COURSE
GUIDE

BIO101
GENERAL BIOLOGY I

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INTRODUCTION

GENERAL BIOLOGY I is a one semester, 16 Units course. It will be suitable to all students to take towards the core module of B.Sc. (Hons) Biological Sciences. It will also be suitable as an elective course for any student in Faculty of Sciences who does not want to complete an NOU qualification but want to learn about Biology. The course involves the study of Cell structure and organization, functions of cellular organelles, characteristics and classification of living things, chromosomes, genes their relationships and importance, general reproduction, interrelationships of organisms (competitions, parasitism, predation, symbiosis, commensalisms, mutualism, saprophytism); heredity and evolution (introduction to Darwinism and Lamarkism, Mendelian laws, explanation of key genetic terms), elements of ecology and types of habitat.

Course Competencies

This course aims to enable you to know/understand the basic concepts of ecology, life support and ecosystem. It will guide your understanding of various natural phenomena in the planet earth.

Course Objectives

The Comprehensive Objectives of the Course as a whole are to;

1. Explain cell structure and organizations,
2. Summarize functions of cellular organelles
3. Characterize living organisms and state their general reproduction
4. Describe the interrelationship that exists between organisms
5. Discuss the concept of heredity and evolution
6. Describe the basic elements of ecology and enumerate habitat types and their characteristics.

Working Through this Course

To successfully complete this course, you are required to read each study unit, read the textbooks and other materials provided.
Reading the reference materials can also be of great assistance. Each unit has self –assessment exercise which you are advised to do.
There will be a final examination at the end of the course. The course should take you about 8 weeks to complete.

This course guide provides you with all the components of the course, how to go about studying and how you should allocate your time to each unit so as to finish on time and successfully

Study Units

The study units in this course are given below:

BIO 101 GENERAL BIOLOGY I (2 UNITS)

MODULE 1 INTRODUCTION TO BIOLOGY

Unit 1	Properties of Life
Unit 2	The Diversity of life and its organization
Unit 3	Introduction to Biological Inquiry
Unit 4	Scientific Inquiry method
Unit 5	Microscopy and the Cell Theory

MODULE 2 STRUCTURE AND FUNCTIONS OF THE CELL

Unit 1	Cell and Cell Components
Unit 2	Cells Communication
Unit 3	Tissues, Organs and Organ Systems
Unit 4	Characteristics and Classification of Living Things
Unit 5	The Study of Genes and Chromosomes
Unit 6	Reproduction Process and Life cycles

MODULE 3 INTERRELATIONSHIP BETWEEN ORGANISMS

Unit 1	Interrelationship between organisms
Unit 2	Heredity and Variation
Unit 3	Introduction to Evolution
Unit 4	Natural selection
Unit 5	Elements of Ecology

References and Further Readings

You would be required to read the recommended references and textbooks as provided in each unit of the course.

Presentation Schedule

There is a time-table prepared for the early and timely completion and submissions of your TMAs as well as attending the tutorial classes. You are required to submit all your assignments by the stipulated date and time. Avoid falling behind the schedule time.

Assessment

There are three aspects to the assessment of this course. The first one is the in-text questions and the second is self-assessment exercises, while the third is the written examination or the examination to be taken at the end of the course. Review the exercises or activities in the unit by applying the information and knowledge you acquired during the course. The work submitted to your tutor for assessment will account for 30% of your total work. At the end of this course, you will have to sit for a final or end of course examination of about a two-hour duration and this will account for 70% of your total course mark.

How to get the Most from the Course

In this course, you have the course units and a course guide. The course guide will tell you briefly what the course is all about. It is a general overview of the course materials you will be using and how to use those materials. It also helps you to allocate the appropriate time to each unit so that you can successfully complete the course within the stipulated time limit.

The course guide also helps you to know how to go about your in-text questions and Self-assessment questions which will form part of your overall assessment at the end of the course. Also, there will be tutorial classes that are related to this course, where you can interact with your facilitators and other students. Please I encourage you to attend these tutorial classes.

This course exposes you to Introductory Ecology, a sub-discipline and very interesting field of Biological Sciences.

Online Facilitation

Eight weeks are provided for tutorials for this course. You will be notified of the dates, times and location for these tutorial classes.
As soon as you are allocated a tutorial group, the name and phone number of your facilitator will be given to you.

The duties of your facilitator is to monitor your progress and provide any necessary assistance you need.
Do not delay to contact your facilitator by telephone or e-mail for necessary assistance if

- You do not understand any part of the study in the course material.
- You have difficulty with the self-assessment activities.
- You have a problem or question with an assignment or with the grading of the assignment.

It is important and necessary you attend the tutorial classes because this is the only chance to have face to face contact with your facilitator and to ask questions which will be answered instantly. It is also a period where you can point out any problem encountered in the course of your study.

Course Information
Course Code: BIO 101
Course Title: **GENERAL BIOLOGY I**
Credit Unit: 2
Course Status: COMPULSORY
Course Blub: This course is designed to enable the students to understand the basic concepts of ecology, life support and ecosystem. It will also guide their understanding of various natural phenomena in the planet earth.

Semester: 2 SEMESTERS
Course Duration: 13 WEEKS
Required Hours for Study: 65 hours

Ice Breaker
Prof. Mohammed Bello Abdullahi is a Professor of Biology (Biodiversity and Environmental Management) in the Department of Biological Sciences, Federal University, Kashere-Gombe. He has been briefly in the Department of Biological Sciences, National Open University of Nigeria from 2017-2021 participating in all academic activities in the Department; examining, moderating and facilitating courses such as; BIO101;

BIO202; BIO204; BIO304 and BIO412, and seminars and practicals.
Prof. Abdullahi's research interest covers phytosociology, climate change, ecological economics, ethnobotany, plant physiology, biodiversity and environmental management, and environmental toxicology.

MODULE 1 INTRODUCTION TO BIOLOGY

Module Structure

In this module we will discuss about the properties, diversity and organization of life and the scientific method of inquiry:

Unit 1 Properties of Life
Unit 2 The Diversity of life and its organization
Unit 3 Introduction to Biological Inquiry
Unit 4 Scientific Inquiry method
Unit 5 Microscopy and the Cell Theory
Glossary
End of the module Questions

MODULE 1 INTRODUCTION TO BIOLOGY

Unit 1 Properties of Life

Unit Structure

1.1 Introduction
1.2 Intended Learning Outcomes (ILOs)
1.3 The Study of Biology
1.4 The origin and nature of life
1.5 Properties of Life
1.6 Summary
1.7 References/Further Readings/Web Sources
1.8 Possible Answers to Self-Assessment Exercises

1.1 Introduction

Biology is the science of life. All living organisms share several key properties such as order, sensitivity or response to stimuli, reproduction, adaptation, growth and development, regulation, homeostasis, and energy processing. Living things are highly organized following a hierarchy that includes atoms, molecules, organelles, cells, tissues, organs, and organ systems. Organisms, in turn, are grouped as populations, communities, ecosystems, and the biosphere.

1.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you will be able to:

- Define Biology
- Trace the origin of life
- Identify and describe the properties of life

1.3 The Study of Biology

Earth provides few hints about the variety of life forms that inhabit it when viewed from space. Microorganisms are assumed to have been the first life forms on Earth, existing for billions of years before the emergence of plants and animals. Our familiar mammals, birds, and flowers are all quite recent, having evolved 130 to 200 million years ago. Only in the last 300,000 years have humans begun to resemble the creatures we are today, despite the fact that humans have only been on this planet for the past 2.5 million years. The science that examines life is called Biology. What is life, exactly? Although it may seem like a frivolous question with a simple solution, it is difficult to define life. For instance, the study of viruses, which share some traits with living things but not all of them, is one area of Biology called virology. Viruses do not fit the criteria that scientists use to define life, despite the fact that they may assault living things, spread diseases, and even reproduce. In the past, the study of living things was limited to fields of pure science, such as botany and zoology, which together make up Biology. However, as time went on, other branches emerged. New technologies emerged in both applied and pure domains, giving rise to a highly expansive concept of science known as biological sciences. The field of biological sciences spans a wide range of topics, from the intricate interactions of chemical elements within living cells to the expansive ideas of ecosystems and planetary environmental changes. Additionally, it is interested in the physical traits and actions of both modern and extinct species. How did they come into being, and what relationships do they have with one another and their surroundings? The biological sciences deal with a close examination of the inner workings of the human brain, the make-up of our genes, and even how our reproductive system functions. Four problems have plagued biology from its earliest days: What characteristics unify things to be considered "alive"? How do the different living things work? How do we organise the various types of organisms so that we can better understand them in the face of the astounding diversity of life? And finally, how did this diversity develop and how is it maintaining itself is what biologists eventually aim to understand. Biologists are constantly looking for solutions to these and other issues as new creatures are found every day. Biology is the study of living things as a result. Because of this, biology is sometimes referred to as "life science." The term "systematic study of living beings or study of nature" refers to the biological sciences. The main focus of teaching life science is to enlighten students on the most recent advancements being made worldwide in the biological sciences. What are the four problems that plagued biology from its earliest days?

Self-Assessment Exercises 1

1. What are the first forms of life that appeared on planet earth?
2. How many years ago did humans starts to inhibit the earth?

1.4 The Origin and Nature of Life

The origin or emergence of life is one of the biggest and most significant emergent phenomena. Science is still divided on the enigma of life's beginning. It is difficult to give a definitive response to the question "what is life?" since we truly want to know why it exists. To put it another way, "we are really asking, in physical terms, why a given material system is an organism and not anything else." In order to respond to this why question, we must comprehend the potential origins of life. There are numerous hypotheses on the beginning of life. These various theories regarding the origin of life are highlighted in the following few sections. The following series of occurrences have occurred during the evolution of life on Earth. Single-celled organisms were the most basic species to first exhibit signs of life. These gave rise to more advanced, multicellular creatures. More cells exhibited cellular specialisation, meaning that some cells within the multicellular organism carried out certain activities, which meant that becoming more complex meant more than just an increase in cell quantity. The evolution of organisms through millions or perhaps billions of years gave rise to the living entities we now refer to as plants and animals. Since most geologists, paleontologists, biologists, and even theologians agree on this basic timeline of events, one would infer that Moses, Aristotle, and Darwin were all sharp observers and naturalists who were capable of logically determining the most likely creation story. Most Scientists agree that our solar system formed around 4.5 billion years ago, and that time has passed since then. People who hold the six-day creationism theory are frequently referred to as creationists. Their approach to research is predicated on the idea that the Bible should be taken as a perfectly accurate account of everything it discusses. On the other side, Scientists apply what they refer to as the scientific method, which enables them to test theories and hypotheses and to create concepts and ideas. The origin of life on earth has been the subject of numerous explanations over the years. As a result, these theories each propose a different explanation for how life might have originated. Here are a few of them:

1. Idea of Special Creation: According to this theory, God, the All-Powerful, created all the many forms of life that exist today on planet Earth. Hypothesis of Spontaneous Generation: According to this theory, any type of non-living material could unexpectedly

and spontaneously give rise to a living organism. Aristotle, a Greek philosopher, was one of the ardent supporters of spontaneous creation (384-322 BC).

2. The notion of catastrophe is merely a special case of the theory of special creation. It claims that God has created life on earth in several ways, each of which was preceded by a disaster brought on by a geological disturbance of some kind. This hypothesis holds that since every catastrophe wiped out all existing life, every new life form that was created was distinct from the preceding ones.
3. Cosmozoic Theory (Theory of Panspermia): In accordance with this theory, some organisms' highly resistant spores travelled to Earth from other heavenly bodies like meteorites. This idea was proposed by Richter in 1865 and supported by Arrhenius (1908) and other contemporary Scientists. The theory did not gain any support. This theory lacks evidence, hence it was discarded.
4. Theory of Chemical Evolution: This theory is also known as the physical-chemical hypothesis or the materialistic theory.

According to this view, the chemical evolution that led to the origin of life on Earth probably took place over the course of 3.8 billion years. Two Scientists separately proposed this theory: A.I. Oparin, a Russian Scientist, in 1923 and J.B.S. Haldane, an English Scientist, in 1928. How do we best refer to the theory of physical-chemical hypothesis or the materialistic theory in Biology?

Self-Assessment Exercises 2

1. What are the four prominent theories on the origin of life?
2. What is the thrust of the t*heory of Chemical Evolution?*

1.5 Properties of Life

All groups of living organisms share several key characteristics or functions: order, sensitivity or response to stimuli, reproduction, adaptation, growth and development, regulation/homeostasis, and energy processing. When viewed together, these eight characteristics serve to define life.

Order

Cells make up organisms, which are highly organised structures. It is amazing how intricate even extremely basic, single-celled organisms are. Molecules are made up of atoms inside each cell. Organelles or cell components are created from these. Multicellular creatures, which can have millions of individual cells, have an advantage over single-celled organisms in that they can specialise their cells to carry out particular tasks and even sacrifice them in some circumstances for the benefit of the organism as a whole. How these specialised cells in creatures like toads combine to generate organs like the heart, lung, or skin.

Sensitivity or Response to Stimuli

Organisms react to a variety of stimuli. For instance, plants might sway in the direction of a light source or react to touch. Even very little bacteria can move in response to chemicals or light (a process known as chemotaxis) (phototaxis). Moving away from a stimulus is regarded as a negative response, but moving toward it is regarded as a good response. The plant returns to normal after a short while.

Reproduction

The genetic material, or DNA, of single-celled organisms is first duplicated, and then it is divided equally when the cell gets ready to divide into two new cells. Numerous species with more than one cell, or multicellular organisms, create specialised reproductive cells that give rise to new individuals. DNA containing genes is transferred to an organism's progeny during reproduction. Because of these genes, the progeny will be of the same species as the parents and will share traits like fur colour and blood type with them.

Adaptation

Every living thing displays a "fit" to its surroundings. This adaptability, as described by Biologists, is the result of evolution by natural selection, which affects every lineage of reproducing creatures. Examples of adaptations range from heat-resistant Archaea that can survive in steaming hot springs to a nectar-eating moth whose tongue length matches that of the flower it feeds on. The ability to survive and reproduce is improved by adaptations in the individual who is displaying them. Adaptations change with time. Natural selection drives the traits of individuals in a population to follow environmental changes.

Growth and Development

Genes encode specific instructions on how organisms should grow and develop. These genes give instructions for cellular growth and development, ensuring that the offspring of a species will develop into adults who share many traits with their parents.

Regulation/Homeostasis

Living organisms are complex and need various regulatory mechanisms to regulate internal processes like nutrition, transport, stimulus response, and stress management.

Homeostasis, which is defined as a "steady state," is a generally stable internal environment needed to support life. For instance, organ systems like the digestive or circulatory systems convey oxygen throughout the body, remove waste, give nutrients to every cell, and cool the body, among other specific tasks.

Cells need the right circumstances to function effectively, including the right temperature, pH, and chemical concentrations. These circumstances could, however, change at any time. By turning on regulatory systems, organisms are able to nearly constantly maintain homeostatic internal conditions within a small range, despite changes in their environment. For instance, many species use a mechanism called thermoregulation to control their body temperatures. Cold-adapted organisms, like the polar bear, have physical characteristics that enable them to survive extreme cold and retain body heat. In hot regions, species have mechanisms to assist them release extra body heat, such as perspiration in humans or panting in canines. By producing heat and preventing heat loss through their thick fur and a layer of dense fat under their skin, polar bears and other mammals that live in ice-covered areas keep their body temperatures stable.

Energy Processing

All living things require a source of energy for their metabolic processes. Some species use chemical energy from molecules they consume, whereas others use chemical energy that is captured from the Sun and transformed into chemical energy in food.

Evolution

Mutations, or chance changes in hereditary material over time, are the cause of the diversity of life on Earth. These mutations give organisms the chance to adapt to a shifting environment. According to the laws of natural selection, an organism with traits adapted to its surroundings will reproduce more successfully. Why do living things require energy?

Self-Assessment Exercises 3

1. How does the process of reproduction in single celled organisms begins?
2. How does organisms respond to environmental changes?

1.6 Summary

You have learned about the concept of Biology as the study of living things. You have studied about the characteristics of living things such as order, sensitivity or response to stimuli, reproduction, adaptation, growth and development, regulation, homeostasis, and energy processing and the organization of life itself into hierarchy that includes atoms, molecules, organelles, cells, tissues, organs, and organ systems.

Organisms, in turn, are grouped as populations, communities, ecosystems, and the biosphere.

1.7 References/Further Readings/Web Sources

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https://www.youtube.com/watch?v=juxLuo-sH6M

https://www.youtube.com/watch?v=ltRApt0IpCE

1.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. The first forms of life that appeared on Earth are thought to have been microorganisms
2. Humans have inhabited this planet for only the last 2.5 million years

Answers to SAE 2

1. Several theories attempts to offer explanation on the possible mechanism of origin of life and prominent of these are:

1. Theory of Special Creation
2. Theory of Catastrophism
3. Cosmozoic Theory
4. Theory of Chemical Evolution

2. According this theory, Origin of life on earth is the result of a slow and gradual process of chemical evolution that probably occurred about 3.8 billion years ago.

Answers to SAE 3

1. Single-celled organisms reproduce by first duplicating their DNA, which is the genetic material, and then dividing it equally as the cell prepares to divide to form two new cells

2. As an environment change, natural selection causes the characteristics of the individuals in a population to track those changes.

Unit 2 The Diversity of life and its organization

Unit Structure

2.1 Introduction
2.2 Intended Learning Outcomes (ILOs)
2.3 The Diversity of Life
2.4 Levels of Organization of Living Things
2.5 Evolutionary Relationships of Life Forms
2.6 Summary
2.7 References/Further Readings/Web Sources
2.8 Possible Answers to Self-Assessment Exercises

2.1 Introduction

You will learn about the diversity of life on planet earth today. You will study about evolutionary relationships of life forms and the levels of organization of living things

2.2 Intended Learning Outcomes (ILOs)

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

- Explain the diversity of life on planet earth.
- Describe the levels of organization of living things and
- Explain the evolutionary relationships of life forms

2.3 The Diversity of Life

Biology is a science with a relatively broad field of study because there is a wide variety of life on Earth. Evolution, the process of progressive change in which new species develop from more established ones is the cause of this diversity. The development of living beings in all spheres of existence, from the microscopic to ecosystems, is studied by evolutionary Biologists. The idea of classifying all known species of creatures into a hierarchical taxonomy was first put forth in the 18th century by a Scientist by name Carl Linnaeus. In this concept, a genus is a collection of the species that are most similar to one another. Additionally, within a family, comparable genera (plural of genus) are grouped together. The level at which all creatures are gathered together

into groups is reached at the end of this grouping. From lowest to highest, the eight levels of the present taxonomic hierarchy are: species, genus, family, order, class, phylum, kingdom, and domain. As a result, species are grouped inside genera, families and orders are grouped within classes, and so on.
The system's highest level, domain, has only recently been added since the 1990s. There are currently three recognised domains of life: Eukarya, Archaea, and Bacteria. Eukaryotic creatures are those that have cells with nuclei. It comprises various protist kingdoms as well as the kingdoms of fungi, plants, and animals. Numerous extremophiles, single-celled organisms without nuclei that can survive in extreme conditions like hot springs, are members of the Archaea. Another distinct category of single-celled organisms without nuclei is the bacteria. Bacteria and Archaea are both prokaryotes, a colloquial term for cells devoid of nuclei. The suggestion to categorise life into three domains was inspired by the 1990s realisation that some "bacteria," now known as the Archaea, were different genetically and biochemically from other bacterial cells as they were from eukaryotes. This abrupt shift in our understanding of the tree of life shows that classifications are subject to change when new data becomes available.

Linnaeus was the first to name creatures using two distinct names, commonly known as the binomial naming system, in addition to the hierarchical taxonomic system. Because there were regional variations in these popular names prior to Linnaeus, using them to refer to species caused confusion. The capitalised genus name and the species name make up binomial names (all lower-case). When printed, both names are put in italics. Every species is given a distinct binomial that is known around the world, allowing any Scientist to identify the species being discussed. As an illustration, the North American blue jay has its own scientific name, *Cyanocitta cristata*. *Homo sapiens* is our own species. Who was the first to come up with the idea of classifying all known species of creatures into a hierarchical taxonomy in the 18th century?

Self-Assessment Exercises 2

1. What is the source of biological diversity?
2. Who was the first scientist to name organisms using two unique names, now called the binomial naming system.

2.4 Levels of Organization of Living Things

Living things follow a hierarchy from little to large and are highly structured and organised. The atom is the lowest and most basic unit of matter that yet has elemental characteristics. It consists of an electron-surrounded nucleus. Moles are made of atoms. A molecule is an organic compound made up of at least two atoms joined by a chemical bond. Numerous biologically significant molecules are macromolecules, which are huge molecules created typically by joining monomers, or smaller building blocks. Deoxyribonucleic acid (DNA), which carries the blueprints for an organism's operation, is an illustration of a macromolecule. Organelles are collections of macromolecules seen in some cells that are encased in membranes, and they carry out specific tasks within cells. The smallest essential unit of structure and function in living beings, the cell, makes up all living things. Some organisms only have one cell, whereas others have several cells. There are two types of cells; eukaryotic or prokaryotic cells. Prokaryotes are single-celled organisms that lack nuclei and organelles that are encased in nuclear membranes. In contrast, eukaryotic cells do include nuclei and organelles that are encased in membranes.

The majority of multicellular organisms combine cells to form tissues, which are collections of comparable cells performing the same function. Organs are assemblages of tissues arranged according to a shared purpose. Organs can be found in both plants and animals. An organ system is a more advanced level of organisation made up of organs with similar functions. Vertebrate animals, for instance, have a variety of organ systems, such as the circulatory system, which carries blood to and from the lungs as well as throughout the body. This system is made up of the heart and blood arteries. Organisms are unique forms of life. For instance, every tree in a forest is a living thing. Even though they are commonly referred to as microbes, single-celled prokaryotes and eukaryotes are also regarded as organisms.

A population is the aggregate term for all members of a species that are present in a given location. For instance, a forest can have a lot of white pine trees. The population of white pine trees in this woodland is represented by all of these trees. Various populations may coexist in the same region. For instance, there are communities of flowering plants, insects, and microbiological colonies in the forest of pine trees. A community is made up of all the people who live in a certain location. For instance, the community of a forest is made up of all the populations of trees, flowers, insects, and other living things. An ecology exists in the forest itself. Abiotic, or non-living, elements of the environment, such as nitrogen in the soil or precipitation, coexist with all the living things in a certain area to form an ecosystem. At the highest level of organization, the biosphere is the collection of all ecosystems, and it represents the zones of life on Earth. It includes land, water, and portions of the atmosphere.

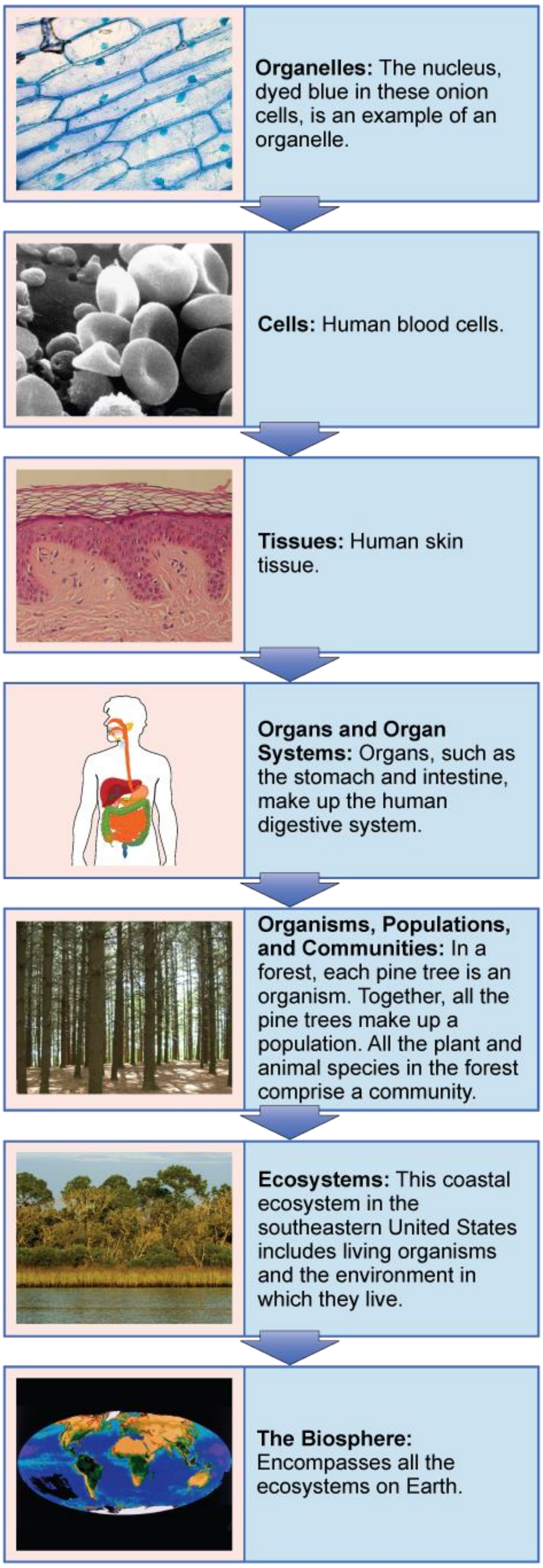

Figure 2.1. Biological Levels of Organization: The biological levels of organization of living things follow a hierarchy, from a single organelle to the entire biosphere, living organisms are part of a highly structured hierarchy, such as the one shown above. What does the biosphere represent at the highest level of organization of living things?

Self-Assessment Exercises 1

Explain the meaning of each of the following
1. molecule
2. macromolecule
3. polymerization

2.5 Evolutionary Relationships of Life Forms

A phylogenetic tree can summarise the relationships between different types of life on Earth in terms of evolution. A phylogenetic tree is a diagram that depicts the relationships between biological species in terms of their shared and unique genetic, physical, or both features. A phylogenetic tree is made up of branches and branch points, or nodes. The internal nodes indicate ancestors and are instances in evolution when two new species are believed to have sprung from a common ancestor, according to scientific data. Each branch's length can be viewed as a relative time estimate. Animals, plants, fungus, protists, and bacteria were the five kingdoms that Biologists previously divided living things into. However, the groundbreaking research of American microbiologist Carl Woese in the early 1970s has demonstrated that the three lineages of life on Earth—Bacteria, Archaea, and Eukarya—have developed over time. To represent the new evolutionary tree, Woese proposed the domain as a new taxonomic level and Archaea as a new domain. Extremophiles are creatures from the Archaea domain that thrive in harsh environments. Woese built his tree using genetic linkages rather than morphological similarities (shape). In phylogenetic analyses, various genes were employed. Woese's tree was created using comparative sequencing of genes that are widely distributed, conserved (meaning that they have undergone only minor changes during evolution), of an appropriate length, and can be found in some form in every organism.

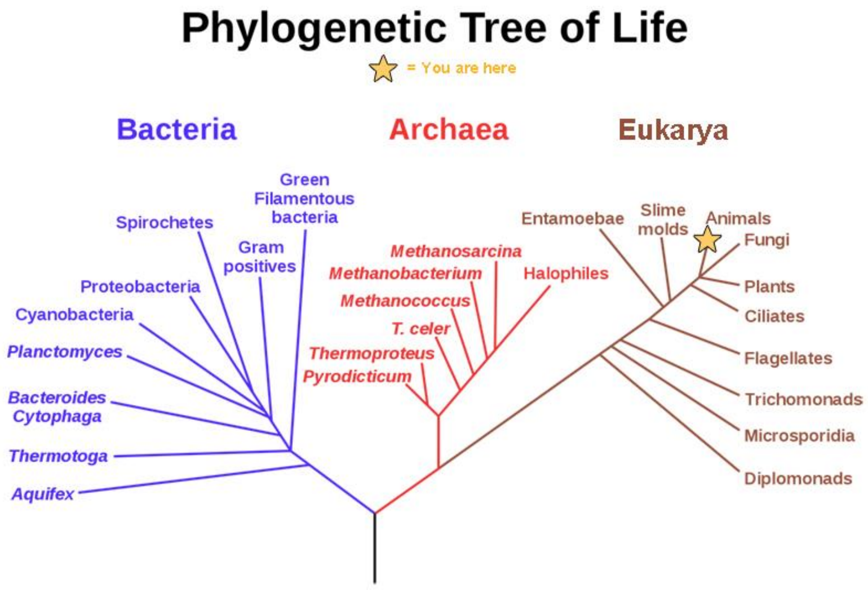

Figure 2.2. The Phylogenetic tree of life

How was Woese's tree built using genetic linkages?

Self-Assessment Exercises 3

1. List the past grouping of living organisms into the five kingdoms
2. Who is the 18th century scientists that first proposed the grouping of organisms into a hierarchical taxonomy?

2.6 Summary

You have studied about evolution as the source of biological diversity on Earth. A diagram called a phylogenetic tree was also used to show evolutionary relationships among organisms. You have also learned about the many branches and sub disciplines of Biology such as molecular biology, microbiology, neurobiology, zoology, and botany, among others.

2.7 References/Further Readings/Web Sources

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2.8 Possible Answers to Self-Assessment Exercises

Answers to SAEs 1

1. The source of the diversity is evolution, the process of gradual change during which new species arise from older species.
2. Carl Linnaeus

Answers to SAEs 2

The meaning of the following terms:

1. **molecule**: The smallest particle of a specific compound that retains the chemical properties of that compound; two or more atoms held together by chemical bonds.
2. **macromolecule**: a very large molecule, especially used in reference to large biological polymers (e.g. nucleic acids and proteins)
3. **polymerization**: The chemical process, normally with the aid of a catalyst, to form a polymer by bonding together multiple identical units (monomers).

Answers to SAEs 3

1. In the past, biologists grouped living organisms into five kingdoms: animals, plants, fungi, protists, and bacteria.
2. In the 18th century, a scientist named Carl Linnaeus first proposed organizing the known species of organisms into a hierarchical taxonomy.

Unit 3 Introduction to Biological Inquiry

Unit Structure

3.1 Introduction
3.2 Intended Learning Outcomes (ILOs)
3.3 Scope of Biology
3.4 The Study of Life
3.5 The Nature of Science
3.6 Summary
3.7 References/Further Readings/Web Sources
3.8 Possible Answers to Self-Assessment Exercises

3.1 Introduction

You will learn that the scope of biology is broad and therefore contains many branches and sub disciplines. You will study about the shared characteristics of the natural sciences and understand the process of scientific inquiry. You will also be able understand the application of forensic science in law and describe the basic scientific ethics in research. Science is *knowing*. Scientists search for knowledge through inquiry, which is a way of questioning and explaining phenomena that occur in nature. Let's begin by exploring how biologists and researchers use the scientific method in the scientific inquiry of life

3.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you will be able to:

- Appreciate the various branches of biology
- Identify the shared characteristics of the natural sciences
- Describe the application of forensic Scientist to answer law matters
- Understand the basic Scientific ethics in research

3.3 The Scope of Biology

Since biology has a wide range of applications, there are numerous branches and subfields within it. It is possible for biologists to specialise in one of such subdisciplines. For instance, the study of biological processes at the molecular level, including interactions between molecules like DNA, RNA, and proteins as well as how they are controlled, is known as molecular biology. The study of the composition and operation of microbes is known as microbiology.

It is a somewhat diverse field in and of itself, with additional specialists including geneticists, ecologists, and microbial physiologists depending on the area of research. Neurobiology is a different area of biological study that focuses on the biology of the nervous system. It is acknowledged as a branch of biology as well as an interdisciplinary subject of study. This sub-discipline, which is interdisciplinary in nature, uses molecular, cellular, developmental, medicinal, and computational approaches to study many aspects of the nervous system.

Another area of biology called palaeontology examines the evolution of life using fossils. The study of animals and plants is known as zoology and botany, respectively. Biotechnologists, ecologists, and physiologists are just a few of the areas in which biologists can specialise. Biotechnologists employ their understanding of biology to develop practical products. Ecologists investigate how creatures interact with their surroundings. Physiologists research how cells, tissues, and organs function. These are just a few of the numerous careers that biologists might choose from. Biology-related discoveries can have a very significant and immediate impact on us, on everything from our bodies to the environment we live in. We rely on these findings for our food security, our health, and the advantages our ecosystem offers. Because of this, having a basic understanding of biology might help us make better judgments in our daily lives. Biology has been altered by the technological advancements of the 20th century, notably those related to the description and manipulation of DNA. This change will make it possible for scientists to continue learning more about the evolution of life, the human body, our ancestry, and how we can continue to exist as a species on this planet despite the pressures brought on by our expanding population. The fact that biologists are still solving complex questions concerning life suggests that we are only at the beginning of our understanding of the planet's history, the origins of life, and our place within it. For these and other reasons, the biology information you acquire from this textbook and other printed and electronic materials should be useful in whichever line of work you choose.
Which area of biology examines the evolution of life using fossils?

Self-Assessment Exercises 1

1. What is the scope of molecular biology?
2. What is the interest of Forensic Science?

3.4 Forensic Science and Scientific Ethics

Forensic science is the application of science to answer questions related to the law. Forensic scientists can be biologists, chemists, or biochemists. The work of forensic scientists involves looking at evidence linked to crimes and providing scientific testimony for use in court. In recent years, interest in forensic science has grown, probably as a result of well-liked television programmes that showcase forensic scientists in action. Additionally, the types of work that forensic scientists can perform have been updated thanks to the advancement of molecular techniques and the creation of DNA databases. The majority of their work is focused on crimes against humans like murder, rape, and assault. Their work entails processing DNA from a variety of locations and materials in addition to evaluating samples including hair, blood, and other bodily fluids. Other biological evidence, such bug fragments or pollen grains, that has been left at crime sites is also examined by forensic specialists. Most likely, students who want to major in forensic science will need to complete chemistry, biology, and some challenging math courses.

Scientists have a responsibility to protect people, animals, and the environment from unwarranted harm. Additionally, they must make sure that their research and communications are impartial and that all relevant factors—including financial, legal, safety, and replicability—are correctly balanced. In the significant and ever-evolving discipline of bioethics, scholars cooperate with other organisations and individuals. They try to establish standards for current practise and are constantly thinking about new innovations and upcoming technology to come up with solutions for the coming years and decades. Unfortunately, a number of patently unethical activities, where biologists failed to treat research subjects with dignity and, in some cases, actually harmed them, preceded the development of the area of bioethics. 399 African American men were diagnosed with syphilis in the Tuskegee Syphilis Study of 1932, but they were never told they had the infection, so they continued to live with it and spread it to others. Because the aim of the study was to comprehend the effects of untreated syphilis on Black males, doctors even withheld proven medicines. While the choices made in the Tuskegee research cannot be justified, certain choices are really challenging. Bioethicists, for instance, may investigate the ethical implications of gene editing technologies, such as the potential for creating species that could supplant others in the ecosystem and the potential for "designing" human beings. Ethicists will probably attempt to strike a balance between the positive and negative effects of their work, such as bettering medicines or preventing specific diseases. Because bioethics is seldom straightforward, scientists frequently must weigh benefits and risks. You will learn about medical advancements that, at their root, have what many people view as an ethical failing in this literature and course. Henrietta Lacks, an African American woman in her 30s, received a cervical cancer diagnosis at Johns Hopkins Hospital in 1951.

Her illness-specific traits allowed her cells to divide continuously, effectively rendering them "immortal." Researchers obtained samples of her cells without her knowledge or consent and used them to make the immortal HeLa cell line. Major medical advancements made possible by these cells include the development of the polio vaccine, as well as studies into cancer, AIDS, cell ageing, and, most recently, COVID-19. Lacks' contributions to those discoveries have largely gone unrecognised, and neither she nor her family have reaped the millions of dollars in pharmaceutical revenues made possible in part by the use of her cells. Even if it could save the lives of other patients, taking tissue or organs without the patient's permission nowadays is not just regarded as unethical but also unlawful. Examining related concerns before, during, and after research or practise is conducted, adhering to accepted professional standards, and taking into account the safety and dignity of all organisms participating or impacted by the work are all part of the function of ethics in scientific research. What is forensic science?

Self-Assessment Exercises 1

1. What is the scope of molecular biology?
2. What is the interest of Forensic Science?

3.5 The Nature of Science

However, what exactly is science? Biology is a science. What connections exist between the study of biology and other scientific fields? The definition of science is "knowledge of the natural world" (from the Latin scientia, "knowledge"). A particularly precise method of learning about or knowing the world is science. The previous 500 years have shown that science is a highly potent way of understanding about the world, and that it has played a significant role in the technological revolutions that have occurred during this time. The tools of science, however, cannot be used to study all fields of knowledge and human experience. These include things like providing answers to only moral questions, questions about aesthetics, or questions that can be broadly characterised as spiritual concerns. These topics are not within the purview of material phenomena, the phenomena of matter and energy, and hence cannot be witnessed or quantified.

The scientific method is a structured approach to research that includes meticulous observation and experimentation. The testing of hypotheses is one of the most crucial parts of this strategy. A testable hypothesis is a theory put out to explain an occurrence. Typically, tentative explanations, or hypotheses, are developed within the framework of a scientific theory. A widely accepted, rigorously investigated, and verified explanation for a collection of observations or a phenomenon is what is known as a scientific theory. The basis of all scientific knowledge is scientific theory. Additionally, there are scientific laws that describe how parts of nature will act under specific circumstances in many scientific disciplines (less so in biology). These laws are succinct descriptions of areas of the world that can be expressed using formulas or mathematics. There is no progression from hypotheses to theories to laws, as though these concepts signified a rise in worldly certainty.

The value of various branches of science has been a topic of discussion within the scientific community for the last few decades. Is it worthwhile to pursue science for the sake of merely learning something, or does scientific information only have value if we can use it to solve a particular issue or improve our quality of life? The distinctions between basic science and applied science are the main subject of this query.

- Basic science or Regardless of how such knowledge might be used in the near future, "pure" science aims to further knowledge. It is not concentrated on creating something with immediate commercial or public benefit. Although knowing for knowledge's sake is the immediate aim of basic research, this does not preclude the possibility of an application in the long run.
- In contrast, The goal of applied science, sometimes known as "technology," is to apply scientific knowledge to solve practical issues. For instance, it could be possible to identify a treatment for a specific disease, increase crop yields, or save animals in danger from a natural disaster. In applied science, the researcher typically has the problem defined for them.

Some people could view basic science as "useless" while viewing applied science as "helpful." These people might ask, "What for?" to a scientist who promotes knowledge acquisition. However, a close examination of the history of science indicates that many outstanding applications of enormous value have been made possible by fundamental knowledge. Since many scientists believe that a fundamental understanding of science is required before an application can be produced, applied science is dependent on the findings of basic science. Others believe it is time to move beyond fundamental research and focus on developing answers for real-world issues. Both strategies are appropriate. It is true that there are problems that demand immediate attention; however, few solutions would be found without the help of the knowledge generated through basic science. The understanding of the molecular mechanisms driving DNA replication that resulted from the discovery of DNA structure is one instance of how basic and applied science can cooperate to solve practical challenges. Our cells contain DNA strands that are particular to each individual and which carry the instructions for life. Before a cell divides to create new cells, DNA replication creates new copies of the DNA. In order to identify genetic illnesses, locate people who were present at a crime scene, and establish paternity, scientists had to first understand the principles of DNA replication. It seems doubtful that applied science would exist without foundational science.

The Human Genome Project, a study in which each human chromosome was examined and mapped to ascertain the specific sequence of DNA subunits and the precise position of each gene, serves as another illustration of the relationship between basic and applied research. (The genome is a person's entire collection of genes; the gene is the fundamental unit of heredity.) As part of this project, research on other organisms has also been done in order to better understand human chromosomes. Basic research using non-human organisms and later the human genome was crucial to the Human Genome Project. Utilizing the data for applied research to find treatments for genetically based diseases eventually became a significant end goal. It is crucial to remember that while research projects in both basic and applied science are typically meticulously planned, some discoveries are made by serendipity, that is, by way of a fortunate accident or a happy surprise. When biologist Alexander Fleming unintentionally left a petri dish of Staphylococcus bacteria uncovered, penicillin was accidently discovered. The microorganisms were killed by an unwelcome mould growth. Penicillium was found to be the mould, and a new antibiotic was found. Even in the highly structured field of science, serendipity can produce surprising discoveries when combined with an attentive, inquisitive mind. What is a genome?

Self-Assessment Exercises 3

1. What is the scientific method?
2. Which is the one of the most important aspects of the scientific method?

3.6 Summary

You must have learned about the scope of biology as containing many branches and sub disciplines. You have also studied the shared characteristics of the natural sciences and the process of scientific inquiry. The nature of science as a critical component of scientific literacy that enhances students' understandings of science concepts and enables them to make informed decisions about scientifically-based personal and societal issues have been highlighted in the unit.

3.7 References/Further Readings/Web Sources

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3.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Life of the body (physical), life of the mind and life of the spirit.
2. The methods of science include careful observation, record keeping, logical and mathematical reasoning, experimentation, and submitting conclusions to the scrutiny of others.

Answers to SAE 2

1. Molecular biology studies biological processes at the molecular level, including interactions among molecules such as DNA, RNA, and proteins, as well as the way they are regulated.
2. Forensic science is the application of science to answer questions related to the law. Biologists as well as chemists and biochemists can be forensic scientists. Forensic scientists provide scientific evidence for use in courts, and their job involves examining trace material associated with crimes.

Answers to SAE 3

1. The scientific method is a method of research with defined steps that include experiments and careful observation.
2. One of the most important aspects of this method is the testing of hypotheses

Unit 4 Scientific Inquiry method

Unit Structure

4.1 Introduction
4.2 Intended Learning Outcomes (ILOs)
4.3 Scientific Inquiry
4.4 Hypothesis in Science
4.5 Basic and Applied Science
4.6 Summary
4.7 References/Further Readings/Web Sources
4.8 Possible Answers to Self-Assessment Exercises

4.1 Introduction

You will learn the meaning and method of the scientific inquiry in this unit. You will study the meaning of hypothesis and how to test and apply it in science research. You will also learn about basic and applied research in science.

4.2 Intended Learning Outcomes (ILOs)

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

- Understand the meaning and method of the scientific inquiry.
- Explain the meaning of hypothesis
- Describe how to test and apply hypothesis in science research.
- Explain the meaning of basic and applied research in science.

4.3 Scientific Inquiry

All branches of science share the same ultimate objective, which is "to know." The advancement of science is fueled by curiosity and enquiry. The goal of science is to comprehend the world and how it works. Inductive reasoning and deductive reasoning are the two types of logical thinking that are employed. Inductive reasoning is a type of logical reasoning that draws a generalisation from a set of related observations. In descriptive science, this kind of thinking is typical. A biologist or other life scientist will make observations and note them. These data may be quantitative (containing of statistics) or qualitative (descriptive), and the raw data may be supplemented with illustrations, photographs, films, or other visual media. The scientist can draw conclusions (inductions) based on evidence from several observations. Formulating generalisations via inductive reasoning requires close observation and in-depth data investigation. This is how many brain studies operate. While people are performing a task, several brains are being watched. It is then shown that the area of the brain controlling the reaction to that task is the part that lights up, signifying activity. Science that is hypothesis-based employs a sort of logic known as deductive reasoning or deduction. In contrast to inductive reasoning, deductive reasoning follows a different pattern of thought. Deductive reasoning is a type of logical reasoning where specific outcomes are predicted using a general principle or law. A scientist can infer and forecast specific conclusions from those broad principles, provided that the general principles are true. For instance, it is expected that as a region's climate warms, the distribution of plants and animals will alter. Distributions in the past and the present have been compared, and numerous alterations have been discovered that are compatible with a warming climate. The discovery of the distributional change serves as support for the validity of the climate change conclusion.

The two primary avenues of scientific inquiry, descriptive science and hypothesis-based research, are connected to both types of logical thinking. While hypothesis-based science begins with a specific issue or problem and a potential response or solution that can be investigated, descriptive (or discovery) science attempts to observe, explore, and discover. Because most scientific activities use both methodologies, the line separating these two fields of study is frequently blurred. Observations spark questions, those questions prompt the creation of a hypothesis as a potential response, and finally the hypothesis is put to the test. As a result, descriptive science and science based on hypotheses are constantly conversing. What are the two primary avenues of scientific inquiry?

Self-Assessment Exercises 1

1. What are the two methods of logical reasoning in science?
2. What are the two main pathways of scientific study?

4.4 Hypothesis in Science

By asking questions about the living world and looking for logical answers, biologists investigate it. Other sciences also use this process, which is frequently referred to as the scientific method. Although Sir Francis Bacon (1561–1626), an Englishman, established inductive methods for scientific investigation, the scientific method was employed already in antiquity. The scientific method can be used to solve practically any logical problem; hence it is not just used by biologists. The scientific method often begins with an observation that prompts a query (often a problem to be solved). Let's consider a straightforward issue that begins with an observation and use the scientific process to find a solution. A student walks into class on a Monday morning and immediately notices that the room is too warm. The classroom is excessively warm, which is an observation that also indicates a problem. The youngster then inquires as to why the classroom is so warm. Remember that a hypothesis is an explanation that has been proposed and may be tested. There may be various hypotheses put out to address a problem. One possible explanation, for instance, could be that "No one switched on the air conditioner, thus the classroom is heated." However, there might be other answers to the query, and as a result, different hypotheses might be put out. Another possibility is that the air conditioner isn't working because there is a power outage, which is why the classroom is heated. A prediction can be made after a hypothesis has been chosen. Similar to a hypothesis, a prediction usually follows the structure "If... then..." For instance, if the student turns on the air conditioning, the classroom won't be overly warm any longer, according to the prediction for the first hypothesis. For a theory to be proven correct, it must be testable. A hypothesis that depends on what a bear thinks, for instance, cannot be tested because it is impossible to know what a bear thinks. Additionally, it must be able to be refuted by the outcomes of experiments, or be falsifiable. The statement "Botticelli's Birth of Venus is beautiful" is an example of an unprovable hypothesis. There is no experiment that might disprove this claim. A researcher will carry out one or more experiments meant to rule out one or more of the hypotheses in order to test a hypothesis. This is crucial. Although a theory can be refuted or rejected, it can never be proven. Like mathematics, science does not deal with proofs. We find evidence in favour of an explanation when an experiment fails to refute a hypothesis, but this does not preclude the discovery of a more convincing explanation or the use of a more meticulously planned experiment in the future. There will be one or more controls and one or more variables in every experiment. Any element of the experiment that is subject to modification or variation is referred to as a variable. A control is a variable that stays the same throughout the experiment. The next example asks you to look for the variables and controls. As a straightforward illustration, a test may be done to see whether phosphorus limits the growth of algae in freshwater ponds. Half of a series of man-made ponds that contain water are treated each week by adding phosphate, while the other half are treated by adding a salt that is known not to be consumed by algae. The phosphate (or lack thereof) is the variable in this situation; the experimental or treatment instances are the ponds with added phosphate, while the control ponds are those with inert additives like salt added. Another safeguard against the likelihood

that adding more matter to the pond has an impact is to just add something. If the treated ponds exhibit decreased algal growth, then our hypothesis is supported. If they don't, we'll have to abandon our hypothesis. Be mindful that rejecting one hypothesis merely eliminates the one that is invalid, not whether the other hypotheses can be accepted or not. The scientific method is used to disprove assumptions that don't match up with the results of experiments. Due to the exponential growth of data deposited in various databases in recent years, a new method of testing hypotheses has emerged. A new discipline known as "data research" (also known as "in silico" research) offers new techniques for data analysis and its interpretation using computer algorithms and statistical analyses of data in databases. The demand for experts in both biology and computer science will rise as a result, creating an exciting employment opportunity.
What does "in silico" research step to offer?

Self-Assessment Exercises 2

1. What is the new approach of testing hypotheses?
2. What happens to the hypotheses that are inconsistent with experimental data using the scientific method?

4.5 Basic and Applied Science

The value of various branches of science has been a topic of discussion within the scientific community for the last few decades. Is it worthwhile to pursue science for the sake of merely learning something, or does scientific information only have value if we can use it to solve a particular issue or improve our quality of life? The distinctions between basic science and applied science are the main subject of this query. Regardless of how such knowledge might be used in the near future, basic or "pure" science aims to advance understanding. It is not concentrated on creating something with immediate commercial or public value. Although knowing for knowledge's sake is the immediate aim of basic research, this does not preclude the possibility of an application in the long run.

In contrast, applied science, also known as "technology," tries to apply research to solve real-world issues. For instance, it may be able to increase crop yields, discover a treatment for a specific illness, or save animals in danger from a natural disaster. In applied science, the researcher typically has the problem defined for them. Some people could view basic science as "useless" while viewing applied science as "helpful." These people might ask, "What for?" to a scientist who promotes knowledge acquisition. However, a close examination of the history of science indicates that many amazing applications of fundamental knowledge have been made. Since many scientists believe that a fundamental understanding of science is required before an application can be produced, applied science is dependent on the findings of basic science. Others believe it is time to move beyond fundamental research and focus on developing answers for real-world issues. Both strategies are appropriate. While it is true that some issues require immediate attention, few would be resolved without the aid of the information produced by basic research. The understanding of the molecular mechanisms driving DNA replication that resulted from the discovery of DNA structure is one instance of how basic and applied science can cooperate to solve practical challenges. Our cells contain DNA strands that are particular to each individual and which carry the instructions for life. Before a cell divides to create new cells, DNA replication creates new copies of the DNA. In order to identify genetic illnesses, locate people who were present at a crime scene, and establish paternity, scientists had to first understand the principles of DNA replication. Applied science is unlikely to exist without foundational science. The Human Genome Project, a study in which each human chromosome was examined and mapped to ascertain the specific sequence of DNA subunits and the precise position of each gene, serves as another illustration of the relationship between basic and applied research. (The gene is the basic unit of heredity represented by a specific DNA segment that codes for a functional molecule.) As part of this initiative, research on other organisms has also been done in order to better understand human chromosomes. Basic research with non-human species and later the human genome was crucial to the Human Genome Project. Utilizing the data for applied research to find treatments for genetically based disorders subsequently became a significant end aim. It is crucial to remember that while research projects in both basic and applied science are typically meticulously planned, some discoveries are made by serendipity, that is, by way of a fortunate accident or a happy surprise. When biologist Alexander Fleming unintentionally left a petri dish of Staphylococcus bacteria uncovered, penicillin was accidently discovered. The microorganisms were killed by an unwelcome mould growth. Penicillium was identified as the mould, and a brand-new, very important antibiotic was found. Similar to this, Percy Lavon Julian was a renowned medicinal chemist who was working on a method to mass synthesise chemicals used in the production of significant medications. It wasn't until water inadvertently leaked into a sizable soybean oil storage tank that he discovered his strategy for using soybean oil to produce progesterone, a hormone crucial to the menstrual cycle and pregnancy. He started the process of reproducing and industrialising the procedure after immediately identifying the produced molecule as stigmasterol, a key component in progesterone and comparable medications. This has benefitted millions of individuals. Even in the highly organized world of science, luck—when combined with an observant, curious mind focused on the types of reasoning discussed above—can lead to unexpected breakthroughs. What is the main aim of applied science research?

Self-Assessment Exercises 3

1. What value of different types of science was the scientific community debating for the last few decades?
2. What can lead to unexpected breakthroughs even in the highly organized world of science?

4.6 Summary

You must have learned about the meaning and method of the scientific inquiry in this unit. You have studied about the meaning of hypothesis and how to test and apply it in science research. You must have also learned about basic and applied research in science.

4.7 References/Further Readings/Web Sources

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4.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. The two methods of logical thinking are inductive reasoning and deductive reasoning.
2. The two main pathways of scientific study are descriptive science and hypothesis-based science

Answers to SAE 2

1. In recent years a new approach of testing hypotheses has developed using computer algorithms and statistical analyses of data in databases, known as "data research" which provides new methods of data analyses and their interpretation.
2. Using the scientific method, the hypotheses that are inconsistent with experimental data are rejected.

Answers to SAE 3

1. The scientific community has been debating for the last few decades about whether it is valuable to pursue science for the sake of simply gaining knowledge, or does scientific knowledge only have worth if we can apply it to solving a specific problem or bettering our lives?
2. Luck—when combined with an observant, curious mind focused on the types of reasoning discussed above— can lead to unexpected breakthroughs even in the highly organized world of science

Unit 5 Microscopy and the Cell Theory

Unit Structure

5.1 Introduction
5.2 Intended Learning Outcomes (ILOs)
5.3 The Cell and Cell Theory
5.4 How Cells Are Studied
5.5 Role of Cell Technologist in the Study of the Cell
5.6 Summary
5.7 References/Further Readings/Web Sources
5.8 Possible Answers to Self-Assessment Exercises

5.1 Introduction

You will study the meaning of cell, structure, and functioning in this unit. The various essential characteristics of cells will also be highlighted. You will also learn about the different types of cells. You will study the differences between Prokaryotic and Eukaryotic Cells. You will also learn how cells are being studied with the use of microscopes. Electron microscopes provide higher magnification, higher resolution, and more detail than light microscopes.

5.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you will be able to:

- Justify that cell is the basic structural and functional unit of all organisms
- List the components of the cell and state cell theory
- Differentiate between prokaryotic and eukaryotic cells
- Describe the roles of cells in organisms
- Compare and contrast light microscopy and electron microscopy

5.3 The Cell and Cell Theory

In biology, the cell is the fundamental building block of all living things. It is the smallest structural unit of living matter capable of functioning on its own. A cell is a collection of cytoplasm that is held together on the outside by a cell membrane. Cells are the smallest structural units of living matter and make up all living things. They are typically tiny in size. Numerous organelles, including one or more nuclei, are present in most cells and perform a range of functions. Like a bacterium or yeast, some single cells are entire organisms. Others serve as specialised components of multicellular organisms like plants and animals. As in the case of bacteria and protozoans, a single cell can be an entire organism in and of itself. In multicellular organisms like higher plants and animals, specialised cell groups are arranged into tissues and organs. Prokaryotic cells and eukaryotic cells are two different types of cells.Eukaryotic cells include those found in animals, plants, fungi, and protists, whereas prokaryotic cells include those found in bacteria and archaea. Prokaryotic and eukaryotic cells have different shapes, yet they have a lot of similarities in their molecular make-up and functions. Proteins, polysaccharides, and nucleic acids make up the majority of the molecules in cells. A membrane that surrounds a cell allows it to exchange specific materials with its environment. This membrane is contained within the rigid cell wall of plant cells.

By the late 1830s, zoologist Theodor Schwann and botanist Matthias Schleiden were researching tissues and putting forth the unified cell hypothesis. According to the unified cell theory, each living entity is made up of one or more cells, each cell is the building block of life, and new cells develop from existing cells. Later, this idea benefited greatly from the contributions of Rudolf Virchow.

Schleiden and Schwann advocated spontaneous generation (also known as abiogenesis) as the mechanism for cell origination, but spontaneous generation was later demonstrated to be false. "Omnis cellula e cellula"—"All cells only come from pre-existing cells"—was a famous phrase used by Rudolf Virchow. "However, the portions of the hypothesis that did not concern the genesis of cells withstood scientific investigation and are now generally accepted by the scientific community. The following are the elements of contemporary cell theory that are commonly acknowledged:

1. The basic unit of structure and functionality in living things is the cell.
2. One or more cells make up every living thing.
3. Cellular division creates new cells from existing ones.

The cell theory can be broadened to cover the following as well: 1). All cells have roughly the same chemical makeup; 2). All cells carry genetic material that is passed on to daughter cells during cellular division. and 3). Energy flow (metabolism and biochemistry) takes place inside of cells. The following are the essential characteristics of cells:

- Cells provide structure and support to the body of an organism.
- The cell interior is organised into different individual organelles surrounded by a separate membrane.
- The nucleus (major organelle) holds genetic information necessary for reproduction and cell growth. Every cell has one nucleus and membrane-bound organelles in the cytoplasm.

- Mitochondria, a double membrane-bound organelle is mainly responsible for the energy transactions vital for the survival of the cell.
- Lysosomes digest unwanted materials in the cell.
- Endoplasmic reticulum plays a significant role in the internal organisation of the cell by synthesising selective molecules and processing, directing and sorting them to their appropriate locations.

What does specialized cells in multicellular creatures like higher plants and animals, come to form as the next level of organization of life?

Self-Assessment Exercises 1

1. How is the unified cell theory stated? 2. What are the components of the expanded version of the cell theory?

5.4 How Cells Are Studied

The majority of cells are too tiny to be seen with the human eye, therefore, in order to study cells, scientists must utilise microscopes. Electron microscopes offer greater magnification, resolution, and details compared to optical microscopes. All organisms are made up of one or more cells. In multicellular organisms, a number of cells of the same kind interact with one another and carry out shared functions to form tissues (eg. muscle tissue, connective tissue, and nervous tissue), a number of tissues come together to form an organ (eg. stomach, heart, or brain), and a number of organs make up an organ system (such as the digestive system, circulatory system, or nervous system). Together, various systems compose an organism (such as an elephant, for example). Now let's examine how biologists study cells.

- Light Microscopes

Sizes of cells differ. Individual cells are typically too small to be observed with the human eye, therefore researchers employ microscopes to investigate them. An instrument that magnifies a thing is a microscope. Micrographs are photographs of individual cells that are typically taken under a microscope. A typical human red blood cell measures eight millionths of a metre, or eight micrometres (abbreviated as m), in diameter. In comparison, the head of a pin measures approximately two thousandths of a metre (millimetres, or mm). Thus, 250 red blood cells or so may fit on the head of a pin. A light microscope's optics adjust how the lenses are oriented. When examined using a microscope, a specimen that is upside-down and facing right on the microscope slide will seem upside-down and facing left, and vice versa. Similar to how the slide would appear to move right and left when viewed through a microscope, moving the slide down will make it appear to move up. This happens as a result of the two sets of lenses that microscopes use to enlarge the image. The way light passes through the lenses in this lens system causes an inverted image to be created (binoculars and a dissecting microscope work in a similar manner, but include an additional magnification system that makes the final image appear to be upright). Light microscopes are the most common type of student microscope. The lens mechanism allows the user to see the specimen by allowing visible light to flow through while also deflecting it. Light microscopes are useful for observing live things, but since individual cells are typically transparent, it is difficult to tell which parts of an organism are which without the use of specific stains. However, staining typically results in cell death. Light microscopes, which are frequently used in lab settings in undergraduate colleges, may magnify up to 400 times. Magnification and resolving power are two factors that are significant in microscopy. The degree of an object's enlargement is known as its magnification. The ability of a microscope to differentiate two nearby structures as separate is known as its resolving power; the greater the resolution, the closer those two items can be and the clearer and more detailed the image would be. Magnification is typically increased to 1,000 times when oil immersion lenses are used to investigate smaller cells, such as the majority of prokaryotic cells. Light microscopy can be used to view a specimen because light entering a specimen from below is directed into the observer's eye. For this reason, a sample must be thin or translucent in order for light to travel through it.

The dissecting microscope is a second kind of microscope utilised in labs. These microscopes can give a three-dimensional image of the specimen and have a lesser magnification (20 to 80 times the object size) than light microscopes. Thick objects allow for the simultaneous examination of numerous components in focus. These microscopes are made to provide a clear, enlarged image of both the anatomy of the entire organism and the tissue structure inside it. The majority of contemporary dissecting microscopes are binocular, meaning that they contain two different lens systems, one for each eye, just like light microscopes. As a result of the distance between the lens systems, the subject appears to have depth, which facilitates manual manipulations. Dissecting microscopes also have optics that correct the image so that it appears as if being seen by the naked eye and not as an inverted image. The light illuminating a sample under a dissecting microscope typically comes from above the sample, but may also be directed from below.

- Electron Microscopes

Electron microscopes, as opposed to light microscopes, employ an electron beam as opposed to a light beam. This offers higher resolving power in addition to increased magnification and, thus, more detail. Live cells cannot be examined using an electron microscope since the preparation of a specimen for viewing under one will kill it. Furthermore, because the electron beam moves best in a vacuum, it is not possible to observe live things.

A scanning electron microscope reveals the specifics of a cell's surface properties by reflection when an electron beam travels back and forth across it. The typical coating on cells and other structures is made of a metal like gold. In a transmission electron microscope, the electron beam is transmitted through the cell and provides details of a cell's internal structures. As you might imagine, electron microscopes are significantly more bulky and expensive than are light microscopes. How is the electron beam transmitted in a transmission electron microscope?

Self-Assessment Exercises 2

1. What is a microscope?
2. What is the contrasting feature between the light and an electron microscope?

5.5 Role of Cell Technologist in the Study of the Cell

Cytotechnologists (cyto- = cell) are professionals who study cells through microscopic examinations and other laboratory tests. They are trained to determine which cellular changes are within normal limits or are abnormal. Their focus is not limited to cervical cells; they study cellular specimens that come from all organs. When they notice abnormalities, they consult a pathologist, who is a medical doctor who can make a clinical diagnosis. Cytotechnologists play vital roles in saving people's lives. When abnormalities are discovered early, a patient's treatment can begin on time, thus increasing the chances of survival. Have you ever heard of a medical test called a Pap smear? In this test, a doctor takes a small sample of cells from the uterine cervix of a patient and sends it to a medical lab where a cytotechnologist stains the cells and examines them for any changes that could indicate cervical cancer or a microbial infection. The microscopes we use today are far more complex than those used in the 1600s by Antony van Leeuwenhoek, a Dutch shopkeeper who had great skill in crafting lenses. Despite the limitations of his now-ancient lenses, van Leeuwenhoek observed the movements of protists (a type of single-celled organism) and sperm, which he collectively termed "animalcules." In a 1665, a scientist Robert Hooke coined the term

"cell" (from the Latin cella, meaning "small room") for the box-like structures he observed when viewing cork tissue through a lens. In the 1670s, Van Leeuwenhoek discovered bacteria and protozoa. Later advances in lenses and microscope construction enabled other scientists to see different components inside cells. By the late 1830s, botanist Matthias Schleiden and zoologist Theodor Schwann were studying tissues and proposed the unified cell theory, which states that all living things are composed of one or more cells, that the
cell is the basic unit of life, and that all new cells arise from existing cells. These principles still stand today. Who is a Cytotechnologist?

Self-Assessment Exercises 3

1. Who is a Cytotechnologist?
2. When did van Leeuwenhoek discovered bacteria and protozoa?

5.6 Summary

You have studied about **the smallest unit that can live on its own and that makes up all living organisms and the tissues of the body**. You have also learned about the different types of cell and the three main parts of the cell: the cell membrane, the nucleus, and the cytoplasm. The cell membrane surrounds the cell and controls the substances that go into and out of the cell.

5.7 References/Further Readings/Web Sources

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https://www.youtube.com/watch?v=kcG1F88KQA0

https://www.youtube.com/watch?v=V6s0xOTNmT4

5.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. The unified cell theory states that: all living things are composed of one or more cells; the cell is the basic unit of life; and new cells arise from existing cells.
2. The expanded version of the cell theory is made up of:

- Cells carry genetic material passed to daughter cells during cellular division
- All cells are essentially the same in chemical composition
- Energy flow (metabolism and biochemistry) occurs within cells

Answers to SAE 2

1. A microscope is an instrument that magnifies an object
2. In contrast to light microscopes, electron microscopes use a beam of electrons instead of a beam of light.

Answers to SAE 3

1. Cytotechnologist (cyto- = cell) is a professionals who study cells through microscopic examinations and other laboratory tests.
2. 1670s

Glossary

Applied science: a form of science that solves real-world problems

Basic science: science that seeks to expand knowledge regardless of the short-term application of that knowledge

Control: a part of an experiment that does not change during the experiment

Deductive reasoning: a form of logical thinking that uses a general statement to forecast specific results

Descriptive science: a form of science that aims to observe, explore, and find things out

Falsifiable: able to be disproven by experimental results

Hypothesis: a suggested explanation for an event, which can be tested

Inductive reasoning: a form of logical thinking that uses related observations to arrive at a general conclusion

Life science: a field of science, such as biology, that studies living things

Natural science: a field of science that studies the physical world, its phenomena, and processes

Physical science: a field of science, such as astronomy, physics, and chemistry, that studies nonliving matter

Science: knowledge that covers general truths or the operation of general laws, especially when acquired and tested by the scientific method

Scientific law: a description, often in the form of a mathematical formula, for the behavior of some aspect of nature under certain specific conditions

Scientific method: a method of research with defined steps that include experiments and careful observation

Scientific theory: a thoroughly tested and confirmed explanation for observations or phenomena

End of the module Questions

1. What process causes the diversity of life?
2. How do we organize diversity of life?
3. How does evolution lead to both the diversity and unity of life?
4. Why is organization of life important?
5. List the levels of organization, ranging from simplest to most complex.
6. Describe what it means to "Construct a Hypothesis."
7. What does a scientist do if the hypothesis is not supported?
8. Outline the steps of a scientific investigation.
9. Give an example of a scientific question that could be investigated with an experiment.

MODULE 2 STRUCTURE AND FUNCTIONS OF THE CELL

Module Structure

In this module we will discuss about the cellular organization, structure and functions

Unit 1 Cell and Cell Components
Unit 2 Cells Communication
Unit 3 Tissues, Organs and Organ Systems
Unit 4 Characteristics and Classification of Living Things
Unit 5 The Study of Genes and Chromosomes
Unit 6 Reproduction Process and Life cycles
Glossary
End of note questions

Unit 1 Cell and Cell Components

Unit Structure

1.1 Introduction
1.2 Intended Learning Outcomes (ILOs)
1.3 Cellular Organization
 1.3.1 Prokaryotic Cell
 1.3.2 Eukaryotic Cell
1.4 Cell Organelles
1.5 Other Organelles
1.6 Summary
1.7 References/Further Readings/Web Sources
1.8 Possible Answers to Self-Assessment Exercises

1.1 Introduction

You will learn in this unit that the cell falls into one of two broad categories: prokaryotic and eukaryotic. You will study that the predominantly single-celled organisms of the domains Bacteria and Archaea are classified as prokaryotes (*pro*- = before; -*karyon*- = nucleus), and all other animal cells, plant cells, fungi, and protists are eukaryotes (*eu*- = true). You will also learn how to draw and describe the structure of the various cell organelles

1.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you will be able to:

- Illustrate the structure of a prokaryote and eukaryote cells
- Describe the structure of plant and animal cells by drawing labelled diagrams;
- Differentiate between a Unicellular and Multicellular organisms
- describe the structure and function of the various cell organelles

1.3 The Cell and its Components

Although all cells share certain features (for example, every cell has a plasma membrane), biologists recognize two fundamentally different categories of cells: prokaryotic and eukaryotic. We compartmentalize cells into several structures, organelles with specific functions. Organelles are subunits in the anatomy of the cell. The compartmentalization inside the cell allows many different functions to be localized in specific places. This brings about a high level of organization and efficiency in the cell. In this unit we will discuss the structures and functions of the different parts of the cell.

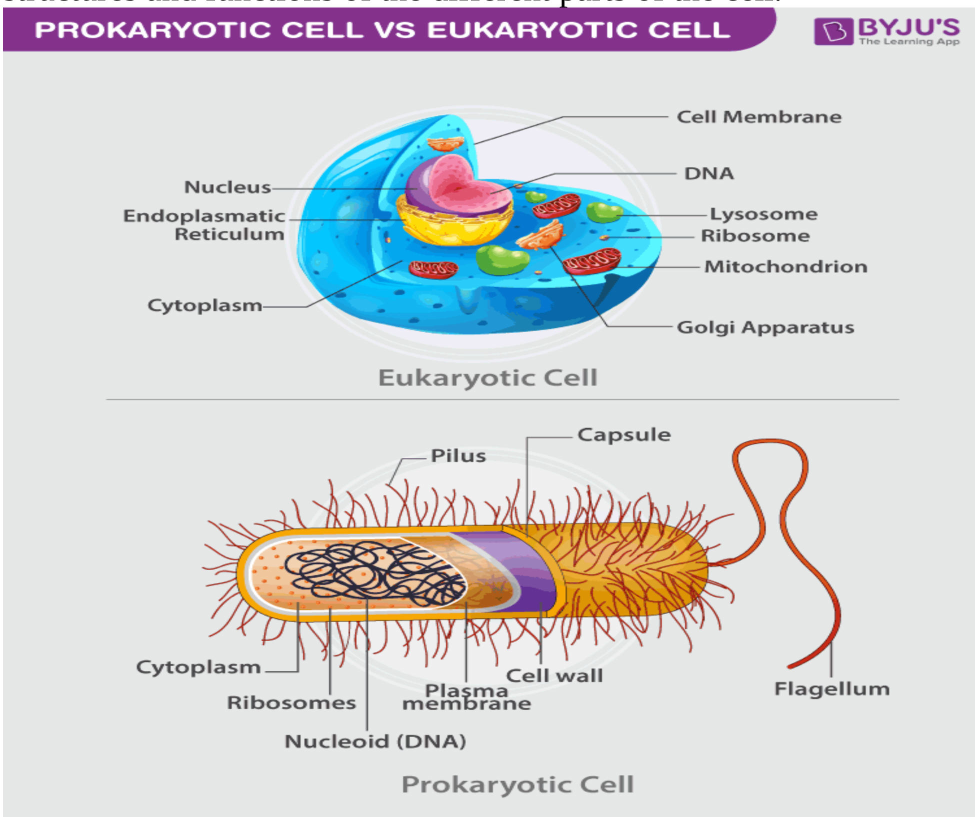

Figure 1. An image illustrating the difference between Prokaryotic and Eukaryotic Cells. Note that the prokaryotic cell is a complete individual organism. Source: www.byjus.com

Advancements in science and technology shed more light into the cell, with new findings and discoveries about its structure and cellular components. In 1950s, scientists postulated the concept of prokaryotic and eukaryotic cells, with earlier groundwork laid by Edouard Chatton, a French biologist in 1925. Anatomically, cells vary in respect to their classification, thus, prokaryotic cells and eukaryotic cells differ from each other drastically. Read on to explore how they differ from each other.

1.3.1 Prokaryotic Cell

The term "**prokaryote**" is derived from the Greek word "*pro*" (meaning: before) and "*karyon*" (meaning: kernel). It translates to "***before nuclei***". Prokaryotes are one of the most ancient groups of living organisms on earth, with fossil records dating back to almost 3.5 billion years ago.

These prokaryotes thrived in the earth's ancient environment, some using up chemical energy and others using the sun's energy. These extremophiles thrived for millions of years, evolving and adapting. Scientists speculated that these organisms gave rise to the eukaryotes. Prokaryotic cells are comparatively smaller and much simpler than eukaryotic cells. The other defining characteristic of prokaryotic cells is that they do not possess membrane-bound cell organelles such as a nucleus, and reproduction is by binary fission.

Structurally, each prokaryote has a capsule enveloping its entire body which functions as a protective coat. This is crucial for preventing the process of phagocytosis (where the bacteria gets engulfed by other eukaryotic cells, such as macrophages). A hair-like appendage found on the external surface of most prokaryotes is called pilus, and it helps the organism to attach itself to various environments. The pilus is commonly observed in bacteria and essentially resists being flushed, hence, it is also called attachment pili.

Right below the protective coating lies the cell wall, which provides strength and rigidity to the cell. Further down lies the cytoplasm that helps in cellular growth, and is contained within the plasma membrane. This separates the inner contents of the cell from the outside environment. Ribosomes exist within the cytoplasm; it is also one of the smallest components within the cell and plays an important role in protein synthesis. Some prokaryotic cells contain special structures called mesosomes which assist in **cellular respiration**. Most prokaryotes also contain plasmids, which contain small, circular pieces of DNA. To help with locomotion, flagella are present, though, pilus can also serve as an aid for locomotion. Common examples of Prokaryotic organisms are bacteria, archaea and all members of Kingdom Monera.

1.3.2 Eukaryotic Cell

The term "**Eukaryotes**" is derived from the Greek word "*eu*", (meaning: good) and "*karyon*" (meaning: kernel), being translated to "***good or true nuclei***." Eukaryotes are more complex and much larger than prokaryotes. They include almost all the major kingdoms except kingdom monera. Structurally, eukaryotes possess a cell wall, which supports and protects the plasma membrane. The cell is surrounded by the plasma membrane which controls the entry and exit of some substances. The nucleus is surrounded by the nuclear membrane and contains DNA, which is responsible for storing all genetic information. Within the nucleus is the nucleolus, and it plays a crucial role in proteins synthesis. Eukaryotic cells also contain mitochondria, which are responsible for the production of energy utilized by the cell.

Chloroplasts are the subcellular sites of photosynthesis present in only plant cells. The endoplasmic reticulum helps in the transportation of materials. Besides these, there are also other **cell organelles** that perform various other functions, these include ribosomes, lysosomes, Golgi bodies, cytoplasm, chromosomes, vacuoles and centrosomes. Examples of eukaryotes include almost every unicellular organism with a nucleus and all multicellular organisms.

1.3.3 Difference between Prokaryotic and Eukaryotic Cells

Though these two classes of cells are quite different, they do possess some common characteristics. For example, both possess cell membranes and ribosomes. The complete list of differences between prokaryotic and eukaryotic cells is summarized as follows:

Feature	**Prokaryotes**	**Eukaryotes**
Organisms	Bacteria	Protists, fungi, plants and animals
Cell size	Average diameter 0.5 - 10µm	Diameter commonly 1000 – 10000 times the volume of prokaryotes
Form	Mainly unicellular	Mainly multicellular
Evolution origin	3.5 thousand million years ago	1.2 thousand million years ago, evolve from prokaryotes
Cell division	Mostly binary fission, no spindle	Mitosis, meiosis or both, spindle formed
Genetic material	DNA is circular and lies freely in the cytoplasm	DNA linear and contained in a nucleus.

	(no true nucleus). DNA is also naked; not associated with RNA to form chromosomes.	DNA is also associated with RNA to form chromosomes
Protein synthesis	70s ribosomes, no endoplasmic reticulum	80s ribosomes, and may be attached to endoplasmic reticulum
Organelles	Few organelles, none surrounded by envelope (two membranes)	Many organelles and envelope-bound organelles present eg. nucleus, mitochondria, chloroplast. There are also some organelles bounded by single membrane eg. golgi apparatus, lysosomes, endoplasmic reticulum.
Cell wall	Rigid and contain polysaccharides with amino acids; murein strengthening compounds.	Cell walls of green plants and fungi are rigid and contain polysaccharides; cellulose is the main strengthening compounds of plant cell walls. Chitin for fungal cell wall while there is no cell wall in animal cells.
Flagella	Simple, lacking microtubules; extracellular, 20nm diameter	Complex with microtubules; intracellular, 200nm diameter
Respiration	Membranes in blue green bacteria	Mitochondria for aerobic respiration
Photosynthesis	No chloroplasts; takes place in membranes which show no stacking	Chloroplasts containing membranes which are usually stacked into lamellae or grana
Nitrogen fixation	Some have the ability to fix nitrogen	None can fix nitrogen

What is the main difference between the ribosomes of prokaryotic and eukaryotic cells?

Self-Assessment Exercises 1

1. Give the general example of a eukaryote.
2. Differentiate between prokaryotes and eukaryotes.

1.4 The Nature and Function of Cells

The plasma membrane that encloses a cell creates a selective barrier that allows nutrients to enter and waste products to exit. Each of the numerous specialised compartments, or organelles, that make up a cell's inside is encircled by a different membrane. The nucleus is one important organelle that houses the genetic materials required for cell division and growth. each cell only has one nucleus, while other organelles are found in many copies in the cytoplasm. These organelles include mitochondria, which carry out the energy exchanges required for cell viability, and lysosomes, which break down waste products inside the cell, the endoplasmic reticulum and the Golgi apparatus, which play important roles in the internal organization of the cell by synthesizing selected molecules and then processing, sorting, and directing them to their proper locations. In addition, chloroplasts, parts of plant cells, are involved in photosynthesis, the process by which carbon dioxide (CO_2) and water molecules are changed into carbohydrates using the energy of sunlight. The region of the cytoplasm known as the cytosol is located between all these organelles. The cytoskeleton, gives a cell its shape, allows organelles to move inside the cell, and provides a mechanism by which the cell itself can move, is an organised framework of fibrous molecules found in the cytosol. The process of producing large biological molecules from smaller ones, known as cellular biosynthesis, involves more than 10,000 different types of molecules, all of which can be found in the cytosol. Specialized organelles are a characteristic of eukaryotic cells. In contrast, prokaryotic cells do not contain organelles and are generally smaller than eukaryotic cells. However, all cells share strong similarities in biochemical functions.

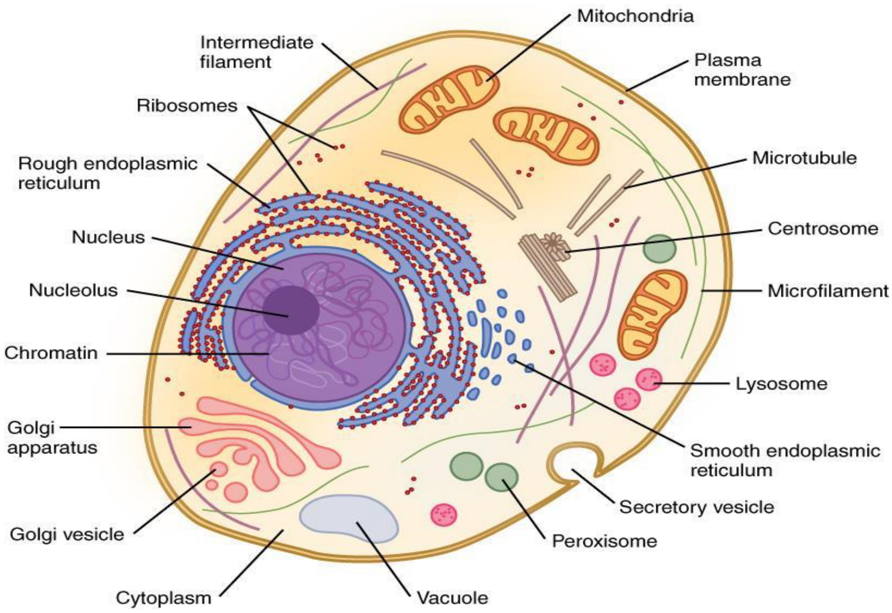

Figure 1.2 Typical example of a cell containing the primary organelles and internal structures.

1.4.1 The Cell Organelles

Cell organelles are the cellular constituents and they differ in their structures and functions. They include both membrane-bound and non-membrane-bound organelles. For the cell to function properly, they coordinate and work effectively. Some of them giving shape and support to a cell, while others are involved in a cell's movement and reproduction. The cells are divided into three groups based on whether they have a membrane or not. However, as we will see in a moment, a semi-permeable plasma membrane protects the cytoplasm that is home to these organelles will be treated as component part of the cell.

1. The Plasma Membrane

Eukaryotic cells, like prokaryotes, have a plasma membrane (Figure 3), a phospholipid bilayer with proteins embedded that seperates the inside of the cell from its external environment. A phospholipid is a lipid molecule that has a phosphate-containing group and two fatty acid chains. The flow of organic molecules, ions, water, and oxygen into and out of the cell is regulated by the plasma membrane. Wastes such as including ammonia and carbon dioxide also exit the cell through the plasma membrane.

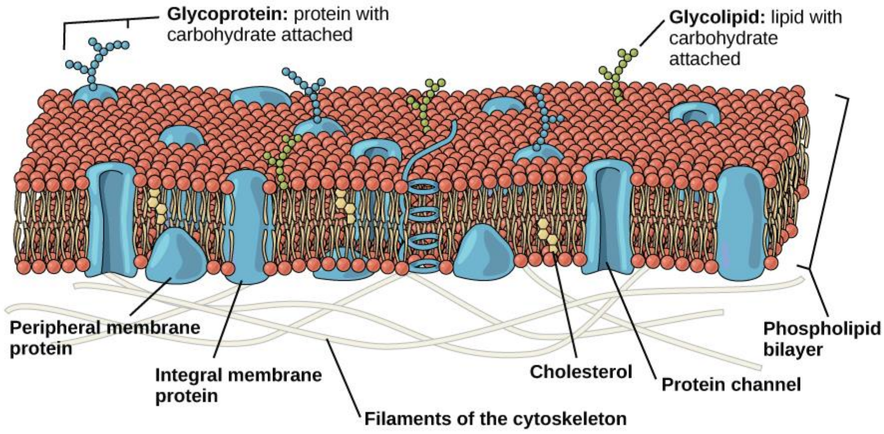

Figure 1.3: The eukaryotic plasma membrane
The eukaryotic plasma membrane is a phospholipid bilayer with proteins and cholesterol embedded in it.

2. Microvilli, the plasma membranes of cells that specialise in absorbing substances are folded into fingerlike projections (Figure 4.).
3. The small intestine, being the organ that absorbs nutrients from digested food, is normally lined by these cells. This is a superb illustration of structure adhering to function. Gluten, a protein included in wheat, barley, and rye, causes an immunological reaction in people with celiac disease. The immune response

harms microvilli, making it impossible for those with the condition to absorb nutrition. Malnutrition, cramps, and diarrhoea result from this. Gluten-free diets are required for celiac disease patients.

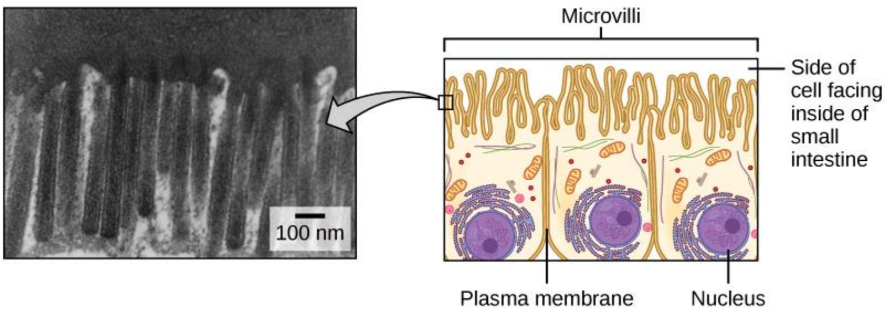

Figure 1.4 Microvilli, shown here as they appear on cells lining the small intestine, increase the surface area available for absorption.

These microvilli are only found on the area of the plasma membrane that faces the cavity from which substances will be absorbed.

2. The Cytoplasm

The total area of a cell between the nuclear envelope and the plasma membrane is known as the cytoplasm. The Cytoplasm is made up of the cytoskeleton, numerous molecules, and organelles suspended in the gel-like cytosol. The proteins in the cytoplasm give it a semi-solid solidity, despite the fact that it contains between 70 and 80 percent water. However, organic compounds other than proteins can also be present in the cytoplasm. In addition, polysaccharides, amino acids, nucleic acids, fatty acids, and glycerol derivatives are present there along with glucose and other simple carbohydrates. The cytoplasm also contains dissolved sodium, potassium, calcium, and many other elemental ions. The cytoplasm is where many metabolic processes, including as protein synthesis, take place.

1.4.2 Organelles without membrane

The Cell wall, Ribosomes, Cytoskeleton (actin filaments, intermediate filaments, centrioles) and microtubules are non-membrane-bound cell organelles. They are present both in the prokaryotic land the eukaryotic cells.

1. The Cell wall

Outside of the plasma membrane is a structure known as cell wall. The cell wall is a thick layer that serves as the cell's defense, structural support, and form. Cell walls are also present in fungus and protozoan cells. While peptidoglycan is the main organic molecule in the cell walls of prokaryotic organisms, cellulose, a polysaccharide comprising of glucose units, is the main organic molecule in the cell walls of plants (figure 1.5). Have you ever noticed how a raw vegetable, like celery, crunches as you chew it? This is due to the fact that you are shredding the celery cells' stiff cell walls with your teeth. The dashed lines at each end of the figure indicate a series of many more glucose units. The size of the page makes it impossible to portray an entire cellulose molecule.

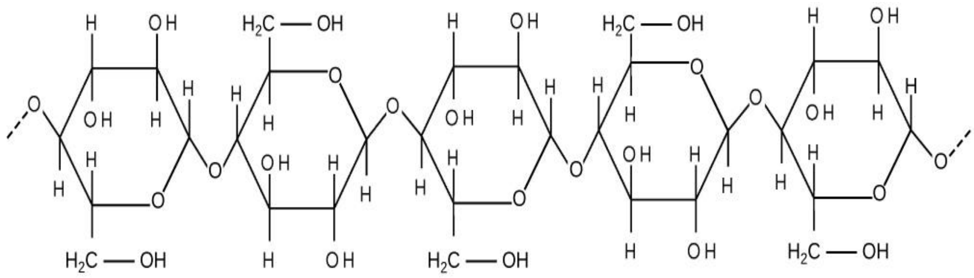

Figure 1.5. Cellulose is a long chain of β-glucose molecules connected by a 1-4 linkage.

2. Ribosomes

Ribosomes are biological elements in charge of producing proteins. Under an electron microscope, ribosomes can be observed as either solitary, tiny specks floating freely in the cytoplasm or as polyribosome clusters. They might be connected to the plasma membrane, the cytoplasmic side of the endoplasmic reticulum, or the nuclear envelope (Figure 6.). Since ribosomes are large complexes of protein and RNA, electron microscopy has shown that they are composed of two subunits known as large and small subunits. The ribosomes receive their "orders" for protein synthesis from the nucleus, where DNA is transformed into messenger RNA (mRNA). The mRNA travels to the ribosomes, which translate the code provided by the sequence of the nitrogenous bases in the mRNA into a specific order of amino acids in a protein. Amino acids are the building blocks of proteins.

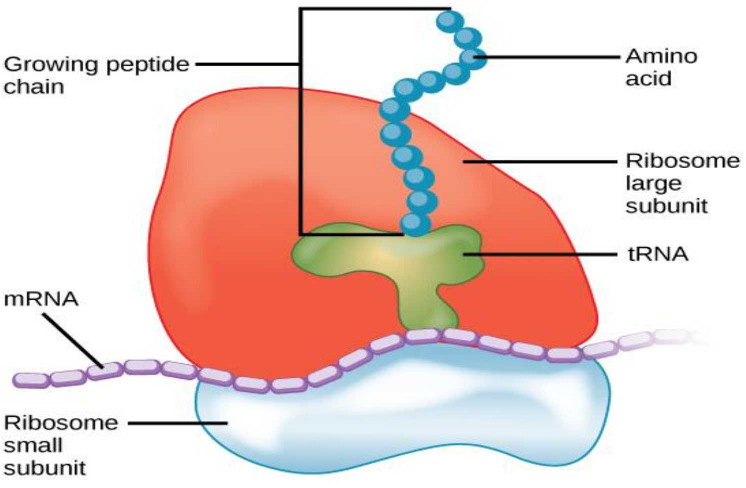

Figure 1.6 Ribosomes are made up of a large subunit (top) and a small subunit (bottom).

Ribosomes put together amino acids into proteins during the process of protein synthesis. All cells including enzymes, hormones, antibodies, pigments, structural elements, and surface receptors must be able to synthesise proteins, hence ribosomes are present in almost all cells. In cells that produce a lot of protein, ribosomes are very prevalent, as seen in the pancreas that is in charge of producing a number of digestive enzymes. We observe another instance of form following function as a result.

3. Cytoskeleton

Would the plasma membrane and the cytoplasm be the only elements left in a cell if all the organelles were taken out? No. Ions and organic molecules would still be present in the cytoplasm, along with a network of protein fibres that support some organelles in particular places, permit movement of cytoplasm and vesicles inside the cell, and allow movement of cells within multicellular animals. The term "cytoskeleton" refers to this web of protein fibres as a whole. The cytoskeleton is made up of three different types of fibres: microfilaments, intermediate filaments, and microtubules (Figure 7.). Here, we'll look at each. Inside the cell, microtubules prevent compressive forces from changing the shape of the cell. Intermediate filaments are found throughout the cell and hold organelles in place.

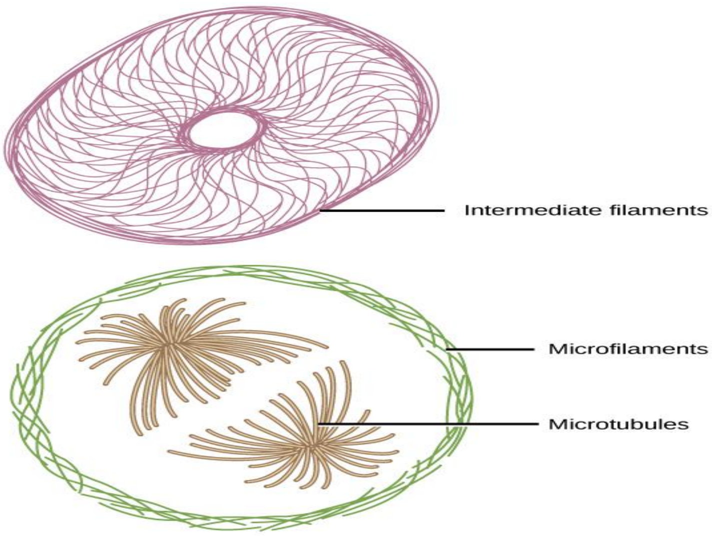

Figure 1.7 Microfilaments thicken the cortex around the inner edge of a cell; like rubber bands, they resist tension.

4. Microfilaments

Of the three types of protein fibers in the cytoskeleton, **microfilaments** are the narrowest. They function in cellular movement, have a diameter of about 7 nm, and are made of two intertwined strands of a globular protein called actin (Figure 7.). For this reason, microfilaments are also known as actin filaments.

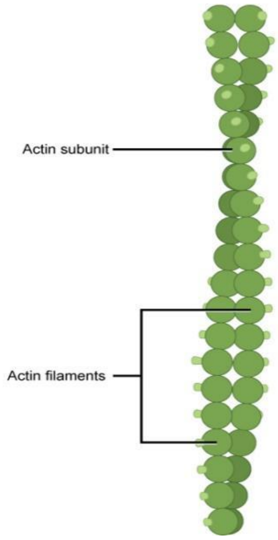

Figure 1.8 Microfilaments made of two intertwined strands of actin.

The filamentous form of actin, which serves as a conduit for the motion of the myosin motor protein, is created using ATP. Actin can now take part in cellular activities that require movement, such as cell division in animal cells and cytoplasmic streaming, the circular movement of the cell cytoplasm in plant cells. Actin and myosin are both abundantly dispersed in muscle cells. As actin and myosin filaments pass by one another, your muscles tighten. Microfilaments also give the cell some form and stiffness. A cell can change and migrate because it has the capacity to depolymerize (disassemble) and reconstruct quickly. The cells in your body that fight infections, called white blood cells, are quite good at using this ability.

5. Intermediate Filaments

Intermediate filaments are made of several strands of fibrous proteins that are wound together (Figure 9.). These elements of the cytoskeleton get their name from the fact that their diameter, 8 to 10 nm, is between those of microfilaments and microtubules.

Figure 1.9 Intermediate filaments consist of several intertwined strands of fibrous proteins.

In the migration of cells, intermediate filaments play no part. Their sole purpose is structural. They support tension, preserving the cell's structure, and serve as anchors for the nucleus and other organelles. Figure 9 demonstrates how internal scaffolding is built by intermediate filaments. The cytoskeletal elements with the highest variety are the intermediate filaments. The intermediate filaments contain several kinds of fibrous proteins known as keratin, which supports your hair, nails, and skin's epidermis, is perhaps the one you know best.

6. Microtubules

Microtubules are little, hollow tubes, as their name suggests. Two globular proteins, α-tubulin and β -tubulin, are polymerized dimers that make up the walls of the microtubule (Figure 10). The largest cytoskeleton elements are microtubules, which have a diameter of roughly 25 nm. They enable vesicles to flow across the cell along a track and draw replicated chromosomes to the opposite ends of a dividing cell. They also aid in the cell's resistance to compression. Microtubules can dissolve and swiftly regenerate, just like microfilaments.

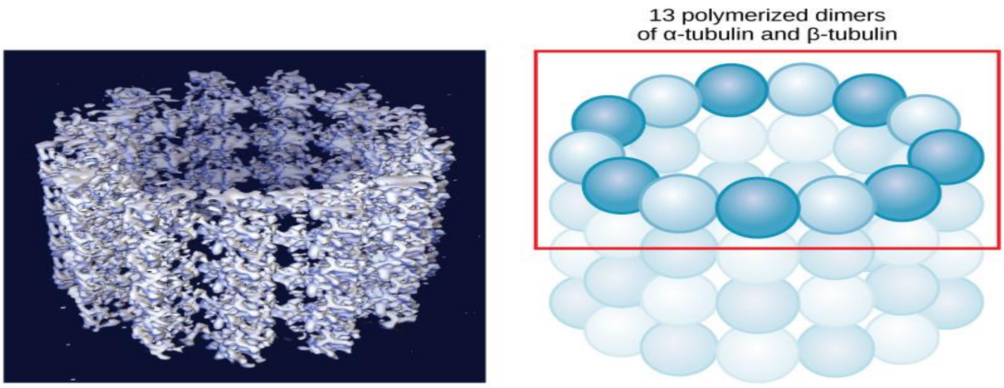

Figure 1.10 Microtubules are hollow. Their walls consist of 13 polymerized dimers of α-tubulin and β-tubulin (right image). The left image shows the molecular structure of the tube.

Microtubules are also the structural elements of flagella, cilia, and centrioles (the latter are the two perpendicular bodies of the centrosome). In fact, in animal cells, the centrosome is the microtubule-organizing center. In eukaryotic cells, flagella and cilia are quite different structurally from their counterparts in prokaryotes, as discussed below.

7. Flagella and Cilia

Recall that flagella are long, hairlike projections that emerge from the plasma membrane and are used to propel an entire cell (for example, sperm, Euglena). The cell may have one or more flagellums when they are present. However, a sizable number of cilia (singular: cilium) cover the whole surface of the plasma membrane when they are present. They are microscopic, hair-like structures that transfer materials or whole cells, like paramecia, along the surface of the cell (for example, the cilia of cells lining the Fallopian tubes that move the ovum toward the uterus, and cilia lining the cells of the respiratory tract that trap particulate matter and move it toward your nostrils.) Despite their differences in length and number, flagella and cilia share a common structural arrangement of microtubules called a "9 + 2 array". This is an appropriate name because a single flagellum or cilium is made of a ring of nine microtubule doublets, surrounding a single microtubule doublet in the center (Figure 10.).

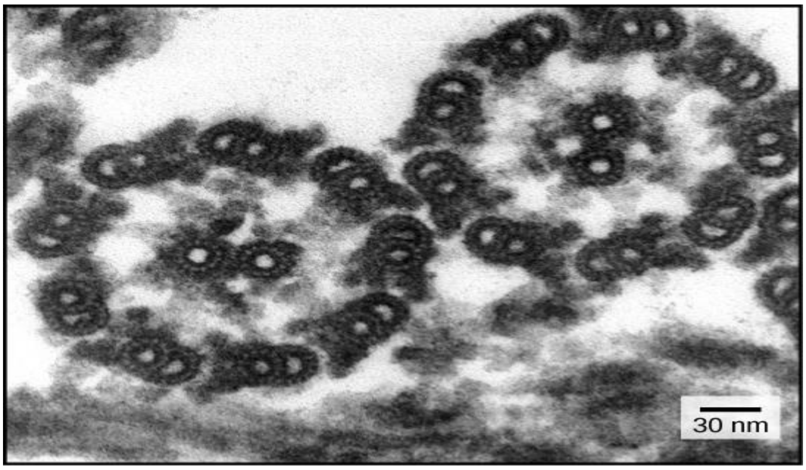

Figure 1.11 This transmission electron micrograph of two flagella shows the 9 + 2 array of microtubules: nine microtubule doublets surround a single microtubule doublet.

1.4.3 Single membrane-bound organelles

Vacuole, Vesicles, Lysosome, Golgi Apparatus, Endoplasmic Reticulum, mitochondria, peroxisomes, and transport vesicles are single membrane-bound organelles present only in a eukaryotic cell.

1. **Vesicles and Vacuoles**

Vacuoles and vesicles are single membrane-bound sacs with storage and transport capabilities. There is a little or no difference between vacuoles and vesicles save the fact that the former are slightly larger: Vesicle membranes are capable of joining with the cell's plasma membrane or other membrane systems. Furthermore, some substances, like the enzymes found in plant vacuoles, degrade macromolecules. A vacuole's membrane does not meld with the membranes of other cellular parts. In response to shifting external conditions, the central vacuole is crucial in controlling the water content within the cell. Have you ever observed that plants wilt if they go without water for a few days? This is due to water moving out of the central vacuoles and cytoplasm as the water concentration in the soil drops below the water concentration in the plants, the cell wall is left unsupported while the central vacuole contracts. The plant appears wilted as a result of the loss of support to the cell walls of the plant cells. The expansion of the cell is also supported by the central vacuole which can store more water, thus allowing the cell to grow without expending a lot of energy on producing new cytoplasm.

2. Lysosome

Lysosomes are thought to be a member of the endomembrane system in addition to serving as the animal cell's organelle recycling facility of digestive system. Lysosomes also use their hydrolytic enzymes to eliminate any pathogens (organisms that cause disease) that might enter the cell. The immune system of your body's macrophages, a class of white blood cells, serves as a good illustration of this. A portion of the macrophage's plasma membrane invaginates (folds in) and engulfs a pathogen during phagocytosis or endocytosis. The pathogen-filled invaginated area subsequently pinches itself off from the plasma membrane and transforms into a vesicle. The pathogen is then eliminated by the lysosome's hydrolytic enzymes (Figure 12.).

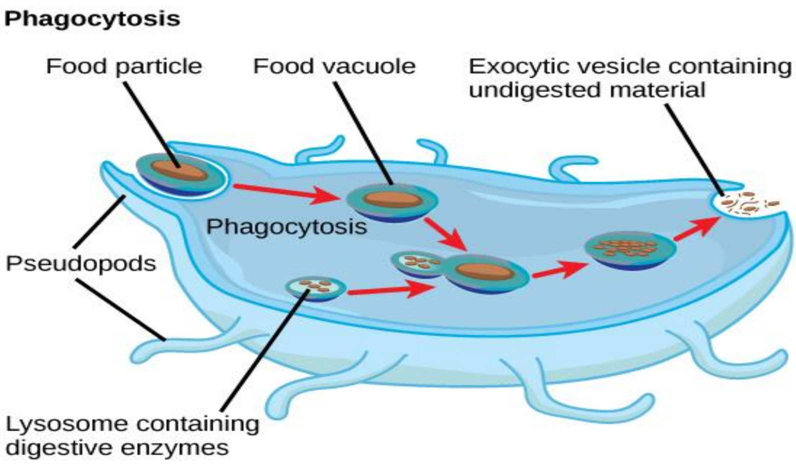

Figure 1.12 A macrophage has engulfed (phagocytized) a potentially pathogenic bacterium and then fuses with lysosomes within the cell to destroy the pathogen. Other organelles are present in the cell but for simplicity are not shown.

3. Golgi Apparatus

The Golgi apparatus, also known as the Golgi body, is a collection of flattened membranes that is responsible for the classification, labelling, packaging, and distribution of lipids and proteins (Figure 13). We have already mentioned that vesicles can form in the emergency room and travel elsewhere with their contents, but where do the vesicles themselves go? The transport vesicles' lipids or proteins still need to be processed, packaged, and labelled before they go to their final location to ensure they end up there.

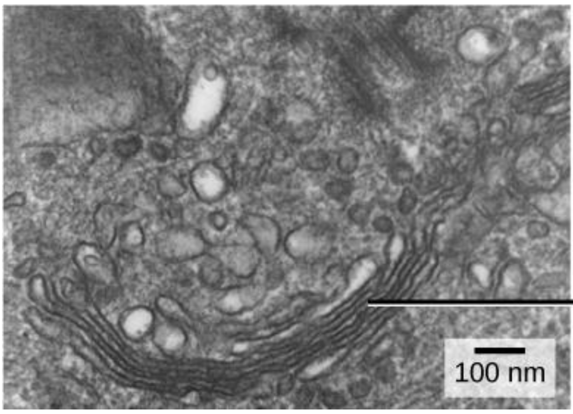

Figure 1.13 The Golgi apparatus in this white blood cell is visible as a stack of semicircular, flattened rings in the lower portion of the image.

The cis face refers to the receiving side of the Golgi apparatus. The trans face is the side that faces the other way. When the transport vesicles from the endoplasmic reticulum (ER) fuse with the cis face, they release their contents into the lumen of the Golgi apparatus. The proteins and lipids go through additional changes in the Golgi apparatus that enable sorting as they move through it. The most common alteration is the insertion of sugar molecules in short chains. Then, in order to direct these newly altered proteins and lipids to their correct locations, they are marked with phosphate groups or other tiny molecules. Finally, secretory vesicles that bud from the trans face of the Golgi are used to package the changed and tagged proteins. Other secretory vesicles fuse with the plasma membrane and release their contents outside the cell, while some of these vesicles deposit their contents into other areas of the cell where they will be utilised. Another example of shape following function is the profusion of Golgi in cells that release a lot of materials, such as salivary gland cells that secrete digestive enzymes or immune system cells that secrete antibodies. The Golgi apparatus in plant cells also plays the additional task of synthesising polysaccharides, some of which are utilised to build the cell wall and others in other regions of the cell.

4. The Endoplasmic Reticulum

The endoplasmic reticulum (ER) (Figure 14.) is a collection of mesh worked sacs and tubules that work together to manufacture lipids and modify proteins. The rough ER and the smooth ER, respectively, are where these two tasks are carried out in the ER. The lumen or cisternal space refers to the hollow area of the ER tubules. The nuclear envelope and the phospholipid bilayer that makes up the ER's membrane are one continuous structure. The two are as follows: I Rough ER: i). The rough endoplasmic reticulum (RER) is named as such because, when studied under an electron microscope, the ribosomes clinging to its cytoplasmic surface give it a studded look. (Figure 5).

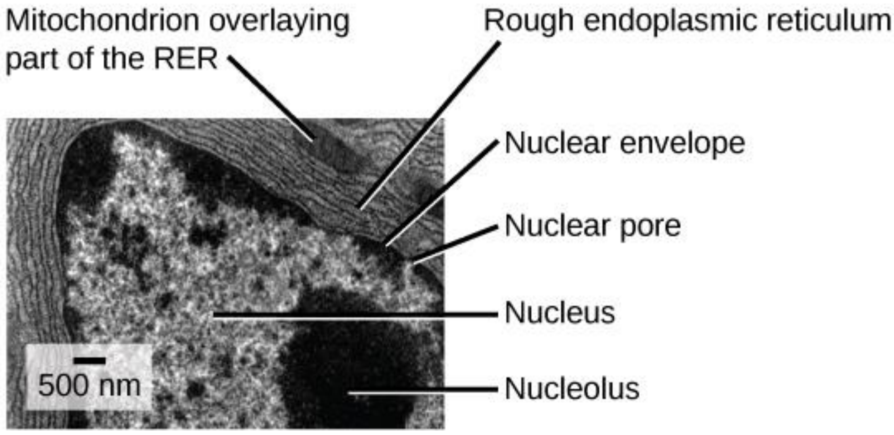

Figure 1.14 This transmission electron micrograph shows the rough endoplasmic reticulum and other organelles in a pancreatic cell.

The freshly synthesised proteins are transferred by ribosomes into the lumen of the RER, where they go through structural changes such folding or side chain acquisition. These altered proteins will either be released from the cell or integrated into cellular membranes, such as the ER membrane or those of other organelles (such as protein hormones, enzymes). Phospholipids for cellular membranes are also produced by the RER. If the phospholipids or altered proteins are not meant to remain in the RER, transport vesicles that sprout from the RER's membrane will carry them to their intended locations (Figure 14) You would be right in believing that the RER is prevalent in cells that produce proteins because it is involved in altering proteins such as enzymes, that will be released from the cell such as liver cells.

ii). The smooth endoplasmic reticulum (SER), which is continuous with the RER, has few or no ribosomes on the surface of its cytoplasm (Figure 4.18). The SER performs several functions, such as calcium ion storage, drug detoxification, and the production of carbohydrates, lipids, and steroid hormones. The sarcoplasmic reticulum, a specific type of SER, is in charge of storing the calcium ions required to start the coordinated contractions of muscle cells.

5. Peroxisomes

Small, spherical organelles called peroxisomes are surrounded by a single membrane. In their oxidation reactions, fatty acids and amino acids are broken down. They also cleanse the body of numerous toxins that might be ingested. (Many of these oxidation events produce hydrogen peroxide, H_2O_2, which can harm cells; however, when these reactions take place inside of peroxisomes, enzymes safely break down the H_2O_2 into oxygen and water.) For example, peroxisomes in liver cells detoxify alcohol. Plants' specialised peroxisomes called glyoxysomes are in charge of converting stored fats into sugars.

Self-Assessment Exercises 2

1. What is a flagellum?
2. Which form of peroxisomes are responsible for the conversion of stored fat into sugars?

1. Flagella are long, hair-like structures that extend from the plasma membrane and are utilised to move a complete cell such as sperm and Euglena cells.
2. Glyoxysomes

1.5 Double membrane-bound organelles

Nucleus, mitochondria and chloroplast are double membrane-bound organelles present only in a eukaryotic cell.

1. Nucleus

Typically, the nucleus is the most prominent organelle in a cell (Figure 1.15). The **nucleus** (plural nuclei) houses the cell's DNA and directs the synthesis of ribosomes and proteins. Let's look at it in more detail (Figure 1.15).

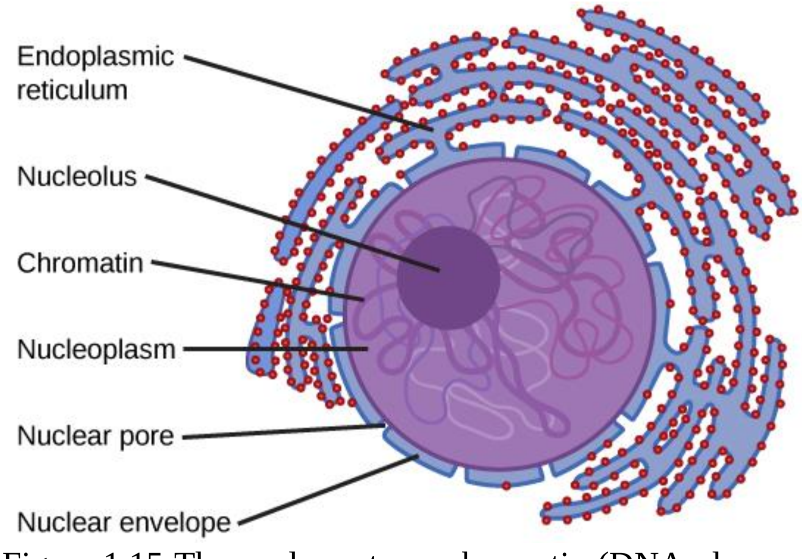

Figure 1.15 The nucleus stores chromatin (DNA plus proteins) in a gel-like substance called the nucleoplasm.

Ribosome synthesis takes place in the nucleolus, a compressed area of chromatin. The nuclear envelope is the term used to describe the nucleus' outside. It is made up of an outer membrane and an inner membrane which are both phospholipid bilayers. The endoplasmic reticulum and the nuclear membrane are one unit. Nuclear pores allow substances to enter and exit the nucleus.

The Nuclear Envelope
The **nuclear envelope** is a double-membrane structure that constitutes the outermost portion of the nucleus (Figure 14). Both the inner and outer membranes of the nuclear envelope are phospholipid bilayers. The nuclear envelope is punctuated with pores that control the passage of ions, molecules, and RNA between the nucleoplasm and cytoplasm.

The **nucleoplasm** is the semi-solid fluid inside the nucleus, where we find the chromatin and the nucleolus.

Chromatin and Chromosomes
It is useful to start with chromosomes in order to comprehend chromatin. Chromosomes are nucleus-located components consisting of DNA, the genetic material. In prokaryotes, DNA is arranged into a single circular chromosome, as you may recall. Chromosomes are organised in a linear fashion in eukaryotes. In the cell nuclei of its body, each eukaryotic species has a certain number of chromosomes.

For instance, the number of chromosomes in humans is 46, whereas it is just eight in fruit flies. Only when the cell is about to divide can the chromosomes be seen and distinguished from one another. Proteins are connected to chromosomes during the growth and maintenance phases of the cell's life cycle, and they take on the appearance of an unravelled, disorganised collection of threads.

These unwound protein-chromosome complexes are called **chromatin** (Figure 15); chromatin describes the material that makes up the chromosomes both when condensed and decondensed.

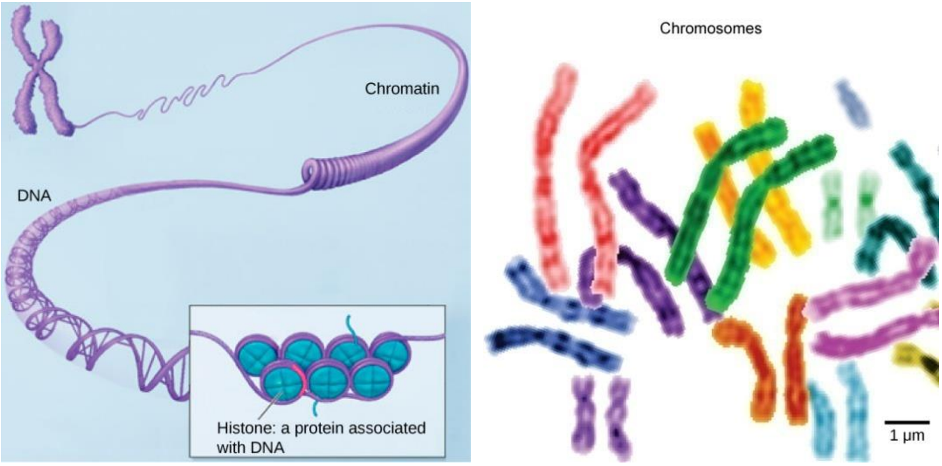

Figure 1.16. (a) This image shows various levels of the organization of chromatin (DNA and protein). (b) This image shows paired chromosomes.

The Nucleolus

We already know that the nucleus directs the synthesis of ribosomes, but how does it do this? Some chromosomes have sections of DNA that encode ribosomal RNA. A darkly staining area within the nucleus called the **nucleolus** (plural = nucleoli) aggregates the ribosomal RNA with associated proteins to assemble the ribosomal subunits that are then transported out through the pores in the nuclear envelope to the cytoplasm.

The Centrosome

The **centrosome** is a microtubule-organizing center found near the nuclei of animal cells. It contains a pair of centrioles, two structures that lie perpendicular to each other. Each centriole is a cylinder of nine triplets of microtubules.

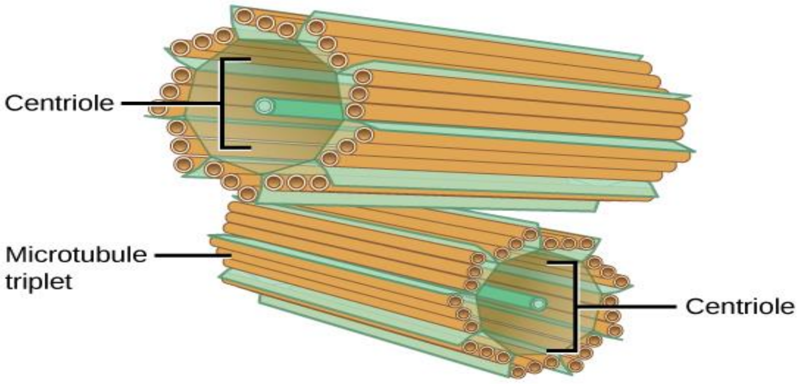

Figure 1.17. The centrosome consists of two centrioles that lie at right angles to each other.

Nine triplets of microtubules make up each centriole, which is shaped like a cylinder. The microtubule triplets are held together by nontubulin proteins, which are represented by the green lines. Before a cell divides, the centrosome (the organelle from which all microtubules originate) copies itself, and centrioles seem to play a part in directing the duplicated chromosomes to the opposing ends of the dividing cell. The precise role of centrioles in cell division, however, is unclear because plant cells, which lack centrosomes, can divide even after having their centrosomes removed from them.

2. Mitochondria

Mitochondria (singular mitochondrion) are often called the "powerhouses" or "energy factories" of a cell because they are responsible for making adenosine triphosphate (ATP), the cell's main energy-carrying molecule. ATP represents the short-term stored energy of the cell. Nine triplets of microtubules make up each centriole, which is shaped like a cylinder. The microtubule triplets are held together by nontubulin proteins, which are represented by the green lines. Before a cell divides, the centrosome (the organelle from which all microtubules originate) copies itself, and centrioles seem to play a part in directing the duplicated chromosomes to the opposing ends of the dividing cell. The precise role of centrioles in cell division, however, is unclear because plant cells, which lack centrosomes, can divide even after having their centrosomes removed from them.

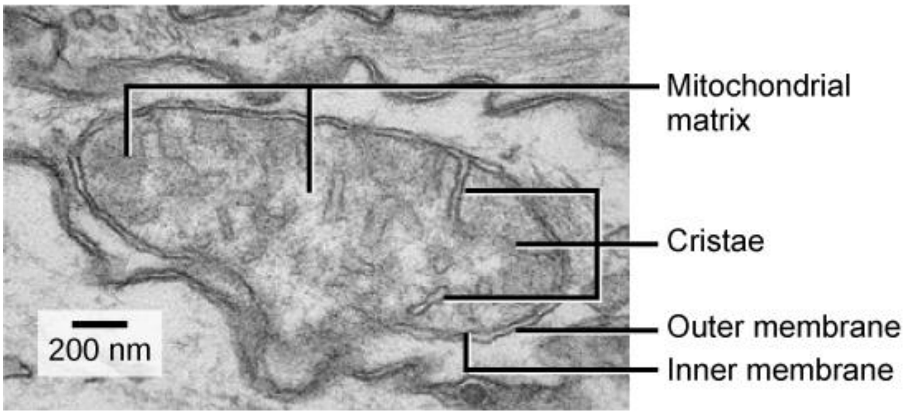

Figure 1.18. This electron micrograph shows a mitochondrion as viewed with a transmission electron microscope.

This organelle has an outer membrane and an inner membrane. The inner membrane contains folds, called cristae, which increase its surface area. The space between the two membranes is called the intermembrane space, and the space inside the inner membrane is called the mitochondrial matrix. ATP synthesis takes place on the inner membrane.

3. Chloroplast

Chloroplasts have their own DNA and ribosomes, just like mitochondria, but they serve a completely different purpose. Organelles in plant cells called chloroplasts are responsible for photosynthesis. The set of chemical processes known as photosynthesis convert carbon dioxide, water, and light energy into glucose and oxygen. This is a key distinction between plants and animals; although animals (heterotrophs) must consume their food, plants (autotrophs) may produce food like sugars on their own. Chloroplasts, like mitochondria, have an inner and an outer membrane. However, the inner membrane of a chloroplast encloses a collection of interconnected and stacked fluid-filled membrane sacs known as thylakoids (Figure 19). A granum (plural: grana) is the name given to each stack of thylakoids. the liquid that fills the space between the inner membrane and the grana

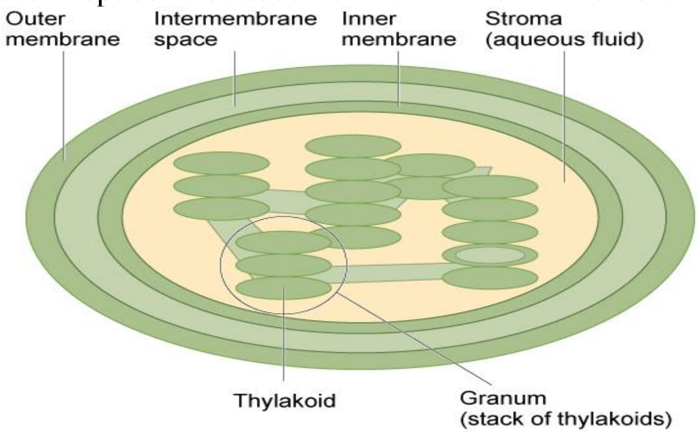

Figure 1.19. The chloroplast has an outer membrane, an inner membrane, and membrane structures called thylakoids that are stacked into grana.

The space inside the thylakoid membranes is called the thylakoid space. The light harvesting reactions take place in the thylakoid membranes, and the synthesis of sugar takes place in the fluid inside the inner membrane, which is called the stroma. Chloroplasts also have their own genome, which is contained on a single circular chromosome.

The chloroplasts contain a green pigment called **chlorophyll**, which captures the light energy that drives the reactions of photosynthesis. Like plant cells, photosynthetic protists also have chloroplasts. Some bacteria perform photosynthesis, but their chlorophyll is not relegated to an organelle.

Comparing the Components of Prokaryotic and Eukaryotic Cells

Components of Prokaryotic and Eukaryotic Cells				
Cell Component	Function	Present in Prokaryotes?	Present in Animal Cells?	Present in Plant Cells?
Plasma membrane	Separates cell from external environment; controls passage of organic molecules, ions, water, oxygen, and wastes into and out of cell	Yes	Yes	Yes
Cytoplasm	Provides turgor pressure to plant cells as fluid inside the central vacuole; site of many metabolic reactions; medium in which organelles are found	Yes	Yes	Yes
Nucleolus	Darkened area within the nucleus where ribosomal subunits are synthesized.	No	Yes	Yes
Nucleus	Cell organelle that houses DNA and directs synthesis of ribosomes and proteins	No	Yes	Yes
Ribosomes	Protein synthesis	Yes	Yes	Yes
Mitochondria	ATP production/cellular respiration	No	Yes	Yes
Peroxisomes	Oxidizes and thus breaks down fatty acids and amino acids, and detoxifies poisons	No	Yes	Yes
Vesicles and vacuoles	Storage and transport; digestive function in plant cells	No	Yes	Yes
Centrosome	Unspecified role in cell division in animal cells; source of microtubules in animal cells	No	Yes	No

Components of Prokaryotic and Eukaryotic Cells				
Cell Component	Function	Present in Prokaryotes?	Present in Animal Cells?	Present in Plant Cells?
Lysosomes	Digestion of macromolecules; recycling of worn-out organelles	No	Yes	No
Cell wall	Protection, structural support and maintenance of cell shape	Yes, primarily peptidoglycan	No	Yes, primarily cellulose
Chloroplasts	Photosynthesis	No	No	Yes
Endoplasmic reticulum	Modifies proteins and synthesizes lipids	No	Yes	Yes
Golgi apparatus	Modifies, sorts, tags, packages, and distributes lipids and proteins	No	Yes	Yes
Cytoskeleton	Maintains cell's shape, secures organelles in specific positions, allows cytoplasm and vesicles to move within cell, and enables unicellular organisms to move independently	Yes	Yes	Yes
Flagella	Cellular locomotion	Some	Some	No, except for some plant sperm cells.

Components of Prokaryotic and Eukaryotic Cells				
Cell Component	Function	Present in Prokaryotes?	Present in Animal Cells?	Present in Plant Cells?
Cilia	Cellular locomotion, movement of particles along extracellular surface of plasma membrane, and filtration	Some	Some	No

What is the set of chemical processes that converts carbon dioxide, water, and light energy into glucose and oxygen known?

Self-Assessment Exercises 3

1. Which cell organelle is referred to as the Powerhouse of the cell?
2. What do you refer to as the double-membrane structure that constitutes the outermost portion of the nucleus?

1.6 Summary

You have learnt in this unit that the cell falls into one of two broad categories: prokaryotic and eukaryotic. You have also learnt that the predominantly single-celled organisms of the domains Bacteria and Archaea are classified as prokaryotes, and all other animal cells, plant cells, fungi, and protists are eukaryotes, and how to draw and describe the structure of the various cell organelles

1.7 References/Further Readings/Web Sources

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https://www.youtube.com/watch?v=8v4HE8dCfgI

1.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Examples of eukaryotes include almost every unicellular organism with a nucleus and all multicellular organisms.
2. Prokaryotes are always unicellular, unlike eukaryotes which are both unicellular and multi-cellular

Answers to SAE 2

1. Flagella are long, hair-like structures that extend from the plasma membrane and are utilised to move a complete cell (for example, sperm, Euglena)
2. Glyoxysomes

Answers to SAE 3

1. Mitochondria
2. Nuclear envelope

Unit 2 Cells Communication

Unit structure

2.1 Introduction
2.2 Intended Learning Outcomes (ILOs)
2.3 Cells Communication
2.4 Transport in Cells
2.5 Active transport
2.6 Summary
2.7 References/Further Readings/Web Sources
2.8 Possible Answers to Self-Assessment Exercises

2.1 Introduction

You already know that a group of similar cells working together is called a tissue. As you may expect, if cells are to work together, they must communicate with each other, just as you need to communicate with others if you work on a group project. Let's take a look at how cells communicate with each other.

2.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you will be able to:

- Explain why and how passive transport occurs
- Understand the processes of osmosis and diffusion
- Define tonicity and describe its relevance to passive transport
- Understand how electrochemical gradients affect ions
- Describe endocytosis, including phagocytosis, pinocytosis, and receptor-mediated endocytosis
- Understand the process of exocytosis

3.3 **Cells Communication**

We have devoted a lot of time to study the components of a cell. Now what exactly is outside? What kind of cell you are looking at makes a big difference. Animal cells have the ability to secrete substances into their environment to create the extracellular matrix, a meshwork of macromolecules that provides support and protection for plants, fungi, and other living things. Here, we'll delve deeper into these extracellular elements and the functions they serve in various cell types.

1. Extracellular Matrix of Animal Cells

Extracellular space is where the majority of animal cells releases stuff; proteins being the main building blocks of these materials, and collagen

the most prevalent protein. Proteoglycans, which are protein molecules with carbohydrates, are woven into collagen fibres. These substances are referred to as the extracellular matrix collectively (Figure 1.). The extracellular matrix not only holds the cells together to form a tissue, but also enables intercellular communication between
The cells. How is this possible?

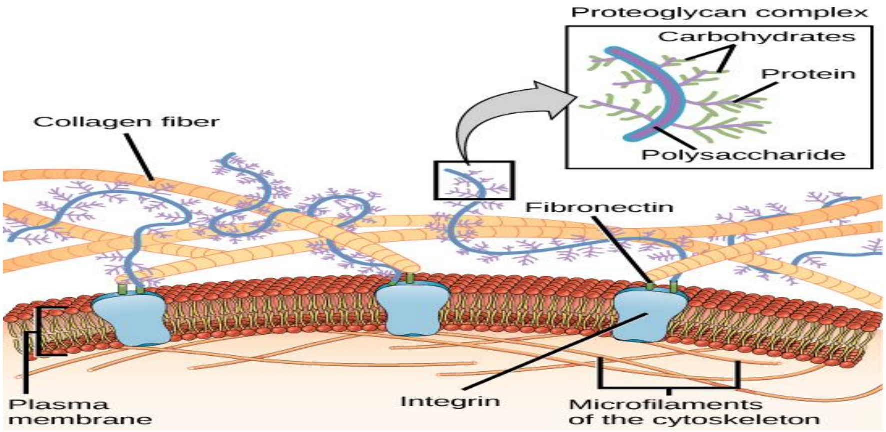


Figure 2.1 The extracellular matrix consists of a network of proteins and carbohydrates.

On the extracellular surfaces of their plasma membranes, cells have protein receptors. The receptor's chemical structure is altered when a molecule from the matrix attaches to it. The microfilaments located immediately inside the plasma membrane are modified by the receptors, which in turn modify their shapes. These conformational changes cause chemical signals to be released inside the cell, which travel to the nucleus and modify the transcription of particular DNA segments. This in turn affects the creation of linked proteins, which alters the activities carried out by the cell. A case study of the extracellular matrix's function in cell communication is blood coagulation. When blood vessel lining cells are harmed, they exhibit a protein receptor known as tissue factor. When tissue factor binds with another factor in the extracellular matrix, it causes platelets to adhere to the wall of the damaged blood vessel, stimulates the adjacent smooth muscle cells in the blood vessel to contract thus, constricting the blood vessel, and initiates a series of steps that stimulate the platelets to produce clotting factors.

2. Intercellular Junctions

Intercellular junctions, which allow cells to communicate directly with one another, are another method of cell communication. Animal and plant cells function in this fashion somehow differently. In contrast to animal cell interactions like tight junctions, gap junctions, and desmosomes, plant cell junctions are called plasmodesmata.

3. Plasmodesmata

In general, the cell wall that encloses each plant cell prevents the lengthy stretches of plasma membranes from nearby plant cells from touching one another. So how does a plant get water and other nutrients from the soil from its roots to its stems and finally to its leaves? Vascular tissues (xylem and phloem) are predominantly used in this transport. Additionally, there are structural alterations known as plasmodesmata (plural: plasmodesma), which are numerous channels that pass through the cell walls of neighbouring plant cells, connect their cytoplasm, and allow materials to be transported from one cell to the next and thus throughout the entire plant.

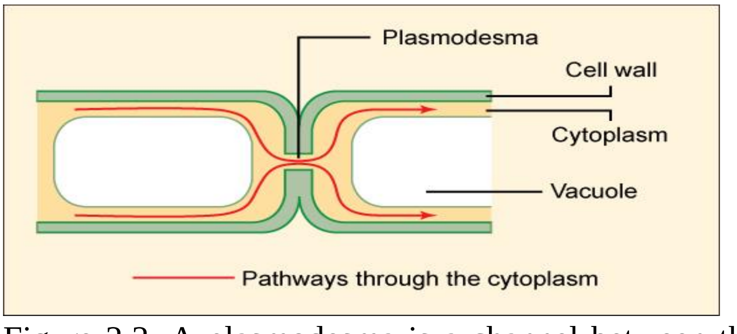


Figure 2.2. A plasmodesma is a channel between the cell walls of two adjacent plant cells. Plasmodesmata allow materials to pass from the cytoplasm of one plant cell to the cytoplasm of an adjacent cell.

4. Tight Junctions

A **tight junction** is a watertight seal between two adjacent animal cells (Figure 2.3). The cells are held tightly against each other by proteins (predominantly two proteins called claudins and occludins).

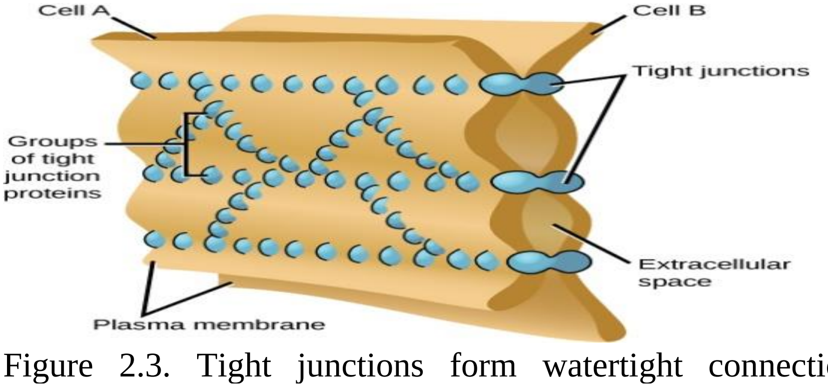


Figure 2.3. Tight junctions form watertight connections between adjacent animal cells. Proteins create tight junction adherence.

This tight adherence prevents materials from leaking between the cells; tight junctions are typically found in epithelial tissues that line internal organs and cavities, and comprise most of the skin. For example, the tight junctions of the epithelial cells lining your urinary bladder prevent urine from leaking out into the extracellular space.

5. Desmosomes

These are found only in animal cells and act like spot welds between adjacent epithelial cells (Figure 2.4.). Short proteins called cadherins in the plasma membrane connect to intermediate filaments to create desmosomes. The cadherins join two adjacent cells together and maintain the cells in a sheet-like formation in organs and tissues that stretch, like the skin, heart, and muscles.

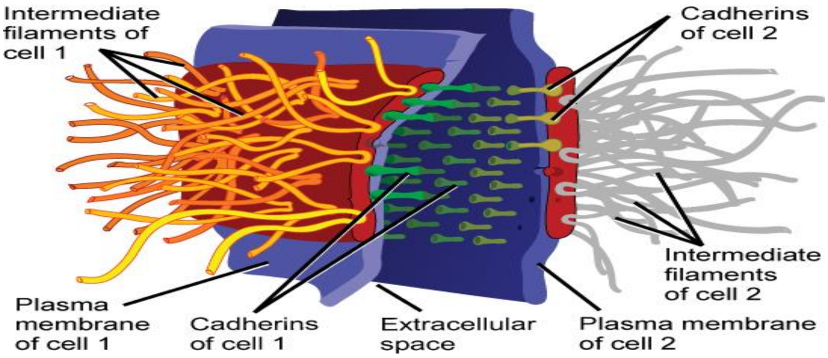


Figure 2.4. A desmosome forms a very strong spot weld between cells. It is created by the linkage of cadherins and intermediate filaments. (credit: modification of work by Mariana Ruiz Villareal)

6. Gap Junctions

Gap junctions in animal cells are like plasmodesmata in plant cells in that they are channels between adjacent cells that allow for the transport of ions, nutrients, and other substances that enable cells to communicate (Figure 6). However, gap junctions and plasmodesmata differ.

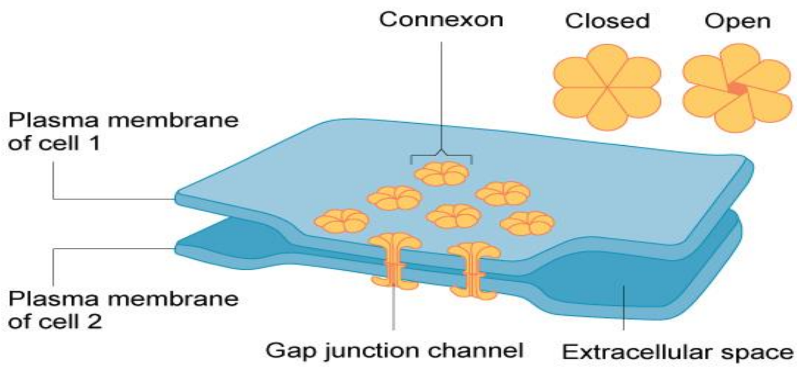


Figure 2.5. A gap junction is a protein-lined pore that allows water and small molecules to pass between adjacent animal cells. (credit: modification of work by Mariana Ruiz Villareal)

Gap junctions develop when a set of six proteins (called connexins) in the plasma membrane arrange themselves in an elongated donut-like configuration called a connexon. When the pores ("doughnut holes") of connexons in adjacent animal cells align, a channel between the two cells forms. Gap junctions are particularly important in cardiac muscle: The electrical signal for the muscle to contract is passed efficiently through gap junctions, allowing the heart muscle cells to contract in tandem. What is the watertight seal between two adjacent animal cells called?

Self-Assessment Exercises 1

1. Gap Junctions
2. What is the role of intercellular Junctions in cells

2.4 Transport in Cells

Transport is the movement of substances across the cell membrane either into or out of the cell. Sometimes things just move through the phospholipid bilayer. Other times, substances need the assistance of a protein, like a channel protein or some other transmembrane protein, to cross the cell membrane. Several types could be noticed:

1. Passive transport

Plasma membranes must permit some compounds to enter and exit a cell while blocking the entry of hazardous molecules and the exit of necessary ones. Plasma membranes are selectively permeable (semipermeable); chemicals pass through them while others do not. The cell would be destroyed if it were to lose its selectivity, which would prevent it from continuing to function. Some cells need certain compounds in greater concentrations than others. These cells must have a method of acquiring these substances from the extracellular fluids. The movement of specific materials back and forth may cause this to occur passively, or the cell may have unique processes to ensure movement. Adenosine triphosphate (ATP), primarily used by cells, is used to establish and maintain an unbalanced distribution of ions on the opposing sides of their membranes. These tasks are aided by the plasma membrane's structure, but it has significant drawbacks. Passive membrane transport methods are the most direct. Passive transport is a phenomenon that occurs naturally and doesn't require energy. Diffusion is the process by which chemicals travel passively from a region of higher concentration to a region of lower concentration. A concentration gradient is a difference in the concentration of one substance throughout a physical region.

2. Selective Permeability

Plasma membranes are asymmetric, which means that despite the phospholipids' creation of a mirror image, the interior and exterior of the membrane are not the same. Integral proteins that function as pumps or channels only move one way. Outside the plasma membrane are also found carbohydrates that are linked to proteins or lipids. These carbohydrate complexes assist the cell in binding components from the extracellular fluid that the cell need. This greatly enhances the selectiveness of plasma membranes. Keep in mind that the hydrophilic and hydrophobic sections of plasma membranes exist. This property facilitates the passage of some elements through the membrane while impeding the passage of others. Lipid-soluble material scan easily pass through the hydrophobic lipid core of the membrane. The plasma membranes in the gastrointestinal system and other tissues are easily permeable to substances like the fat-soluble vitamins A, D, E, and K. Drugs that are soluble in fat are also easily absorbed by cells and are quickly absorbed by tissues and organs of the body. Carbon dioxide and oxygen molecules have no charge and go through via simple diffusion. The membrane has trouble with polar chemicals. While some polar molecules can easily connect with a cell's exterior, they cannot easily travel through the plasma membrane's lipid core. Small ions could also easily pass through the cracks in the mosaic of the membrane, but they can't because of their charge ions.

3. Diffusion

Transport that is done passively is called diffusion. Until the concentration is the same throughout the space, a single substance has a tendency to travel from an area of high concentration to an area of low concentration. You are aware of how compounds diffuse through the air. Consider the scenario of someone opening a perfume bottle in a crowded space. The perfume is most concentrated in the bottle and least concentrated at the room's perimeter. As the perfume vapour diffuses, or spreads from the bottle, more and more individuals will eventually be able to smell it. Diffusion is the process by which certain substances pass through the plasma membrane and others diffuse within the cytoplasm of the cell (Figure 2.6).

Rather the different concentrations of materials in different areas are a form of potential energy, and diffusion is the dissipation of that potential energy as materials move down their concentration gradients, from high to low.

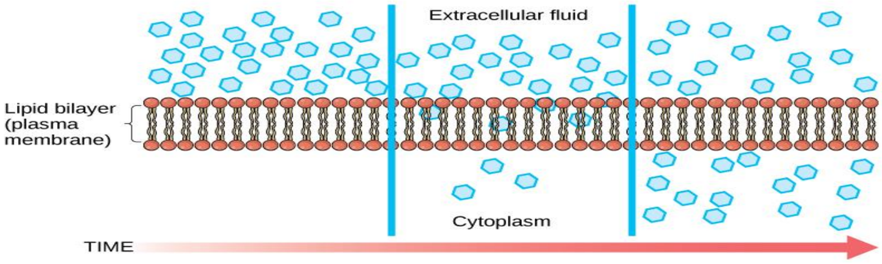


Figure 2.6. Diffusion through a permeable membrane follows the concentration gradient of a substance, moving the substance from an area of high concentration to one of low concentration.

Each separate substance in a medium, such as the extracellular fluid, has its own concentration gradient, independent of the concentration gradients of other materials. In addition, each substance will diffuse according to that gradient. The rate of diffusion is affected by several factors. These include:

- Extent of the concentration gradient: The greater the difference in concentration, the more rapid the diffusion. The closer the distribution of the material gets to equilibrium, the slower the rate of diffusion becomes.
- Mass of the molecules diffusing: More massive molecules move more slowly, because it is more difficult for them to move between the molecules of the substance they are moving through; therefore, they diffuse more slowly.
- Temperature: Higher temperatures increase the energy and therefore the movement of the molecules, increasing the rate of diffusion.
- Solvent density: As the density of the solvent increases, the rate of diffusion decreases. The molecules slow down because they have a more difficult time getting through the denser medium (facilitated transport).

Material flows across the plasma membrane with the help of transmembrane proteins along a concentration gradient (from high to low concentration) in assisted transport, also known as facilitated diffusion, without using up any cellular energy. The compounds that are transported more easily and quickly would not otherwise diffuse over the plasma membrane. The proteins that cover the plasma membrane's surface hold the key to transporting polar chemicals and other compounds across it. The substance being transported is initially anchored to protein or glycoprotein receptors on the plasma membrane's outer surface. This enables the substance that the cell requires to be taken out of the extracellular fluid. The substances are then transferred to particular integral proteins that help them pass through the membrane by forming channels or pores that allow specific substances to do so. Transport proteins are the collective name for the integral proteins that play a role in facilitated transport and serve as either carriers or material channels.

4. Osmosis

The process of osmosis involves the passage of free water molecules across a semipermeable membrane in response to the gradient of water concentration across the membrane, which is inversely proportional to the concentration of the solutes. Osmosis moves just water across a membrane, and the barrier restricts the diffusion of solutes in the water, whereas diffusion transports material across membranes and within cells. A specific example of diffusion is osmosis. Water flows from a region with a high concentration of free water molecules to one with a low concentration of free water molecules, just like other things do. Imagine a beaker with two sides or halves separated by a semipermeable membrane (Figure 2.7). The water level is the same on both sides of the membrane, but the concentration of a dissolved material, or solute, that cannot cross the barrier varies on each side. Water, the solvent, will have different concentrations on either side of the membrane if the volume of water is the same but the solute concentrations are different.

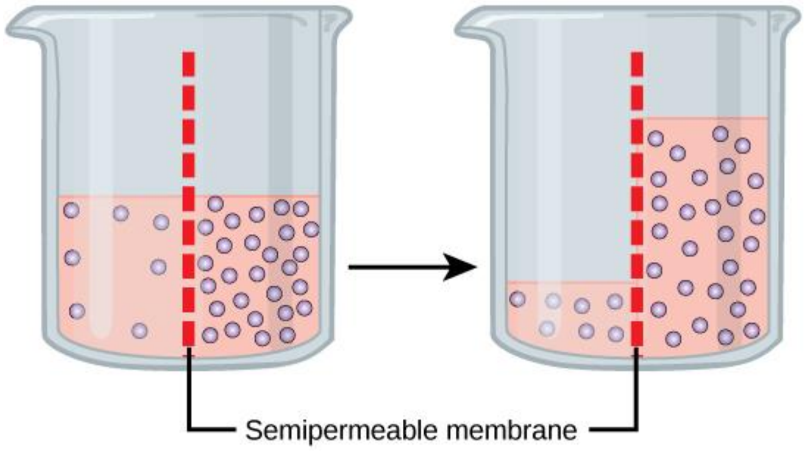
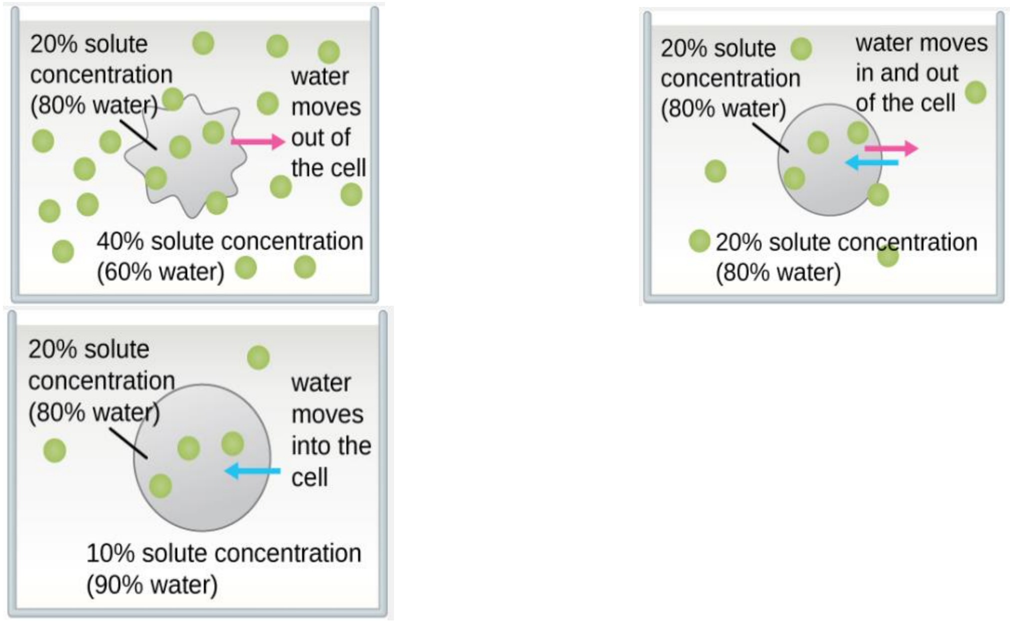


Figure 2.7. In osmosis, water always moves from an area of higher concentration (of water) to one of lower concentration (of water).

The selectively permeable membrane in this system is impermeable to the solute. The molecules travel and, if possible, distribute uniformly throughout the medium, according to a diffusion principle. Only substances that can pass through the membrane, however, will diffuse across it. In this case, the water can permeate through the barrier even though the solute cannot. In this system, water exhibits a gradient in concentration. Water will therefore diffuse along its gradient of concentration and cross the membrane to the side where it is less concentrated. Osmosis, the process of water diffusing through a membrane, will continue until the water's concentration gradient is zero. Living systems continually undergo osmosis, the classic example used to demonstrate osmosis and osmotic pressure is to immerse cells into sugar solutions of various concentrations. There are three possible relationships that cells can encounter when placed into a sugar solution.



A B C

Figure 2.8. Shows what happens in osmosis through the semi-permeable membrane of the cells.

A= Hypertonic solution. A solution that has a higher solute concentration than another solution. Water particles will move out of the cell, causing crenation.

B= Isotonic solution. A solution that has the same solute concentration as another solution. There is no net movement of water particles, and the overall concentration on both sides of the cell membrane remains constant.

C= Hypotonic solution. A solution that has a lower solute concentration than another solution. Water particles will move into the cell, causing the cell to expand and eventually lyse.

The concentration of solute in the solution can be greater than the concentration of solute in the cells. This cell is described as being in a hypertonic solution (hyper = greater than normal). The net flow or water will be out of the cell

The concentration of solute in the solution can be equal to the concentration of solute in cells. In this situation, the cell is in an isotonic solution (iso = equal or the same as normal). The amount of water entering the cell is the same as the amount leaving the cell

The concentration of solute in the solution can be less than the concentration of solute in the cells. This cell is in a hypotonic solution (hypo = less than normal). The net flow of water will be into the cell

5. Tonicity

The quantity of solute in a solution is referred to as tonicity. The osmolarity of a solution is a measurement of its tonicity, or the total number of solutes dissolved in a given volume of solution. The relationship between the osmolarity of a cell and the osmolarity of the extracellular fluid in which the cell is contained is termed hypotonic, isotonic, and hypertonic. Water enters the cell in a hypotonic solution, eg. tap water, since the extracellular fluid has a lower solute concentration than the fluid inside the cell. The prefix hypo- denotes that the extracellular fluid has a lower concentration of solutes or a lower osmolarity than the cell cytoplasm. Also, it implies that the extracellular fluid contains more water than the cell does. In this case, water will enter the cell by following its gradient of concentration. An animal cell may lyse or burst as a result of this. The extracellular fluid, such as saltwater, has less water than the cell does in a hypertonic solution (the prefix hyper- alludes to the extracellular fluid having a higher concentration of solutes than the cell's cytoplasm). The water will leave the cell since the solute concentration is lower there. The solute is actually sucking water out of the cell. An animal cell may shrink or crenate as a result of this. The extracellular fluid and the cell have the same osmolarity in an isotonic solution. There won't be any net flow of water into or out of the cell if the solute content of the cell and the extracellular fluid are equal. Blood cells have distinctive appearances in hypertonic, isotonic, and hypotonic solutions. Certain species have cell walls that enclose the plasma membrane and inhibit cell lysis, including some plants, fungi, bacteria, and protists. The plasma membrane can only stretch as far as the cell wall allows, preventing the cell from lysing. In fact, water always enters a cell if water is available, and the cytoplasm in plants is always slightly hypertonic in comparison to the cellular environment. This increase in water pressure creates turgor pressure, which stiffens the plant's cell walls (Figure 2.9). Turgor pressure provides support for non woody plants. Water will leak out of the cell if the plant cells become hypertonic, which happens during droughts or if a plant is not given enough water. In this situation, plants wilt as they lose turgor pressure.

When is a solution said to be isotonic?

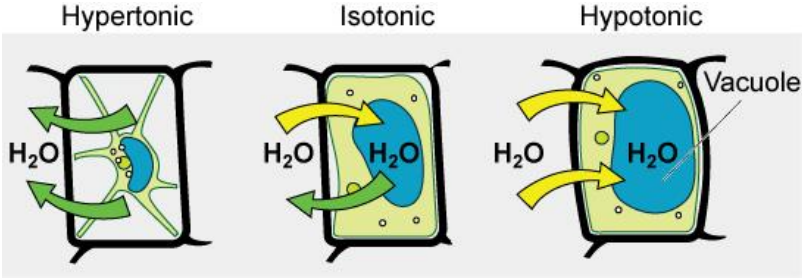


Figure 2.9. The turgor pressure within a plant cell depends on the tonicity of the solution that it is bathed in.

Self-Assessment Exercises 2

1. How is the relationship between the osmolarity of a cell and the osmolarity of the extracellular fluid in which the cell is contained described?
2. Outline factors affecting rate of diffusion.

2.5 Active transport

The usage of the cell's energy, often in the form of adenosine triphosphate (ATP), is necessary for active transport processes. The cell must expend energy to transfer a material into the cell when it must move against its concentration gradient, or when the concentration of the substance inside the cell must be higher than its concentration in the extracellular fluid. Small-molecular weight substances, such as ions, are transported through the membrane via several active transport processes. Cells must expel and take in bigger molecules and particles in addition to transporting tiny ions and molecules via the membrane. Some cells have the capacity to completely engulf unicellular creatures. You may have guessed properly when you said that the cell needs energy to take in and release big particles. A large particle, however, cannot pass through the membrane, even with energy supplied by the cell.

1. Electrochemical Gradient

While simple concentration gradients—differential concentrations of a chemical across a region or a membrane—have been covered, gradients in living systems are more intricate. There is an electrical gradient, or difference in charge, across the plasma membrane because cells contain proteins, the majority of which are negatively charged, and because ions migrate into and out of cells. Living cells have an electrically negative interior compared to the extracellular fluid in which they are bathed. Cells also have higher potassium (K^+) and lower sodium (Na^+) concentrations than the extracellular fluid does. Therefore, in a live cell, the electrical gradient of Na+ (a positive ion) tends to pull it inward to the negatively charged interior, while the concentration gradient of Na^+ favours diffusion of the ion into the cell. However, the situation is more complicated for some elements, including potassium; while the concentration gradient of K^+ promotes diffusion out of the cell, the electrical gradient of K^+ favours diffusion of the ion into the cell (Figure 2.10). Its electrochemical gradient, which refers to the combined gradient that influences an ion, is crucial for muscle and nerve cells in particular.

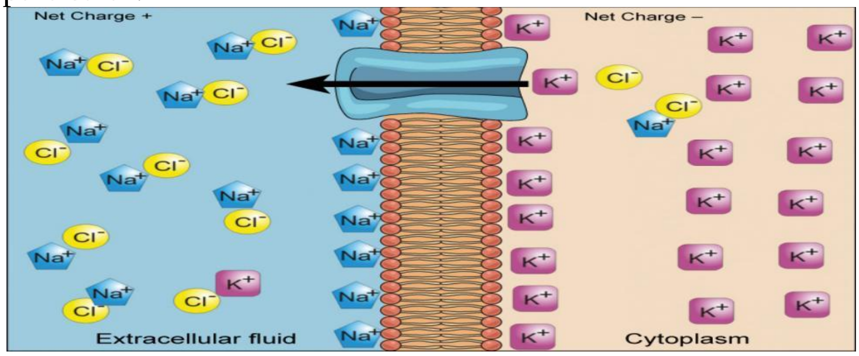


Figure 2.10. Electrochemical gradients arise from the combined effects of concentration gradients and electrical gradients. (credit: modification of work by "Synaptitude"/Wikimedia Commons)

2. Moving Against a Gradient

The cell must use energy to transfer materials against a concentration or electrochemical gradient. ATP is used to generate this energy, which is produced by cellular metabolism. Pumps or carrier proteins collectively refer to active transport systems that operate against electrochemical gradients. Small compounds continuously move through plasma membranes, with the exception of ions. In the face of these passive variations, active transport keeps concentrations of ions and other chemicals needed by live cells constant. A significant portion of a cell's metabolic energy supply might go into supporting these processes. Active transport mechanisms are vulnerable to several metabolic toxins that disrupt the flow of ATP since they rely on cellular metabolism for energy. There are two methods for moving macromolecules and materials with modest molecular weights. **Primary active transport** generates a difference in charge across a membrane while moving ions across it. A material, such as an ion, is transported into the cell via the major active transport system using ATP, and frequently at the same time, a different substance is transported out of the cell. An essential pump in animal cells called the sodium-potassium pump uses energy to transfer potassium ions into the cell and a different number of sodium ions out of the cell (Figure 2.11). This pump's operation causes a concentration and charge differential to exist across the membrane.

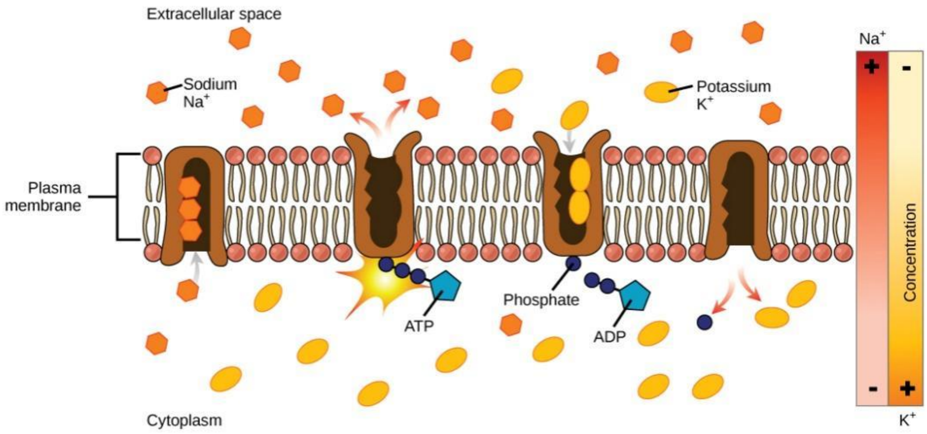


Figure 2.11. The sodium-potassium pump moves potassium and sodium ions across the plasma membrane.

The movement of material utilising the primary active transport-created electrochemical gradient is referred to as **secondary active transport**. Other molecules, including amino acids and glucose, can enter the cell through membrane channels by utilising the energy of the electrochemical gradient produced by the major active transport mechanism through secondary active transport utilising a hydrogen ion gradient in the mitochondrion, ATP being created.

3. Endocytosis

Active transport, such as endocytosis, transports particles into a cell, including big molecules, fragments of cells, and even complete cells. Endocytosis comes in a variety of forms, but they all have one thing in common: Invasion of the cell's plasma membrane creates a pocket around the target particle. The particle is held in a freshly generated vacuole made of the plasma membrane after the pocket pinches off.

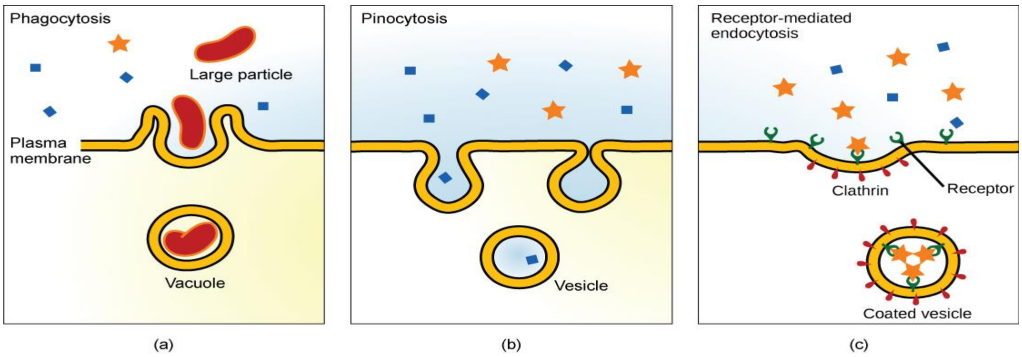


Figure 2.12. Three variations of endocytosis are shown. (a) In one form of endocytosis, phagocytosis, the cell membrane surrounds the particle and pinches off to form an intracellular vacuole. (b) In another type of endocytosis, pinocytosis, the cell membrane surrounds a small volume of fluid and pinches off, forming a vesicle. (c) In receptor-mediated endocytosis, uptake of substances by the cell is targeted to a single type of substance that binds at the receptor on the external cell membrane.

A cell takes in huge objects like cells through a process called phagocytosis. For example, a kind of white blood cell known as a neutrophil removes the intruder when bacteria enter the human body through this mechanism, encircling and engulfing the bacterium, which is subsequently destroyed by the neutrophil (Figure 2.12). Pinocytosis is an alternative to endocytosis. This term, which literally translates to "cell drinking," was given to a cell when it was thought that the cell was actively ingesting extracellular fluid at the time it was named. Actually, this process draws the necessary solutes from the extracellular fluid that the cell needs. Utilizing binding proteins in the plasma membrane that are specific for particular compounds, a targeted version of endocytosis is carried out (Figure 2.12.). The substance and the proteins enter the cell after the particles bind to the proteins and the plasma membrane protrudes. It won't be eliminated from the tissue fluids or blood if passage across the membrane of the target of receptor-mediated endocytosis is unsuccessful. Instead, it will persist and become more concentrated in those fluids. Failure of receptor-mediated endocytosis is a contributing factor in some human illnesses. For example, receptor-mediated endocytosis is used to remove low-density lipoprotein, or LDL, generally known as "bad" cholesterol, from the blood. LDL receptors are damaged in the human hereditary condition familial hypercholesterolemia or missing entirely. People with this condition have life-threatening levels of cholesterol in their blood, because their cells cannot clear the chemical from their blood.

4. Exocytosis

This process stands in contrast to these mechanisms for introducing material into a cell. Exocytosis serves to expel material from the cell into the extracellular fluid, which is the polar opposite of the activities outlined above. Membrane-encased particles combine with the inside of the plasma membrane. The particle is released into the extracellular space as a result of this fusion, which makes the membranous envelope of the cell accessible to the outside (Figure 10.)

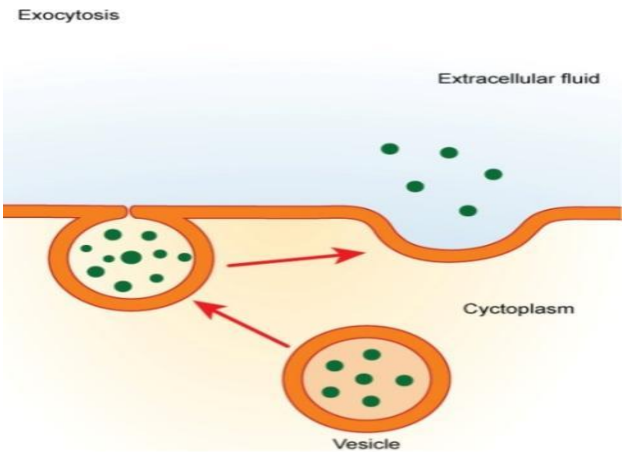


Figure 2.13. In exocytosis, a vesicle migrates to the plasma membrane, binds, and releases its contents to the outside of the cell. What is Pinocytosis?

Self-Assessment Exercises 3

Differentiate between the following type of solutions:
1. Hypertonic solution
2. Isotonic solution
3. Hypotonic solution

2.6 Summary

You must have learned why and how passive transport occurs within the cells of multicellular organisms. You have also studied the processes of osmosis, diffusion, tonicity and describe its relevance to passive transport. You have also learned about how electrochemical gradients affect ions.

You have also studied the processes;

- Describe endocytosis, including phagocytosis, pinocytosis, and receptor-mediated endocytosis
- Understand the process of exocytosis

2.7 References/Further Readings/Web Sources

Reece, B. , L. A. Urry, M. L. Cain, S. A. Wasserman, P. V. Minorsky, R. B. Jackson.Biology, 9th edition, Benjamin Cummings p. 104-118

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organelles https://youtu.be/tgMZcHpL_ts
cyto https://youtu.be/9kb_JJwapRg
membrane https://youtu.be/gh4ciqmXLsU)

2.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Gap junctions in animal cells are like plasmodesmata in plant cells in that they are channels between adjacent cells that allow for the transport of ions, nutrients, and other substances that enable cells to communicate
2. Intercellular junctions, allow cells to communicate directly with one another, are another method of cell communication.

Answers to SAE 2

1. It is described by the following terms: terms hypotonic, isotonic, and hypertonic.
2. Factors affecting rate of diffusion

- Extent of the concentration gradient
- Mass of the molecules diffusing
- Temperature
- Solvent density

Answers to SAE 3

1= Hypertonic solution. A solution A solution that has a higher solute concentration than another solution. Water particles will move out of the cell, causing crenation.

2= Isotonic solution. A solution that has the same solute concentration as another solution. There is no net movement of water particles, and the overall concentration on both sides of the cell membrane remains constant.

3= Hypotonic solution. A solution that has a lower solute concentration than another solution. Water particles will move into the cell, causing the cell to expand and eventually lyse.

Unit 3 Tissues, Organs and Organ Systems

Unit Structure

3.1 Introduction
3.2 Intended Learning Outcomes (ILOs)
3.3 Tissues, Organs and Organ Systems
 1.3.1 Types of Animal Tissues
 1.3.2 Types of Plant Tissues
3.4 The Organs and Organ System
 1.4.1 The Organ Systems in Animals
 1.4.2 The Organ Systems in Plants
3.5 Organs in a system work together.
3.6 Summary
3.7 References/Further Readings/Web Sources
3.8 Possible Answers to Self-Assessment Exercises

3.1 Introduction

You will Learn about the various tissue types of both plants and animals and organ and organ systems of plants and animals. You will also learn how the organs in a system work together.

3.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you will be able to:

- Define tissues, organs and organ system as part of the level of organization of living things
- Describe the organ in both animals and plants
- Describe the major organ systems of the animal and plant bodies
- Explain how organs in a system work together and
- Explain the workings of organ systems in animals and plants.

3.3 Tissues, Organs and Organ Systems

In physiology, a group of physically and functionally related cells and their intercellular materials make up a tissue, which is a level of organisation in multicellular organisms. Tissues are by definition absent in unicellular organisms. Even the most basic multicellular animals, like sponges, lack or have poorly differentiated tissues. However, highly developed multicellular animals and plants have specialised tissues that can plan and control an organism's response to its environment. Life would be simple if you were a single-celled organism and you were in a nutrient-rich environment. If you were an amoeba living in a pond, for example, you could directly take in nutrients from the water. Through your cell membrane, the oxygen you need for metabolism could enter, and carbon dioxide and other waste products could exit. You could simply divide yourself in half when the time comes to reproduce!

3.3.1 Types of Animal Tissues

There are four different types of tissues in animals: connective, muscle, nervous, and epithelial. Groups of tissues make up organs in the body such as the brain and heart.

1. Connective

Groups of various tissues are connected or divided by connective tissue. It can be found between every other tissue and organ in the body. Cells and ground material, a gel that surrounds cells, make up connective tissue. Except for lymph and blood, the majority of connective tissues comprises fibres, which are long, slender proteins. Collagenous fibres attach bones to tissues, elastic fibres enable the movement of organs such as the lungs, and reticular fibres give cells structural support. In addition, connective tissue enables the diffusion of oxygen from blood vessels into the cells. About 1 in every 10 people have a disorder involving connective tissues. Some connective tissue disorders include sarcomas, Marfan syndrome, lupus, and scurvy; is a Vitamin C deficiency that leads to fragile connective tissues.

2. Muscle

All the muscles in the body are made of muscular tissue, and the ability to contract is due to the tissue's specific makeup. Skeletal muscle, cardiac muscle, and smooth muscle are the three different forms of muscle tissue. Skeletal muscle holds tendons to bones and permits movement of the body. The heart contains cardiac muscle, which contracts to pump blood. In addition to the intestines, where it aids in the passage of food through the digestive tract, smooth muscle is also present in blood arteries, the uterus, and the bladder. The sarcomeres (a unit of muscle tissue) in skeletal and cardiac muscles are striated, which means they are arranged in a predictable pattern. Sarcomeres are absent in the smooth muscle. One condition of the muscle tissue is Duchenne muscular dystrophy. Muscle atrophy is brought on by this genetic condition over time. As the muscles deteriorate, they shorten, which can result in scoliosis and stiff joints. Due to the disorder's X chromosome-associated gene, those who have it are often male (of which males have only one).

3. Nervous

The brain, spinal cord, and peripheral nerves are all components of the nervous system and contain nervous tissue. Neurons, which are nerve cells, and neuroglia, which support the transmission of nerve impulses, make up this structure. Gray matter and white matter in the brain, as well as nerves and ganglia in the peripheral nervous system, are two of the four categories of nervous tissue. The primary distinction between grey and white matter is that although white matter's axons are myelinated, grey matter's are not. A white, fatty material called myelin protects neurons and is essential for the proper operation of the neurological system. Memory loss, irritability, and confusion are some of the signs of Alzheimer's disease that are brought about by the degeneration of nerve tissue. Another condition that involves the degeneration of neural tissue and, over time, the loss of higher brain functions is Amyotrophic Lateral Sclerosis (ALS). Other conditions affecting the nervous system include multiple sclerosis, in which the immune system attacks and damages the nervous system, Huntington's disease, in which an abnormal protein results in the death of neurons, and Parkinson's disease, in which the dopamine-producing region of the brain is compromised.

4. Epithelial

The skin, trachea, reproductive system, and inner lining of the digestive tract are only a few of the organ surfaces covered in epithelial tissue, or epithelium. It functions to absorb water and nutrients, get rid of waste, and secrete enzymes or hormones in addition to forming a barrier that aids in protecting organs. All of the glands in the body are created by epithelial ingrowths. Skin conditions like eczema and psoriasis, which can result in rashes, are examples of prevalent epithelial tissue illnesses. A carcinoma is a form of cancer that arises from epithelial tissue. Asthma is characterised by airway inflammation that causes shortness of breath and is caused by epithelial cells in the airways.

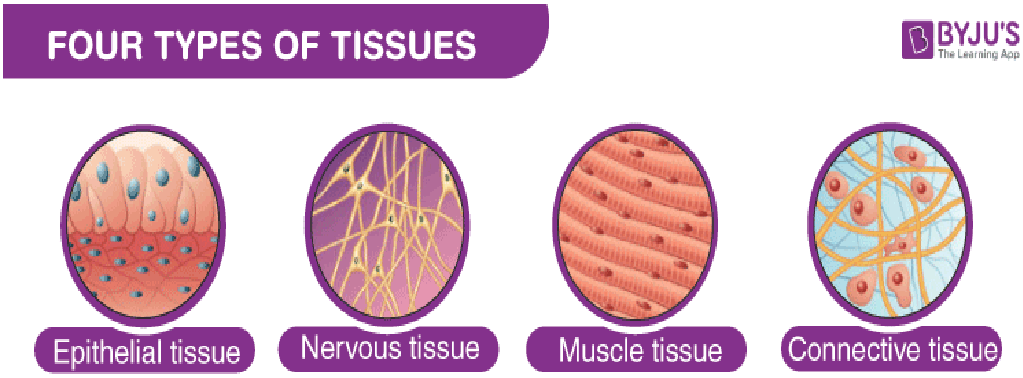

Figure 3.1. The different types of Tissues: Source: https://byjus.com/biology/structural-organization-animals/

3.3.2 Types of Plant Tissues

Plants are multicellular eukaryotes, and their tissue systems are made up of many cell types that serve distinct purposes. Meristematic tissue and permanent (or non-meristematic) tissue are the two main forms of plant tissue systems. Meristems, which are areas of plants that experience continuous cell division and expansion, are where the meristematic tissue's cells may be located. Meristematic tissue cells continue to divide and support plant growth despite being either undifferentiated or incompletely differentiated. The meristematic tissue in a plant's apical meristems, which are found at the tips of its stems and roots, allows it to grow longer. A mature plant's lateral meristems enable increase in thickness or girth. Only monocots have intercalary meristems, which are found at the bases of leaf blades and at nodes (the areas where leaves attach to a stem). The monocot leaf blade can lengthen from the leaf base because of this tissue; for example, it permits lawn grass leaves to lengthen even after frequent mowing.

Meristems generate cells that swiftly specialise or differentiate into permanent tissue, dormant plant cells, which are no longer actively dividing. Such cells acquire particular functions and stop proliferating. Based on where they are located in the plant, meristematic tissues are divided into three categories; Dermal, vascular, and ground tissues. Vascular tissue carries water, minerals, and sugars to various areas of the plant, while dermal tissue covers and protects the plant. In addition to acting as a photosynthetic site and vascular tissue support matrix, ground tissue also helps to store water and sugars. Secondary tissues can be straightforward (made up of similar cell types) or complex (composed of different cell types). For instance, dermal tissue is a straightforward tissue that covers the plant's exterior and regulates gas exchange. One example of a complex tissue is vascular tissue, which is composed of the specialised conducting tissues; xylem and phloem. Xylem tissue conducts water and nutrients from the roots to various sections of the plant and are made up of three main cell types; xylem parenchyma, vessel elements, and tracheids (two of which conduct water). The phloem tissue transports organic compounds from the centre of photosynthesis to other sections of the plant are made up of four distinct cell types; companion cells, sieve cells (which conduct photosynthates), phloem parenchyma, and phloem fibres. Phloem conducting cells are alive at maturity, in contrast to xylem conducting cells. Phloem and xylem are constantly next to one another (Figure 3.2). The xylem and phloem combine to produce a structure in stems known as a vascular bundle; in roots, this structure is known as a vascular stele or vascular cylinder.

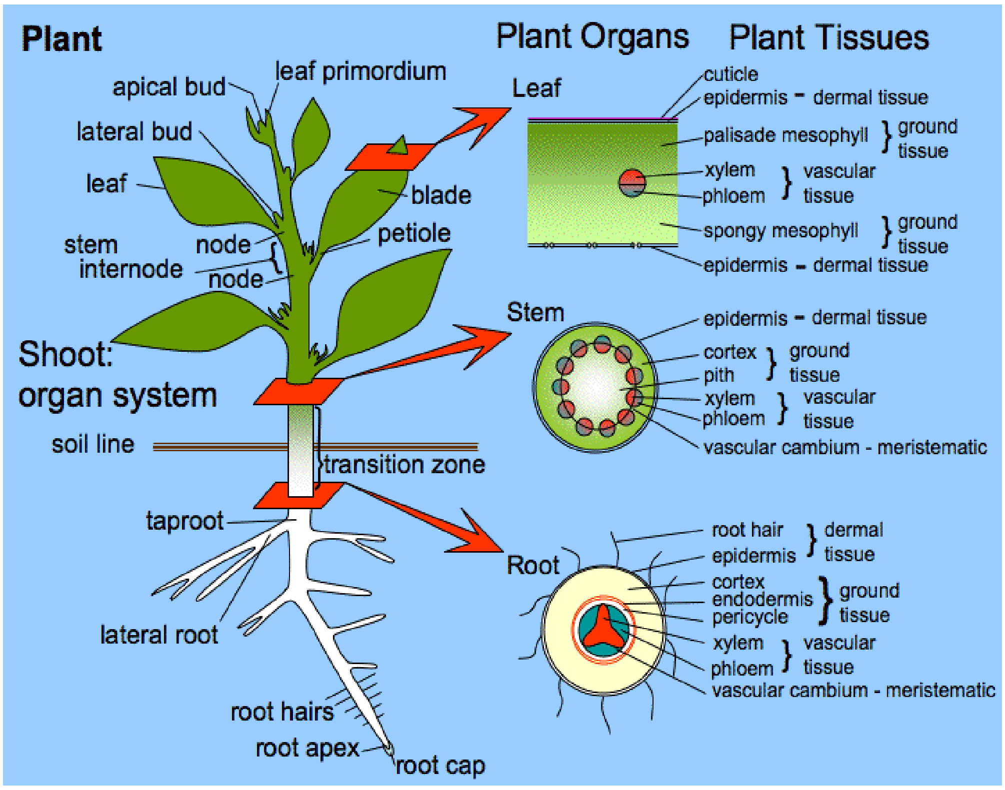

Figure 3.2. Plant Organs and Tissues (Each plant organ contains all three tissue types).
Source: http://plantphys.info/plant_physiology/plantbasics1.shtml.

Assessment Exercises 1

1. What are different types of animal tissues?
2. What is the function of an epithelial tissue?

3.4 The Organs and Organ System

The organ is the next level of animal organisation. An organ is a group of tissues that structurally constitute a functional unit that is specialised to carry out a specific function. The word organ comes from the Latin word "organum," which means an instrument or tool. Tissues with a similar structure and function make up each organ. The heart, skin (the biggest human organ), lungs, stomach, kidneys, and heart are a few examples of organs. Organs are composed of two or more types of tissue that are arranged to perform specific functions. For example, the heart pumps blood, the lungs bring in oxygen and eliminate carbon dioxide, and the skin provides a barrier to protect internal structures from the external environment. The small intestine's stratified walls serve as a good illustration of how tissues combine to form an organ. Epithelial cells line the interior of the colon; some of these cells release hormones or digesting enzymes, while others absorb nutrition. There are layers of smooth muscle and connective tissue surrounding the epithelium layer, as well as glands, blood arteries, and neurons. Under the direction of the accompanying neuronal networks, the smooth muscle contracts to convey food through the intestine.

Plants have four main organs:

i). The primary organs for absorbing sunlight for photosynthesis are leaves;
ii. The primary organs that draw water and nutrients from the soil are the roots;
iii). The primary organs for moving materials between leaves and roots are stems; and
iv). Similarly, flowers, reproductive organs release seeds that develop into new plants.

Typically, flowers have vibrant petals that entice bees, butterflies, and other pollinators. The next level of organisation are the organ systems. An organ system is made up of two or more organs that cooperate to carry out a certain task for the organism. The circulatory, neurological, skeletal, muscular, integumentary, endocrine, digestive, immunological, reproductive, excretory, and respiratory systems are the main organ systems that make up the human body. The integumentary system, for instance, consists of the skin, hair, nails, and glands. The deeper tissues and organs of the body are safeguarded by this system, which receives impulses from the outside world. There are several organs that make up the digestive system. The stomach aids in digestion and stores food. Intestines break down food and take in nutrients. The liver contributes to the function of the digestive system by secreting bile, a lipid-degrading agent that aids in the digestion of fats. Multiple organ systems can cooperate with a single organ. For example, the liver and circulatory system collaborate to filter wastes from the blood. Although we frequently refer to the various organ systems as though they were separate, components of one system may have an impact on another. The various systems also have a lot of functional overlap. For example, although we frequently associate the circulatory system with the delivery of oxygen and nutrients to cells, it also contributes to the regulation of body temperature. White blood cells are an essential part of the immune system, and the blood also carries hormones produced by the endocrine system's glands.

1.4.1 The Organ Systems in Animals

S/ NO	Organ system/Function	Organs and tissues involved
1.	Cardiovascular: Transports oxygen, nutrients, and other substances to the cells and transports wastes, carbon dioxide, and other substances away from the cells; it can also help stabilize body temperature and pH	Heart, blood, and blood vessels
2.	Lymphatic: Defends against infection and disease and transfers lymph between tissues and the blood stream	Lymph, lymph nodes, and lymph vessels
3.	Digestive: Processes foods and absorbs nutrients, minerals, vitamins, and water	Mouth, salivary glands, esophagus, stomach, liver, gallbladder, exocrine pancreas, small intestine, and large intestine
4.	Endocrine: Provides communication within the body via hormones and directs long-term change in other organ systems to maintain homeostasis	Pituitary, pineal, thyroid, parathyroids, endocrine pancreas, adrenals, testes, and ovaries.
5.	Integumentary: Provides protection from injury and fluid loss and provides physical defense against infection by microorganisms; involved in temperature control	Skin, hair, and nails
6.	Muscular: Provides movement, support, and heat production	Skeletal, cardiac, and smooth muscles
7.	Nervous: Collects, transfers, and processes information and directs short-term change in other organ systems	Brain, spinal cord, nerves, and sensory organs; eyes, ears, tongue, skin, and nose
8.	Reproductive: Produces gametes—sex cells—and sex hormones; ultimately produces offspring	Fallopian tubes, uterus, vagina, ovaries, mammary glands (female), testes, vas deferens, seminal vesicles, prostate, and penis (male)

S/ NO	Organ system/Function	Organs and tissues involved
9.	Respiratory: Delivers air to sites where gas exchange can occur	Mouth, nose, pharynx, larynx, trachea, bronchi, lungs, and diaphragm
10.	Skeletal: Supports and protects soft tissues of the body; provides movement at joints; produces blood cells; and stores minerals	Bones, cartilage, joints, tendons, and ligaments
11.	Urinary: Removes excess water, salts, and waste products from the blood and body and controls pH	Kidneys, ureters, urinary bladder, and urethra
	Immune: Defends against microbial pathogens—disease-causing agents—and other diseases	Leukocytes, tonsils, adenoids, thymus, and spleen

Although we frequently refer to the various organ systems as if they were separate, components of one system may have an impact on another. For example, the mouth is a part of both the digestive and respiratory systems. The various systems also have a lot of functional overlap. For example, although we frequently associate the circulatory system with the delivery of oxygen and nutrients to cells, it also contributes to the regulation of body temperature. White blood cells are an essential part of the immune system, and the blood also carries hormones produced by the endocrine system's glands.

1.4.2 The **Organ Systems in Plants**

A tissue is created by comparable cells coming together, exactly like in animals and plants. An organ is created when many tissue types collaborate to carry out a certain function; organ systems are created when multiple organs act as a unit. A shoot system and a root system are the two separate organ systems found in vascular plants. The root and any accompanying fibres that branch off the main root are included in the root system, which is normally underground. This structure holds the plant in place and draws moisture and nutrients from the soil. The stem, leaves, and reproductive organs, such as flowers, are all parts of the shoot system, which is normally above ground. Photosynthesis and reproduction are just two of the many tasks performed by this system.

As with animals, the organ systems of plants work together to make up the structure and function of the entire organism.

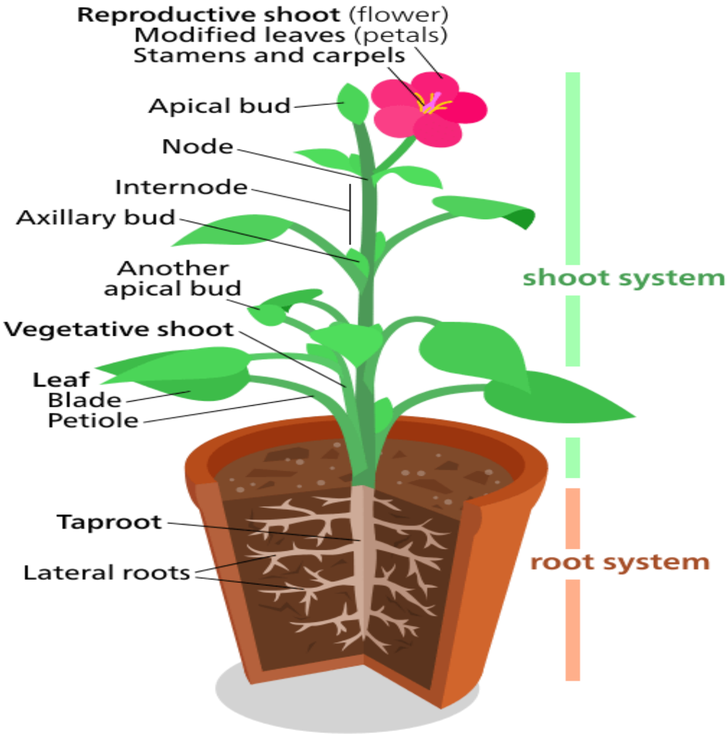

Figure 3.3 The organ system in plants. Source: http://plantphys.info/plant_physiology/plantbasics1.shtml.

Self-Assessment Exercises 2

1. Name the main organs in the digestive system.
2. Which plant organ is most important?
3. What are the organ system of plants working together?

3.5 Organs in a system work together

The organs in an organ system must cooperate with one another in order for the system to function as a whole, just like employees on an assembly line. For example, the digestive system relies on each succeeding organ performing its particular task in order to function—that is, to take in food, break it down into molecules small enough to be absorbed, absorb it, and eliminate undigested waste items. Food is broken down during digestion so that its nutrients can be absorbed. It consists of both chemical and mechanical digestion. Smaller particles of food are broken down into larger ones during mechanical digestion. Large molecules like proteins and carbohydrates are broken down into smaller, more easily absorbed pieces during chemical digestion. In the mouth and stomach, mechanical digestion takes place in addition to some initial chemical digestion. Food is broken down into tiny bits through chewing, and is then mixed with fluid in the stomach. In addition, the stomach serves as a storage space, allowing for the controlled release of partially digested food into the small intestine.

Chemical digestion takes place mostly in the small intestine and is accomplished by pancreatic and liver-derived enzymes. Majority of nutrient absorption occurs in the small intestine, where cells pick up substances like carbohydrates and amino acids and transfer them into circulation for usage. Efficiency in food digestion and nutrient absorption depends on the cooperation of the mouth, stomach, small intestine, and other digestive system organs. If your stomach stopped turning or if one of your glands that makes enzymes, like the pancreas, take a day off, digestion wouldn't function as well. Plants have two organ systems; the shoot and the root systems. The leaves, stems, and flowers are all a part of the shoot system. The soil's nutrients and water are absorbed by the roots. These two systems supply the entire plant with water and nutrients. The various organ systems collaborate to keep the body functioning, just as the organs in an organ system work together to accomplish their mission. For example, the respiratory system and the circulatory system work closely together to deliver oxygen to cells and to get rid of carbon dioxide from the cells. The circulatory system transfers carbon dioxide from the tissues into the lungs, where it is ultimately reconverted to oxygen by the lungs. The carbon dioxide is expelled by the lungs, and fresh air containing oxygen is breathed in. Oxygen and carbon dioxide can only be successfully exchanged between cells and the environment when both systems are functioning properly. Similarly, without the kidneys' filtration and the nutrients from your digestive system, the blood in your circulatory system would not be able to support your body's cells and flush out the wastes they create. Chemical messengers are used by these two regulatory systems to influence the operation of other organ systems and to synchronise activity across the body.

How are the nerve and endocrine systems different? Hormones are secreted into the blood serve as the chemical messengers in the endocrine system. Neurotransmitters are chemical messengers that are delivered directly from one cell to another across a very small gap in the nervous system.

The endocrine system often coordinates operations on a slower time scale than the neurological system because hormones must travel through the bloodstream to reach their targets. In contrast, the neural system delivers messages immediately to the target cell. For example, during the fight-or-flight reaction to a serious threat, the neurological and endocrine systems collaborate to create a physiological response.

Self-Assessment Exercise 3

1. What are the two main organ systems of a plant?
2. Give examples of organ systems working together?

3.6 Summary

You must have learned how to draw and describe the various cell organelles. You have also studied the main tissue types and organ systems of both plants and animals. How the various organ systems work in tandem was also highlighted. In this unit you have learned about the organs and organ systems of organisms. In animals there are about twelve major organs, while plants consists of four organs and two organ systems. The shoot system includes the aboveground vegetative portions (stems and leaves) and reproductive parts (flowers and fruits).
You have also studied how the organs in a system work together, and the workings of organ systems in both animals and plants.

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3.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. An organ system consists of two or more organs working together to perform a specific function for the organism.
2. Yes, there is a functional overlap among the different systems, for example, while we tend to think of the cardiovascular system as delivering oxygen and nutrients to cells, it also plays a role in maintaining temperature.

Answers to SAE 2

1. The main organs of the human digestive system participate in the following order in process of digestion:

Mouth, esophagus, stomach, small intestine, large intestine, rectum, and anus.

2. Leaves: Leaves are the most important part of a plant. They contain chlorophyll that helps the plants to prepare their food using sunlight, carbon dioxide and water. A leaf consists of three main parts- petiole, leaf base and lamina.

3. Plant organs are organized into two organ systems. The shoot system includes the leaves, stems, and flowers. The root system takes up water and nutrients from the soil. These two systems work together to deliver water and nutrients to the entire plant.

Answers to SAE 3

1. Each plant has two main organ systems. They are;
   Root system and Shoot system

2. Some body systems work together to complete a job. For example, the **respiratory and circulatory systems** work together to provide the body with oxygen and to rid the body of carbon dioxide. The lungs provide a place where oxygen can reach the blood and carbon dioxide can be removed from it.

Unit 4 Characteristics and Classification of Living Things

Unit Structure

4.1 Introduction
4.2 Intended Learning Outcomes (ILOs)
4.3 Characteristics of Living Things
 4.3.1 Non-living things
 4.3.2 Difference between living and non-living things
4.4 The use of the hierarchical classification system
 4.4.1 The hierarchical classification system
 4.4.2 Properties of the Five Kingdoms
4.5 Systems of Classification
 4.5.1 Evolutionary relationships
 4.5.2 Artificial classification and the binomial system
4.6 Summary
4.7 References/Further Readings/Web Sources
4.8 Possible Answers to Self-Assessment Exercises

4.1 Introduction

In this Unit, you will learn the main characteristics and developments in the classification of organisms, and the scientific method of naming of organisms using the binomial nomenclature. All organisms have only one scientific name but many common names. The division of organisms into prokaryotes and eukaryotes, and the major differences between the two. The classification of living organisms into five major kingdoms: Monera, Protista, Fungi, Plantae and Animalia and the unique characteristics of each kingdom.

4.2 Intended Learning Outcomes (ILOs)

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

- Understand and describe the characteristics of living and non living things.
- Know the definition of the biological classification system.
- Explain the hierarchical manner of grouping of living organisms based on similarities and differences.
- Describe living organisms into five major kingdoms.

4.3 Characteristics of Living Things

We can find many things around us, from mountains and oceans to plants and animals. The earth in which we live is made up of several things. These “things” can be categorized into Living and Non-living Things.

- All living things breathe, eat, grow, move, reproduce and have senses.
- Non-living things do not eat, grow, breathe, move and reproduce.

Even though some living organisms may not display obvious symptoms, they all have "life". For example, a tree definitely wouldn't respond the same way a person would when we struck it, but it is not be able to move. The fact that they don't exhibit many observable indicators of life does not imply that they are not alive. Cells are the building blocks of all living organisms, and they develop and show signs of motility. They go through metabolism, which involves both catabolic and anabolic processes. Through the process of reproduction, living beings are able to create brand-new lives that are of their own types. Everything that is alive has a finite lifespan and is not eternal.

Cellular Respiration enables living organisms to acquire energy used by cells to perform their functions. They digest food for energy and also excrete waste from their bodies. Their life cycle can be summarised as follows – birth, growth, reproduction and death. Examples of living things are animals, birds, insects, and human beings.

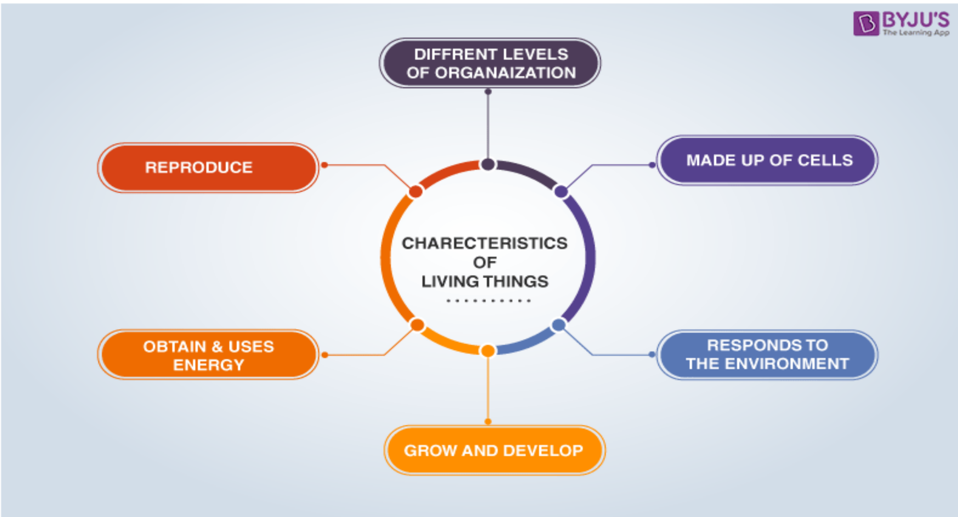

Fig. 4.1. Characteristics of Living Things. Source: www.byjus.com

The important characteristics of living things include:

1. Living things move and display locomotory motion. Animals can move because they have specific locomotory organs. For example, earthworms use their circular and longitudinal muscles to

move across the soil surface. Movement helps plants capture sunlight for photosynthesis.

2. Life forms breathe. A chemical mechanism called respiration takes place inside of cells to extract energy from food. Through the process of digestion, food is broken down to release energy which is used by the body to create the byproducts of water and carbon dioxide.
3. Living things are capable of detecting changes in their surroundings and are sensitive to touch (as well as other stimuli).
4. They grow: Living things grow and mature through different stages of development.
5. One of the remarkable characteristics is that through the process of reproduction, in which genetic information is conveyed from the parents to the offspring, living beings are able to produce offspring of their own type.
6. Through the process of nutrition and digestion, which involves ingesting and digesting the food, they obtain and fulfil their nutritional needs. Autotrophs can produce food using sunlight or chemical energy.
7. The body expels the food that has been digested through the excretion process.

4.3.1 Non-Living Things

Non-living things don't have life in them. They do not develop, have cells, or exhibit motility or movement. They don't go through anabolic and catabolic responses throughout metabolism, neither do they procreate nor have a lifespan. Since they do not need food for energy, they do not breathe or excrete. They are not subject to any cycle of birth, development, or demise. External influences both build and destroy them. Examples of non-living things are stones, pencils, books, bikes, and bottles. Following are some of the crucial traits of non-living things:

1. Non-living things are lifeless. They do not have cells, and there is no protoplasm which forms the basis for life to exist.
2. Lack of protoplasm leads means no metabolic activities.
3. They do not have a definite and certain size of their own. They take the shape of the substance they are contained in, for example, a liquid takes the shape of its container. Stones, rocks and boulders are mould by the changing environment and landscape. The change in the state of a non-living thing is due to an external influence.
4. Non-living things "grow" by accretion which occurs through adding materials externally. For example, A snowball may increase in size due to the accumulation of smaller units of its own on its outer surface.

5. Non-living things never die as they do not have cells with a definite lifespan. Immortality is a distinguishing factor.
6. Fundamental life processes such as reproduction, nutrition, excretion, etc. are absent in non-living things.

4.3.2 Difference Between Living and Non-Living Things

Scientists have developed qualities or characteristics exclusive to living things in order to distinguish them from non-living things. The classification standard is required to prevent erroneous grouping. As a result, science created a framework for classification. A live thing is defined as anything that has life. Examples include people, pets, and trees. Non-living things are those that do not have any form of life. For example, a watch, a stone, or a mountain. The following are some key distinctions between living and non-living things:

Living Things	**Non-Living Things**
They possess life.	They do not possess life.
They are capable of giving birth to their young ones.	They do not reproduce.
They depend on water, air and food for survival.	They have no such requirements
They are sensitive and responsive to stimuli.	They are not sensitive and do not respond to stimuli.
Metabolic reactions constantly occur in all living things.	There are no metabolic reactions in Non-living things.
They undergo growth and development.	They do not grow or develop.
They have a lifespan and are not immortal.	They have no lifespan and are immortal.
They move from one place to another.	They cannot move by themselves.
They respire and the exchange of gases takes place in their cells.	They do not respire.
Example: Humans, animals, plants, insects.	Example: Rock, pen, buildings, gadgets.

What are non-living things?

Self-Assessment Exercises 1

1. What is the one characteristic that enables living organisms to acquire energy used by cells to perform their functions?
2. What is the process that is lacking in non-living things which distinguishes them from living things?

4.4 The Use of Hierarchical Classification System

We can impose order and a broad scheme on the diversity of living things by classifying them. Scientists have always attempted to categorise and organise the surrounding items, including biological things. Classification means grouping organisms based on structural similarity. This implies that species with comparable traits are grouped together. These groups are arranged from the group to the smallest. Kingdom, phylum (plural phyla), class, order, family, genus (plural genera), and species are the groups as listed in order of largest to smallest. The smallest class of organisms is the species. As you move up the classification hierarchy, you will notice that scientists classified organisms into kingdoms, which are the largest groups of organisms, using broader features. The characteristics become more specialised as you get closer to the species, which are the smallest groups of organisms. In other woeds, two organisms from the same species have more traits in common than two organisms from the same kingdom but different species. A group of organisms with comparable characteristics that are able to reproduce and give birth to healthy offspring are referred to as species. You are undoubtedly already aware that although horses and donkeys come from separate species, they are members of the same kingdom, phylum, class, order, family, and genus. As a result, if a donkey and a horse were to breed, the result would be a creature known as a mule. The mule cannot produce children because it is a hybrid of various species of organisms, making it sterile. Hierarchical classification has various applications. First, it aids scientists in the classification of organisms. Secondly, it helps in finding out which category a new organism belongs helping them recognise it. Thirdly, grouping organisms makes it simpler to research with them.

4.4.1 The Hierarchical Classification System

Based on very fundamental, common traits, groups of all living things are identified. The organisms within each category are subsequently sorted into even more compact groups. These more specific similarities within each bigger group form the basis for these smaller groups. It is simpler for scientists to investigate particular groupings of species; thanks to this classification scheme. The kingdom is the biggest group. Prokaryotes, which comprises bacteria, protoctista, fungus, plants, and animals make up the five kingdoms. Based on a few traits that certain organisms share, phyla are smaller groups that are further subdivision of each kingdom. For example, the arthropod phylum, which includes insects, crustaceans, and spiders, includes all organisms without a backbone who also have jointed legs and a hard covering over their bodies. The subdivisions within a phylum are classes, orders, families, genera, and finally species. The various categories in this classification scheme are referred to as taxa (singular: taxon). The classification hierarchy is depicted in figure 4.2 below. The taxonomy of living things refers to all of these specific divisions, and seven categories that make up the taxonomy of living things are kingdom, phylum, classes, order, families, genus, and species.

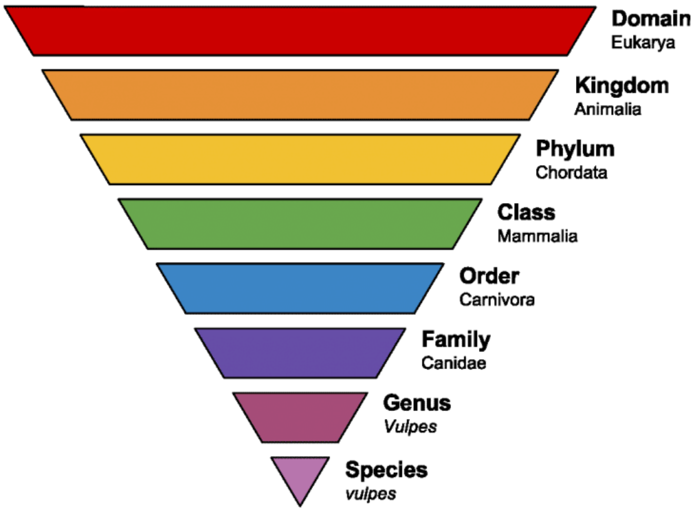

Figure 4.2. The Hierarchical Classification System. Source: www.byjus.com

The most basic classification of living things is kingdoms. Currently there are five kingdoms. Living things are placed into certain kingdoms based on how they obtain their food, the types of cells that make up their body, and the number of cells they contain.

Phylum

The phylum is the next level following kingdom in the classification of living things. It is an attempt to find some kind of physical similarities among organisms within a kingdom. These physical similarities suggest that there is a common ancestry among those organisms in a particular phylum.

Classes

Classes are way to further divide organisms of a phylum. As you could probably guess, organisms of a class have even more in common than those in an entire phylum. Humans belong to the Mammal Class because we drink milk as a baby.

Order
Organisms in each class are further broken down into orders. A taxonomy key is used to determine to which order an organism belongs. A taxonomy key is a checklist of characteristics that determines how organisms are grouped together.

Families
Orders are divided into families. Organisms within a family have more in common than with organisms in any classification level above it. Because they share so much in common, organisms of a family are said to be related to each other. Humans are in the Hominidae Family.

Genus
Genus is a way to describe the generic name for an organism. The genus classification is very specific so there are fewer organisms within each one. For this reason, there are a lot of different genera among both animals and plants. When using taxonomy to name an organism, the genus is used to determine the first part of its two-part name.

Species
Species are as specific as you can get. It is the lowest and most strict level of classification of living things. The main criterion for an organism to be placed in a particular species is the ability to breed with other organisms of that same species. The species of an organism determines the second part of its two-part name.

4.4.2 Properties of the Five Kingdoms

The properties of the five kingdoms are as follows:

Monera
The cell type is prokaryotic. The cell wall is present and it is non-cellulosic. The nuclear membrane is absent. It is a unicellular organism and the mode of nutrition is autotrophic and heterotrophic. Bacteria are an example of an organism in the monera kingdom.

Protista
The cell type is eukaryotic. The cell wall is present. The nuclear membrane is also present. It is a unicellular organism and the mode of nutrition is autotrophic.

Fungi
The cell type is eukaryotic. The cell wall is present. The nuclear membrane is also present and it is a multicellular organism and the mode of nutrition is heterotrophic. Example mushroom is a fungus. They cannot make their own food.

Plantae
The cell type is eukaryotic. The cell wall is non-cellulosic. The nuclear membrane is present. The organism is tissue or organ. The mode of nutrition is autotrophic. Examples are plants, trees, and a bush.

Animalia
The cell type is eukaryotic. The cell wall is absent. The nuclear membrane is present. The organism is a tissue, organ or organ system. The mode of nutrition is heterotrophic.
Which kingdom has a prokaryotic cell type?

Self-Assessment Exercises 2

1. What are the levels of classification of organisms?
2. What does genus represent in the classification scheme?

4.5 Systems of Classification

There are two different systems that can be used for classification: natural and artificial. First, let's examine natural classification. Natural categorization The aforementioned hierarchical categorization method is based on a natural classification scheme that makes use of traits that all living things have in common. Two concepts serve as the foundation for natural classification: 1) homologous structures, and 2) evolutionary links. Homologous structures are characteristics of organisms that share a similar structure, but can have extremely distinct appearances and serve various functions. Homologous features are frequently seen in the forelimbs of vertebrates, where the forelegs of four-legged vertebrates like dogs and crocodiles, as well as the arms of primates, whales' front flippers, and bats' and birds' wings, are all descended from the same ancestral tetrapod. Their identical bone count and arrangement indicates that they most likely descended from a single type of structure that existed in a common ancestor millions of years ago. The wing of a fly and the wing of a bat are not analogous. Despite having a similar appearance and performing the same function, it has a totally different beginning. The wing of the fly is not covered with feathers and has no bones. It is said that a fly's wing and a bat's wing are comparable. You wouldn't mix a fly and a bat together! Relationships formed through the worldwide process of evolution between two separate creatures are known as evolutionary relationships. They are, in other words, the connections between two species that shared an ancestor. Evolutionary relationships are crucial to research because they provide insight into the timing and processes by which particular traits were developed in particular species. Phylogenetics is the study of evolutionary relationships and their effects. There is frequently remarkable physical resemblance between persons who have a shared ancestry, like a grandmother or great grandparent. The individuals in the pictures are undoubtedly linked to one another and have traits that they got from their ancestors. Biologists classify species according to their common ancestry and structural similarities in a natural classification system. A branching collection of associations is produced via natural classification. This demonstrates how the key plant subgroups, including mosses, ferns, conifers, and flowering plants, are separated out. It is possible to divide each of these groupings; humans, *Homo sapiens,* and cockroach *Periplaneta americanus* are in the animal kingdom. Humans and cockroaches share a common ancestor more than 500 million years ago! You can see many structural differences between humans and cockroaches and so there is no natural relationship, thus we classify *Homo sapiens* and *Periplaneta americanus* into very different groups.

4.5.1 Artificial classification and Binomial system

You are free to use whichever grouping you like while using artificial classification. You could classify all flying animals together. Birds, bats, and a variety of insects would then be included in this group. All aquatic creatures with bodies that are streamlined and resemble those of fish could be grouped together. Fish and whales would then be included in this group. Biologists employ dichotomous keys to distinguish different types of organisms, and these dichotomous keys are based on artificial classification systems species naming using the binomial system. The hierarchical classification scheme that we have so far examined was first proposed by the Swedish naturalist Carl Linnaeus, who lived from 1707 to 1778. He also assigned a Latin scientific name to each and every species giving each living thing two Latin names known as the "binomial" system of species naming (scientific names). Binomial literally translates to "two names" because "bi" stands for "two" and "nomial" stands for "name." Scientific names for organisms were derived by Linnaeus from their genus and species. The genus name is written first and begins with a capital letter when writing a scientific name, and the species name is written second and begins with a small letter. When typing or handwriting the scientific name, it should be printed in italics or underlined individually. The tiger is a member of the Panthera genus and the tigris species, hence its scientific name will be written as <u>Panthera</u> <u>tigris</u> or typed as *Panthera tigris*. Scientific names are universal because, for example, every biologist will understand that Felis catus means 'house cat' without resorting to the dictionary, no matter what language they speak. Can you think of the scientific names for some other organisms?

4.5.2 History and the Study of Evolutionary Relationships

The evolution of interactions between species dates back to the dawn of time. Small microorganisms in water were the first organisms to be produced on land. Amphibians started to evolve over time, old World monkeys were the first to diverge from the primary root of the primate family tree approximately 25–30 million years ago. The earliest relatives of modern humans diverged from their forebears about 6 million years ago, starting the evolutionary tree that produced many humanoid and ape species, including the Ardipithecus family, *Australopithecus afarensis*, *Homo habilis*, and many others. Homo erectus eventually evolved between 1.5 and 2 million years ago. Numerous variations of Homo sapiens have descended from this species. *Homo sapiens*, the current species, is a combination of all of these previous versions. Understanding the relationships between numerous non-human species as well as those between humans and similar species can be aided by an understanding of evolutionary relationships. For instance, it is possible to determine who descended from whom and how by comparing two species of birds that are similar to one another. The comprehensive field of phylogenetics focuses on scientifically classifying and analysing the traits of various species to ascertain their evolutionary ties, which is why people investigate evolutionary relationships. The following are characteristics of phylogenetic research:

- Systematics- the method through which species are placed into particular families and how their connections to one another are established. In other words, this is the system that establishes taxonomy.
- Taxonomy - Taxonomy is the labelling of certain species in order to highlight the connections between various species and investigate their interconnections. A taxon is the name for a certain group or family's designation. Classes, orders, families, and species, for instance, each have their own distinct taxa. A taxa is a group of taxons.
- Evolution- Without the basis of evolution to build on, phylogenetics would be functionally meaningless. The study of phylogenetics was founded on the theory of evolution. To understand how evolution works, systematic research is conducted at all taxonomic levels.

What is Systematics in taxonomy?

Self-Assessment Exercises 3

1. The tiger belongs to the genus called Panthera and the species called tigris, therefore what is its scientific name?
2. Describe the binomial classification.

4.6 Summary

You have learned the main characteristics and developments in the classification of organisms.

You have studied the scientific method of naming of organisms using the binomial nomenclature. The division of organisms into prokaryotes (simple, unicellular) and eukaryotes (mostly multicellular) and the major differences between the two has been highlighted. You have also learned about the classification of living organisms into five major kingdoms

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4.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1
1. Cellular respiration
2. Life processes

Answers to SAE 2
1. The classification of living things include 7 levels: kingdom, phylum, classes, order, families, genus, and species .
2. The genus classification is very specific so there are fewer

organisms within each one. Genus is a way to describe the generic name of an organism.

Answers to SAE 3

1. *Panthera tigris*
2. The binomial system of naming species means giving organisms two names in Latin (scientific names)

Unit 5 The Study of Genes and Chromosomes

Unit Structure

5.1 Introduction
5.2 Intended Learning Outcomes (ILOs)
4.3 Study of Genes and Chromosomes
5.3.1 Proteins and DNA
5.3.2 Structure of DNA
5.4 Synthesizing Proteins
5.5 Gene replication and Mutations
5.6 Summary
5.7 References/Further Readings/Web Sources
5.8 Possible Answers to Self-Assessment Exercises

5.1 Introduction

In this unit we shall highlight the occurrence and significance of genes and chromosomes. The contribution of proteins and DNA in heredity will be explained. You will learn about the structure of DNA and be able to explain the process of synthesizing proteins. You will also learn the process of gene replication and mutations, coding, transcription and translation, and the control of gene expression

5.2 Intended Learning Outcomes (ILOs)

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

- Describe the occurrence and significance of genes and chromosomes
- Describe proteins and the structure of DNA
- Explain the synthesizing proteins
- Describe the process of gene replication and mutations
- Explain the meaning of **c**oding**,** transcription and translation, and the control of gene expression

5.3 The Study of Genes and Chromosomes

Deoxyribonucleic acid (DNA) segments called genes are responsible for carrying out specified protein functions in one or more types of bodily cells. The sizes of the proteins that genes code for determine the size of the genes. Chromosomes, found in the cell nucleus, are where genes are found. Any characteristic that is influenced by more than one gene is called a trait. Some features are brought about by mutated genes, either ones that are passed down from parents or ones that arise from new gene mutations. A person's genotype (or genome) is their particular set of genes or genetic make-up. As a result, the genotype has a comprehensive set of instructions for how that person's body should synthesise proteins, and consequently, how their body should be constructed and operate. The physical makeup and capabilities of an individual make up their phenotype. Not all the instructions in the genotype may be followed out, and the phenotype is how the genotype manifests in an individual (or expressed). The environment (including sicknesses and diet) and other factors, some of which are unknown, as well as the genotype affect how a gene is expressed. The structures called chromosomes found in cells house a person's genes. Each cell in the human body normally contains 46 chromosomes; two sex chromosomes and twenty-two pairs of autosomes.

There are between 20,000 and 25,000 genes on these chromosomes, new genes being discovered on daily basis. According to size, the paired chromosomes are numbered from 1 to 22. (The largest chromosome is number one.) Autosomes are the name for these non-sex chromosomes, each chromosome typically has two copies in an individual. Their mother passes one copy on to them through the egg, while their father passes the other one along (via the sperm). Each egg and sperm have a single set of 23 chromosomes. Two copies of each chromosome and two copies of each gene are present when the sperm fertilises the egg, resulting in the formation of an embryo. Sex chromosomes are the X and Y chromosomes, which are responsible for a baby's sex. An X chromosome is typically contributed by the mother's egg, and either an X or a Y chromosome is contributed by the father's sperm. The biological gender of a person with a XX pairing of sex chromosomes is female, while the biological gender of a person with an XY pairing is male. The sex chromosomes contain genes that regulate numerous bodily activities in addition to determining sex. Fewer genes are found on the Y chromosome than there are on the X chromosome. The term "X-linked" refers to genes that are located on the X chromosome. Y-linked genes are those that reside on the Y chromosome. A karyotype is a representation of a person's entire chromosomal set as seen in their cells.

5.3.1 Proteins and DNA

The most significant class of substance in the body is likely proteins. Proteins serve as more than only the building blocks for skin, connective tissue, muscles, and other organs. The production of enzymes also requires them. Nearly all chemical reactions and functions in the body are controlled and carried out by sophisticated proteins called enzymes. There are thousands of distinct enzymes that the body makes. As a result, the kinds and quantities of proteins the body synthesises control the overall structure and operation of the body. Genes, which are found on chromosomes, regulate the production of proteins. There is deoxyribonucleic acid in genes (DNA). The instructions, or blueprint, needed to synthesise a protein are found in DNA. Each DNA molecule is a lengthy double helix with millions of steps, resembling a spiral staircase. The steps of the staircase consist of pairs of four types of molecules called bases (nucleotides). In each step, the base adenine (A) is paired with the base thymine (T), or the base guanine (G) is paired with the base cytosine (C). Each extremely long DNA molecule is coiled up inside one of the chromosomes.

5.3.2 Structure of DNA

The genetic substance of the cell is DNA (deoxyribonucleic acid), which is found in chromosomes within the cell nucleus and mitochondria. The nucleus of every cell includes 23 pairs of chromosomes, with the exception of some cells (such as sperm and egg cells and red blood cells). Many genes are found on one chromosome. A gene is a section of DNA that contains the instructions needed to build a protein. The DNA molecule is a lengthy, double-helix structure that coils around itself like a spiral staircase. In it, bases—pairs of four molecules that make up the staircase's steps—connect two strands of sugar (deoxyribose) and phosphate molecules. In the process, guanine and cytosine are coupled with adenine and thymine, respectively. A hydrogen bond holds each pair of bases together. A gene consists of a sequence of bases. Sequences of three bases code for an amino acid (building blocks of proteins) or other information.

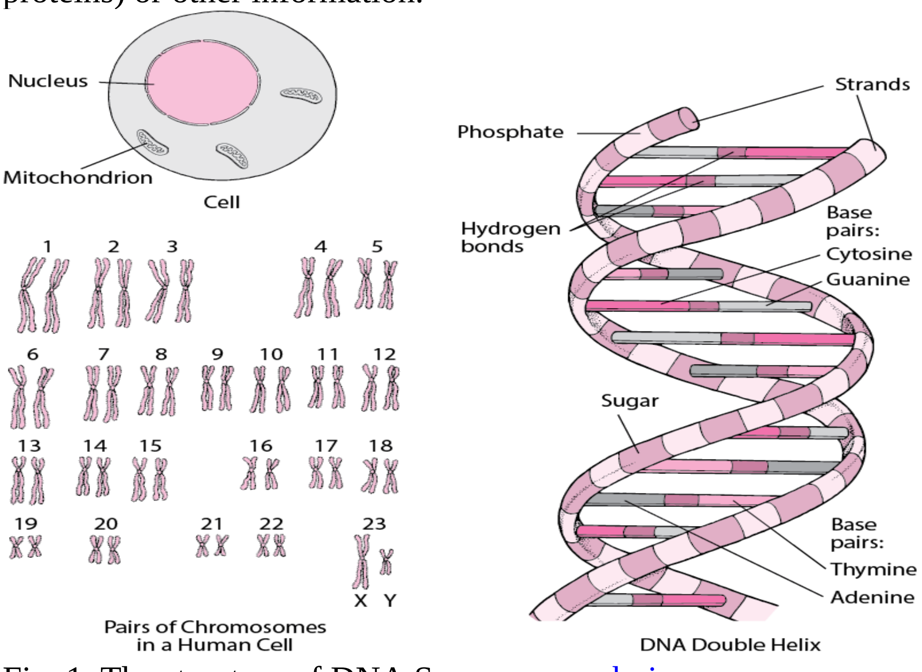

Fig. 1. The structure of DNA Source: www.byjus.com

Self-Assessment Exercises 1

1. What are Genes?
2. What is deoxyribonucleic acid?

5.4 Protein Synthesis

A lengthy chain of consecutively linked amino acids makes up proteins. There are 20 different amino acids that can be used to make proteins; some must be obtained through diet (essential amino acids), while others are produced by the body's own enzymes. A chain of amino acids forms a complicated three-di5.mensional shape when it folds in on itself during synthesis. The function of the folded structure in the body is determined by its shape. Every individual sequence produces a different protein because the specific sequence of amino acids controls how the protein folds. Some proteins, such as haemoglobin, have many folded chains in them. DNA contains codes that specify how to make proteins.

5.4.1 Coding, Transcription and Translation

The order of the bases (A, T, G, and C) in DNA serves as a code for information. Triplets are used to write the programme. In other words, the bases are placed in three-base groups. DNA codes for precise instructions, such as the insertion of one amino acid to a chain, using specific three-base sequences. For example, the addition of the amino acid, alanine is coded for by GCT (guanine, cytosine, thymine), and the addition of the amino acid, valine is coded for by GTT (guanine, thymine, thymine). As a result, the arrangement of triplet base pairs in the gene for a protein on the DNA molecule determines the order of amino acids in that protein. Transcription and translation are required for the conversion of genetic information encoded in a protein.

The process of transcription involves transferring (transcription) data encoded in DNA to ribonucleic acid (RNA). Similar to a strand of DNA is RNA, a lengthy chain of bases, except that the base uracil (U) is used instead of the base thymine (T). So, like DNA, RNA carries triplet-coded information too.

A portion of the DNA double helix opens and unwinds when transcription starts. A complementary strand of RNA is created using one of the unwound DNA strands as a template. The name of the RNA's complementary strand being messenger RNA (mRNA). The mRNA dissociates from the DNA, leaves the nucleus, and enters the cytoplasm of the cell, and connect to the ribosome, a small cell structure where protein synthesis takes place. The mRNA coding (from the DNA) instructs the ribosome how and what kind of amino acids to bind with during translation. An RNA subtype known as transfer RNA (tRNA), which is much smaller, transports the amino acids to the ribosome. One amino acid is added by each tRNA molecule to the expanding protein chain, which is folded into a complicated three-dimensional structure by the action of neighbouring molecules known as chaperone molecules.

5.4.2 Control of Gene Expression

A person's body contains a variety of cells which cells have varied appearances, behaviours, and chemical outputs. However, because each cell is descended from a single fertilised egg cell, they all have the same DNA. However, since different genes are expressed in different cells, cells have extremely distinct looks and activities. DNA also contains codes that specify when a gene should be expressed. The kind of tissue, the individual's age, the availability of particular chemical signals, and a variety of other factors and methods all affect how genes are expressed. Although our understanding of these additional factors and mechanisms that regulate gene expression is rapidly expanding, many of them remain poorly understood. The processes by which genes regulate one another are extremely intricate. Chemical markers in genes serve as start and stop signals for transcription. Numerous chemicals in and around the DNA including histones either prevent or allow transcription. In addition, translation can be stopped by pairing with a complementary strand of mRNA known as antisense RNA.

Cells divide into two to reproduce. When a cell divides, the DNA molecules in the original cell must replicate themselves because each new cell needs a full set of DNA molecules. Replication also involves the double-stranded DNA molecule unwinding and splitting in two. Following the splitting, bases on each strand bind to floating complementary bases (A with T and G with C). Two identical double-strand DNA molecules result from this procedure.

5.3.3 Gene replication and Mutations

Cells feature a "proofreading" mechanism helps to make sure that bases are matched correctly in order to prevent errors during replication. Chemical processes are also available to fix improperly duplicated DNA. However, errors could occur due to the complexity of the protein synthesis process and the billions of base pairs that are involved. Such errors may happen from a variety of causes such as exposure to radiation, medications, or infections, or seemingly for no reason at all. Majority of people have extremely little variances in their DNA. Mutations are errors that appear twice in successive copies. Mutations that are passed on to offspring are referred to as inherited mutations.

Majority of mutations have little impact on the gene's subsequent copies. The majority of mutations have little impact on the gene's subsequent copies. The mutation could modify the amino acid sequence in a protein or reduce the amount of protein generated, depending on its size and position. A protein may operate differently or not at all if it has a different amino acid sequence. Proteins that are missing or dysfunctional are frequently damaging or lethal. For example, phenylalanine hydroxylase is deficient or absent in phenylketonuria due to a mutation. This defect enables the body to accumulate the amino acid phenylalanine, which is consumed through food, leading to severe intellectual impairment. Rarely does a mutation bring about a beneficial alteration. For example, if a person receives two copies of the defective sickle cell genes, he would experience sickle cell disease. However, a person who has only one copy of the sickle cell gene (a carrier) obtains some immunity against malaria. Sickle cell disease generates symptoms and problems that may limit life span, even though the immunity against malaria can help a carrier survive.

According to the theory of natural selection, mutations that reduce survival in a particular environment are less likely to be passed on to children (and thus reduce in frequency in the population), but mutations that increase survival gradually increase the frequency. Thus, beneficial mutations, although initially rare, eventually become common. The slow changes that occur over time caused by mutations and natural selection in an interbreeding population collectively are called evolution.

Self-Assessment Exercises 2

1. What is Transcription?
2. What are the factors controlling gene expression?

5.5 General Reproduction

In general, reproduction is one of the most important concepts in biology: it means making a copy, a likeness, and thereby providing for the continued existence of species. Although reproduction is often considered solely in terms of the production of offspring in animals and plants, the more general meaning has far greater significance to living organisms. To appreciate this fact, the origin of life and the evolution of organisms must be considered. One of the first characteristics of life that emerged in primeval times must have been the ability of some primitive chemical systems to make copies of themselves, thus its lowest level, reproduction is chemical replication. As evolution progressed, cells of successively higher levels of complexity must have arisen, and it was absolutely essential that they had the ability to make likenesses of themselves. In unicellular organisms, the ability of one cell to reproduce itself means the reproduction of a new individual; in multicellular organisms, however, it means growth and regeneration. Multicellular organisms also reproduce in the strict sense of the term—that is, they make copies of themselves in the form of offspring—but they do so in a variety of ways, many involving complex organs and elaborate hormonal mechanisms. There are several levels of reproduction: Molecular replication and reproduction, Cell Reproduction, Reproduction of organisms, Life cycle Reproduction.

5.3.1 **Molecular replication and reproduction**

The characteristics that an organism inherits are largely stored in cells as genetic information in very long molecules of deoxyribonucleic acid (DNA). In 1953 it was established that DNA molecules consist of two complementary strands, each of which can make copies of the other. The strands are like two sides of a ladder that has been twisted along its length in the shape of a double helix (spring). The rungs, which join the two sides of the ladder, are made up of two terminal bases. There are four bases in DNA: thymine, cytosine, adenine, and guanine. In the middle of each rung a base from one strand of DNA is linked by a hydrogen bond to a base of the other strand. However, they can pair only in certain ways: adenine always pairs with thymine, and guanine with cytosine. This is why one strand of DNA is considered complementary to the other.

The double helices duplicate themselves by separating at one place between the two strands and becoming progressively unattached. As one strand separates from the other, each acquires new complementary bases until eventually each strand becomes a new double helix with a new complementary strand to replace the original one. Because adenine always falls in place opposite thymine and guanine opposite cytosine, the process is called a template replication—one strand serves as the mold for the other. The steps involving the duplication of DNA thus do not occur spontaneously; they require catalysts in the form of enzymes that promote the replication process.

In **Molecular reproduction, t**he sequence of bases in a DNA molecule serves as a code by which genetic information is stored. Using this code, the DNA synthesizes one strand of ribonucleic acid (RNA), a substance that is so similar structurally to DNA that it is also formed by template replication of DNA. mRNA serves as a messenger for carrying the genetic code to those places in the cell where proteins are synthesized. The way by which the mRNA is translated into specific proteins is a remarkable and complex process.

For more detailed information concerning DNA, RNA, and the genetic code, see the articles nucleic acid and heredity: Chromosomes and genes. The ability to synthesize enzymes and other proteins enables the organism to make any substance that existed in a previous generation. Proteins are reproduced directly; however, other substances such as carbohydrates, fats, and other organic molecules found in cells are produced by a series of enzyme-controlled chemical reactions, each enzyme being derived originally from DNA through mRNA. It is because all the organic constituents made by organisms are derived ultimately from DNA that molecules in organisms are reproduced exactly by each successive generation.

5.3.2 Cell Reproduction

The chemical constituents of the cytoplasm are not resynthesized from DNA every time a cell divides. This is because each of the two daughter cells formed during cell division usually inherits about half of the cellular material from the mother cell, and is important because the presence of essential enzymes enables DNA to replicate even before it has made the enzymes necessary to do so. Cells of higher organisms contain complex structures, and each time a cell divides the structures must be duplicated. The method of duplication varies for each structure, and in some cases the mechanism is still uncertain. One striking and important phenomenon is the formation of a new membrane. Cell membranes, although they are very thin and appear to have a simple form and structure, contain many enzymes and are sites of great metabolic activity. This applies not only to the membrane that surrounds the cell but to all the membranes within the cell. New membranes, which seem to form rapidly, are indistinguishable from old ones. Thus, the formation of a new cell involves the further synthesis of many constituents that were present in the parent cell. This means that all of the information and materials necessary for a cell to reproduce itself must be supplied by the cellular constituents and the DNA inherited from the parent cell.

Binary fission

Of the various kinds of cell division, the most common mode is binary fission, the division of a cell into two separate and similar parts. In bacteria (prokaryotes) the chromosome (the body that contains the DNA and associated proteins) replicates and then divides in two, after which a cell wall forms across the elongated parent cell. In higher organisms (eukaryotes) there is first an elaborate duplication and then a separation of the chromosomes (mitosis), after which the cytoplasm divides in two. In the hard-walled cells of higher plants, a median plate forms and divides the mother cell into two compartments; in animal cells, which do not have a hard wall, a delicate membrane pinches the cell in two, much like the separation of two liquid drops. Budding yeast cells provide an interesting exception. In these fungi the cell wall forms a bubble that becomes engorged with cytoplasm until it is ultimately the size of the original cell. The nucleus then divides, one of the daughter nuclei passes into the bud, and ultimately the two cells separate.

In some cases of binary fission, there may be an unequal cytoplasmic division with an equal division of the chromosomes. This occurs in a large number of higher organisms during meiosis—the process by which sex cells (gametes) are formed: originally, each chromosome of the cell is in a pair (diploid); during meiosis these diploid pairs of chromosomes are separated so that each sex cell has only one of each pair of chromosomes (haploid). During the two successive meiotic divisions involved in the production of eggs, a primordial diploid egg cell is converted into a haploid egg and three small haploid polar bodies (minute cells). In this instance the egg receives far more cytoplasm than the polar bodies.

Multiple fission

Some algae, protozoans, and true slime molds (Myxomycetes) regularly divide by multiple fission. In such cases the nucleus undergoes several mitotic divisions, producing a number of nuclei. When the nuclear divisions are complete, the cytoplasm separates, and each nucleus becomes encased in its own membrane to form an individual cell. In the Myxomycetes, the fusion of two haploid gametes or the fusion of two or more diploid zygotes (the structures that result from the union of two sex cells) results in the formation of a plasmodium—a motile, multinucleate mass of cytoplasm. The nuclei are in a syncytium, that is, there are no cell boundaries, and the nuclei flow freely in the motile plasmodium. As it feeds, the plasmodium enlarges, and the nuclei divide synchronously about once every 24 hours. The plasmodium may become very large, with millions of nuclei, but, ultimately, when conditions are right, it forms a series of small bumps, each of which becomes a small, fruiting body (a structure that bears the spores). During this process the nuclei undergo meiosis, and the final haploid nuclei are then isolated into uninucleate spores (reproductive bodies).

Many algae (eg. the Siphonales and related groups) are multinucleate. In most cases, the nuclei are in one common cytoplasm within a large and elaborate organism surrounded by a hard cell wall. As the wall becomes extended, the nuclei, which wander freely in the central cavity, undergo repeated mitoses. Again, either during the formation of zoospores (asexual reproductive cells) or after meiosis (gamete formation), a massive progressive division occurs. The most unusual of such organisms is the marine alga, Acetabularia; many nuclei stay clumped together in one compound nucleus in the rootlike base,

which often is as much as two inches (five centimetres) away from the tip of the plant. The compound nucleus breaks up just before gamete formation, and the minute individual nuclei undergo meiosis and wander to the elaborate tip structures, where they are released as uninucleate gametes.
Syncytial organisms raise the question of whether or not cells, in the strict sense, are necessary for the development of large organisms. Syncytia are also found in animals—e.g., in the early stages of development of fishes and insects, and in the voluntary muscles of man. The proposal of the 19th-century botanist Julius von Sachs is generally considered a satisfactory answer to this question; he suggested that the important matter was the existence not of a cell membrane but of a certain amount of cytoplasm surrounding a nucleus and acting as a unit of metabolism, which he called an energid. Cell reproduction, therefore, might be considered a special case of energid reproduction. What is the role of the sequence of bases in a DNA molecule?

Self-Assessment Exercises 3

1. What is Binary fission?
2. Why is it that the chemical constituents of cytoplasm are not resynthesized from DNA every time a cell divides?

5.6 Summary

You must have learned about the meaning and significance of genes and chromosomes in the body of organisms. The contribution of proteins and DNA in heredity, and process of synthesizing proteins was explained. You have also learned about the structure of DNA, the process of gene replication and mutations, coding, transcription and translation, and the control of gene expression in organisms.

5.7 References/Further Readings/Web Sources

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5.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Genes are segments of deoxyribonucleic acid (DNA) that contain the code for a specific protein that functions in one or more types of cells in the body hormosomes
2. DNA (deoxyribonucleic acid) is the cell's genetic material, contained in chromosomes within the cell nucleus and mitochondria.

Answers to SAE 2

1. Transcription is the process in which information coded in DNA is transferred (transcribed) to ribonucleic acid (RNA)
2. Gene expression depends on the type of tissue, the age of the person, the presence of specific chemical signals, and numerous other factors and mechanisms.

Answers to SAE 3

1. Of the various kinds of cell division, the most common mode is binary fission, the division of a cell into two separate and similar parts.
2. This is because each of the two daughter cells formed during cell division usually inherits about half of the cellular material from the mother cell, and is important because the presence of essential enzymes enables DNA to replicate even before it has made the enzymes necessary to do so.

Unit 6 Reproduction Process and Life cycles

Unit Structure

6.1 Introduction
6.2 Intended Learning Outcomes (ILOs)
6.3 Reproduction Process and Molecular Replication
6.4 Cell reproduction
6.5 Life cycles
6.6 Summary
6.7 References/Further Readings/Web Sources
6.8 Possible Answers to Self-Assessment Exercises

6.1 Introduction

In this unit you will learn about reproduction, a process by which organisms replicate themselves in both unicellular and multicellular organisms, study about the differences in reproduction between organisms. You will learn about cell reproduction and life cycles

You will also learn about the number of cells in our bodies in this unit, and the two ways in which cells divide—mitosis and meiosis, and cell cycles. In addition, you will learn how cells regulate their division by communicating.

6.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you will be able to:

- Explain and describe the meaning and process of reproduction in both unicellular and multicellular organisms.
- Differentiate between Binary fission and Multiple fission
- Describe the cell reproduction and life cycles
- Describe animal and plant life cycles
- Explain the meaning of natural selection
- Illustrate and describe the Mitosis and Meiosis divisions and Cell Cycles
- Recognize the function and products of mitosis and meiosis
- Compare and contrast the behaviors of chromosomes in mitosis and meiosis
- Recognize when cells are diploid vs. haploid
- Predict DNA content of cells in different phases of mitosis and meiosis
- Recall and describe the phases of the cell cycle

6.3 Reproduction of organisms

In single-celled organisms (*e.g.,* bacteria, protozoans, many algae, and some fungi), organismic and cell reproduction are synonymous, for the cell is the whole organism. Details of the process differ greatly from one form to another and, if the higher ciliate protozoans are included, can be extraordinarily complex. It is possible for reproduction to be asexual, by simple division, or sexual. In sexual unicellular organisms the gametes can be produced by division (often multiple fission, as in numerous algae) or, as in yeasts, by the organism turning itself into a gamete and fusing its nucleus with that of a neighbour of the opposite sex, a process that is called conjugation. In ciliate protozoans (*eg., Paramecium*), the conjugation process involves the exchange of haploid nuclei; each partner acquires a new nuclear apparatus, half of which is genetically derived from its mate. The parent cells separate and subsequently reproduce by binary fission. Sexuality is present even in primitive bacteria, in which parts of the chromosome of one cell can be transferred to another during mating.

Multicellular organisms also reproduce asexually and sexually; asexual, or vegetative, reproduction can take a great variety of forms. Many multicellular lower plants give off asexual spores, either aerial, motile or aquatic (zoospores), which may be uninucleate or multinucleate. In some cases, the reproductive body is multicellular, as in the soredia of lichens and the gemmae of liverworts. Frequently, whole fragments of the vegetative part of the organism can bud off and form a new individual, a phenomenon found in most plant groups. In many cases a spreading rhizoid (rootlike filament) or, in higher plants, a rhizome (underground stem) gives off new sprouts. Sometimes, other parts of the plant have the capacity to form new individuals; for example, buds of potentially new plants may form in the leaves; even some shoots that bend over and touch the ground can give rise to new plants at the point of contact.

Among animals, many invertebrates are equally well endowed with means of asexual reproduction. Numerous species of sponges produce gemmules, masses of cells enclosed in resistant cases, that can become new sponges. There are many examples of budding among coelenterates, the best known of which occurs in freshwater *Hydra*. In some species of flatworms, the individual worm can duplicate by pinching in two, each half then regenerating the missing half; this is a large task for the posterior portion, which lacks most of the major organs; brain, eyes, and pharynx. The largest animals that exhibit vegetative reproduction are the colonial tunicates (*e.g.,* sea squirts), which, just like plants, send out runners in the form of stolons, small parts of which form buds that develop into new individuals. Vertebrates have lost the ability to reproduce vegetatively; their only form of organismic reproduction is sexual. In the sexual reproduction of all organisms except bacteria, there is one common feature: haploid, uninucleate gametes are produced that join in fertilization to form a diploid, uninucleate zygote. At some later stage in the life cycle of the organism, the chromosome number is again reduced by meiosis to form the next generation of gametes. The gametes may be equal in size (isogamy), or one may be slightly larger than the other (anisogamy); the majority of forms have a large egg and a minute sperm (oogamy). The sperm are usually motile and the egg passive, except in higher plants, in which the sperm nuclei are carried in pollen grains that attach to the stigma (a female structure) of the flower and send out germ tubes that grow down to the egg nucleus in the ovary. Some organisms, like most flowering plants, earthworms, and tunicates, are bisexual (hermaphroditic, or monoecious)—*i.e.,* both male and female gametes are produced by the same individual. All other organisms, including some plants (*eg.*, holly and the ginkgo tree) and all vertebrates, are unisexual (dioecious): the male and female gametes are produced by separate individuals. Some sexual organisms partially revert to the asexual mode by a periodic degeneration of the sexual process. For example, in aphids and in many higher plants the egg nucleus can develop into a new individual without fertilization, a kind of asexual reproduction that is called parthenogenesis.

Self-Assessment Exercises 1

1. How is sexuality in primitive bacteria?
2. Give example of a condition where some sexual organisms partially revert to the asexual mode by a periodic degeneration of the sexual process.

6.4 Life Cycle of Organisms

A series of changes that members of a species undergo as they pass from the beginning of a given developmental stage to the inception of that same developmental stage in a subsequent generation is called life cycle.

1. Animals Life Cycle

Invertebrate animals have a rich variety of life cycles, especially among those forms that undergo metamorphosis, a radical physical change. Butterflies, for eg. have a caterpillar stage (larva), a dormant chrysalis stage (pupa), and an adult stage (imago). One remarkable aspect of this development is that, during the transition from caterpillar to adult, most of the caterpillar tissues disintegrate and are used as food, thereby providing energy for the next stage of development, which begins when certain small structures (imaginal disks) in the larva start growing into the adult form. Thus, the butterfly undergoes essentially two periods of growth and development (larva and pupa–adult) and two periods of small size (fertilized egg and imaginal disks). A somewhat similar phenomenon is found in sea urchins; the larva, which is called a pluteus, has a small, wartlike bud that grows into the adult while the pluteus tissue disintegrates. In both examples it is as if the organism has two life histories, one built on the ruins of another.

Another life-cycle pattern found among certain invertebrates illustrates the principle that major differences between organisms are not always found in the physical appearance of the adult but in the differences of the whole life cycle. In the coelenterate Obelia, for example, the egg develops into a colonial hydroid consisting of a series of branching Hydra-like organisms called polyps. Certain of these polyps become specialized (reproductive polyps) and bud off from the colony as free-swimming jellyfish (medusae) that bear eggs and sperm. As with caterpillars and sea urchins, two distinct phases occur in the life cycle of Obelia: the sessile (anchored), branched polyps and the motile medusae. In some related coelenterates the medusa form has been totally lost, leaving only the polyp stage to bear eggs and sperm directly. In still other coelenterates the polyp stage has been lost, and the medusae produce other medusae directly, without the sessile stage. There are furthermore, intermediate forms between the extremes.

2. Plants Life Cycle

Most life cycles, except perhaps for the simplest and smallest organisms, consist of different epochs. A large tree has a period of seed formation that involves many cell divisions after fertilization and the laying down of a small embryo in a hard resistant shell, or seed coat. There then follows a period of dormancy, sometimes prolonged, after which the seed germinates, and the adult form slowly emerges as the shoots and roots grow at the tips and the stem thickens. In some trees, the leaves of the juvenile plant have a shape that is quite different from that of the taller, more mature individuals. Thus, even the growth phase may be subdivided into epochs, the final one being the flowering or gamete bearing period. Some of the parasitic fungi have much more complex life cycles. The wheat rust parasite, for example, has alternate hosts. While living on wheat, it produces two kinds of spores; it produces a third kind of spore when it invades its other host, the barberry, on which it winters and undergoes the sexual part of its life cycle.

In plants, variations in the epochs of the life cycle are often centred around the times of fertilization and meiosis. After fertilization, the organism has the diploid number of chromosomes (diplophase); after meiosis it is haploid (haplophase). The two events vary in time with respect to each other. In some simple algae eg. Chlamydomonas, most of the cycle is haploid; meiosis occurs immediately after fertilization. Yet in other algae, such as the sea lettuce (Ulva), two equal haploid and diploid cycles alternate. The outward morphological structures of mature Ulva are indistinguishable; the two cycles can be differentiated only by the size of the cell or nucleus, those of the haploid stage being half the size of those of the diploid stage.

In many of the higher algae, there is a progressive diminution of the haplophase and an increase in the importance of the diplophase, a trend that is especially noticeable in the evolution of the vascular plants (e.g., ferns, conifers, and flowering plants). In mosses, the haplophase, or gametophyte, is the main part of the green plant; the diplophase, or sporophyte, usually is a sporebearing spike that grows from the top of the plant. In ferns, the haplophase is reduced to a small, inconspicuous structure (prothallus) that grows in the damp soil; the large spore-bearing fern itself is entirely diploid. Finally, in higher plants the haploid tissue is confined to the ovary of the large diploid organism, a condition that is also prevalent in most animals.

3. Natural selection and reproduction

The significance of biological reproduction can be explained entirely by natural selection. In formulating his theory of natural selection, Charles Darwin realized that, in order for evolution to occur, not only must living organisms be able to reproduce themselves but the copies must not all be identical; that is, they must show some variation. In this way the more successful variants would make a greater contribution to subsequent generations in the number of offspring. For such selection to act continuously in successive generations, Darwin also recognized that the variations had to be inherited, although he failed to fathom the mechanism of heredity. Moreover, the amount of variation is particularly important. According to what has been called the principle of compromise, which itself has been shaped by natural selection, there must not be too little or too much variation: too little produces no change; too much scrambles the benefit of any particular combination of inherited traits.

Of the numerous mechanisms for controlling variation, all of which involve a combination of checks and balances that work together, the most successful is that found in the large majority of all plants and animals—ie., sexual reproduction. During the evolution of reproduction and variation, which are the two basic properties of organisms that not only are required for natural selection but are also subject to it, sexual reproduction has become ideally adapted to produce the right amount of variation and to allow new combinations of traits to be rapidly incorporated into an individual.

4. The Evolution of Reproduction

An examination of the way in which organisms have changed since their initial unicellular condition in primeval times shows an increase in multicellularity and therefore an increase in the size of both plants and animals. After cell reproduction evolved into multicellular growth, the multicellular organism evolved a means of reproducing itself that is best described as life-cycle reproduction. Size increase has been accompanied by many mechanical requirements that have necessitated a selection for increased efficiency; the result has been a great increase in the complexity of organisms. This means a great increase in the permutations of cell reproduction during the process of evolutionary development.

Size increase also means a longer life cycle, and with it a great diversity of patterns at different stages of the cycle. This is because each part of the life cycle is adaptive in that, through natural selection, certain characteristics have evolved for each stage that enable the organism to survive. The most extreme examples are those forms with two or more separate phases of their life cycle separated by a metamorphosis, as in caterpillars and butterflies; these phases may be shortened or extended by natural selection, as has occurred in different species of coelenterates.

To reproduce efficiently in order to contribute effectively to subsequent generations is another factor that has evolved through natural selection. For example, an organism can produce vast quantities of eggs of which, possibly by neglect, only a small percent will survive. On the other hand, an organism can produce very few or perhaps one egg, which, as it develops, will be cared for, thereby greatly increasing its chances for survival. These are two strategies of reproduction; each has its advantages and disadvantages. Many other considerations of the natural history and structure of the organism determine, through natural selection, the strategy that is best for a particular species; one of these is that any species must not produce too few offspring (for it will become extinct) or too many (for it may also become extinct by overpopulation and disease). The numbers of some organisms fluctuate cyclically but always remain between upper and lower limits. The question of how, through natural selection, numbers of individuals are controlled is a matter of great interest; clearly, it involves factors that influence the rate of reproduction.

Self-Assessment Exercises 2

1. What is an organism’s life cycle?
2. What are the main stages of the life cycle of a typical plant?

6.5 Body Cells

You and I began as a single cell, or what you would call an egg. By the time you are an adult, you will have trillions of cells. That number depends on the size of the person, but biologists put that number around 37 trillion cells. Yes, that is trillion with a "T." In cell division, the cell that is dividing is called the "parent" cell. The parent cell divides into two "daughter" cells. The process then repeats in what is called the cell cycle.

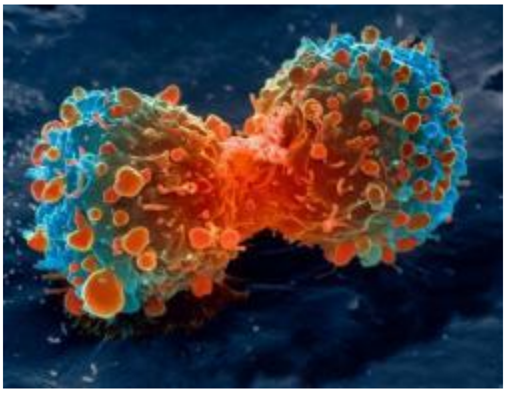

Figure 6.1 Cell division of cancerous lung cell
Source: https://askabiologist.asu.edu/cell-division

Cells regulate their division by communicating with each other using chemical signals from special proteins called cyclins. These signals act like switches to tell cells when to start dividing and later when to stop dividing. It is important for cells to divide so you can grow and your cuts heal. It is also important for cells to stop dividing at the right time. If a cell cannot stop dividing when it is supposed to stop, this can lead to a disease called cancer. Some cells, like skin cells, are constantly dividing. We need to continuously make new skin cells to replace the skin cells we lose. Did you know we lose 30,000 to 40,000 dead skin cells every minute? That means we lose around 50 million cells every day. This is a lot of skin cells to replace, making cell division in skin cells so important. Other cells, like nerve and brain cells, divide much less often.

Depending on the type of cell, there are two ways cells divide—mitosis and meiosis. Each of these methods of cell division has special characteristics. One of the key differences in mitosis is a single cell divides into two cells that are replicas of each other and have the same number of chromosomes. This type of cell division is good for basic growth, repair, and maintenance. In meiosis a cell divides into four cells that have half the number of chromosomes. Reducing the number of chromosomes by half is important for sexual reproduction and provides for genetic diversity.

6.5.1 Mitosis Cell Division

Mitosis is how somatic—or non-reproductive cells—divide. Somatic cells make up most of your body's tissues and organs, including skin, muscles, lungs, gut, and hair cells. Reproductive cells (like eggs) are not somatic cells. In mitosis, the important thing to remember is that the daughter cells each have the same chromosomes and DNA as the parent cell. The daughter cells from mitosis are called diploid cells. Diploid cells have two complete sets of chromosomes. Since the daughter cells have exact copies of their parent cell's DNA, no genetic diversity is created through mitosis in normal healthy cells.

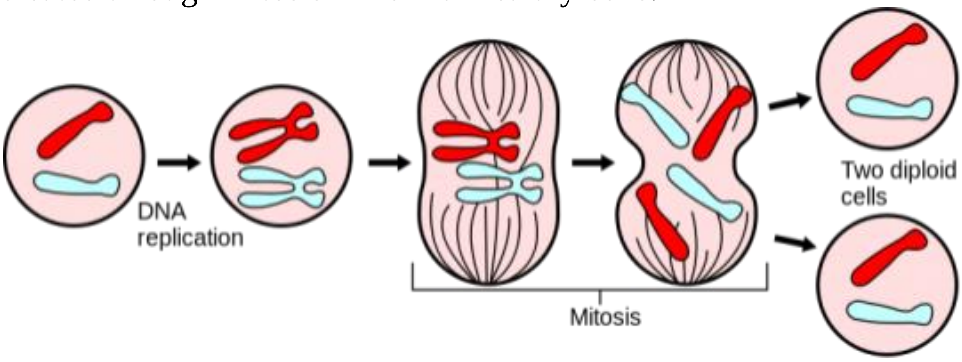

Figure 6.2. Mitosis cell division creates two genetically identical daughter diploid cells. The major steps of mitosis are shown here.
Source: https://askabiologist.asu.edu/cell-division

The Mitosis Cell Cycle

Interphase is the period when a cell is getting ready to divide and start the cell cycle. During this time, cells are gathering nutrients and energy. The parent cell is also making a copy of its DNA to share equally between the two daughter cells. The mitosis division process has several steps or phases of the cell cycle—interphase, prophase, prometaphase, metaphase, anaphase, telophase, and cytokinesis—to successfully make the new diploid cells.

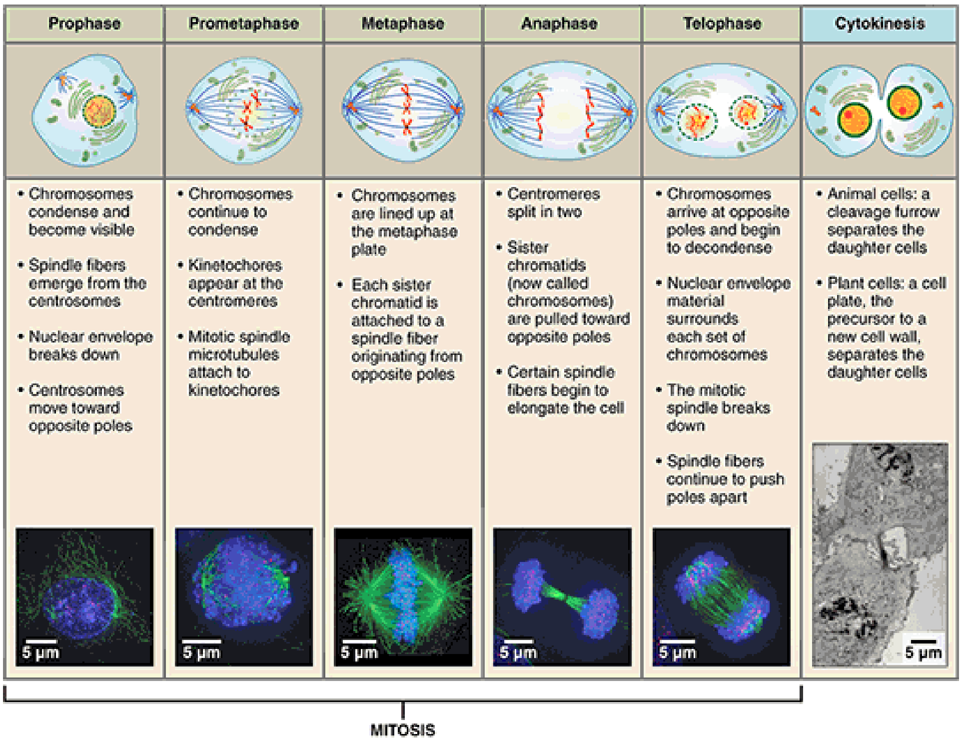

Figure 6.3 The mitosis cell cycle includes several phases that result in two new diploid daughter cells. Each phase is highlighted here and shown by light microscopy with fluorescence. Click on the image to learn more about each phase.
Source: https://askabiologist.asu.edu/cell-division

When a cell divides during mitosis, some organelles are divided between the two daughter cells. For example, mitochondria are capable of growing and dividing during the interphase, so the daughter cells each have enough mitochondria. The Golgi apparatus, however, breaks down before mitosis and reassembles in each of the new daughter cells. Many of the specifics about what happens to organelles before, during and after cell division are currently being researched.

6.5.2 Meiosis Cell Division

Meiosis is the other main way cells divide. Meiosis is cell division that creates sex cells, like female egg cells or male sperm cells. What is important to remember about meiosis? In meiosis, each new cell contains a unique set of genetic information. After meiosis, the sperm and egg cells can join to create a new organism. Meiosis is why we have genetic diversity in all sexually reproducing organisms. During meiosis, a small portion of each chromosome breaks off and reattaches to another chromosome. This process is called "crossing over" or "genetic recombination." Genetic recombination is the reason full siblings made from egg and sperm cells from the same two parents can look very different from one another.

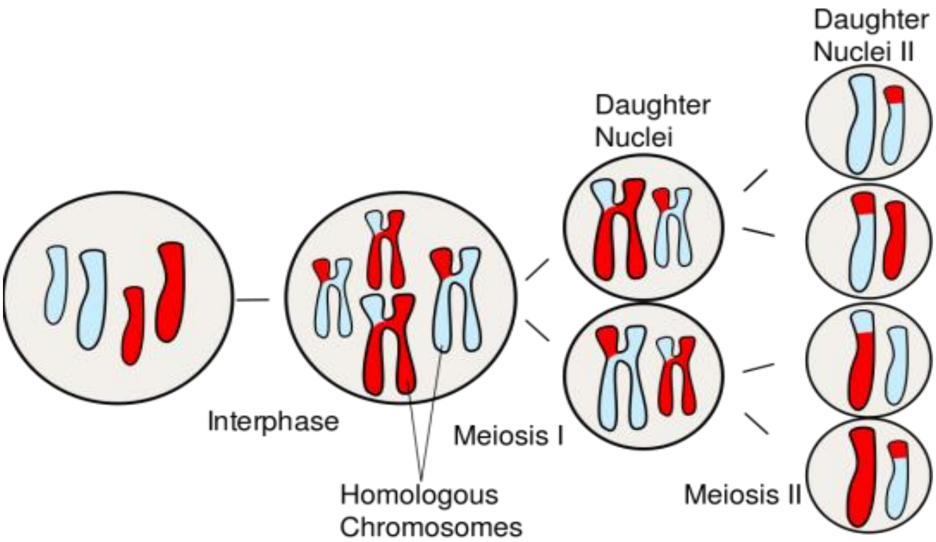

Figure 6.4 The meiosis cell cycle has two main stages of division -- Meiosis I and Meiosis II. The end result of meiosis is four haploid daughter cells that each contain different genetic information from each other and the parent cell.
Source: https://askabiologist.asu.edu/cell-division

The Meiosis Cell Cycle

Meiosis has two cycles of cell division, conveniently called Meiosis I and Meiosis II. Meiosis I halves the number of chromosomes and is also when crossing over happens. Meiosis II halves the amount of genetic information in each chromosome of each cell. The end result is four haploid daughter cells. Haploid cells only have one set of chromosomes - half the number of chromosomes as the parent cell. Before meiosis I starts, the cell goes through interphase. Just like in mitosis, the parent cell uses this time to prepare for cell division by gathering nutrients and energy and making a copy of its DNA. During the next stages of meiosis, this DNA will be switched around during genetic recombination and then divided between four haploid cells. So remember, Mitosis is what helps us grow and Meiosis is why we are all unique!

Self-Assessment Exercises 3

1. Depending on the type of cell, what are the two ways cells divides?
2. How do cells regulate their division?

6.6 Summary

You have learned about the meaning and process of reproduction in both unicellular and multicellular organisms, which at the lowest level, is a chemical replication and in multicellular organisms, however, means growth and regeneration. You have studied about the differences between Binary fission and Multiple fission. The life cycles of animals and plants has also been highlighted as invertebrate animals have a rich variety of life cycles, especially among those forms that undergo metamorphosis, a radical physical change and in vascular plants , they have a period of seed formation that involves many cell divisions after fertilization and the laying down of a small embryo in a hard resistant shell or seed coat. You have also learned about the chromosomal makeup of a cell using the terms chromosome, sister chromatid, homologous chromosome, diploid, haploid, and tetrad. The unit also highlighted the function and products of mitosis and meiosis, this has enabled for the comparison of the behaviors of chromosomes.

6.7 References/Further Readings/Web Sources

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6.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Sexuality is present even in primitive bacteria, in which parts of the chromosome of one cell can be transferred to another during mating.
2. Some sexual organisms such as in aphids and in many higher plants partially revert to the asexual mode by a periodic degeneration of the sexual process where the egg nucleus develops into a new individual without fertilization, a kind of asexual reproduction that is called parthenogenesis.

Answers to SAE 2

1. Organisms Life cycle is the series of changes that the members of a species undergo as they pass from the beginning of a given developmental stage to the inception of that same developmental stage in a subsequent generation.
2. A large tree has a period of seed formation that involves many cell divisions after fertilization and the laying down of a small embryo in a hard resistant shell, or seed coat. There then follows a period of dormancy, sometimes prolonged, after which the seed germinates, and the adult form slowly emerges as the shoots and roots grow at the tips and the stem thickens.

Answers to SAE 3

1. mitosis and meiosis
2. Cells regulate their division by communicating with each other using chemical signals from special proteins called cyclins.

Glossary

Anaphase - a stage in mitosis where chromosomes begin moving to opposite ends (poles) of the cell.

Animal Cells - eukaryotic cells that contain various membrane-bound organelles.

Allele - an alternative form of a gene (one member of a pair) that is located at a specific position on a specific chromosome.

Biology - the study of living organisms.

Cell - the fundamental unit of life.

Cell Biology - the subdiscipline of biology that focuses on the study of the basic unit of life, the cell.

Cell Cycle - the life cycle of a dividing cell, including Interphase and the M phase or Mitotic phase (mitosis and cytokinesis).
Cell Membrane - a thin semi-permeable membrane that surrounds the cytoplasm of a cell.

Cell Theory - one of the five basic principles of biology, stating that the cell is the basic unit of life.

Centrioles - cylindrical structures that are composed of groupings of microtubules arranged in a 9 + 3 pattern.

Centromere - a region on a chromosome that joins two sister chromatids.

Chromatid - one of two identical copies of a replicated chromosome.

Chromatin - the mass of genetic material composed of DNA and proteins that condense to form chromosomes during eukaryotic cell division.

Chromosome - a long, stringy aggregate of genes that carries heredity information (DNA) and is formed from condensed chromatin.
Cilia and Flagella - protrusions from some cells that aid in cellular locomotion.

Cytokinesis - the division of the cytoplasm that produces distinct daughter cells.

Cytoplasm - all of the contents outside of the nucleus and enclosed within the cell membrane of a cell.

Cytoskeleton - a network of fibers throughout the cell's cytoplasm that helps the cell maintain its shape and gives support to the cell.

Cytosol - semi-fluid component of a cell's cytoplasm.

Daughter Cell - a cell resulting from the replication and division of a single parent cell.

Diploid Cell - a cell that contains two sets of chromosomes—one set of chromosomes is donated from each parent.

Endoplasmic Reticulum - a network of tubules and flattened sacs that serve a variety of functions in the cell.

Gametes - reproductive cells that unite during sexual reproduction to form a new cell called a zygote.

Genes - segments of DNA located on chromosomes that exist in alternative forms called alleles.

Golgi Complex - the cell organelle that is responsible for manufacturing, warehousing, and shipping certain cellular products.

Haploid Cell - a cell that contains one complete set of chromosomes.

Interphase - the stage in the cell cycle where a cell doubles in size and synthesizes DNA in preparation for cell division.

Lysosomes - the membranous sacs of enzymes that can digest cellular macromolecules.

Meiosis - a two-part cell division process in organisms that sexually reproduce, resulting in gametes with one-half the number of chromosomes of the parent cell.

Metaphase - the stage in cell division where chromosomes align along the metaphase plate in the center of the cell.

Microtubules - fibrous, hollow rods that function primarily to help support and shape the cell.

Mitochondria - cell organelles that convert energy into forms that are usable by the cell.

Mitosis - a phase of the cell cycle that involves the separation of nuclear chromosomes followed by cytokinesis.

Nucleus - a membrane-bound structure that contains the cell's hereditary information and controls the cell's growth and reproduction.

Organelles - tiny cellular structures, that carry out specific functions necessary for normal cellular operation.

Peroxisomes - cell structures that contain enzymes that produce hydrogen peroxide as a by-product.

Plant Cells - eukaryotic cells that contain various membrane-bound organelles. They are distinct from animal cells, containing various structures not found in animal cells.

Polar Fibers - spindle fibers that extend from the two poles of a dividing cell.

Prokaryotes - single-celled organisms that are the earliest and most primitive forms of life on earth.

Prophase - the stage in cell division where chromatin condenses into discrete chromosomes.

Ribosomes - cell organelles that are responsible for assembling proteins.
Sister Chromatids - two identical copies of a single chromosome that are connected by a centromere.

Spindle Fibers - aggregates of microtubules that move chromosomes during cell division.

Telophase - the stage in cell division when the nucleus of one cell is divided equally into two nuclei.

End of Module Questions

1. Define a cell.
2. What are tissues? What are the basic tissues in humans?
3. Describe organ systems.
4. How many organ systems are in the human body?
5. Organisms can carry out all basic life processes. Explain this sentence.
6. Describe the levels of organization of a complex, multicellular organism
7. What is the cell structure and organization?
8. Outline some examples of cellular organization.
9. What are the types of cell organization?

MODULE 3 INTERRELATIONSHIP BETWEEN ORGANISMS

Module Structure

In this module we will discuss about the interrelationship between organisms and the theories of evolution and natural selection. We shall also study some basic elements of ecology

Unit 1 Interrelationship between organisms
Unit 2 Heredity and Variation
Unit 3 Introduction to Evolution
Unit 4 Natural selection
Unit 5 Elements of Ecology
Glossary
End of Module Questions

Unit 1 Interrelationship between organisms

Unit Structure

1.1 Introduction
1.2 Learning Outcomes
1.3 Concept of Interrelationship
1.4 Interactions Between Organisms
1.5 The Environment and the Organisms
1.6 Summary
1.7 References/Further Readings/Web Sources
1.8 Possible Answers to Self-Assessment Exercises

1.1 Introduction

You will learn in this unit that every organism is shaped by, and in turn shapes its environment in its life and reproduction. You will also learn that ecological scientists study organism-environment interactions across ecosystems of all sizes, ranging from microbial communities to the Earth as a whole.

1.2 Intended Learning Outcomes (ILOs)

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

- Recognize that every organism is shaped by, and in turn shapes its environment in its life and reproduction.
- Explain the Concept of Interrelationship
- Describe how ecological scientists study organism-environment interactions across ecosystems of all sizes, ranging from microbial communities to the Earth as a whole.
- Describe the various interactions between organisms

1.3 Concept of Interrelationship

The diversity and scope of life on Earth is astounding, ranging from microscopic viruses and bacteria that have gone unnoticed for millennia to 200-ton blue whales and fungus that cover hundreds of hectares underground. Inside a certain geographic area, within an ecological community, entities reside in an assemblage of populations with at least two different species that are constantly interacting with one another, either directly or indirectly. Numerous biological processes in ecosystems, such as the food chain and the nutrient cycle, are based on interactions between species. These interactions take in many forms depending on their surroundings and evolutionary history. These interactions, which can be found in various ecosystems, can be categorised in a number of ways. These interactions can be used as a framework for ecological community analysis to characterise naturally occurring processes, which can then be used to forecast human adjustments that may affect the characteristics and processes of ecosystems. These interactions might be intra-specific or inter-specific (involving distinct species) (interactions between same species). The environment is in a whirlwind with all living things. The organism develops a certain kind of relationship with respect to resources; some organisms compete with one another while others depend on one another for survival. These traits are broken down into four categories: parasitism, commensalism, predation, and mutualism. Both organisms profit from a symbiotic connection. With commensalism, one organism gains and the other is, in a sense, neutrally affected—neither aided nor damaged. There are two forms of parasitic relationships: ectoparasites and endoparasites, where one organism gains while the other suffers. Predation occurs when one organism kills and consumes another. Some species have extremely close symbiotic interactions with one another, meaning that both of them depend on the other to survive.

Inside a certain geological region in a natural network, animals coexist in a variety of populations that at least have two separate species that are constantly interacting with one another, either directly or indirectly. Some organic processes in biological systems, such as the cycle of nutrients and evolved forms of life, are shaped by interactions between species. The concept behind these interactions depends on the environmental factors and evolutionary perspectives that have led to their existence. Different contexts have different ways of characterising these interactions. These interactions can be used as a foundation for breaking down the environmental network to show patterns that naturally occur, which can then be used to predict changes made by humans that might affect the characteristics and workings of biological systems. These interactions might be intraspecific or specific (involving different species) (interactions between same species). We will acquire in-depth information on the various kinds of partnerships and interactions between species in this unit. As an illustration, the cat represents the predator and the bird is the prey. The predator is the cat, one who kills and eats; the target is the bird, one who gets killed and eaten. Any animal that hunts other organisms down, kills, and eats them for survival is known as a predator. This process is called predation. What do we refer the interactions between and within species as?

Self-Assessment Exercises 1

1. What is a predator?
2. Upon what does the idea of species interactions rely on an ecosystem?

1.4 Interactions Between Organisms

In a symbiotic connection known as parasitism, one organism gains while the other suffers, and in certain cases, even perishes. Consider a few instances: mosquitoes frequently attend picnics and consume food at your cost. Some of the deadliest diseases that affect humans are spread by mosquitoes. Thus, the mosquito eats, and you run the risk of being ill. Ticks will behave similarly toward you, dogs, and even livestock. When they begin to eat, they latch on to their hosts and spread a variety of infections, including Lyme disease, to them. Leech, a segmented worm that attaches to a host like you and feeds on your blood, is one of many parasitic worms; They really release a chemical that stops the blood from clotting. In addition to being crippling, if present in large enough numbers, it may also be fatal.

Animals live in spaces known as niches. A niche is the area where an organism lives, how it uses the resources in that area, and how it interacts with other organisms there. Five different types of connections can be used to describe how organisms interact inside or between overlapping niches: parasitism, commensalism, competition, predation, and commensalism. Symbiotic connections are traditionally classified as the last three kinds, but predation and competition are also examples of symbiotic relationships. A close relationship in which one or both organisms profit is referred to as symbiosis.

Competition and Predation

When one organism feeds on another to get nutrients, this is called predation. The prey is the living thing that is consumed. Predators include owls that consume mice and lions that consume gazelles. Individuals or communities engaging in competition for the same resource can be between or within species. Consumptive or exploitative competition occurs when organisms compete for a resource (such food or building materials). They engage in interference competition when vying for territory. Preemptive competition is when two parties compete for new territory by showing up first. The conflict between lions and hyenas over prey is one example.

Commensalism

A relationship known as commensalism occurs when one organism gains while the other is neither aided nor hurt. Examples are the barnacles that develop on whales and other aquatic creatures. The barnacle serves no purpose for the whale, but it gives the barnacles greater movement, which enables them to avoid predators and exposes them to a wider variety of eating options. Commensal relationships come in four different fundamental varieties. When one bacterium generates a chemical that supports another bacterium, this is known as chemical commensalism. When one organism occupies a nest, burrow, or place of residence of another species, this is known as inquilinism. Commensalism that depends on another species for survival is known as metabiosis. Phoresy is the temporary attachment of one organism to another for the purpose of transportation.

Parasitism

In a connection known as parasitism, one organism gains and the other is sometimes injured but not always killed. The parasite is the organism that gains, and the host is the organism that suffers. When an organism lays its egg inside of another organism, which is later consumed by the hatchlings, this is known as parasitoidism, which is distinct from parasitism because the host is always destroyed. Ectoparasites reside on the host's surface eg. ticks, fleas, and leeches. Endoparasites, such as intestinal worms, are another type of parasite that lives inside the host. Endoparasites can also be divided into intracellular (which live inside cells) and intercellular (which dwell between cells) parasites. There is also something called hyperparasitism, a situation where a parasite is infected by another parasite, such as a microorganism living in a flea, which lives on a dog. Lastly, a relationship called social parasitism is exemplified by an ant species that does not have worker ants, living among another ant species that do, by using the host species' workers.

Mutualism

A partnership in which both species profit is known as mutualism. Three types of mutualistic interaction patterns exist. When one organism cannot thrive without the other, there is obligatory mutualism. When an organism coexists with multiple partners, this is referred to as diffuse mutualism. When one species can live on its own in specific circumstances, this is known as facultative mutualism. Mutualistic interactions also provide three other general goals. Lichens, which are made up of either algae or cyanobacteria and fungi, are an excellent example of trophic mutualism. The partners of the fungi produce sugar through photosynthesis, while the fungi themselves provide nutrition by breaking down rock. Ants and aphids are an example of a defensive mutualism where one organism provides protection from predators while the other provides food or refuge. Dispersive mutualism is when one species receives food in return for transporting the pollen of the other organism, which occurs between bees and flowers.

Self-Assessment Exercises 2

1. What is parasitism?
2. List the two types of parasites.

1.5 The Environment and the Organisms

The environment is dynamic because physical processes drive change in Earth's attributes over time. However, research demonstrates that life itself drives equally important environmental changes. Other organisms being part of each individual's environment, changes in species distributions can profoundly alter ecological interactions within communities. In some cases, the loss of a native species, or introduction of a non-native one, can threaten the survival of other organisms. For this reason, conservation of endangered organisms and control of invasive species are of broad concern. Organisms inhabit nearly every environment on Earth, from hot vents deep in the ocean floor to the icy reaches of the Arctic. Each environment offers both resources and constraints that shape the appearance of the species that inhabit it, and the strategies these species use to survive and reproduce. Some of the broadest patterns of environmental difference arise from the way our planet orbits the Sun and the resulting global distribution of sunlight. In the tropics, where solar radiation is plentiful year-round, temperatures are warm, and plants may photosynthesize continuously as long as water and nutrients are available. In polar regions, where solar radiation is seasonally limited, mean temperatures are much lower, and organisms must cope with extended periods when photosynthesis ceases.

Across ecosystems, environmental resources and constraints shape the structure and physiology of organisms. One of Earth's oldest environmental legacies is the array of chemical elements it contains. At its birth, Earth inherited carbon atoms produced by stars that burned out long before our sun was formed. These carbon atoms, with their unique capacity to build chains and four-way links with other elements, provide the backbone of all the organic molecules that make up life today. Nitrogen and phosphorus are also essential elements in living organisms, where they play central roles in the makeup of proteins, nucleic acids, and energetic compounds. These elements are not always readily available to organisms, so nutrient limitations can powerfully constrain biological strategies. For example, inert nitrogen gas makes up 78% of Earth's atmosphere, but nitrogen forms readily useable by organisms are typically much scarcer in terrestrial ecosystems. Over evolutionary time, symbioses that developed between nitrogen-fixing bacteria and plants helped increase the availability of nitrogen in many ecosystems. Nonetheless, given strong competition for nitrogen and other elements, ecologists find that nutrient limitations constrain life in many environments. Organisms are shaped further by the physical properties of the media in which they live, including the media's densities and temperatures. For example, marine mammals like Stellar sea lions (*Eumetopias jubatus*) have developed streamlined bodies that move efficiently through water, which is more than 700 times denser than air, but that slow them down on land. As a result, sea lions sleep on shore, but hunt for food primarily in the water, where their speed is optimized.

Ecologists have found that interactions among organisms come in several different forms. In antagonistic relationships, organisms compete for resources, spread disease to their neighbors, or consume each other. In more mutualistic associations, one organism shelters another, two organisms exchange resources, or tighter dependencies evolve, such as coevolved relationships between specialized pollinators and flowers. In some cases, species even cultivate others. For example, ecologists recently found that coral reef damselfish tend underwater algal gardens, where they remove less desirable algae species and chase away predators. In other cases, species with large structures become habitat for smaller organisms. For example, the human digestive tract harbors so many bacteria that they outnumber the cells in the human body by tenfold. Investigating how digestive tract microbes influence their hosts is now a promising area of microbial ecology and medicine. At a bigger scale, the evolutionary rise of flowering plants (angiosperms) and the development of extensive rainforest canopies produced novel environments in which animals tested new ecological strategies.

Scientists suggest that evolution of the open branch structure of rainforest trees helped drive the evolution of forelimb structure in apes, permitting tree-to-tree swinging, and bequeathing manual dexterity to humans.

Self-Assessment Exercises 3

1. Over evolutionary time, what helped increase the availability of nitrogen in ecosystems?
2. Why may plants photosynthesize continuously as long as water and nutrients are available in the tropics?

1.6 Summary

The species interactions discussed above are only some of the known interactions that occur in nature and can be difficult to identify because they can directly or indirectly influence other intra-specific and inter-specific interactions. In addition, the role of abiotic factors adds complexity to species interactions and how we understand them. That is to say, species interactions are part of the framework that forms the complexity of ecological communities.

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1.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Any animal that hunts other organisms down, kills, and eats them for survival is known as a predator.
2. Species interactions relied on the environmental conditions and evolutionary angles wherein they exist

1. Any animal that hunts other organisms down, kills, and eats them for survival is known as a predator.
2. Species interactions relied on the environmental conditions and evolutionary angles wherein they exist

Answers to SAE 2

1. Parasitism is a relationship in which one organism benefits and the other organism is harmed, but not always killed.
2. Parasites can be ectoparasites -- such as ticks, fleas, and leeches -- that live on the surface of the host. Parasites can also be endoparasites -- such as intestinal worms – that live inside the host.

Answers to SAE 3

1. Over evolutionary time, symbioses that developed between nitrogen-fixing bacteria and plants helped increase the availability of nitrogen in many ecosystems.
2. Solar radiation is plentiful year-round, temperatures are warm

UNIT 2 GENETICS AND EVOLUTION

Unit Structure

2.1 Introduction
2.2 Intended Learning Outcomes (ILOs)
2.3 Heredity
    2.3.1 Contribution of Gregor Johann Mendel to the Study of Genetics
    2.3.2 Principle of segregation and independent assortment
2.4 Variation and its importance
2.5 How characteristics are inherited
    2.5.1 Dominant and recessive genes
    2.5.2 Gene changes and Co-dominant genes
2.6 Summary
2.7 References/Further Readings/Web Sources
2.8 Possible Answers to Self-Assessment Exercises

2.1 Introduction

In this unit you shall learn some fundamental aspects of genetics such as Mendel's laws, chromosomes, genes, how DNA duplicates, what makes a fertilized egg male or female and about dominant and recessive genes, and gene changes and co-dominant genes

2.2 Intended Learning Outcomes (ILOs)

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

- define the term heredity and variation;
- state pattern of Mendelian inheritance;
- describe the location, structure and function of chromosomes and genes
- give an account of the four blood groups in humans and the manner of their inheritance;
- explain the chromosomal basis of sex determination in humans;

2.3 Heredity

Why does a baby who looks like a human also resemble its parents, grandparents, or even distant cousins, uncles, or aunts? Why does a kitten look like a tiny cat to you? Why do a seedling's leaves, stems, or flowers develop similarly to those of its parents' plants? Why, in addition, do all organisms share their parents' structural characteristics? Heredity is the scientific term for the transmission of traits from one generation to the next. The phenomenon of passing on characteristics or qualities from one set of parents to another is known as heredity. Any quality that is passed down from parent to child is referred to as a trait. The fertilised egg or zygote has characteristics that carry over from one generation to the next. That zygote grows into a certain kind of organism. Genes are in charge of heredity. Even among members of the same family, variances or differences result from different gene combinations. Genetics is the study of heredity and genetic variation. Many scientists in the past were fascinated by the topic of heredity. A monk from Austria named Gregor Johann Mendel (1822–1884) undertook the arduous process of doing so. He chose a few pea plants, raised them year after year, gathered a lot of data, examined it, and for the first time theorised a few inheritance laws. His remarkable work, however, got recognized years after his death when Correns, Tschermak and Hugo de Vries came to the same conclusions as Mendel did, after independently carrying out experiments in their own countries.

2.3.1 Contribution of Gregor Johann Mendel to the Study of Genetics

Mendel established that certain qualities appear in offspring without any mixing of parent characteristics through the selective cross-breeding of common pea plants (Pisum sativum) over many generations. For example, the pea bloom is either purple or white; cross-pollinated pea plants do not produce offspring with intermediate colours. Mendel identified seven features that are instantly recognisable and seem to only exist in two forms:

1. Flower color is purple or white
2. Flower position is axil or terminal
3. Stem length is long or short
4. Seed shape is round or wrinkled
5. Seed color is yellow or green
6. Pod shape is inflated or constricted
7. Pod color is yellow or green

Mendel picked common garden pea plants for the focus of his research because they can be grown easily in large numbers and their reproduction can be manipulated. Pea plants have both male and female reproductive organs. As a result, they can either self-pollinate themselves or cross-pollinate with another plant. In his experiments, Mendel was able to selectively cross-pollinate purebred plants with particular traits and observe the outcome over many generations. This was the basis for his conclusions about the nature of genetic inheritance.

Reproductive structures of flowers

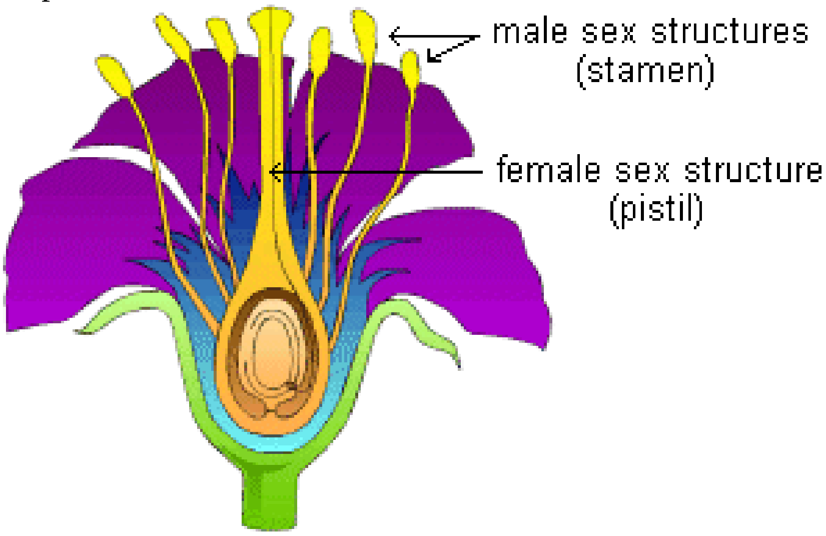
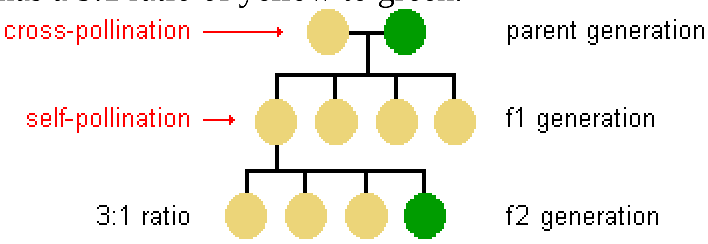
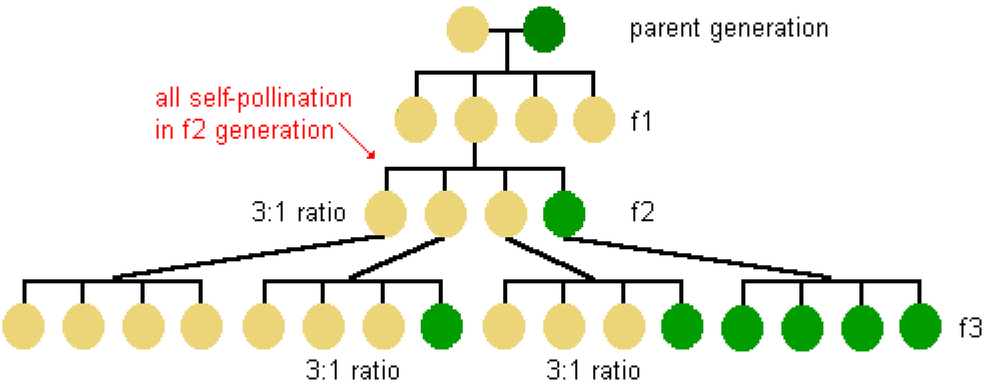


Figure 1.1 Reproductive structures of flowers. Source:www.byjus.om

In cross-pollinating plants that either produce yellow or green pea seeds exclusively, Mendel found that the first offspring generation (f1) always has yellow seeds. However, the following generation (f2) consistently has a 3:1 ratio of yellow to green.



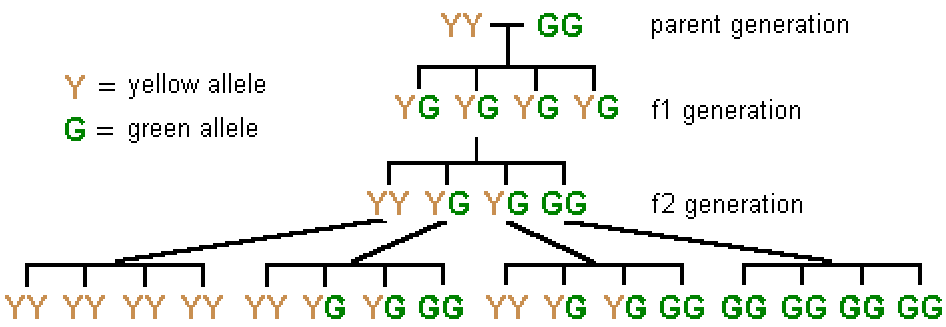
This 3:1 ratio occurs in later generations as well. Mendel realized that this underlying regularity was the key to understanding the basic mechanisms of inheritance.



He came to three important conclusions from these experimental results:

1. that the inheritance of each trait is determined by "units" or "factors" that are passed on to descendents unchanged (these units are now called genes)
2. That an individual inherits one such unit from each parent for each trait
3. That a trait may not show up in an individual but can still be passed on to the next generation.

It is important to realize that, in this experiment, the starting parent plants were **homozygous** for pea seed color. That is to say, they each had two identical forms (or **alleles**) of the gene for this trait--2 yellows or 2 greens. The plants in the f1 generation were all **heterozygous**. In other words, they each had inherited two different alleles--one from each parent plant. It becomes clearer when we look at the actual genetic makeup, or **genotype** of the pea plants instead of only the **phenotype**, or observable physical characteristics.



Note that each of the f1 generation plants (shown above) inherited a Y allele from one parent and a G allele from the other. When the f1 plants breed, each has an equal chance of passing on either Y or G alleles to each offspring.

With all of the seven pea plant traits that Mendel examined, one form appeared **dominant** over the other, which is to say it masked the presence of the other allele. For example, when the genotype for pea seed color is YG (heterozygous), the phenotype is yellow. However, the dominant yellow allele does not alter the **recessive** green one in any way. Both alleles can be passed on to the next generation unchanged.

2.3.2 Principle of Segregation and Independent Assortment

Mendel's observations from his pea plant experiments lead to the principles of segregation and principle of independent assortment. According to the **principle of segregation**, for any particular trait, the pair of alleles of each parent separate and only one allele passes from each parent on to an offspring. Which allele in a parent's pair of alleles is inherited is a matter of chance. We now know that this segregation of alleles occurs during the process of sex cell formation (i.e., meiosis).

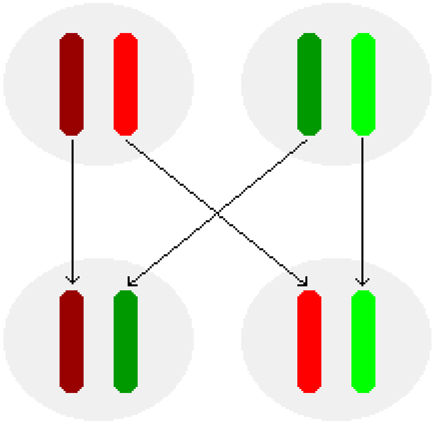


Figure 1.2. Segregation of alleles in the production of sex cells

According to the **principle of independent assortment**, different pairs of alleles are passed to offspring independently of each other. The result is that new combinations of genes present in neither parent are possible. For example, a pea plant's inheritance of the ability to produce purple flowers instead of white ones does not make it more likely that it will also inherit the ability to produce yellow pea seeds in contrast to green ones. Likewise, the principle of independent assortment explains why the human inheritance of a particular eye color does not increase or decrease the likelihood of having 6 fingers on each hand. Today, we know this is due to the fact that the genes for independently assorted traits are located on different chromosomes .

Five parts of Mendel's discoveries were an important divergence from the common theories at the time and were the prerequisite for the establishment of his rules.

1. Characters are unitary. That is, they are discrete (purple vs. white, tall vs. dwarf).
2. Genetic characteristics have alternate forms, each inherited from one of two parents. Today, we call these *alleles*.
3. One allele is dominant over the other. The phenotype reflects the dominant allele.
4. Gametes are created by random segregation. Heterozygotic individuals produce gametes with an equal frequency of the two alleles.
5. Different traits have independent assortment. In modern terms, genes are unlinked

What are the alternate forms of Genetic characteristic inherited from one of two parents referred?

Self-Assessment Exercises 1

1. What is heredity?
2. What were the prerequisite for the establishment of Mendel's rules from his discoveries?

2.4 Genetic Variation and its Importance

Genetic variety describes variations in the genomes of individuals within the same species. All an organism's genes and genetic material are contained in its genome. For example, there are around 20.000–25000 genes in the human genome. Genes are inherited informational units that contain the blueprints for making proteins. Cells can operate because of the genes that are encoded in these proteins. Because each parent cell or organism gives one copy of its genes to its offspring, most sexually reproducing organisms have two copies of each gene. Genetic variation can also be further increased by the existence of alleles, which are slightly different versions of genes. The genotype for a given attribute, such as hair texture, is determined by the mixture of alleles of a gene that an individual receives from both parents. The phenotype—the observable characteristics—that an individual has for a trait, such as whether they truly have straight, wavy, or curly hair, is determined by the genotype that person carries for that feature.

Multiple factors can cause genetic variation within a species. Genetic diversity can come from various sources, one of which being mutations, or alterations in the DNA's gene sequences. Gene flow, or the transfer of genes between several groups of organisms, is another source. The development of new gene combinations through sexual reproduction can also result in genetic variety. Some animals in a group can survive in their environment more successfully than others thanks to genetic variety. Even among members of a small population, the degree to which an organism is adapted to a given environment might vary noticeably. Moths of the same species with variously coloured wings serve as an illustration. Moths of a different hue are less effective at concealing themselves than those with wings that resemble tree bark. The tree-colored moths have a higher chance of surviving, procreating, and passing on their genes as a result, a process known as natural selection, and it is the primary driver behind evolution. The importance of variation can be outlined as follows:

1. They enable the organism to adapt in a changing environment.
2. Variation forms the basis of heredity
3. They form raw material for evolution and development of new species.

Variations may or may not help organisms to survive:

a) Some variations help organisms to survive: Green bushes are homes to several beetles. They multiply, which increases their population. The red beetles are easily spotted by crows, who then consume them. Due to some fluctuation, some green beetles rather than red beetles are produced during reproduction. Crows cannot see the green bugs and do not consume them. The population of red beetles then progressively declines while the population of green beetles gradually rises. The organisms' ability to live is due to this variation.

b) Some variations do not help organisms to survive: Red beetles undergo a colour change during sexual reproduction, and some blue beetles are produced in place of red beetles. Crows can see the red and blue insects, and they consume them both. The population of red and blue beetles then starts to decline. The organisms have not fared better as a result of this modification.

c) Acquired traits cannot be passed from one generation to the next: Beetle population growth and plant disease both result in a reduction in the amount of food accessible to them, which also affects their body weight. The body weight of the beetles will also increase if, after a few years, there is more food available. Since their genetic makeup has not changed, this acquired trait cannot be passed from one generation to another.

Self-Assessment Exercises 2

1. What is genetic variation?
2. Outline the importance of variation?

Parents pass on traits or characteristics, such as eye colour and blood type, to their children through their genes. Some health conditions and diseases can be passed on genetically too. Sometimes, one characteristic has many different forms. For example, blood type can be A, B, AB or O. Changes (or variations) in the gene for that characteristic cause these different forms. Each variation of a gene is called an allele (pronounced 'AL-eel'). These two copies of the gene contained in your chromosomes influence the way your cells work. The two alleles in a gene pair are inherited, one from each parent. Alleles interact with each other in different ways called inheritance patterns. Examples of inheritance patterns include:

- **autosomal dominant** – where the gene for a trait or condition is dominant, and is on a non-sex chromosome
- **autosomal recessive** – where the gene for a trait or condition is recessive, and is on a non-sex chromosome

- **X-linked dominant** – where the gene for a trait or condition is dominant, and is on the X-chromosome
- **X-linked recessive** – where the gene for a trait or condition is recessive, and is on the X-chromosome
- **Y-linked** – where the gene for a trait or condition is on the Y-chromosome
- **co-dominant** – where each allele in a gene pair carries equal weight and produces a combined physical characteristic
- **mitochondrial** – where the gene for a trait or condition is in your mitochondrial DNA, which sits in the mitochondria (powerhouse) of your cells.

2.5.1 Dominant and recessive genes

The most common interaction between alleles is a dominant/recessive relationship. An allele of a gene is said to be dominant when it effectively overrules the other (recessive) allele. Eye colour and blood groups are both examples of dominant/recessive gene relationships.

1. Eye colour

The allele for brown eyes (B) is dominant over the allele for blue eyes (b). So, if you have one allele for brown eyes and one allele for blue eyes (Bb), your eyes will be brown. (This is also the case if you have two alleles for brown eyes, (BB). However, if both alleles are for the recessive trait (bb) you will inherit blue eyes.

2. Blood groups

For blood groups, the alleles are A, B and O. The A allele is dominant over the O allele. So, a person with one A allele and one O allele (AO) has blood group A. Blood group A is said to have a dominant inheritance pattern over blood group O. If a mother has the alleles A and O (AO), her blood group will be A because the A allele is dominant. If the father has two O alleles (OO), he has the blood group O. For each child that couple has, each parent will pass on one or the other of those two alleles. This is shown in figure 2.1. This means that each one of their children has a 50 per cent chance of having blood group A (AO) and a 50 per cent chance of having blood group O (OO), depending on which alleles they inherit.

		O	O
Mother's blood group	A	AO (group A)	AO (group A)
(AO, group A)	O	OO (group O)	OO (group O)

Figure 2.1: Father's blood group (OO, group O)

The combination of alleles that you have is called your genotype (eg. AO). The observable trait that you have – in this case blood group A – is your phenotype.

Recessive genetic conditions

If a person has one changed (q) and one unchanged (Q) copy of a gene, and they do not have the condition associated with that gene change, they are said to be a **carrier** of that condition. The condition is said to have a **recessive** inheritance pattern – it is not expressed if there is a functioning copy of the gene present. If two people are carriers (Qq) of the same recessive genetic condition, there is a 25 per cent (or one in four) chance that they may both pass the changed copy of the gene on to their child (qq, see figure 2.2). As the child then do not have an unchanged, fully functioning copy of the gene, they will develop the condition. There is also a 25 per cent chance that each child of the same parents may be unaffected, and a 50 per cent chance that they may be carriers of the condition.

Q	P		
Mother (carrier)	Q	QQ (unaffected)	Qq (carrier)
	q	Qq (carrier)	qq (affected)

Figure 2.2: Father (carrier)

Recessive genetic conditions are more likely to arise if two parents are related, although they are still quite rare. Examples of autosomal recessive genetic conditions include **cystic fibrosis** and **phenylketonuria (PKU)**.

2.5.2 Gene changes and Co-dominant genes

A cell reproduces by copying its genetic information then splitting in half, forming two individual cells. Occasionally, an alteration occurs in this process, causing a genetic change. When this happens, chemical messages sent to the cell may also change. This spontaneous genetic change can cause issues in the way the person's body functions. Sperm and egg cells are known as 'germ' cells. Every other cell in the body is called 'somatic' (meaning 'relating to the body').

If a change in a gene happens spontaneously in a person's somatic cells, they may develop the condition related to that gene change, but won't pass it on to their children. For example, skin cancer can be caused by a build-up of spontaneous changes in genes in the skin cells caused by damage from UV radiation. Other causes of spontaneous gene changes in somatic cells include exposure to chemicals and cigarette smoke. However, if the gene change occurs in a person's germ cells, that person's children have a chance of inheriting the altered gene.

Not all genes are either dominant or recessive. Sometimes, each allele in the gene pair carries equal weight and will show up as a combined physical characteristic. For example, with blood groups, the A allele is as 'strong' as the B allele. The A and B alleles are said to be **co-dominant**. Someone with one copy of A and one copy of B has the blood group AB. The inheritance pattern of children from parents with blood groups B (BO) and A (AO) is given in figure 2.3. Each one of their children has a 25 per cent chance of having blood group AB (AB), A (AO), B (BO) or O (OO), depending on which alleles they inherit.

B	O		
Mother's blood group	A	AB (group AB)	AO (group A)
(group A)	O	OB (group B)	OO (group O)

Figure 2.3: Father's blood group - (group B)
Differentiate between X-linked dominant and X-linked recessive characters.

Self-Assessment Exercises 3

1. When is an allele of a gene is said to be dominant?
2. Distinguish between autosomal dominant and autosomal recessive

2.6 Summary

In this unit you have learned some fundamental aspects of genetics such as Mendel's laws, chromosomes, genes, how DNA duplicates, what makes a fertilized egg male or female and about dominant and recessive genes, and gene changes and co-dominant genes.

2.7 References/Further Readings/Web Sources

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1.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Heredity is known as the phenomena of inheritance of traits or features of parents to offspring or progeny. A trait is any characteristic that is transferred from parent to offspring.
2. Five parts of Mendel's discoveries were an important divergence from the common theories at the time and were the prerequisite for the establishment of his rules.

i. Characters are unitary. That is, they are discrete (purple vs. white, tall vs. dwarf).
ii. Genetic characteristics have alternate forms, each inherited from one of two parents. Today, we call these *alleles*.
iii. One allele is dominant over the other. The phenotype reflects the dominant allele.
iv. Gametes are created by random segregation. Heterozygotic individuals produce gametes with an equal frequency of the two alleles.
v. Different traits have independent assortment. In modern terms, genes are unlinked

Answers to SAE 2

1. The differences in the DNA sequences among every organism leading to the diverse gene pool are called genetic variations.
2. The importance of variation can be outlined:
    i. They enable the organism to adapt them in changing environment.
    ii. Variation forms the basis of heredity
    iii. They form raw material for evolution and development of new species

Answers to SAE 3

1. An allele of a gene is said to be dominant when it effectively overrules the other (recessive) allele.
2. Autosomal dominant – where the gene for a trait or condition is dominant, and is on a non-sex chromosome and Autosomal recessive – where the gene for a trait or condition is recessive, and is on a non-sex chromosome

UNIT 3 INTRODUCTION TO EVOLUTION

Unit Structure

3.1 Introduction
3.2 Intended Learning Outcomes (ILOs)
3.3 Introduction to Evolution
3.4 Theories of Evolution
3.5 Encapsulating the concepts of Heredity and Evolution
3.6 Summary
3.7 References/Further Readings/Web Sources
3.8 Possible Answers to Self-Assessment Exercise

3.1 Introduction

You will learn about evolution as the gradual change of organisms on the earth over long periods, with new forms replacing old ones. The unit will explain the various theories of evolution, namely the theories of Special creationism, evolutionary creationism, spontaneous generation, eternity of life, Cosmozoan, and Biochemical theory

3.2 Intended Learning Outcomes (ILOs)

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

- Explain the meaning of evolution as the gradual change of organisms on the earth over long periods, with new forms replacing old ones.
- Explain the various theories of evolution, namely the theories of Special creationism, evolutionary creationism, spontaneous generation, eternity of life, Cosmozoan, and Biochemical theory
- You will also study how evidences of evolutionist theory support the process of evolution

3.3 Introduction to Evolution

Evolution is the long-term, gradual replacement of previous forms by new ones in all living things on Earth. Larger, more complex animals have replaced smaller ones as evolution has proceeded, expanding the diversity of the earth. Some species have also gone extinct. Another definition of evolution is the shift in a population's genetic make-up through time, which can be brought about by meiosis, hybridization, natural selection, or mutation. As a result, the population begins to diverge from other populations of the same species, which may result in the emergence of a new species. theories concerning how life came to be on Earth. The theory of evolution describes how the various forms of life on earth (including humans) emerged and developed. There are five main theories of the origin of life on Earth:

- special creationism
- spontaneous generation
- eternity of life
- cosmozoan theory
- biochemical origin

a) Special creationism

According to the special creation idea, a Supreme Being/God created all of the different types of life on Earth simultaneously over the course of six days. Special creativity is always associated with religion and mostly concentrated on spiritual issues that cannot be adequately felt, touched, or quantified. There are two perspectives on how life came to be various creationist theories

Gap creation – talks about the significant time lag between the earth's origin and the emergence of all the creatures and vegetation. The difference could amount to billions or millions of years. Progressive creation acknowledges the Big Bangs as the universe's point of beginning. It acknowledges that all living things have a history of creation as evidenced by their fossil records, but it rejects the idea that this process is ongoing (each is seen as unique creation).

Evolutionary creationism (Theistic evolution)

This view of evolution maintains that God 'invented" evolution and takes some form of an active part in the ongoing process of evolution.

Intelligent design – states that life developed (formed) from a combination of natural forces and the intervention of a supernatural being.

b) Spontaneous generation theory

Suggests that life can evolve 'spontaneously' from non-living objects. Eg. people believed that rotting meat turned into flies.

c) Eternity of life

The theory of eternity of life states that the universe has always existed and that there has always been life in the universe. There is no beginning and no end to life on earth and so life is neither created nor generated from non-living matters.

d) Cosmozoan Theory

According to this, life on Earth first evolved elsewhere in the universe (possibly from another planet). For example, meteorites introduced bacteria and other pathogens to the earth. However, because it lacks proof and is closely related to the "eternity of life" explanation of the genesis of life, this theory did not get much favour.

e) Biochemical theory

This suggests that life on earth originated as a result of a number of biochemical reactions producing organic molecules, which combined (associated) to form cells. This theory is also called abiogenesis; states that life originated from chemical inanimate (abiotic substances). The two scientists (biologists) who developed the theory of abiogenesis (origin of life from chemicals) were- Aleksander Oparin (1924) and John Haldane (1929).

What does the Cosmozoan Theory postulates?

Self-Assessment Exercises 1

1. State the theory of Special creationism in evolution 2.Who are the two scientist that develop the theory of abiogenesis?

3.4 Theories of Evolution

There have been many theories of evolution that have explained how does evolution occur, and what drives the population to become a new species?

A. Lamarck Theory of evolution: In the 19th century (1809), Lamarck published a paper entitled Philosophic ‘Zoologique‟ in which he described the two-part mechanism by which change was gradually introduced into the species and passed down through the generations. This theory is also called ‘theory of transformation‟ or Lamarckism. The two parts of Lamarck theory are:

i). Use and disuse: Lamarck suggested that a structure or process in organism that can be used continuously will become enlarged or more developed than any structure that is not. Example, According Lamarck, giraffe had short neck but they stretched their neck to reach high branches, an elongated neck use theory. The wings of penguins would have become smaller than those of other birds because penguins do not use their wings to fly, disuse theory.

ii). Inheritance acquired traits: Lamarck believed that traits changed (acquired) during an organism’s lifetime could be passed on to its offspring. Example: - Giraffes that had acquired long necks would have offspring with long necks.

However, nowadays, Lamarck’s theories are not accepted because the environmental changes that were believed by Lamarck have brought about the changes in the phenotypes (Physical appearance) of the organisms have no effect on their gametes and hence their heredity.

B. Charles Darwin and Natural Selection: In 1858, both Charles Darwin and Alfred Wallace jointly published a scientific paper that proposed species were modified by natural selection. Darwin visited five of the Galapagos Islands, made drawings, and collected species. In particular, Darwin studied the finches found on the different islands and noted there were many similarities between them but they have some obvious differences. Darwin concluded that an "ancestral finch" had colonized the Islands from mainland and been able to adapt to the different conditions on the islands and evolve into different species. Eg. He suggested that some finches had evolved into insect eaters (pointed peak), others into seedeaters (crushing peak). Darwin summarized his observations in two main ideas:

- all species tend to produce more offspring than can possibly survive (Fecundity)
- there is a variation among the offspring.

From these observation Darwin deduced (concluded) that:

- There will be a "struggle for existence" between members of a species because they are over – reproduced and resources are limited.
- Some members of a species will be better adapted than others to the environment because there is a variation in the offspring.

Darwin proposed that hose members of a species, which are best adapted to their environment, will survive and reproduce in greater number than other less adapted (died out).

C. Neo – Darwinism Theory Charles Darwin knew very little about genetics and did not propose how variations in the population was passed to the next generation. Nowadays, genes and gene action are the driving force of evolution in the theory of Natural selection. A Gene pool is all the alleles in the population. It might be evolving a population into a new species. Suppose an allele determines a feature that gives an organism an advantage in its environment. The following will happen:

- Those individuals with the advantageous allele of a gene will survive to reproduce in greater number than other types
- Advantageous allele pass to their offspring in greater numbers than other genes (alleles).
- The frequency of the advantageous allele will be higher in the next generation of a population. Mutations are important in introducing variation into population. Any mutation could produce an allele which:
- Increase in frequency if they are beneficial in their effect, may increase slowly, stable or decrease if they are neutral and

decrease and could disappear if they are harmful (disadvantages) in their effects. Neo-Darwinism is a modification of Darwin's original theory that takes into account:- genetics and ethology (behavioural pattens can also be advantageous or not). Eg. Young geese 'imprint" upon the first moving object after they are hatched. State the Lamarck's theory of Use and disuse.

Self-Assessment Exercises 2

1. State the theory of Inheritance acquired traits.
2. Why is Lamarck's theories are not accepted nowadays?

3.5 Encapsulating the concepts of Heredity and Evolution

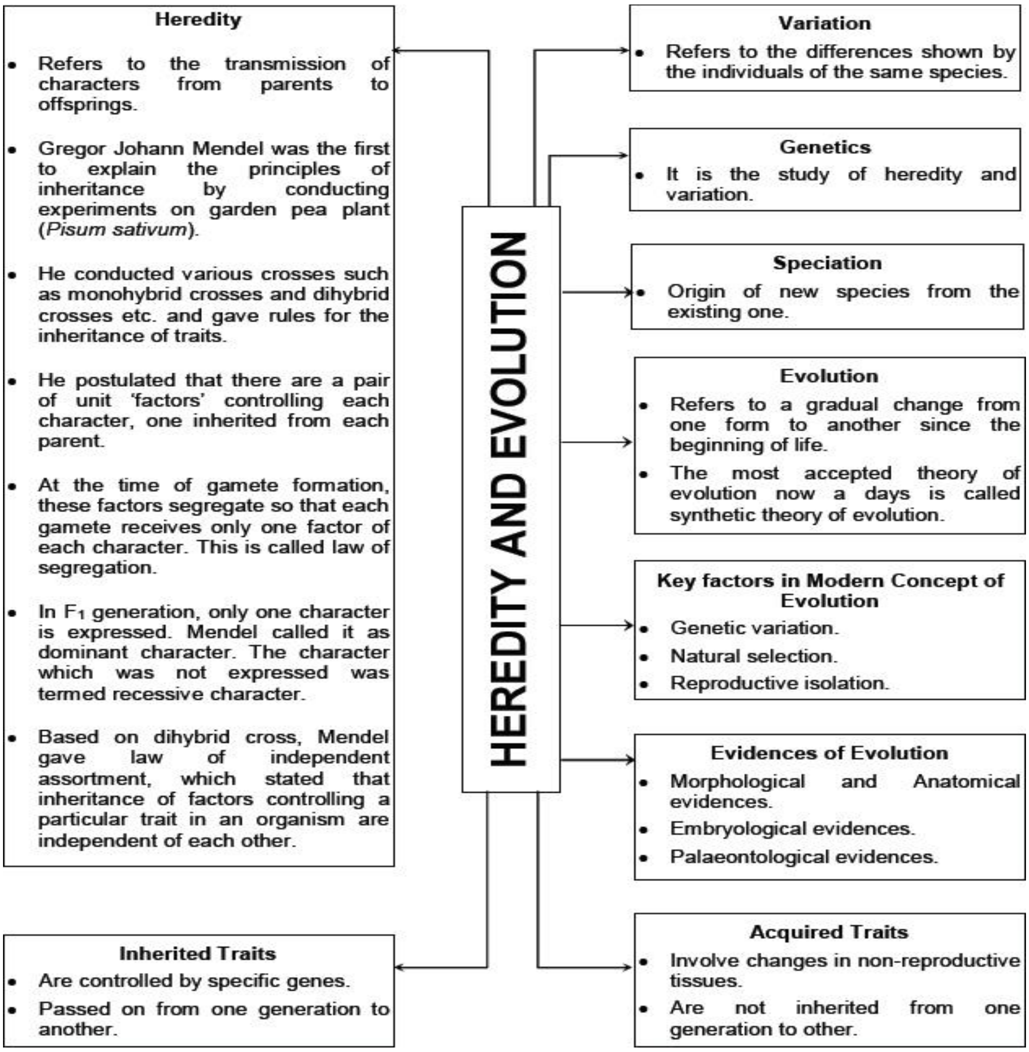

Figure 3.1 **Encapsulating the concepts of Heredity and Evolution**

What are the features of acquired traits in Heredity?

Self-Assessment Exercises 3

1. What are the key factors in modern concept of evolution? 2. What are inherited traits?

3.6 Summary

You must have learned the meaning of evolution as the gradual change of organisms on the earth over long periods, with new forms replacing old ones. The unit also highlighted the various theories of evolution, namely the theories of Special creationism, evolutionary creationism, spontaneous generation, eternity of life, Cosmozoan, and Biochemical theory. The evidences of evolutionist theory that supports the process of evolution was also explained.

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3.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Special creation theory states that the different forms of life on earth were created by a Supreme Being/ God/ at once with six days.

2. The scientists who developed the theory of abiogenesis were:- Aleksander Oparin (1924) and John Haldane (1929).

Answers to SAE 2

1. Lamarck believed that traits changed, acquired during an organism’s lifetime could be passed on to its offspring's.

2. Lamarck’s theories are not accepted because the environmental changes that were believed by Lamarck have brought about the changes in the phenotypes (Physical appearance) of the organisms have no effect on their gametes and hence their heredity.

Answers to SAE 3

1. Factors in modern concept of evolution
   - i. Genetic variation
   - ii. Natural selections and
   - iii. Reproductive isolation

2. They are traits controlled by specific genes passed on from one generation to another

Unit 4 Natural selection

Unit Structure

4.1 Introduction
4.2 Intended Learning Outcomes (ILOs)
4.3 Natural Selection
    4.3.1 The Process of Natural Selection
    4.3.2 Natural Selection and the Evolution of Populations
4.4 Evolutionary Adaptation
4.5 The Concept of the Survival of the Fittest
4.6 Summary
4.7 References/Further Readings/Web Sources
4.8 Possible Answers to Self-Assessment Exercises

4.1 Introduction

You will learn about the Natural Selection as a mechanism of evolution. You will equally study about the concept of the 'survival of the fittest' and the process of natural selection.

4.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you shall be able to:

- Explain the meaning of natural selection as a mechanism of evolution.
- Describe the process of natural selection
- Explain the concept of the 'survival of the fittest'

4.3 Natural Selection

English naturalist Charles Darwin developed the idea of natural selection after a five-year voyage to study plants, animals, and fossils in South America and on islands in the Pacific. In 1859, he brought the idea of natural selection to the attention of the world in his best-selling book, *On the Origin of Species*. Natural selection is the process through which populations of living organisms adapt and change. Individuals in a population are naturally variable, meaning that they are all different in some ways. This variation means that some individuals have traits better suited to the environment than others. Individuals with adaptive traits—traits that give them some advantage—are more likely to survive and reproduce. These individuals then pass the adaptive traits on to their offspring. Over time, these advantageous traits become more common in the population. Through this process of natural selection, favorable traits are transmitted through generations. Natural selection can lead to speciation, where one species gives rise to a new and distinctly different species. It is one of the processes that drives evolution and helps to explain the diversity of life on Earth.

Darwin chose the name natural selection to contrast with "artificial selection," or selective breeding that is controlled by humans. He pointed to the pastime of pigeon breeding, a popular hobby in his day, as an example of artificial selection. By choosing which pigeons mated with others, hobbyists created distinct pigeon breeds, with fancy feathers or acrobatic flight, that were different from wild pigeons. Darwin and other scientists of his days argued that a process much like artificial selection happened in nature, without any human intervention. He argued that natural selection explained how a wide variety of life forms developed over time from a single common ancestor. Darwin did not know that genes existed, but he could see that many traits are heritable—passed from parents to offspring.

Mutations are changes in the structure of the molecules called DNA that make up genes. The mutation of genes is an important source of genetic variation within a population. Mutations can be random (for example, when replicating cells make an error while copying DNA), or happen as a result of exposure to something in the environment, like harmful chemicals or radiation. Mutations can be harmful, neutral, or sometimes helpful, resulting in a new, advantageous trait. When mutations occur in germ cells (eggs and sperm), they can be passed on to offspring. If the environment changes rapidly, some species may not be able to adapt fast enough through natural selection. Through studying the fossil record, we know that many of the organisms that once lived on Earth are now extinct eg. Dinosaurs. An invasive species, a disease organism, a catastrophic environmental change, or a highly successful predator can all contribute to the extinction of species.

Today, human actions such as overhunting and the destruction of habitats are the main cause of extinctions. Extinctions seem to be occurring at a much faster rate today than they did in the past, as shown in the fossil record.

4.3.1 The Process of Natural Selection

Darwin's process of natural selection has four components.

1. Variation: Organisms (within populations) exhibit individual variation in appearance and behavior. These variations may involve body size, hair color, facial markings, voice properties, or number of offspring. On the other hand, some traits show little to

no variation among individuals—for example, number of eyes in vertebrates.

2. Inheritance: Some traits are consistently passed on from parents to offspring. Such traits are heritable, whereas other traits are strongly influenced by environmental conditions and show weak heritability.
3. High rate of population growth: Most populations have more offspring each year than local resources can support leading to a struggle for resources. Each generation experiences substantial mortality.
4. Differential survival and reproduction: Individuals possessing traits well suited for the struggle for local resources will contribute more offspring to the next generation.

From one generation to the next, the struggle for resources (what Darwin called the "struggle for existence") will favor individuals with some variations over others and thereby change the frequency of traits within the population. This process is natural selection. The traits that confer an advantage to those individuals who leave more offspring are called adaptations.

In order for natural selection to operate on a trait, the trait must possess heritable variation and must confer an advantage in the competition for resources. If one of these requirements does not occur, then the trait does not experience natural selection. (We now know that such traits may change by other evolutionary mechanisms that have been discovered since Darwin's time.)

Natural selection operates by comparative advantage, not an absolute standard of design. "*…as natural selection acts by competition for resources, it adapts the inhabitants of each country only in relation to the degree of perfection of their associates*" (Charles Darwin, On the Origin of Species, 1859).

During the twentieth century, genetics was integrated with Darwin's mechanism, allowing us to evaluate natural selection as the differential survival and reproduction of genotypes, corresponding to particular phenotypes. Natural selection can only work on existing variation within a population. Such variations arise by mutation, a change in some part of the genetic code for a trait. Mutations arise by chance and without foresight for the potential advantage or disadvantage of the mutation. In other words, variations do not arise because they are needed.

4.3.2 Natural Selection and the Evolution of Populations

Though each has been tested and shown to be accurate, none of the observations and inferences that underlies natural selection is sufficient individually to provide a mechanism for evolutionary change. Overproduction alone will have no evolutionary consequences if all individuals are identical. Differences among organisms are not relevant unless they can be inherited. Genetic variation by itself will not result in natural selection unless it exerts some impact on organisms' survival and reproduction. However, any time all of Darwin's postulates hold simultaneously—as they do in most populations—natural selection will occur. The net result in this case is that certain traits (or, more precisely, genetic variants that specify those traits) will, *on average,* be passed on from one generation to the next at a higher rate than existing alternatives in the population. In other words, when one considers who the parents of the current generation were, it will be seen that a disproportionate number of them possessed traits beneficial for survival and reproduction in the particular environment in which they lived.

The important points are that this uneven reproductive success among individuals represents a *process* that occurs in each generation and that its effects are cumulative over the span of many generations. Over time, beneficial traits will become increasingly prevalent in descendant populations by virtue of the fact that parents with those traits consistently leave more offspring than individuals lacking those traits. If this process happens to occur in a consistent direction—say, the largest individuals in each generation tend to leave more offspring than smaller individuals—then there can be a gradual, generation-by-generation change in the *proportion* of traits in the population. This change in proportion and not the modification of organisms themselves is what leads to changes in the average value of a particular trait in the population. Organisms do not evolve; *populations* evolve. How would Genetic variation results in natural selection?

Self-Assessment Exercises 1

1. What is meant by natural selection?
2. Outline the four Darwin's process of natural selection components.

4.4 Evolutionary Adaptation

The term "adaptation" derives from *ad* + *aptus*, literally meaning "toward + fit". As the name implies, this is the process by which populations of organisms evolve in such a way as to become better suited to their environments as advantageous traits become predominant.

The definition of **evolutionary adaptation** is the mechanism by which an animal or plant alters itself to accommodate its changing environment. Organisms can display three types of adaptation, each of which increase the organism's chance of survival and reproduction, thereby maximizing its number of descendants across time:

1. *Behavioral adaptation:* The organism changes how it interacts with its environmental surroundings as well as other animals and plants.
2. *Physiological adaptation:* The organism changes how its body functions internally.
3. *Structural adaptation:* The organism changes at least one of its physical features.

Consider the natural history of emperor penguins in Antarctica. To survive in a frigid environment, emperor penguins mate in the winter. This breeding schedule lets the chicks have enough time to mature into independent juveniles before prey become abundant enough for them to feed on their own. In addition, the males huddle together in tight circles to share body heat throughout the winter. To accommodate the shortage of prey during the winter season, only female emperor penguins voyage to the ocean to feed. All three adaptations are the penguin's behavioral responses to its extremely harsh living environment.

Physiologically, male emperor penguins can live for 100 consecutive days without eating any food during the winter time. Emperor penguins also can significantly reduce their heart rate so that they can stay underwater for long periods of time when feeding before resurfacing to breathe.

In terms of structural adaptations, the emperor penguins have tails that are short and stiff enough to serve as a prop while they balance on their heels. This standing position minimizes how much heat is lost from their feet while standing on the snow and ice. In additionally, the bicolor pattern of penguins serves as a camouflage while swimming in the ocean. The penguins' black back blends in with the sea when predators, such as leopard seals, look down upon them. Their white underside blends in with the sky when predators are positioned far below them.

Evolutionary adaptation does not mean that only the best specimens survive or that only the best genetic traits are passed from one generation to the next. Instead, it means that the organisms *better suited* for their environment survive; and that the genetic traits *most likely to confer success* will be inherited among their offspring. What do you understand by Evolutionary adaptation?

Self-Assessment Exercises 2

Outline and define the three types of adaptation that Organisms can display from evolutionary point of view?

In terms of evolution, an animal that is 'fit' is one that is adapted to its environment. This concept is at the core of natural selection, although the term 'survival of the fittest' has often been misunderstood and may be best avoided. There is also a degree of randomness to evolution, so the best-adapted animal won't always be the one to survive. Adrian explains, 'If you're going to get hit by a rock or something, it's just bad luck. But on average and over time, the ones that survive are the ones that are fittest - the ones that have the best adaptations.' Some important theories of evolution are as follows:

1. Darwin's theory: Charles Robert Darwin was a British naturalist who formulated his hypothesis that evolution took place due to natural selection. Darwin's theory of evolution tells us how life evolved from simple to more complex forms.

- Over production.
- Almost constant population.
- Struggle for existence- Intraspecific, Interspecific, Environmental Struggle.
- Variation: Appearance of variation in organisms during struggle for existence.
- Natural selection / Survival of the fittest
- Inheritance of useful variation

2. Lamarckism

Lamarckism is a theory named after French naturalist Jean-Baptiste Lamarck (1744-1829). It proposes that animals acquire characteristics based on use or disuse during their lives, rather than through hard-coded genetic changes. In Lamarckian theory, giraffes stretch their necks to make them longer. These animal's offspring would inherit longer necks as a result of their parents' efforts. Adrian says, 'If you tried to stretch your neck for 10 minutes each morning, then you would probably end up with your neck being a few millimetres longer for a few years. However, your children would not inherit it. That's where this theory fails.'

Lamarck's theory:

- Organisms and their organs tend to increase their size continuously due to some unknown forces of life.
- New organs in the organisms are found due to new needs which occur due to change in the environment.
- Theory of use and disuse of organs.
- Theory of inheritance of acquired character.

3. Mutation Theory: by Hugo de Vries

"A new species is originating from pre-existing species slowly in single step due to genetic variation called 'mutation''. Mutation is sudden inheritable change. It occurs commonly in naturally breading population. Mutation is directional, less occurring in any direction. It is a subject for natural selection and most of the mutation is lethal or fatal. Changes in the genetic material, i.e., mutation, could introduce a wide range of variability in a natural population. With a complex or shifting environment, a particular variation may give an individual or its offspring a slight edge. Most mutations are considered deleterious, as they interfere with a genotype that works. However, occasionally, a mutation arises that increases success. Mutation introduces variability and the environment determines its value for survival and success. What is the genetic variation that causes a new species to originate from pre-existing species slowly in a single step?

Self-Assessment Exercises 3

1.From evolutionary point of view, which organism is being described as 'fit'?
2. What is the thrust of Lamarckism theory in evolution?

4.6 Summary

You have learned about natural selection as a mechanism of evolution in this unit. Darwin's theory of evolution fundamentally changed the direction of future scientific thought, though it was built on a growing body of thought that began to question prior ideas about the natural world. The core of Darwin's theory is natural selection, a process that occurs over successive generations and is defined as the differential reproduction of genotypes. Natural selection requires heritable variation in a given trait, and differential survival and reproduction associated with possession of that trait.

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4.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. The process through which organisms adapt and change themselves in huge populations is known as natural selection.
2. Darwin's process of natural selection has four components.
   a) Variation.
   b) Inheritance.
   c) High rate of population growth.
   d) Differential survival and reproduction.

Answers to SAE 2

1. *Behavioral adaptation:* The organism changes how it interacts with its environmental surroundings as well as other animals and plants.
2. *Physiological adaptation:* The organism changes how its body functions internally.
3. *Structural adaptation:* The organism changes at least one of its physical features.

Answers to SAE 3

1. In terms of evolution, an organism that is 'fit' is one that is adapted to its environment
2. It proposes that animals acquire characteristics based on use or disuse during their lives, rather than through hard-coded genetic changes.

Unit 5 Elements of Ecology

Unit Structure

5.1 Introduction
5.2 Intended Learning Outcomes (ILOs)
5.3 Defining of Ecology
5.4 Definitions of Ecological Terminologies
5.5 The meaning of Habitat in Ecology
  5.5.1 Ecological Niche
  5.5.2 Niche Formation and Partitioning
5.6 Summary
5.7 References/Further Readings/Web Sources
5.8 Possible Answers to Self-Assessment Exercises

5.1 Introduction

You will learn the meaning and elements of ecology in this unit. You will appreciate the importance of the study of Ecology and understand some basic ecological terms. The various branches of ecology and the criteria employed for the classification of the various branches will be highlighted.

5.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you shall be able to:

- Define ecology
- Appreciate the importance of the study Ecology
- Understand some basic ecological terms.
- Describe the various branches of ecology
- Explain the criteria employed for the classification of the various branches
- Explain the meaning of habitat and describe the various types

5.3 Defining Ecology

The word 'Ecology" was coined from Greek word 'oikos' meaning 'house' or 'a place to live' and 'logos' meaning study. Ecology is the study of the households of the planet earth. Living things depend on each other and on the non-living components of the environment for survival. Based on this, it is possible to say ecology is the study of the relationship of living organisms among themselves and with the non-living components of the environment. Different Authors defined ecology differently. Some of them are:

- Ecology is the scientific study of the interactions between organisms and their environments
- The study of the relationships, distribution, and abundance of organisms, or groups of organisms, in an environment

Ecology studies the interactions of living things with their physical environments, with other organisms of the same species, different species, and with the movement of matter and energy within biological systems (Environment includes not only the physical but also the biological conditions under which an organism lives). Ecologists research these relationships to comprehend the variety and richness of life throughout the ecosystems on Earth. In other words, why are there so many different kinds of plants and animals? They may utilise laboratory trials that examine processes like predation rates in controlled settings, field measures like species counts and observations of behaviour in their habitats, and other methods to try and find answers to these problems; or field experiments, such as testing how plants grow in their natural setting but with different levels of light, water, and other inputs. Information about these interactions is used in applied ecology to tackle problems like building land and marine conservation areas for threatened species, managing fisheries without overharvesting, and simulating how natural ecosystems may react to climate change. Ecosystems are constantly changing due to natural phenomenoa such climate change, species extinction, and ecological succession. We can better forecast how ecosystems will react to environmental changes by understanding how they work. However, because living things in ecosystems are interconnected in complicated ways, it is sometimes difficult to predict how a decision like introducing a new species would impact the ecosystem as a whole.

Branches of Ecology

Ecology can be divided depending on the following concepts:

- Hierarchical organization –according to level of organization
- Taxonomic –according to organisms studied
- Time/Place -According to time/place

Many other ways to subdivide ecology:

A) Hierarchic: organism, population, community, ecosystem, biosphere

B) Taxonomic: plant ecology, animal ecology, microbial ecology, avian ecology, etc.

C) Time/Place: marine ecology, tropical ecology, freshwater ecology

Hierarchical structure of ecological systems

1. Organism: fundamental unit of ecology. No smaller unit in biology has an independent life in the environment.

2. Population: A group of organisms consisting of a number of different populations that live in defined area and interact with each other.
3. Community: A group of organisms consisting of a number of different species that live in an area and interact with each other
4. Ecosystem: a biological community plus all of the abiotic factors influencing that community.
5. Biome: A distinct ecological community of plants and animals living together in a particular climate.
6. **Biosphere**: the aggregation of all ecosystems (the sum of all of the organisms of the earth and their environment). Biome is the living zone of the planet.

Self-Assessment Exercises 1

1. Outline the concepts upon which Ecology can be divided
2. What is the Hierarchical level of organization of ecology?

5.4 Definitions of Ecological Terminologies

You are expected to understand the meaning of the following terminologies since they are important throughout the course to grasp its concept.

1. **Abiotic:** all non-living components in the biosphere, e.g., air, water, soil, climate.
2. **Autotrophic:** when an organism is able to produce its own food using abiotic components.
3. **Biotic:** all the living components in the biosphere: animals, plants, microorganisms**,** etc.
5. Biomass is the total dry weight of living organisms at a particular tropic level or per unit area eg. total weight of maize crop per hectare.
6. Carrying Capacity is the maximum number of organisms an area can comfortably support without depletion of the available resources.
7. Endemic species are found only in a particular area, eg. kangaroos found in Australia
8. Key-stone species is mostly a predator species, which is not present in large number but has a major influence on the characteristics of a community, eg. lion in the forest.
9. Critical Link species; help other species in the vital activities, e.g. pollinators for plants, parasitic and symbiotic relationships.
10. Habitat: It is a natural environment of an organism where it grows, lives and reproduces. It is an ecological area best-suited

for an organism. Habitats vary in the physical and chemical composition. It includes abiotic components like water, temperature, light and soil and biotic components too, eg. parasites, competitors, pathogens and predators interacting with them constantly. Life exists not only in the most favourable habitat but also in the most extreme and harsh environment. Ecology at an organism level tries to understand how different species adapt to their environments for their survival and reproduction.

11. Niche: includes all the interaction of a species with the biotic and abiotic factors of its environment. Each species has a defined range of various abiotic factors that it can tolerate, a number of resources it utilises for survival and performs a specific functional role in an ecosystem, all these together form a niche, which is unique to a species.
12. **Carnivores:** animals that eat only meat. They are generally predators, eg. lions, cheetahs etc., in a specific environment.
13. **Ecosystem**: the combined physical and biological components of a specific habitat where animals and plants are interdependent on each other for survival.
14. **Herbivores:** animals that only eat plants, eg., buck, cows, goats, sheep, rabbits etc.
15. **Heterotrophic:** Organisms that are unable to produce their own food, and must eat other organisms
16. **Omnivores:** animals that eat both plant and animal matter, eg., humans, pigs, baboons.
17. **Saprophytic organisms:** organisms that live on dead organic matter because they are able to decompose (break down) dead plant and animal matter.
18. **Scavengers:** animals that eat what is left over by predators. Examples are hyenas, crayfish and vultures.
19. **Photosynthesis:** a process where plants use sunlight energy, water and CO_2 from the air, to produce organic compounds like glucose and inorganic compounds like O_2.
20. **Vegetation:** the plant life that is found in a biome.

Self-Assessment Exercises 2

Explain what is the meaning of the following ecological terminologies: 1. Autotrophic 2. Biosphere

5.5 The meaning of Habitat in Ecology

Habitat ecology is a fascinating branch of natural science that deepens our comprehension of the processes that influence the distribution and abundance of species. It can also be described as a particular natural setting with both physical and biological characteristics where only a few species of an organism can coexist. A plant, animal, or other organism's natural environment or home is known as its habitat. It gives the creatures that inhabit the area food, water, shelter, and a place to live. There are many distinct sorts of habitats, such as those for wildlife, aquatic life, grazing land, and coastal life, and each one supports a unique ecosystem. Which wildlife species can be found there depends on the habitat type. Each and every animal has a unique natural habitat in which it can dwell. Different animals can be found in various habitats. "Habitat" refers to a variety of things. Ecology refers to either an assembly of living things along with their abiotic environment or the space and resources utilised by a certain species (the habitat of a species). This introduction's main concern is the latter. There are various habitat types which include:

1. Aquatic Habitats

The world's lakes, rivers, wetlands, lagoons, and swamps are all considered to be parts of the aquatic biome. There are mangroves, salt marshes, and mud flats where freshwater and saltwater mix. These aquatic habitats support aquatic plant and animal lives, where they are safeguarded, provided with shelter, and provided with a steady supply of food and water. These environments may house a variety of aquatic ecosystems, including the coral reef ecosystem, which is a mechanism for producing reefs made up of coral polyps linked together by calcium carbonate. A wide variety of wildlife species call each of these habitats home. Almost every animal group, including mammals, bird species, amphibians, reptiles, and invertebrates, can be found in aquatic settings. The intertidal zone, for example, is a mesmerizing place that is wet during high tide and dries up as the tide goes out. The organisms that exist in these parts must endure thrashing waves and survive in both water and air. This is where you will be able to locate mussels and snails as well as kelp and algae.

2. Desert Habitats

Scrublands and deserts are examples of areas with little rainfall. They are known to be the driest places on Earth, which makes life there extremely difficult. Desert animals dwell in arid areas and have unique adaptations that allow them to survive there. Due to their ability to tolerate the intense heat and inconsistent water supplies, desert animals stand out from other species that inhabit different ecosystems thanks to their richness. The same idea also applies to desert flora. It is possible for human activities to push a drier region of land into the classification of the desert biome. This phenomenon is termed desertification, and typically results from agricultural mismanagement and deforestation.

3. Forest Habitats

Trees cover the forests and woods biomes. There are forests in many places around the world, covering around one-third of the planet's land area. There is a huge genetic diversity seen in forests. More bird species are reportedly found there than in any other natural area. There are many different types of forests, such as temperate, tropical, cloud, coniferous, and boreal types. Each one of them has a unique range of climatic characteristics, species compositions, and wildlife groups. For example, the Amazon rain forest is a varied bionetwork and is home to a tenth of all animal species in the world. It encompasses a substantial section of the Earth's forest biome, at around three million square miles.

4. Grassland Habitats

Grasslands are environments with a lot of large trees or shrubs but predominantly grasses. Tropical grassland eg. Savannas, and temperate grassland are the two types of grasslands. The world is covered in the wild grass biome, which includes the American Midwest grasslands as well as the African Savanna. There are organisms there that are specific to that type of grassland, but you'll normally find a lot of hoofed animals and some predators to hunt them. Grasslands have both dry and rainy seasons. They are susceptible to cyclical flames because of these extremes, and these fires can quickly spread across the landscape.

5. Tundra Habitats

It's frigid in the tundra. Low temperatures, minimal vegetation, long winters, short growing seasons, and limited drainage are its defining characteristics. Despite being a severe area, a variety of species call it home. For example, the Arctic National Wildlife Refuge in Alaska is home to 45 different species, including hardy rodents and bears and whales. Close to the North Pole, Arctic tundra extends southward to where coniferous trees are found. Alpine tundra can be found on mountains all over the world, above the tree line. Permafrost is typically located in the tundra biome. This is known as any rock or soil that remains frozen throughout the year and it can be unstable ground when it does defrost.

6. Microhabitats

The minimal physical requirements of a particular organism or population are referred to as a microhabitat. Numerous microhabitats with subtly different exposure to light, moisture, temperature, air movement, and other factors make up every habitat. The lichens that grow on the north face of a rock are different from those that grow on the south face, the flat top, and the neighbouring soil; those that grow in ruts and on elevated surfaces are also distinct from those that grow on quartz veins. The micro-fauna, various invertebrate species, is present among these tiny "forests," each of which has specific environmental requirements.

7. Extreme Habitats

Despite the fact that the bulk of life on Earth occurs in mesophyllic (moderate) environments, a small number of organisms, primarily bacteria, have been able to tolerate hazardous environments that are inhospitable to more complex life forms. For example, microorganisms can be found in Lake Whillans in Antarctica, which is half a mile below the ice. Because of the lack of sunlight, these organisms must obtain their organic material from other sources, such as decomposing matter from glacier melt water or minerals from the underlying rock.

5.5.1 Ecological Niche

An ecological niche refers to the interrelationship of a species with all the biotic and abiotic factors affecting it. This definition of *niche* though has changed over time. Joseph Grinnell in 1917 coined the term *niche*, which he used as mostly equivalent to a species habitat. George Evelyn Hutchinson used the term *niche* to describe the multi-dimensional space of resources available to and used by a species. In niche biology, a niche pertains to any of the following: i). The specific area where an organism inhabits; ii). The role or function of an organism or species in an ecosystem; iii). The interrelationship of a species with all the biotic and abiotic factors affecting it. Despite the fact that niches have been defined differently, it is now generally accepted that it has to do with how an organism or a population adapts to competition and the distribution of resources. It specifically indicates the position of a population or an organism in an ecosystem. An ecosystem's biotic and abiotic variables may have an impact on a niche. However, a species' ecological niche will influence the characteristics of its surroundings because these characteristics are essential to its existence. The different ecological niches.

- A *fundamental niche* is defined as the niche of a species in the absence of competition. Conversely, a *realized niche* is the niche that a species occupies due to pressures, eg. the arrival of a competing species to its habitat.
- *Niche overlap* is defined as that when two organisms use the same resources or other environmental variables. Often, niches overlap only partially as the resources are shared.
- A *vacant niche* is a niche that is yet to be occupied in an environment. However, the existence of a vacant niche is still a matter of debate. Nevertheless, possible causes of vacant niches are presumed to be habitat disturbances (eg. forest fires and droughts) and evolutionary eventualities (ie. when species failed to evolve).

5.5.2 Niche Formation and Partitioning

Both abiotic and biotic factors help shape the niche of an ecosystem. Abiotic factors, such as temperature, climate, and soil type, of an ecosystem will help form the niches while natural selection works to set which niches would be favored and not. Through time, the species eventually develop special features that help them adapt to their environment. If they fit in, they could thrive and survive in surroundings that match their features. Nevertheless, the extent of their population may be controlled by biological constraints, such as predation, competition, and parasitism.

- *Competition* in a habitat could limit the population of a species as co-habitats could compete for available nutrients, space, light, and other vital resources.
- *Predation* could also restrain the species' population depending on the number of predators and the extent of predation.
- In parasitism, the presence of parasites that take the species as their host and the vulnerability to pathogens causing diseases are also factors that can restrain the species population. The niches in an ecosystem form and evolve as these factors change.

As each niche is occupied by a single species, natural selection will divide up the market for that species, a process known as niche partitioning. Different species cannot share the same niche. However, coexistence can enable rival species to carve out distinct ecological niches. To prevent competing for scarce resources, they must be able to cohabit, perhaps through resource differentiation (or niche partitioning). If not, natural selection will favour one of the two competing species while eventually eradicating the other.

Self-Assessment Exercises 3

1. Why Does an Organism Need Habitat?
2. Outline the major types of habitats in ecology

1.6 Summary

You have learned the meaning and elements of ecology in this unit. The importance of the study Ecology and basic ecological terms were also highlighted. The various branches of ecology and the criteria employed for the classification of the various branches was also studied. The unit explained the concept and types of habitats in ecology.

1.7 References/Further Readings/Web Sources

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1.8 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

1. Ecology can be divided depending on the following concepts:

- Hierarchical organization –according to level of organization
- Taxonomic –according to organisms studied
- Time/Place -According to time/place

2. A way to divide ecology could be Hierarchic:
organism, population, community, ecosystem, biosphere

Answers to SAE 2

1. **Autotrophic:** when an organism is able to produce its own food using abiotic components.
2. **Biosphere:** it is the global sum of all ecosystems, and is the zone where all living organisms live on earth.

Answers to SAE 3

1. As a good habitat is a good combination of food, water, cover, and space to survive and reproduce. All these things are necessary for good habitat and species cannot survive without them.

2. There are different types of Habitats as follows:

a. Aquatic Habitats
b. Desert Habitats
c. Forest Habitats
d. Grassland Habitats
e. Tundra Habitats
f. Microhabitats
g. Extreme Habitats

Glossary

Applied ecology -A branch of ecology which uses ecological principles and insights to solve environment.

Amensalism -An interaction between two organisms, where one suffers a reduction in resources, or an increase in costs imposed by conditions, due to the presence of another organism.

Biodiversity -An accepted shortening of the phrase 'biological diversity' commonly used to describe species richness.

Climate Change -Long-term changes in the climatic variables experienced in a defined spatial area

Commensalism -This refers to the interaction between two species where one organism gains resources or shelter from conditions, due to the presence of the other species.

Community-This refers to all species in a defined spatial area or ecosystem, which interact via trophic, competitive, commensal, amensal or mutualistic interactions.

Competition -Competition is the process where organisms gain a greater or lesser share of a limited resource.

Ecological niche -The sum total of all the resources used by, and the biotic and abiotic conditions suffered by, a species.

Ecology -The scientific study of the distribution, abundance and dynamics of organisms, their interactions with other organisms and with their physical environment.

Ecosystem -All organisms and the abiotic environment found in a defined spatial area, generally assumed to be the collective description of a community and its physical environment.

Evolution -Change in the relative frequencies of heritable genetic information across generations of organisms.

Mutualism -A biotic interaction between two organisms, where they gain an increase in resources, or a reduction in stressful conditions, from the presence of the other organism.

Parasitism -A trophic interaction in which individuals of one species, called the parasite, feeds upon the tissues of living individuals of another species called the host.

Predation -A trophic interaction in which individuals of one species (the predator) kills and eats individuals of the other species (the prey).

climax community -A community of biological species that has reached a stable state, occurring when the different species are best adapted to average conditions in a given area.

End of Module Questions

1. List any five (5) interactions between or within species.
2. Discuss the interrelationships of organisms.
3. Give examples of mutualistic versus antagonistic interactions discuss some ecological and evolutionary consequences of these interactions.
4. Discuss scenarios where predation plays an important ecological role and others where it appears to be less important.
5. To what extent are the outcomes of species interactions context-dependent?
6. Which factors drive the variable outcomes of interactions?
7. In which type of interactions, one entity hunts another animal to suffice its nutritional requirement?