereby increasing agricultural yields.

Green Chemistry: In a bid to improving the standard of life, chemical processes may generate potentially harmful substances to the environment. Going by the above premise, there is a need for *green chemistry*. Green chemistry can be defined as the sustainable exercise of chemical science and technology within the framework of good practice of industrial ecology such that the use and handling of hazardous substances are minimized and that such substance are never released to the environment. The 12 principles of green chemistry are summarized below:

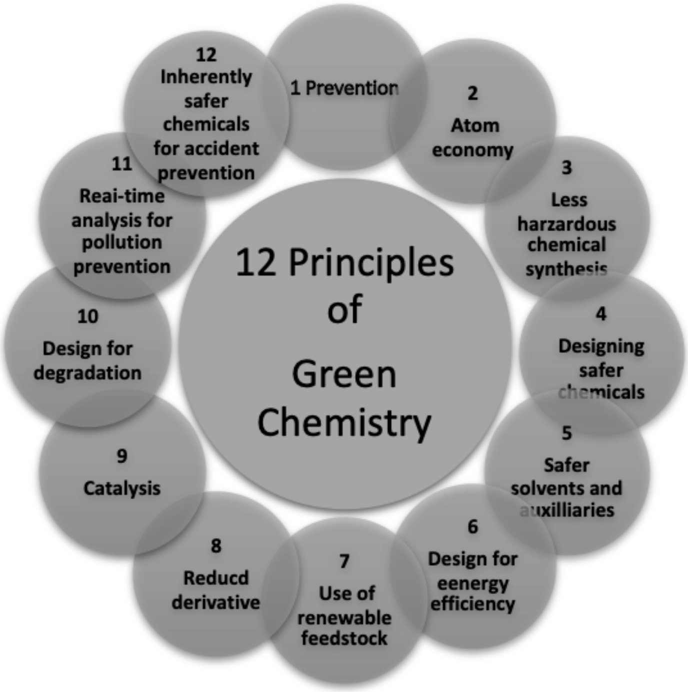


Fig. 4.2: 12 principles of green chemistry

Conclusion

Increased industrialization, good medical and infrastructural amenities are all pivotal to the socio-economic growth of a nation. All these however involve different chemical processes that have led to the developments and technological advancement achieved today by man. With the increasing and profound understanding of the underlying chemical principles underlying natural and synthetic processes, Chemists are improving on existing materials and designing new materials with superior and specific properties in a bid to providing cutting edge technologies that cuts through multi disciplines. Thus, Chemistry will continue to be relevant in societal development as its role cuts through practically all aspects of human endeavours.

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CHAPTER 5

THE ENVIRONMENT AND CHEMICALS OF CONCERN

L.O. Oladele

Definition of Environment

Environment refers to the surroundings where both living (biotic) and non-living (abiotic) things live, grow, interact and perish. It involves all the conditions needed by an organism to survive or maintain its life process. The environment impacts the growth and development of living things. There are two types of environments:

(a) Natural environment
(b) Man-made or built environment

Natural environment involves the natural existence of all living and non-living things with little or no human intervention or impact.

Man-made/built environment involves the area and components that are strongly influenced by humans e.g. zoo, bridges, roads etc.

Components of Environment

Environment consists of four major components, which are (i) atmosphere (air), (ii) hydrosphere (water), (iii) lithosphere (rocks) and (iv) biosphere (life).

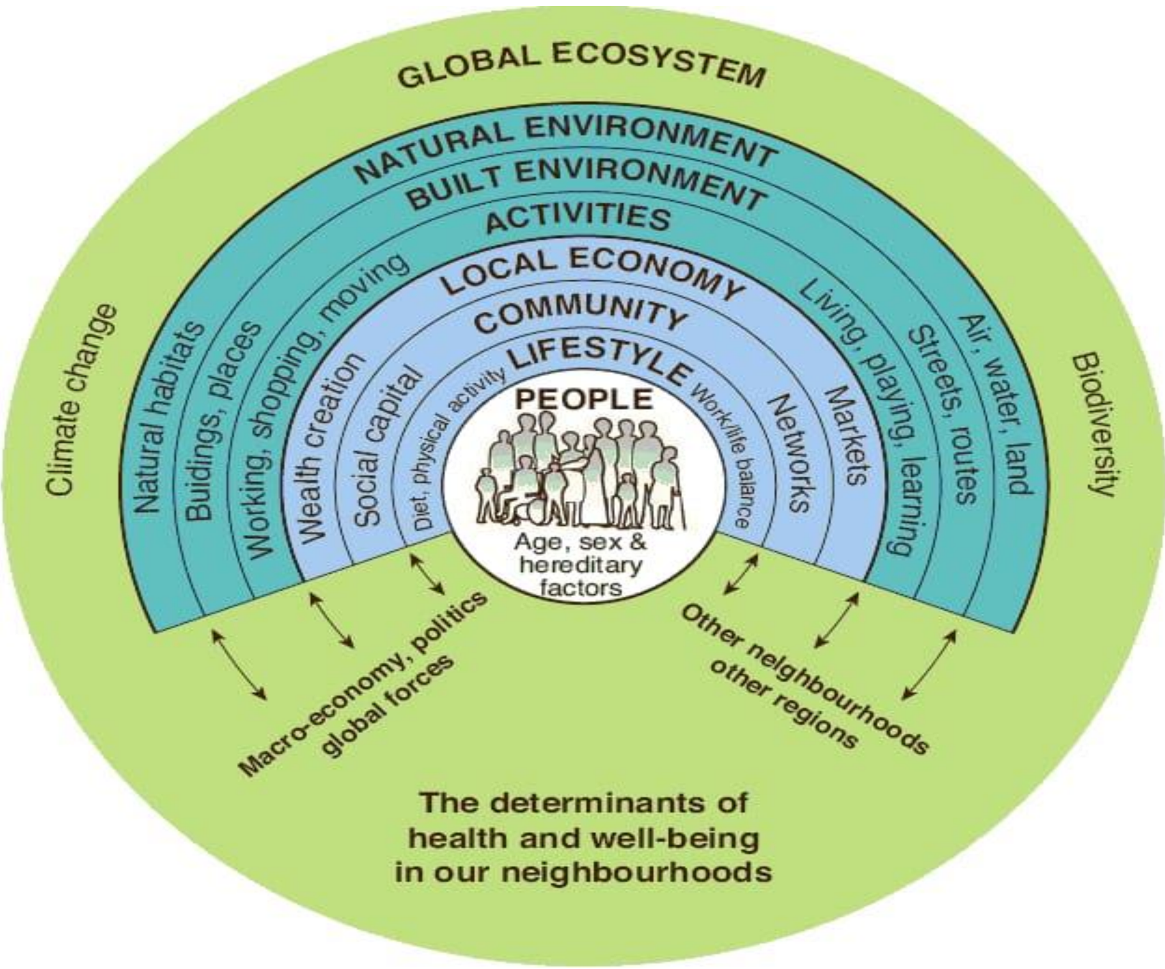
- *Atmosphere* is a gaseous layer serving as a protective cover which promotes life on earth and keeps the earth from hostile environment of outer space. The atmosphere helps to absorb most of the cosmic rays from outer space and electromagnetic radiation from the sun. It supplies gases needed by plants and animals for life sustenance. The atmosphere mainly comprises 78.08% Nitrogen (serves as a diluent), 20.95% Oxygen, 0.93% Argon, 0.0365% Carbon dioxide and Water Vapour which varies in quantity ranging from 0.5% - 3.5%.
- *Hydrosphere* is made up of all forms of water bodies on earth. It covers 70% of earth's surface. 97.5% of water found on earth is in the oceans in form of saltwater having a TDS (Total Dissolved Solids) concentration greater than 15,000 ppm (parts per million). Just 2.5% of water on earth is freshwater out of which 30.8% is available

as groundwater, 68.9% is in frozen forms as glaciers, only 0.3% is easily accessible to man in rivers, reservoirs and lakes.

- *Lithosphere* is the outermost layer of the earth called 'crust'. The crust comprises different minerals that can be found on both land and oceans.
- *Biosphere* refers to the part of the environment where life exists. The term 'biosphere' was coined by Geologist Edward Suess to mean the place where life can be found on earth.

Environmental Health

The natural environment is under threat than ever before because of human activities, with its resultant consequences on environmental health. As seen in plate 1, the activities of man at the centre kept impacting the natural environment leading to environmental factors that contribute about 23% of death globally (Pruss-Ustun and Corvalan, 2006)



Environmental health describes the effects of chemical, physical, biological, social and psychological factors on human health. It involves the assessment and control of environmental factors that can cause adverse health effects in the natural and built environment. The environment is very complex; therefore, environmental indicators help to provide a practical way to track what is happening in the environment. Some environmental health indicators that monitor the relationship between the environment and health include

- Health status – e.g. mortality, diseases/disorder
- Physical environment – e.g. air quality, water quality, transport, radiation, climate change
- Working conditions – e.g. occupational exposure
- Health protection – e.g. regulations on food and drug safety/quality
- Health services – e.g. hospital discharges by disease group

These indicators help to assess the potential risk to human health from the environment.

Concept and Differences between Hazard and Risk

"Hazard" and "Risk" are terms that have specific definitions with respect to chemistry.

- ***Hazard*** is the potential harm or injury that a chemical causes. This potential is intrinsic or domicile in the chemical and cannot be altered; simply put, hazard points to the built-in properties of a chemical substance that make it capable of causing harm to a person or environment.
- ***Risk*** refers to the probability or likelihood that an organism will experience harm or injury on exposure to chemical substances under specific conditions. Generally, the greater the exposure, the greater the risk.

Hazard Classification and Associated Risk

Chemicals are categorised based on the type of hazard they pose. Chemical hazards can be classified into <u>three</u> main types which include (i) Physical hazard (ii) Health hazard and (iii) Environmental hazard

Physical hazards are caused by changes which occur within the chemical and its reactants. Classes of physical hazard include:

- **Combustible**: any material or substance that will burn off when ignited at a temperature between 130º F and 200º F
- **Asphyxiant**: a gas or material that has vapour and can displace oxygen in air to cause suffocation
- **Explosive**: any material that abruptly releases pressure or high temperature whenever it is subjected to sudden shock or pressure or high temperature.
- **Pyrophoric**: this can either be a liquid or solid that spontaneously ignite in air at ≤ 130ºF
- **Oxidiser**: any substance which promotes the burning of other substances
- **Reactive/ unstable:** any chemical or material that spontaneously form different chemicals that are inflammable or explosive.
- **Water reactive**: any material that react with water to release a flame or toxic gas e.g. sodium
- **Organic peroxide:** any compound that contains carbon and oxygen that is explosively unstable.

Health hazard occurs when chemicals react with living tissues. Such health hazards can be

- **Carcinogenic**: causes cancer
- **Corrosive**: burns living tissues on contacts leading to irreversible damage
- **Irritant**: any non-corrosive chemical that causes temporary aching, soreness or inflammation on exposure to skin, eyes or mucus membrane
- **Mutagenic**: chemicals that cause change in the genetic content of a cell
- **Poisonous**: a chemical that can cause death
- **Toxic**: causes damage to tissues or organs and even death at high doses
- **Sensitizer**: a chemical that causes allergic reaction
- **Teratogen**: chemicals that cause defect in developing foetus.

Environmental hazard occurs when chemicals damage the natural environment. Such negative impact can be on the ozone layer (atmosphere) or the aquatic environment (hydrosphere). When toxic chemicals are constantly released into the aquatic environment, they bio-accumulate in the organs of aquatic organisms such as fish. For chemicals having pollutants that are mobile, fat-soluble, persistent and biologically active, the toxicity can bio-magnify, thereby getting to human when polluted organisms are consumed, leading to acute or chronic toxicity.

Hazard Communication (GHS)

Hazard communication is a set of processes and procedures employed to protect people from injuries and illnesses associated with the use of chemicals. Chemicals are manufactured in different parts of the world, with hazard signs/symbols written in different languages confusing end-users, whereas these symbols or signals are very useful in the management of chemicals. For this reason, the United Nations set up a Global Harmonised System (GHS) of Classification and Labelling of Chemicals and this took effect in 2008. The objective of GHS is to make all labels and Safety Data Sheets (SDS's) the same and written in English. The goal is to protect human health and the environment. GHS covers all hazardous chemical products used.

According to GHS, a chemical label communicates through the following <u>six</u> categories

- Product identifier
- Signal words
- Hazard statement
- Pictogram (s)
- Precautionary statement and
- Name, address and telephone number of chemical manufacturer

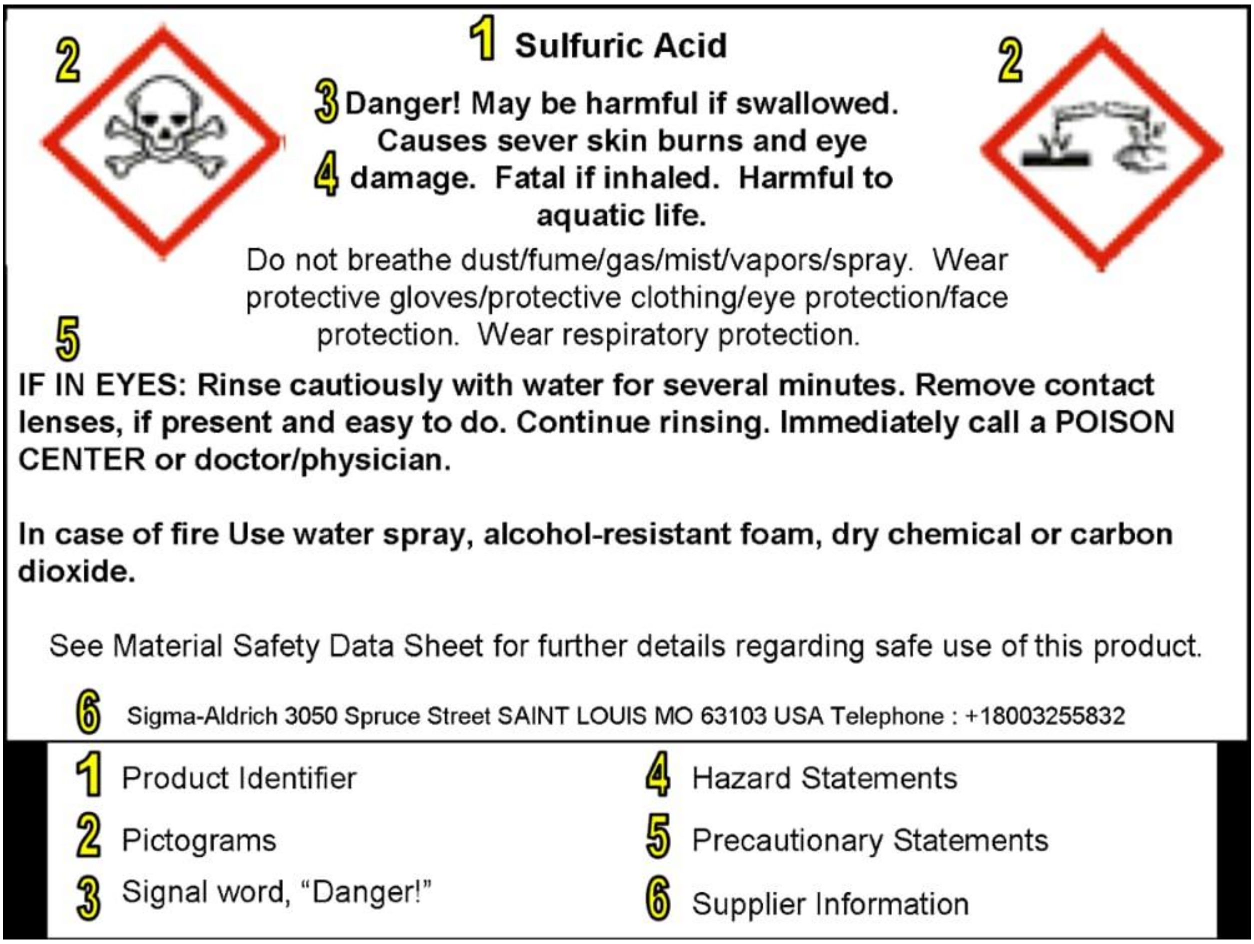


Plate 5.2: A typical chemical label showing the six categories (Source: GHS, 2011).

Two signal words are used by GHS – **danger** and **warning**. These signal words are used to pass information about the severity of hazard. The risk is higher for a chemical marked '*danger*' and less for those marked '*warning*'. A hazard statement means a phrase assigned to a hazard class. It explains the nature and degree of hazards of a chemical. Hazard pictograms are one of the key elements for the labelling of containers. They provide visual clues of chemical hazards. Some common hazard signs are shown in plate 3. Precautionary statement illustrates the measures to be taken to inhibit or minimise potential effects associated with exposure to a hazardous product.

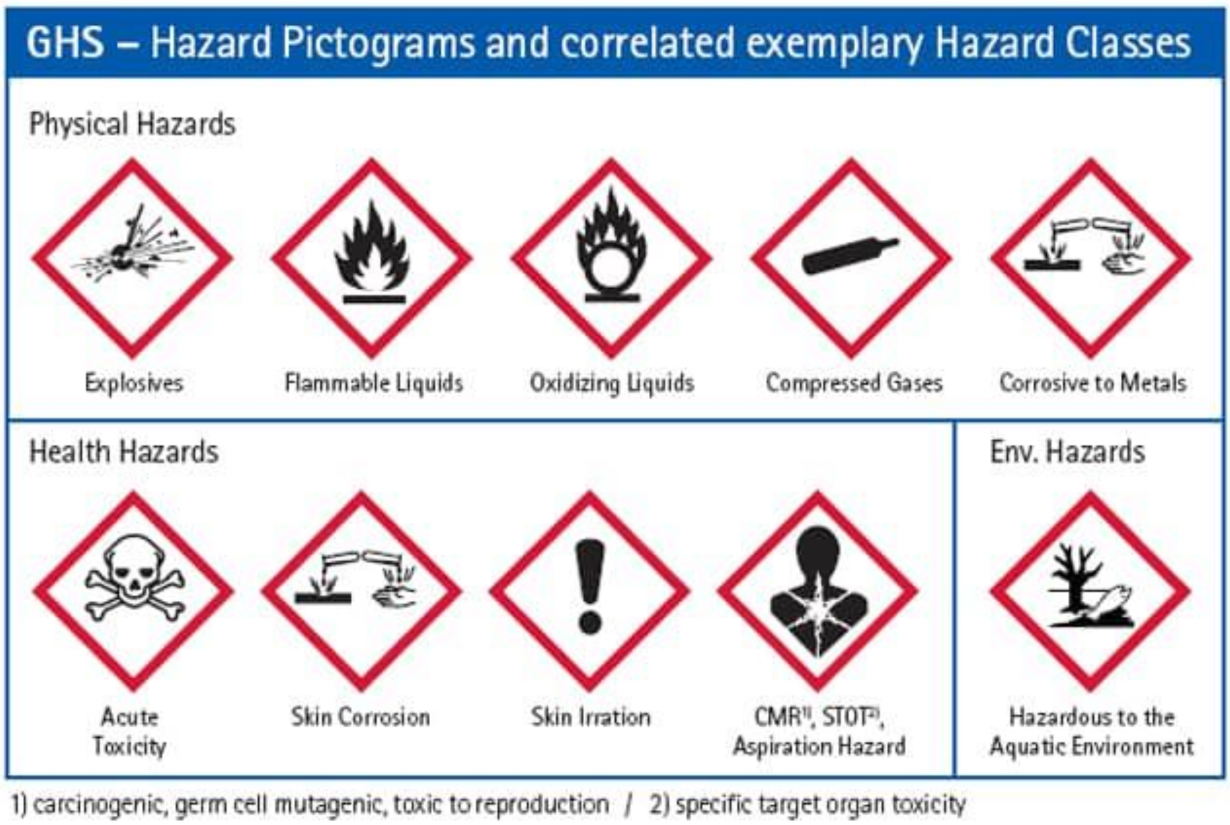


Plate 5.3: Hazard pictograms

Safety Data Sheets (SDS) communicate chemical hazards through the following 16 categories:

- Identification of the substance and the supplier
- Hazard identification
- Ingredients composition/information
- First aid measures
- Firefighting measures
- Accidental release measures
- Handling and storage
- Exposure controls/personal protection
- Physical and chemical properties
- Stability and reactivity
- Toxicological information
- Ecological information

- Disposal considerations
- Transport information
- Regulatory information
- Other information

Chemical Classifications and Toxicity

Chemicals are part of our daily lives with wide range of benefits which include its use in agricultural and industrial activities. However, they have the potential to cause considerable health and environmental problems when they are not well regulated or controlled. Chemicals are therefore '*Elixirs*' of life and '*Harbingers*' of death

Chemicals may be classified according to the intended use, and this leads to these categories:

- Industrial chemicals
- Drugs and pharmaceuticals
- Narcotics
- Agro chemicals e.g. pesticides, herbicides, fertilizers
- Consumer products and domestic chemicals
- Explosives
- Chemical ammunition or warfare chemicals

Chemicals can also be classified according to their ability to cause harm – **hazardous and non-hazardous.**

Hazardous chemicals are of special concern because they are harmful to human beings and other organisms. The properties of hazardous chemicals include:

Explosive	Flammability
Chemical reactivity	Corrosive
Radioactivity	Toxic
Oxidizing	Carcinogenic
Irritating	Mutagenic
Infectious	Teratogenic

Chemical Toxicity

The toxicity of a chemical is best explained by its potency and the types of effects it causes. Certain conditions can make any chemical toxic.

Potency (strength) is a measure of how toxic a chemical is. The more potent a chemical is, the more toxic. For example, sodium chloride (NaCl) is less potent than sodium cyanide (NaCN) since ingesting a smaller amount of cyanide can be poisonous. Cyanide's high affinity for metals leads to its high toxicity. Therefore, the potency and toxicity of a chemical can be affected by its breakdown within the human body. The chemical structure of a substance may be changed or metabolised to a substance that is more toxic or less toxic when absorbed by the body. For example, the body converts carbon tetrachloride (CCl_4), (a commonly used solvent) to toxic chemical that causes liver damage, whereas, for some other chemicals, the body breaks them down to forms that are easily eliminated by the body.

A chemical toxicity can be acute or chronic. Acute effects occur immediately in minutes, hours or a day while chronic effects occur after a long time of being exposed to the chemical.

Different chemicals can cause different toxicity effects. For example, a particular chemical may cause loss of appetite, but not cancer while another chemical may have no observable consequences upon exposure but may later lead to cancer.

Factors Influencing Human Response to Toxic Chemicals

Factors	Effect
Dose	A larger dose corresponds to more acute effect
Rate of administration	Has effect on metabolism and excretion if not kept low
Method of administration	Some chemicals are not toxic by one route but very potent by another
Age	Elderly persons and children are more susceptible
Sex	Each sex has hormonal control hypersensitivities
Body weight	This is inversely proportional to the effect it

	causes
Body fat	Body fat bio-accumulates some toxic chemicals
Psychological factors	Stress increases vulnerability to poison
Immunological factors and genetic	These influence metabolic rate
Presence of other diseases	This is similar to immunological factors
Pollutants' physical state, pH and ionic rate	These facilitate absorption into the body
Weather condition	Temperature, humidity, biometric pressure and season enhance absorption

Health Effects Associated with Some Toxic Chemicals Overdoses

Health Effects	**Chemicals**	**Types of Responses**
Cancer/fibrosis	Vinyl chloride, cotton dust, or asbestos	Tumour, death, irritation, pneumonia
Asphyxiation	Hydrogen sulphide	Dizziness, nausea, dis-orientation
Mutagenic	Dichlorodiphenyltrichloroethane (DDT)	Reproductive defects due to chromosomal changes
Teratogenic	Dimethylacetamide	Birth defect, foetal death
Systemic poisoning	Lead	Organ or brain damage, anaemia or death

Routes of Exposure to Toxic Chemicals

The three possible exposure routes to toxic chemicals are

- Ingestion or oral: This involves swallowing toxic chemicals accidentally or intentionally.
- Inhalation: Involves the breathing-in of toxic gases, dusts or mists and

- Direct contact with the skin (dermal): Involves absorption of toxic substances through the skin into the bloodstream.

The way a chemical gets to human can dictate the effect of its toxicity. For example, swallowing or breathing Lead (a heavy metal) can lead to health effects, but touching Lead is not harmful because it cannot be absorbed through the skin.

Toxic Chemicals in the Environment

Once toxic chemical gets into the environment, it distributes itself into compartments such as air, water, soil and biota. This is because pollutants do not remain where they are released or deposited, they move from a source to a receptor, and this occurs through different pathways. The mechanism of chemical uptake in the environmental component depends on certain properties of the chemicals. These properties include:

(i) Persistence or degradability of the chemical
(ii) Volatility of the chemical
(iii) The chemical's vapour pressure
(iv) The transformation/metabolism tendencies of the chemical
(v) Long range transport potentials of the chemical
(vi) Toxicity (acute or chronic) of the chemical

Classes of Toxic Chemicals in the Environment

There is no conclusive list of toxic chemicals in the environment. However, there are six classes of toxic chemicals grouped by the Green Science Policy Institute founded in 2008. These classes are

- **Highly Fluorinated Chemicals or per-fluoroalkyl substances (PFAS)**: Examples of chemicals in this class are (i) perfluoro octane sulfonate (PFOS), (ii) perfluorooctanoic acid (PFOA) and other related compounds

  Uses: They are used in cookware, clothing, food packaging and other products as water and oil repellent.

  Health effects: Highly Fluorinated chemicals have related to obesity, kidney and testicular cancer, decreased fertility in humans.

  Fate in the environment: The chemicals are persistent in the environment. They have long range transport potentials polluting even the remote places.

Exposure route: Ingestion and inhalation

- **Antimicrobials:** Examples of chemicals in this class are (i) triclosan, (ii) quaternary ammonium compounds e.g. benzalkonium chloride.

  Uses: They are used in soaps, deodorant, toothpaste, lunchboxes and other products to inhibit the growth of microbes.

  Health effects: These chemicals can cause skin irritation, adverse endocrine, thyroid and reproductive changes in humans. They are toxic to aquatic organisms and some bios accumulate in marine food web.

  Fate in the environment: The chemicals persist in sludge from waste-water treatment.

  Exposure route: Inhalation, Ingestion and skin contact

- **Flame retardants:** Example of chemicals in this class is polybrominated diphenyl ethers

  Uses: They are used in electronics, household textiles and other products to prevent ignition of the materials.

  Health effects: Associated health problems with these chemicals are endocrine disruption, neurologic, reproductive and immune impairment.

  Fate in the environment: They persist in soil and aquatic environment where they bio accumulate.

  Exposure route: Ingestion

- **Bisphenols and phthalates:**

  Bisphenols are found in polycarbonate plastic products such as water bottles, sport equipment, and other products while **phthalates** can be found in some polyvinyl chloride plastic products such as pharmaceutical pills coatings, catheters, blood transfusion devices, food packaging products, air fresheners and other products.

  Health effects: They are hormone disrupting chemicals associated with foetal death and birth defect. In children, bisphenol A is linked to asthma and neurodevelopmental problems. In adult, it causes obesity, heart disease, decreased fertility and prostate cancer.

  Phthalates has been linked with reproductive problems in boys, asthma, allergies, cognitive and behavioural problems. In adult men, phthalates are associated with reduced fertility.

Fate in the environment: The chemicals enter the environment through manufacturing and recycling processes, leaching from products (phthalates do not bond chemically with plastics) into the hydrosphere (water bodies). Significant degradation of the chemicals occurs in the environment, hence, do not persist in the environment.

Route of exposure: ingestion, inhalation and through skin absorption

- **Organic solvents:** Chemicals in this class include (i) Organic solvents such as aromatic hydrocarbon e.g. benzene and (ii) halogenated organic solvents e.g. methylene chloride
  Uses: In paints, cosmetics, household cleaners and other products.
  Health effects: Some of these solvents relate to neurotoxicity and carcinogenic effects.
  Fate in the environment: These chemicals get into air, soil and water through emissions from products, spills or accidental release. Chlorinated solvents degrade slowly in soil. They react with sunlight to yield ground-level ozone resulting in smog.
  Route of exposure: Through inhalation, absorption through skin, and ingestion of polluted water.

- **Toxic metals:** These are metals that can adversely affect human health and the environment. These metals find their way into the environment largely from industries, wastes and automobile exhausts. Dose, chemical forms and route of exposure are important factors that affect the toxicity of metals; small dose of a metal may be beneficial but toxic at high levels. The following are examples of toxic metals
  Lead (Pb): This metal is used for car batteries, ammunition, cable sheathing and other products. This gets into man through diet and inhalation. It accumulates in the body to cause physiological and neurological toxicity effects.
  Cadmium (Cd): This metal is present in solar cells, batteries, alloys, pigments and other products. The disease caused by cadmium poison is known as *itai-itai.* The disease makes bone to soften, the body shrinks, and the patient eventually dies. When inhaled, cadmium causes acute bronchitis, pneumonitis and inflammation of the liver. Cases of high blood pressure have been attributed to cadmium toxicity.
  Mercury (Hg): This metal occurs as liquid, and it is used in fluorescent lamps, thermometers, dental amalgams and other products. It becomes more toxic in the vapour form. The toxicity of mercury occurs at three levels depending on the chemical form of the metal. The order of toxicity is alky mercury (especially methyl mercury, CH_3Hg^+) >

mercury metal vapour > Hg (II) salts, phenyl and methoxy mercury salts. Mercury substance is retained in the body for months after ingestion or inhalation, affecting the brain and causing crippling neurological disorders. Mercury bio accumulates and bio-magnifies in aquatic organisms and through the food chain.

Arsenic (As): Arsenic is used in the processing of glass, textiles, ammunition etc. Nausea, vomiting, diarrhoea are acute effects of arsenic poisoning by oral intake; respiratory effects due to inhalation include nose and throat irritations. Severe arsenic toxicity via direct contact leads to skin cancer. The metal can also cause spontaneous abortion and loss of hearing.

Beryllium (Be): Beryllium in its elemental form is used in the production of light-weight materials, springs, electrical contacts etc. The toxic effects of this metal most often occur through occupational exposure in mining. Beryllium poisoning leads to lung and skin disease in exposed workers.

Hexavalent Chromium (Cr): Chromium is used to harden steel, produce stainless steel etc. Calcium chromate, chromium trioxide, lead chromate, strontium chromate, and zinc chromate are cancer-causing substances. An increase in the incidence of lung cancer has been recorded among workers in industries that promote chromate and produce pigments that contain chromate.

Selenium (Se): This metal is both essential and toxic. It becomes toxic at a concentration of 4μg/g while exposure routes to this metal are ingestion and inhalation. Some of the diseases caused by selenium are gastro-intestinal irritation, drop in blood pressure, hair loss, nail discolouration etc. They also bio-accumulate in aquatic organisms.

Air Pollutants

Air pollution is the contamination of the atmosphere by any chemical, physical or biological agents. These agents modify natural air characteristics leading to harm/damage of normal functions of man, and the environment.

Common Sources of Air Pollution

- Household combustion devices (fossil fuel, generator, cooking)
- Waste disposal (incineration, biodegradation, spontaneous combustion)
- Exhausts from motor vehicles
- Emissions from industrial facilities

- Natural phenomenon (forest fires, volcanic eruption)

Some air pollutants of major health concerns are:

Particulate matter: Particulate matter can be primary or secondary. It is primary if it exists in the same chemical form as it was released into the atmosphere and secondary if it is produced by chemical reactions in the atmosphere. Particulate matter contains tiny pieces of solids or liquids present in the air. Examples include dust, soot, smoke and dirt. The concentration of primary particles depends on their emission rate, transport, dispersion and removal rate from the atmosphere.

Inhaled particles greater than 10μm penetrate no further than the bronchi as they are filtered out by the cilia. Thoracic particles with particle size less than 10μm can penetrate right into terminal bronchioles while respirable particles with ultra-fine particles can penetrate to alveoli and hence the circulatory system leading to respiratory problems.

Carbon monoxide (CO): Anthropogenic sources derived from incomplete combustion of organic matter such as internal combustion engines; carbonaceous fuels account for about 60% of CO emissions. Carbon monoxide imitates oxygen (O_2) because it is diatomic, stable and of comparable size to O_2. Therefore, when CO is present in the lungs through inhalation, it combines strongly with the haemoglobin of blood to form carboxy haemoglobin. This process immobilises haemoglobin, leading to oxygen starvation/shortage and subsequently death.

To control the emission of CO, mobile automobiles use catalytic exhaust reactors.

Nitrogen oxides (NO_x): The important oxides of nitrogen that are involved in air pollution are: Nitic Oxide, NO (colourless, odourless) and Nitrogen dioxide, NO_2 (has pungent smell, reddish-brown in colour). These are collectively called NO_x. Natural sources of NO_x include lightning, biological emissions, volcanic action, and intrusion of stratospheric nitrogen oxides while anthropogenic sources are combustion of fossil fuels and non-combustion industrial processes. Nitric oxide is not as active as Nitrogen dioxide, and thus, less toxic. NO like CO, bond with haemoglobin and lessen the efficiency of oxygen movement in the body. However, in a polluted atmosphere, NO levels are usually much lower than CO, thus NO effect is much less.

Acute exposure to NO_2 is harmful to human health. The effect varies with the degree of exposure, with exposure to 500ppm or more resulting to death. NO_2 attacks vegetation by causing leaf spotting and breakdown of plant tissue.

NO_x emission can be controlled using sorption processes, catalytic reduction, low-excess-air firing technique.

Sulphur dioxide (SO_2): Sulphur compounds enter the atmosphere mainly through human activities (anthropogenic) via the combustion of fossil fuel primarily. Sulphur dioxide in the atmosphere has its primary effect on the respiratory tract, causing irritation and increasing airway resistance. Acute exposure of plants to high levels of SO_2 kills leaf tissue.

To control the emission of SO_2, Sulphur and Sulphur oxides can be removed before/during combustion physically, chemically or through scrubbers.

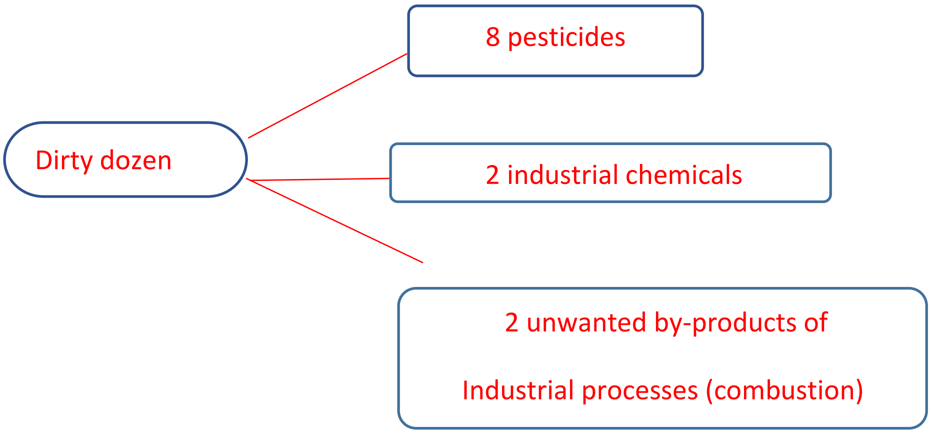
Persistent organic pollutants (POPs): Are a class of organic pollutants that do not degrade easily in the environment. Their pollutants can move over a long distance from the point of pollution. They bio-accumulate in human and animal tissue and bio-magnify in food chains, posing significant adverse impacts on human health and the environment.

Bioaccumulation of chemicals refers to how pollutants are stored up in individual organisms. This occurs when the rate of ingestion is greater than excretion.

Biomagnification: This is the increase in the concentration of a pollutant from one trophic level to the next within a food web. For biomagnification to occur, the pollutant must be persistent, mobile, soluble in fat and biologically active.

Many POPs have been applied industrially in the production of goods such as solvents, pesticides and pharmaceuticals. Few natural sources of POPs exist but most POPs are generated by humans intentionally or as by-products in industrial processes.

Twelve (12) persistent organic pollutants have been found to be extremely hazardous based on scientific and toxicological evidence. These twelve are referred to as *dirty dozen*. They are a group of carbon-based chemical compounds and classified as follows:



Eight (8) pesticides	Two (2) industrial chemicals	Two (2) unwanted by-products
Aldrin Chlordane Dichlorodiphenyltrichloroethane (DDT) Dieldrin Endrin Heptachlor Mirex Toxaphene	Hexachlorobenzene (HCB) Polychlorinated biphenyls (PCBs)	Dioxins Furans

There are nine newly added POPs. These include

Two pesticides:

- Chlordecone
- Lindane

Four industrial chemicals which are used as flame retardants:

- Hexabromobiphenyl (HBBs)
- Pentabromodiphenyl ether

- Octabromodiphenyl ether (Brominated flame retardants)
- Perfluoro octane sulfonic acid (PFOS) fluorinated flame retardants

Two which are both pesticides and by-products of lindane

- α-hexachlorocyclohexane (α-HCH)
- β-hexachlorocyclohexane (β-HCH)

One which is a pesticide

- Pentachloro benzene (PCBs)

Adverse environmental impacts of POPs

- Causes endocrine disruption.
- Suppression of immune system
- Reproductive and developmental defects
- Destruction of the ecosystem.

Radioactive Substances

These can occur naturally or by anthropogenic activities through leakage/dissolution of radioactive elements or leakage of oil and gas, mining activities respectively. Natural radioactive substances whose concentrations are low in Earth's crust are unearth by the activities of man. Examples of radioactive elements are uranium, thorium.

Radioactive elements have unstable nucleus; they achieve stability through the process of radioactive decay or transformation where their nucleus is changed via spontaneous fission, release of alpha particles or transformation of neutrons to protons or the reverse and this is often followed by the emission of ionizing radiation (beta particles, neutrons or gamma rays).

Routes of exposure to radioactive substances are inhalation, ingestion and direct contact through skin. Health effects associated with radioactive substances include bone abnormalities, skin redness, hair loss and even death.

Global Environmental Issues: Causes and Implications

Climate Change and its Indicators

Climate change is the change in weather patterns of an area over a long period of time. The environmental threats linked to climate change are better understood using climate change indicators. Climate change indicators which may be physical or ecological are parameters that can be used to track changing climate and its trends. An indicator is selected based on its relevance, representativeness, traceability, timeliness and data adequacy. These parameters help in monitoring changes in climatic conditions and assessing potential risk and vulnerabilities.

Six primary indicators as identified by World Meteorological Organisation (WMO 2017) include:

1. Global temperature
2. Atmospheric concentration of greenhouse gases
3. Ocean heat content
4. Global mean sea level
5. Mass of the cryosphere or global extent
6. Global precipitation

Global Warming and Greenhouse Effect

Global warming is the rise in the average temperature of the earth's atmosphere and oceans in recent times. Increased amount of greenhouse gases [carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapour (H_2O) and tropospheric ozone (O_3)] are the primary causes of the human-induced component of warming.

Global warming occurs when the greenhouse gases forming a blanket in the atmosphere absorb energy from the sun and solar radiations, trap it (prevents the return of the radiation) and then, emit heat energy in all directions, thereby increasing the earth's temperature.

Greenhouse Effect

The greenhouse effect occurs naturally to keep the earth warm; without this, earth's temperature would be very low, making it impossible for life to exist on earth. Greenhouse effect is therefore the warming of the planet by the energy from the sun.

Effects of Global Warming

(a) Rise in sea level
(b) Changes in the amount and pattern of rainfall
(c) Extreme/irregular weather events
(d) Reduced summer stream flows
(e) Species extinction
(f) Glacier retreat
(g) High/Low agricultural yield
(h) Disease vectors increase

Ozone Layer Depletion

Ozone is present in both the troposphere (0-10km above earth surface) and stratosphere (10-50km from the earth surface) with different roles and effects. In the troposphere, it is a pollutant but acts as a 'good ozone' in the stratosphere.

Ozone is formed in the troposphere, when nitrogen dioxide (a pollutant) absorbs radiation from sunlight to produce atomic oxygen.

$$NO_2\,(h\nu,\ \lambda < 400nm) \rightarrow NO + O$$

The oxygen atom then interacts rapidly with oxygen molecule in the presence of a third body (usually N_2 or another O_2) to produce ozone as seen below

$$O_2 + O + M \rightarrow O_3 + M.$$

Hazardous Nature of Tropospheric Ozone

It leads to the formation of smog and the formation of hydroxyl radicals by reaction with water. The radical is involved in the oxidation of a variety of organic compounds.

Ozone causes damage to vegetation. This may occur as chlorotic stippling (yellowing spots on green leaves, reduction in plant growth and reduction in rate of photosynthesis) which affects economic crops and wild vegetation, causing severe economic losses.

Ozone in the Stratosphere

The dissociation of molecular oxygen by short wavelength of ultraviolet (UV) radiation forms ozone in the upper stratosphere. Stratospheric ozone helps to absorb most of the biologically damaging ultraviolet radiation and helps to keep tropospheric oxygen from being converted to bad ozone. However, the depletion of the good ozone has been linked to human activities.

Chemical compounds or gases that contain only carbon (C), bromine (Br), fluorine (F) and in some cases chlorines (Cl) are generally called *organ halogen compounds;* examples of such compounds are chlorofluorocarbons (CFCs), Bromo fluorocarbons. They have been used in many applications as fire extinguishers, solvents, cleaning of electronic components, and foam blowing. The release of these highly stable compounds has increased the concentrations of chlorine and bromine sources in the atmosphere whose and can deplete the ozone layer.

When bromine and chlorine get to the stratosphere, their radicals are given-off by the effect of ultraviolet light. Each free radical then starts and catalyse a chain reaction capable of depleting numerous ozone molecules. Other free radical catalysts capable of depleting the ozone layer include nitric oxide (NO), nitrous oxide (N_2O) and hydroxyl (OH).

Effects of Ozone Layer Depletion

The main effect of ozone layer depletion is the increase in ultraviolet radiation (UV). A decrease in atmospheric ozone leads to significant increase of UV-B near the surface causing

- Some skin cancer, eye cataract, sun burn and immune system damage
- Low yield of economically important species of plants such as rice
- Reduced survival rates of aquatic organisms
- Breakdown of synthetic polymers and biopolymers, thereby reducing their durability

Acid rain: This can also be called “acid deposition”. Carbon dioxide-free distilled water has a neutral pH of 7; once the pH of any liquid is less than 7, it is said to be acidic and alkaline if greater than 7. The pH of natural rain is slightly acidic with a pH less than 5.7 because of the presence of carbon dioxide (CO_2) in the atmosphere. However, sulphur and nitrogen oxides generated through human activities are converted to sulfuric and nitric acids in the atmosphere. These acids dissolve in water and are deposited on the earth surface as Acid Rain (wet deposition).

$$H_2O_{(l)} + CO_{2\,(g)} \rightleftharpoons H_2CO_{3\,(aq)}$$

H_2CO_3 ionises in neutral solution (H_2O) to produce hydronium and trioxocarbonate ions.

$$H_2O_{(l)} + H_2CO_{3\,(aq)} \rightleftharpoons HCO_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

Natural Sources of Acid Rain

- Emissions from volcanoes
- Biological processes e.g. production of dimethyl sulphide $[(CH_3)_2S]$ produced by bacteria transformation of dimethyl sulfoniopropionate (DMSP)
- Electrical activity in the atmosphere e.g. lightning

Anthropogenic Sources of Acid Rain

- Combustion of fuel
- Livestock production (NH_3 generation)

Some Impacts of Acid Rain

- It makes exposed metals corrosive
- It damages soil biology and chemistry by killing soil microbes and changing soil's Ph
- Metals present in water distribution pipes can be dissolved by acid rain
- Damages historic monuments and buildings
- Reduction in forest and crop productivity
- Headwater streams and high-altitude lakes especially may suffer loss of aquatic life.

What can be done to mitigate/reduce chemical impact on health and environment?

- Eco-friendly chemicals can be used as alternatives to toxic ones
- Appropriate training should be given to workers and end-users on safe handling and use of chemicals
- Import/export and sales of hazardous chemicals should be controlled
- Chemicals should be appropriately labelled and not advertised in misleading ways
- Routine check should be carried out by designated bodies professionally
- Industrial wastes should not be indiscriminately discharged into the environment

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CHAPTER 6
SUSTAINABLE DEVELOPMENT GOALS (SDGs)

B. Folarin

Sustainable Development

Although the term "sustainability" has gained immense popularity in recent years, it has deep historical roots. Sustainability is fundamentally about preserving harmony and balance between human activity and the natural world. It aims to make sure that the future generations' wellbeing is not jeopardised by our activities now. This definition emphasises the dual imperative of addressing urgent societal needs while safeguarding the environment for the long term. Sustainable development, as coined by the Brundtland Commission in 1987, is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The idea of sustainable development has emerged as a ray of hope and a guiding principle for determining our shared future in a time of unparalleled global problems [1].

Sustainable Development Goals

A special summit of United Nations (UN) member states was held to adopt the post-2015 development agenda from September 25–27 during the 70th session of the UN General Assembly. The proclamation "Transforming Our World - the 2030 Agenda for Sustainable Development" was adopted at the end of this special summit. It is an unprecedented global call to action for prosperity, peace, and partnership for people, the planet, and humankind. The 2030 Agenda features a set of 17 universally applicable, integrated objectives for sustainable development, along with a total of 169 concrete targets and 230 key performance indicators, in order to spur cooperative, transformative action on a global scale. The Sustainable Development Goals (SDGs) are the official name for these goals [2].

The Role of the Sustainable Development Goals

The Sustainable Development Goals (SDGs), often known as the Global Goals, mark a turning point in humanity's commitment to sustainability. The SDGs, which were adopted by all UN members in September 2015, offer a common framework for solving the most important global issues. The 2030 Agenda for Sustainable Development, which lists 17 precise objectives and 169 targets to be accomplished by 2030, is the foundation of the

SDGs. These objectives cover a wide range of topics, such as gender equality, clean energy, combating climate change, poverty, hunger, and health. The SDGs are exceptional in that they involve governments, corporations, civil society, and people on an equal footing [3].

They understand that attaining sustainability necessitates global cooperation. The SDGs offer a blueprint for a better future by outlining specific solutions and quantifiable goals. They push us to reconsider how we approach growth and to embrace innovation and teamwork in our quest for a more just and sustainable world. Sustainable development is not just an objective, it is also a way of thinking and doing that enables us to address the difficult problems of our day while preserving the environment for future generations [4].

Before SDGs

Several significant worldwide efforts and conferences laid the groundwork for a more sustainable society before the SDGs emerged. There are two significant predecessors worthy of mentioning.

The Earth Summit

The Earth Summit, also known as the United Nations Conference on Environment and Development, was held in Rio de Janeiro, Brazil, in 1992. It signaled a turning point in environmental governance around the world. The Rio Declaration on Environment and Development and the Agenda 21 action plan, which outlined methods for sustainable development, are two fundamental agreements that came out of the Earth Summit. Although the conference emphasised the significance of sustainable development, it lacked clear objectives [5].

The Millennium Development Goals (MDGs)

The United Nations committed to eradicating extreme poverty and the problems it brings by 2015, issued the Millennium Goals in 2000. The eight goals and targets that make up the Millennium Development Goals (MDGs) were created to address problems including gender equality, poverty, and health. Below are the eight Millennium Development Goals (MDGs) [6].

1. Eradicate extreme poverty and hunger

2. Achieve universal primary education

3. Promote gender equality and empower women

4. Reduce child mortality

5. Improve maternal health

6. Combat HIV/AIDS, malaria and other diseases

7. Ensure environmental sustainability

8. Develop a global partnership for development

The SDGs are significantly more extensive and ambitious than the MDGs and are generally applicable to all UN member states, as opposed to the MDGs, which were primarily focused on developing nations.

Rio+20 - Sustainable Development Summit

Preparations for the 2012 Rio+20 United Nations Conference on Sustainable Development, also known as Rio+20, were prompted by the need for a more inclusive and comprehensive global agenda. Rio+20 gathered world leaders, decision-makers, and members of civil society to evaluate achievements since the Earth Summit and set new guidelines for sustainable development. The call for the creation of a set of Sustainable Development Goals (SDGs) to address the most urgent global concerns was one of Rio+20's major outcomes. The importance of the 2030 Agenda and the demand for a comprehensive set of goals were both reiterated at the conference [4].

The Birth of the SDGs

The Open Working Group on Sustainable Development Goals (OWG) was established by the UN during Rio+20 to create a proposal for the SDGs. With input from member states, civil society, and specialists from diverse sectors, the OWG engaged in a multi-year process of negotiation, dialogue, and deliberation. At the United Nations Sustainable Development Summit on September 25, 2015, world leaders approved the 2030 Agenda for Sustainable

Development. The 2030 Agenda offers a thorough and integrated framework for solving global concerns with its 17 Sustainable Development Goals and 169 goals [2].

One of the most remarkable aspects of the SDGs is their universality. Unlike the MDGs, which primarily targeted developing countries, the SDGs apply to all countries and emphasise a shared responsibility for global well-being. The SDGs acknowledge that without addressing global concerns jointly, no country can experience genuine prosperity and stability [7].

SDGs in Nigeria

Following her independence on October 1, 1960, the Federal Republic of Nigeria was admitted as a member state of the United Nations on October 7 of the same year. Nigeria started implementing the SDGs nearly right away after the 2030 Agenda was adopted. To facilitate successful implementation, it first developed institutional frameworks at the national and sub-national levels. Several strategic initiatives were put into action between 2016 and the present thanks to this head start, while others are still in progress [8]. However, the COVID-19 outbreak occurred just before Nigeria began the 'Decade of Action' for the SDGs in January 2020, posing a threat to that country's chances of meeting the goals. It is noteworthy that the aftermath of COVID-19 significantly impacted how the SDGs were implemented across the world [9]. The SDGs offer a collective vision for a future that is more just, sustainable, and affluent for all. It is crucial to keep in mind the spirit of cooperation and global dedication that made these objectives a reality. By directing our efforts to creating a more equitable and sustainable world by 2030 and beyond, they act as a blueprint for the entire globe.

The Global Challenges

Recognising and comprehending the global issues that endanger the welfare of both present and future generations is essential for the pursuit of sustainable development. These issues transcend national boundaries and are interconnected and complicated, necessitating coordinated global efforts. The primary global issues that served as inspiration for the Sustainable Development Goals (SDGs) are highlighted, along with the significant effects they have on people and ecosystems around the world [10].

Inequality and Poverty

Poverty is an ongoing and pervasive global issue. As of 2020, 9.2% of the world's population (those who made less than $1.90 a day) lived in extreme poverty. In addition to denying people access to basic necessities, poverty also restricts people's access to economic opportunities, healthcare, and educational chances.

The impacts of poverty are exacerbated by inequality, both within and across nations. In addition to being unfair, disparities in wealth, access to resources, and access to healthcare and education all undermine social cohesion and economic development. Inequality reduction is a key component of sustainable development [11].

Environmental Degradation and Climate Change

One of the most important issues facing our generation is climate change. The main cause of it is the buildup of greenhouse gases in the atmosphere brought on by human activities like the combustion of fossil fuels and deforestation. Rising global temperatures, more frequent and severe weather events, and disturbances to ecosystems and agriculture are all effects of climate change [12].

In addition to climate change, environmental degradation refers to a variety of problems, such as deforestation, habitat loss, and air and water pollution. These environmental changes endanger biodiversity, are detrimental to human health, and reduce ecosystems' capacity for resilience [13].

Hunger and Food Insecurity

Despite agricultural breakthroughs, many people still lack access to enough food that is both safe and nourishing. The quality and accessibility of the food are just as important as its availability in terms of food security. Malnutrition and hunger continue to be serious global problems. Food production and consumption have a big impact on the environment and society. To achieve food security while protecting the environment, sustainable agriculture practises that encourage biodiversity, cut waste, and the use of harmful chemicals as little as possible are crucial [14].

Access to Sanitation and Clean Water

Having access to clean, safe drinking water is a fundamental human right. Millions of people experience water scarcity, which has a negative impact on their health, sanitization difficulties, and water resource disputes. For the health and dignity of people, proper sanitation facilities are essential. The transmission of infections is facilitated by a lack of access to sufficient sanitation, which is a major problem in many areas [15], [16].

Physical and mental health

Health disparities continue within and between nations, with vulnerable and marginalised groups frequently suffering increased health risks and restricted access to medical care. The necessity of achieving global health equity has been made clear by the COVID-19 pandemic [17].

It is now well acknowledged that maintaining one's mental health is essential to overall wellbeing. Sustainable development and the creation of resilient communities depend on addressing mental health issues.

Education and Lifelong Learning

Access to high-quality education is essential for sustainable development because it gives people the knowledge, they need to improve their lives and give back to society. However, many people still face obstacles to receiving a high-quality education, especially in low-income areas. The idea of lifelong learning has grown in importance because of the fast-changing nature of both the work market and technology. In order to adapt to a changing world, it is crucial to have access to education and training throughout one's life [18].

Global Injustice and Conflict

Significant barriers to sustainable development include injustice, discrimination, and war. Communities are disrupted by social unrest and violence, which also impedes advancement in fields like economic development, health, and education. One of the SDGs calls for the creation of inclusive and peaceful societies. In order to achieve this objective, it is necessary to address the underlying causes of conflict, advance justice, and promote social cohesiveness [19], [20].

The issues that the Sustainable Development Goals aim to address are urgent and complex, as is highlighted by the list of global concerns. These issues are linked, so improvements in one area frequently depend on those in others.

The Sustainable Development Goals: An Overview

A remarkable worldwide commitment to solving urgent socioeconomic and environmental concerns is embodied in the Sustainable Development Goals (SDGs). Every one of the 17 SDGs is examined in depth, including a summary of its goals, benchmarks, and the interconnectedness that supports its execution.

SDG 1- No Poverty

Objective: To eradicate poverty in all forms worldwide.

Targets: These include reducing severe poverty (those who survive on less than $1.90 per day), putting in place social safety nets, and guaranteeing equal access to financial resources.

SDG 2- Zero Hunger

Objective: To end hunger, achieve food security and improved nutrition, and promote sustainable agriculture.

Targets: These targets encompass ending hunger and malnutrition, promoting sustainable farming practices, and ensuring access to nutritious and affordable food for all.

SDG 3- Good Health and Well-being

Objective: To ensure healthy lives and promote well-being for all at all ages.

Targets: Targets under SDG 3 include reducing maternal and child mortality, combating major diseases, and achieving universal health coverage.

SDG 4- Quality Education

Objective: To ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Targets: Achieving universal access to quality education, eliminating gender disparities, and enhancing skills for employment and global citizenship are among the key targets of this goal.

SDG 5- Gender Equality

Objective: To achieve gender equality and empower all women and girls.

Targets: Targets under SDG 5 aim to eliminate discrimination and violence against women, ensure equal participation in decision-making, and provide equal access to education and economic opportunities.

SDG 6- Clean Water and Sanitation

Objective: To ensure availability and sustainable management of water and sanitation for all.

Targets: Targets include providing universal access to clean water and sanitation, improving water quality, and protecting and restoring water-related ecosystems.

SDG 7- Affordable and Clean Energy

Objective: To ensure access to affordable, reliable, sustainable, and modern energy for all.

Targets: Targets encompass expanding access to electricity, increasing the share of renewable energy in the global energy mix, and enhancing energy efficiency.

SDG 8- Decent Work and Economic Growth

Objective: To promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.

Targets: Targets under SDG 8 aim to achieve higher levels of economic productivity, reduce youth unemployment, and ensure fair and safe working conditions for all.

SDG 9- Industry, Innovation, and Infrastructure

Objective: To build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.

Targets: These targets include enhancing infrastructure, upgrading industries, increasing research and development, and facilitating access to information and communication technologies.

SDG 10- Reduced Inequalities

Objective: To reduce inequality within and among countries.

Targets: Targets under SDG 10 seek to progressively achieve greater income equality, ensure equal opportunities, and empower and promote the social, economic, and political inclusion of all.

SDG 11- Sustainable Cities and Communities

Objective: To make cities and human settlements inclusive, safe, resilient, and sustainable.

Targets: These targets include ensuring access to affordable housing, improving urban transport, reducing the environmental impact of cities, and enhancing disaster resilience.

SDG 12- Responsible Consumption and Production

Objective: To ensure sustainable consumption and production patterns.

Targets: Targets encompass reducing waste generation, promoting sustainable resource use, and minimising the adverse environmental impact of consumption and production.

SDG 13- Climate Action

Objective: To take urgent action to combat climate change and its impacts.

Targets: Targets under SDG 13 include strengthening resilience to climate-related disasters, integrating climate change measures into policies, and enhancing climate education.

SDG 14- Life Below Water

Objective: To conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

Targets: Targets aim to prevent and significantly reduce marine pollution, protect marine ecosystems, and regulate overfishing.

SDG 15- Life on Land

Objective: To protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Targets: These targets encompass conserving biodiversity, restoring degraded land, and halting the loss of species.

SDG 16- Peace, Justice, and Strong Institutions

Objective: To promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.

Targets: Targets include reducing violence, ending abuse, and ensuring access to justice, as well as promoting accountable governance.

SDG 17- Partnerships for the Goals

Objective: To strengthen the means of implementation and revitalise the global partnership for sustainable development.

Targets: Targets encompass enhancing international cooperation, supporting developing countries in achieving the SDGs, and promoting multi-stakeholder partnerships.

These 17 Sustainable Development Goals, collectively known as the 2030 Agenda, provide a comprehensive and integrated framework for addressing global challenges. They represent a shared vision for a more equitable, sustainable, and prosperous future [21].

The 2030 Agenda, which consists of these 17 Sustainable Development Goals, offers a thorough and well-rounded framework for addressing global issues. They stand for a common vision of a future that is fairer, more sustainable, and affluent.

Measuring Progress and Accountability

Setting high standards for measuring, monitoring, and accountability is not enough to ensure that the Sustainable Development Goals (SDGs) are accomplished by 2030. In this section we examine the critical function of data gathering, reporting, and accountability in monitoring SDG achievement [22].

Data is the foundation of the SDGs. Understanding the extent and effect of complex global concerns is the first step in finding solutions. The basis for well-informed decision-making is high-quality, timely data. There are metrics and targets for each SDG. Targets are defined objectives to be attained by 2030, whereas indicators are quantifiable factors that can be used to gauge progress. Together, they make it possible for nations to monitor their development [23]. To guarantee that disadvantaged and marginalised groups are taken into consideration in progress evaluations, statistics that disaggregate information by income, gender, age, disability, and other relevant variables is required as part of the SDGs' core tenet of "leaving no one behind."

The main UN forum for assessing global progress towards the SDGs is the High-Level Political Forum on Sustainable Development (HLPF). Governments, civil society, and other stakeholders come together annually at the HLPF to discuss issues and successes, share best practices, and offer political leadership. The provision of Voluntary National Reviews (VNRs) by various nations is a crucial part of the HLPF [24]. Through these assessments, countries can demonstrate their development and share their experiences, including their accomplishments and problem areas. Nigeria's first VNR occurred in 2017, the second followed in 2020 [25].

Data collection and reporting are extremely difficult in many nations, especially in low-income areas. Accurate judgments of progress can be hampered by data inconsistencies and gaps. Political unpredictability, a lack of resources, and competing objectives can occasionally undermine a nation's commitment to open data reporting and accountability [26].

The SDGs' interconnectedness means that advancement in one area may influence advancement in another. It takes complex analysis and data integration to follow these connections. Organisations from the civil society are essential for holding institutions and the government responsible. They frequently carry out independent evaluations and promote accountability and transparency in SDG implementation. Citizens' participation in data collecting and reporting can improve accountability systems. Official statistics can be complemented by citizen-generated data, which can also offer useful insights.

It takes time to develop reliable data collection and reporting systems. To increase the reliability, accessibility, and disaggregation of data, governments, international organisations, and civil society must collaborate. Big data analytics, satellite images, and mobile apps are just a few examples of the technological breakthroughs that provide new ways to collect and analyse data, allowing for more in-the-moment monitoring of progress [27].

The SDGs require global cooperation to be accomplished. This involves exchanging best practices for data collecting and reporting, assisting developing nations in increasing their capacities, and promoting an environment of openness and accountability. It is critical to understand that accountability and data are the foundations of real growth rather than merely administrative tasks. We can better track our collective efforts and guide the world towards a more sustainable and equitable future by 2030 if we make sure that no one is left behind, develop the data infrastructure, and promote a culture of transparency and accountability.

Challenges and Controversies

Undoubtedly an ambitious and important endeavour of achieving the Sustainable Development Goals (SDGs) is not without its challenges, critics, and discussions [28], [29]. Discussion of some of the major issues and debates surrounding the SDGs are presented in this section.

1. Keeping Environmental Sustainability and Economic Growth in Balance: The SDGs' fundamental discussion centres on how to strike a balance between economic expansion and environmental protection. Critics contend that the drive of economic expansion may result in environmental damage, compromising sustainability objectives.
2. Disentangling resource use and growth: According to proponents of "green growth," economic expansion can be achieved while minimising negative effects on the environment by utilising cutting-edge technology, resource management practises, and the shift to a circular economy.
3. Taking Social and Cultural Differences into Account: No matter a country's level of development, the SDGs apply to all of them. The viability of a one-size-fits-all strategy is called into doubt due to the fact that the specific difficulties and solutions differ significantly across nations and cultures. Certain SDGs may necessitate

modifications to local customs or ethical standards. Promoting gender equality, for instance, could conflict with some nations engrained patriarchal norms.

4. Problems with Inequality and Distribution: Critics claim that the SDGs may not go far enough in addressing the underlying factors that contribute to economic inequality, such as unequal access to wealth, resources, and opportunities. There are worries that the SDGs are being achieved unevenly, with some groups and regions benefiting more so than others. This might make existing disparities worse.
5. Trade-offs and Related Issues: Some SDGs can be at odds with one another. Policies aiming at boosting agricultural productivity, for instance (SDG 2), may put pressure on SDG 15's goals of conserving biodiversity and land usage. A difficult topic is how international commerce fits into accomplishing the SDGs. Critics claim that excessive global trade can result in social inequality, worker exploitation, and environmental deterioration.
6. Problems with Implementation: The SDGs demand substantial financial resources to be achieved. Many developing nations struggle to get sufficient finance for important programmes and initiatives. The SDGs' implementation frequently calls for increasing institutional capacity and knowledge. It may be difficult for many nations to build these capacities, particularly those with low resources.
7. Coherence of Policy: It can be difficult to coordinate government departmental policies, so they are all in line with the SDGs. Although difficult, achieving policy coherence is important.
8. Cultural and Ethical Sensitivity: The SDGs advocate for ideals including inclusivity, environmental responsibility, and gender equality. These values, however, could not be compatible with some societies firmly held cultural practises and beliefs. Some SDGs' pursuit may present moral conundrums. For instance, initiatives to fight poverty may unintentionally uproot local populations or damage the ecosystem.
9. Relevance after 2030: Some detractors contend that the SDGs' deadline of 2030 is arbitrary and that the problems they aim to solve will continue to exist after that time. This calls into question the SDGs' continued applicability. Even after 2030, adherence to the SDGs may still be necessary in order to maintain development and solve upcoming obstacles.

The ongoing debate about the SDGs must include how to deal with these obstacles and controversies. The goals offer a framework for solving global concerns, but in order to maximise their influence and make sure they actually lead to a more sustainable and equitable world, it is crucial to recognise and address these challenges.

Case Studies and Success Stories

The pursuit of the Sustainable Development Goals (SDGs) has resulted in several examples of innovation and achievement in the real world. These success tales and case studies show the potential for progress and provide encouraging illustrations of the significant contributions that people, communities, organisations, and governments can make in the direction of a more sustainable and equitable future [30].

Bangladesh's Remarkable Progress in Eliminating Extreme Poverty (SDG 1)

Case Analysis:

- Bangladesh, which was formerly noted for having high rates of extreme poverty, has made significant headway in doing so.
- Microfinance initiatives, healthcare and education spending, and specialised social safety net programmes are important strategies.
- Millions of people in Bangladesh have been brought out of extreme poverty by focusing on economic growth that benefits all facets of society.

Rwanda's Transformation: Gender Equality and Empowerment (SDG 5)

Case Analysis:

- Rwanda is praised for its dedication to empowering women and promoting gender equality.
- Women are now more involved in politics, education, and the economy because to the nation's progressive laws and practises.
- Rwanda has one of the greatest percentages of women in parliament in the world, illustrating the effectiveness of policy-driven transformation.

Germany's Energiewende (SDG 7): Sustainable Energy Transition

Case Analysis:

- The Energiewende, or energy transition, initiative in Germany seeks to reduce reliance on fossil fuels while increasing reliance on renewable energy sources.
- The nation has made major investments in biomass, solar, and wind energy, which has significantly reduced greenhouse gas emissions.
- The Energiewende is used as a benchmark for sustainable energy policies around the world.

Bangladesh (SDG 13): Climate Resilience and Disaster Preparedness

Case Analysis:

- Bangladesh has achieved significant strides in disaster preparedness and climate resilience despite its vulnerability to climate change and frequent natural catastrophes.
- Improved infrastructure, community-based adaptation initiatives, and early warning systems have helped to save lives and lessen the effects of disasters.

Finland's Education System (SDG 4): Quality Education for All

Case Analysis:

- Finland routinely ranks among the best nations for equality and high-quality education.
- Equity, teacher professionalism, and a wholistic approach to learning are prioritised in the Finnish educational system.
- Finland has achieved outstanding educational results by giving high-quality education a priority for all students.

Global Health Progress: HIV/AIDS Prevention and Treatment (SDG 3)

Case Analysis:

- The effectiveness of international cooperation is demonstrated by the global response to the HIV/AIDS pandemic.

- The lives of people who are impacted have substantially improved thanks to multilateral initiatives, access to antiretroviral medicine, and community-based strategies that have significantly slowed the spread of HIV.

Brazilian programme to end hunger: Sustainable Agriculture and Food Security (SDG 2)

Case Analysis:

- The Brazilian government's comprehensive Zero Hunger Programme aims to end hunger and advance sustainable agriculture.
- The programme has dramatically decreased the rates of hunger and poverty by putting a strong emphasis on social protection, family farming, and food distribution.

Costa Rica's Trailblazing Efforts in Conservation and Biodiversity (SDG 15)

Case Analysis:

- Costa Rica is well known for its forward-thinking conservation initiatives and financial support for protected areas.
- The nation has improved forest cover and reversed deforestation trends, protecting its rich biodiversity.
- The strategy taken by Costa Rica shows the importance of striking a balance between environmental preservation and economic development.

Rural Water Supply Programme in Cambodia (SDG 6): Access to Clean Water and Sanitation

Case Analysis:

- The goal of Cambodia's Rural Water Supply Programme is to supply rural areas with safe, dependable water.
- The availability of clean water and sanitary facilities has improved significantly in Cambodia because to creative solutions and community involvement.

Inclusive Urban Development: Sustainable Urban Planning in Curitiba, Brazil (SDG 11)

Case Analysis:

- Brazil's Curitiba is renowned for its efficient public transit system and commitment to sustainable urban planning.
- The city's avant-garde strategies for urban planning, green areas, and public transportation serve as a template for inclusive, sustainable cities.

These case studies highlight how crucial commitment, innovation, and leadership are important in the journey toward achieving the SDGs. They show that real advancement is achievable despite difficult obstacles. We can advance our joint efforts to build a more sustainable, just, and prosperous world by 2030 and beyond by taking inspiration from these success stories and learning from their techniques.

The Role of Technology and Innovation

Innovation and technology are essential to achieving the Sustainable Development Goals (SDGs) [31]. The transformative potential of technical developments and cutting-edge methods to tackle the difficult problems described in the SDGs is explored in this section.

Benefits of Technology and Innovation

1. The SDGs and technological innovation: The SDGs can be reached more quickly thanks to technological innovation because it makes better, more efficient solutions possible. Technology provides means and instruments for addressing difficult global concerns like poverty, sickness, and climate change.
2. Digital Inclusion and Connectivity: The global digital divide can be reduced by increasing access to the internet and digital technology, opening opportunities for education, economic involvement, and information sharing. To support SDG 16 (Peace, Justice, and Strong Institutions), digital platforms can increase government transparency, streamline public services, and include individuals in decision-making [27]v.
3. Sustainable practises and renewable energy: For SDG 7 (Affordable and Clean Energy) to be achieved, advancements in renewable energy technologies, such as solar, wind, and hydropower, are essential.

4. Sustainable Food Production and Agriculture: Precision agriculture, biotechnology, and environmentally friendly farming methods can all contribute to achieving SDG 2 (Zero Hunger) while reducing negative environmental effects.
5. Access to Healthcare and Health Technologies: To support SDG 3 (Good Health and Well-Being), telemedicine and digital health technologies can increase access to healthcare in rural and underserved areas. SDG 3 (Good Health and Well-Being) and SDG 13 (Climate Action) are both addressed by big data analytics and artificial intelligence, which are used in illness monitoring and early warning systems.
6. Lifelong Learning and Education: E-learning resources and digital education platforms can increase access to high-quality education, advancing SDG 4 (Quality Education). Technology makes it easier for people to obtain new skills throughout their lives, which helps them adapt to changing employment markets and work towards SDG 8 (Decent Work and Economic Growth).
7. Environmental Observation and Protection: Monitoring ecosystems, preserving biodiversity (SDG 15), and addressing climate change (SDG 13) all depend on satellite technology and remote sensing. Sustainable consumption and production are made possible by cutting-edge approaches like 3D printing and circular economy principles (SDG 12).

Challenges of Technology and Innovation

1. Technological disruption: Technology is advancing at a rapid rate, which might cause disruptions that need for cautious planning and adaptability.

2. Digital inequality: To guarantee that technological improvements benefit everyone, it is imperative to address the digital divide, not just those with access to technology.

3. Privacy and Ethical Issues: Ethical problems and data privacy issues are becoming more significant as technology advances.

Collaboration and Partnerships

To fully utilise innovation and technology, partnerships between the public and private sectors and civil society are essential. For the purpose of solving problems that cut across national boundaries, global cooperation and knowledge exchange are crucial. Innovation and technology are potent tools that can advance the Sustainable Development Goals, increase effectiveness, and open up new prospects for sustainable development. But to realise their full potential, ethical, social, and environmental issues must be carefully considered, and everyone must have access to the benefits. We can use technology to hasten the transition to a more just, sustainable, and wealthy society by promoting a culture of invention and cooperation [32], [33].

The Future of Sustainable Development

It is crucial to consider the advancements made thus far and look ahead to the future of sustainable development as we get closer to the 2030 deadline for meeting the Sustainable Development Goals (SDGs). The future opportunities and challenges are examined in this part, along with the crucial steps that must be taken to create a more just and sustainable world after 2030. The adoption of renewable energy sources, poverty reduction, and access to education are just a few of the areas where the SDGs have significantly accelerated development. The SDGs have taught us a lot about the value of international collaboration, data-driven decision-making, and inclusive development strategies. Even after 2030, the 2030 Agenda for Sustainable Development will act as a framework for addressing global issues [10], [34].

Beyond 2030, countries must reconfirm their dedication to the SDGs and establish new benchmarks and development routes. Some crucial areas are presented below.

1. Climate change still needs to be addressed urgently, necessitating more ambitious mitigation and adaptation measures.
2. Stronger global health systems and pandemic preparedness are required, as the COVID-19 pandemic has shown.
3. Questions of ethics, governance, and ensuring that innovation benefits everyone are brought up by the quick pace of technological progress.
4. Recovery from the pandemic offers a chance to restructure economies and communities with an emphasis on equality, resilience, and sustainability.
5. Building a more equitable world requires addressing systematic disparities in healthcare, education, and income.
6. In order to address global concerns, multilateralism and international collaboration will continue to be crucial.

7. Innovation and development will be fuelled by partnerships between governments, corporations, and civic society.
8. Youth empowerment and participation in decision-making are essential for long-term sustainable development.
9. Governments and institutions will continue to be held accountable for their commitments through the efforts of civil society organisations.
10. Future sustainable development initiatives that build on the SDGs will need better data collecting, analysis, and accountability procedures.
11. For informed decision-making and public participation, transparency in reporting success and difficulties is crucial.
12. Nations may think about establishing a new vision for sustainable development in 2050, which would cover a longer term for radical transformation, after 2030.
13. The objectives of combating climate change, advancing equity, eliminating poverty, and protecting biodiversity must continue to be intertwined.

Sustainable development needs a long-term commitment, creative solutions, and inclusive strategies. The SDGs offer a roadmap for action up until 2030, but they are just one step in the process of creating a more just and sustainable world. We can create a better future that ensures the welfare of both the present and future generations by solving growing difficulties, fortifying alliances, and involving all facets of society.

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Additional Resources

Our World in Data: This website provides a wealth of data visualizations and articles on global trends, including those related to sustainable development. (Website: https://ourworldindata.org/)

Sustainable Development Solutions Network (SDSN): SDSN offers various resources, including research papers, policy briefs, and data tools related to the SDGs. (Website: https://www.unsdsn.org/)

The Guardian's Sustainable Business Section: This section of The Guardian covers news and features related to sustainable development and corporate sustainability. (Website: https://www.theguardian.com/sustainable-business)

The World Economic Forum: Explore the Forum's reports and insights on sustainability and global development issues. (Website: https://www.weforum.org/)

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CHAPTER 7
AN OVERVIEW OF MICROBIOLOGY AND ROLE IN SUSTAINABLE DEVELOPMENT

M. Taiwo

Introduction

Microbiology is the science (logy) of small (micro) life (bios). It is the study of microorganisms and/or agents that are not visible to the unaided eye. These include Bacteria, Fungi (yeast and mold), Viruses, Prions, Algae, Protozoa, etc.

Microorganisms are ubiquitous (i.e. they are found everywhere) from the human body to soil, air, foods, ocean, hot springs, frozen sea ice, etc. They had been in existence for several years but began to get noticed when Antoni Van Leeuwenhoek started his pioneering microscope work in 1673. Microscopes are devices that magnify microorganisms when viewed under them.

Importance and Applications of Microbiology

Microorganisms could be pathogenic, causing some of the deadliest human diseases; or, beneficial, serving as agents for the manufacture of several items with which life on our planet depends. Microorganisms or their derivatives have been used to make or modify products or processes for specific use. Through technology, microbial processes have influenced the production of goods and services for human and industrial welfare**.**

The importance of Microbiology is wide due to its involvement in many fields like medicine, food science, research, pharmacy, agriculture, chemical technology, environment, industry, public health, genetics, nanotechnology, etc. Their applications in these fields to enhance sustainable development are:

1. Applications of Microbiology in Medical Science

i. Production of vaccine, antibiotics, and medicinal drugs:

Microbiology through Genetically Engineered Microorganisms develops vaccines to combat diseases. For example, Bacillus Calmette-Guerin (BCG) vaccine is made from *Mycobacterium tuberculi*, Hepatitis B Vaccine from Hepatitis virus, Poliomyelitis vaccine from polio, Measles Vaccine from measles virus. Antibiotics are metabolic by-products of microorganisms.

ii. Diagnosis and treatment of diseases:

Several diseases have been successfully diagnosed and treated through microbial applications. For example, bacterial and fungi culture, sensitivity testing, microscopy are microbiological diagnostic tests used to detect the presence of diseases causing organisms in patient samples. Likewise, antibiotics (treat bacterial infections), antiviral drugs (treat viral infections).

2. Applications of Microbiology in Food Science

Through Bioprocess Engineering, microorganisms have been used to manufacture foods, beverages, additives, and supplements. Examples:

i. Through fermentation, yeast, a type of fungi known as *Saccharomyces cerevisiae* has been used to produce alcoholic beverages (beer, wines) from Vinegar, Cocoa tea from Cacao seed, and Bread from flour.
ii. Through fermentation, lactic acid bacteria (especially *Lactobacillus spp, Streptococcus lactis* and *S. cremoris*) has been used to produce milk derivatives such as cheeses, butter, soured cream, yoghurt, etc.
iii. Through fermentation, certain products have been produced from plants. For example, Using *Leuconostoc brevis,* Sauerkraut was produced from Cabbage, Pickles from Cucumber, etc.
iv. Microbial process has been used to produce food additives and supplements (flavours, proteins, vitamins, enzymes, and carotenoids). For example, Lysine, an amino acid added to animal feed, is produced in fermenters using the bacterium *Corynebacterium glutamicum;* an enzyme, glucose isomerase, important in the production of fructose syrup, is produced by using immobilized Lactobacillus cells.
v. Some microorganisms are also used as a food substitute. For example, mushroom (*Agaricus bisporus*), the stalked fruiting bodies of certain species of basidiomycete is an edible fungus. *Fusarium,* a fungus, is also a basis of QuornTM, a processed mycoprotein and has been a meat substitute in the United Kingdom, etc.

3. Applications of Microbiology in Environmental Science

Through Microbiology, environmental problems such as pollution control, energy renewal, depletion of natural resources for non-renewable energy, conservation of biodiversity, etc, are being adopted. For example,

i. Through microbial processes, Biofuels, the liquid or gaseous fuels derived from microorganisms or their fermenting biomass and the waste they produce have been manufactured. These biofuels include bioethanol, biodiesel, and biogas produced using microorganisms through biochemical pathways such as alcoholic fermentation, anaerobic fermentation, and trans-esterification.

ii. Microorganisms have been used for the detoxification of industrial effluents and other harmful chemicals through the process of Biodetoxification/Bioaccumulation

iii. Microorganisms have been used to clean up oil spillage (Bioremediation), treat sewage, purify water for drinking, recycle waste and recover metals from mining wastes and low-grade ores.

4. Applications of Microbiology in Agricultural Science

The major aim of Agricultural Microbiology is to ensure food security to the people in a sustainable way which must be sufficient, healthy, and safe. This is done through.

i. Control of plant/animal pests and diseases

Certain soil microorganisms can produce antagonistic/inhibitory substances which kill/control plant pests/diseases. For example, *Bacillus thuringiensis*, is a spore-forming bacterium containing crystalline protein inclusions which are highly toxic to specific pests and have been widely used for over 30 years against *Lepidoptera* (caterpillar) pests. *Agrobacterium tumefaciens* have been reported to control diseases of host plants (like peas, maize, onion, tobacco, tomato, and cucumber). Influenza vaccines are made from microorganisms to immunize animals such as chickens from diseases.

ii. Improvement of crop yields

Microorganisms liberate growth-promoting substances which help to maintain soil fertility and crop yield. For example, *Rhizobium* is known to stimulate the production of vitamin B complex, Indole acetic acid, Gibberellic acids, etc. Brand names of Rhizobium fertilizer in the market are Rhizo-Enrich, Rhizoteeka, Green Earth Reap N4 to grow on pulses *Bacillus megaterium* serve as biofertilizers to grow all crops e.g. Brand names in the market include Biophos, Get-Phos, MYCORISE, Kisaan P.S.B. culture, etc

iii. Several other microorganisms have been used in plant agriculture to improve nutrition, maintain quality, tolerate stress (such as pH, salinity, drought, temperature), improve productivity, and post-harvest characteristics; However, in animal agriculture, microorganisms have been used to improved animal species, meat quality, flavour, taste and promote microbial safety.

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CHAPTER 8
PHYSICS, SPACE EXPLORATION AND EXPLOITATION
O. E. Awe

What is Physics?

In the beginning, the word "physics" was used to represent the whole of scientific knowledge. Hence, the alternative name for physics at that time was "natural philosophy". Today, different aspects of the study of nature have developed as sciences in their own rights and physics is now considered to be the branch of science that deals with the study of the nature and properties of matter and energy. [Simon G.G. MacDonald and Desmond M. Burns, Physics for the life and health sciences, Addison-Wesley Publishing Company 1975pp.750] Physics may simply be defined as the science that is concerned with the study of matter in relation to energy. By matter we mean anything that has mass and volume (that is occupies a space). The Greek word ***physikos*** in English could mean Physics, the study of nature or could mean physical which referred to the study of nature or material universe and the human body.

On the premise that physics explains natural phenomena in the universe, it is common to consider physics as the most fundamental science as it provides a basis for all the other disciplines of science. Hence, without physics, there would be no biology or chemistry or geology or any other science subject. Also, without Physics, there would be no engineering or medicine.

Physics is one of the oldest academic disciplines. Within the last two millennia, physics was a part of natural philosophy along with chemistry, certain branches of mathematics, and biology. However, during the Scientific Revolution in the 16th century, the natural sciences emerged as unique research programs in their own right. Today, physics intersects with many interdisciplinary areas of research, such as biophysics and quantum chemistry to the extent that the boundaries of physics are not rigidly defined. It is important to note that new ideas in physics often explain the fundamental mechanisms of other sciences, while opening new avenues of research in areas such as mathematics and philosophy.

There are two main branches of physics: Classical Physics and Modern Physics. Physics up to 1900 A.D is Classical Physics. The division of classical physics are Mechanics, optics, waves and sound, heat and thermodynamics, and electromagnetism. The twentieth century physics is the Modern Physics. The division of modern physics are Atomic physics, Nuclear physics, Quantum physics, relativity, Cosmology and space exploration, and Mesoscopic physics.

A physicist is a person who studies physics. He/she explores and identifies the basic principles that govern the structure and behaviour of matter, the interaction between energy and matter, and the generation and transfer of energy. A degree holder in Physics or Engineering Physics could pursue careers in research and development, science, engineering, education, medicine, law, business, and military. A physicist could be employed as Academic researcher, Acoustic consultant, Astronomer, Clinical scientist, medical physicist, Geophysicist, Lecturer in higher institution, Metallurgist, Meteorologist, Nanotechnologist, Radiation protection practitioner, Sound engineer etc.

Many students whose course of study in the University has nothing to do with any of the science courses including physics may have the natural fear that this GES/ GSP course is difficult due to their backgrounds. But there is no cause for alarm, since we shall make conscious effort to ensure that we present further information on Physics, Space Exploration and Exploitation in a way that will take care of these non-science-based backgrounds and bearing it in mind that this course is not meant to make anyone a physicist in the real sense of the word. So, fear not as you read the rest of this chapter.

1. Application of Physics in Medicine

Modern medical science is based on the knowledge of basic sciences such as chemistry, biology and physics. In fact, it is a requirement that anyone that desires to pursue a career in medical science should have among other things, at least credit passes in each of chemistry, biology, and physics at the ordinary level examination before being considered for an admission. This in a way underlie the relevance of physics and the other two subjects in medical science. Knowledge of physics is crucial in medical science because: (a) the subject teaches how to deduce why, and how whatever happens and ~~how~~ to inductively reason on the question of what would happen based on whatever, with a view to solving problems and (b) the operations of many of the modern medical equipment are based on a good knowledge of physics. Furthermore, many medical technologies, diagnostic tools, and treatment methods have emerged as a result of discoveries in physics. Thus, physics comes into play in medicine in the use of the following areas:

(i) X-ray in the detection of fractures, (ii) radiation in cancer treatment, (iii) laser surgery, (iv) high-resolution ultrasound scans, (v) Computerized X-Ray Tomography (CT) scans, (vi) Magnetic Resonance Imaging (MRI), (vii) Positron Emission Tomography scan (PET scan), and (viii) Electroencephalogram (EEG).

2. Application of Physics in Engineering

What is engineering? Engineering can be defined as a profession in which mathematics and scientific knowledge are employed for the purpose of innovations or for the purpose of developing new things that are beneficial to human. Engineering equips human with the skills of thinking out of the box. In general, a good knowledge of the basic sciences enables engineers to understand the constraints inherent in a problem of interest and how to develop a solution. It is a statement of fact that the study of physics develops logical thinking, problem solving and intellectual abilities. Hence, concepts of physics such as classical mechanics, thermodynamics and statistical mechanics, and others play significant roles in the processes that result in innovations, which is a clear indication that physics is important in the development of the various branches of engineering.

In truth, engineering (civil, electrical, mechanical, industrial, agricultural, chemical or whatever engineering) is basically application of physics to create something practical. Also, there is no complex engineering problem that can be solved without a good understanding of physics. For examples, in civil engineering, an understanding of some laws of physics and other concepts of physics are needed to be successful in making necessary calculations relevant to designing and construction works; a good understanding of concepts of physics such as mechanics, dynamics, thermodynamics, materials science, structural analysis, and electricity is needed by a successful mechanical engineer in handling the construction of aircraft, watercraft, engines, robotics, weapons, cars, etc.; electrical engineers need a good understanding of concepts of physics such as mechanics and thermodynamics in order to convert electrical energy to other forms of energy and also need a good understanding of electromagnetism (a concept in physics) in order to grasp the fundamentals of electrical engineering. So, it is obvious that to build a successful career in any engineering, knowledge of physics is crucial.

Mechanics

Motion is the action of an object in changing location or position over a period. In other words, when a body does not change its position or location with time, we can say that the body is at rest, while if a body changes its position or location with time, it is said to be in **motion**. Everything in the universe moves since we live in a universe that undergoes continual motion. Examples of motion are walking, running, falling off a book an object from a table, the flow of air in and out of lungs, flow of water from the tap, automobile moving passenger from one place to another, the movement of the blades of a fan, and dust falling from the carpet. A close look at the examples of motion just given will show that there are various types of motion. Also, motion can be classified according to the nature of the movement experienced by the object in motion (e.g. linear or translational motion, rotatory or rotational motion, oscillatory or vibrational motion and reciprocating motion), according to the direction of the motion (e.g. one dimensional motion, two dimensional motion and three dimensional motion), and according to the state of the motion (e.g. uniform motion and non-uniform motion).

The branch of physics that deals with the study of motion and force(s) responsible for motion is known as mechanics. This branch of physics was developed before any other branch of physics due to the fact that the motions of bodies or parts of bodies have always been of great importance to humans. There are three divisions of mechanics, and these are dynamics, kinematics and statics (Fig1).

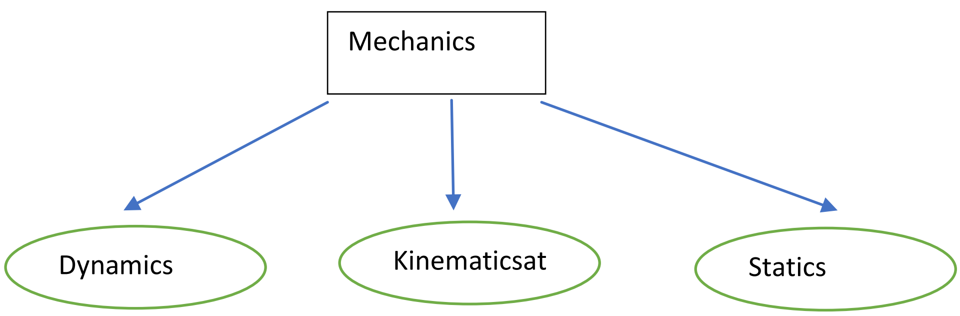

Fig. 1: Divisions of mechanics

Dynamics, Kinematics and Statics

Dynamics is the study of the motion of objects or bodies with explicit reference to the force (s) responsible for the motion, while kinematics is the study of the motion of objects or bodies without explicit reference to the force(s) responsible for the motion. Statics is the branch of mechanics that deals with the study of equilibrium state of objects (bodies) under the action of forces.

The motion of an object can be either swift or slow depending on how much distance is covered with respect to time in comparison with the motion of another object that covered the same distance. The quantities that are used to describe the motion of a body are speed, velocity and acceleration.

Speed

Speed is a measure of how fast or how slow an object moves. It is simply the rate at which distance is covered. Hence, mathematically, or in terms of formula, we can write,

$$Speed = \frac{Distance\ covered\ or\ traveled}{Time\ taken} \quad \text{Equation 1}$$

Although the commonly used units of speed are kilometre per hour (km/h) and miles per hour (mi/h or mph), on the International System of units (SI unit), speed is measured in metre per second (m/s) or ms^{-1}.

Average speed

A moving object may not always have to move at the same speed. For example, when a car is moving on a road, due to various reasons, the speed of the car may not remain the same throughout the time the journey lasts. On a trip, the speed usually varies. Thus, it is good to consider the average speed and not just the absolute speed. In terms of formula or mathematics,

$$Average\ speed = \frac{Total\ distance\ covered}{Total\ time\ taken\ to\ cover\ the\ distance} \quad \text{Equation 2}$$

Instantaneous speed

This is the speed of a moving object at an instant. The speedometer of a vehicle measures instantaneous speed. For a large time interval, the instantaneous speed and the average speed are usually different. But for extremely short time intervals, the instantaneous speed and the average speed are equal.

Fig 2a: Speedometer in km/h

Fig 2b: Speedometer in mph

Displacement

If the direction of the motion and the distance covered by an object are indicated, then we no longer talk in terms of just distance, but we now talk in terms of another quantity known as Displacement which is defined as the distance moved in a specified direction. Please, kindly note that displacement is not the same thing as distance.

Velocity

The velocity of an object in motion is the rate of change of the displacement of the object. In terms of formula, we can write

$$Velocity = \frac{Displacement}{Time}$$ Equation 3

The SI unit of velocity is metre/second or ms^{-1}.

The velocity of an object may be uniform (i.e. constant/remain the same) or non-uniform. Can you give thought to a situation where the velocity is non-uniform? In a uniform velocity, there will be no change in both the magnitude and direction of the velocity, while in a non-uniform velocity, either the magnitude or the direction of the velocity or both the magnitude and direction of the velocity have changed. Just as we have average speed, we also have average velocity in the instance when the velocity is non-uniform.

Additionally, when there is a change in the velocity, the change may be positive or negative. For example, a velocity change from 5m/s to 8m/s is a positive change (i.e. an increase), while a velocity change from 5m/s to 4m/s is a negative change (i.e. a decrease). When the change in velocity of an object in motion is positive, such an object is said to be accelerating, otherwise, the object is decelerating. In terms of formula, we can write:

$$Acceleration = \frac{Change\ in\ velocity}{Time}$$ Equation 4

Hence, if a stands for acceleration, and the initial velocity is represented by u, while the final velocity is represented by v, then, the acceleration for the time t when the velocity changes from u to v is given by

$$a = \frac{v-u}{t}$$ Equation 5

The SI unit of acceleration or deceleration is m/s2 or ms-2. If a body is moving with a constant acceleration, then such a body is said to perform uniform motion. An example of such a body is a body falling freely under gravity. The velocity of the body increases from zero when it is released at a height until it hits the ground. The constant acceleration is called the acceleration due to gravity - usually represented by the letter g. Its value is about 9.8 m/s2 or in many instances taken as 10 ms-2.

Mechanical Energy

When you observe that you are weak and do not have the stamina to carry out an activity, it is most likely that what will come to your mind is that you need to eat, especially when you know that you are not sick. Food gives you the energy you need for the work you intend to do. Hence, energy is defined as the ability of a body to do work. There are different forms of energy, and it is good to note that energy can be changed from one form to another. But in this course, we shall limit ourselves to discussing mechanical energy. There are two forms of mechanical energy. These are potential energy and kinetic energy (as in Fig.2)

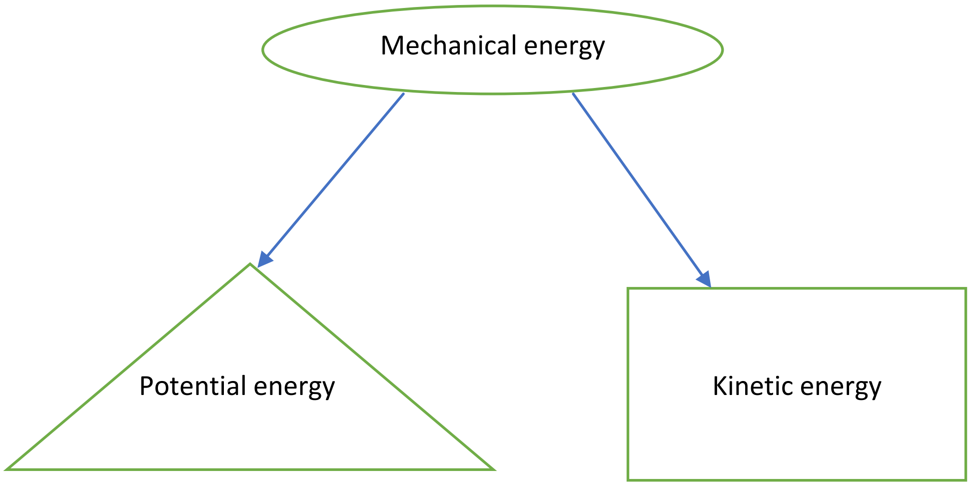

Fig. 2: The two divisions of mechanical energy.

Potential energy (P.E) is the energy which a body possesses on the basis of its elevation/height from the ground surface. It is an energy that is stored in the body. The quantity of P.E of a body is given by the multiplication (or product) of the mass (the quantity of matter in the body) of the body, the height of the body above the ground level and the acceleration due to the force of gravity. Hence, if the mass of the body is m, while h and g represent the height of the body above the ground, and the acceleration due to the force of gravity, respectively, then, mathematically or in terms of formula:

$$P.E. = m \; x \; g \; x \; h = mgh \qquad \text{Equation 6}$$

If in Equation 6, m is measured in kg (kilogramme), g is measured in m/s2 (meter per second squared) and h is measured in m (meters), then the unit of P.E. is Joule (J). In fact, the SI. unit of all forms of energy is Joule (J). Also, since the value of g in Equation 6 is about the same in different locations near the earth's surface (i.e. g equals 9.8m/s2 or approximately 10m/s2), one can predict that two different bodies having different masses or at different heights will not have the same P.E. Do you believe this? The P.E. of water high up in a dam, relative to the ground level, is utilised at hydroelectric power generating stations.

When an object or a body is in motion, the mechanical energy that comes into play due to the motion is known as Kinetic Energy (K.E). It is the energy a body possesses by virtue of being in motion. The quantity of the K.E. of a body has long been obtained by scientists by experiments to be given by

$$K.E. = \frac{1}{2}\ x\ m\ x\ v^2 = \frac{1}{2}mv^2 \qquad \text{Equation 7}$$

The SI. unit of K.E. is Joule (J)

Principle of Conservation of Energy

The principle of conservation of energy states that energy can neither be created nor destroyed but may be transformed from one form (or type) of energy to another form (or type) of energy. For example, when a mango falls from a tree, the total amount of energy of the mango due to its height is potential energy. When the mango begins to fall, the total energy will be equal to part of its original potential energy and some kinetic energy due to its motion during the fall. As the height of the mango from the ground level due to its fall decreases, its potential energy decreases while its kinetic energy increases (Can you explain this using your understanding of Equations 6 and 7?). Due to the principle of conservation of energy, the total amount of energy of the mango before the fall will always be equal to the total amount of energies (P.E.+ K.E.) during the fall, even when the height is very small until when the height is approximately zero (i.e. when the mango is almost touching the ground) at which point the total energy of the mango has been converted to kinetic energy. The principle of conservation of energy forms the basis of energy utilisation.

Hydroelectric Power Generation

Hydroelectric energy, also called Hydroelectric power or hydroelectricity or hydroelectric energy is electricity generated by man by using the cost-free potential energy of water falling from a hill or a mountain to generate electricity. The water falling from a height is directed through pipes and its energy, now in the form of K.E, is used to turn turbines (i.e. water wheels). The turbines are usually connected to coils which rotate in a magnetic field. These rotations result in the conversion of energy from mechanical energy to electrical energy. In practice, a flowing river is dammed (i.e. blocked) to create an artificial lake so that a fairly constant height (energy) can be maintained at all seasons. In Nigeria, Kainji and Shiroro power stations are examples of hydroelectric power stations. Other power stations in Nigeria source their energy inputs from other forms of energy, usually heat energy, obtained by burning coal or natural gas.

Heat Energy

Heat is a form of energy. Heat energy flows from one body to another body whenever there is a temperature (a measure of how hot or cold a body is) difference between the two bodies. Heat energy usually flows from the body with higher temperature to the body with lower temperature and the heat energy flow will continue until the two bodies have the same temperature. During heat energy flow, the K.E. of the building blocks of matter known as molecules. Please, do note that heat is not a form of matter, and this is contrary to what was wrongly believed up till around 1750.

When heat flows to a body, the K.E. of the tiny particles called atoms, molecules or ions in the body (a solid or a liquid or a gas) increases. The quantity of heat energy in a body determines its temperature. A reliable device for measuring temperature is known as thermometer. There are different types of thermometers. It is very likely that you are quite familiar with the clinical thermometer used in the hospital. The construction of any thermometer is based on a thermometric property (physical property that changes measurably with temperature) of the material of the thermometer. Examples of thermometric properties include the volume of a liquid, length of a solid rod, gas pressure, electrical resistance and electromotive force. The SI. unit of temperature is Kelvin (K). However, common units of temperature are Celsius or centigrade (0C), and Fahrenheit (’F). The normal human body temperature is 37°C (98.6'F). The ancient unit of heat energy was the calorie, and this unit is defined as the amount of heat energy required to raise the temperature of lg of water by 1°C. Today, heat energy is measured in the SI. unit of Joule (J). It is good to note that it is customary to express the amount of heat energy derivable from an amount of food or fuel in Calories.

When a body is heated it is usual that the temperature of the body will rise in response to the heat energy gained from the source of heat. Similarly, when a material is losing heat energy, its temperature will be falling. However, when a material is making transition from one state of matter to another, its temperature will remain constant until after the transition. For example, when a solid is changing to liquid or a liquid is changing to solid, the temperature will remain constant. This is the case as well when a liquid is changing to gas, or a gas is changing to a liquid. The heat energy absorbed during transition is said to be hidden and is referred to as latent heat. Thus, the absorbed by a solid to change it completely to a liquid is called the *latent heat of fusion, while the heat* required to change a liquid to a gas is called the *latent heat of vaporization.*

Conversely, the same amount of heat is released when a liquid fuses to a solid or when a gas condenses to a liquid. This phenomenon of latent heat explains why methylated spirit (a volatile liquid) appears cold to the touch. It appears cold because it extracts its latent heat of vaporization from its surroundings. The phenomenon of latent heat also explains why the water in a clay pot is much colder than its environment. This also happens because the tiny pores in the pot allow the liquid to move to the outer surface of the pot where vaporization, and extraction of heat from the pot and its content, takes place. But can you explain how a clay pot compares with the refrigerator?

Thermal-electricity plants

As earlier being mentioned, electricity is generated when a coil rotates in a magnetic field. In truth, the primary task in the process of electricity generation is how to obtain appropriate mechanical energy needed for turning the coil. On the premise that most countries do not have waterfalls required for hydroelectricity generation and in many countries where waterfalls exist, the electrical energy requirements cannot be met through only hydroelectricity alone, man have sourced for other means to generate electricity. Hence, man has been able to obtain sufficient heat needed for generating electricity by burning fuel. The electricity generated by this process of burning fuel is known as thermal electricity. An example of a power station that is generating thermal electricity is the Egbin power station near Lagos which is using natural gas piped from the oil field as fuel.

Furthermore, another source of heat energy which can be used to generate electricity is nuclear fuel. The top ten countries in the decreasing order of how nuclear fuel they produced as of 2021 are United States, France, China, Japan, Russia, South Korea, Canada, and Ukraine. Although nuclear fuel is an enormous source of heat energy, the process, however, is usually accompanied by the production of very small quantity of extremely toxic radioactive pollutant which can remain toxic for thousands of years. At present, nuclear waste is stored since there is no way to destroy or permanently dispose of it.

Solar Energy

A large amount of energy is generated through nuclear fusion processes in the sun. This energy is transmitted in the form of light and heat waves through space in all directions. The amount of this energy that gets to the earth's surface provides warmth and helps in keeping life going. This energy from the sun is known as solar energy. It is an energy that can be converted to electrical energy. Solar energy is the cleanest and most abundant renewable energy source available. The U.S. is known to have some of the richest solar resources in the world. Solar energy has been used since time immemorial for various purposes by man.

Even prior to any of the modern-day uses of solar energy, man has long learnt how to use this energy to dry agricultural products, to provide space heat in cold seasons or to create ventilation in homes. It is also on record that more than two thousand years ago, Heron of Alexandria constructed a simple water pump driven by solar energy and in 214 B.C. Archimedes of Syracuse used concentrating solar mirrors to set fire to Roman ships. The latest invention of man that converts solar energy into electrical energy is known as the solar cell. The common type of solar cell is a semi-conductor device sensitive to the photovoltaic effect (a phenomenon in which light falling on a prepared boundary between certain pairs of substances such as a P-N junction in a semi-conductor produces an electrical potential difference across the boundary). When a number of solar cell units are combined, we get what is called a solar battery which produces a large amount of electrical energy that can be used in homes and industries.

Waves, Sound and Optics

A wave is a travelling disturbance. It is a propagation of energy through a medium or space without the particles of the medium being displaced. There are many kinds of waves, depending on the kind of disturbance that is created by the source of the wave and the kind of material or medium the wave travels through. All waves can be classified as either mechanical or electromagnetic waves. A mechanical wave needs a medium of travel unlike an electromagnetic wave which does not. The ripple generated when a pool of water is disturbed at a point, and which then spreads to other parts, is a form of wave. Can you categorise this wave? So also, is the vibration produced at one end of a string which then travels to the other end. A diagram of surface waves in water is shown below.

Fig.3 Water wave (Source: ducksters.com)

In a mechanical wave, the particles of the medium vibrate to and fro about their mean position as the wave travels from one point to another. Sound is an example of a mechanical wave. Can you guess why sound wave is categorized as a mechanical wave? Sound waves often emanate from a vibrating source (such as the diaphragm of a drum or the vocal cord of a human being when he/she talks). Sound wave usually travels in air with a velocity of about 340 m/s.

Properties of Waves

Each wave has amplitude, frequency, wavelength, and velocity or speed. These are the four basic properties or characteristics of a wave. Sometimes, period is also listed as one of the properties of a wave.

The Amplitude of a wave is the maximum excursion of a particle of the medium from the particle's undisturbed position or the maximum vertical displacement of the wave or the maximum height of the wave from the rest position. Its SI. unit is metre (m).

The Wavelength of a wave is the distance between successive crests (a crest is the peak or the highest vertical part of a wave) or successive troughs (a trough is the lowest part of the wave or the bottom of the wave) of the wave. Its SI. unit is metre (m).The *Frequency* of a wave is the number of times each particle in a wave completes one to-and-fro vibratory motion per second or the number of times per second that the wave cycles. The SI.unit of frequency is Hertz (Hz). The *Period* of a wave is the time required for the wave to travel a distance of one wavelength or the time it takes the wave to complete one cycle. Its SI. unit is second (s). The speed or velocity of a wave is a measure of how fast or how slow the disturbance of the wave is moving. Its SI. unit is metre per second (m/s)

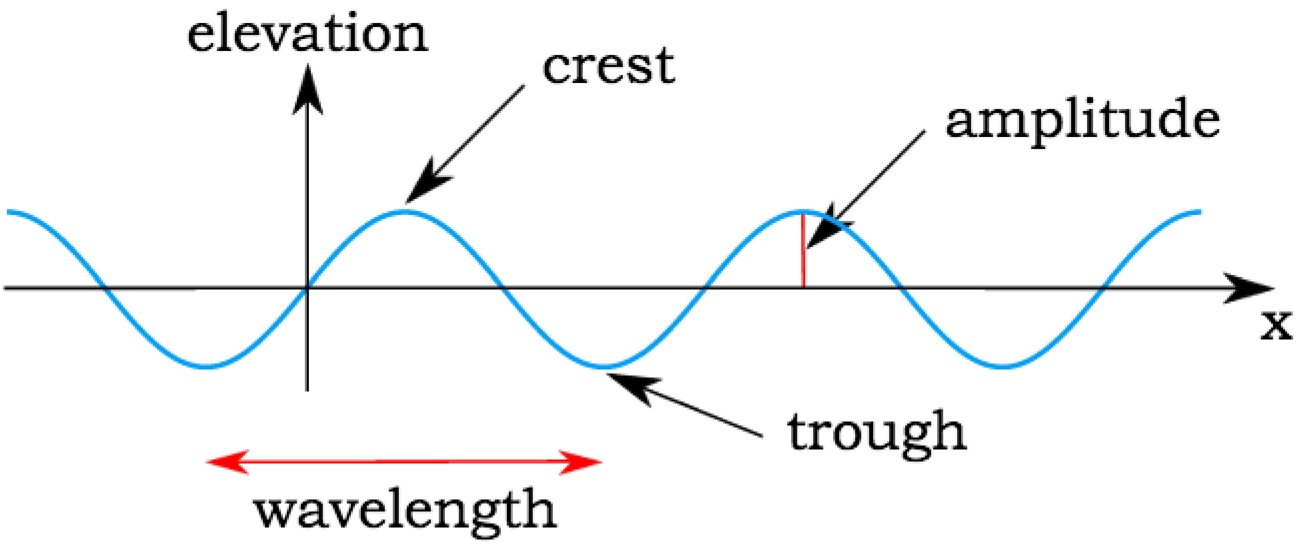

Fig. 4

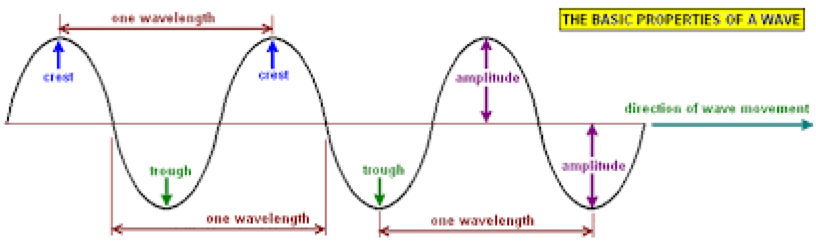

Fig. 5 The Basic Properties of a Wave

Sound

Sound is a longitudinal wave that is created by a vibrating object like a guitar string, the human vocal cords, or the diaphragm of a hi-fi speaker. It can only be created in a medium such as a solid, a liquid and a gas. Sound reaches the listeners' ears as waves in the air or waves in other media. When an object vibrates, it results in slight changes in air pressure. These air pressure changes travel as waves through the air and produce sound. Scientifically, there is no difference between sound and noise since what may be considered as difference between the two depends on the listener and the circumstances. In fact, a noise is a sound from one or more sources at a time which cannot be heard clearly. Music is a pleasant sound while noise is an unpleasant sound. Sound travels with a speed of about 340 m/s in air. Sound cannot travel in a vacuum. The loudness of a sound is the sensation of the perceiver to the sound intensity, and it is a very subjective quantity. The intensity, I, of a sound is defined as the energy per second (Watts) flowing through a square metre normal to the direction of the sound waves. Hence, the SI unit of sound intensity is W/m^2. Also, the SI. unit of sound pressure is Pascal (Pa). A sound intensity of $1W/m^2$ corresponds to about the loudest sound which normal human can tolerate, while the faintest sound detectable by the human ear is about $10^{-12} W/m^2$.

Experiments have shown that a healthy young person can hear all sound frequencies within the range 20-20,000 Hz. This is known as the audible range of sound. The ability for humans to hear the high frequencies decreases with age. It should be noted that some dogs can pick sound frequency as much as 30 kHz and bats can hear sound frequency as high as 100 kHz. Can you give possible benefit(s) of the high sound frequencies endowment to these animals? Additionally, sound are classified into three types: Infrasonic sound (a sound whose frequency is below 20Hz, elephants use Infrasonic sounds to interact with herds hundreds of kilometre away, sound produced in earthquake is inclusive), Sonic sound (a sound whose frequency lies between 20 to 20,000Hz, healthy young person can hear this sound), and Ultrasonic sound (sound whose frequency is higher than 20,000Hz, some animals are endowed with this).

Electromagnetic Waves and Optics

An electromagnetic wave consists of varying electric and magnetic fields which are at right angles to the direction of propagation. The wave does not require a medium to propagate, unlike a mechanical wave such as a sound wave. The electromagnetic spectrum is the arrangement of all electromagnetic waves in the order of their frequency or wavelength or energy. All electromagnetic waves travel through a vacuum at the speed of $3.0 \times 10^8 m/s^2$. The electromagnetic spectrum is as shown below:

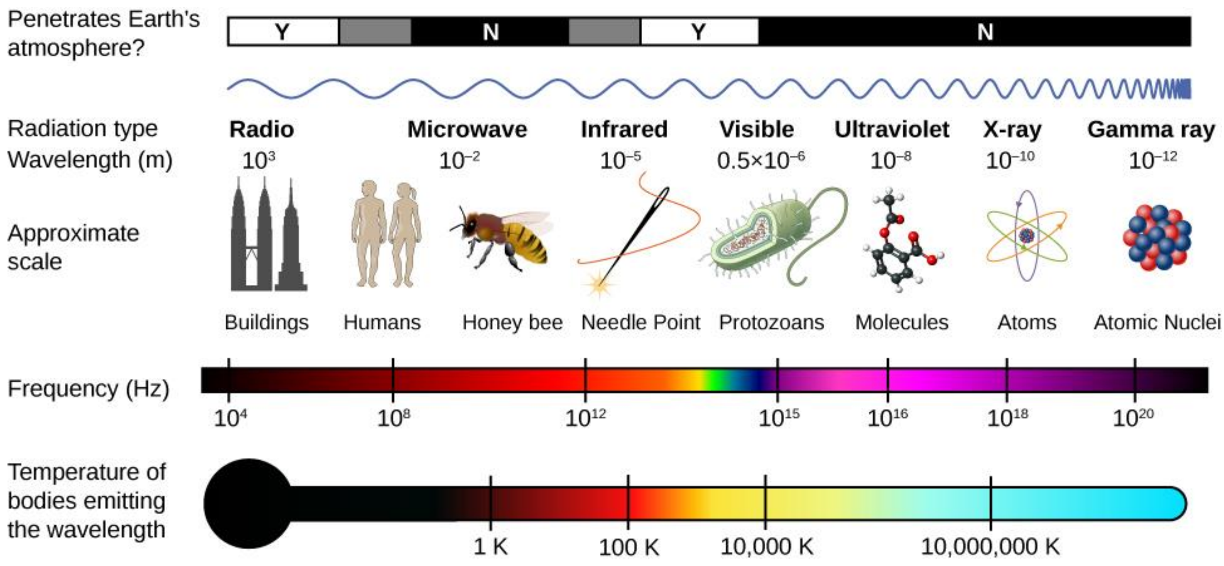

Fig.6 *Electromagnetic spectrum, showing the major components of electromagnetic waves* (Source: https://openpress.usask.ca/)

The portion of the electromagnetic spectrum that is visible to the human eye is the visible light and it contains seven different colours: Red, Orange, Yellow, Green, Blue, Indigo and Violet. When light travels in a single medium, it travels in a straight line. Also, when light is incident at the boundary between two media, three things can happen to it depending on the nature of the media: the light waves may be partly or completely reflected, partly or completely transmitted, or partly or completely absorbed by the media. These happen at proportions which depend on the nature of the boundary (for example, between glass and air, up to 56% of light will be transmitted, whereas wood will absorb up to 98% while a mirror will reflect as much as 99%). The construction of optical instruments such as the camera, microscope, telescope, and eyeglasses is based on these properties of light.

Electricity

Electrical phenomena have been studied since antiquity, although advances in the science were not made until the seventeenth and eighteenth centuries. Hence, practical applications of electricity remained scanty, and it was not until the late nineteenth century that engineers were able to put electricity to industrial and residential use. At present, it is obvious that the rapid expansion in electrical technology has transformed industry and society. Electricity's extraordinary versatility as a source of energy means can be put to an almost limitless set of applications which include transport, heating (this includes the central heating often used in cold climates to heat private houses and public buildings), lighting (e.g. the light bulb), refrigeration, air-conditioning, communications and computation. Electrical power is the backbone of modern industrial society and is expected to remain so for a long time in the future.

The region surrounding a static, charged body is called an electric field and any other charge placed in this field will experience a force called Coulomb's force. The nature of the force is such that like charges repel and unlike charges attract. In a conductor, there are free charges which will move when an electric field is maintained across the conductor. The direction of motion is according to the direction of the electric field. The moving charges constitute an electric current.

The charge flow in an electrical conductor (such as electric wire) is similar to the flow of water in a pipe when one end of it is elevated. The elevated end of the electrical conductor is the end to which negative charge (electrons) will move. Battery terminals or the terminals of an electric power generator can maintain the required field in a conductor when connected across it.

The moving charge in a conductor has some kinetic energy which it constantly loses to the atoms of the materials as it continuously collides with them. This leads to, a heating effect on the material. This is simply the source of the heat generated in electrical appliances such as the electric heater, and filament bulbs. Electrical energy can also be converted to mechanical energy in electric motors, light energy in electric lamps, sound energy in radio and T.V. sets, and chemical energy in electrolysis.

Magnetism

When a charge is in motion, a magnetic field exists around it in addition to the electric field. Thus, an electromagnetic field is said to exist around a moving charge. Also, a moving charge in a magnetic field will experience a magnetic force. A magnet is a piece of metal which, in a magnetised state, can establish a magnetic field around itself. These metals include cobalt, nickel and iron, and their alloys. They all have the ability to attract pieces of the same group of metals. Magnetic force of this nature has found significant applications in the telephone, electric fans, electric motors, electric bell, and telephone receiver.

When a bar magnet is suspended horizontally in the air, usually, it will settle in an approximately North-South orientation due to the earth's magnetic field. The end pointing towards the south pole is termed south pole, while the other end pointing towards the north pole is called the north pole. This is the property of the magnet being used in a compass widely used in air and sea navigations. When a coil rotates in a magnetic field, electric current is established in the coil which indicates the conversion of mechanical energy to electricity. This is called electromagnetic induction, and it is responsible for over 70 percent of the electrical energy generation in the world. The remaining 30 percent of the electrical energy generated is due to nuclear power generation, chemical cells, solar cells, etc.

Electronics

Electronics is the applied science that deals with the development and behaviour of electron tubes, semi-conductors and other devices in which the motion of electrons can be controlled. Its theoretical basis lies in the principle of electromagnetism and solid-state physics. Electronics began to grow with the development of the radio in the l920s and radar systems during the Second World War. The invention of the transistor in 1948 as a small, cheap replacement for the vacuum tube led to the rapid development of computers, transistor radios, etc. Now with the widespread use of integrated circuits (ics), electronics plays a vital role in all activities of the contemporary society, ranging from communications and entertainment to information storage and processing for business and military use, and to measurement and control in manufacturing and science.

All electronic circuits contain active and passive components which change energy from one form to another. Sensors of light, temperature, sound pressure, etc. may also be present. Passive components are normally conductors and are characterised by their properties of resistance, R; capacitance, C; and inductance, L; one of which dominates the others, depending on the function required of a given circuit. Active components in electronic circuits are semiconductor chips (formerly electron tubes) which control electron flow.

Semiconductor Electronics

Semiconductors like Germanium and Silicon belong to a class of materials that have electrical resistivity between that of good conductors such as metals and that of insulators like Perspex. Semiconductors are used in the electronics industry. In pure state, a semiconductor has both positive and negative charge carriers in equal amount. The population of these carriers is sensitive to temperature, and this is the reason why semiconductors are used as temperature measuring transducers called thermistors.

When doped with certain impurity atoms, a great majority of positive carriers can be introduced to increase their concentration relative to negative charge carriers. This type of semiconductor is called the p-type. Doping can also be done such that there is a majority of negative charge carriers. When this is the case, we have an n-type semiconductor. A special industrial melting process can produce an alloy with p- and n-type semiconductors in contact. Their junction is called a p- n junction and allows current to flow only when the p- end is connected to the positive terminal of a battery, that is, when forward biased. Very little or no current flows when the junction is reverse biased. This implies that That is, the junction allows current to flow only in one direction and can thus convert an alternating current into a direct current. Such devices are called rectifiers. The p-n junction device, which is a tiny component made for the purpose of rectifying alternating current, is called a junction diode.

Space Exploration and Exploitation

Space exploration is the act of investigating the universe from the space (the physical universe immediately outside of earth's atmosphere), while space exploitation is the act of making use of and benefiting from resources in the outer Space. Man has been involved in space investigations for many decades and has been able to explore the space through the use of spacecrafts (a spacecraft is a space vehicle designed for travel or operation, with or without a crew, in a controlled flight pattern above Earth's lower atmosphere; a satellite is a sort of spacecraft). The first spacecraft named Sputnik 1 was launched on October 1957 and is a Soviet Union’s spacecraft.

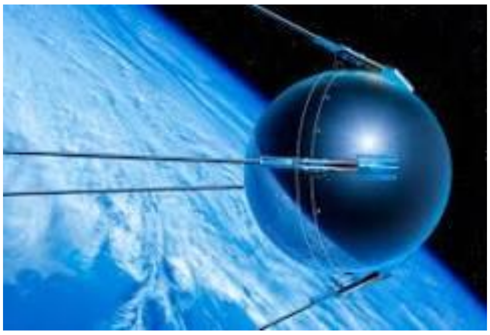

Fig. 7 Sputnik 1:

Benefits of Space Exploration and Exploitation

There are many benefits associated with space exploration and exploitation. These include:

1. investigating the universe from the space allow man to have access to the details of far-off galaxies, and events marking the birth, evolution and death of stars which man will not have access to due to the blurring effects of the atmosphere coupled with the lack of access to wavelengths of electromagnetic radiation not easily accessible from the ground

2. to look back at the Earth with a view to study its rich complexity and the effects of humans on the terrestrial environment

3. for satellite communications meant for entertainment, information (on weather patterns, security) and environmental monitoring

4. to study the climates of other planets to provide better understanding of the earth's climate

5. to excite young ones and provide encouragement for them to pursue career in science and technology.

Downsides and Hazards Associated with Human Spaceflight and Space Exploration:

The major hazards and downsides of spaceflight and space exploration include:

1. higher levels of damaging radiation from flows that results from space in the form of cosmic rays and electromagnetic waves which emanate from the sun and other stars
2. altered gravity fields
3. long periods of isolation and confinement
4. a closed and potentially hostile living environment devoid of air, food, or water. Everywhere it is either too hot or too cold for human life
5. the stress associated with being a long distance from Mother Earth, and
6. Space exploration has often been used as a proxy competition.

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CHAPTER 9

AN OVERVIEW OF THE STUDY OF GEOGRAPHY AND GEOLOGY: EMPHASIS ON THE AREAS OF APPLICATIONS

F.F. Ajayi

Introduction

Geography is a field of study that is concerned with the features of the earth's surface. It is more concerned with the components found on the surface of the Earth including Humans, Mountains, low-lands, waterbodies, atmosphere and so on. The locations both in time and space of these components as well as the processes that shapes them are also of interest.

Geology on the other hand, is the study of the whole Earth; including the compositions of the solid earth's interior, exterior, the interactions going on within its numerous components and its relation to other members of the system within which it is found.

Both Geography and Geology are fields of studies in sciences (Geosciences) but Geography has the part of Social-sciences incorporated into it. The two fields having the prefix "Geo" means they both have to do with the study of the Earth but while Geology is more all-encompassing about the complete details of the Earth, Geography only deals with the study of the physical aspect of the planet. In essence we can say:

GEOGRAPHY = PHYSICAL GEOLOGY + SOCIAL SCIENCE

Physical Geology is an area of specialisation in Geology that examines the materials composing the earth and seeks to understand the many processes that operate beneath and upon its surface as well as the resulting landforms, while ***Historical Geology*** focuses on the understanding of the origin of the earth and its development or evolution through time. Other fields of Geology are Geochemistry, Mineralogy, Petrology, Geophysics, Palaeontology, Sedimentology, and so on.

The Earth

Our **Planet Earth** is part of a larger system known as the **Solar System**. The Solar System consists of a star- **the Sun**, and everything bound to it by gravity, including the planets - Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, dwarf planets such as Pluto, dozens of moons and millions of asteroids, comets and meteoroids (coursehero.com).

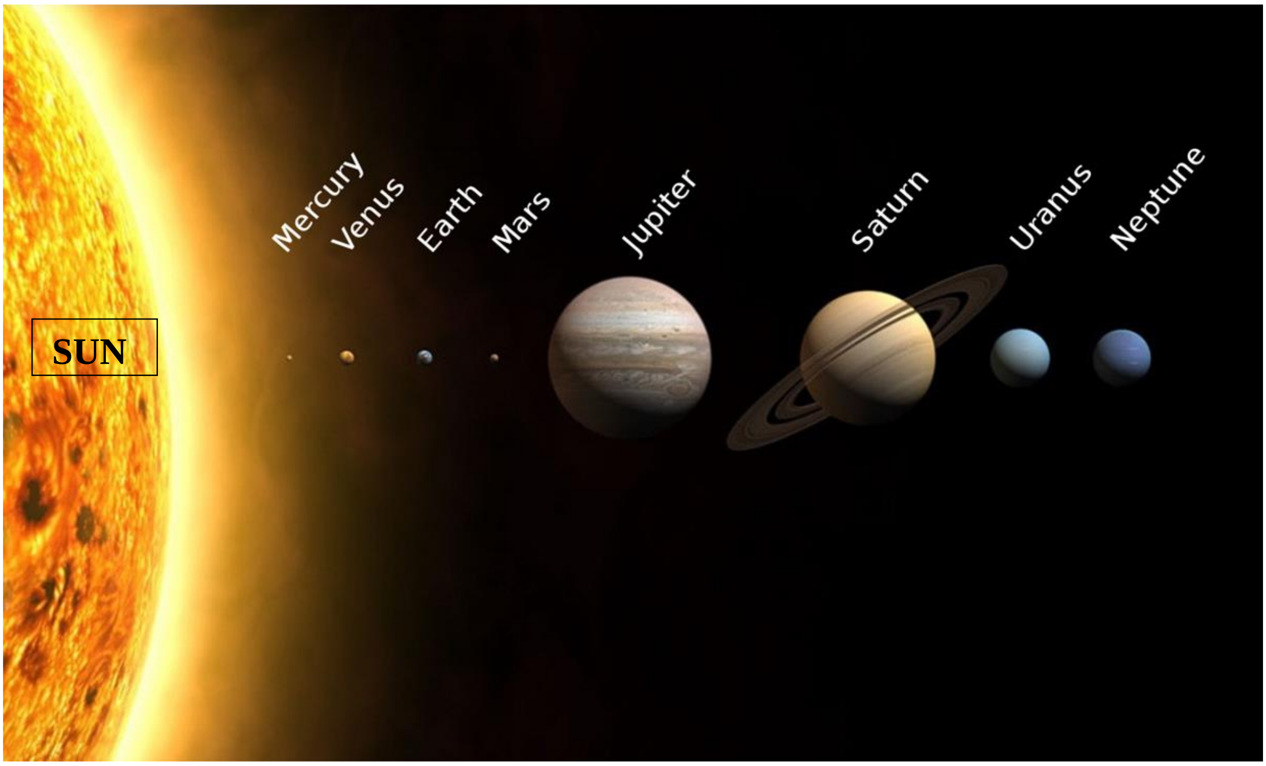

Fig 1: The Solar System (Source: **African Cat** https://myfreeschooltanzania.blogspot.com/)

The Zonal Structure of the Earth

Atmosphere: The atmosphere is gaseous envelope that surrounds the earth. The atmosphere is rather simple in composition, being made up of mainly N_2 and O_2, with minor amounts of other gases like CO_2, H_2O, O_3 and so on, which although constitute a small percentage by volume, but are very significant in the atmosphere.

Biosphere: The Biosphere is the totality of organic matter distributed throughout other component of the earth such as the Hydrosphere, the Atmosphere and on the surface of the crust. The term Biosphere is used in two senses, -one denoting that part of the earth capable of supporting life and the other is - sum of living matter including plants, animals, macro and microorganisms. In the first sense, it appears to comprise a narrow zone at surface of the hydrosphere and the lithosphere which is the region in which life is most prolific, as result of the favourable conjunction of water, air and sunlight (krishikosh. egranth)

However, the zone of life is more extensive than this, as life has been found to exist at the highest mountain top, the bottom of the ocean and deep within the crust. In addition, the remains of some of these lives may become incorporated into rocks especially sedimentary rocks in which case, they are called **fossils**.

Hydrosphere: It is the discontinuous shell of water encompassing the earth. It includes the fresh water and salty water that may be in the form of solid or liquid at the earth surface or deep within. This means it comprises of the oceans and their connected seas, gulfs and lakes. The waters of the rivers and stream including groundwater found below the surface in rock crevices, regoliths and overburden. It also includes the snow and ice as well as Glacier. Water is a very vital component to life or the existence of life. It also supports various geological and geochemical activities (Ajayi 2020). The oceans are clearly of first magnitude for they cover an area of $361 \times 10^6 Km^2$ or 70.8% of the earth's surface (Ajayi & Sikiru 2020).

Internal Structure and Composition: From the interpretation of seismic data and other significant information such as the relative abundance of elements and the composition of meteorites, we are provided with information of the earth being composed primarily of 3-fold divisions which are the Crust, the Mantle and the Core.

The Crust: the outermost zone, is the hardened exterior of the earth and varies in thickness from about 5 to 70 kilometres (3-30 miles). It is heterogenous, of variable thickness and composition, it comprises of two divisions called the **Continental Crust** and the **Oceanic Crust**.

Continental Crust is about 10-70km thick. It underlies all continental areas on the surface of the earth and has average composition of granite to andesite rocks (felsic to intermediate rocks), mainly Na, K and Al silicate rocks. The rocks of the Crust fall into two major categories – SiAl (Continental) and SiMg (Oceanic).

The Oceanic Crust ranges in thickness between 8-10km, it is not as thick as the Continental crust, underlies all ocean basin and primitive subduction zones. It has an average composition of (mafic) Fe, Mg silicate igneous rocks like basalt, which means it is basaltic in nature.

The Mantle: is a solid yet putty-like rock that can flow, it is up to 3488km in thickness approximately as reported by seismic data. It is made up of ultramafic igneous rocks like peridotite. Various evidence supporting this comes from seismic wave velocity experiment' result and peridotite xenolith brought to the surface by magma.

The Core: is about 2883km in radius. It is made up of Fe and Ni. The core of the earth is further subdivided into two; an **outer-core** which is believed to be a layer of molten liquid rich in nickel and iron, and an **inner-core** which is thought to be a solid, spherical mass of iron.

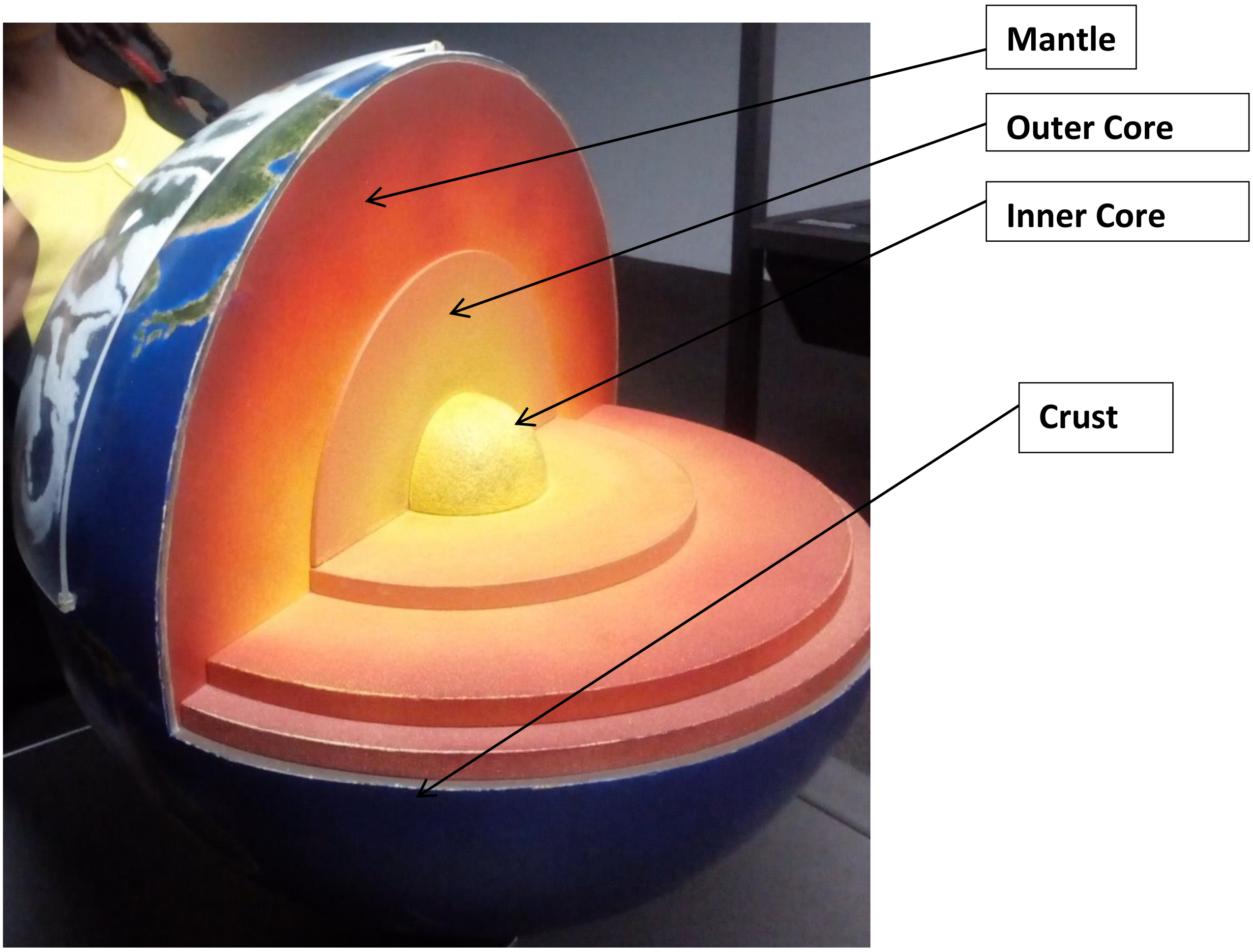

Fig 2: Internal Structure of the Earth

Table 1: The Zonal structure of the Earth

Name	Important Chemical characteristics	Important physical characteristics
Atmosphere	N_2, O_2, H_2O ,CO_2, Inert gas	Gas
Biosphere	H_2O, Organic substances, skeletal matters	Solid liquid and often colloidal

Hydrosphere	Salt and freshwater, ice	Liquid (in part solid)
Crust	Normal silicate rocks	Solid
Mantle	Silicate minerals olivine, pyroxene or their high-pressure equivalents	Solid (in part ductile)
Core	Iron- nickel alloy	Inner part solid Outer part liquid

Plate Tectonics and Isostacy

The **Crust** forms less than 1% of the Earth by volume and less than 0.5% by mass, however it is the only major subdivision yet directly accessible to man. **Continental crust** is thicker and denser than **Oceanic crust.** The solid **Lithosphere** is composed of the Crust and the upper part of the Mantle. The softer, more flexible part of the mantle underneath the lithosphere is the **Asthenosphere** (Fig.3).

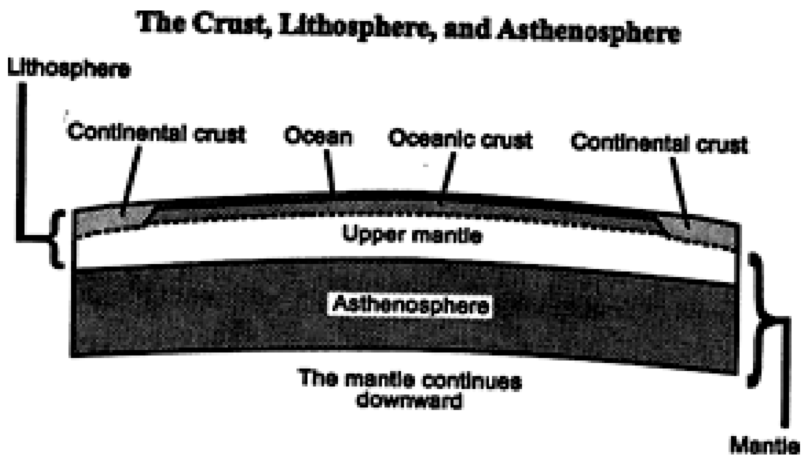

Figure 3: The Crust, Lithosphere, and Asthenosphere

(cliffsnotes.com)

As the earth cools, the intense heat being produced in the core creates **convection currents** in the mantle that bring hot mantle material up toward the crust, and colder mantle and crustal rocks sink downward. This heat engine drives **Plate tectonics**, or the movements of large segments of the earth's crust (plates) that are separated along deep cracks called **faults.** The plates move over the asthenosphere, which is softer and less resistant. The crust breaks into these segments because of the upward movement of molten material below. The powerful internal tectonic forces squeeze and fold solid rock, creating massive changes in the earth's crust, such as rugged mountains and deep submarine canyons.

Types of Plate Boundaries

There are various movements taking place at the boundary in-between the crustal plates. A **Divergent boundary** is one marked by plates that move away from each other but are not completely separated from each other because new crustal materials are upwelling from the mantle, therefore the movement is a kind of spreading out. Examples are regions that coincides with crests of submarine mountain ridges, like the mid-Atlantic ridge between the African plate and South American plate. New oceanic crust is formed along the mid-oceanic ridges by outpouring of mantle magma on the ocean floor, the process is referred to as **sea floor spreading** and this point of spreading is called **spreading-centres.** This is why Divergent plate boundaries are otherwise known as **Constructive Plate Boundaries** (Figure 4).

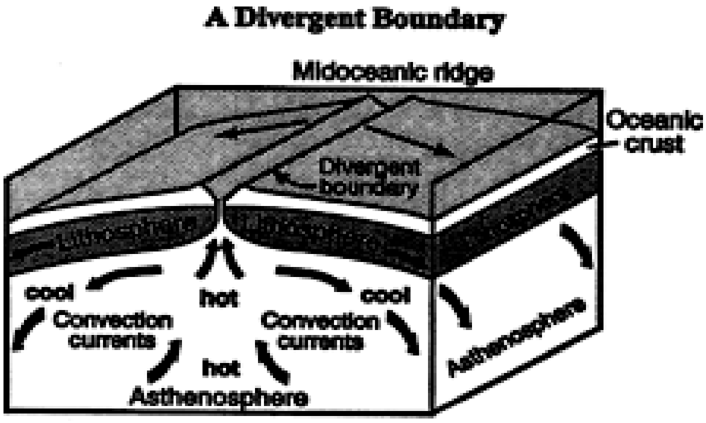

Figure 4 A Divergent Boundary

Convergent Boundary is otherwise known as **Destructive Margins** occur at locations of deep ocean trenches where the Continental crust and Oceanic crust push against each other, resulting to the Oceanic crust sliding down under the Continental crust, the point at which this takes place is known as **Subduction zone**. The jolting or rubbing of plate result in high heat flow causing some natural phenomenon such as **Volcanic eruption** or **Mountain building**. The Subduction zones create an ideal place for rocks to melt into magma as they are subjected to friction and higher geothermal gradient which contribute heat to the melting process. Examples exist between the western pacific plate and the Philippine Sea plate, also the Indian plate and the Eurasian plate which is building the Himalayas Mountain range (Figure 5).

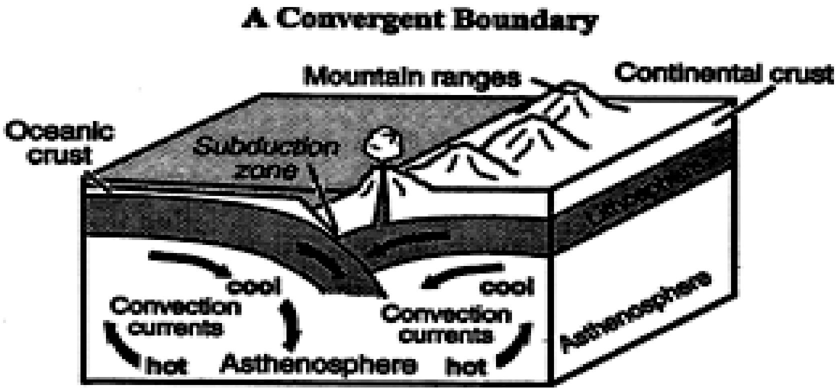

Figure 5 A Convergent Boundary

Transform Boundaries are **fault** zones or regions of faulting where plates slide past one another as a result of tectonic forces. Examples exist between the North American plate and the East Pacific Plate. This is the region of the of the San Andres fault in California. The resultant effects include earthquakes, hot springs, and so on. (Figure 6).

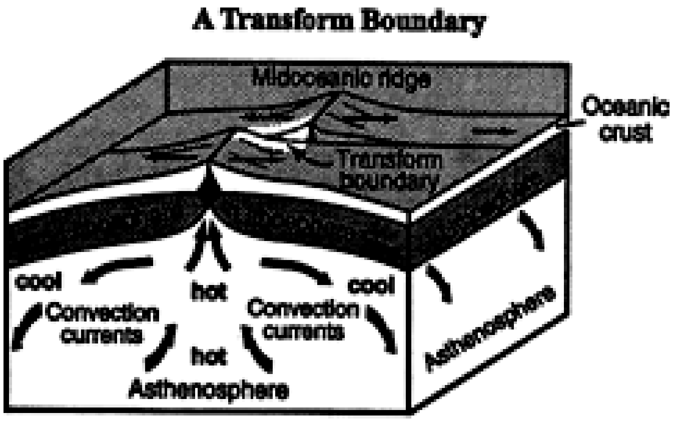

Fig. 6 A Transform Boundary

Isostacy is the process of adjustment constantly taking place within the earth crust e.g. the vertical movement of sections of earth rust to achieve balance after been thrown out of balance by tectonic forces or the process of erosion in a particular locality which leads to a corresponding/eventual deposition in another place.

The Earth's Processes

The Earth’s system even though it is about **4,500 million years old**, is still a very active system and a lot of processes are observed to be taking place both within the interior (Endogenous Processes) and on the surface (Exogenous processes). **The principle of uniformitarianism**—otherwise known as “the present is the key to the past”— is still applicable. Ancient rocks show textures that can be seen forming today from processes such as volcanic eruptions, earthquakes, hot springs, wind, weathering, river action, sedimentation, and erosion. (cliffsnotes.com)

Endogenous Processes the Earth’s internal engine is driven by heat moving from the interior of the earth towards the cooler exterior, the moving tectonic plates, earthquakes, etc. are products of this heat engine. The heat energy produced from the earth’s internal reaction may be stored and then released suddenly in the form of mechanical energy causing the various movements observed on the surface of the earth. The energy in the form of heat causes rocks to melt resulting into magma flow and ultimately volcanoes.

Exogenous Processes are directly driven by the earth’s external heat energy which is the solar power of the sun. Heat from the sun provides energy for circulating the atmosphere and the oceans producing ocean currents which causes the circulation of the atmosphere and the hydrosphere. Therefore, our **climate and weather** are largely products of the solar heat engine. For instance, hot air rises near the equator and sinks in cooler zones towards the North and South poles creating winds and ocean waves which can grow to enormous sizes to produce phenomenon such as hurricane, tornadoes, etc. When moist air cools, it rains or snow to the earth surface, the rainfall flows down into streams, lakes or seas causing erosion, denudation, landslides and mudflows. Glaciers will grow where there is abundant snowfall, glaciers can grind and carry away underlying rocks as they move. In this way, rocks originally brought u by earths internal processes are worn down by the **earth’s external processes**. As materials are removed through erosion and other processes, **isostacy** works to move the land mass upward, in due time, rock bodies found at deeper depths are seen at the earth’s surface.

Weathering

Weathering can be defined as the mechanical disintegration or chemical/biological decomposition of rocks in situ by natural agents at the surface of the earth. The process of weathering alters rocks at the earth's surface and breaks them down over time into fine-grained particles of sediment and soil. (onsgeography.com) The **agents of weathering** include air, water and temperatures which acts on the exposed rock surfaces and prepares the rock for erosion. **Erosion** involves physical removal of rock pieces by physical agent such as water or glaciers. Weathering helps breakdown a solid rock into loose particles that are easily eroded. The particles then get **transported** by water, ice and wind to the region of deposition or place of deposition. **Transportation** is the movement of eroded particles by agents such as river, waves, glaciers and wind to where they are **deposited** to form sedimentary deposits, which can be later eroded again or transformed into sedimentary rocks. The weathering of the sediment grains continues during erosion and transportation. Weathering is generally a long, slow process that is continuously active at the earth's surface. (factsanddetails.com)

Note: Weathering is clearly different from erosion because erosion is the movement of weathered rock material while weathering is the initial phase in the denudation of any landscape as the rock must be weathered first before the debris would be eroded or transported.

Types of Weathering

Mechanical Weathering

It is the disintegration or breaking up of rocks by external physical agents, such as the freezing of water in cracks within the rock thereby increasing the surface area. This leads to a greater exposed surface for the attack of the agent of chemical and or biological weathering. The nature of mechanical weathering could be in the form of frost wedging, exfoliation and thermal expansion.

Frost wedging is the mechanical effect of freezing water on rocks. It results from the expansion of freezing water within cracks and joints that pushes rock apart, widens and deepens the cracks, breaking off pieces and slabs. Frost wedging is most effective in those climates that have many cycles of freezing and thawing. **Frost heaving** is the process by which rocks are lifted vertically from soil by the formation of ice. Water freezes first under rock fragments and boulders in the soil; the repeated freezing and thawing of ice gradually pushes the rocks to the surface.

Exfoliation is due to the exposure of large intrusive rocks to the earth surface which leads to a reduction of the confining pressure acting above them while the pressure acting underneath is still being exerted. This forces the rock to expand on the outer surface, because the outer layers expand, cracks and sheet joints develops parallel to the curved outer rock surface. The sheet joint surfaces become surfaces along which curved pieces of rock break loose exposing a new surface in the process.

Exfoliation Domes are large, rounded landforms developed in massive rocks such as **Granite,** by exfoliation processes, it is a common feature observable in rocks of the **Basement complex** of Nigeria.

Fig. 7: Exfoliating Dome of Granite (qudra.com)

Chemical Weathering involves the breaking down of pre-existing rocks chemically by adding or removing chemical components and changing or altering them into other materials. Chemical weathering consists of chemical reactions or chemical processes, most of which involves water, oxygen and weak natural acids. Various processes of chemical weathering include **Dissolution, Hydrolysis** and **Oxidation.** Chemical weathering tends to establish **equilibrium** between rocks of different composition and the surface or near surface environment. The stable minerals from chemical weathering are mostly quartz, aluminium-silicate clays, iron-oxides and calcite (in desert regions where there is no water). It should be noted that the principal product of chemical weathering are the clay minerals. Soluble minerals like calcite will dissolve completely in the presence of water while quartz is very resistant to weathering. Parent rocks form soils easily in the tropics where chemical weathering is enhanced by abundance of water, humidity and warm temperature.

Differential Weathering is a term used to describe varying weight of weathering in an area where some rocks or part of the component of a rock body are more resistant to weathering than other rock parts creating uneven rate of weathering and erosion. This phenomenon often forms arched natural bridges or spectacular mush-room shaped rock formation where a broad more resistant sand stone ledge is perched on a narrowed column of less resistant shale that has eroded faster.

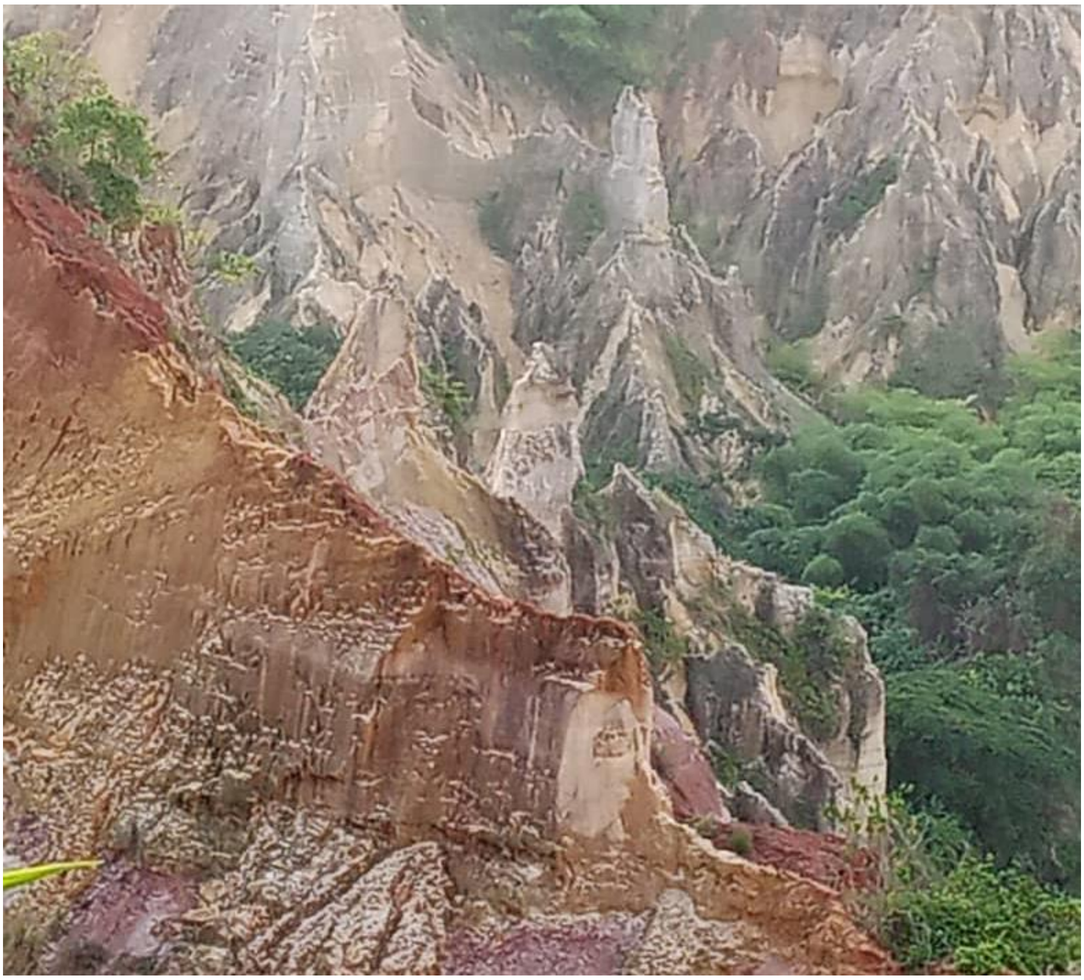

Fig. 8: Features of Differential weathering at Erosional site in Amakwor, Nanka town, Anambra Basin, Southwestern Nigeria. (Okafor 2021)

Biological Weathering is the process of weathering normally aided by living organisms. The slow process of weathering is eventually seen when plant roots grow into cracks within rocks thereby gradually enlarging and presenting wider surfaces for chemical weathering processes.

Minerals and Rocks

A Mineral is a naturally occurring inorganic crystalline solid material that has its own definite chemical composition and a set of distinguishing physical properties. The word crystalline refers to the ordered arrangement of atoms in the physical structure of the mineral constituents of a rock body or solid. A Crystalline solid mineral would be referred to as being Euhedral when it has its crystal faces well developed. It is Anhedral when the faces are not well developed. It is called Subhedral when the faces are partially developed.

The Physical and Determinative Properties of Minerals

There are several physical properties which can be used in the identification of minerals, these set of properties can be grouped into the following:

Properties dependent on Light: these include:

2. Colour:

It is the most obvious characteristics of minerals. It is dependent on the process of absorption and reflection of light of different wavelength, by the mineral. Most minerals vary considerably in colour. E.g. the mineral quartz can take several different colours, when it is pink, it’s called rose-quartz and when it is purple it is called amethyst, the numerous colours results because of presence of impurities, therefore, colour is not a one hundred percent diagnostic property in most of the minerals. Colour is a deceptive means of identification, but in some others, it is certain, such minerals can be identified by colour e.g. Azurite is a characteristics blue coloured mineral. If the mineral is associated with a green colour it may be malachite. Graphite also has a diagnostic colour which is the colour of pencil (gray/black).

3. Lustre:

This the way light interacts with the surface of a mineral to reflect, refract or absorb light falling on its surface. Hence lustre is the colour of mineral in reflected light. Various descriptive terminologies of lustre of different minerals that can be described include:

- **i.** Metallic lustre: it refers to the lustre of metals e.g. iron rod
- **ii.** Vitreous: Like that of glass
- **iii.** Resinous Lustre: the lustre of resin e.g. resin is sticky transparent substance that comes out of the bark of tree when it is cut
- **iv.** Pearly lustre: it is the lustre of e.g. talc
- **v.** Silky lustre: displayed by asbestos.
- **vi.** Earthy lustre: like chalk
- **vii.** Adamantine: the lustre of Diamond

4. Streak:

This is the colour of a mineral in its powdered form when the mineral is scratch on a streak-plate or porcelain plate e.g. pyrite and gold have same colour, but different streak. Other examples include haematite that has a black colour, while the streak is rusty brown.

Transparency, Tranluscency and Opaquecity: are other light dependent physical properties that can be used to describe minerals.

Properties dependent on Taste:

The physical property of Taste is usually used for minerals that are soluble in water. The various means of descriptions are:

- Saline - when it tastes like salt. E.g. Halite
- Alkaline - when it tastes like soda e.g. Potash (KCl)
- Sour - lime or lemon
- Astringent - sweetness you don't want to swallow, like alum.
- Horse-radish - taste like moringa
- Bitter: bitter-leaf taste or Epsom salt.

Properties dependent on Smell:

This is the odour produced when the mineral is heated (flame), breathed-upon or is struck (i.e. strike on it). The following terms are used to describe odour in minerals:

- Alliaceous odour - when it smells like garlic
- Horse-radish odour
- Sulphurous odour: Smell like burning matches e.g. Sulphur
- Pungent odour: kind of choking, like acid.'
- Argillaceous: smell of clay

Properties dependent on Touch or Feel:

A mineral can be described from the way it feels to touch e.g.:

- Smooth,
- Hard,
- Rough,
- Harsh, etc.

Properties dependent on State of Aggregation of Mineral:

1. **Crystal Form:** under favourable conditions, Mineral Crystals will grow without interference and assume characteristic geometrical shape. Form is the shape, external

structure or geometry of the mineral crystal. Based on the extent of development, we can have: Crystal beads or Crystalline form: if the crystals possess well-formed arrangement, i.e. quite developed.

2. **Crypto crystalline:** Possession of mere traces of crystal outline and not well developed.
3. **Amorphous:** There is absence of a crystal structure (when you can't pick out individual crystals of the minerals e.g. Sulphur.
4. **Hardness:** of a mineral is defined as its resistance to abrasion (scratching). It is a very important test used in identifying minerals. The test is conducted in several ways; by rubbing the mineral over a rough surface and noting the amount of powder that is formed from the rubbing operation. However, there is a Moh's scale of hardness.

The Moh's Scale of Hardness is a relative scale which measures the hardness of minerals the hardest of all minerals and it is not an arithmetic scale.

i. Talc
ii. Gypsum
iii. Calcite
iv. Fluorite
v. Apatite
vi. Orthoclase (Feldspar)
vii. Quartz
viii. Topaz
ix. Corundum
x. Diamond

5. **Fracture:** it is the breakage of a mineral along irregular surfaces. It is a property displayed by the broken or chipped mineral surface. It can be described as:

i. even
ii. uneven.
iii. Conchoidal: when the surface produced is curved (concave or convex) like the surface of a broken glass e.g. as seen in quartz
iv. Achilles: when it has sharp and jagged elevation.
v. Earthy fracture: similar to fractures observed on a broken chalk surface.

6. **Cleavage:** This is the property of a mineral to break along smooth plane surfaces or

regular plane of preferred orientation. It is a form of parting with the tendency to split along certain definite planes. Cleavage is a very diagnostic property of minerals, and it has direction e.g. Mica splits easily along certain planes which are the crystal faces or zones of weakness in the crystal lattice. Therefore, mica is said to have Single direction of cleavage while Pyroxene and Amphibole will have double directions of cleavage. Various terms by which we can describe cleavage are Poor, Fair, Good, Perfect or Prominent.

7. **Tenacity:** is the level of the mineral to adjust to various remoulding action that is performed on it. It is said to be

- Malleable: when it is heated, and it can spread out like sheet e.g. hematite
- Ductile: when it can be stretched like wire e.g. copper
- Brittle: most minerals when they are heated, or force is applied they break off.

Other Special Properties Displayed by some minerals are:

- Magnetism: in which the mineral magnetite and some other iron ores (like pyrrhotite) are known to be attracted to magnet.
- Electrical property: displayed by some minerals such as Quartz, similar to static electricity.
- Effervescence
- Radioactivity

Broad Classification of Minerals

1. Primary minerals:

These are minerals that result from the very process that produce the rock that contain them. They are formed when the hosting rock was formed and result from the consolidation of magma e.g. magnetite, Ilmenite, Olivine.

2. Secondary minerals: They are minerals that are formed after the formation of the hosting rocks. They are usually converted to their present form by atmospheric agent. Examples of Secondary minerals include some clay minerals, malachite, etc.

3. Essential minerals: These are minerals which when present in the rock are essential in naming it (useful in the identification of rock) e.g. granite must contain quartz before it can be named granite, unlike zircon.

4. **Accessory minerals:** They are minerals that are not usually depended upon for naming rock.

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Rocks

Petrology is a branch of Geology that deals with the origin, occurrence, structure and history of rocks. **Petro** is from the Greek word **Petre** which means **Rock**; and **logy** means "to study". A rock is a naturally formed consolidated material usually composed of grains of one or more **minerals**. The three main types of rock are the **Igneous, Sedimentary** and **Metamorphic**.

Igneous Rock

An Igneous rock is any crystalline or glassy rock that is being formed from the cooling of magma. A magma consists of hot molten rock matter. It will also contain crystals of various minerals as well as a gas phase that may be dissolved in the liquid melt. They are always very hot as they come at very hot temperature and pressure. They originate from deep within the mantle and from pre-existing rocks that have been buried.

Classification of Igneous Rocks

There are various factors that guide the classification of igneous rock which includes Texture, Mode of emplacement, Mineralogy, Colour index and Chemistry.

Texture: texture refers to the rock's appearance with respect to the size, shape and arrangement of its grains as well as the other constituent. The most significant aspect of texture in Igneous rock is **Grain –size**, classified as follows:

Fine-grained: Igneous rock will be grouped as fine grains when the grain size range is less than one millimetre in diameter **(<1mm)**. They result from the rapid cooling of magma on the earth surface (**Lava**), or few kilometres below the earth. This texture is otherwise referred to as **Aphanitic texture**.

Coarse-grained: is the texture of Igneous rocks whose grain-size is greater than one millimetre when measured across **(>1mm)**. The rock grains usually have an inter-locking mosaic pattern. They are closely packed **Phaneritic texture**.

Obsidian texture: is extremely fine-grained texture of igneous rocks which results due to rapid uniform cooling. This texture is also called **Glassy texture,** it is normally found in rocks formed from lava that lost heat very quickly after coming in contact with the atmosphere.

***Pegmatitic texture*:** this is seen in Igneous rocks with extremely large grain sizes or mineral sizes, usually greater than five centimetres in diameter **(> 5cm).** The common rock name is **Pegmatite,** and it is commonly sought for because of its large mineral contents which can be mined for Gemstones or individual minerals.

***Vesicular texture*:** is found in Igneous rocks that has little holes or depressions within it. The little depressions are referred to as **vesicles**, they formed when the gases trapped within the lava escapes making the rock to be very light and having rough abrasive surfaces suitable for scrubbing e.g. **Pumice**.

***Porphyritic texture*:** is a kind of texture that results when coarse-grained mineral pieces are enclosed within fine-grained mix in a rock. The larger grained contents are called **Phenocrysts** while the fine-grained is called the **Matrix.**

Mode of emplacement: refer to the location or depth at which a molten magma solidifies to form an igneous rock. **Intrusive** or **Plutonic igneous rocks** are formed deep within the ground e.g. **Granite**. While those that are formed close to the earth surface are called

Hypabyssal or **Intermediate igneous rocks** e.g. Diorite**.** Those formed at the surface of the earth are the **Extrusive** or **Volcanic igneous rocks** e.g. Rhyolite.

Colour Index: the colour of an Igneous depend largely on its mineral content and grain-size. Based on appearance, light-coloured igneous rocks are called **Felsic igneous rocks** e.g. Granite, Rhyolite. The intermediate coloured are called **Intermediate Igneous rocks** e. g. Andesite which is usually green in colour. The dark coloured are called **Mafic Igneous rocks**, e.g. Gabbro, Basalt, etc. while the very dark coloured are known as **Ultramafic Igneous Rocks** e.g. Peridotite.

Chemical composition: based on the chemistry and silica content of magma, Igneous rock is grouped into **Acid Igneous rocks** if the silica (**SiO_2**) content is >65% by weight, **Intermediate Igneous rocks** if the silica (**SiO_2**) content range between 55% to 65% by weight, **Basic Igneous rocks** if the silica (**SiO_2**) content range between 45% to 55% by weight and **Ultrabasic Igneous rocks** if the silica (**SiO_2**) content is < 45% by weight. The silica content of the magma is also a determining factor of some of its physical characteristics, for example, a magma with high silica content will be a **highly viscous** magma and will have a relatively **lower eruption temperature** in the range of 650^0C – 800^0C while a magma with low silica content will be a **less viscous** magma and will have a very **high eruption temperature** in the range of 1000^oC – 1200^oC.

Sedimentary Rocks

Sedimentary rocks are a type of rock formed from the consolidation of particles derived from the **weathering** of **pre-existing rocks**. The pre-existing rock may be Igneous, Metamorphic or Sedimentary rocks. After **weathering** the rocks get **eroded**, the eroded particles are then **transported** by either water, wind or ice to new locations where they are **deposited** and **consolidated** through **cementation**, **lithification** and other **diagenetic** processes. As the sediments become buried under other sediment layers, pressures and temperatures increase. The sediments harden into a sedimentary rock or **lithifies** after it has gone through the stages of **compaction**, **dewatering**, and **cementation**. During **compaction**, the grains of sediment are packed more tightly together. With increasing pressure some of the water between the sediment particles is squeezed out, **dewatering** the sediments. This process reduces the **pore space**, or open spaces between the grains. At this point, pressure and temperature conditions are such that certain minerals, usually calcite or quartz, fill some or all the pore spaces and adhere to the sediment fragments, **cementing** them into a sedimentary rock. Sedimentary rocks are of great **economic importance** because they serve as **reservoirs** for water, oil and mineral deposits. **Sediments** refers to the unconsolidated fragments deposited, while sedimentary rocks are the **lithified** equivalence that has been consolidated.

Major Sedimentary Rocks

Sedimentary rocks can be classified into **Clastic or Detrital Sedimentary rocks** and **Chemical or Organic Sedimentary rocks**. Clastic rocks can be further sub-divided based on their **grain-sizes** while Chemical/Organic rocks can be subdivided based on their Chemical composition.

Clastic or Detrital Sedimentary rocks can be subdivided into 3 broad classes:

- Pebbly rocks: Gravels, Conglomerates, Breccias, Boulders
- Sandy rocks: Sands, Sandstone, Arkose, Greywackes
- Clayey rocks: Mudstone, Mud, Shale, Siltstone

Chemical or Organic Sedimentary rocks can be subdivided as follows:

- Carbonate rocks: Limestone, Dolomite, Chalk
- Siliceous rocks: Chert, Flint, Agates
- Aluminous rocks: Bauxite, Laterite, Kaolinite
- Ferruginous rocks: Iron formation, Limonite
- Evaporites: Gypsum, Anhydrite, Halite or Rocksalt, Trona, etc.
- Organic rocks (from plant remains): Peat, Lignite, Coal, Anthracite, Tar-sand

Metamorphic Rocks

"Meta" is a Greek word which means "to change" while "morphism" means "form", therefore metamorphism means to change form. In Geology, this refers to the changes in mineral assemblage and texture that results from subjecting a rock to conditions such as Pressure, Temperature and Chemical environment different from those from those under which the rock originally formed. **Metamorphism** is defined as the mineralogical and structural adjustment of solid rock to physical and chemical conditions that have been imposed at depth and below the near surface zone of weathering and diagenesis.

Note that digenesis is also a change in form that occurs in sedimentary rocks, however it is restricted to those which occur below 200^0C temperature and pressure below 3Kilobar, while Metamorphism occurs at **a higher temperature and pressure**. **Grades of Metamorphism** is a general term for describing the relative temperature and pressure conditions under which metamorphic rocks forms, as the temperature/pressure increases in the body of rock, it will be described as undergoing **Prograde metamorphism**. And as the metamorphism temperature/pressure decreases it is described as **Retrograde metamorphism**. From the foregoing it is obvious that the main factors of metamorphism include **Temperature**, **Pressure**, some **Chemically active fluids**, original rock composition otherwise known as the **Protolith** and **Time**.

The process of metamorphism on pre-existing Igneous, Sedimentary or previously metamorphosed rocks produces a new **Metamorphic rock**, which has undergone a change in its structure and texture but essentially retains the previous mineralogical and chemical composition. Common stress induced structure/ texture seen in Metamorphic rocks include **Foliation** –a planar feature caused by the preferred orientation of sheet silicate as well as the arrangement of minerals and **Striation** – a preferred parallel alignment of elongated features such as mineral grains. As Metamorphism prograde, changes take place in rocks and new metamorphic minerals crystallise along foliation planes making it more prominent, e.g. the metamorphism of Shale (a Sedimentary rock) changes (metamorphosed) it to Slate, later to Phyllite – Schist – Gneiss – Migmatite. Here the Foliation graded from **slaty** to s**chistose** to **gneissose** and eventually **migmatitic**. But there are other non-foliated metamorphic rocks such as Quartzite, Marble, Soapstone and so on.

Geologic Time

From geochronological studies or dating analysis conducted by geoscientist, Earth has been estimated to be about **4.5 billion years old.** As the crust cooled, early geologic processes were largely volcanic, building up of continental crust and a primitive atmosphere (without oxygen), bacterial forms of life have been found in rocks that are billions of years old. Complex oceanic organisms such as trilobites began to appear only about 600 million years ago. From about 66 million to 245 million years ago, dinosaurs and other reptiles flourished all over the world. In contrast, human beings have existed in only about the last 3 million years, less than a thousandth of the age of Earth. Ancient rocks show textures that can be seen forming today from processes such as volcanic eruptions, earthquakes, hot springs, wind, weathering, river action, sedimentation, and erosion.

Climate Change simply put are the changes we are observing in the climate of the world. It is the changes associated with **Global warming** which is a term often used interchangeably with climate change, it is defined as a change of climate attributed directly or indirectly to human activities that alters the composition of the global atmosphere. In addition to natural climate variability observed over comparable time limits. In recent times, it is the resultant effects of many human activities, or actions related to it that has brought about most of these changes observed in our climate. Activities including burning of Fossil fuel, destruction of forest and vegetation (deforestation) and so on are causing relatively rapid increase in Carbon dioxide concentration in the Earth's atmosphere. **Green-house gases** are a group of gases of which **Carbon dioxide** is chief, others are methane, tropospheric ozone, nitrous oxide and the Chloro-floro-carbons or **CFCs**. Industrial and human activities have caused the concentration of Green-house gases to rise well above pre-industrial levels within our atmosphere and they have the capacity to trap most of the heat introduced upon the surface of the earth by the sun. The normal reaction should have been most of these heats get reflected to space but the greenhouse gases trap the heat within their molecules. So, retaining this heat they continuously warm up the earth causing earth's surface temperature to rise over the years. The global warming effect bring about several negative impact on our ecosystem functions and biodiversity. It is likely to cause increase in the severity and frequency of extreme weather events such as flooding, heavy rainfall, heatwaves, melting of large icesheets, seawater expansion and indirect effects like disruption in food production, escalation in water crises and increased public health risks.

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CHAPTER 10

THE ROLE OF COMPUTER SCIENCE IN SOCIETAL DEVELOPMENT

O.F.W. Onifade

Introduction

It is generally accepted that social development means investing in people. This is with a view towards improving the well-being of everyone in society with a bid to attaining their potentials. Overtime the society has continued to evolve with new technologies impacting the world while managing day to day activities. As the world progresses especially with the use of computer for personal, social and economic development, the society has come to know and appreciate the importance and role of computer. While the advantages of using a computer in the society clearly outweighs it disadvantages, perhaps you are indifferent, at the end of this modules, you should be able to learn the following:

Application Areas of Computer in selected Industries of the society

The computer is a major invention of the 20th century. It is remarkable to see how the creation of this incredible machine has brought a ray of hope to a previously dark world. These "mechanical brains" are all around us and play a significant role in our daily lives. The impact they have made, and continue to make, on today's society is limitless. To name just a few examples, in most parts of the world, including developing countries, it is now nearly impossible to run a business, interact with people, develop a product, or provide services without relying on the power of computers. In socio-economic development, computers now play a significant role, having an increasingly profound impact. Below are some examples of the influence of computers in selected industries:

a. **Banks and Financial Institutions:** In handing customers, money, loan among other activities of the bank, computer plays significant role. For instance,

i. **Bank - CRM software** – The computer is used to store and access basic information about a customer, staff and management of a bank. Thus, it’s more coinvent to access account balance, make deposit and withdrawal without necessarily visiting the four-walls of a banking hall.

ii. **Automated Teller Machine (ATM)** – At the instance in which a customer makes withdrawal, deposit, money transfer alongside other important modular operation of the ATM, such is using a computer.

iii. **Digital Currency** – A computer is used to keep track of how money is securely kept in customers account by converting the deposits to a stored digital record.

iv. **Stock Trading:** Trading is one of the important sectors of the financial institution wherein different Computers with advanced algorithms are used to handle stocks and commodities without the influence of man on a distributed system.

b. Communication: in today's business world, communications are almost digitally executed on distributed computers. Thus, in the communication industry, here are few examples of how computer is used to implement effective communication

i. **Email:** As an alternate to the old methods of sending private information to friends and family members, computer now handles the creation and distribution of electronic mails confidential using a computer.

ii. **Smartphone:** An average person with a smartphone automatically has a mobile computer that can be used for many things including communication. This has been duly experimented with the increasing number of data generated by the social media daily.

iii. **Voice Over Internet Protocol Communication (VoIP):** Through the power of internet protocols, computer is used for information exchange irrespective of the distance.

iv. **Voice Recognition:** The advent of text to speech synthesis and vice versa, as enable the computer as useful object that can translate recorded audio into text and/or other data format.

Since the advent of internet, the usage of computer has been greatly increased with people connecting with one another without boarder. Some of the few trademark features of any good online communication system include:

a. It is sent in the digital format.
b. Immediate delivery
c. It is interactive
d. Privacy and individuality
e. It helps build communities
f. Entertainment and Enjoyment

With online communication, people, society, businesses, and the world are brought closer together. And it is very useful in almost all fields of industry and businesses

c. Health Care: Against traditional methods of administering and running daily activities in the hospital, here are some medical fields where computer is used to make a difference.

i. **Electronic Medical Records:** in more recent times, hospitals now use the computer to store patients' medical records for quick access and treatment of medical cases by doctors. The medical history of a patient can be viewed by just a click while laboratory, pharmaceutical and billing are also managed adequately.

ii. **Expert System:** Computers have now been used to diagnose patient symptoms with the goal to ascertaining the type of sickness with adequate recommendation without having to see a doctor.

iii. **Remote Care/Telemedicine:** With the advent of Internet of Things, Computers are now being used to monitor patient body vitals like temperature, blood pressures etc. This is to alert the hospital staff in case of emergency.

iv. **Research:** The continuous growth in medical data has created rooms for impactful research, which is difficult to execute without the use of a computer.

v. **Genomics and Gene Sequencing:** In this regard, computer science with other technologies is facilitating the sequencing of human and animal genomes towards predictive analytics and formulation of new drugs and better understanding of the composition of diseases.

d. Education: Another important thriving field where computer has become a necessity for all and sundry is the education industry. Computers are used in schools for teaching and learning. Through this learning designs are created; students can have audio visual experience and improved document writing. Other areas where computer is used in the education sector includes:

i. **Computer Based Test (CBT):** Students can use the computer for CBT with remote access monitoring in real time to writing different examination modes like

ii. **Course Registration and Result Computation:** Now, students use their computer for course registration while results are computed automatically once schools ascertain registration for each student.

iii. **Online Payment:** The days of long queues are now over for students since with the use of a computer estimated bills can be paid.

iv. **E-learning and associated platforms:** this concept has never been as relevant as it is currently due to the outbreak of Covid-19 pandemic. It has enhanced the educational content delivery in a suitable manner for the new normal.

e. **Transportation:** Another thriving field where computer is used for basic activities is the transportation area. Examples of this include:

i. **Traffic Lights:** Computer are used to run traffic lights which helps to prevent gridlock on the road.

ii. **Cars:** in more recent times and towards a productive future, modern card now have multiple computers that controls and manages the workings of the vehemence.

iii. **Airplane:** This is a transport system that is filled with computers, which have control panels that manages one process or the other.

iv. **Self-Driving Car:** This unique car also relies on the computer to take decision when driving.

f. **Robotics:** With the emerging technologies of industrial robots, artificial intelligence, and machine learning; advancing at a rapid pace, the computer is used for pattern learning, monitoring and controlling. Different robotic have evolved in health, security, sport and other sectors.

g. **Work:** Aside the selected industries in section 1 above, the computer now serves as an all-important tool in every domain, field, sectors and the industry to perform a variety of task, application and activities to enhance optimal performance across board. It also influences job opportunity as the knowledge and use of computer is now a major criterion for job opportunity. With this and more, it is now relatively important for everyone to learn how to use the computer. Among other reasons, learning how to use a computer is necessary for the following reasons:

i. Computers help you work faster
ii. Computers can answer almost any question
iii. A computer can teach you almost anything
iv. Understanding computer terminology helps with other technology
v. Reduces the chance of being tricked or scammed
vi. Resolve problems and questions faster

vii. Computers and robots are replacing some jobs.

With this and more, computers can be used to improve administration in the workplace by providing daily accurate information to different departments and changing the way decisions are taken across the globe. As computers, software, and hardware improve, so do their capabilities. With computer science been responsible for smartphones, internet and network, social media, we now live in a society that consumes content, a digital age driven by computer science. Therefore, the next section identifies sampled specialised areas of computer in society.

Specialised Areas of Computer Science in the Society

Computer science is a big umbrella that encompasses a number of fields with specific goals. It spans a range from its theoretical and algorithmic foundations to cutting-edge developments like robotics, computer vision, intelligent systems, bioinformatics, and others in more recent times. Here, some specialised areas of computer science and their roles in the society is discussed.

1. **Software Engineering**

   Software engineering is the process of analysing user needs and then designing, constructing, and testing end-user applications that will satisfy these needs through the use of software programming languages. While it also focuses on the systems and protocols for using any developed applications, as a vast field, it also covers professions from business to graphic designs or video game development. Professionals in these roles may have a number of different specialties, which include but not limited to requirement gathering, debugging and testing, security and scalability, or the ability of an application to add users or features without a negative impact on performance. Thus, Software engineers spend their time designing, coding and deploying software solutions based on specific needs. These solutions can be a traditional software program, cloud-based software-as-a-service, mobile apps or the operating systems that create the framework in which other software runs.

2. **Computer Networks**

   Computer networks focus on how organisations use both wired and wireless networks to exchange information with internal and external stakeholders. By this, people are able to share ideas more easily and work more efficiently. Computer networks help in addressing software vulnerabilities while mitigating security risks. It also increases work productivity and improves the way companies offer their services to the world. The main benefits of networks include:

a. **File sharing** – data can easily be shared or accessed remotely between users if the devices are well connected.
b. **Resource sharing** - using network-connected peripheral devices like printers, scanners and copiers, or sharing software between multiple users, saves money.
c. **Sharing a single internet connection** – Proper security of networks is not only cost-efficient; it also helps protect your systems.
d. **Increasing storage capacity** - images and music among other multimedia and be access remotely on other machines or network-attached storage device.

Thus, a Network Engineer is responsible for managing bandwidth, traffic, user access, and the security of networks themselves, as well as any devices connected to the network

3. Information Systems

Information system is an umbrella term for the systems, people and processes. The field is used to bridge the gap between business and computer science. It focuses on integrating information technology solutions and business processes to meet the information needs of businesses and other enterprises towards achieving their objectives in an effective, and efficient way. It improves the quality of life while providing flexibility of time and location in business activities.

4. Human Computer Interaction:

Human-computer interaction (HCI) is a multidisciplinary field of study focusing on the design of computer technology, and particularly the interaction between humans (the users) and computers. Today, only a small percentage of computer users read the software's documentation, assuming one exists. The goals of HCI are to produce usable and safe systems, as well as functional systems. To produce computer systems with good usability, developers must attempt to:

i. understand the factors that determine how people use technology
ii. develop tools and techniques to enable building suitable systems
iii. achieve efficient, effective, and safe interaction

iv. put people first

Thus, HCI is about understanding what it means to be a user of a computer and therefore how to create related products and services that work seamlessly. It equips designers with the ideas, strategies, and resources they need to create intuitive, easy-to-use interfaces that don't require training. HCI is significant for any company that relies on technology or computers in its day-to-day operations.

5. **Artificial Intelligence:**

   Artificial Intelligence (AI) is a way of making a computer, a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think. The easiest way to understand how a machine becomes intelligent with AI is to compare it to how humans learn. The goal of AI is:

1. **To Create Expert Systems** − The systems which exhibit intelligent behaviour, learn, demonstrate, explain, and advice its users
2. **To Implement Human Intelligence in Machines** − Creating systems that understand, think, learn, and behave like humans

AI has been dominant in various fields such as – Gaming, Natural Language Processing, Expert Systems, Vision Systems, Speech Recognition, Handwriting Recognition, Intelligent Robots among others. As suggested by Microsoft, here are six principles to put humans at the centre of the systems around artificial intelligence. These are ethical principles deeply rooted in timeless values. They are:

a. **Fairness** – systems should be designed not to include bias against anyone
b. **Reliability** – systems need to go through rigorous testing and people should play a critical role in making decisions around how they are used
c. **Privacy and security** – privacy laws must be complied with and personal information should only be used in accordance with high standards
d. **Inclusiveness** – barriers should be removed from products and environments that can exclude people, this must be considered in the design process
e. **Transparency** – people must be able to understand how key decisions are made and be able to identify and feedback potential errors and unintended outcomes

f. **Accountability** – those who design and deploy AI systems must be accountable for how those systems operate. This should be ongoing during the design and operational periods

Although the future of Al's integration into society is a controversial subject, current rapid advances in artificial intelligence are resulting in a profound impact on productivity, employment, and competition globally.

In conclusion, the term computing covers every kind of digital technology that we employ to create, store, communicate, exchange, and use information. As the field of computer science is becoming increasingly important, the global economy is becoming more dependent on computers and the Internet. It has become the foundation for small and large businesses to build their strategies and grow. Through this, computer hardware and software technology are rapidly increasing in power and sophistication. In both human to human and human to machine interactions, computers are re-defining human relationship with both human and machines. It is no longer uncommon to see humans interacting with devices some of which are autonomous and display some level of intelligence too. Consequently, it is making our personal lives easier with a lot of fun through mobile phones, online shopping, social media among others. However, since the changes are happening so quickly, it can be difficult to predict where the field of computer science and what impact it will bring to the society over the next 10 to 20 years. But with the fast-changing connected world, computer science is a key area for future careers across the world.

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CHAPTER 11

OVERVIEW OF STATISTICS AND ITS APPLICATIONS

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What is Statistics?

Statistics, according to Merriam Webster dictionary, is the branch of mathematics that deals with the methods of collection, organisation, analysis, interpretation and presentation of data. It provides simple and advanced methods for organisation, analysis and interpretation of data.

Types of Statistics

There are two main branches of statistics, namely: descriptive statistics and inferential statistics.

Inferential Statistics: This aspect of statistics draws a general conclusion about a larger population based on the findings from the data collected from representative samples. These conclusions cannot be 100% correct but can be said to have some level of certainty or uncertainty (more about this will be discussed later in this chapter). It is also known as inductive statistics. It entails drawing information about a situation from an available data set.

Descriptive Statistics: This type of statistics is also known as deductive statistics. This is the type of statistics that summarizes the behaviour of a data set. Under this, there is the measure of central tendency and measure of dispersion. These will be briefly looked at later.

Data

Since "data" is one main thing that statistics is concerned with, its definition should be given. Data, the plural of datum, are facts or numeric information gathered for the purpose of processing and summarising into meaningful ideas that can be used to make decisions or form opinions.

Types of Data

Quantitative Data: These, also known as quantitative variables, are facts about an object which can be measured on a numerical scale. It is also further subdivided into *continuous variable* and *discrete variable*. The continuous are in the sense that they can only be within a range of values. Examples are height of persons, ages of students in a level and the like. On the other hand, discrete variables only take whole numbers. Examples of this include number of persons. In any case, these types of data can be subjected to basic arithmetic rules of adding, subtracting, multiplying and dividing.

Qualitative Data: These are information about objects that mainly describe their qualities. These include gender, colour, personality traits and the like. These cannot be subjected to any arithmetic operations.

Sources of Data

Data can be obtained either from a primary source or a secondary source. Primary sources include direct observation, interviews, surveys, use of questionnaires and so on. The secondary sources include data that have already been collected in a repository by an individual or an organisation which may be published (in the national dailies, periodicals, technical reports etc.) or unpublished.

Population and Samples

To collect a meaningful data set, one must have a target population and choose an appropriate sample from it.

Population: This is like a universal set which includes all entities or objects concerning which observations are going to be made. For example, if a study is to be conducted about the life of students in Chrisland University, the population is all admitted students at the university.

Samples: Sometimes, population is larger than what anyone can deal with in a survey. Then, a representative percentage called *sample* is chosen by appropriate technique.

Importance of Statistics

The role of statistics cannot be over emphasised in the society as it plays a major role. For instance, most reports on finance, electricity utility, the living standard of people in a country and the like are made available to the public through statistical tools. Hence, statistics is applicable in everyday activities.

Applications of Statistics

Statistics can be applied to a number of disciplines since data are generated in each discipline for several reasons. In each discipline, different scientific methods are developed or applied to solve the research question in view. Below is the list but not limited to sectors that generate data for their day-to-day running: Information Sector, Health Sector, Education Sector, Economic Sector and the Social Sciences

Information Sector

The internet is used by over 50% of the world population. While in use, a wealth of data is generated. Data such as what people buy online the sites they visit, the videos they watch, the adverts they click and so on are harvested. Useful insights can be drawn from these data using appropriate statistical methods. These insights are subsequently used by companies to make predictions on individuals, a group of individuals or even the world at large. Recommendations are also made based on such collected data. Companies such as Google, Bing, Yahoo etc. have thrived on the use of statistical methods for predicting what one is likely to search for when surfing the internet even while still typing the questions on their search bars. They also collect little datasets called cookies when they are visited. These data are analysed and are used to predict future likely activities.

Using data, modern taxi companies use statistical methods to analyze street traffic data, GPS data, and public transport routes to estimate fares, arrival times and traffic heat maps. These data are used to ensure that their customers get the best experience. Furthermore, Facebook uses the statistics of users to match data, show targeted advertisements and recommend videos and groups.

Economic Sector

Statistics is useful for providing solutions to economic problem with high degree of accuracy and clarity. It helps in economic planning as it analyses quantitative information regarding different sectors of the economy using tools such as time series. Price analyses in statistics such as consumer price index, producer price index, inflation and gross domestic products (GDP) help the government in economic planning and give a quantitative glance of the economy. These indicators help us to compare how price differ between time periods and geographical location.

Health Sector

When it comes to policy formulation in the health sector to improve health conditions, statistical tools are often employed. Accurate and reliable analysis of quality data helps government organizations achieve better health management procedures in communities and reduce health inequalities.

The analysis of health statistics is vital for policy makers to pay good attention to the key aspects of public health. During the COVID-19 pandemic statistics was extremely useful in providing visual glances at the extent to which the disease was spreading. It also helped to assess the risk of the disease and how likely an individual is to contract it. Insight from statistical analysis helped leaders to identify the most vulnerable social cliques. This helped them to respond more effectively to the pandemic. In pharmaceutical research, statistics is important as it is used to process and summarize experimental data. It enables pharmacists to determine whether the effect of one drug is superior to another thereby giving clue to the next action plan.

Education Sector

The field of education has several challenges in terms of policy making, planning and decision making. Statistics helps the individual comparison of students on how each differ from the other with respect to age, abilities, distance from school and intelligence quotient. The analysis of this differences and how it affects their score helps in guiding educational managers and also the students on career counselling.

Social and Natural Sciences

Statistics is used in the social sphere to observe and analyse human behavioural changes and differences. This helps to answer important cultural questions and find out relationships between them.

Religious Sector

Religion is a very sensitive aspect of the national life of a country like Nigeria. The religious leaders do always and often use statistics to plan and execute their programmes.

Some Everyday Statistical Tools

Measure of Central Tendency

This is also known as measure of averages. The tools are mean, median and mode. As earlier mentioned, this is descriptive statistics.

Mean ($\bar{x} = \frac{\sum x}{n}$)

This is simply arithmetic average. The symbol $\sum$ means summation of each item.

<u>Example 1</u>

Consider if a data set was collected on different ages of people that use the university library in a day as follows: 23, 22, 22, 22, 21, 23, 24, 25, 23, 26. There are 10 data so $n = 10$.

$$\bar{x} = \frac{23 + 22 + 22 + 22 + 21 + 23 + 24 + 25 + 23 + 26}{10} = \frac{231}{10} = 23.1$$

In interpreting this, it could be said that most people that come to use the library are rather close to age 23. But one must be careful when using mean to ensure that there are no outliers (data with unusual values).

<u>Example 2</u>

Consider that the data 23, 22, 22, 22, 21, 23, 24, 75, 23, 26 are incomes of people in thousands of naira. The mean

$$\bar{x} = \frac{23 + 22 + 22 + 22 + 21 + 23 + 24 + 75 + 23 + 26}{10} = \frac{281}{10} = 28.1$$

This can lead to a wrong deduction that the income of most is around 28, 000 naira. In such a case, it is not advisable to use mean as an average.

Median

This is simply the middle number in a data set. To find the median in a data set, it is better to first arrange the number in a particular order, ascending or descending. Then, the middle number is picked. If, however, there are two numbers in the middle position, their average is found.

Example 3

Consider if a data set was collected on different ages of people that use the university library in a day as follows: 23, 22, 22, 22, 21, 23, 24, 25, 23. Upon arranging, 21, 22, 22, 22, **23**, 23, 23, 24, 25. The media is 23.

Example 4

Consider that the data 23, 22, 22, 22, 21, 23, 24, 75, 23, 26 are incomes of people in thousands of naira. When arranged, 21, 22, 22, 22, **23**, **23**, 23, 24, 26, 75. The two middle numbers are 23 and 23 and their mean is 23. Comparing this with Example 2, this is more reasonable to say that most people earn near 23 000 naira.

Mode

This is the number that occurs most. Occurrence of a value is called its frequency. Hence, the value(s) with the highest frequency is called *mode*. A data set can have one or two modes and are respectively called *unimodal* and *bimodal*. In the two data sets used above, the modes are 22 and 23. It is appropriate to say that the people who us the library most are in the age of 22-23.

Dealing with Larger Data Set

There are times that we are dealing with a data set that is relatively larger than what we used in the previous examples. The computation is a bit different but actually addressing the same thing. In this case, a frequency table will be appropriate. Frequency table is the table that shows the distribution of the occurrence of each item. This can be done by grouping the data or by not grouping the data. The choice of grouping or not grouping a frequency distribution depends on the *range* of the values. Range is the difference between the largest value and the lowest value in the data set. But our discussion will be limited to the ungrouped frequency distribution table. For convenience of counting, tally is introduced in the table. Tallies are strokes that are in bundles of five (5).

Example 5

Consider the following ages of students in Chrisland University

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 24, 25, 23, 26

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 25, 25, 23, 26

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 24, 26, 23, 26.

Find the mean, median and mode.

Scores	**Tally**	**Frequency (*f*)**	***Fx***
21	~~IIII~~ I	6	126
22	~~IIII~~ ~~IIII~~ ~~IIII~~ III	18	396
23	~~IIII~~ ~~IIII~~ ~~IIII~~ III	18	396
24	~~IIII~~	5	120
25	~~IIII~~ I	6	150
26	~~IIII~~ II	7	182
Total		**60**	**1370**

Total frequency is *n*.

Mean

$$\bar{x} = \frac{\sum fx}{n} = \frac{1370}{60} = 22.83$$

Median

If *n* is even, count *(n-2)/2* from the bottom and top of the frequency table. This implies that there will be two numbers at the middle. As done earlier, find the average of the two numbers. In this example, *(n-2)/2= (60-2)/2=29.* Counting 29 from both top and bottom leads to 23 in both cases. Hence, the two numbers at the middle are both 23 and their average is also 23. Hence, median of this data set is 23.

However, if *n* is odd, count *(n+1)/2* from either the bottom or the top of the frequency table. There can only be one item at the middle and that is in the *(n+1)/2* position. For instance, if there are 13 items, *(13+1)/2=7* implies that the number in the 7th position in the arranged data set is the median.

Mode

It is obvious that the ages that occur most are 22 and 23. This data set is bimodal.

Measure of Spread

Considering measure of spread also called measure of dispersion, the following are the concepts: range, mean deviation, quartiles, variance and standard deviation.

Range

This was briefly discussed earlier. It is the difference between the largest and the lowest of the data set.

Absolute Deviation

This is the absolute values (i.e. positive values) of differences between each item and the mean. It measures how far away an item is from the centre. The computation is done using

AD = $|x - \bar{x}|$

Mean Deviation

This is the mean of all the absolute deviations.

MD $= \frac{\sum |x-\bar{x}|}{n}$

or

MD $= \frac{\sum f|x-\bar{x}|}{n}$

<u>Example 6</u>

Consider the different ages of people that use the university library in a day as follows: 23, 22, 22, 22, 21, 23, 24, 25, 23, 26. There are 10 data so $n = 10$.

$$\bar{x} = \frac{23 + 22 + 22 + 22 + 21 + 23 + 24 + 25 + 23 + 26}{10} = \frac{231}{10} = 23.1$$

The next is to compute the absolute deviations $|x - \bar{x}|$

$|23-\bar{x}|$ = 0.1, $|22-\bar{x}|$ = 1.1, $|21 - \bar{x}|$ = 2.1, $|24 - \bar{x}|$ = 0.9, $|25 - \bar{x}|$ = 1.9 and $|26 - \bar{x}|$ = 2.9.

MD $= \frac{\sum |x-\bar{x}|}{n} = \frac{0.1+0.1+0.1+1.1+1.1+1.1+2.1+0.9+1.9+2.9}{10} = 1.14$

Example 7

Consider the following ages of students in Chrisland University

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 24, 25, 23, 26

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 25, 25, 23, 26

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 24, 26, 23, 26.

Find the mean deviation.

Scores	**Tally**	**Frequency (*f*)**	$\boldsymbol{|x - \bar{x}|}$	$\boldsymbol{f|x - \bar{x}|}$
21	~~IIII~~ I	6	1.83	10.98
22	~~IIII~~ ~~IIII~~ ~~IIII~~ III	18	0.83	14.94
23	~~IIII~~ ~~IIII~~ ~~IIII~~ III	18	0.17	3.06
24	~~IIII~~	5	1.17	5.85
25	~~IIII~~ I	6	2.17	13.02
26	~~IIII~~ II	7	3.17	22.19
Total		**60**		**70.04**

For this data,

Mean ($\bar{\boldsymbol{x}}$) = 22.83

MD $= \frac{\sum f|x-\bar{x}|}{n} = \frac{70.04}{60} = 1.1673$

Variance

This is an alternative to mean deviation; it also measures the spread of each number from the mean. It can also be regarded as measure of variability from the mean.

Variance = $\frac{\sum(x-\bar{x})^2}{n-1}$

Or

Variance = $\frac{\sum f(x-\bar{x})^2}{n-1}$

<u>Example 8</u>

Consider the different ages of people that use the university library in a day as follows: 23, 22, 22, 22, 21, 23, 24, 25, 23, 26. There are 10 data so $n = 10$.

$$\bar{x} = \frac{23+22+22+22+21+23+24+25+23+26}{10} = \frac{231}{10} = 23.1$$

The next is to compute $\sum(x-\bar{x})^2$

And divide by 10.

$(23-\bar{x})^2$ = 0.01, $(22-\bar{x})^2$ = 1.21, $(21-\bar{x})^2$ = 4.41, $(24-\bar{x})^2$ = 0.81, $(25-\bar{x})^2$ = 3.61 and $(26-\bar{x})^2$ = 8.41.

Variance $= \frac{\sum(x-\bar{x})^2}{n-1} = \frac{0.01+0.01+0.01+1.21+1.21+1.21+4.41+0.81+3.61+8.41}{9} = 2.32$

<u>Example 9</u>

Consider the following ages of students in Chrisland University

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 24, 25, 23, 26

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 25, 25, 23, 26

23, 22, 22, 22, 21, 23, 24, 25, 23, 26 23, 22, 22, 22, 21, 23, 24, 26, 23, 26.

Find the variance.

This data has already been used and the mean already found. The calculated mean in the previous example can just be used.

Mean ($\bar{x}$) = 22.83

Scores	Tally	Frequency (f)	$(x - \bar{x})$	$(x - \bar{x})^2$	$f(x - \bar{x})^2$
21	~~IIII~~ I	6	1.83	3.35	20.10
22	~~IIII~~ ~~IIII~~ ~~IIII~~ III	18	0.83	0.69	12.42
23	~~IIII~~ ~~IIII~~ ~~IIII~~ III	18	0.17	0.03	0.54
24	~~IIII~~	5	1.17	1.37	6.85
25	~~IIII~~ I	6	2.17	4.71	28.26
26	~~IIII~~ II	7	3.17	10.05	70.35
Total		**60**			**138.52**

Variance $= \frac{\sum f(x-\bar{x})^2}{n-1} = \frac{20.1+12.42+0.54+6.85+28.26+70.35}{59} = 2.35$

Standard Deviation

This is just the square root of the variance.

SD = $\sqrt{\frac{\sum f(x-\bar{x})^2}{n-1}}$

Representing Processed Data

There are different ways by which processed data can be represented in order to make meanings to those who are non-statisticians. The following are the ways to represent data:

1 Tables

2 Charts and graphs

- Bar Chart

- Pie Chart
- Histogram

3 Pictures

Statistical Uncertainty

Uncertainty is inherent in any statistical operation. Uncertainty is the measure of how far a statistical result might be from the true value. It can be termed as error or bias.

In Statistics, uncertainty or error comes from many sources. Errors can come from any of the followings:

1. Human error: Human errors happen when imputing data.
2. Observational error: This happens due to the variability of the experiment
3. Use of models: Models are algorithms that gives approximations or best guess of what a true distribution or statistic looks like. Some of them have peculiar error margin.

Measurement of Uncertainty:

Confidence Interval and Confidence Level are the main tools for showing the measure of uncertainty that is associated with a particular statistical process. Confidence interval is used with margin of error for instance. It is used along with confidence level.

For instance, it could be said that there is a survey on a group of students to see how many books they read in a year and the analysis is done at a 95% confidence level and get a confidence interval of say (40,50). This means that there is a 95% assurance that all students read 40-50 books per year and if the survey is repeated, there is a 95% chance that the same results would be obtained.

Statistics as a Guide to Living and Decision Making

To make informed decisions, reliable data must be obtained. After that, there is need for appropriate statistical tools to make the data useful. This process facilitates critical discussions and research within the government and various communities and cliques. When solving economic issues, there exist pain points that needs to be attended to and non-pain points that need to be ignored. This can be effectively observed when statistics is used to display them quantitatively and visually.

This further ensures that new policies to satisfy the major objective can be formed and modification can be made to the existing ones to satisfy other areas that need redressing.

In day to day living, statistics is very essential to the preservation of lives. For instance, someone may decide to stay in the house when the weather forecast states that a hurricane is coming. This prediction, before broadcast, has passed through various statistical operations and iterations.

In health and medicine, the formula for the drugs that are being produced and dispensed were carefully modelled with the use of experimental data. This ensures that all substances have correct measurements and ensures that the drug cures ailments it was purportedly designed for.

In sports, Statistics is beyond valuable. Teams rely on quantitative data to keep dominating over their opponents. Statistics is used to measure the ratio of wins to losses, ball possession, number of successful passes, and number of assists. These statistics, when combined, helps the coaches to train the players more effectively. It also helps the fans to look beyond the scores and evaluate the players' performance.

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CHAPTER 12
WASTE: TYPE, NATURE AND MANAGEMENT

R.A. Adedokun

Types and Nature of Waste

Waste is a universal concept, and its nature, disposal and management has been a subject of discourse in many local, national and global conventions and summits. What then is waste? The Basel convention defines wastes as “substances or objects which are disposed or are intended to be disposed of or are required to be disposed of by the provision of law”. Generally, to the average man, waste is simply a discarded material that is considered useless and unsuitable for use. Although nature on its own can generate wastes such as oxygen, carbon (IV) and dead organic matter, most waste is generated because of human activities. The factors that have been associated with increased waste generation include increased:

- Population
- Industrialization
- Agriculture
- Commercialisation
- urbanisation

Waste can be classified based on source, composition, or nature of degradation and management. However, based on legislation and policy, waste can be classified as **solid waste** (non- hazardous) and **hazardous waste.**

1. Solid Waste: Solid waste is non- hazardous. However, it can pose serious health concerns and environmental problems if not properly managed. This can be subdivided into Municipal and non-municipal solid waste.

A. Municipal: This can be classified as **domestic, commercial** and **institutional** waste. It consists majorly of waste such as food waste, paper, leather, textiles, metals wood, plastic and glass

B. Non-Municipal Solid Waste: These are non-hazardous waste from agriculture, mining, industry such as organic matter, rocks, plastics.

2. **Hazardous Waste:** is waste with great potentials of causing serious health and environmental problems through explosion, fire hazards, corrosion, toxicity to environment or other detrimental effects and therefore requires special treatment. Hazardous waste therefore may possess any one or more of the following characteristics:

- Flammability
- Corrosiveness
- Reactivity
- Toxicity

Hazardous waste sometimes illegally shipped and dumped in developing countries. Hazardous waste is mostly generated from industrial activities. It includes E- waste, radioactive waste and biomedical waste, industrial waste.

E -waste: This is generated from the disposal of electrical appliances and electronics such as televisions, phones and computers. E-waste is considered hazardous because it contains toxic components like **polychlorinated biphenyls** (PCBs) and **heavy metals** such as mercury, nickel, arsenic, copper. A heavy metal is a metal having a density greater than 5 g/cm^3. However, the term heavy metal generally refers to a metal which inflicts its toxicity on the environment. Examples of incidents of heavy metal poisonings are:

- The 1956 Minamata disease that occurred in Japan (which was due to industrial waste containing methyl mercury).
- Lead poisoning cases in Zamfara state Nigeria in 2010 that led the loss of lives of adults and children (the poisoning was most likely caused from illegal mining activities). Lead is a chemical element that can be found in materials such as pencils, paints and pigments.
- The Itai-Itai disease which occurred in Japan because of cadmium

Radioactive Waste (Nuclear Waste): is waste that contains radioactive materials such as hydrogen-3 (tritium), uranium- 238, thorium- 234, and strontium 90. Radioactive substances exist naturally at low levels in the environment. However, increased levels of radioactive substances are because of mining activities, medical diagnosis, nuclear power plants, production and testing of military weapons, biological and chemical research and other industrial activities. Radioactive substances are atoms of unstable nucleus. In attaining stability these unstable nuclei spontaneously decay by emitting energy in the form of radiations. The period it takes for a radionuclide to decay to half its original amount is known as its half - life. Radionuclides all have varying half-lives which may vary from fractions of a second to millions of years for example, the half-life of hydrogen-3 is 12.5 years, lead-210 is 22 years uranium–90 is 4. 5 x10^{9} years, polonium-218 is 3.05 minutes and polonium-214 is 1.5 x 10^{-4} seconds. Typically, the principal radioactive decay processes are alpha decay, beta decay, gamma decay and spontaneous fission. While alpha radiation cannot penetrate the skin and can be blocked by paper, beta, gamma and neutron emissions can penetrate the skin but can be blocked by aluminium, lead and concrete respectively. Depending on the duration of exposure, amount and the nature of radiation, these radiations all have potentials of being hazardous to health and can cause cancer, birth defects and other abnormalities.

Radioactive waste can be classified as low level or high level depending on the half- life of radionuclide, nature of radionuclide, amount of radionuclide and the amount of heat generated from the decay process. Low level radioactive waste includes clothing, glassware, paper etc. while high level radioactive waste includes spent fuel rods and assemblies produced during nuclear fission as well as the principal waste generated during the reprocessing of spent fuels, waste from military facilities and nuclear power plants. High level radioactive waste is very hazardous and requires special shielding when handling such waste. It is recommended that nuclear waste should be stored deep underground, and the storage site should be geological stable with little or no water flowing nearby in order not to cause accidental corrosion of radioactive waste into surrounding water bodies.

Biomedical Waste: Generated from health care systems. It Includes needles, run off hospitals' effluents, laboratories etc., bandages, gloves, radioactive materials etc. biomedical waste are considered hazardous because of the following reasons:

- It could serve as reservoirs for pathogens including the drug-resistant microorganism
- It may contain radioactive materials

Classification Based on Source: The following types of waste can be identified based on the source of waste. This includes domestic, commercial, biomedical, mining, industrial and agricultural wastes.

Agricultural Waste: Agricultural wastes are wastes arising from agricultural activities. They include fertilizers, herbicides and fungicides, drugs, animal dropping. Indiscriminate use and disposal of agricultural waste could lead to environmental problems such as:

- Eutrophication (a process where waterbodies such as lakes, estuaries and slow flowing stream are enriched by inorganic plant and algal nutrients): Nutrient enrichment from fertilizers (nitrogen, phosphorus and potassium) and manure often leads to increased photosynthetic productivity and propagation of plants and algae. When these plants and algae die, they settle to the bottom of the waterbody and their remains further enrich the water. In addition, the dissolved oxygen present at the bottom gets depleted as microorganisms make use of the dissolved oxygen in decomposing the dead remains of plants and algae. Low levels of dissolved oxygen may lead to the death of aquatic lives of species that cannot tolerate low levels of oxygen (microorganisms will also decompose their dead remains further depleting the dissolved oxygen). These dead aquatic lives maybe replaced with species that can tolerate low amounts of dissolved oxygen. Over time eutrophic lakes may turn to land. While oligotrophic lakes (unenriched) are clear, eutrophic lakes cloudy because of the large amounts of algae and cyanobacteria.

- Water pollution: In Nigeria, the population of cattle, pigs, goat sheep and birds run into millions. However, animal husbandry is not organised, and livestock are allowed to roam through streets. Consequently, the livestock faeces which could have served as manure litter the streets and constitute a nuisance. During rainfall the faeces are washed into water bodies, and this could cause water pollution because of the presence of pathogens present in the faecal matter.

- Environmental Toxicity: pesticides like dichlorodiphenyl trichloromethane (D.D.T) aldrin, dieldrin that are used in agricultural have been found to be toxic and are considered hazardous.

Industrial Waste: Industrial wastes are difficult to characterize. They include chemicals, plastics, heavy metals, textile, dyes, pigments mineral and organic acid, nitrogenous substances, tanning agents, etc. Industrial waste can pose a serious threat to the environment as it may contain hazardous chemicals.

Selected hazardous waste and their sources:

Hazardous Waste	**Sources**
Chloroflurocarbons (CFCs)	Refrigerants, obsolete refrigerators and air conditioners
Heavy metals (for example lead, cadmium, mercury, nickel, chromium)	Paints, pigments, batteries, sewage sludge, industrial waste
Infectious waste	Hospital, research labs, farms, abattoirs,
Pesticides	Farms and homes
Radioactive waste	Nuclear plants, hospitals, weapons production, mining of minerals
Dioxins	Emission from incinerators
Polychlorinated biphenyls (PCBs)	Obsolete electrical appliances, electrical transformers and capacitors

Methods of Waste Disposal

The method of waste disposal depends on the nature of waste. While non-hazardous solid waste may require little or no treatment, hazardous waste will usually require treatment before disposal. Since the production of waste is inevitable, recent trends and campaigns in the disposal and management of waste is to turn waste into wealth (useful product).

Collection and Disposal of Municipal Solid Waste

The first step in solid waste management is to collect the waste. In cities and towns in Nigeria, the house-to-house collection is done by trucks but however some areas may not be easily accessible. In such inaccessible places, community bins are provided. In some cases, waste is packed in polythene bags put along roadsides for vehicles to pick up. Once waste is collected by the trucks, they are disposed in low lying areas or outskirts of the cities approved by the waste management body.

Fig 12.1 Indiscriminate disposal of waste in open dumps

Open Dumps: This practice is very common in developing countries. Most times solid wastes are dumped openly on land, drainages and canals. In developing countries, it is common to find persons dumping their wastes in drainages and erosion water during rainfall. These wastes finally end up in the rivers and streams or sometimes block drainages resulting in flooding. These **open dumps** are characterised with offensive/pungent smells and are ideal breeding grounds for pests and diseases. Other ways in which open dump sites can cause adverse pollution to the environment include:

- The production of methane (a greenhouse gas) and other toxic gases during anerobic and aerobic decay of the solid waste
- Hazardous waste present in the waste can get dissolved and leached into soils, underground water and surface water causing soil and water pollution
- The smouldering smoke that comes from burning of the garbage can cause air pollution

Although banned in developed countries (at least in urban areas), this practice is still illegally practiced.

Ocean Dumping: Although banned by many countries, industrial waste and sludge are sometimes illegally dumped into oceans. These practices are highly unsustainable as these wastes may contain hazardous materials such as PCBs, radionuclides and heavy metals that can adversely affect aquatic lives and surrounding environment. Currently there are serious concerns on the accumulation of plastics in ocean. The ocean has become a reservoir for micro and nanoplastics. Vast circulating currents known as **gyres** collect floating plastics and over time allow them to accumulate in regions several thousand kilometres wide. These regions are often referred at as "**garbage patches"**. An example is the Great Pacific Garbage Patch discovered by Captain Charles Moore in 1997. Eighty percent of these plastics are from land while the remaining twenty percent are from garbage generated from fishing nets, ships and recreational activities. Plastic is not readily biodegradable and thus when ingested by aquatic lives remain undigested. This causes the stomach of the aquatic organism to get filled up and prevents it from eating and it eventually dies. Moreover, these plastics may contain additives such as stabilizers and plasticizers which when broken down releases secondary pollutants that can affect the environment adversely. These toxic degradation products can equally enter the food chain and thus affect both man and aquatic lives.

Open Burning: This is an old method of solid waste disposal. In some household, the waste is usually burnt at the backyards of the houses. This method has its own draw backs as in that during combustion, there are no devices to trap potential air pollutants. Details are described in the incineration method.

Sanitary Landfills

The open dump system has been replaced by sanitary landfill. In open dumps, wastes are heaped on the surface of the soil however in landfills solid waste is disposed in the upper layer of the earth's mantle which has been excavated to the depth of about 4 m. The waste is then covered with thin layer of soil and compacted daily. In this way the influx of large numbers of insects, rodents and disease carrying pest are checked unlike in the open dump system. The waste compacted daily until about 3 to 3.5 m of the landfill is filled. Ideally landfills should be cited at locations where the geological and geographical features of the area will not support leaching into ground water and contaminating it especially during raining season. It is recommended that sealants (clay, fine grained sand, plastic) should be used to line the bottom to prevent liquids leaching into underground water while sophisticated instruments should be used to collect leachates and gas formed during decomposition. In recent times sanitary landfill is becoming less popular because of the cost in meeting modern specified requirement.

Challenges/Drawbacks

- Sanitary landfills require strict regulatory restrictions. The construction and maintenance of sanitary landfills therefore requires high environmental and economic cost.
- Landfills consume space especially in highly populated cities. Equally important is that most times the proximity of a property to landfills depreciates the value of the property. Host communities will thus be less willingly to use viable arable and residential plots of land for landfills. This will result in the scarcity of land for landfills.
- Landfills may contain plastics and heavy metals which are not biodegradable, these heavy metals and toxins present in plastics may become dissolved and seep through the soil to cause pollution of ground water.
- During anaerobic decay of waste (decay in the absence of oxygen), methane is produced. If not collected, the large volume of methane gas produced may seep through the waste and accumulate in underground pockets causing explosion. Interestingly the generated methane gas can be collected and used as a source of energy.

Incineration: This is an age-old method of disposing waste. Unlike open burning, these wastes are burnt in incinerators and special devices are used to trap potential air pollutants. In developed countries some household consumables are burnt in incinerators provided at the backyards where non-combustible materials (such as glass, metals, florescent lights and batteries) are removed while combustible materials such as paper, plastics and rubber are incinerated. These materials however can release toxic gases and particulate matters when burnt. For instance, some types of paper can release dioxins when burnt. To avoid the release of potential air pollutants, devices such as lime scrubbers and electrostatic precipitators are used to neutralise and trap gases respectively. The ash obtained after incineration should be disposed of properly. Most preferable in licensed hazardous waste landfills.

Advantages:

- Incineration eliminates the emission of offensive odours and gases
- The burning of combustible materials especially rubber (tires) can generate lots of heat energy that can be used for electricity and domestic heating.

- It reduces the volume of waste and thus saves space as the ash that is produced after incineration is much more compact than un-burnt solid waste.

Challenges/Drawbacks

Particulate matter, toxic gases and dioxins can be released during the combustion of plastic, rubbers, papers etc. These emissions can be fatal when inhaled as they can settle deep in the lungs causing difficulty in breathing and several other body harm. They can also have carcinogenic effects on body tissues.

- It can lead to the emission of gases and particulates that can dissolve in water to form acid rain. For instance, the burning of chlorinated materials such as polyvinyl chloride (PVC) causes the release of acidic gases which dissolves in water to form acid rain.
- Can create secondary disposal problems
- could lead to smog and poor visibility
- In countries where legislative laws are strictly adhered to, pollution control devices are required. These devices are costly making the method difficult to practice.
- Similar to landfills, individuals are not likely to accept incinerators near their homes. This will result in the scarcity of land for landfills.

Composting and Municipal Waste Composting Project

This is a biological process whereby microorganisms are used to decompose moist solid organic wastes into compost or mulch under controlled condition. This is the preferred method for the disposal and management of municipal waste such as food scraps, agricultural waste, yard waste and paper. In fact, to reduce the demand posed on sanitary landfills, yard waste is banned from sanitary landfill, and it is rather converted to compost. In most of these cities, the composting is centralised. This process of composting can be carried out in many ways. The steps involved in one of such processes are outlined below:

- The crude refuse is loaded into a container, digester or a conveyor belt
- Nonorganic matter such as metals particles are removed (metals are often removed by using magnetic separator)
- The moist waste is thereafter loaded into the rotatory cylinder where it is pulverized. Air at low pressure is allowed to circulate throughout the cylinder where aerobic microorganisms decompose the waste into humus (compost/ mulch), carbon (IV) oxide

and water. The decomposition process may take three to four (3-4) days. For maximum decomposition moisture, carbon dioxide and nitrogen ratio are monitored by adding water or fertilizers.

- The composted waste is then placed outside for several months to cure during which further decomposition occurs. This completes the process of composting, and the compost is ready to be used in gardens and others such as greenhouses and golf courses.

Advantages

- It reduces the demand for sanitary landfills.
- Wastes can be turned into soil conditioners.
- Disease causing microbes are killed by the heat generated during decomposition.
- Composting can also produce methane fuel that can be burnt to generate energy for cooking and lighting. Compared to sanitary landfills, it is easier to capture methane gas from anaerobic digesters than from sanitary landfills. Anaerobic digesters can be designed for both industrial and domestic use.

Drawbacks/Challenges

- Waste such as agricultural waste may contain pesticide residues that can find their way into the compost, however most pesticides are broken down into harmless substances by microbes or by heat generated during composting.
- Waste such as sewage sludge and consumer items may contain non-biodegradable matter such as heavy metals which can contaminate the compost. Contamination by heavy metals can be minimised by sorting the waste to remove sources of heavy metals before composting. In addition, industries should be restricted from disposing untreated wastewater (effluent).

Vermicomposting

Vermiculture or use of earthworm in biotechnology, where the earthworm feed on and degrade a variety of organic waste, eliminate noxious elements and convert the waste into vermicompost, which is high grade, nutrient rich compost and a very significant biofertilizer and a soil conditioner vermicompost enhances soil productivity and increase crop yield.

Waste Prevention

The best way of preventing the generation of waste is to **reduce, reuse,** or **recycle** waste. The aforementioned ways of waste prevention are known as the "three Rs" of waste management. Among the three Rs, the order of importance in ascending order is recycle, reuse and reduce

Source Reduction or "Reduce"

It is the cheapest and preferred strategy to prevent and manage waste. Ironically it is the most underused. It is much cheaper to prevent the generation of waste in the first place than to manage the enormous volume of waste generated. For instance, beverage and soft drink bottling companies have realised that it saves money to reduce the weight of packaging materials such as plastics and aluminium cans. Ways of reducing the generation of waste include:

- Reducing the amount of raw materials used in the manufacturing of a product without compromising the quality of the product. For instance, dry cell batteries contain lesser amount of mercury than they did in the past.
- Using alternative methods or raw materials that produce lesser volume of waste. However, a method that generates hazardous waste should not be substituted for more friendly methods or raw materials.
- Reusing and recycling waste at the sources where there are generated.
- Using minimal packaging materials during individual shopping so as to reduce the volume of waste.

Reuse

This is the multiple use of an item. This is preferable to recycling because the item does not need to be reprocessed. Reuse prolongs a product's usable life. In the light of this, the following practices are recommended:

- Consumers should purchase durable items such as metal spoons, under wears, refillable glasses rather than disposable items.
- Items that are still useable should be repaired, sold or donated to charity.

Recycle

Some products once used cannot be reused. These products can however be recycled. Recycling thus involves converting an unwanted product and into another useful product. Examples of recycled materials include plastics, glass, plastics, metals, paper, water etc. For example, an abandoned automobile can be recycled into fan blades, cutlasses, hoes and many other utensils while paper can be recycled into tissues and newsprint papers.

Recycling of Plastic Waste Plastics are most times made from polymers that are not biodegradable especially in developing countries.

Over the years, there has been an increased demand for plastics because of their desirable properties such as strength, low cost, longevity and good barrier properties. Plastics have thus become an integral part of our society. Sadly, these plastics which are most times not biodegradable are often indiscriminately dumped into the surrounding. It is estimated that plastics contribute to 12% of municipal waste. Although plastic pollution has continually remained a global challenge, countries like Japan and Germany have developed recycling technologies for their plastics. In one of such technologies, plastics are subjected to incineration and gasification and the gaseous product are converted to raw materials such as water gas ($CO + H_2$) which can be used for the synthesis (production) of methanol and other alcohols. Another benefit of recycling is that the heat generated from the incineration process can be used for electrical generation units or domestic heating. In fact plastics have higher energy content than coal.

Disadvantages of plastic recycling:

- Recycling of plastics through incineration can lead to the production of harmful gases and fumes (HCl, Cl_2, HCN, CO, CO_2 and dioxins). This could result in environmental pollution (greenhouse effect, acid rains).
- Furthermore, it can lead to the formation of gases and particulates. Persons who come in contact with theses pollutants may develop allergies and bronchial diseases, cancer and so on.
- The cost of recycling plastics is at times higher than the cost of producing virgin materials.

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CHAPTER 13

THE BASIC COMPONENT OF LIFE: THE CELL AND HOW IT WORKS

A. Gbadebo & O. Babalola

Introduction

In the vast tapestry of our world, life emerges as one of the most intricate and captivating phenomena. From the towering trees in lush forests to the microscopic organisms that thrive in the deepest oceans, the diversity of life is a testament to the complexity of nature's design. At the heart of this breath-taking design lie two foundational components that form the basis of all living organisms: **the cell** and **DNA**. These entities, both elegant and enigmatic, serve as the cornerstones of life as we know it, encapsulating the essence of existence and heredity.

Cell: The Basic Unit of Life

The cell is the fundamental unit of life. It is a marvel of intricate organization. Comprising several distinct parts, each with a specific function, cells collectively form the basis of all living organisms. Cells can be broadly categorized into two main types: prokaryotic cells and eukaryotic cells.

Prokaryotic Cells: Simple, Single-Celled Organisms

Prokaryotic cells lack a true nucleus and membrane-bound organelles (Fig. 1). Their genetic material (DNA, bundled together as chromosome) lies free within the cytoplasm in a region known as nucleoid. They are typically smaller and simpler than eukaryotic cells. Bacteria and archaea are examples of prokaryotic organisms. Despite their simplicity, prokaryotic cells exhibit remarkable adaptability and diverse metabolic capabilities.

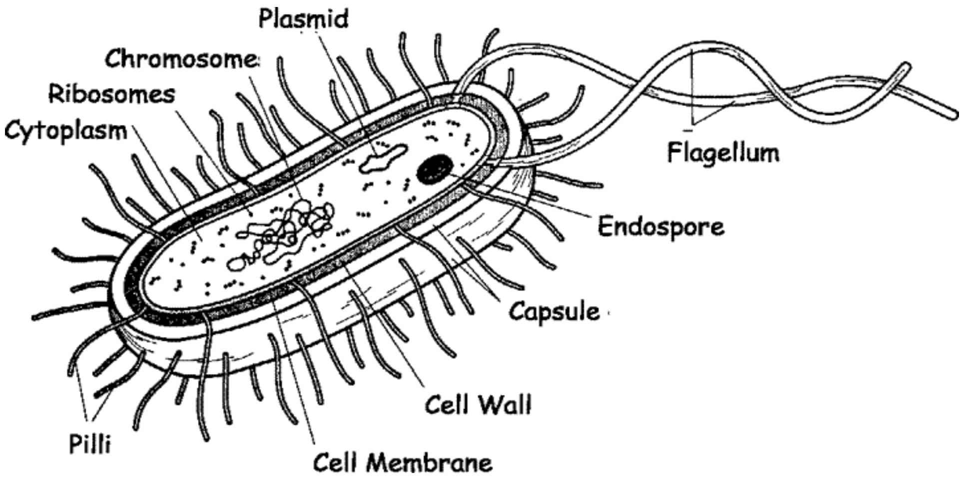

Fig. 1: A typical bacterial cell

Eukaryotic Cells: Complex Cells with a Nucleus

Eukaryotic cells, on the other hand, are more complex and larger. They possess a defined nucleus that houses their genetic material. Eukaryotic cells are found in plants, animals, fungi, and protists. The presence of membrane-bound organelles, such as mitochondria and the endoplasmic reticulum, enables eukaryotic cells to carry out specialised functions (Fig. 2 & 3). Eukaryotic organisms are mostly multicellular except for the protists that are unicellular. These multicellular organisms range from simple forms such as algae to complex forms as seen in mammals. In advanced multicellular organisms like the mammals, cells make up tissues, tissues make up organs and organs performing related functions make up an organ-system.

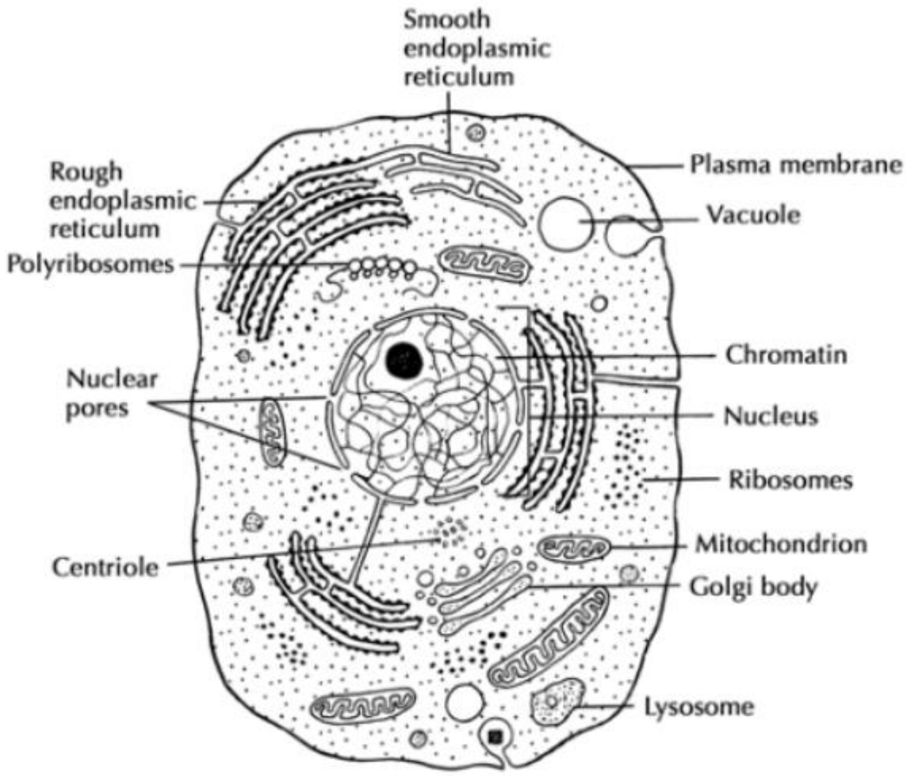

Fig. 2: A typical animal cell.

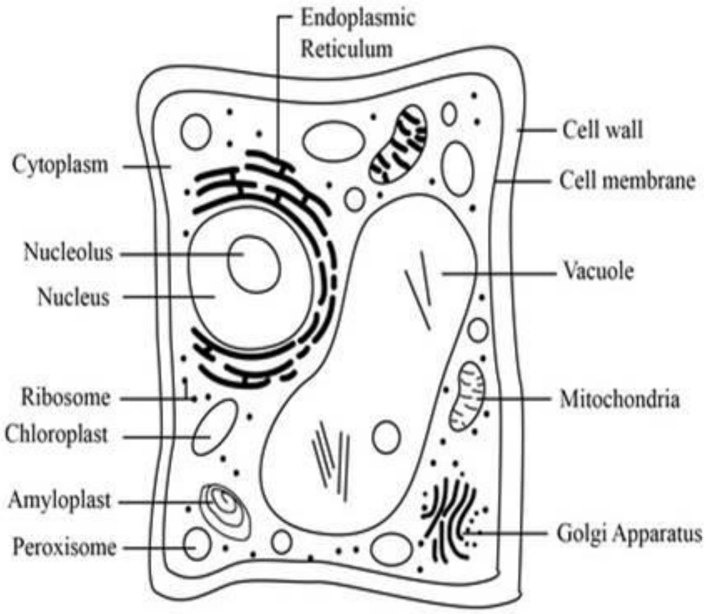

Fig. 3: A typical plant cell.

Table 1: Differences between prokaryotic and eukaryotic cells

S/N	Prokaryotic cells	Eukaryotic cells
1	No membrane-bound nucleus	They have membrane-bound nucleus
2	Genetic material (DNA) is bundled together in the nucleoid region	Store their genetic information in the nucleus
3	Membrane bound organelles are absent	They have other membrane bound organelles like mitochondria, endoplasmic reticulum, golgi apparatus, etc.
4	Prokaryote has single circular double-stranded DNA	Eukaryotic DNA consists of multiple molecules of double-stranded linear DNA

Similarities between prokaryotic and eukaryotic cells:

All cells, whether prokaryotic or eukaryotic, share these four features: they all have DNA, plasma membrane, cytoplasm, and ribosomes.

Table 2: Differences between plant cell and animal cell

	Plant cell	Animal cell
1	Has cell wall outside the plasma membrane which makes them less flexible	Does not have cell wall and are very flexible
2	Has chloroplasts used in photosynthesis	Does not have chloroplast
3	Has a large central food vacuole for storing nutrients and wastes	Food vacuoles when present are much smaller and numerous

The Cell Theory

The cell theory is a fundamental concept in biology that describes the basic unit of life and the organisation of living organisms. It consists of three main principles:

1. **All living organisms are composed of cells:** This principle states that all living things, whether they are single-celled organisms like bacteria or complex multicellular organisms like humans, are made up of one or more cells. Cells are the building blocks of life.

2. **The cell is the basic structural and functional unit of life:** This principle emphasises that the cell is the smallest unit of life capable of carrying out all the functions necessary for an organism's survival. Cells can perform various functions, such as metabolism, reproduction, and responding to their environment.

3. **All cells arise from pre-existing cells:** This principle asserts that new cells are formed through the process of cell division, and they inherit genetic material from the parent cell. This concept contradicts the earlier idea of spontaneous generation, which posited that life could arise from non-living matter.

The cell theory, developed in the 19th century by scientists like Matthias Schleiden, Theodor Schwann, and Rudolf Virchow, revolutionised our understanding of biology and laid the foundation for modern cell biology. It continues to be a fundamental concept in the field of biology, shaping our knowledge of how living organisms are organised and function.

Structures and Functions of Cell Components

Below are the essential components that make up a typical eukaryotic cell:

1. Cell Membrane: Gateway to the Cell's Interior

The cell membrane, or plasma membrane, is a selectively permeable barrier that encases the cell's contents. Composed of a phospholipid bilayer embedded with proteins, the cell membrane regulates the passage of substances in and out of the cell. This dynamic interface ensures that the cell maintains its internal environment while interacting with its surroundings.

2. Cytoplasm: The Fluid Medium

The cytoplasm is a gel-like substance that fills the space between the cell membrane and the nucleus. Within this fluid medium, a multitude of chemical reactions occur, facilitating vital cellular processes. Organelles, enzymes, and other molecular components are suspended in the cytoplasm, collectively contributing to the cell's functioning.

3. Nucleus: The Control Centre

The nucleus is often referred to as the control centre of the cell, housing the cell's genetic information. Within the nucleus, the DNA is organised into chromosomes, each carrying instructions for the cell's functions and characteristics. The nucleus also contains the nucleolus, responsible for the production of ribosome, which is important for protein synthesis.

Within eukaryotic cells, specialised organelles contribute to various cellular functions, these include:

4. Mitochondria (sing. Mitochondrion): The Powerhouse of the Cell.
Mitochondria are the energy generators of the cell, producing energy in form of adenosine triphosphate (ATP) through cellular respiration. These double-membraned organelles play a crucial role in breaking down nutrients and converting their energy into a form that the cell can utilise.

Note that in prokaryotes lacking mitochondria, cellular respiration takes place on the inner side of the plasma membrane.

5. Endoplasmic Reticulum: Protein Synthesis and Lipid Metabolism
The endoplasmic reticulum (ER) is a network of membranes involved in protein synthesis, modification, and transport. The **Rough** ER has ribosomes on it and is dedicated to protein synthesis, while **smooth** ER does not have ribosomes on it and participates in lipid metabolism, detoxification, and calcium storage.

6. Golgi Apparatus: Packaging and Distribution
The Golgi apparatus receives proteins and lipids from the ER, modifies them, and packages them into vesicles for distribution. This organelle plays a central role in sorting, modifying, and packaging cellular products before they are transported to their final destinations.

7. Ribosomes: Sites of Protein Synthesis
Ribosomes are cellular structures where proteins are synthesised. Composed of ribosomal RNA (rRNA) and protein molecules, ribosomes read the genetic information encoded in

messenger RNA (mRNA) and link together amino acids to form polypeptide chains, the building blocks of proteins.

8. Lysosomes: Recycling Centers

Lysosomes are membrane-bound organelles containing digestive enzymes that break down waste materials and cellular debris. They play a crucial role in recycling cellular components and maintaining a clean and functional cellular environment.

Cellular Processes

Understanding the basic processes that occur within cells is fundamental to comprehending the complexity of life:

Cell Division: Growth and Reproduction

Cell division is the process by which cells replicate and give rise to new cells. The cells replicate their genetic material and duplicate their organelles before dividing into two. There are two types of cell division: mitosis and meiosis.

Mitosis, the division of somatic cells, ensures growth, tissue repair, and maintenance. Meiosis, a specialised form of cell division, takes place in reproductive organs and helps to generate gametes (sperm and egg cells) for sexual reproduction.

Cellular Respiration: Converting Nutrients into Energy

Cellular respiration is the process by which cells break down organic molecules, typically glucose, to produce energy in the form of ATP. This energy conversion occurs in the mitochondria and is vital for various cellular activities. Respiration could be aerobic (oxygen-dependent) or anaerobic (does not need oxygen).

Photosynthesis: Harnessing Light Energy

In plant cells, chloroplasts play a pivotal role in photosynthesis, a process that converts light energy (sunlight) into chemical energy stored in glucose in form of starch. Through this process, plants make use of carbon dioxide and release oxygen, supporting the entire ecosystem.

The Molecule of Life - Deoxyribonucleic Acid (DNA)

The journey into the heart of life's mysteries leads us to DNA, a molecule that holds the key to heredity, diversity, and evolution. The understanding of DNA's significance was not an overnight revelation; it emerged through a series of scientific breakthroughs and persistent inquiry. Before the discovery of DNA, scientists speculated about the mechanisms underlying heredity. Gregor Mendel's experiments with pea plants in the 19th century laid the foundation for understanding the inheritance of traits, while others proposed theories involving "inheritance factors" or "germ plasm." These early notions set the stage for the eventual unveiling of DNA's role.

In the mid-20th century, Rosalind Franklin's pioneering X-ray crystallography experiments provided crucial insights into the structure of DNA. Her work, combined with the innovative model-building efforts of James Watson and Francis Crick (1953), led to the elucidation of DNA's double helix structure. This breakthrough unveiled how DNA's structure held the code for hereditary information and opened the door to a deeper exploration of its functions.

Structure of DNA

The structure of DNA, often described as the "twisted ladder" or double helix, is a masterpiece of molecular architecture.

Nucleotides: The Building Blocks of DNA

DNA is composed of nucleotides (Fig. 4), each consisting of a phosphate group, a sugar molecule (deoxyribose), and one of four nitrogenous bases: adenine (A), thymine (T), cytosine (C), and guanine (G). The sequence of these bases along the DNA strand forms the genetic code.

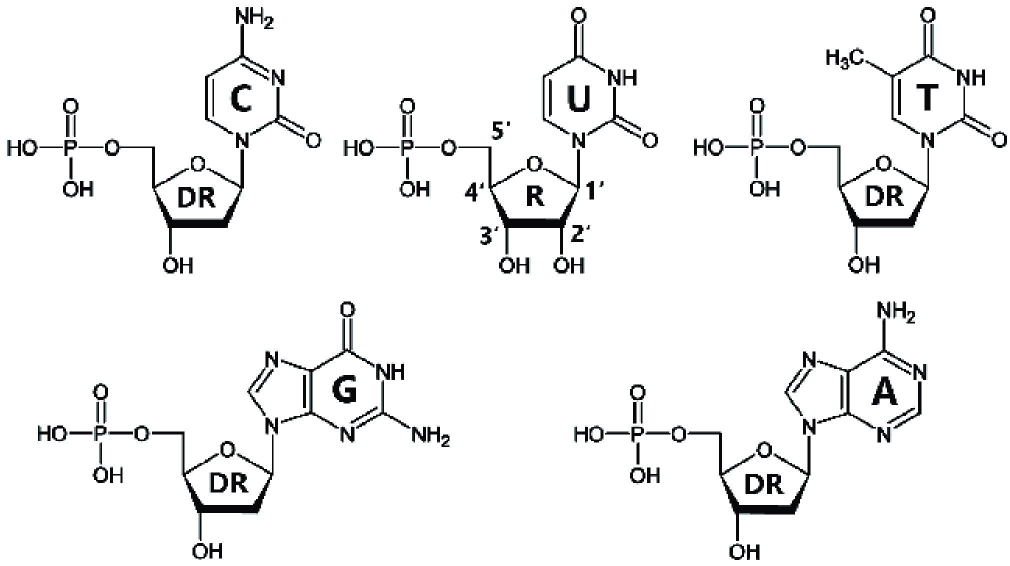

Fig. 4: Structure of nucleotides in DNA and RNA. RNA contains uracil (U) instead of thymine as in DNA.

Double Helix: **Implications for Replication and Stability**

The double helix structure of DNA consists of two strands that wind around each other (Fig. 5). The complementary pairing of nitrogenous bases (A with T, and C with G) forms the rungs of the ladder. This specific base pairing is crucial for DNA replication and ensures the stability and fidelity of genetic information transfer.

DNA Replication

DNA replication is a remarkable process that ensures the faithful transmission of genetic information from one generation to the next. The process of DNA replication follows a semiconservative pattern.

Semiconservative Replication: Copying the Genetic Code

In semiconservative replication, each DNA strand serves as a template for the synthesis of a new complementary strand. Enzymes such as helicase unwind and separate the original strands, and DNA polymerase adds complementary nucleotides to each template, resulting in two identical DNA molecules.

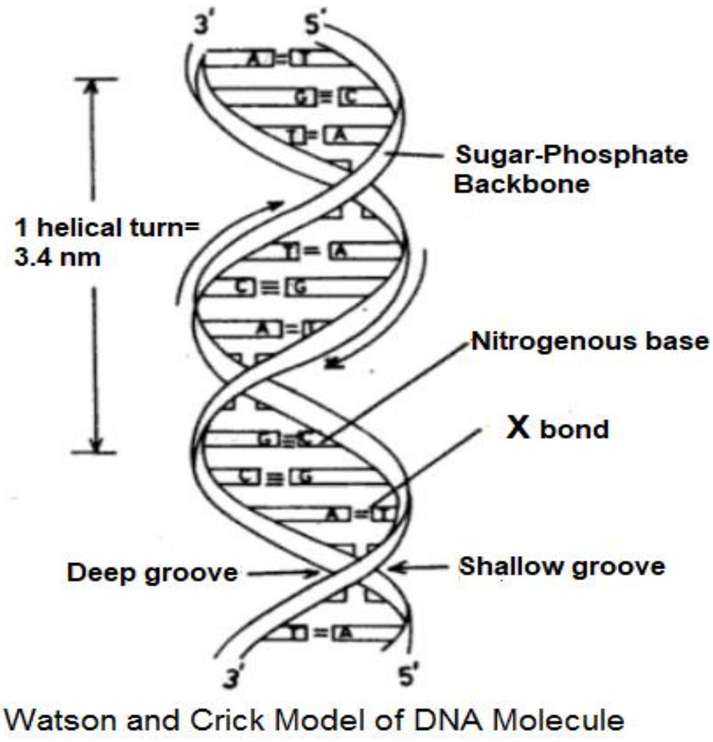

Fig. 5: Double helix structure of DNA

Enzymes Involved: Helicase, DNA Polymerase, Ligase

Several enzymes are integral to DNA replication. Helicase unwinds the double helix, creating single-stranded regions where DNA polymerase can work. DNA polymerase adds nucleotides to the growing strand, and ligase seals any gaps in the newly synthesised DNA.

Transcription and Translation

DNA's role extends beyond replication; it serves as a template for creating functional molecules within the cell.

Transcription: Converting DNA to RNA

During a process known as transcription, a segment of DNA is used as a template to synthesise a complementary RNA molecule called messenger RNA (mRNA). This process occurs in the cell nucleus and is catalysed by the enzyme RNA polymerase.

RNA Types: mRNA, tRNA, rRNA

The cell produces different types of RNA molecules. mRNA carries the genetic code from DNA to the ribosomes. Transfer RNA (tRNA) transports amino acids to the ribosome for protein synthesis, and ribosomal RNA (rRNA) forms the structural component of ribosomes.

Translation: Building Proteins Using mRNA Instructions

Translation is the process by which the sequence of nucleotides in mRNA is decoded into a sequence of amino acids, forming a protein. Ribosomes facilitate this process by coordinating the interaction between mRNA and tRNA.

Genetic Code and Protein Synthesis

At the heart of heredity and biological diversity lies the **genetic code** (Table 1).

Codons: The Triplet Code for Amino Acids
The genetic code is a set of rules that specifies the correspondence between codons (triplets of nucleotides) in mRNA and the amino acids they encode. This code governs the sequence of amino acids in proteins, determining their structure and function.

Role of tRNA in Delivering Amino Acids to Ribosomes
tRNA molecules have specific anticodons that pair with complementary codons on mRNA. Each tRNA carries an amino acid that corresponds to the codon it recognises. This process ensures the correct assembly of amino acids in the growing polypeptide chain.

Ribosomes: The Molecular Machines for Protein Assembly
Ribosomes are intricate molecular complexes that facilitate protein synthesis. They bring together mRNA and tRNA, allowing the sequential addition of amino acids to the growing protein chain.

Table 1: The genetic code table showing the amino acid of each triplet codes. ~~for~~

UUU UUC } Phe UUA UUG } Leu	UCU UCC UCA UCG } Ser	UAU UAC } Tyr UAA UAG } Stop	UGU UGC } Cys UGA Stop UGG Trp
CUU CUC CUA CUG } Leu	CCU CCC CCA CCG } Pro	CAU CAC } His CAA CAG } Gln	CGU CGC CGA CGG } Arg
AUU AUC AUA } Ile AUG Met*	ACU ACC ACA ACG } Thr	AAU AAC } Asn AAA AAG } Lys	AGU AGC } Ser AGA AGG } Arg
GUU GUC GUA GUG } Val	GCU GCC GCA GCG } Ala	GAU GAC } Asp GAA GAG } Glu	GGU GGC GGA GGG } Gly

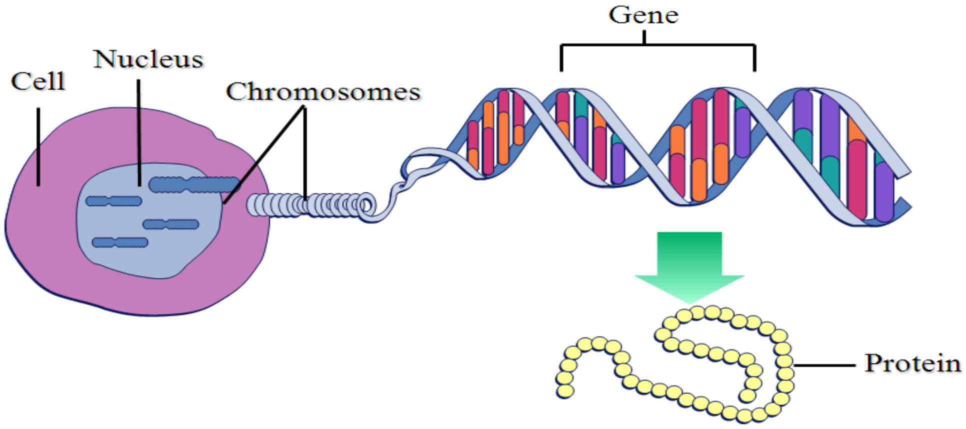

Fig 6: The flow of genetic information within a eukaryotic cell

Mutations and Variation

While DNA replication and protein synthesis are remarkably accurate processes, occasional errors—mutations—can occur.

Types of Mutations: Substitution, Insertion, Deletion

Mutations are changes in the DNA sequence. Substitution mutations replace one base with another, while insertion and deletion mutations add or remove nucleotides. Mutations can impact protein structure, function, and ultimately, the organism's phenotype (physical characteristics or observable traits)

Impact of Mutations on Proteins and Phenotypes

Some mutations have no discernible effect, while others can lead to significant changes in protein structure and function. Beneficial mutations may confer advantageous traits, while harmful mutations can lead to genetic disorders such as sickle cell disease.

Genetic Diversity and Evolution

Mutations, combined with genetic recombination through sexual reproduction, contribute to genetic diversity within populations. This diversity is the raw material for natural selection, driving evolution and adaptation over generations.

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CHAPTER 14
THE WORLD OF BIOTECHNOLOGY

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Introduction

Biotechnology is the scientific manipulation of biological systems, living organisms, their parts or derivatives for the production, alteration of products or processes for particular use. It is the controlled employment of biological agents such as microorganisms or cellular components for a productive use. Biotechnology dates to as early as the history of man as these processes were used in the improvement of food condiments such as iru, ogiri and dadawa, production of local foods like ogi, kunnu, fufu, gari and in the production of bread, cheese, wine, etc. The process involved in the processes listed above is known as **fermentation**.

Biotechnology can be divided into: Non-gene biotechnology and Gene biotechnology.

Non-gene biotechnology is the earliest form of Biotechnology, and it has to do with the manipulation of whole cells, tissues or individual organisms as in the case of fermentation. Whole organisms such as certain strains of bacteria, yeasts and fungi are employed in the fermentation process. Other non-gene biotechnology processes include production of hybrid plant and animals and production of vaccines. Hybrid organisms are products of the combination of two related specie with different desirable characteristics.

Gene biotechnology is the direct manipulation of DNA, the genetic material and this aspect of Biotechnology is known as Recombinant DNA technology (rDNA technology) or genetic engineering. This aspect of Biotechnology began with the discovery of the DNA by Watson and Crick in 1953.

Fields and Applications of Biotechnology

Biotechnology is applied in every area of human life and hence, different areas can be identified including: Yellow Biotechnology refers to its application in improving the nutritional content of foods, White Biotechnology which refers to its industrial application, green biotechnology applied to agricultural processes, Red Biotechnology in the manipulation of organisms to manufacture antibiotics and other drug-like products, grey biotechnology in environment preservation and contaminant removal, Brown Biotechnology in the use and management of desert land, Gold Biotechnology which involves primarily bioinformatics and computational biology.

Let us have a look at some of these areas.

Food Biotechnology

The process mainly employed in food biotechnology is **microbial fermentation.** Microbial fermentation is the breakdown of sugar molecules (in organic substrates) by microscopic organisms such as bacteria and fungi in an anaerobic (absence of oxygen) environment to produce energy. There are different types of fermentation with different end-products, but the one most commonly employed in the food industry is the alcoholic fermentation (by yeast such as *Saccharomyces cerevisae*) and lactic acid fermentation carried out by bacteria such as *Lactobacillus* and *Streptococcus.*

Alcoholic fermentation produces ethanol and carbon (IV) oxide (CO_2). This is usually employed in the baking industry. When yeast is added to the dough, the yeast begins the process of fermentation (anaerobic respiration). As it uses up the sugar molecules in the dough, ethanol and CO_2 are produced. As the CO_2 (being a gas) tries to find its way out of the dough, it creates tiny holes in the dough, and this makes the dough to rise. This gives the bread or puff-puff its fluffy texture. This type of fermentation is also used in making wine and beer. The ethanol end-product is the alcohol component. Wine is made from the fermentation of grapes while beer is produced by fermentation of grains such as corn, wheat, barley, rice, oats, rye, etc.)

Lactic acid fermentation is used in milk products such as cheese and yoghurt. Lactic acid bacteria are also able to ferment meat (sausages), fish, vegetables (sauerkraut) and legumes. Fermentation of legumes results in increased availability of nutrients and improved taste, while reducing the anti-nutritional components. Examples of legumes commonly fermented in Nigeria include locust beans (iru, ogiri, dadawa), soybeans and melon seeds. These are used as food condiments for improved taste and nutrition. Another staple food that undergoes fermentation is ‘fufu’ made from cassava. The process of fermentation helps to soften the cassava and remove compounds that may be toxic to the body

Natural colourings and flavours like aroma glycosides are also employed in improving food appearance and flavour. Aroma glycosides are products of secondary metabolism in plants. When the glycoside compounds are broken down by certain enzymes, the aroma is released. Gums which are used as thickening agents and low-calorie sweeteners are also being produced from natural ingredients. Certain contents in food can also be increased by means of biotechnology. For example, the quantity of amylose starch in potatoes can be increased by genetic modifications. This starch is in great demand and its unique properties are useful in food and industrial applications.

Industrial Biotechnology

A lot of the advances in food biotechnology are being employed on an industrial scale, such as the production of yeast, yoghurt, cheese, vinegar, butter, beer and wine. The manufacture of chemicals, textiles, pulp and paper, detergents, materials and polymers are other areas in which biotechnology processes have been employed. Industrial biotechnology has witnessed some historical advancement that has made available products such as baker's yeast and alcohol since as early as 1940, probiotics, enzymes and vaccines in the 1980's. Genetically engineered enzymes and yeast lines are now being used in cheese and bread production.

Enzymes are organic catalysts found in living cells which speed up the rate of reaction. Microbial enzymes are components of detergents used in laundry and dish-washing liquids. Such enzymes include proteases which remove stains of protein origin, amylases remove starch stain and lipases digest fat, oil and grease stains. These enzymes can digest stains of biological origin. Pectinase enzyme from the mould *Aspergillus* can be used to improve juice yields from fruits such as apples. Aroma glycosides are also employed in the production of perfumes, sanitary pads, detergents and dish-washing liquids.

Biotechnology has made the extraction of ores from metals possible through a process called bioleaching or bacteria leaching. Bacteria through their metabolic activities convert insoluble metals to their soluble forms. These soluble forms are then pumped out and the metals easily extracted from it. This process of mining is cost effective when compared with the conventional method of mining. Biological mining is highly effective in the low-grade ores and this method is also prevents damage to the environment.

The continuous increase in the price of petroleum around the world has led to measures to obtain biological fuels. Biofuels are alternatives to fossil fuels, and they are used in the industrial, domestic, and space sectors. In our present day, the need and awareness for Clean Energy has increased in the last decade. By using biofuel, we can preserve natural resources and save the atmosphere from more damage.

Ethanol is produced from various sources, such as cassava, cereals, potato, sugarcane, pineapple, sugar beet, etc. They act as a solvent and substrate for the synthesis of many components such as dyes. Kernels of corn, mats of algae, and stalks of sugarcane are some of the materials that can also be used to produce biofuels. Brazil has successfully produced ethanol from sugarcane raw materials and some of their cars are now powered with ethanol and the US has also been producing ethanol from corn.

Biodiesel can be produced from vegetable oils and liquid animal fats, and green diesel from algae and other plant sources. Biogas formation and methanogenesis are although ancient forms, today they are in great demand. Methane fermentation is widely practiced and is one of the easily available sources of energy. Agricultural waste and farmyard waste have been efficiently used for this purpose.

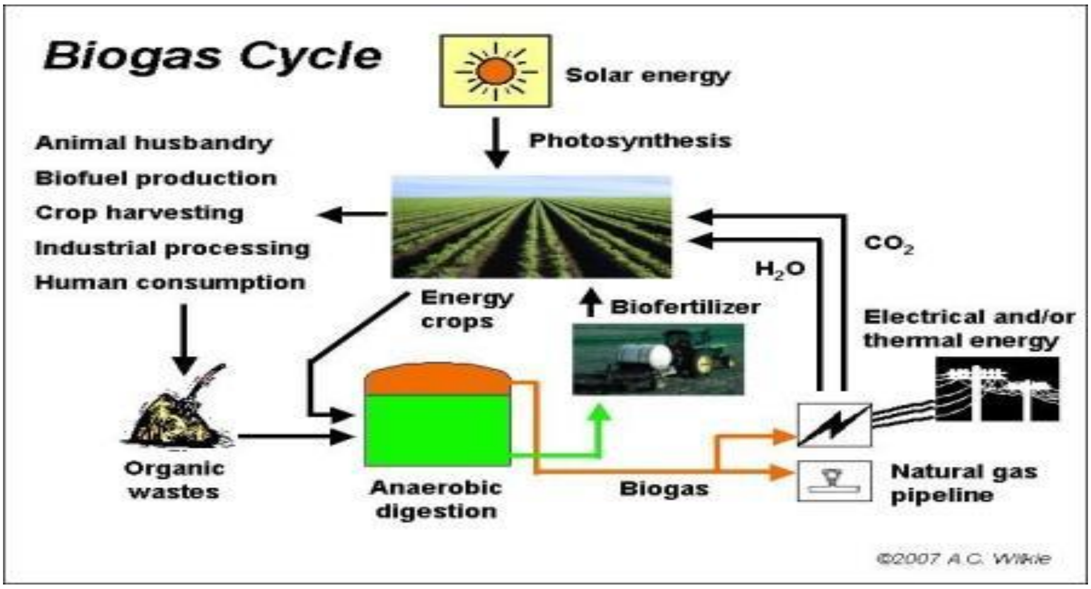

Fig 1: The Biogas cycle (Source: https://biogas.ifas.ufl.edu/biogas/digesters.asp)

Agricultural Biotechnology

Scientific and technological principles and tools are applied to improve agricultural processes and enhance crop and livestock production. Challenges related to food security and sustainability are addressed with less harmful environmental impacts. Scientists can manipulate the genetic makeup of plants, animals, and microorganisms to produce or improve desired traits such as yield, disease resistance, nutritional content, and environmental adaptation.

Plant Biotechnology: is one aspect of agricultural biotechnology which has been greatly developed in recent times. Plant biotechnology was mainly about breeding methods such as hybridisation and selection. Hybrids are products of crossbreeding between two related species of plants or animals. For example, tangelo is a hybrid of tangerine and grapefruit. With recent developments in recombinant DNA technology, scientists can now transfer genes from one organism to another to produce specific traits. These crops are known as genetically modified (GM) crops.

The commercialisation of GM crops gained momentum in the 1990's. The first GM crop to be approved for commercial use was the Flavr Savr tomato, which was developed to have a longer shelf life (delayed ripening). This was followed by the introduction of other GM crops such as herbicide-tolerant soybeans and insect-resistant cotton. For the insect-resistant cotton (known as Bt cotton), a gene from a bacterium, *Bacillus thuringiensis* was engineered into the plant. The product of the gene is a toxin that can kill insect pests. When insect pests feed on this transgenic plant, the toxin kills them.

Golden rice is a genetically modified rice which contains a high amount of beta-carotene and other pro-vitamin A carotenoids while normal rice contains no beta-carotene, and no vitamin A. Apples are modified to reduce browning after being cut, this is achieved by reducing the enzyme (Polyphenol oxidase) responsible for browning. Yellow cassava for making 'yellow gari' is now also available. This cassava contains Vitamin A, unlike the conventional white one. Conventionally, palm oil, which contains Vitamin A, is added to gari during frying to make it yellow.

Fig. 2: Normal rice and golden rice

Fig. 3: Non-GMO apple and GM apple

In addition to genetic engineering, tissue culture techniques have been used to regenerate plants from small pieces of plant tissue, enabling the rapid propagation of elite crop varieties. This is known as micropropagation. Micropropagation is used to multiply plants such as those that have been genetically modified or bred through conventional plant breeding methods. It is also used to provide enough plantlets for planting from a stock plant which does not produce seeds or does not respond well to vegetative reproduction. Gene editing enables scientists to make precise changes to the DNA of organisms without introducing foreign DNA. This technology has the potential to enable the development of crops with specific traits, such as increased yield and improved disease resistance.

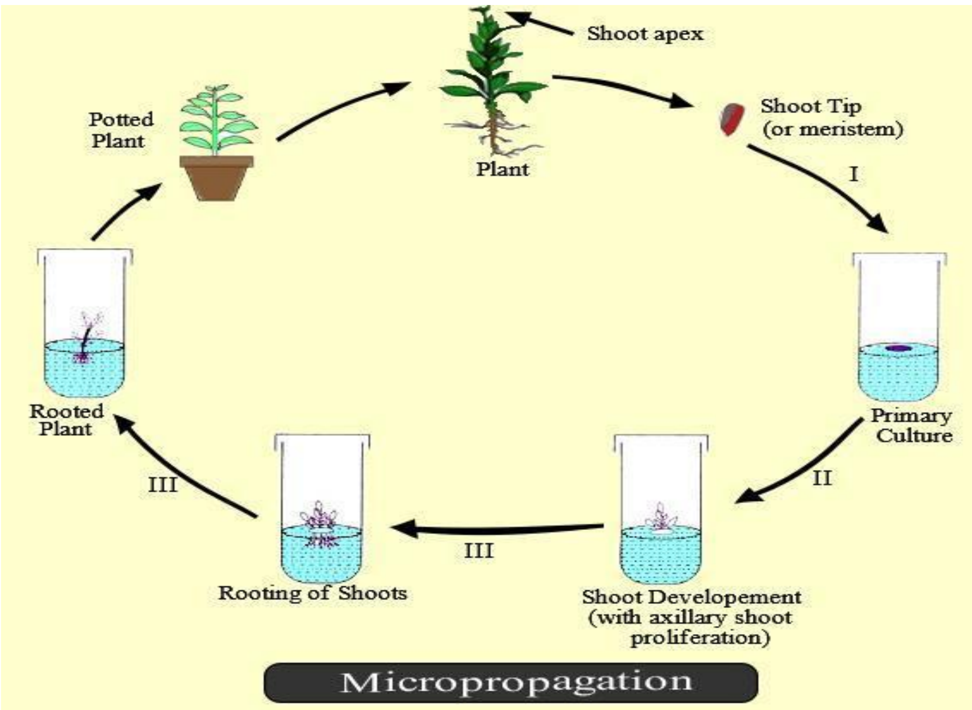

Fig.4: Micropropagation cycle

Plant biotechnology has been developed as a new age of science and technology where production of secondary metabolites, and production of large numbers of disease-free and new varieties are preferred. Production of artificial seeds, plant-made pharmaceuticals, recombinant or other therapeutic proteins, transgenic, and plant-made vaccines or antibodies is part of the current research work in plant tissue biotechnology.

Recent advances in plant genetic engineering strategies for the management of bacterial, fungal, and viral diseases are now widely used. Genetically modified plants are less susceptible to disease, there is increased yield, increased income of farmers, and also ensures adequate availability of food. Disease among crop plants was incredibly difficult to control and was previously only managed by complete removal of the affected crop but now agricultural biotechnology offers a solution through genetically engineering resistance varieties. Developed disease resistant crops now include cassava, maize, sweet potato, tomato, cotton, soybeans etc.

Biotechnology has also enabled farmers to produce crops with a higher nutritional value and enhanced flavour and texture. For instance, technology has made it possible to cultivate soybeans with high protein content, beans with more amino acids, and potatoes with higher starch content.

Improvement in the taste and flavor of crops has been achieved by enhancing the activity of enzymes present in plants. Also, it helps in keeping the yield fresh for longer. Post-harvest technologies have provided solutions to reducing losses and improving quality of commodities in transit through delay ripening of commodities and hermetic technology which reduces moisture, controls humidity and temperature of commodity. This is of topmost benefits to reducing loss of vegetables and fruits. This results in increased amount of food to farmers and consumers, lower food prices and improved access to food.

Vaccines are obtained from some plant cultures which contain inactivated pathogens. The transgenic plants have the ability to produce certain protein antigens e.g. tomato and banana. Transgenic sugar beet can treat foot and mouth disease of animals, transgenic bananas and tomato can cure diseases such as cholera and hepatitis B.

In **Animal Biotechnology**, molecular biology techniques are used to genetically engineer (i.e. modify the genome of) animals in order to improve their suitability for agriculture, industrial, or pharmaceutical applications. Animal biotechnology has been used to produce genetically modified animals that synthesise therapeutic proteins, have improved growth rates or are resistant to disease. Animal biotechnology can be applied to all animals: livestock, poultry, fish, insects, companion animals and laboratory animals. Animal Biotechnology has led to advancements in four primary areas: Improved animal health and welfare, enhancements of animal products, advances in human health and environmental and conservation benefits.

In livestock production, the use of biotechnology has facilitated improvements in the productivity of animals via increased growth, quality of carcass and reproduction, improved nutrition and feed utilisation, increased quality and food safety, improved health and welfare of animals and reduced waste through more efficient utilization of resources. Livestock production is one of the fastest-growing agricultural sectors in the world, both in developed and developing countries. The increase in demand for animal proteins as a result of insatiable plant protein for the growing population will not only contribute to the economic growth but also reduce malnutrition and then death in developing countries.

Current Animal Biotechnology Techniques for Livestock Production

Animal cloning: Using somatic cell nuclear transfer, livestock breeders can create an exact genetic copy of an existing animal – essentially an identical twin. Cloning does not manipulate the animal's genetic makeup nor change an animal's DNA: it is simply another form of sophisticated assisted reproduction.

Transgenic animals: A transgenic animal is one which has had genetic material from another species added to its DNA. This breakthrough technology allows scientists to precisely transfer beneficial genes from one species to another. Transgenic dairy cows are being bred for improved milk production.

Artificial insemination (AI): Artificial insemination has become the most widely spread biotechnology applied to livestock and especially in cattle production. It remains as one of the most important assisted reproductive technologies (Jacquelyn and Laura, 2008). The success of AI highly relies on the viability of sperm (Jindal and Sharmal, 2010). Sperm cryopreservation is the technique applied for the sperm to be viable for a longer time. It indicates the long-term preservation and conservation of biological substances at very low temperatures at -196°C of liquid nitrogen. Movement of preserved semen instead of live bulls would also improve trade, reduce production cost and also decrease the spread of cattle diseases usually transmitted by direct contact between cattle in cattle farms. The use of AI also prevents the rearing of bulls that involve added cost along with the possibility of causing injury or death to farmers or staff. Controlling and recording the time of AI helps to avoid indiscriminate mating (often observed in natural mating), thereby facilitating proper farm record-keeping and fertility management.

Fig 5: A cloned sheep named Dolly.

Multiple ovulation and embryo transfer (MOET): Embryo transfer biotechnology refers to a step in the process of assisted reproduction in which embryos are placed into the uterus of a female with the intent to establish a pregnancy. The technique generated a lot of interest among the people in the past. This biotechnique enables achieving a greater number of calves from selected females than was possible by applying traditional means of animal production. By increasing the number of calves, MOET has the potential for genetic improvement by increasing the selection intensity of the female. The advantages of embryo transfer are the preservation of breeds and conservation, disease-free herds creation, economical transport of livestock, for rapid multiplication of the elite female breeding stock, and for research applications. Through MOET, the numbers of imported highly valuable and scarce cattle breeds could be multiplied rapidly, leading to increased genetic improvement of cattle populations.

Sperm sexing: By using AI with sexed sperm, hundreds of thousands of calves have been born. This technology is useful when calves of a particular sex are more valuable than those of the opposite. Although this technology has been used for many species, most pregnancies have been in cattle, almost all because of sexed sperm and subsequently frozen. For instance, dairy farmers would prefer most of their calves to be female (replacement for heifers in a milking herd) whereas beef farmers would prefer bull calves for their higher body mass and beef production. AI using sexed sperm in dairy cows results in a sex-match ratio of 81%.

Embryo splitting: Embryo splitting refers to the formation of twins or multiples through the artificial microsurgical splitting of an embryo. After separation, the genetically identical embryos can continue to develop. The morula or blastocyst stages of embryos may be cut into two equal halves by using an inverted microscope connected with a micromanipulator and a microsurgical knife before transfer to a surrogate female. Genetically identical animals can be produced by this method. This process seems to duplicate the natural process of the production of monozygotic twins.

Embryonic stem cell: Embryonic stem cells (ESCs) are cells derived from the undifferentiated inner cell mass of an embryo which is harvested from the donor mother animal. Stem cells are pluripotent cells that can self-replicate and grow into specialised cells. It can be found at different stages of fetal development and are present in a wide range of adult tissues. Stem cells are manipulated in the laboratory to make them accept new genes that can then change their behaviour. This process includes removing the donor mother's ovaries and dosing her with progesterone, changing the hormone environment, which causes the embryos to remain free in the uterus. After 4–6 days of this intrauterine culture, the embryos are harvested and grown in vitro until the inner cell mass forms egg cylinder-like structures.

Medical Biotechnology

The application of biotechnological processes to health-related issues did not start recently. As far back as 1796, Edward Jenner successfully established the foundation for modern day vaccination. It was observed that milkmaids exposed to cowpox were not affected by smallpox, a deadly disease. Based on this observation, Edward Jenner inoculated a boy, James Phipps with cowpox scabs which resulted in a mild illness. Thereafter, the boy was inoculated with smallpox pustules and the boy did not come down with any illness. The successful outcome of this experiment laid the foundation for vaccination. Vaccines are weakened disease-causing organisms or parts of the organism that can trigger protective immune responses (one of which is antibodies) without causing disease in the recipient, so that on subsequent natural infection, the recipient is able to mount a fast and adequate immune response for protection. In essence, the recipient may get infected after the vaccination but does not come down with the disease because of the previous 'experience' (vaccination).

Many other vaccines have been developed, and some are routinely administered, especially to children and foreigners visiting places endemic for certain deadly diseases. These include vaccines for polio, hepatitis B, yellow fever, smallpox, measles, hepatitis B, tetanus, whooping cough, etc.

In recent times however, recombinant DNA technology has markedly improved the production of vaccines. Instead of using weakened whole organisms or parts of the organism, the genetic material is used. A good example is the Astrazeneca COVID-19 DNA-based vaccine. The COVID-19 virus utilises its surface spike proteins to gain entrance into cells for the establishment of an infection.

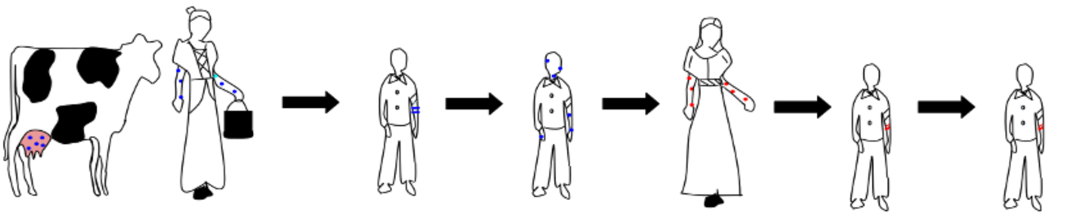

Fig 6: Steps in the discovery of immunization and vaccination by Edward Jenner, 1796 (Source: Wikipedia)

DNA that codes for the spike protein of the COVID-19 virus is engineered into an adenovirus. The adenovirus has also been engineered not to replicate in humans. Once the vaccine is given, the adenovirus finds its way into cells of the recipient. The adenovirus integrates its DNA and that of the COVID-19 spike protein into the host's genome. As the host makes its own mRNA and proteins, the COVID-19 spike mRNA and proteins are also made. The body recognises the spike protein as foreign, and the body mounts a specific immune response against it. If the recipient of the vaccine is later infected with the COVID-19 virus, the immune response mounted to the spike protein is quickly called into action and this prevents the individual from coming down with the disease. Some COVID-19 vaccines, like that produced by Pfizer is RNA-based.

Another revolution in medicine came with the discovery of penicillin in 1928. Alexander Fleming while working in his laboratory in London discovered that a mould of the Penicillium sp. produced a susbstance that prevented the growth of bacteria. This substance was later extracted and purified for use against certain strains of bacteria. This marked the beginning of the use of antibiotics against infections. Other types of antibiotics in use today that are also microbial products include: streptomycin from *Streptomyces griseus,* tetracycline from *Streptomyces rimosus,* griseofulvin from *Penicillium griseofulvum,* gentamicin from *Micromonospora purpurea,* etc.

Biologic drugs are also being developed. Good examples include insulin used in treating diabetic patients, human clotting factor VIII used in treating people with haemophilia (inability of blood to clot after an injury) and human growth hormone used in treating dwarfism. The DNA that codes for these proteins are engineered into the bacterial cells. Enzymes in the bacterial cells transcribe the DNA into mRNA, and the mRNA is translated into the desired proteins. When these proteins are produced, they are harvested, purified and processed for administration to patients.

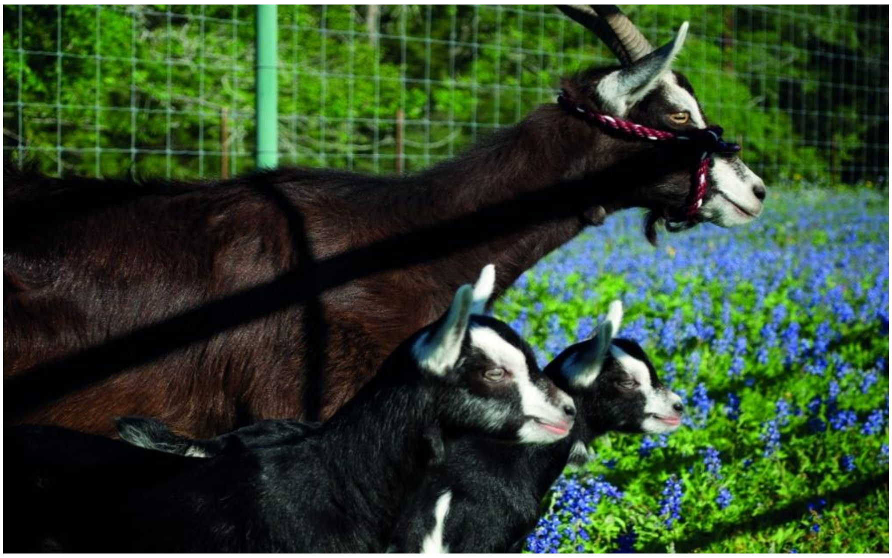

Fig 7: Goats that produce a malaria vaccine in their milk (Source: www.scientia.global)

Other areas include stem cell engineering and gene-editing for curing genetic diseases. Genetic diseases are caused by mutations in DNA. These mutations could involve only one nucleotide base pair or a few base pairs and may also involve large segments of DNA or parts of a chromosome. Stem cells are cells that have not differentiated to become specialised for a particular function; hence they can be engineered to differentiate and develop into specific tissues in the body. Stem cells without the mutation are introduced into the recipient, and these cells develop into cells and tissues without the disease-causing characteristics. Gene-editing can be used to replace mutated single nucleotide base pairs with the correct nucleotide base pairs. The CRISPR-Cas9 technology is one of the technologies used for this process. This technology involves harnessing the cell's DNA repair mechanism towards the mutated base pair after cutting the DNA strand with a particular enzyme found in bacteria. Diseases which can be cured with stem cell engineering and gene-editing include sickle cell disease and beta-thalassemia.

A lot of pharmaceuticals are also produced from plants using tissue culture. These are products of secondary metabolism in plants. They include the following:

Table 1: A list of some pharmaceuticals obtained from plants

Plant products	*Plant species*	*Industry*	*Industrial uses*
Codeine (alkaloid)	*Papaver sominifera*	Pharmaceutical	Analgesic
Diosgenin (steroid)	*Dioscorea deltoidea*	"	Antifertility agent
Quinine (alkaloid)	*Cinchona leitgeriana*	"	Antimalaria
Digoxin (glycoside)	*Digitalis lanata*	"	Cardiactonic
Scopolamine	*Dhatura stramonium*	"	Antihypersensitive (alkaloid)
Vincristine (alkaloid)	*Catharanthus roseus*	"	Antileukaemic
Pyrethrin	*Chrysanthemum cinerariaefolium*	Agrochemical	Insecticide
Quinine (alkaloid)	*C. ledgeriana*	Food & drink	Bittering agent
Jasmine	*Jasmium* sp.	Cosmetics	Perfume
Saffron	*Crocus sativa*	Food	Flavoring/coloring agent
Taxol	*Taxus brevifolia*	Pharmaceutical	Ovarian and breast cancer

Environmental Biotechnology

As the human population grows, its demand for food from crops increases, making soil conservation crucial. Our environment is constantly threatened every day by the activities of man and industrialization. Deforestation, over-development, and pollution from man-made chemicals are just a few of the consequences of human activity and carelessness. The indiscriminate use of fertilizers and other agricultural chemicals, industrial and domestic waste-disposal practices have led to the increasing concern of soil pollution. Soil pollution is simply because of persistent or buildup of toxic compounds, chemicals, salts, radioactive, materials, or disease-causing agents, which have adverse effects on plant growth and animal health.

Environmental protection is a key component of sustainable development. Despite escalating efforts to prevent waste accumulation and to promote recycling, the amount of environmental damage caused by over-consumption, the quantities of waste generated, and the degree of unsustainable land use appear likely to continue growing. Biotechnology processes are being applied to the protection and restoration of the quality of the environment. The processes can be used to detect, prevent, and remove pollution in the environment. Biotechnology makes it possible to modify various forms of waste (liquid, solid and gaseous wastes) to make new products which are less harmful to the environment by exploiting the diverse metabolic abilities of microorganisms. This is known as biodegradation.

In biodegradation, microorganisms, and sometimes certain plants convert contaminants to harmless products by mineralization, generation of carbon (IV) oxide and water, or by conversion to microbial biomass. Many species of fungi can be used for soil treatment. *Lipomyces **sp*** can degrade herbicide paraquat. *Rhodotorula sp* can convert benzaldehyde to benzyl alcohol. *Candida sp* degrades formaldehyde in the soil. *Aspergillus niger* and *Chaeto mium cupreum* are used to degrade tannins found in tannery effluents. *Deinococcus radiodurans* has been modified to consume and digest toluene and ionic mercury from highly radioactive nuclear waste, Bacillus cereus is used to remediate diesel oil, Spirogyra hyaline to remediate mercury and Aspergillus sp to remediate cobalt. During this process, fertilizers, oxygen, and other conditions are provided to the pollution-eating microorganisms to encourage their growth.

Bioremediation processes involve biodegradation, the restoration of the original natural surroundings and prevention of further pollution. Polluted water bodies, soil and air can be bioremediated. Reforestation through micropropagation, development of stress tolerant plants, use of mycorrhizae, use of microbes for improving soil fertility are some of the measures in this regard.

Water pollution is a serious problem in many countries of the world. Rapid industrialisation and urbanisation have generated large quantities of wastewater that resulted in deterioration of surface water resources and groundwater reserves. Biological, organic, and inorganic pollutants contaminate the water bodies.

Five Key Stages are Recognised in Wastewater Treatment

a) Preliminary treatment – grit, heavy metals and floating debris are removed.
b) Primary treatment – suspended matters are removed.
c) Secondary treatment – bio-oxidise organic materials by activities of aerobic and anaerobic microorganisms.
d) Tertiary treatment – specific pollutants are removed (ammonia and phosphate).
e) Sludge treatment – solids are removed (final stage)

Fig 8: Pictures showing aquatic environments before and after bioremediation.

With the onset of human civilization, the air is one of the first and most polluted components of the atmosphere. Most air pollution comes from one human activity: burning fossil fuel (natural gas), coal, and oil used to power industrial processes and motor vehicles. When fuels are incompletely burned, various chemicals called volatile organic chemicals (VOCs) are released into the air. Other sources of air pollutants include decomposing garbage in landfills and solid waste disposal sites which release methane gas, many household products give off VOCs, increasing industrial activities and have added more contaminants in the air.

The concept of biological air treatment at first seemed impossible. With the development of biological waste gas purification technology using **bioreactor** which includes bio filters, bio trickling filters, bio scrubbers and membrane bioreactors air treatment is now possible. In the bio filters, the air is passed through a bed packed with organic materials that supplies the necessary nutrients for the growth of the microorganisms. This medium is kept damp by maintaining the humidity of the incoming air. Biological off-gas treatment is generally based on the absorption of the VOC in the waste gases into the aqueous phase followed by direct oxidation by a wide range of voracious bacteria such as *Nocardia* sp. and *Xanthomonas* sp.

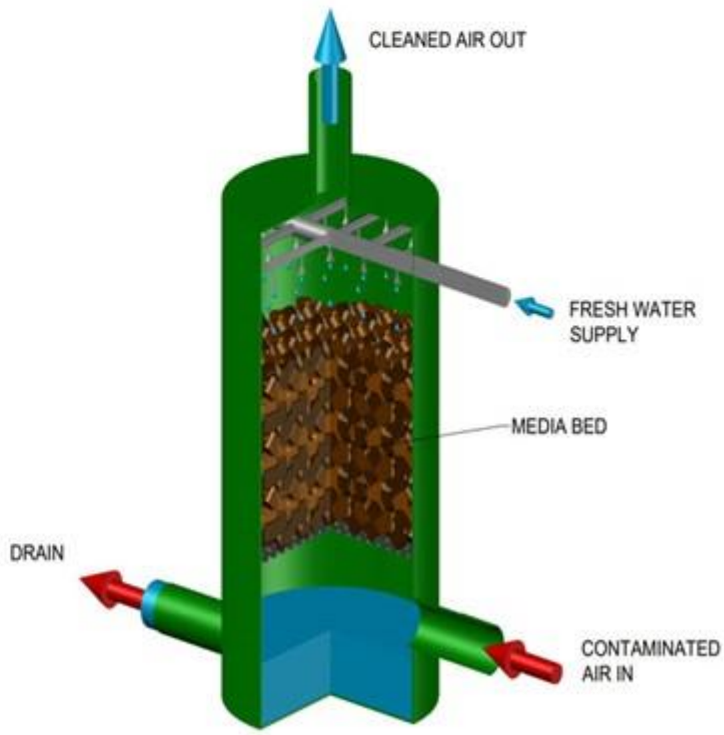

Fig 9: A Biofilter

Environmental Detection and Monitoring

A wide range of biological methods are in use to detect pollution and for the continuous monitoring of pollutants. The techniques of biotechnology have novel methods for diagnosing environmental problems and assessing normal environmental conditions so that human beings can be better- informed of the surroundings.

Biosensors are biophysical devices which can detect and measure the quantity of specific substance in a variety of environments and thus may be used in environmental monitoring. Applications of these methods are cheaper, faster, and portable. Rather than gathering soil samples and sending them to a laboratory for analysis, scientists can measure the level of contamination on site and know the results immediately. Microbes such as *Saccharomyces cerevisiae* (yeast) is used to detect cyanide in river water while *Selenastrum capricornatum* (green alga) is used for heavy metal detection. Immunoassays use labelled antibodies (complex proteins produced in biological response to specific agents) and enzymes to measure the level of pollution. If a pollutant is present, the antibody attaches itself to it making it detectable either through colour change, fluorescence, or radioactivity.

Biomass Energy Production (Biofuels)

Environmental biotechnology also deals with various sources of energy. Biomass (living matter or its residues), is a perpetual or renewable source of energy. The exploration of oil (fossil fuels) in Nigeria has led to the contamination of many soils and water bodies in the Niger Delta and has resulted in a huge economic loss for the locals. Certain microorganisms are employed in the cleaning up of oil spills.

Biotechnology and Sustainable Development

Sustainable development is a type of development that can meet current needs without compromising the ability of future generations to meet their own needs. It allows for the renewability or recycling of used resources to make them available for future generations.

Sustainable development has three pillars:

a) The economy
b) The society – food production, health, medicine, etc.
c) The environment

Biotechnology contributes to the economy by enhancing productivity, increasing efficiency and improving resource management in meeting the needs of the society while minimising the environmental impacts. For instance, biotechnology plays a crucial role in meeting the growing demand for food, feed, fiber, and bioenergy while minimising the environmental impact of agricultural and industrial practices by employing sustainable and resilient agricultural systems. Biotechnology is also providing plant-based proteins as an alternative to animal-based protein. Biomilq in the USA has been able to produce a lab-grown infant milk from the culture of mammary cells, while another agri-tech company produces meat directly from animal cell culture. The production of alternative proteins in place of meat-based proteins will go a long way to reduce global warming, water use and land use all over the world. Environmental biotechnology is one of the fastest growing and applicable scientific field. This aspect of science is contributing immensely to sustainable development. Environmental biotechnology seeks to prevent, arrest and reverse environmental degradation through the appropriate use of biotechnology to protect our environment from hazards of over reliance on industrialisation.

Biosafety concerns

Biotechnology, as promising as its potentials are, is not without its safety concerns. Some of these concerns are:

1. Escape of engineered gene into the environment - accidental crossbreeding of GMO plants and traditional varieties through pollen transfer can contaminate the local varieties with GMO genes resulting in the loss of landraces species of certain crops.
2. Risk of toxicity, due to the nature of the product or the changes in the metabolism and the composition of the organisms resulting from gene transfer. New proteins consumed from transgenic crops can result in development of allergens.
3. Resistance build up in plants resulting from gene flow through cross-pollination for the traits involving resistance can result in the development of tolerant or resistant weeds that are difficult to eradicate.

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