Biology

Student Textbook

Grade 10

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Ministry of Education

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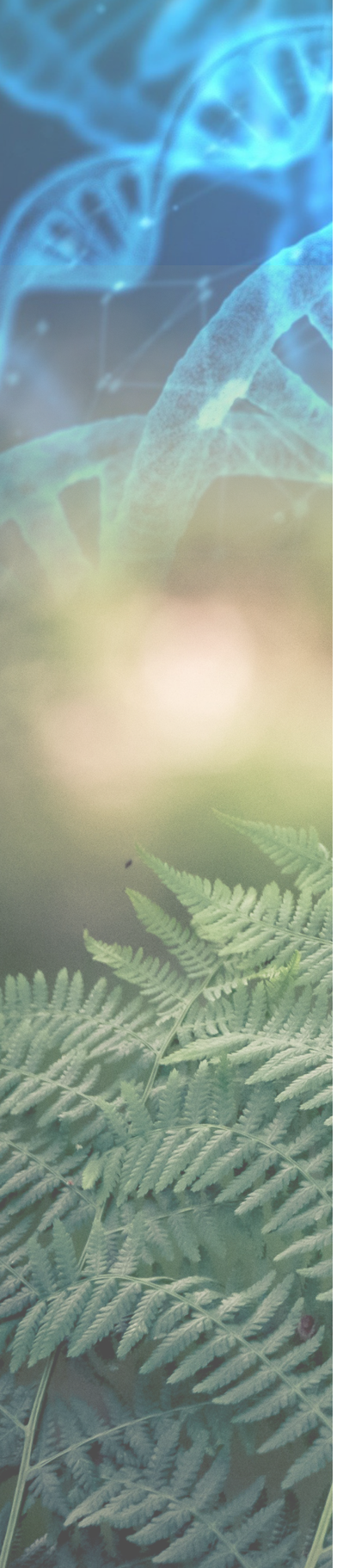


Contents

Unit 1: Sub-fields of Biology

Contents	Learning competencies
1.1. Sub-fields of biology 1.2. Pure and applied fields of biology 1.3. Major discoveries in Biology 1.4. The contributions of biological discoveries to society and the environment (e.g. microscope, penicillin, inheritance, etc.) 1.5. Major discoveries by Ethiopian Biologists (e.g. Aklilu Lemma, Gabissa Ejeta)	• list the Sub-fields of biology • classify the different Sub-fields of Biology into pure and applied • discuss at least five major discoveries that revolutionized Biology • appreciate the contribution of biological discoveries to society/environment e.g. microscope, penicillin, inheritance, etc. • appreciate Ethiopian scientists and their discoveries

1.1 Sub-fields of Biology

Objectives

At the end of this section, the student will be able to:

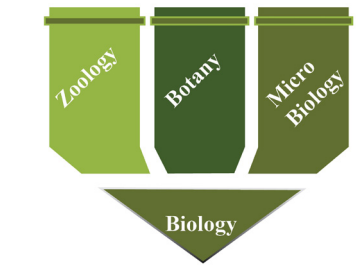
- *List the sub-fields of biology*
- *Define the sub-fields of biology*

Recall

You have defined the term 'biology' in grade nine unit 1, and briefly discussed what biology studies about. In this unit, you will study the different sub-field of biology.

Which sub-fields of biology do you know?

The scope of biology is so broad that it contains many branches and sub-disciplines. In this unit, thus, you will study the sub-fields of biology. Based on the type of organism it studies, biology is subdivided into three: Zoology, Botany, and Microbiology. In addition to these three sub-fields, there is a huge array of sub-disciplines or fields of biology. Many have been around for hundreds of years whilst others are far newer and are often developing very rapidly. The three major sub-divisions and their area of concern are described in the next page.



Activity 1.1: THINK-PAIR-SHARE

Make a group of three students and write down the names of organisms you know that would be categorized under the three major divisions of biology. Share with other groups what you have written and compare with yours.

Zoology

Figure 1.1 *Capra walie (Waliya ibex)* (in Simien Mountains of Ethiopia)

Animal biology, also known as zoology, is the study of animals and includes disciplines such as herpetology (reptiles), ichthyology (fish), mammalogy (mammals), ornithology (birds), and entomology (insects). Zoology is concerned with all aspects of animal life, such as embryonic development to mature adulthood; behavior, such as interactions with other animals or food finding; and genetics. Figure 1.1 showes one of the endemic wild animals of Ethiopia.

Botany

Figure1.2 *Ruta chalepensis L.* (Tena Adam)

Botany is a field of biology that studies about plants. It deals with plants' structure, properties, and biochemical processes. It also studies about classification and diseases of plants and their interactions with the environment. The principles and findings of botany have provided the base for such applied sciences as agriculture, horticulture, and forestry.

Plants have long been used as a source of food, shelter, clothing, medicine, ornament, and tools. Green plants are now known to be essential to all life on earth. In addition to their practical and economic values, through the process of photosynthesis, plants convert energy from the Sun into the chemical energy of food, which allows all life to exist. The formation and release of oxygen as a byproduct of photosynthesis is the second unique and important capability of green plants. Ruta chalepensis L. ('Tena Adam' in Amharic), a known traditional herbal medicine of Ethiopia, is shown as an example (see Fig 1.2).

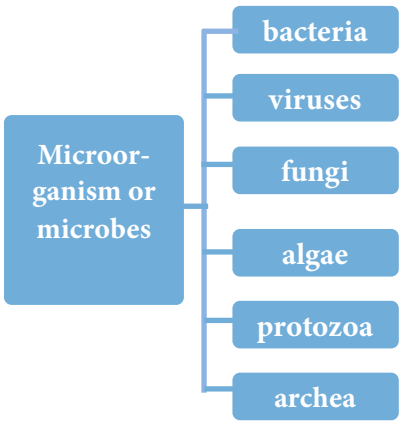


Figure 1.3. The microorganisms

Microbiology

Microbiology is the study of microscopic organisms or microbes that cannot be seen by unaided eye. It includes bacteria, archaea, protists, viruses, microscopic algae and fungi. This branch of biology is further subdivided into sub-disciplines, which are frequently defined by specific microbes. Bacteriology, for example, is the study of bacteria, whereas mycology is the study of fungi. The majority of bacteria and other microbial species have yet to be identified due to

the difficulty of isolating a single microscopic species. Microbiology is a rapidly expanding field of study; however, new technology and developments in the field are constantly assisting in the identification of new species. Activity 1.2 below will help you study the different types of microorganisms independently.

Activity 1.2 The Microorganisms

Microorganisms of different types are given in this activity. Work in a pair and do the following activities:

1. Define bacteria, viruses, fungi, algae, microscopic protozoa and archaea.
2. Draw typical bacteria, viruses, fungi, algae, microscopic protozoa and archaea.

Table 1.1 shows how various branches of biology are related to the structure we are studying. Anatomy, for example, is a branch of biology that studies the physical structures and parts of organisms, whereas morphology is a branch of biology that studies the form and structure (internal and external) of organisms and their specific structural features. Table 1.1 shows the various fields of biology based on the structure they study.

Do you know how different branches of biology are related to the structure we study?

Table1.1 Different fields of biology based on the structure studied

Sub-branch of biology	Definition	Example of the structures studied
Morphology	Study of external form and structure	Shape, the texture of leaves, stem, etc
Anatomy	Study of the bodily structure of humans, animals, and other living organisms, especially as revealed by dissection and the separation of parts	Stomach, liver, heart, etc
Histology	Study of the details of tissue structure	Parenchyma, connective tissue
Cytology	Study of cells	A plant cell, a nerve cell
Cell biology	Study of the structure, function, and various aspects of cell and its components	Mitochondrion, ribosome, nucleus, etc
Molecular Biology	Study of structure and function of informational molecules	DNA, RNA

Many other branches of biology are concerned with the various life processes, such as how an organism multiplies or forms identical copies of itself, its evolution over millions of years, and its relationship with the environment. Table 1.2 lists some of these fields with the environment.

What other branches of biology do you know?

Table 1.2 Subjects studied in various branches of Biology

Branch of biology	Subject studies	Examples
Physiology	The normal functions of living organisms and their parts	Photosynthesis, digestion, etc
Embryology	The embryo, from a single-celled zygote (fertilized ovum) to the formation of form and shape	Structure and development of ova, sperm, blastula (an embryo at early stage of development consisting of a hollow ball of cells), gastrula(the stage in embryonic development after blastula during which the embryo develops two layers), etc
Ecology	Interaction of organisms with the environment	Food chain, biomass, biosphere, etc
Taxonomy	Identification, nomenclature, and classification of organisms	The biological name of a human is Homo sapiens and it was placed in the animal kingdom
Paleontology	Origin, growth, and structure of organisms of the past	Fossils of organisms
Evolution	The change in the characteristics of a species over several generations that relies on the process of natural selection	The beaks of Darwin's finches
Genetics	Heredity and variation	Gene concept, Mendel's laws
Exobiology	The origin, evolution, distribution, and future of life in the Universe	Life on Moon, life on Mars

Do you have any idea about the relationship between biology and other sciences?

Biology is related to other sciences that study life as an energy state of all living things, their interrelationships, and links to their surroundings. Table 1.3 shows some of the interrelationships.

Table1.3 Knowledge taken from other subjects that help to explain biological phenomenon

Structure/ mechanism studied	Example	Related Science	Knowledge of other sciences is required because
Cell membrane	Structure of lipids and proteins	Chemistry	Living organisms are made of inorganic and organic compounds
Transportation of Oxygen (O2) in the body	Formation of Oxyhaemoglobin (haemoglobin with oxygen)	Chemistry	All metabolic pathways involve chemical change
Excretory system	Absorption and elimination of salts	Chemistry	Homeostasis involves acid-base equilibrium to maintain the pH of living organisms
Absorption of food/ water	Absorption of sugars, amino acids, fatty acids, water, or salts	Chemistry	During diffusion and osmosis molecules move into and out of the cell
Transportation of water in plants	Conduction of water from root to leaves	Physics	Liquids have certain properties like cohesion and adhesion to result in surface tension and capillary action which helps in certain processes
Release of energy during respiration	Electron transport chain (transfer electrons from electron donors to electron acceptors via redox reactions)	Chemistry	Energy transfer and transport

Activity 1.3: Group Discussion

Which other relationships of biology with other disciplines do you know? Discuss in groups of four of five and present to your classmates.

1.2 Pure and applied fields of biology

Objectives

At the end of this section, the student will be able to:

- *Classify the different sub-fields of Biology into pure and applied*
- *Define each sub-field of biology*

Recall

The previous section described and briefly addressed various sub-fields of biology. Now, you will learn the category of biology as pure and applied sub-fields.

What do we mean by pure and applied fields of biology?

Pure biology is the study of how life functions in nature (behavior, internal and external structure, reproduction, etc.) whereas applied biology refers to using what you have learned in biology for (gardening, nursery work, agriculture, plant disease, forestry, poultry, etc.). Therefore, applied biology is the use of your knowledge of biology to manage life. The relationship is similar to anatomy and surgery.

Activity 1.4: Categorizing pure and applied fields of biology

Select pure and applied fields of biology from the list given in the columns on the left side in the table below and categorize them in their appropriate column on the right side (columns A & B).

Table 1.4 Pure and Applied fields of Biology

Fields of Biology		Pure Biology (A)	Applied Biology (B)
Agriculture	Biotechnology		
Morphology	Molecular Biology		
Taxonomy	Evolution		
Horticulture Cytology	Pathology		
Embryology	Physiology		
Histology	Forestry		
Poultry	Pharmacognosy		
Agroforestry	Pisciculture		
Apiculture	Paleontology		
Animal Husbandry	Bacteriology		
	Entomology		
	Sericulture		

Activity 1.5: THINK-PAIR-SHARE

In the previous parts of this unit, you have studied the different branches of biology. Now, in pair, take at least 3 fields of biology and think of their importance in other branches of science. Finally, share your ideas with each other.

In some branches of science, biology has become very important in this millennium. With the above idea, let us discuss some of the biological importance of the branches of biology in other branches of sciences.

1) Biotechnology: is the use of living organisms or their products for the welfare of humanity. It involves the technical manipulation of a living organism's genetic makeup (Genetic Engineering). A genetically modified and improved variety of crops and animals have been produced by biotechnology.

2) Bioinformatics: is concerned with the acquisition, storage, analysis, and dissemination of biological data, most often DNA and amino acid sequences. Bioinformatics uses computer programs for a variety of applications, including determining gene and protein functions, establishing evolutionary relationships, and predicting the three-dimensional shapes of proteins.

3) Genetic Engineering: is a means of extracting selected genes from an organism or synthesizing selected genes and these genes are inserted into another organism; as a result, an organism develops with a new combination of genes, and this process is called genetic engineering.

4) Biomedical Engineering: is the application of the principles and problem-solving techniques of engineering to biology and medicine. Biomedical engineering focuses on the advances that improve human health and health care at all levels

5) Environment Management: deals with environmental observation and finding out the solution to maintain the balance of nature.

6) Forensic Science: is the application of the knowledge of biological science (DNA fingerprints (unique patterns in DNA molecule), blood typing) to criminal and civil laws.

1.3 Major discoveries that revolutionized biology

Activity 1.6 Group discussion

In a group of 4 -5 students, discuss at least five major discoveries that revolutionized biology.

Let your group's secretary present your findings to the whole class.

Objectives

At the end of this section, the student will be able to:

- *Discuss at least five major discoveries that revolutionized biology*

Biology is a fascinating and diverse subject area. If you're thinking of studying Biology, here are the twelve famous discoveries to inspire you.

1. Aristotle (384–322 BC)

Despite the fact that his name is rarely mentioned when discussing important biological discoveries, the ancient Greek philosopher Aristotle was responsible for a breakthrough classification system for living things. Aristotle's classification system was known as the 'Ladder of Life' until the nineteenth century. For the first time, he established species relationships and grouped them correctly.

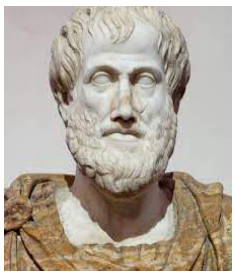


Figure 1.6 Aristotle

2. Galen (129–161 AD)

Galen's efforts transformed medical science. Galen had a significant impact on the advancement of numerous medical specialties, including Anatomy, Pathology, Physiology, and Neurology. Among his important findings were the distinctions between veins and arteries, as well as the recognition that the larynx produces voice. Although many of his concepts contained scientific mistakes, his contribution to medical science is undeniable

Figure 1.7 Galen

3. Antonie van Leeuwenhoek (1632–1723)

Antonie van Leeuwenhoek is well renowned for his contributions to microscopy and how he applied it to the field of biology. He invented a method for making strong lenses that, according to some, could magnify up to 500 times. Leeuwenhoek employed microscopes to learn more about the biological world; among his findings were bacteria and the vacuole of the cell.

Figure 1.8 Antonie van Leeuwenhoek

4. Carl Linnaeus (1707–1775)

Carl Linnaeus, a botanist, physician, and naturalist, devised the method for naming, ordering, and classifying creatures that we still use today. His extensive collection of plant, animal, and shell specimens inspired him to devise a system for classifying and naming species. He separated items into three categories – animals, plants, and minerals – and further organized living things into classes, orders, genera, and species. 'Homo sapiens,' for example - 'homo' is the genus and 'sapiens' is the species.

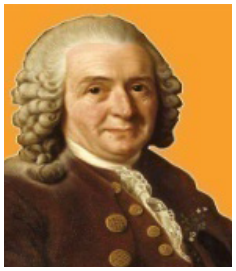


Figure 1.9 Carl Linnaeus

5. Charles Darwin (1809–1882)

Probably the most famous naturalist of all time, Charles Darwin's contribution to biology and society is immense. He established that all species of life descended over time from common ancestors, with species continuing to exist through the process of natural selection. His theory of evolution was published in On the Origin of Species in 1859 and it caused quite the stir – he was disputing the long-held belief that all species had been created by God at the beginning of the world. Evolution by natural selection combined with Mendelian genetics is now accepted as the modern evolutionary synthesis and forms the foundations of much biological scientific endeavor.

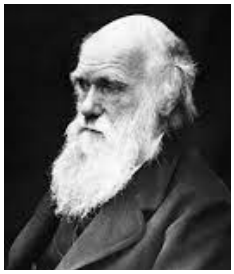


Figure 1.10 Charles Darwin

Figure 1.11 Gregor Mendel

6. Gregor Mendel (1822–1884)

Gregor Mendel's extraordinary contribution didn't get the recognition it deserved until long after the friar's death. He used peas to discover and demonstrate the laws of genetic inheritance, coining the terms 'dominant' and 'recessive' genes in the process. The laws were rediscovered at the turn of the 20th century and provided the mechanism for Darwin's theory of natural selection to occur. The two theories combine to form our current understanding of the evolutionary process.

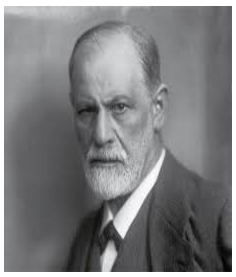


Figure 1.4 Louis Pasteur

7. Louis Pasteur (1822-1895)

Louis Pasteur is regarded as the father of medical microbiology. His contributions to science, technology, and medicine are nearly unparalleled in history. He pioneered molecular asymmetry research, demonstrated that bacteria cause fermentation and disease, introduced pasteurization, rescued France's beer, wine, and silk industries, and developed anthrax and rabies vaccines.

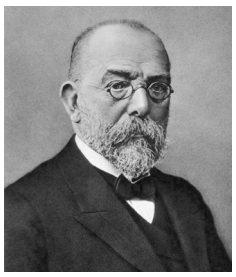


Figure 1.5 Robert Koch

8. Robert Koch (1843-1910)

Robert Koch was a well-known German physician who pioneered microbiology. As the father of modern bacteriology, he is credited with pinpointing the precise causal agents of tuberculosis, cholera, and anthrax, as well as providing experimental support for the concept of infectious disease.

Figure 1.14 Jane Goodall

9. Jane Goodall (1934)

Our knowledge of wildlife and conservation has been transformed by Jane Goodall, the UK ethologist. Best known for her career-long studies of chimpanzees, she discovered the animals are omnivores and tool users. She's a global leader in animal rights and was awarded a Ph.D. degree from the University of Cambridge without holding a bachelor's degree.

Figure 1.12 Barbara McClintock

10) Barbara McClintock (1902–1992)

American geneticist Barbara McClintock spent her career analyzing maize, where she developed a technique for identifying and examining chromosomes individually. Despite it not being immediately recognized, her work made it possible for us to map human genomes. She was awarded the Nobel Peace Prize in 1983 for her discovery of transposition and how genes could turn their physical characteristics on and off.

11. Watson (1928–) and Crick (1916–2004)

James Watson and Francis Crick were shot to fame in 1962 for their discovery of the structure of DNA, winning the medical Nobel Prize in the process. Their model of DNA (double helix) explains how DNA replicates, and hereditary information is coded and passed on to descendants. The discovery of DNA structure has led to a much more developed understanding of function – used in disease diagnosis and treatment, forensics, and more.

Figure 1.13 Watson and Crick

12. Wilmut (1944) and Campbell (1954–2012)

In 1996 Ian Wilmut and Keith Campbell cloned a mammal, famously named Dolly the Sheep. The pair cloned Dolly using a single adult sheep cell and a process of nuclear transfer. Dolly died after six years but cloning continues, although still not perfect, and certainly not ready for human application.

Figure 1.15 Wilmut and Campbell

Activity 1.7 Group and individual work

1. Mention at least ten more biological findings and explore their central issues in pairs. Finally, present them to the entire class.
2. What do you feel about biological discoveries? Do you have any possible issue in mind that can be discovered? Share with your friends.

1.4 The contributions of biological discoveries to society and the environment

Objectives

At the end of this section, the student will be able to:

- *Appreciate the contribution of biological discoveries to society/ environment (e.g. microscope, penicillin, inheritance, etc.)*

The invention of devices such as microscopes and curative medications such as penicillin has transformed human life. The biological discoveries aided humans in developing abilities required for the use of living systems or influencing natural processes to produce products, systems, or settings that aid in human development. Some biological discoveries and their impact on human society and the natural environment are described further in this sub-section.

Figure 1.16 The Microscope

The Microscope

The microscope is a device that magnifies objects or organisms that are too small to be seen with the naked eye. A milestone in the science world, the microscope has had an enormous influence on

Recall

Mention and discuss types of microscopes with the highest magnification and resolution power (refer back to grade 9 textbook on the microscopes).

the development of modern medical, forensics, and environmental sciences. The invention of the microscope has revolutionized the science industry while developing other fields:

Medical field

The use of microscopes in medicine began in the 1860s when Louis Pasteur reported that the microscopic organisms he saw in the microscope caused certain diseases. Until that time, people thought diseases came from evil spirits or God. Pasteur's germ theory revolutionized the process of identifying, treating, and preventing infectious diseases. Today, hospital laboratories use microscopes to identify which microbe is causing an infection so physicians can prescribe the proper medicine. They are also used to diagnose cancer and other diseases.

Ecosystem study

The microscope is used to study the health of an ecosystem. Field biologists utilize microscopes to observe a specific habitat, such as a marine environment, by identifying the types and numbers of microscopic organisms found in ecosystem samples. This helps scientists in defining the ecosystem, detecting threats to an ecosystem, and determining the relationship of the organisms with their environments.

Forensic Science

The microscope has greatly affected the field of forensic science. Forensics is a field of science used to gather and analyze evidence to establish facts that are used in a legal scenario. The microscope is used to examine pieces of evidence collected at a crime scene that may have information not visible to the human eye, For example, striations in bullets can be examined under a microscope to see if they match bullets shot from a particular gun.

Atomic Study

The invention of the powerful atomic force (electron) microscope has enabled scientists to study cells at an atomic level. This enables scientists to scrutinize viruses at their atomic level and influence them for the delivery of innovative treatments. The electron microscope also enables scientists to study and understand the types of viruses and understand how they infect the body.

Genetic Study

The microscope has had a significant impact on genetics research. A microscope is used by scientists to examine certain genetic makeup. This also allows scientists to evaluate genetic abnormalities, regeneration, and tissue death. The science of genetics is used to

Activity 1.8 Answer to the question

In your previous classes, you may have studied about discoveries in medicine. Can you mention some of them? Tell at least two of such discoveries and their importance to human wellbeing and proceed working on the next activity.

examine infected tissue. Histologists will be able to explore future therapies and preventive drugs as a result of this research.

Tissue Analysis

It is common for histologists to study cells and tissues using a microscope. For example, if a section of tissue is taken for analysis, histologists can use a microscope in combination with other tools to determine if the sample is cancerous.

2. Discoveries in Medicine

Science has never moved at such a rapid rate as it is happening now. As each discovery brings with it countless more developments, it stands to reason that our scientific understanding has upgraded with time. So great are many of these developments in fact, and they have impacted our daily life styles so much; it's sometimes almost impossible to imagine a world *before* many of these breakthroughs. This is particularly true of medical discoveries, and while we might complain of long hospital waiting lists or the poor bedside manner of some of the nurses, we shouldn't forget that only a few generations ago, how 'irritating it was' to amputate a limb without anaesthesia.

Activity 1.9: Fill in the space with benefits of the discoveries

Discoveries in medicine and their relevance: To honour these advances and put things into perspective, let us take a look at the eleven most important medical discoveries, as well as how they have impacted us today. This activity in table 1.5 outlines the type of discovery and the person who made it. You are required to explain its benefits to people.

Table 1.5 Types of discoveries

Type of discovery	Who discovered and year of discovery	Benefits
The Circulatory System	1242 by the physician Ibn al-Nafis, and first brought to prominence in 1628 by William Harvey	
Vaccination	Jenner' France, 1799	
Cell theory	Theodor Schwann and Matthias schleiden, 1838	
Germ Theory	Louis Pasteur, 1861	
X-Ray	Conrad Rontgen, 1895	
Vitamins	Frederick Hopkins, 1900s	
Insulin	Frederick Banting, 1920	
Penicillin	Alexander Fleming, 1928	
DNA	Swiss chemist Friedrich Miescher, 1860/70s	
Anaesthetics	Sigmund Freud and Karl Koller 1st clinical use in 1884; Albert Niemann extracted from leaves of Coca in 1860	
HIV	Robert Gallo and Luc Montagnier, 1980s	

Activity 1.10: Application of Genetics

Write about the application of genetic discoveries in:

1. agriculture
2. medicine
3. biological diversity
4. immunity
5. inheritance

3. Inheritance (Application of Genetics)

Before 1900, the history of genetics was related to cytology. This owes to "Robert Hooke", who elaborated various smaller things in a thinly sliced cork section from a mature tree. In 1831, Brown discovered a consistent structure present in a regular way, called "nucleus". Then Schleiden and Schwann presented "cell theory" (1836-1840) to depict various structures present in the cell and their nature. It was a great contribution to understanding cell structure. After other contributions, in 1884-1885, four scientists (Hertwig, Kolliker, Weismann (all zoologists), and Strasburger (botanist) derived that heredity matter existed in the nucleus in that material which makes up chromosomes.

After the discovery of Mendel's work and his laws, Genetics took a progressive turn and revolutionized. Working on this subject is still moving. Genetics is providing numerous services to humanity in almost every field of life. Thus, its prominent role never is neglected in the welfare and betterment of human lives, in one way or the other. To study more about the role of genetics for a human, do the following activity (Activity 1.10).

1.5 Ethiopian biologists and their contributions

Objectives

At the end of this section, the student will be able to:

- *appreciate major discoveries contributed by Ethiopian Scientists*
- *discuss the importance of discoveries contributed by Ethiopian scientists to human beings*

Do you know some of the major discoveries of Ethiopian biologists? Mention at least 3 of them and explain their contributions.

Three of the Ethiopian scientists and their discoveries are given below.

1. Professor Yalemtsehay Mekonnen

Prof. Yalemtsehay is a biologist and an academic member of staff at the Department of Biology, Faculty of Science, Addis Ababa University. She has worked in this department for the last 30 years. She received her Ph.D., specializing in human physiology, from the University of Heidelberg in Germany. One of her research areas is the assessment of the impact of chemical pesticide hazards on humans.

This research covers almost all government farms including the Upper Awash agricultural farms and some private horticultural farms in the Rift Valley region. The other area of her research is in the use of plants as medicine against human and animal diseases.

Figure 1.17 Prof. Yalemtsehay Mekonnen

Professor Yalemtsehay has published over 100 scientific papers in reputable journals in the areas of plants of medicinal and nutritional value in vivo and in vitro physiological tests of useful plant extracts, assessment of health hazards to humans, animals and the environment, advocacy and collaborative work for the promotion of safe and sustainable use of natural resources, to name but few. She has done notable research on medicinal plants especially on Moringa Stenopetala (shiferaw/Alekko Shekatta).

2. Dr. Aklilu Lemma

Schistosomiasis is a common parasitic disease. It affects 200–300 million people in Africa (including Ethiopia), South America, Asia, and parts of the Caribbean. It is caused by parasitic flatworms which spend part of their lifecycle in freshwater snails and part in humans. Anyone washing, working, or playing in shallow freshwater is at risk.

Figure 1.18 Dr. Aklilu Lemma

Once inside a person, the parasites mature and produce eggs which are passed out in the urine and feces. They also infest the blood vessels, liver, kidneys, bladder, and other organs. The body sets up an immune reaction and an infected person can become weakened and ill for many years. Some of the most important work in finding a way of controlling this parasite, which is effective but does not cost too much, was carried out by Dr. Aklilu Lemma, one of Ethiopia's most renowned biologists.

Dr. Aklilu began his work in 1964 when he was investigating the freshwater snails that carry the Schistosomiasis parasite around Adwa in northern Ethiopia. He saw women washing clothes in the water and he noticed that downstream of the washing party there were more dead snails than anywhere else he had collected. The women were using the soapberry, 'Endod' in Amharic (Phytolacca dodecane Dr.a), to make washing suds. Dr. Aklilu collected some live snails from above the washing party and asked one of the women to give him some of her Endod suds. Not long after the suds were put in the snail container, all the snails died. This was the start of years of work for Dr. Aklilu. Back in the laboratory, he showed that if the Endod berries were dried, crushed, and diluted in water they would kill snails at very low concentrations.

Other scientists carried out similar investigations and got the same results. If the freshwater snails can be controlled, the spread of

schistosomiasis can be greatly reduced. The World Health Organization recommended a chemical molluscicide (i.e. a compound that kills mollusks including snails) but it was extremely expensive. Endod works well, it is cheap and well known by local people who are likely to use it and it is environment friendly as it breaks down naturally within about two days. Dr. Aklilu Lemma worked for many years to convince scientists all around the world that his ideas would work. Trials using locally collected Endod showed that using the molluscicide worked. Before the water was treated, 50% of children 1–6 years old were infected. After treatment, only 7% were infected by the flatworm.

Dr. Aklilu's results were published in journals around the world. He found the best species of the soapberry plant and developed programs for local communities to treat their water. Eventually, people were convinced and the use of Endod-based molluscicides is spreading throughout Africa and beyond. He has been honored and recognized in many different ways both in Ethiopia and around the world for his work.

3. Professor Gebissa Ejeta

Figure 1.19 Prof. Gabissa Ejeta

When Prof. Gebissa Ejeta was born in a small rural village his mother was determined her son would receive a good education. He walked 20 miles to school every sun day evening, returning home on Friday after a week of studying. It all paid off as he joined Jimma Agricultural and Technical School and then Alemaya College.

He specializes in plant breeding and genetics. Prof. Gebissa Ejeta did his research on sorghum He got his Ph.D. from Purdue University in the USA where he still holds a professorship. He has helped to develop Africa's first commercial hybrid strain of sorghum. This sorghum variety not only needs less water and so is resistant to drought, but it also yields more grain than traditional varieties.

Prof. Gebissa Ejeta developed other varieties of sorghum that are also resistant to the parasitic Striga weed, which can destroy a big percentage of a crop. Prof. Gebissa's work has made a very big difference to the food availability in many areas of Ethiopia and other African countries. His varieties yield up to ten times more than others. In 2009, Prof. Gebissa Ejeta was awarded the World Food Prize, which is the most prestigious agricultural prize in the world. He has also been awarded the National Hero award of Ethiopia for his work in science and technology. These are just some of the many renowned Ethiopian biologists who have carried out work of great value both in Ethiopia and across the world. You will have the opportunity to find out more about some of the other scientists with your teacher in activity 1.11.

Activity 1.11 Fill in the column with contributions

In section 1.5 of this unit, you have learned about the contributions of three Ethiopian scientists. In the table below, you are given the names of other known biologists who have contributed to the development of Ethiopian biological science and scientific research. Write the date and type of their contributions in the right hand column of the table below.

Ethiopian Biologist	Contribution to the development of biological education and research
Prof. Beyene Petros	
Dr. Brihane Asfaw	
Prof. Ensermu Kelbesa	
Prof . Legesse Negash	
Dr. Melaku Wolde	
Prof. Mogessoe Ashenafi	
Dr. Tewoldebrihan G/Egziabiher	
Prof. Tilahun Yilma	
Dr. Tsehaynesh Asfaw	
Dr. Zeresenay Alemseged	

Unit Summary

- Zoology, Botany, and Microbiology are the three major branches of biology.
- Some sub-fields of biology have existed for hundreds of years, while others are much newer and often developing rapidly.
- Anatomy, physiology, bacteriology, mycology, genetics, cytology, histology, embryology, taxonomy and evolution, are some of the subfields of biology.
- Every scientific discovery is remarkable, and some are truly life-changing.
- There have been numerous great discoveries throughout the lengthy history of biology.
- Almost all scientific discoveries help us learn a little bit more about this magnificent world we live in, and some discoveries help us discover more.
- Some scientific breakthroughs allowed biologists to see even deeper into life, the world, and everything: the microscope (Antonie van Leeuwenhoek), the law of inheritance (Gregor Mendel), are some examples.
- The biological discoveries aided people in developing abilities required for using living systems or influencing natural processes to produce products, systems, or environments that aid in human development.
- Some biological discoveries that have had an impact on human civilization and the natural environment include: microscopes, medications, and laws of heredity, germ theory, blood circulation in human, etc.
- Discoveries of Ethiopian biologists have made significant contributions to society and development.
- Dr. Aklilu Lemma's discovery of soapberry 'Endod' against bilharzia (Schistosomiasis), a prevalent parasitic ailment, and Prof. Gebissa Ejeta's series of study findings on Sorghum varieties and productivity are only a few examples of contributions of Ethiopian biologists.

Review Questions

I. True False

Write "True" for correct statements and "False" for the incorrect once on the space provided.

1. X-ray was discovered by Frederick Bating in 1895.
2. Biochemistry deals with the chemical reactions that take place in living organisms.
3. Microscope was discovered by Theodor Schwann in 1838.
4. Genetics is the study of heredity and variation.
5. The scientific contribution of Prof. Gabissa Ejeta is on the application of Endod to control Bilharzia.

II. Matching

Match the description of field of study given under Column A with the field of study given under column B, and write the letter of your answer on the space provided.

	Column "A"	Column "B"
1	The study of insects	A. Cytology
2	Embryological development of the fetus	B. Agroforestry
3	The study of tissue	C. Histology
4	The study of mixed agriculture	D. Entomology
5	The study of cells	E. Embryology

III. Multiple Choice

Choose the best answer from the given alternatives (A, B, C & D).

1. The evolutionary history of an organism is known as
   A. Anatomy B. Ancestry Palaeontology D. Phylogeny
2. Who discovered the circulation of blood?
   A. Ibn al-Nafis B. McCollum C. Scottish naval D. Edward Mellanby
3. The study of the internal structure of an organism is
   A. Morphology B. Anatomy C. Histology D. Systematic
4. Anatomy is the study of
   A. Life B. Body parts C. Animals D. Ocean
5. Who is regarded as the father of genetics?
   A. Grogor Mendel B. Gabissa Ejeta C. Scottish naval D. Edward Mellanby
6. Who first discovered the germ theory of disease?
   A. Louis Pasteur B. Alexander Flaming C. Frederick Banting D. August Weismann
7. Who discovered vitamins?
   A. Anton Van Leeuwenhoek B. Frederick Hopkins C. James Watt D. All of the above
8. Bilharzia is caused by:
   A. Snails B. Bacteria C. Parasitic flatworms D. Viruses

IV. Short answer

1. How biology and chemistry are interrelated in biochemistry?
2. Discuss the role of genetic discoveries in agricultural development.
3. How biological studies help human to keep healthy life?
4. What are the major discoveries of Louis Pasteur?
5. How does biology and physics interrelation form a study termed biophysics?

Unit 2: Plants

Contents	Learning competencies
2.1. Characteristics of plants 2.2. Non-flowering and flowering plants 2.3. Structure and function of plant parts 2.4. Reproduction in plants 2.4.1. Non-flowering 2.4.2. Flowering 2.4.3. Pollination 2.5. Seeds (monocots, dicots) 2.6. Seed Dispersal and Germination 2.7. Photosynthesis 2.8. Transport in plants 2.9. Response in plants 2.10. Medicinal plants 2.11. Renowned Botanists in Ethiopia	2.1 explain the characteristics of plants 2.2 differentiate between flowering and non-flowering plants 2.3 draw and label the internal and external structure of angiosperms 2.4 draw and label the floral parts 2.5 list different types of agents of pollination 2.6 draw and label the reproductive cycles of flowering and non-flowering plants using typical examples 2.7 infer seed dispersal mechanisms by looking at the nature of seeds 2.8 discuss the process and mechanisms of photosynthesis 2.9 conduct experiment on germination of dicot and monocot seeds 2.10 discuss the mechanism of water, mineral, and organic molecules transport in plants and its implication on agricultural productivity 2.11 conduct experiments to demonstrate plant responses (geotropism, hydrotropism, phototropism) 2.12 investigate medicinal plants used by the local people to treat different ailments 2.13 appreciate the works of Ethiopian Botanists

2.1. Characteristics of plants

Objectives

At the end of this section, the student will be able to:

- *list the characteristics of plants*
- *distinguish unique features of plants*

What are the common characteristics of all living things?
What are the characteristics of plants?

Recall

Revise what you learned in Grade 9: Unit 2 about

- Definition of life
- Characteristics of living things

The word plant includes a range of living organism which share many characteristics in common. Some of their characteristics are common with other living things, while they have unique characteristics that belong to plants. Major characteristics of plants are listed hereunder. You are expected to distinguish characteristics plants share with other

ACTIVITY 2.1 THINK– PAIR-SHARE

Direction:

Pair with a friend sitting next to you and share what you think of the following key issues. Write down points you discussed to share to your classmates

- Would there be life in the absence of plants? Give justification to your answer.
- What is your reaction to a person who is using nail to fix notice board or plate on a tree or firmly tying metal wire or plastic wire around the stem of growing plants to hang wet clothes for sun drying ?
- List down your reasons to convince the person.

living things from those features which are unique to plants.

- Plants are living things. Like other living things plants grow, reproduce and respond to changes in the environment.
- Plants are multicellular. They are made up of many eukaryotic cells. These cells have well-defined nuclei and membrane-bound organelles. In addition to the cell membrane, plant cells have a rigid cell wall made primarily of cellulose.
- Plants are autotrophic (self–feeding). Plant cells contain the green pigment chlorophyll which enables them to absorb sunlight and produce their own food. Thus, they are also named Producers.
- Plants are sessile. They cannot move by themselves. They remain fixed at one place, firmly anchored to the soil by their root. However, the leaves of plants can turn towards light and some respond to touch. The roots of plants can also orient towards water or moist soil.
- Plants practice asexual and sexual reproduction patterns. In lower plants such as mosses and liverworts, asexual reproduction through spores is the dominant form. On the other hand, in higher and seed-bearing plants such as gymnosperms and angiosperms, sexual reproduction which involves the union of gametes or sex cells is the dominant and visible form

2.2 Flowering and non – flowering plants

Recall

Revise what you learned in Grade 9: Unit 2 about

The five kingdom classification

Objectives

At the end of this section, the student will be able to:

- *differentiate between flowering and non – flowering plants,*
- *use plant reproductive structure for classifying plants and*
- *realize floral structure as a strong marker for classification*

What do you know about flowers and flowering plants?

How do plants reproduce without flowers?

What comes to your mind when you think about plants?

Indeed, the concept "plant" is widely associated with those that have flowers, root, stem and leaves having transporting vessels (vascular bundles). However, as shown in Figure 2.1 there is a huge number of lower plants, such as mosses and liverworts which are non – vascular, i.e., do not have transporting system or conducting vessels, essential to transport water, nutrient and food needed for the plant. The non – vascular plants, are generally small with limited height and restricted to moist and shaded areas. These lower plants are seedless and do not have flowers and fruits.

There are still large numbers of plants known as gymnosperms with

well-developed root stem and leaves but have no flowers. Their reproductive organ is cone, instead of flowers. Moreover, the seeds produced in their cone are without cover (naked seeds).

Flowering plants, commonly known as Angiosperms, are also vascular with well-developed root, stem and leaves. But unlike gymnosperms, they have flowers and produce seeds within a fruit.

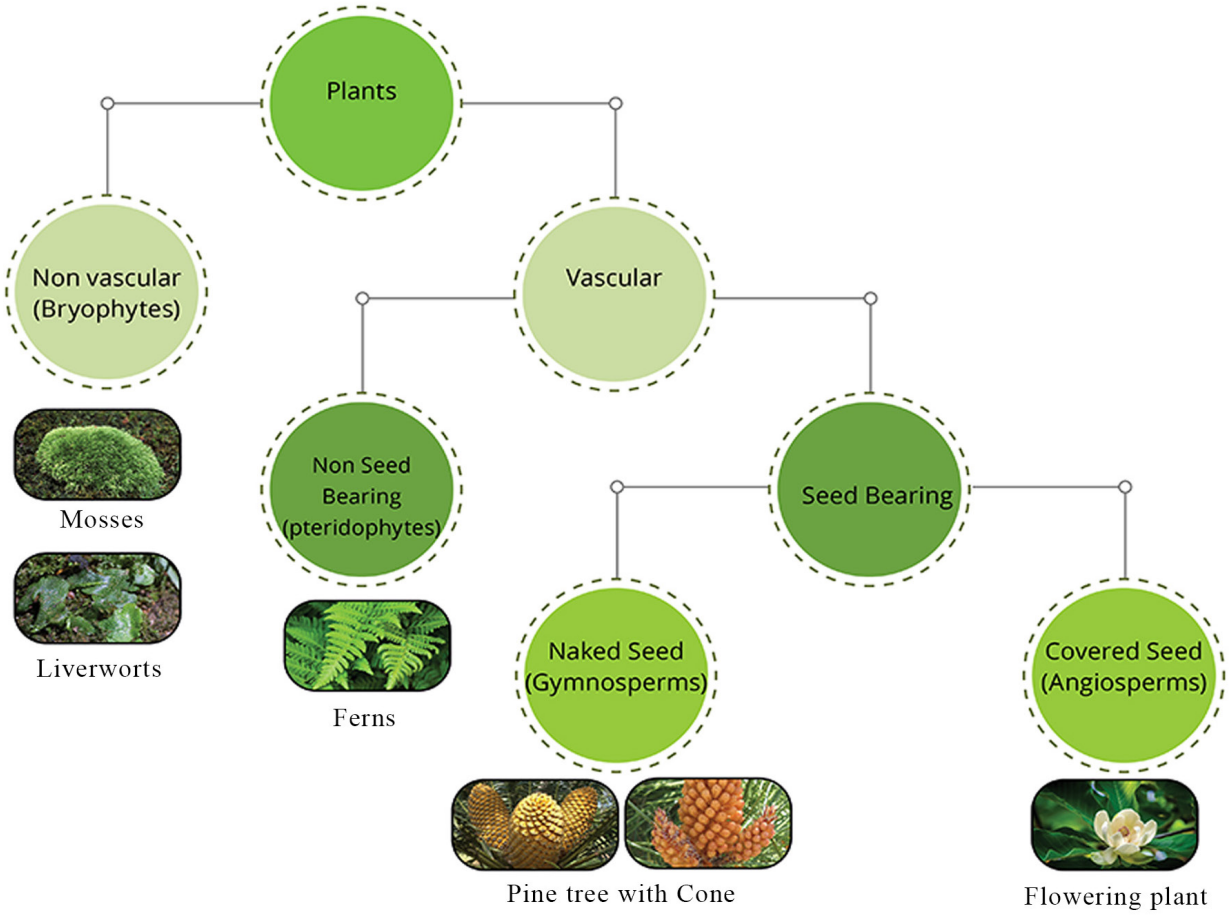


Figure 2.1 Major groups of plants

ACTIVITY 2.2 COOPERATIVE LEARNING

Direction:

Form a group of four students (two neighboring pairs). Critically look at Figure 2.1 and answer the following questions. Then compare your answers with other groups of your classmates

- Which plant groups would be included under non – flowering plants?
- Why is flower important marker of classification? (This may need library work or browsing on the Internet to collect more information)
- Construct a table that shows similarities and differences between gymnosperms and angiosperms?

2.3 Structure and function of plant parts

Think of flowering plant, which is found around your home or school campus. List major structures and describe their functions before you learn about structures of a plant in class.

Objectives

At the end of this section, the student will be able to:

- *draw the external and internal structure of angiosperms,*
- *label the external and internal structure of angiosperms and*
- *relate the structure of plants with the function they perform*

Like any organism, plants have different structures which perform a vital function essential for the plant life. In this sub-topic, we will focus on the external and internal structure of a flowering plant (angiosperm).

As illustrated in Figure 2. 2, the external structure of a typical angiosperm has two major systems.

The shoot system: This is the plant part usually found above the ground and includes the organs such as stem, branches, leaves, buds, flowers and fruits. The last two organs may be missing depending on the reproductive stage of the plant.

The root system: This is the part of the plant that usually grows downward into the ground. It includes the primary or tap root, lateral or branch roots, root hairs and root cap. Roots are distinguished from an underground stem in that, it does not bear either leaves or buds.

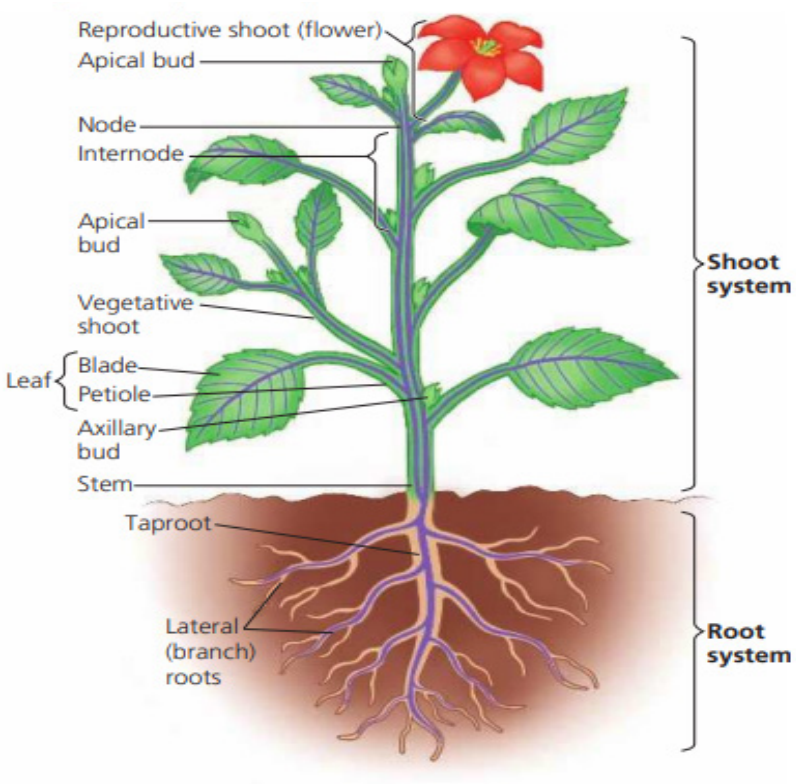


Figure 2.2 External structure of a typical angiosperm (flowering plant)

ACTIVITY 2.3 FIELD WORK

Material needed: A typical plant having complete organs of a flowering plant as illustrated in Figure 2.2

Direction

Form a group of three to four students and

- Collect a plant from your school campus or locality that resembles Figure 2.2
- Look at the plant collected and identify the shoot systems , buds (apical and axillary bud), leaves, flower and root system (tap root and lateral root)
- Prepare a properly labeled diagram of your life specimen (Real plant) showing all the parts that you have identified
- Discuss how you differentiate underground stems from root.

How do you relate the structures of leaf and roots to their function?

Figure 2.3 shows the external structure of leaf and the types of root. The external structure of a typical leaf consists of the petiole (leaf stalk), lamina (blade – broadest part), midrib, margin, base and tips (Figure 2.3 a). The lamina is the broadest part, which is flat, wide and commonly thin. It provides large surface area, which enables leaf to collect light. Its thinness creates short distance for gas exchange through the stomata (tiny pores). The midrib is harder and contains the vein (transporting vessels) of the leaf as well as supportive tissues with hard cell wall. Leaves of different plants show difference in absence or presence of petiole, leaf shape (variation in leaf margin, base and tips) and arrangement of veins.

With regard to root, there are basically two types of roots (Figure 2.3b) , namely tap-roots and fibrous roots

A tap-root consists of one large, primary vertical root. It has very few lateral roots that develop and grow from this main root. By penetrating deep into the soil, tap roots provide stability (anchorage) and absorb water located deep in the ground. Tap root system is a feature of dicot plants.

A fibrous root is usually formed by thin, moderately branching roots growing from stems. They are more or less similar size and length. In grasses they develop as consists of fine hair – like root that. Spread out from the base of the stem. Fibrous root is very efficient for absorbing water and minerals close to soil surface. It creates a thick network of roots that are good at holding soil together and protect soil from erosion. Fibrous roots are features of monocot plants .

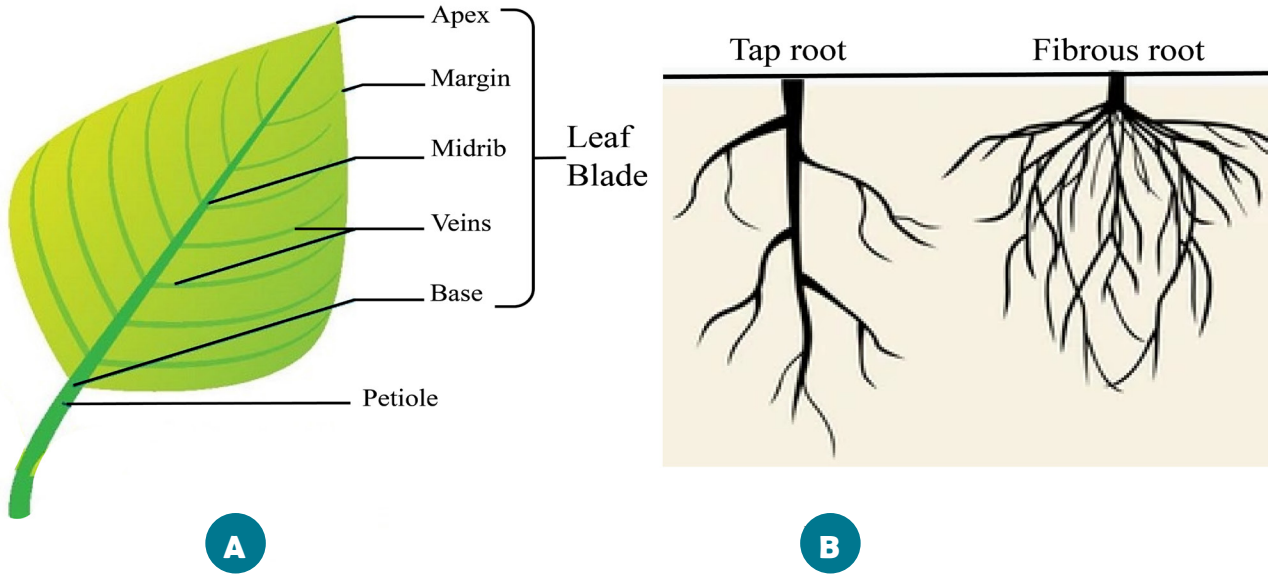


Figure 2.3 External structure of a typical leaf (A) and Types of roots (B)

ACTIVITY 2.4 PEER DISCUSSION

Material needed: A typical leaf and roots as shown in Figure 2.3

Direction: Form a group of four students (two neighboring pairs) and

- Collect a leaf and roots from your school campus or locality that resembles Figure 2.3
- Identify the different parts of a leaf (petiole, leaf base, margin, apex and midrib). Draw prepare a properly labeled diagram of the leaf in your exercise book
- Describe and show how leaves of different plants differ in their morphology
- Use a hand lens and examine the leaf veins and distributions of tiny pores. What is the function of these structures?
- Use the real root you collected and label the different parts of the tap root of Figure 2.3B
- Examine the root hairs with a hand lens and note why root hairs are best suited for absorption..

2.3.1 The internal structure of a leaf

In this section, you will explore the internal structure or tissues of a green leaf that made it best suited for food synthesis. Figure 2.4 shows components of the two internal layers of a leaf, namely; Outer layer and middle (inner) layer.

A) Outer layer

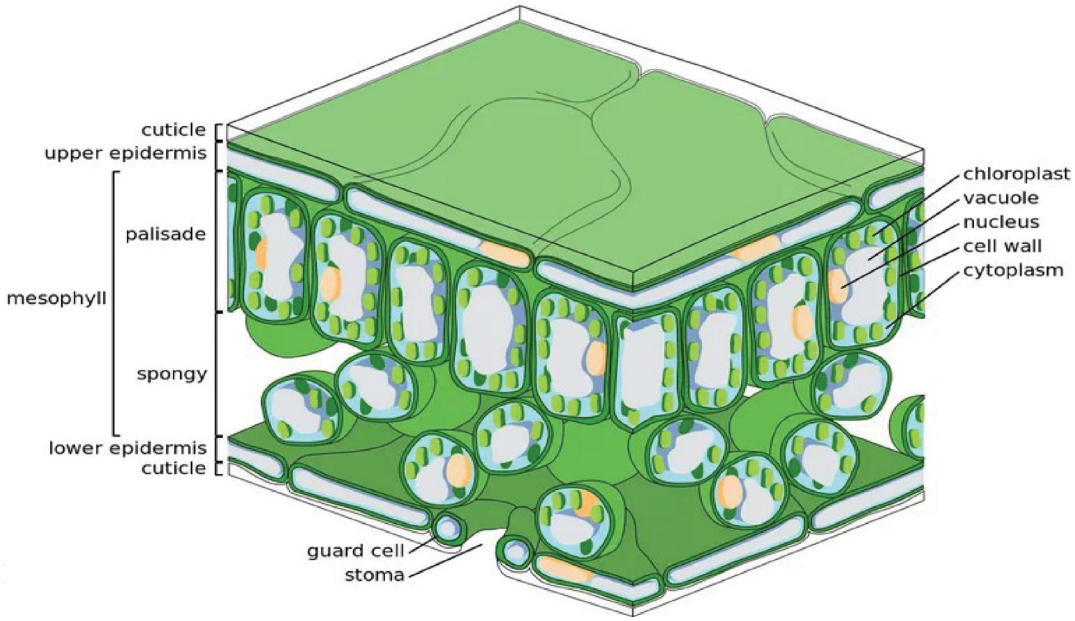
This is also known as the epidermis, a single layer of tightly packed cells that covers the upper and lower surface of the leaf. The upper epidermis is usually covered by a waxy cuticle, which transmits sunlight for photosynthesis but restricts water loss by evaporation from the leaf tissue. The lower epidermis usually contains bean-shaped guard cells that leave open spaces known as stomata (singular stoma). Stomata are "little mouths" or " little noses", which regulate O_2 release, CO_2 intake and water loss. In most leaves, stomata are more abundant in the lower epidermis, reducing water loss due to direct sunlight.

B) Middle layer

This is known as the mesophyll ("middle leaf") layer. It lies between the upper and lower epidermis. It includes tissues that are directly or indirectly involved in photosynthesis. There are two regions in the mesophyll layer

The palisade layer is composed of regularly arranged and closely packed columnar (vertically elongated) cells. The cells contain the largest number of chloroplasts per cell. As the layer is immediately beneath the upper epidermis, it is in the best position to capture most of the sunlight and this enables it to carry out most of the photosynthesis. The slight but precise separation of the columnar cells maximizes the diffusion of CO_2 and capillary movement of H_20.

The spongy layer – lies below the palisade cells. Spongy cells are irregularly shaped with fewer chloroplasts. They are very loosely arranged with numerous airspaces. These air spaces, which are very close to the stomata allow the diffusion of O_2, water vapour and CO_2.



2.3.2 The internal structure of a stem

Figure 2.5 shows the internal structure of a typical dicot stem of a flowering plant. Accordingly, the detailed internal structure includes the following fundamental tissue systems.

The epidermis is the outermost layer of the stem. The outer walls are greatly thickened with cuticles, which minimizes the rate of transpiration. Moreover, the cells are compactly arranged, which in turn protect the underlying tissues from mechanical injury and prevent the entry of harmful organisms.

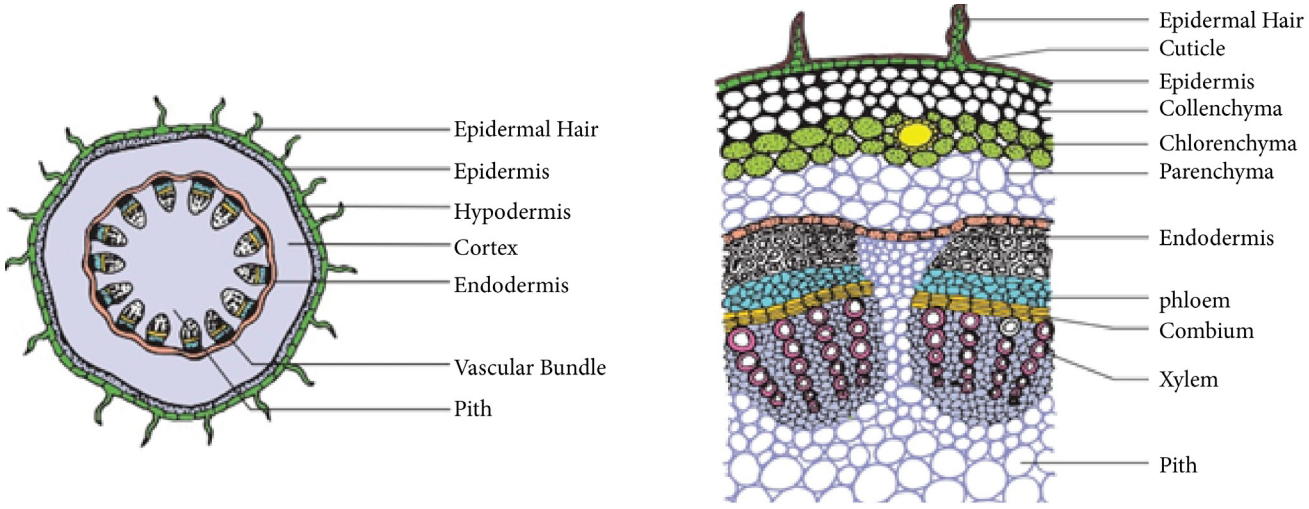


Figure 2.5 Internal structure of a typical dicot stem (A = Ground plan; B = Transverse section)

Hypodermis lies below the epidermis. It is mainly composed of collencyma cells that are specially thickened at the corners due to the deposition of thick cellulose. This enables the layer to give mechanical strength to the stem.

Cortex consists of few layers of thin-walled, large, round, or oval cells, having intercellular space and serving for storage of food.

Endodermis is the innermost layer of the cortex that separates the cortex from the vascular bundles. The cells are compactly arranged and usually contain starch grains. Thus, the endodermis serves as a food reserve and may be termed as a starch sheath.

Vascular bundles are longitudinal strands of conducting tissues or transporting vessels, consisting essentially of xylem and phloem arranged in a ring around the central pith. Each bundle has a patch of xylem towards the pith and a patch of phloem towards the endodermis and a strip of actively dividing young cells (cambium) in between them. Xylem transports water and dissolved minerals to the photosynthetic tissues, mainly to the leaf while phloem transports synthesized food to different tissues, either for utilization or storage.

Pith – occupies the central portion of the stem, composed of thin-walled cells, which are rounded or polygonal, with or without intercellular space. It stores food and helps in the internal translocation of water.

https://pediaa.com/what-is-the-difference-between-monocot-stem-and-dicot-stem

ACTIVITY 2.5 LIBRARY WORK

Note: Angiosperms have their seeds enclosed inside fruits. They can be classified as "Monocots" and "Dicots", having one and two cotyledon (s) respectively. Typical examples include maize (a monocot) and bean (a dicot).

Direction:

- Using illustration (Figure 2.5), you can learn the internal structure of a dicot stem. For a contrast, you need to know the internal structure of a monocot stem.
- Refer to biology books available in your library or download pictures showing the internal structure of monocot stem from the internet. Then draw and label the picture in your exercise book.
- Complete the following table of comparison to show the differences between the internal structure of the dicot and monocot stem. The column under dicot is filled to you for references.

Dicot stem	Monocot stem
Contains distinct regions known as cortex , vascular bundles and pith (stele)	
Has few number (4 to 8) of set of vascular bundles	
Vascular bundles are arranged regularly in the form of one or two rings	
Pith is present and well developed	

2.3.3 The internal structure of a root

As illustrated in Figure 2.6 below, the transverse section of the dicot root shows the following plan of arrangement of tissues from the periphery to the centre.

Peliferous layer is the outermost layer made up of single-layer cells. The cuticle is absent. . It consists the single-celled root hairs.

Cortex is a multi-layered large zone made of thin-walled oval or rounded loosely arranged cells with intercellular spaces. It stores food and water.

Endodermis is the innermost layer of the cortex, made of barrel-shaped closely packed cells. The layer helps the movement of water and dissolved nutrients from the cortex into the xylem.

Pericycle is a single layer inner to endodermis. It is the site of origin of lateral roots.

Vascular bundles consist of xylem and phloem with meristematic (cambium) or actively dividing cells between them

Pith is present in young roots while absent in old roots.

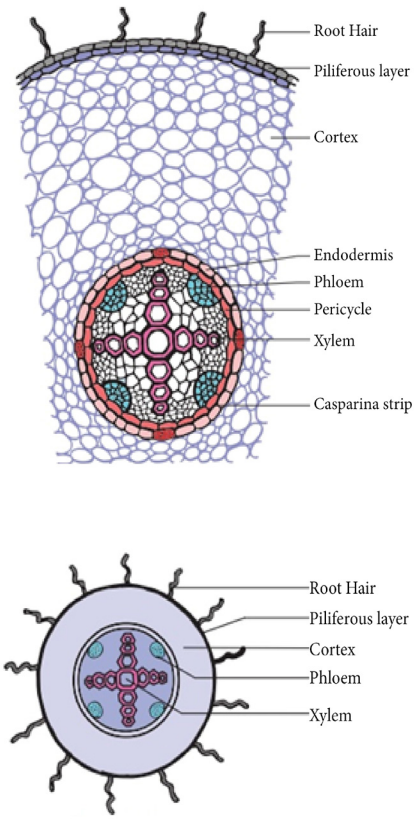


Figure 2.6 Internal structure of a typical dicot root

ACTIVITY 2.6: COMPARATIVE TABLE

Direction:

- Follow the direction stated in activity 2.6, but this time you will draw and label the internal structure of monocot root in your exercise book.
- Complete the following table of comparison to show the differences between the internal structure of dicot and monocot root. The column under dicot is filled to you for reference

Dicot root	Monocot root
The cortex area is narrow	
Vascular bundles limited in number between 2 – 6	
Pith is either extremely small or absent	
Show secondary growth due to the presence of cambium	

Self Test

In Grade 9, you have learned that one of the unifying principles in Biology is complimentary of structure and function i. e, a particular structure is best suited for a particular function. Explain how leaf and root of a plant can be described with this unifying principle.

https://www.visiblebody.com/learn/biology/monocot-dicot/roots

2.4 Reproduction in plants

How do non – flowering and flowering plants reproduce?

Think of a fruit bearing plants like "Avocado" or "Papaya". Collect information about these fruits and point out the stages of their life cycle starting from the matured plant.

Objectives

At the end of this section, the student will be able to:

- *draw and label floral parts,*
- *outline the reproductive cycle /pattern of non – flowering and flowering plants ,*
- *list different types of pollinating agents and*
- *appreciate the diversity in floral colour to attract pollinators*

2.4.1 Reproductive structure and life cycle of non-flowering plants

In this section, you will learn the reproductive structure and life cycle of higher seed-bearing non–flowering plants known as gymnosperms. Figure 2.7 shows common gymnosperm trees in Ethiopia and reproductive structure, male and female cones, of pine tree. These higher plants belong to a group of gymnosperms known as conifers.

Figure 2.7 Common gymnosperms and reproductive cones

Attention

Most conifers have narrow, needle shaped leaves with thick cuticle, which enable them to live in extremely cold and hot environments. They are evergreen and do not shade their leaves both in winter and summer, a feature which makes them to be ornamental plants decorating parks, recreational areas and streets in town and big cities.

ACTIVITY 2.7 : FIELD VISIT

- Arrange a field visit with small groups (3 to 4 students) to a park or recreational places or street gardens during your weekend. Look for gymnosperm trees, particularly indigenous trees such as Podocarpus falcatus ("Zigba ") and Juniperus procera ("Tid"). You can also look for gymnosperm shrub, which is used as a hedge grown in a row and used for partition in gardens.
- If you have a smart phone, take picture of the gymnosperm tree to share with your classmates.
- Take note on the external structure of the gymnosperm tree you encountered with special attention on the nature of leaf and the cones (if there are any). Collect some leaf and the cones and bring them to class as specimen for class discussion.
- Ask your elders or parents about the reproduction and economic importance of gymnosperm trees and prepare a report to submit to your teacher for whole class discussion.

After the field visit and preparation of the field report, you are now able to distinguish and describe gymnosperms. In this lesson, you will learn the life cycle of gymnosperm, using the pine tree as a typical representative of conifers as well as gymnosperms in general.

As shown in Figure 2.8 the pine tree has male and female cones on one plant. Initially, pollen is transferred from the male cone to the female cone. The process is called pollination and occurs with the help of wind. Following pollination, the pollen completes its germination and produces the male gamete inside the female cone. The female gamete is also produced in the female cone. Here, the male and female gametes fuse (unite) and form a zygote. This process is known as fertilization.

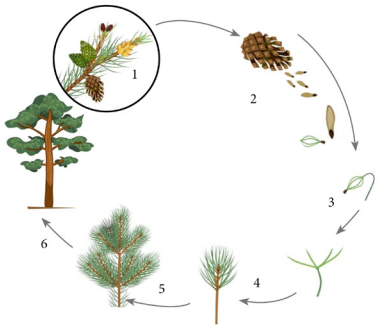


Figure 2.8 Life cycle of a pine tree representing gymnosperms

A zygote develops into a seed embryo inside the female cone. After the seed is matured, it is liberated upon drying and opening of the female cone. Then the seed will be dispersed or scattered away from the parent plant and germinates into a seedling (young pine plant) upon getting favorable conditions. Finally, the young plant grows and develops in to mature plant with female and male cones and the reproductive cycle of the pine tree is complete.

Have you ever thought that removing a flower is depriving its opportunity to reproduce or substitute itself? What does this mean for plants with solitary (single flower)?.

ACTIVITY 2.8 COOPERATIVE LEARNING

Carefully read the description on the reproductive cycle of a pine tree. Share ideas with a friend sitting next to you and list down developmental stage denoted by numbers (1 to 6) in Figure 2.8 to show major stages of gymnosperms' life cycle in general.

2.4.2 Reproductive structure and life cycle of flowering plants

What is flower? What are the major floral parts and their role in reproduction ?

A flower is the reproductive organ of angiosperms, plants with seeds covered by or contained in a fruit. Figure 2.9 illustrates a typical flower has four floral parts, namely Sepals, Petals, Stamen, and Pisti.
Sepals (calyx) – usually green leaf-like structure protecting the lower part of female and male parts

Petals (corolla) – mostly brightly coloured and attract pollinating agents like insects

Stamen (Androecium) – is the male part, consisting of the filament and bilobed anther

Pistil (Gynoecium or carpel) – is the female part, consisting of the ovary with ovules, style and stigma.

Attention

A complete flower has the four floral parts. It is called incomplete flower if it does not have any one of the floral parts.

A perfect flower has both stamen and pistil. If a flower does not have either stamen or pistil, it is known as imperfect flower. It is either pistilated (has pisitil and no stamen), or staminated (has stamen but no pistil) flower.

Self Test

An imperfect flower is incomplete flower, but an incomplete flower may or may not be an imperfect flower. Explain how this is so?

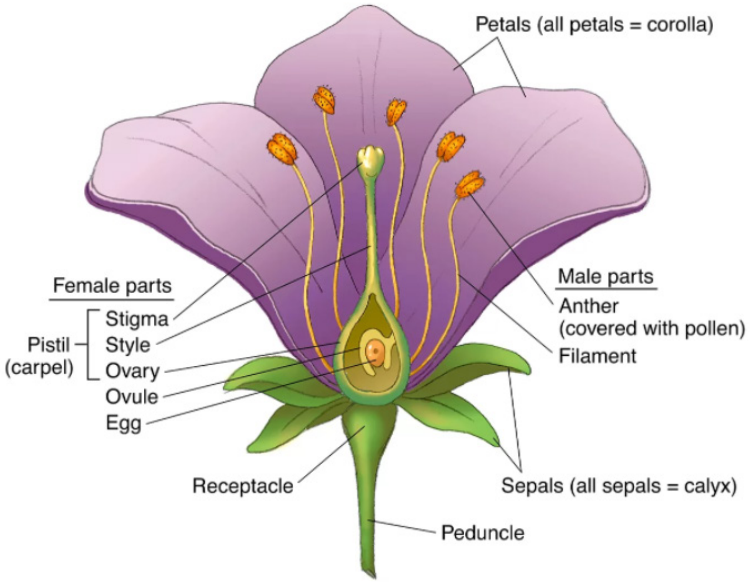


Figure 2.9: Structure of typical flower

ACTIVITY 2.9 COOPERATIVE LEARNING

- Let one group of five students from each class bring one complete flower and another group of five students incomplete flower, without harming the plant from your school campus or your locality. Put your flowers in a plastic bag and bring them to your class for your group work
- In the class room students should carefully examine the complete flower. They should identify the different floral parts by comparing the real flowers to Figure 2.9. Then students draw and label the parts, focus in on the male part (stamen) and female part (pistil) in your exercise book.
- Let students look at the incomplete flower and identify the part (s) missed. Ask students if the flower is incomplete and imperfect? Why did they say so?
- During collection, students will observe that some flowers are bright in colour while the others are not. Which floral part is so bright with colour and how does this be related to pollinating agents?

2.4.3 Pollination

What is pollination ?

This is the transfer of pollen grains from the anther of a stamen to the stigma of the pistil. The transfer can be between stamen and pistil on one flower or between flowers on one plant (Self Pollination) or between two flowers on different plants (cross-pollination). Pollination requires pollinating agents such as insects or wind. There is a strong relationship between the nature of the flower and the pollinating agents.

Following pollination, a flowering plant passes through distinct stages described as follows and illustrated in Figure 2.10.

Pollen tube formation

Pollen grains landing on the stigma will form pollen tubes that grow down in the style and form the male gamete as it approaches the ovule.

Fertilization

This is the union of the male gamete and the female gamete, occurring in the ovule within the ovary. As a result, a zygote that develops into a seed embryo will be formed

Seed and fruit formation

Following fertilization and formation of seed embryo, the ovule matures into seed while the ovary matures into a fruit. Thus seed is a matured ovule while the fruit is a matured ovary.

Seed dispersal

This is a mechanism of scattering seeds around or away from the parent plant. Seed dispersal like pollination requires agents such as animals or wind.

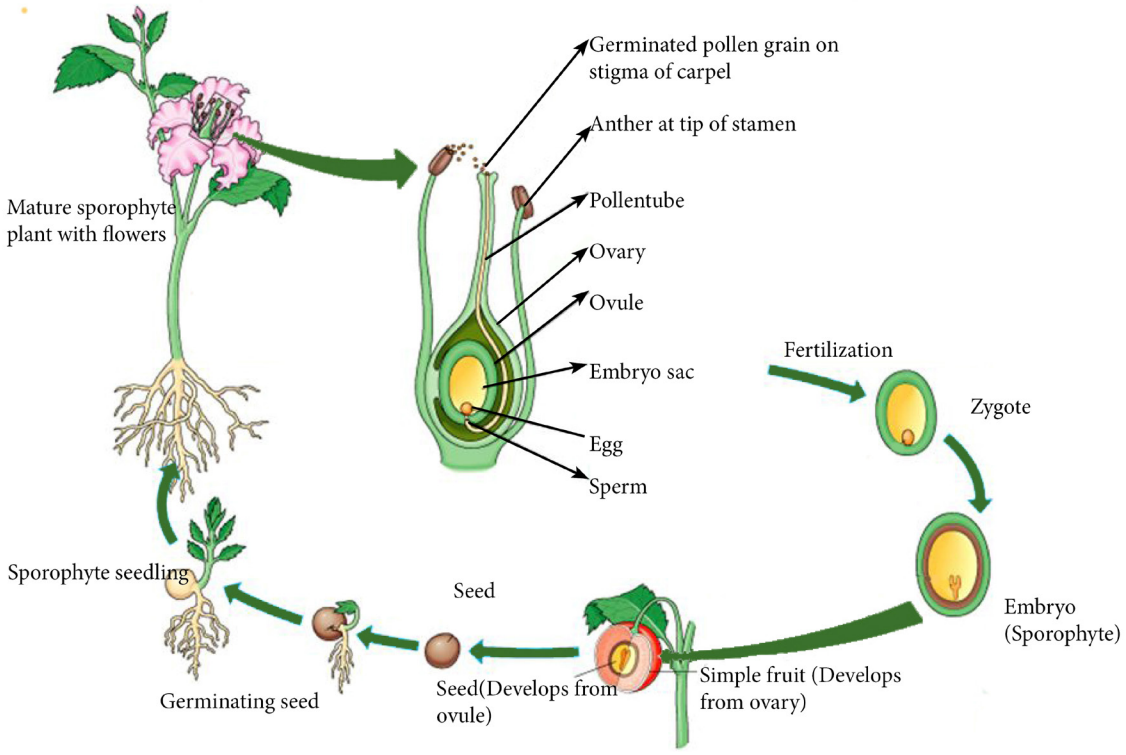
Seed dormancy /Seed germination

The fate of a seed landing at a certain place will be either dormancy or germination. A dormant seed is inactive and waiting for the favourable condition to start germination. If there is enough water and nutrients the seed will break dormancy and the seed embryo starts to develop into a seedling (Young and new plant). This process is called seed germination.

ACTIVITY 2.10 LIBRARY SEARCH

- Refer to books or browse on the internet and prepare a table of summary that shows the difference between insect-pollinated flowers and wind-pollinated flowers
- Show your table of summary to your teacher for comment

Figure 2.10 Life cycle of typical flowering plant (angiosperm)



2.5 Seeds

What makes seeds of flowering plants to be different from those of gymnosperms ?

Objectives

At the end of this section, the student will be able to:

- *describe the structure of seed and embryo and*
- *list down the difference between dicot and monocot seed*

The seed (fertilized ovule) contains three parts: the seed embryo, cotyledon/endosperm (reserve food) and seed coat. In Angiosperms, the seed is additionally covered by the fruit. Thus it is called covered seed as opposed to the naked seed of gymnosperm. A naked seed has nothing on except its own seed coat.

The seed embryo, in turn, consists of the radicle (future root), epicotyl, hypocotyl and the plumule (future shoot) (Fig. 2.11). Cotyledon and endosperm are food storing tissues, essential for the seed embryo (future plant) until it forms leaf and starts manufacturing its own food. A seed of angiosperm may have one cotyledon (monocot) or two cotyledons (dicot).

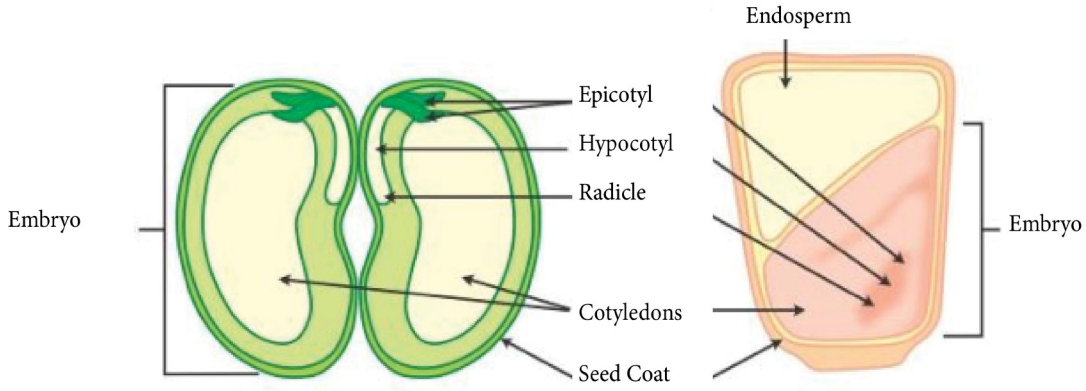


Figure 2.11 Section of a dicot (Bean) and monocot (Corn/Maize) seed and the associated structures.

Table 2.1 Differences between dicot and monocot seeds

Dicot seed	Monocot seed
Two cotyledons are present in the embryo	Only one cotyledon present
Cotyledons are fleshy and store food materials	Cotyledon is very thin and lacks food materials
Endosperm is absent	Endosperm is large and well developed
Primary root produced from the radicle bears many lateral roots.	Primary root formed from radicle is replaced by adventitious fibrous roots

Self Test

An imperfect flower is incomplete flower, but an incomplete flower may or may not be an imperfect flower.

Explain how this is so?

2.6 Seed dispersal and germination

Objectives

At the end of this section, the student will be able to:

- *relate nature of seeds with the mechanism of dispersal,*
- *explain the process of seed germination and*
- *conduct experiment that demonstrates the germination of seed*

Is seed alive or dead? How can you know this?

What is the importance of seed dispersal ?

2.6.1 Seed dispersal

At the beginning of unit 2, under section 2.1, you have learned that plants are sessile or fixed at one place. However, plants at their seed stage display long-distance mobility and they do so with the help of seed dispersal agents. Seed dispersal is an adaptive mechanism of plants that ensures seed will be separated from the parent plants distributed over a large area to safeguard the germination and survival of the seeds to adult plants, thereby minimizing overcrowding at one place.

Seeds can be dispersed by animals, wind or water. For instance, fleshy fruits that have seeds in them can be ingested by birds and due to hard seed coats, the seeds escape digestion and are dropped at a distance upon defecation. Seeds that have additional hairy or winged structures can be dispersed by wind or float in water and taken away to a new habitat.

ACTIVITY 2.5 LIBRARY WORK

- Attempt the following activity with a friend sitting next to you.
- Carefully read the description on the nature of the seed or look at the picture of seeds included in the next table and infer the mechanism of dispersal.
- Finally, write the conclusion that you can arrive with regard to the nature of seed and mechanism of dispersal

Nature of seed	Mechanism of dispersal
Seeds that stick or cling to fur or clothes	
	
Seeds within fruits act as kites or propellers	
	

What are the essential conditions for seed germination?

2.6.2 Gemination of seed

The life of a flowering plant starts with a tiny seed embryo that stays dormant until the essential conditions for active growth are fulfilled. The resumption of active growth of the embryo after a period of dormancy is known as germination.

There are three essential conditions for seed germination.

Water (moisture)

Water is important for the germinating seed because the hydration of the seed coat increases its permeability to O2. Water is essential for the enzymatic hydrolysis of organic food and acts as an agent of transport in the translocation of soluble substances.

Oxygen (Aeration)

Oxygen is necessary for aerobic respiration by which the seeds get energy for the growth of the embryo.

Temperature (warmth)

Seeds require optimum temperature for germination.

How do we demonstrate that moisture, air and warmth are required for seed germination? The following experimental activity will answer this question.

ACTIVITY 2.12: GROUP ACTIVITY

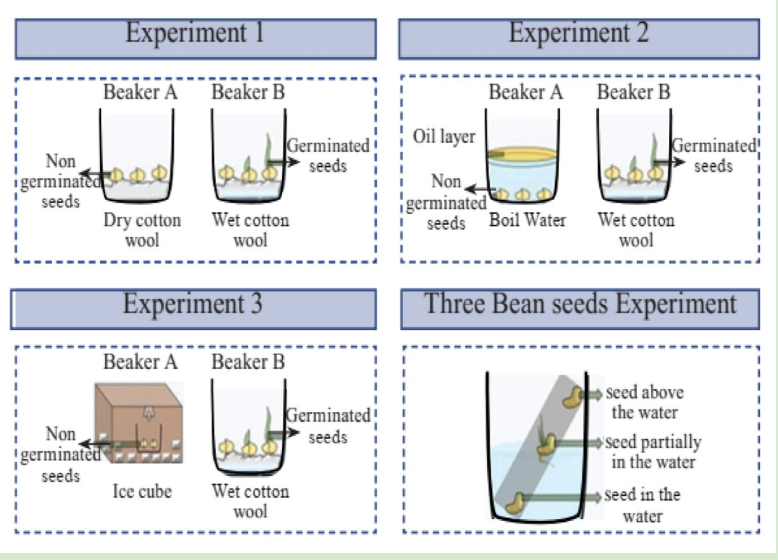
Materials required: Bean seeds, oil, cotton, water, beakers, short wooden bar, glue (to fix seeds on the wooden bar)

Direction:

Carefully look at the experiment designed to show what is required for seed germination. You may do the experiment individually at home to confirm the results indicated

Note that the beakers should be placed where they get sunlight (light and heat). The seeds are allowed to germinate, waiting up to 2–3 days

- Discuss the results with your small group and answer the following questions
- Identify the experiment that shows the need for optimum moisture (water), temperature (warmth) and air (oxygen) respectively
- What is the importance of the oil layer in experiment 2?
- What does the three-bean seeds experiment demonstrate?



As depicted in Figure 2.12, seed germination covers all the processes that occur from the time that seed embryo starts growth up to the formation of young independent plant with photosynthetic leaves.

Optimum moisture, air and warmth activate the embryo to start growth. With more and more nourishment from the food stored in cotyledon and endosperm, the tiny embryo grows more. The outward sign of growth is a radicle that develops from the hypocotyl. It is the first to come out of the seed and grow down to the soil as the primary root. The root is essential for anchorage and access to water and nutrients from the soil. Meanwhile, the shoot that develops from the plumule grows upward towards sunlight. Soon, a young plant (seedling) with photosynthetic leaf start manufacturing its own food

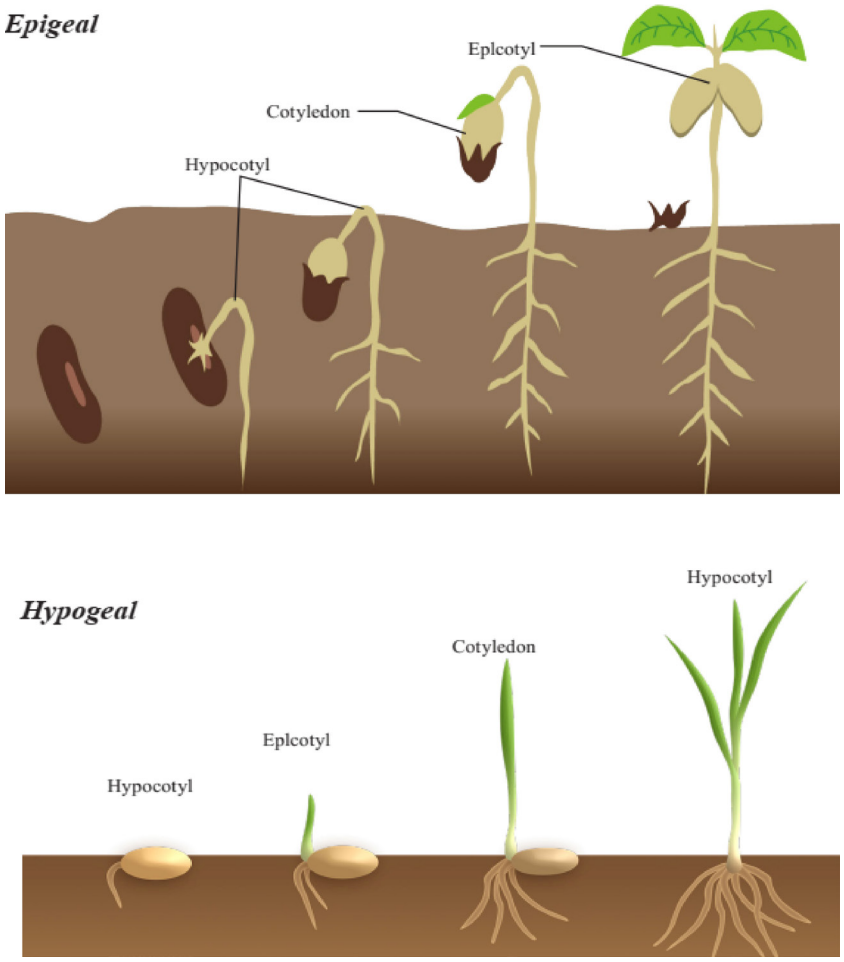


Figure 2.12. Epigeal and Hypogeal germination

Attention

- It is the position and fate of cotyledon which differentiate hypogeal germination from epigeal germination
- In epigeal germination, the cotyledon is pushed up to become the photosynthetic surface of the seedling by the elongation of a region of the embryo.
- In hypogeal germination, the cotyledon remains under the soil

Self Test

Plants show the highest mobility during seed dispersal, but the movement is not as we see in animals. Explain

2.7 Photosynthesis

It is amazing that plants that are fixed at one place make their own food , while animals that move from place to place cannot synthesize food and depend on plants. Why is this so?

What do plants provide to animals other than food?

What do animals give to plants?

Objectives

At the end of this section, the student will be able to:

- identify inputs and outputs of photosynthesis,
- outline the process or mechanism by which food is synthesized in green plants,
- recognize the importance of photosynthesis to life and
- appreciate leaves of green plants in their function as food factories

Do you know that the leaves of green plants are the largest food factories on Earth? The product of leaves together with the photosynthetic productivity of algae provides food that supports nearly all life on earth. Plants can prepare their own food by photosynthesis. Thus they are called producers or autotrophs (self-feeding). Besides making food for themselves, plants produce excess food for the vast consumers known as heterotrophs (feeding on plants and on one another).

The basic source of energy that sustains life begins with sunlight. In turn, sunlight is absorbed by a green pigment known as chlorophyll. Thus, it occurs in organisms bearing chlorophyll such as green algae and higher plants, which enables them to trap solar energy and transform it into chemical energy. This process is known as photosynthesis. In this section, you will learn more about photosynthetic apparatus - Chloroplast

2.7.1 The photosynthetic apparatus

Where does photosynthesis take place?

You have learned, in sub-topic 2.3.1 of this unit, that the mesophyll layer of the leaf contains the largest number of chloroplasts and is in the best position to trap the maximum amount of solar energy. Figure 2.13 illustrates the internal structure of the chloroplast, which is termed as photosynthetic apparatus.

Accordingly, there are two distinct parts in chloroplasts: Granum and Stroma.

i) Granum: consists of stacks of flattened sacks, each of which is called thylakoid. The granum contains the chlorophyll, enzymes and co-factors that participate in the light trapping phase of photosynthesis. It is here that the light reaction takes place.

ii) Stroma: is a gel-like colourless matrix, which is a site for sugar (carbohydrate) synthesis through carbon fixation. It is from the sugar produced in the stroma that is directly or indirectly converted to all organic compounds (including amino acids, proteins and lipids) virtually found in all organisms.

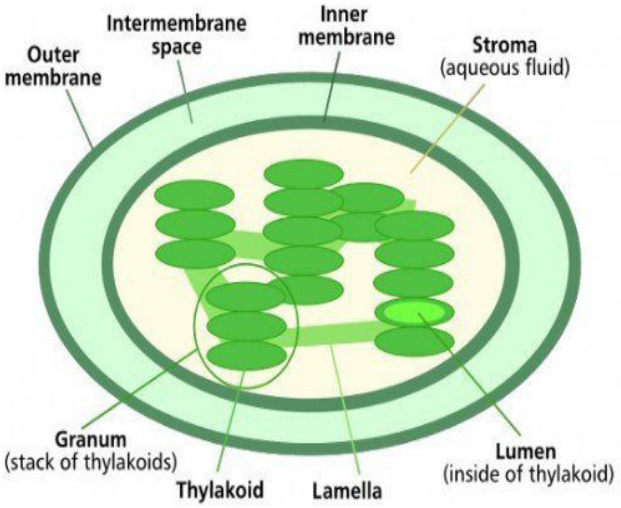


Figure 2.13: Chloroplast – the photosynthetic apparatus

How is the structure of chloroplast best suited for its function?

2.7.2 The light absorbing system in chloroplast

In this sub section you will learn the role of light absorbing pigments, mainly chlorophyll and sunlight absorbed serves as agent of photochemical reaction in food synthesis (photosynthesis).

The chloroplast contains chlorophyll (particularly chlorophyll a and b) and other light absorbing accessory pigments capable of absorbing light at different wavelengths. As shown in Figure 2.14, the light absorbing pigments of chloroplasts absorb most of the visible light, ranging from 400 – 700 nm. Maximum light absorption occurs at wavelengths from 400 – 500 nm and 600 – 700 nm, blue and red light respectively. Light ranging from 500 to 600nm that includes green light is not absorbed, it is rather reflected. This is the reason why leaves look green.

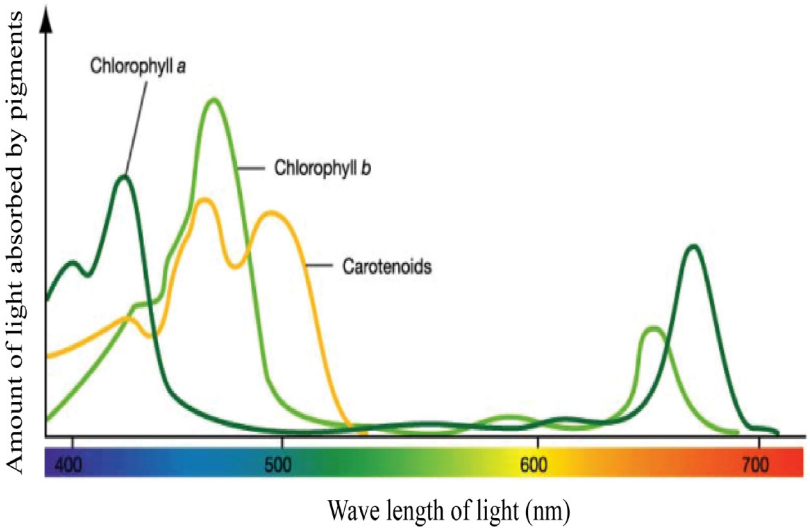


Figure 2.14 The action spectrum for different wavelengths

ACTIVITY 2.13: PEER DISCUSSION

Direction:

Discuss on the sub reactions and over all equation of photosynthesis with a friend sitting next to you. Then, answer the questions written hereunder. Compare your answers to your classmates' answer

- What is the source of oxygen?
- What are the inputs (reactants) and outputs (products) of photosynthesis?
- Point out the importance of water with regard to food that we eat and air we breathe

2.73. Mechanism of photosynthesis

Photosynthesis consists of a number of photochemical and enzymatic reaction. It is the sum total of the following two sub reaction

1. Light reaction this is also known as the light dependent stage, It takes place in the granum, where the light absorbing system – mainly chlorophyll occurs. Here, the granum is organized as Photosystems and Electron Transporting System. The photosystem consists of chlorophyll that absorbs sunlight maximally at blue and red range of light spectrum. The light absorbed by the chlorophyll will

- split of water molecules (H_2O) into H+ and O_2. This is known as photolysis. The O_2 is released to the atmosphere through leaf stomata.
- excite some electrons in the chlorophyll molecule to higher energy level which pass down the ETS and generate high energy ATP molecule. The ATP and H+ harvested during light reaction will be used as an input in the Stroma where conversion of CO2 to carbohydrate takes place.

2. Dark reaction this is also known as light – independent stage, because it can occur in the absence of light as long as there is sufficient amount of H+ and ATP supplied from the light reaction. The dark reaction and enzymatic reaction H+ indirectly combines with CO_2, in the stroma of chloroplast. The process is known as carbon fixation. Glucose (carbohydrate) is the immediate result of the dark reaction.

The overall chemical reaction of photosynthesis can be summed up in the following equation

$$6CO_2 + 6H_20 \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2$$

2.7.4. Testing a leaf for starch

A simple way of demonstrating food synthesis in leaves is testing a leaf for starch. You can easily see the effect of iodine on starch, if you put iodine solution on powdered starch, piece of bread or potato slice a blue-black colour will develop confirming the presence of starch. However, the cuticle of the leaf is impermeable to iodine. Moreover, the leaf has green pigment chlorophyll that interferes with the colouring effect of iodine. The next experiment will enable what you should do to solve these two problems before testing the leaf for starch.

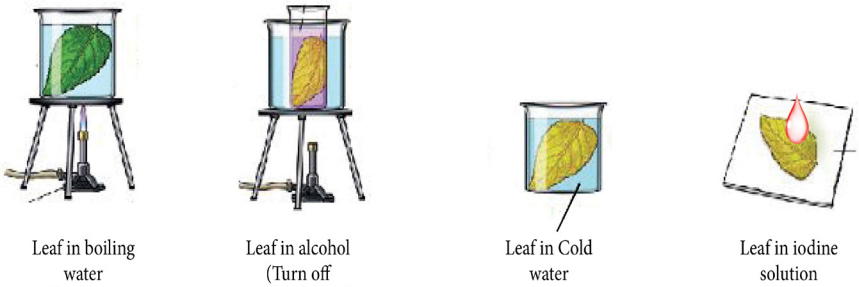
ACTIVITY 2.14: TESTING LEAF FOR STARCH

Materials required: fresh green leaf, beaker, heat source (Bunsen burner or electric stove), test tube, alcohol, iodine solution

Procedure

- Depending on the availability of the materials required, you can perform the experiment in a group or follow your teacher when the experiment is demonstrated in class.
- Follow the experimental design illustrated hereunder and write the purpose of each step (Steps 1 – 4).
- For the sake of safety use forceps to put the leaf into or take it out from beakers with boiling water and hot alcohol.

What is the danger that can possibly happen in step 2 if you do not first turn off the Bunsen burner?



2.8 Transport in plant

Objectives

At the end of this section, the student will be able to:

- identify routes of water, mineral, and organic matter transport in plants,
- discuss the mechanism of transport in plants,
- tell the importance of transport in plants and
- demonstrate water transport in plants using simple experiments

How are different materials, such as water, mineral and food transported to and from different parts of the plant such as root, stem and leaf?

What are the routes of material transport in plants?

2.8.1 Transporting systems in plants

You know that higher plants have a green leaf that is capable of photosynthesis. But, do you know the route through which the raw materials, water and minerals, move from roots to leaves and how food manufactured from the leaves reach the rest of the plant? This will be clear after you learn about the transporting vessels of higher plants commonly called vascular bundles.

Figure 2.15 illustrates the arrangement of the two transporting vessels, xylem and phloem in the root. They are collectively known as vascular bundles. Water and minerals are transported from the root to the leaf via the stem through conducting vessel known as

xylem, which consists of elongated dead cells, joined end to end to form continuous vessels. On the other hand, organic matter (food) manufactured in the leaf is transported to the rest of as opposed to xylem, phloem consists of living cells arranged end to end and allows transport of food (sucrose and amino acids) up and down the plant. This is called translocation. In general, it happens between where these substances are made (Sources) and where they are used or stored (the sinks).

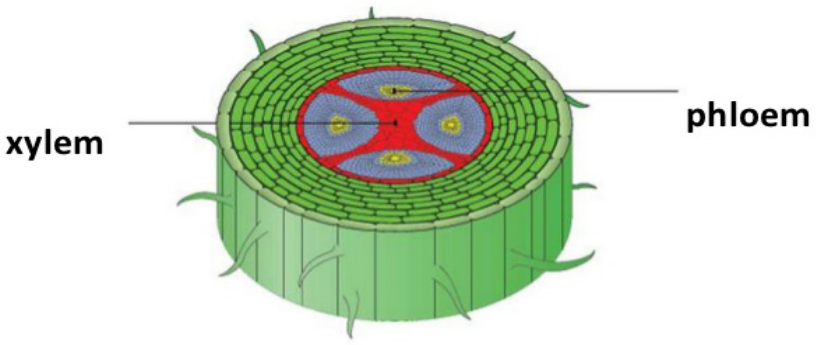


Figure 2.15 Root vascular bundles

Do you know why the stem of sugar cane or stem tuber of sweet potato is so sweet? Sugars synthesized in the leaf is converted to starch and accumulated in the storage organs of plants, such as root and stem tubers, leaves, seeds and fruits of a plant. We, human beings take advantage of food in these storage organs. Starch from plants is a good source of energy that we need in our diet.

ACTIVITY 2.15: GROUP WORK

Hint

Water is a raw material for photosynthesis. Water is badly required at the seedling stage as it gives strength to the plant. A young seedling is delicate and easily wilts if there is a scarcity of water or loss of water by evaporation.

Direction

- Discuss with your small group how drought affects agricultural productivity or food production.
- Why are rainy months the best time for agriculture? Why is irrigation needed, particularly during drought or in dry areas?

2.8.2 Mechanism of transport in plant

i. Uptake of water and minerals

Water from the soil first enters the root through root hairs. These are elongated single cells that provide a large surface area allowing more water to enter into the root. Minerals also enter the root together with the water. This process is known as absorption. Water entering the root passes from cell to cell either by osmosis across the cell membrane and cytoplasm or freely flow by diffusion along the porous cell wall. Thus, water passes passively (without spending additional energy from the cell) across the root cells and reaches the root xylem (Figure 2.16).

Water in the root xylem is pulled upward passively by transpiration pull. This is pulling force caused by transpiration ; it is the main force responsible for the water passing all the way from the root to the leaves through the xylem vessel. During transpiration water that evaporates from the leaves serve as a mechanism to pull or drag water from the root.

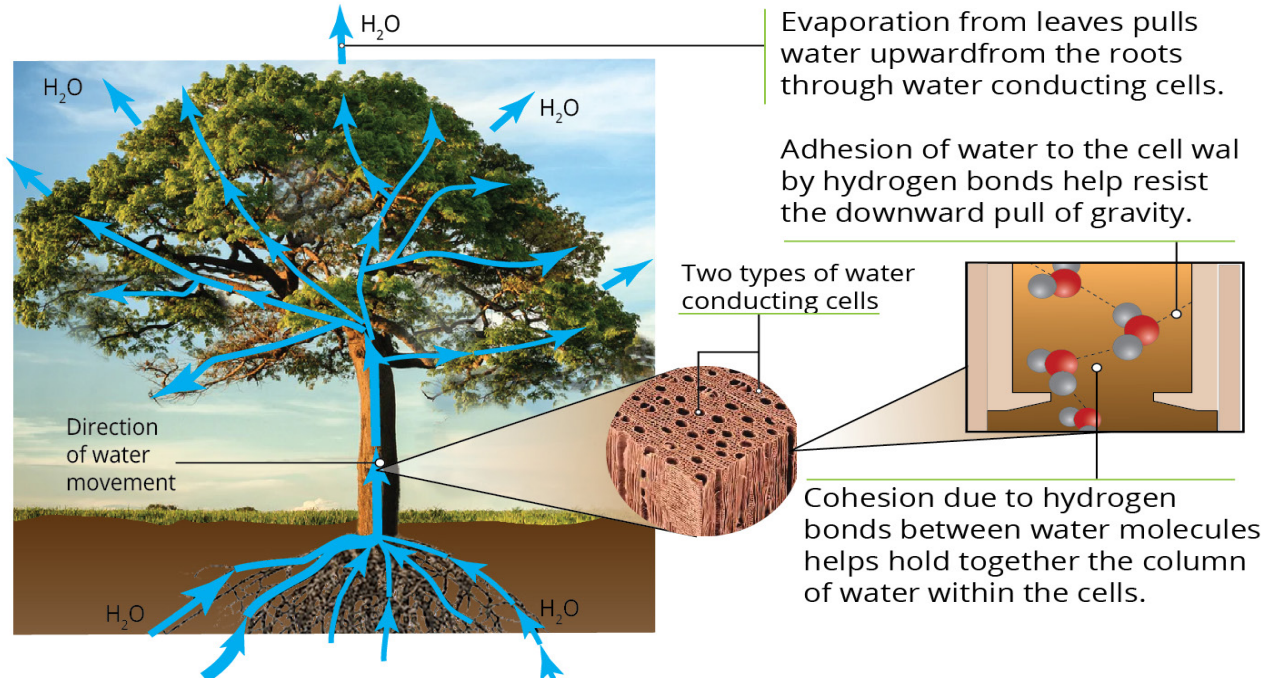


Figure 2.16 Transport of water and minerals from root to the leaf via the stem

Minerals enter the root in the ionic (charged) form either passively or actively. They are taken actively (cell spends energy) when concentration is higher in plant cell than outside the cell and, therefore accumulation of salts or their ions occur as a result of active transport against a concentration gradient.

ACTIVITY 2.16: COLOURED CELERY EXPERIMENT

Have you ever wondered how water rises upward in the stem towards the leaf? You can see how this happens in the following home experiment. You can do it alone or with your pair in class.

- All you should do is to repeat the classic dyed celery experiment that shows water rises up in the stem and how transpiration helps to suck up water. The celery plant is a leafy small plant with a transparent stalk or stem. You can use any other plant with a similar feature as long as it is available in your locality
- Cut your celery stem diagonally to provide a large surface area for the coloured water to pass through (like as it is done to put the fresh flower into a vase)
- Take photographs or make observational drawings of the celery appearance initially
- Put Beaker "A" in dark place (fully sheltered), Beaker "B" in partially sheltered place and Beaker "C" where there is a bright sunlight. Leave the beakers for some time (4 to 6 hours).
- Again take photographs or make observational drawings and compare the initial and final result
- Write a short report on dyed celery experiment and what has been demonstrated. Prepare yourself for class presentation as you may be randomly invited by your teacher for class presentation.

A B C

How can we demonstrate that food transport occurs through phloem ?

ii. Translocation of organic matter (food)

Translocation in plants is a shift or transport of food from the site of synthesis (source), which is the leaf, to the site of utilization or storage (sink), which can be either the stem or the root. Translocation occurs through the phloem, which is made up of living cells. It is an active transport, where the living phloem cells use energy obtained by metabolic process.

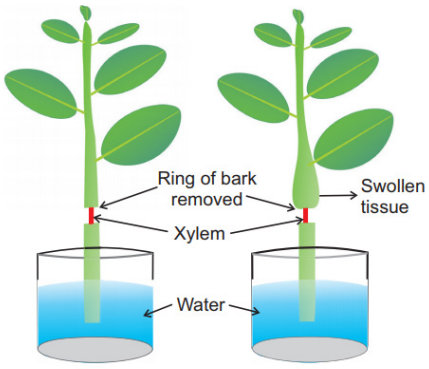


Figure 2.17 Ringing /Girdling experiment

The ringing or girdling experiment as designed in Figure 2.17 helps to identify the food conducting vessels. The experiment involves removing the ring of bark with the phloem and the plant is placed in a beaker of water. Xylem will be the only vessel in the girdled area, which connects the upper and lower part of the plant. After few days, a swelling will be observed in the upper girdle. This is due to the accumulation of food materials, mainly sugar which was translocated from the photosynthesizing leaf towards the root. The sugar can be sucked with syringe or using aphids and can be confirmed with food test. Aphids are soft – bodied insects that use piercing and sucking mouth parts to feed on phloem sap.

Ringing will ultimately kill the plant, because of disruption of food transport through the phloem. The root dies first, because supply of food to the root will be discontinued. As the root dies, the upper part and finally the whole plant, which depends on root for water and minerals, will die.

2.9 Response in plants

Objectives

At the end of this section, the student will be able to:

- recognize that plants are capable of giving response
- explain some common responses in plant
- tell the importance response in plants and
- demonstrate response in plants using simple experiments

If you have potted plant placed near the window of your room, to which direction does the plant turn its shoot? Why is this so?

If you add water to one side of your potted plant, what do you think will happen to the root?

2.9.1 Tropism as growth response

In section 2.1 of this unit, you learned that plants like other living things share basic characteristics. One of their important characteristics is to respond to stimuli, that is, changes in the environment. In this section, you will learn mainly tropism, how plants respond to light (phototropism), water (hydrotropism) and gravity (geotropism). Thus, we will deal with these three common and useful tropisms.

Tropism is bending towards (positive response) or opposite (negative response) to the direction of the stimulus. The cause of the response is a unilateral stimulus (coming from one side only), which causes unequal production or distribution of growth hormone resulting in unequal growth. This means one side grows more or less than the other side and these results in bending towards or away from the stimulus. Tropism is exhibited by the shoot and root of a plant due to unequal concentration of growth hormone, commonly auxin, resulting in unequal growth.

Auxin, particularly Indole Acetic Acid (IAA), is plant growth hormone. It is produced at the tips of shoot and root. It is transported to the region of active growth and affects cell elongation, Shoot and roots respond differently to different auxin concentration. Figure 2.18 helps to know how shoots and roots respond differently to unilateral (one sided) stimulus The graph (Figure 2.18) shows that auxin concentration that promotes shoot growth (10 -2 to 101 ppm) inhibits root growth . It also shows that root requires minimum auxin concentration, which is about 10 -4 ppm and such concentration has no effect on the shoot growth.

How does auxin affect shoot and root growth?

What is the response of the shoot to unilateral (one - sided) light ?

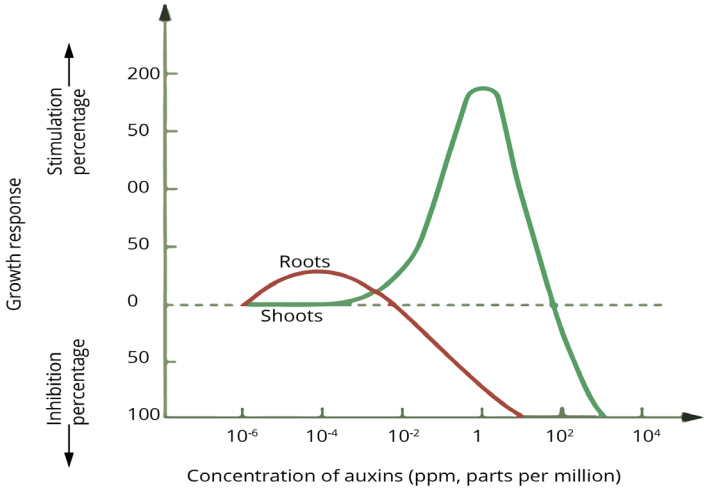


Figure 2.18 Effects of auxin concentrations on the growth of shoots and roots

How shoot and root respond to unilateral light is well demonstrated by Figure 2.19. As a result of unilateral light, auxin move from illuminated side to shaded side of shoot and root. In shoot higher auxin concentration on the shaded side causes more growth by cell elongation than the illuminated side. As a result, the shoot bends towards light. In the mean time, more auxin on the shaded part of the root inhibits cell elongation as compared to the illuminated side. Thus, root bends away from light.

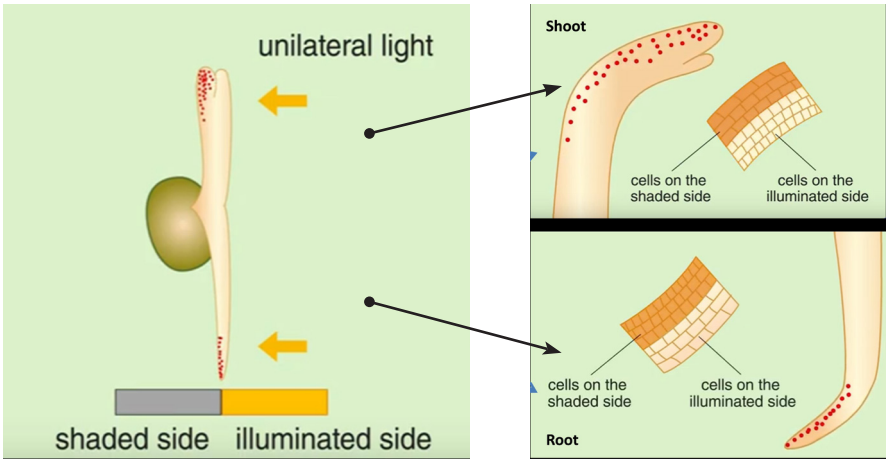


Figure 2.19 How unilateral light affects shoot and root response

Phototropism

Plants need sunlight for photosynthesis. Phototropism is a plant response to light, mainly exhibited by the shoot. The tips of the plant shoot bend towards the side where there is sunlight. Thus shoot is positively phototropic. The earliest experiment on phototropism was conducted by Charles Darwin, "father of evolution", (Figure 2.20). He noticed that if the light is shone on a coleoptile (shoot tip of young seedling) from one side, the shoot bends or curves (grows) toward the light (Seedling '1' and partially seedling '4'). The bending did not occur in the tip itself but in the elongating part just below.

When the tip is removed (Seedling '2') or covered with opaque foil

(Seedling '3'), the shoot could no longer bend toward the light. Moreover, covering the lower shoot part (Seedling '5') did not affect the response to light at all. Based on his experiment, Darwin concluded that "some influence is transmitted from the tip to the more basal regions of the shoot thereby regulating growth and inducing curvature or bending". At present, it is well known that it is a growth hormone known as auxin that will be distributed more on the tip side opposite to light. This causes more growth on the shaded side and curving will occur toward the light.

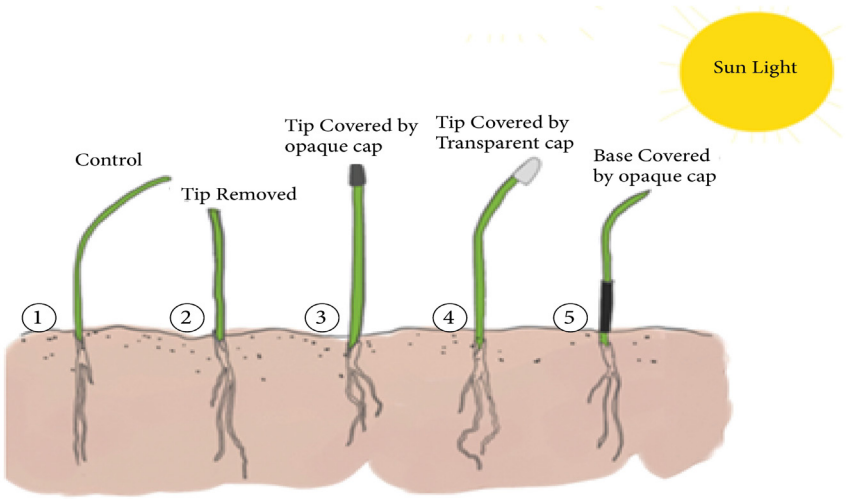


Figure 2.20 Darwin's experiment on phototropism

Hydrotropism

The survival of terrestrial plants depends upon the capacity of roots to obtain water and nutrients from the soil. Roots search for and grow toward water because it is needed for photosynthesis and to support cell structure (make them turgid and strong). Thus, hydrotropism exhibited by root is biologically important and vital for the survival of plants.

ACTIVITY 2.17: Experiment on phototropism

Materials required

- Two pots, soil, bean seeds, dark cloth, hard paper box (cartoon)

Procedure

- Germinate some bean seeds in two different pots
- Prepare a hard box and cover it with light proof dark cloth and make a small round hole on one side
- When the shoots are about 6cm, put one pot in the dark box, and the other pot open (without the box).
- Leave both pots in a well illuminated (with light) place
- After 2–3 days observe what has happened to the seedlings in the two pots
- Write your conclusion and prepare a short report on the experiment

What is the effect of water on root growth ?

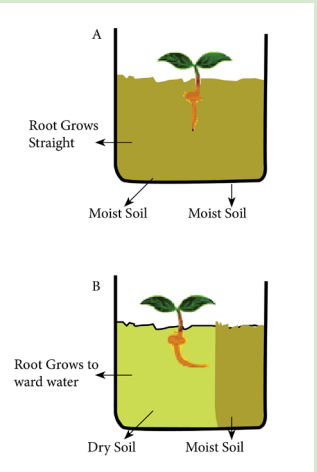
ACTIVITY 2.18: Demonstration of hydrotropism

Procedure

Take two beakers – "A" and "B". Follow the picture below and add moist soil and sow the seed in Beaker "A". In beaker "B" add dry soil in half part and moist soil in another part and sow the seeds. keep both beakers for 2–3 days for germination to take place

Questions

1. How do you explain what you observed in Beaker "A" and "B"?
2. If you had filled the whole beaker with dry soil and put wet cotton or wet sponge on the top of the soil at one side, how would the root have grown? Downward (toward gravity) or upward (against gravity)? Is the root response stronger, for water or gravity? [You need to do the experiment in order to answer these questions]



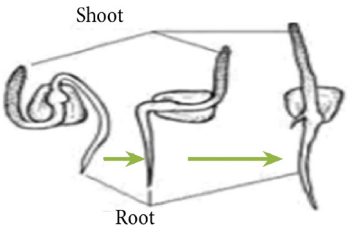


Figure 2.21 Seed embryo developing into a seedling in an upright position

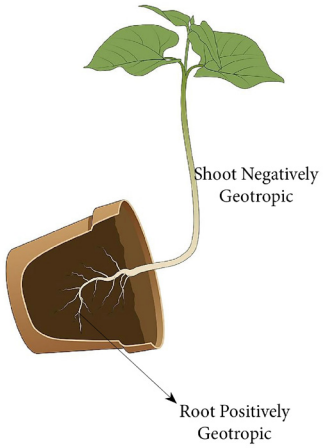


Figure 2.22 Plant responses to gravity

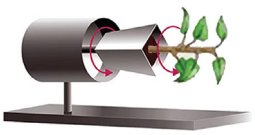


Figure 2.23 Effect of clinostat on gravity (geotropism)

Geotropism

What is the effect of gravity on shoot and root growth at seedling? stage?

You have learned that the seed embryo that develops into a seedling will form root from the radicle and shoot from the plumule. The most fascinating phenomena are how the seedling (young plant) stands erect (Figure 2.21). This is the result of a response to gravity, known as geotropism. The root progressively bends downward while the shoot bends upward until root–shoot system orient itself in an upright (standing position), when there is a uniform effect of gravity.

As shown in Figure 2.22, a horizontally placed seedling responds to gravity in that its root is positively geotropic (grow downward or towards gravity) and shoot is negatively geotropic (grow upward or against gravity).

ACTIVITY 2.15: GROUP WORK

Materials required

Bean seeds , Blotting /soft paper, Petridish

Procedure

- Germinate some bean seeds placed on wet blotting paper in a petridish
- When the radicles and plumules emerged, arrange the seedling in to two different position. Place some seedlings in a horizontal position and others vertically with the radicle facing upwards.
- Leave the set up for 2 to 3 days in the dark to eliminate the effect of light.
- Observe what happens to the direction of growth of the radicles and plumules;
- Make careful drawing. Note what the experiment verified as to the effect of gravity on shoot and root growth.

How can we overcome the effect of gravity on root and shoot growth of a seedling?

The effect of gravity in a horizontally placed seedling can be overcome by a clinostat, which is a rotating instrument. A seedling fixed horizontally in a rotating clinostat grows straight (Figure 2.23), because the rotation overcome (gravity acts equally for all sides) the effect of gravity. You can see the effect of rotation by using another seedling fixed to the clinostat but not rotated as a control.

Self Test

What will happen to a plant if it does not exhibit phototropism, hydrotropism and geotropism?

2.10 Medicinal plants

Objectives

At the end of this section, the student will be able to:

- *tell the importance of medicinal plants and*
- *list down locally available medicinal plants*

What are medicinal plants? What is their importance to local people?

From sub-topic 2.7 of this unit, you learned that plants synthesize a variety of organic products that have food value. But, plants also produce other organic products that have ornamental, commercial and medicinal values. Here, we will focus on the medicinal plants that play a vital role in treating diseases and fighting infections. Globally, more than 60 % of the total world population depends on traditional or locally available plant medicines for their health care. (According to World Health Organization (WHO), nearly 3.5 billion people in developing countries including Ethiopia believe in the efficiency of plant medicines and widely use them to overcome their health problems. The list of some Ethiopian medicinal plants, parts used, mode of administration and some examples of human diseases treated are presented in table 2.3.

Self Test

What is the contribution of medicinal plants and traditional healers (herbalists) to modern medicine?

Table 2.2 List of medicinal plants and disease treated

No.	Scientific name	Local name (Amharic)	Habit	Plant part used	Route of administration	Disease treated
1.	*Ruta chalepensis*	Teenadem	Herb	Leaf	Oral	Abdominal pain
2.	*Zingiber officinalis*	Jinjibil	Herb	Rhizome (underground stem)	Oral	Tonsilitis , abdominal pain, cough
3.	*Hagenia abysinica*	Ye–kosso Zaf	Tree	Female flower (Seed)	Oral	Tapeworm
4.	*Artemesia absinthium*	Aritii	Herb	Leaf	Oral	Unexplained stomach ache (Megagna)
5.	*Niglella sativa*	Tikur Azmud	Herb	Seed	Oral	Intestinal parasites
6.	*Ocimum lamifolium*	Damakesse	Shrub	Leaf	Nasal	Headache, General body illness (Mich)
7.	*Rosmarinus officinalis*	Rosmery	Herb	Leaf	Oral	Bronchial asthma. Prostate disorder inflammatory diseases
8.	*Cymbopogen ciratus*	Tejsar	Herb/ Grass	Leaf	Oral	Used for stomach complaint
9.	*Alium sativum*	Nechshinkurt	Herb	bulb	Oral	Abdominal pain, toothache, tonsillitis, common cold
10.	*Eucalyptus golbulus*	Nech–Bahir-zaf	Tree	Leaf	Nasal	Common cold, fever with headache
11.	*Curcurbita pepo*	Dubba	Herb	Seed	Oral	Tapeworm
12.	*Trigonella foenumgraecum*	Abish	Herb	Seed	Oral	Mixed with garlic to treat asthma , used to treat gastritis
13.	*Ocimum basilicum*	Besobilla	Herb	Leaf	Oral	Abdominal pain
14.	*Lepidium sativum*	Feto	Herb	Seed	Oral	Treatment of diarrhea

ACTIVITY 2.20: Group work

Procedure

Divide the following local medicinal plants among your small group.

- *Lippia adoensis* ("Kosseret")
- *Thymus schimperi* ("Tossign")
- *Echinos kebericho* ("Kebericho")
- *Taverniera abyssinica* ("Dingetegna")
- *Moringa stenopetala* ("*Shiferaw*" or "*Aleko*")

Ask your parents or elders in your locality about parts of the medicinal plant used, mode of administration and some examples of human diseases treated

Prepare summary as it is done for the 14 medicinal plants indicated in the previous table.

Submit your summary table to your teacher for comment and presentation to your classmates

Remark :

While collecting medicinal plants student need to use hand gloves (some students can be allergic to the plants), not taste and ingest them or inhale if they have volatile substance. It will be safe to wash hands after handling the plants

Students in the pastoralist areas can form a group to collect key information and the medicinal plants used for livestock. They should ask their teacher for guidance and finally present their result in class as summarized in table 2.2.

2.11 Renowned Ethiopian Botanist

Objectives

At the end of this section, the student will be able to:

- *appreciate the work of a renowned botanist and*
- *look for more Ethiopian Botanists who contributed a lot to plant science*

Sebsebe Demissew is a professor of Plant systematics and Biodiversity at Addis Ababa University and Executive Director of the Gullele Botanic Garden in Addis Ababa. He was awarded the Kew international medal in 2016. Professor Sebsebe Demissew, a leading Ethiopian botanical scientist, has been elected as a Foreign Member of the Royal Society in London in 2018 for his lifelong work on promoting Ethiopian biodiversity. He is the first Sub – Saharan African scientist to be elected in the Society's 357 – year history.

In 2021, Professor Sebsebe was awarded the "Cuatrcases Medal" for Excellence in Tropical Botany by the Smitheonian National Museum of Natural History ", USA, for his lifetime works in conserving and recording the very diverse Ethiopian flora with many endemic species and leadership of the Ethiopian flora project and the Ethiopian National Herbarium at Addis Ababa University.

ACTIVITY 2.21 LIBRARY SEARCH

Direction

- Carefully read the work of Prof. Sebsebe and share your impression to a friend sitting with you
- Form a group of four students and perform team work to look for more renowned Ethiopian Botanists from books and /or internet. Organize a report to share to your classmates.

Unit Summary

- Plants are living things that are multicellular, autotrophic, and sessile and exhibit both asexual and sexual reproduction pattern.
- Higher plants are vascular with well – developed root, stem and leaf, Based on their reproductive system , they can be categorized as non- flowering and flowering plants
- The non – flowering, known as gymnosperms have no flowers. Instead, their reproductive organ is cone. Moreover, the seeds produced in their cone are without cover (naked seeds).
- Flowering plants, commonly known as Angiosperms, are also vascular with well-developed root, stem and leaves. But unlike gymnosperms, they have flowers and produce seeds within a fruit.
- A typical angiosperm has shoot and root system in its external structure. The shoot system grows above the ground and includes the organs such as stem, branches, leaves, buds and flower
- The root system usually grows down ward into the ground. It includes the primary or tap root, lateral or branch roots and root hairs.
- The internal structure of a leaf consists two layers, namely the outer layer (upper and lower epidermis) and the inner or middle layer. The epidermis contains cuticle and stomata, to minimize water loss and allow gas exchange respectively.
- The middle layer consists of the palisade and mesophyll cells that are contain chlorophyll to absorb sunlight. They also contain vascular bundles to transport water, minerals and food.
- The internal structure of a stem consists of different layers including epidermis, hypodermis, cortex, endodermis and pith.
- A cross-section of a root shows different layers, namely epiblema, cortex, endodermis, pericycle, vascular bundles and pith.
- The sexual reproduction of an angiosperm starts with pollination, followed by the fusion of gametes, which results in a zygote. The zygote develops into a seed embryo within a seed (matured ovule). Then seed will be dispersed away from the parent plant by animals, wind and water.
- Seed undergoes germination if it gets optimum moisture, warmth and nutrients.
- The ultimate source of energy that sustains life comes from the sun. Chlorophyll bearing algae and higher plants trap solar energy and transform it into chemical energy.
- The process of photosynthesis is the result of light absorbed by chlorophyll and other accessory pigments resulting in the release of oxygen from water and in the formation of reduced carbon compounds (e.g carbohydrates) from carbon dioxide.
- Transport in plants occurs through vascular bundles, xylem and phloem. Water and minerals are transported through the xylem while food (organic matter) is translocated through the phloem.
- Passive transport of water occurs as a result of diffusion, osmosis and transpiration pull, while minerals are transported as ions passively or actively. Food transport in phloem occurs by the expenditure of energy (actively).
- Tropism is a common response displayed by plants. It is response unidirectional or unilateral (one-sided) stimulus by bending towards (positive tropism) or away (negative tropism).
- Phototropism, hydrotropism and geotropism are a response to light, water and gravity respectively.
- The root is positively hydrotropic and geotropic, while the shoot is positively phototropic but negatively hydrotropic.
- Medicinal plants play a vital role in treating diseases and fighting infections.

Review Questions

True – False items: Say "True" or "False" for the following statements on your exercise book.

1. Cone is reproductive structure of fruit bearing plants.
2. CO_2 is used in the stroma of the chloroplast.
3. A root hair is single cell.
4. Self pollination is possible in imperfect flower.

Multiple choice items: Choose the correct answer from A – D and write on your exercise book.

1. Which structure transports water to the leaf of a plant?

   A) Guard cell B) Phloem C) Stomata D) Xylem

2. Clinostat is used in the study of

   A) Osmosis B) Growth movements C) Leaf transpiration D) Photosynthesis

3. Which leaf part or layer contains the largest number of chloroplasts?

   A) Epidermis B) Palisade C) Cortex D) Spongy

4. One of the following is not major characteristics of plants

   A) Plants are composed of many eukaryotic cells

   B) Plants are sessile or do not show mobility

   C) Plants are hetrotrophic in their feeding habit

   D) Plants show both sexual and asexual reproduction

5. The two products of photosynthesis include

   A) Carbondioxide and Oxygen C) Carbon dioxide and water

   B) Water and carbohydrate D) Oxygen and Carbohydrate

6. Given the following

   1= Pollination; 2 = Seed dispersal; 3 = Pollen grains germination;

   4 = Flowering; 5 = Seed germination

   The correct order of steps in the reproduction of a mature plant is

   A)1, 3, 2, 4, 5 c) 4, 2, 5, 1, 3

   B) 2, 5, 4, 1,3 d) 4, 1, 3, 2,5

Matching Items: Match the terms under "Column B" with the description under "Column A".

Column A	Column B
1. May be termed as starch sheath	A) Cone
2. Cells that leave an open space in leaf epidermis	B) Endodermis
3. Give mechanical strength to the stem	C) Flower
4. Single cells best suited for absorption	D) Guard cells
5. Is the site of origin of lateral roots	E) Hypodermis
6. Reproductive structure of angiopserms	F) Pericycle
	G) Root hair
	H) Stomata

Short Answer Items

1. How do you distinguish a root from an underground stem?
2. What is the difference between an incomplete flower and an imperfect flower?
3. What is the importance of rainfall to agriculture?
4. Write the type of tropism illustrated by the pictures below.




Unit 3: Biochemical molecules

Content	Learning objectives
3.1. Biochemical molecules 3.1.1. Inorganic molecules: water 3.1.2. Inorganic ions 3.1.3. Organic molecules • Carbohydrates • Lipids • Proteins • Nucleic acids	• Identify inorganic and organic biochemical molecules • Explain the properties of water and its importance for life • Discuss different inorganic ions and their contribution to the cell • Classify organic molecules based on their constituent elements and the monomers from which they are constructed. • Discuss the role of biological molecules in the cell structure • Elaborate the functions of carbohydrates, proteins, lipids, and Nucleic acids to the body. • Conduct experiments to identify nutrients in different foodstuff • Appreciate why Ethiopians use malting seeds to make local drinks (Tella, Areke)

3.1. Biochemical Molecules

Recall

Grade 9 Unit 5

nutrients

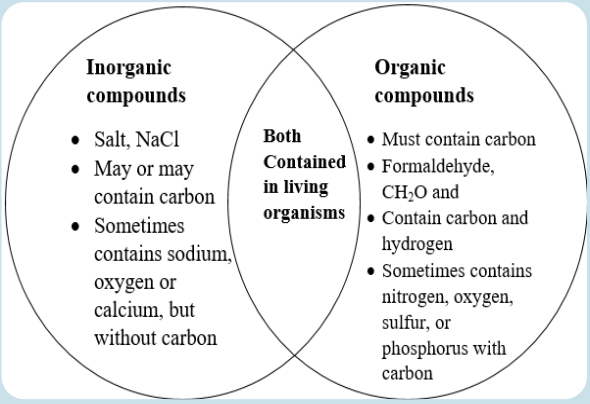
balanced diet as a source of energy and health

Objectives

At the end of this section, the student will be able to:

- *identify inorganic and organic biochemical molecules,*
- *discuss different inorganic ions and their contribution to the cell,*
- *explain the properties of water and its importance for life.*

What are biological molecules, and how would you define them? Make a list of all the biological molecules you are familiar with and divide them into two categories: inorganic and organic. Finally, talk about how they affect cell structure and function. After that, do activity 3.1 given below.



Attention

Our body is made up of two types of biochemical molecules: organic and inorganic molecules.

Biochemical molecules that do not contain both carbon and hydrogen are known as inorganic biochemical molecules. Many inorganic compounds, such as water (H_2O) and the hydrochloric acid (HCl) generated by your stomach, include hydrogen atoms. Only a few inorganic compounds, on the other hand, contain carbon atoms. One of such examples is carbon dioxide (CO_2).

Organic biological molecules are made up of both carbon and hydrogen atoms. Covalent bonds are used to make organic biochemical compounds in living creatures, including the human body. Carbon and hydrogen, respectively, are the second and third most abundant elements in your body. You will soon figure out how these two elements interact in the meals you eat, the compounds that make up your bodily structure, and the chemicals that keep you running.

Activity 3.1 Write the bio-molecules

Based on the knowledge you have and referring to books and internet, write about 1) Inorganic compounds 2) Organic compounds and 3) both inorganic and organic molecules contained in living organisms as shown in the chart at the left hand corner. Finally, your teacher will provide you with possible list of molecules.

3.1.1 Inorganic molecule: Water

Objectives

At the end of this section, the student will be able to:

- *mention properties of water,*
- *discuss the importance of water for the living organisms.*

Why water is considered as a biochemical molecule?

Inorganic molecules, as previously stated, do not contain carbon and were not created through biological means except oxides of carbon and carbonate ions. Certain inorganic molecules play critical roles in the survival of living organisms. Water is an example of an inorganic molecule. Section 3.1.1.1 below discusses the properties of water and its importance in the living system. Before reading this section, please answer the following question and complete activity 3.2.

3.1.1.1. The properties of water

Water is an inorganic molecule composed of two elements: hydrogen and oxygen. H_2O is its chemical formula. Each water molecule is composed of two hydrogen atoms linked to a single oxygen atom. Life would not exist on our planet if it did not have access to water. It is significant for two reasons: it is a key component of cells, accounting for 70 to 95 percent of the cells mass. You are around 60% water.

Water, although being a simple molecule, has some surprising qualities. In a water molecule, each hydrogen atom shares an electron pair with the oxygen atom. In the O-H bonds in water, oxygen is more electronegative than hydrogen. Thus, the sharing of electrons

Activity 3.2 Group work

Form a group of 3-4 students and list down the properties of water and how these are related to its importance to life.

between H and O is unequal; the electrons are more often in the vicinity of the oxygen atom than hydrogen. This unequal electron sharing creates two electric dipoles in the water molecule with oxygen-bearing a partial negative charge and hydrogen bearing a partial positive charge. This makes water a polar molecule (see Figure 3.1). The polarity of water has important chemical implications conferring its typical properties. Another important consequence of the polarity of the water molecule is that water molecules attract one another. The partially positively charged hydrogen atom of one water molecule can interact with the partially negatively charged oxygen atoms of another molecule of water. This interaction is called a hydrogen bond. The hydrogen bond network of water molecules confers several unique properties on water that are important for sustaining life.

What typical properties of water do you know?

Some typical properties of water are:

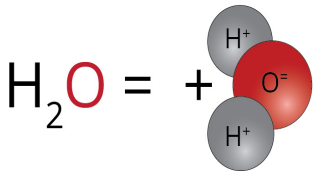


Figure 3.1 Structure of water molecule

1. Water as a solvent

Water is an effective solvent for ions and polar molecules (molecules with an unequal charge distribution, such as sugars and glycerol) because the water molecules (Figure 3.1) are attracted to the ions and polar molecules, causing them to congregate and separate (Figure 3.2).

Figure 3.2 shows what happens when a chemical dissolves in water. Once a chemical is in solution, it is free to move about and react with other chemicals.

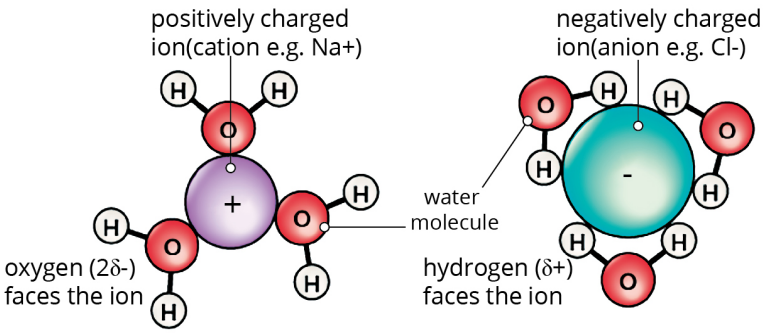


Figure 3.2 Distribution of water molecules around ions in a solution.

However, non-polar molecules such as lipids are insoluble in water and, if surrounded by water, tend to be pushed together by the water, since the water molecules are attracted to each other.

2. High specific heat capacity

A substance's heat capacity is the amount of heat required to raise its temperature by a particular amount. The specific heat capacity of water is the amount of heat energy necessary to raise the temperature of one kilogram of water by one degree Celsius. The heat capacity of

water is rather high. To raise the temperature of a liquid, the molecules must obtain energy and so move more quickly. The hydrogen bonds that cause water molecules to adhere together make it difficult for the molecules to move freely; the ties must be broken to allow free mobility. This explains why more energy is required to raise the temperature of water than would be required if hydrogen bonds did not exist. In effect, hydrogen bonding permits water to store more energy than would otherwise be feasible for a given temperature increase. Water's high heat capacity has crucial biological results since it makes the water more resistant to temperature changes.

3. High latent heat of vaporization

The latent heat of vaporization is a measure of the thermal energy required to vaporize a liquid, converting it from a liquid to a gas. In the case of water, it entails the transformation of liquid water into water vapour. Water has a comparatively high latent heat of vaporization. This is due to its high heat capacity. Because water molecules tend to stick together via hydrogen bonds, very significant quantities of energy are required for vaporization to occur because hydrogen bonds must be broken before molecules can escape as gas.

4. Density and freezing properties

Water is a unique molecule in that its solid form, ice, is less dense than its liquid form. Water density begins to fall below 4°C. As a result, ice floats on liquid water and insulates the water beneath it. This minimizes the likelihood of big amounts of water freezing entirely and increases the likelihood of life surviving under cold temperatures. Changes in water density as a result of temperature generate currents, which aid in the circulation of nutrients in the oceans.

5. High surface tension and cohesion

Water molecules have very high cohesion; in other words, they tend to stick to each other. These cohesive forces are connected to water's adhesion property, or the attraction of water molecules to other molecules. This attraction can be stronger than water's cohesive forces, especially when the water is exposed to charged surfaces like those found on the interior of thin glass tubes known as capillary tubes (Figure 3.3). Water "climbs" up the tube placed in a glass of water, causing the water to look higher on the sides of the tube than in the middle. This is due to the fact that water molecules are more attracted to the charged glass walls of the capillary than to each other and hence adhere to it. Capillary action is the name given to this sort of adhesion. As described in unit 2, figure 2.16, cohesive and adhesive forces are crucial for the transport of water from the roots to the leaves in plants.

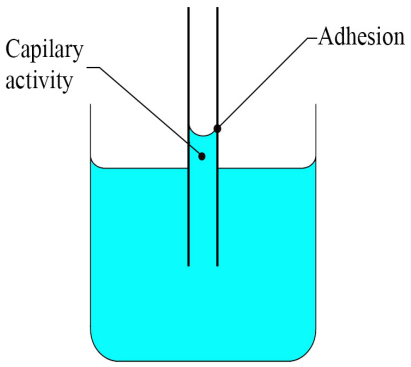


Figure 3.3 Cohesion and adhesion (H2O)

Figure 3.4 Surface tension allowing Raft spider to walk on the water surface

Activity 3.3 Answer to the question

Explain the importance of properties of water in:

a. transpiration

b. the movement of organisms on water surface

c. during temperature fluctuations in water bodies

High cohesion also results in high surface tension at the surface of the water. This allows certain small organisms, such as raft spiders, to exploit the surface of the water as a habitat, allowing them to settle on or skate over its surface (Figure 3.4).

6. Boiling and Freezing Points

The ability of water molecules to form hydrogen bonds, as shown in figure 3.5, is responsible for many of water's unique properties. Despite its low molecular weight, it has a very high boiling point (100°C). This is due to the fact that water requires more energy to break its hydrogen bonds before it can begin to boil. The same concept is used to calculate the freezing point. The boiling and freezing points of water is important for aquatic ecosystems. If water is easily frozen or boiled, drastic changes in the environment would affect bodies of water such as oceans or lakes, killing all organisms that live in water. This is also why sweat can keep our bodies cool. Consider how water differs from most other compounds in terms of its boiling and freezing points (Table 3.1).

Table 3.1 Boiling and freezing points of water

Compound	Boiling Point	Freezing Point
Ethanol	78.4^{0}C	-114.6°C
Acetic acid	117.9°C	16.6°C
Hydrogen Sulfide	-62°C	-84°C
Water	100°C	0°C

3.1.2 Inorganic ions

What are inorganic ions?

Objectives

At the end of this section, the student will be able to:

- *mention important inorganic ions that are necessary for life,*
- *mention diets that contain inorganic ions,*
- *discuss the effect of deficiency of nutrient elements in our body,*
- *explain the importance of each nutrient element to the human body.*

Inorganic ions are charged entities because they are atoms with unshared electrons in their outer shell. They are either positively or negatively charged. They are virtually usually coupled with an oppositely charged ion. Inorganic ions are found in living bodies in two forms: free and dissolved in the cytoplasm and associated with complex organic substances. They participate in a variety of critical functions in living beings. Although they are only found in trace amounts in our bodies, their significance cannot be overstated. Any variations in their concentrations inside the human body can have catastrophic implications.

Activity 3.4 Group discussion

Form a group of 2-3 students and discuss what inorganic ions are and their contribution to our body. Then present your findings to your classmates.

When discussing inorganic ions in the context of the human body, they are frequently referred to as minerals. In this section, you will go over some of the most important inorganic ions in the human body, including their occurrence, sources, and role in homeostasis maintenance. You will also investigate the clinical conditions caused by alterations in their usual concentrations as part of your tasks.

What is the difference between inorganic ions and minerals?

Classification of inorganic ions

Based on their requirement in the daily diet of a normal individual, inorganic ions or minerals in the human body are divided into two categories; Macro-nutrients & Micro-nutrients

Table 3.2 Macro and micro-nutrients in living systems

Macro-nutrients: required in the daily diet	Micro-nutrients/trace elements: required in small amounts
Sodium, Phosphorus, Magnesium, Potassium, Sulfur, Chloride	Iron, Copper, Iodine, Manganese, etc

a. Hydrogen ions

These are the most important ions to maintain balance and equilibrium in living systems. They are released in the cells during various metabolic processes. They are found in the cytoplasm of cells as well as in the intercellular fluid, blood, cerebrospinal fluid (CSF), and other body fluids.

Why macronutrients are required more than micronutrients in our diet?

What is the importance of the hydrogen ion?

The concentration of hydrogen ions is expressed as pH. The pH scale ranges from 1 to 14. The pH value has an inverse relationship with the concentration of hydrogen ions; that is, the higher the pH, the lower and the concentration of hydrogen ions.

b. Sodium ions

The sodium ion is the body's second most important positively charged ion. The concentration of sodium ions in extracellular fluids is higher than in cell cytoplasm. It is a critical nutrient that must be consumed in order for the human body to function normally.

How much is the body requirement of sodium ions for a human being?

The average person's salt need is between 3 and 6 grams per day. It is commonly consumed in the form of common salt found in our foods. The average daily sodium intake exceeds the body's requirements. The urines of the body eliminate excess salt. To maintain normal blood pressure in patients with high blood pressure, lesser salt intakes are required.

What is the other importance of Sodium ions?

It is an extracellular cation that is common in body fluids but is present in lower concentrations within cells.

c. Potassium ions

These are also positively charged ions abundantly present in our bodies. Contrary to sodium ions, potassium ions are the major intracellular cations, being in higher concentration within the cytoplasm of the cells.

How much is the body requirement of potassium and where do we get it from?

Potassium ions must be taken in daily diet. An average human being must intake 3 to 4 grams of potassium daily. It is abundantly present in fruits like bananas, oranges, vegetables like potatoes, and meat like that of chicken and liver.

What is the importance of Potassium ions?

Potassium is one of the body's electrolytes that carry an electric charge when dissolved in body fluids such as blood. Most of the body's potassium is located inside the cells. Potassium is necessary for the normal functioning of cells, nerves, and muscles. The body can use the large reservoir of potassium stored within cells to help maintain a constant level of potassium in blood. Its concentration in plasma is much raised during hemolysis (destruction) of red blood cells.

d. Calcium ion

Calcium is the most abundant inorganic ion present in our body having great importance. It is a positively charged ion mainly present in the cytoplasm of cells. Bones and teeth are the major organs having a lot of calcium.

How much is the body requirement of calcium and where do we get it from?

The calcium requirements of a healthy human are around 800 mg/day. Milk and milk products are the ideal sources of calcium in our diet. Besides, leafy vegetables, egg yolk, fish, and beans, etc. also contain a lot of calcium.

What is the importance of Calcium ions?

Calcium makes around 1 to 1.5 kg of our body weight. Although 99% of calcium is present in bones and teeth, around 1% of calcium is in the cytoplasm of other cells and extracellular fluid performs several important functions in our body. Calcium concentration in the plasma is around 9-11 mg/dl.

e. Phosphate ions

These are the negatively charged inorganic ions abundantly present in our bodies. The body of an average man contains around 1 Kg of phosphate ions. Most of the phosphate ions are presently combined with calcium in bones and teeth.

Its requirements are equivalent to calcium. An adult male needs to take 800 mg of phosphate ions daily in his diet. Milk, cereals, meat, and eggs are rich sources of phosphate ions. The plasma concentration of phosphate ions is around 3-4 mg/dl. It is more abundantly present in the cells.

How much is the body requirement and from where do we get Phosphate ions?

f. Chloride ions

These are the negatively charged inorganic ions present in extracellular fluids. Its concentration in the body is almost similar to that of sodium ions, the major extracellular cations.

What are the sources and body requirements of Chloride ions?

Its average daily requirement is 5 to 10 grams. It is usually taken along with sodium in the form of NaCl present in cooked food.

Chloride ions perform their role in combination with sodium ions. They are involved in maintaining the osmotic pressure, fluid balance, and acid-base balance in our body, just like sodium. They are required to make Hydrochloric acid (HCl) present in gastric juice, which is necessary to digest proteins in the stomach. Hydrochloric acid (HCl) in return kills bacteria and other pathogens in food when it enters the stomach. Salivary amylase is an enzyme to digest starch that is activated by chloride ions.

What is the importance of Chloride ions to human beings?

g. Iron ions

These are the positively charged ions present in or body. Around 70% of iron ions in our body are present in haemoglobin within the red blood cells. Source of iron: legumes such as beans, red meat, liver, spinach, pumpkin seeds, fish, etc.

What is the importance of Iron ions to human beings?

As a component of haemoglobin and myoglobin, iron is needed for the transport of oxygen and carbon dioxide in our bodies. It is an essential component of cytochromes that are a component of the electron transport chain. Iron is a component of the peroxidase enzyme, a lysosomal enzyme necessary for bacteria and other phagocytosed particles in the white blood cells.

What could be the consequence of abnormal Iron metabolism in our body?

Three clinical conditions associated with the abnormal iron metabolism in our body are:

Iron-deficiency Anemia: a common condition in individuals with an iron-deficient diet,

Hemosiderosis: characterized by excess iron in the body, and

Hemochromatosis: a condition which abnormal iron deposits are formed in the liver, spleen, skin, and pancreas.

h. Copper ions

What are Copper ions?

Copper ions are the positively charged inorganic ions that are present in our bodies. Source of copper ions include: shellfish, seeds and nuts, organ meats, wheat, whole-grain, chocolate, etc. It is an essential component of several important proteins and enzymes. They are needed for the synthesis of haemoglobin, collagen, and elastin. Also, it is required for the normal development of the nervous system.

What happens during abnormal copper metabolism?

Wilson disease is a rare clinical condition caused by abnormal copper metabolism in our body. It is characterized by abnormal copper deposition in the liver and brain causing hepatic cirrhosis and brain damage. The copper deposition in kidneys can cause renal failure.

i. Iodine ions

What are the sources and body requirements of Chloride ions?

Iodine is a type of mineral found naturally in the earth's soil and ocean waters. Many salt water and plant-based foods contain iodine, and this mineral is most-widely available in iodized salt. Iodine plays a vital role in the thyroid health. Thyroid gland, which is located at the base of the front of the neck, helps regulate hormone production. These hormones control metabolism, heart health, etc.

To make thyroid hormones, thyroid gland takes up iodine in small amounts. Without iodine, thyroid hormone production can decrease. A "low" or underactive thyroid gland can lead to a condition called hypothyroidism. You can get enough iodine from your diet by eating dairy products, fortified foods, and salty water fish. Iodine is also available in plant foods that grow in naturally iodine-rich soil. You can also get the mineral by adding iodized salt in your food.

Goiter is an enlarged thyroid gland. Your thyroid may become enlarged as a result from either hypothyroidism or hyperthyroidism.

Hyperthyroidism is an overactive thyroid gland. Amount of iodine ions required for the normal function is 150kg/day.

In order to summarize what you have studied in this section (3.1.2) fill-in the blank spaces given in activity 3.5 below.

Activity 3.5 Fill in the blank spaces in the table

Fill in the blank spaces in the table with appropriate answers

Type of Inorganic Ions	Source of inorganic ions	Amount required	Importance	Type of deficiency disease	Excess intake results in
Hydrogen ions					
Sodium ions					
Potassium ions					
Calcium ions					
Phosphate ions					
Chlorine ions					
Chloride ions					
Iron ion					
Copper ions					
Iodine ions					

3.1.3. Organic molecules

Objectives

At the end of this section, the student will be able to:

- *discuss the role of biological molecules in the cell structure,*
- *Classify organic molecules based on their constituent elements and the monomers from which they are constructed.*
- *elaborate the functions of carbohydrates, proteins, lipids, and Nucleic acids to the body,*
- *conduct experiments to identify nutrients in different foodstuffs,*
- *appreciate why Ethiopians use malting seeds to make local drinks (Tella, Areke), and*
- *appreciate the significance of local drinks prepared from malting seeds in Ethiopia.*

An organic molecule is a compound that contains carbon and is found in living things. Carbon forms the basis of organic life due to its ability to form large and complex molecules via covalent bonding. Four principal groups of organic compounds contribute to much of the structure and function of living things. These are carbohydrates, lipids, proteins, and nucleic acids.

What are organic molecules?

Activity 3.6 Group work

After defining what the organic molecules are (above), in group of 3-4 students, explore the different kinds of organic molecules, for instance, food items you know, and sort them into different types of organic molecules. Then let one of your members reflect on your classification. Let him/she explain the basis for classification of e.g. the type of elements that constitute the organic molecule.

After your work on activity 3.6 above your teacher will introduce you to the major organic molecules. The type of food items from which we get the major organic molecules, the elements that form each organic molecule, the monomers and the results of polymerization of the monomers will be slightly introduced. Finally, you will do laboratory activities (food tests) for each of the food item you study.

What monomers do make up organic molecules?

Organic molecules including carbohydrates, lipids, proteins, and nucleic acids are made up of small, single molecular units (monomers). Monomers are connected by strong covalent bonds to create polymers. Polymers are long chains of molecules formed of many single units bonded one after the other. Table 3.3 lists the basic monomers that combine to produce organic molecules.

Table 3.3 Elements and monomers forming organic molecules

Organic molecules	Elements forming the molecule	Monomer
Proteins	C, H, O and N	Amino acids
Lipids	C, H, O	Glycerol and fatty acid
Carbohydrates	C, H, O	Monosaccharides Glucose Galactose Fructose
Nucleic acids	C, H, O, N and P	Nucleotides

Carbohydrates

What are carbohydrates?

Objectives

At the end of this section, the student will be able to:

- *name the different types of carbohydrates,*
- *discuss the importance of monosaccharides, and disaccharides,*
- *explain which food items are sources of carbohydrates, and*
- *tell the types and importance of polysaccharides*

Carbohydrates are macromolecules with which most consumers are somewhat familiar. To lose weight, some individuals adhere to "low-carbohydrate" diets. Athletes, in contrast, often use more carbohydrates before important competitions to ensure that they have sufficient energy to compete at a high level. Carbohydrates are, in fact, an essential part of our diet; grains, fruits, and vegetables are all-natural sources of carbohydrates. Carbohydrates provide energy to

the body, particularly through glucose, a simple sugar. Carbohydrates also have other important functions in humans, animals, and plants. Some carbohydrates rich food items are given in figure 3.5 below.

Figure 3.5 Food items rich in carbohydrate

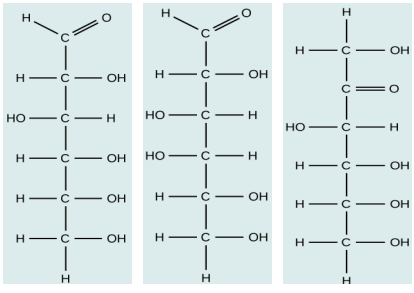
Carbohydrates are made of three major elements; carbon, hydrogen, and oxygen. In carbohydrates, the ratio of hydrogen to oxygen is 2:1. There are three main groups of carbohydrates; monosaccharides, disaccharides, and polysaccharides.

a. Monosaccharides

Monosaccharides are molecules that contain only one sugar unit. Sugars dissolve quickly in water, forming sweet-tasting solutions. Monosaccharides have the general formula (CH2O)n (CnH2nOn) where 'n' refers to the number of carbon. In monosaccharides, the ratio of carbon to hydrogen to oxygen is 1:2:1. Monosaccharides are made up of a single sugar molecule (the term "mono" refers to one). When categorizing monosaccharides based on the number of carbon atoms in each molecule, the following are the most common: 1) trioses (3C), 2) pentoses (5C), and 3) hexoses (6C).

Which types of monosaccharide do you know? Mention and discuss the roles of commonly known monosaccharide for cells.

C6H12O6 is the chemical formula for hexose sugar. This is referred to as the molecular formula. It is also useful to show how the atoms are arranged, which can be done with a diagram known as the structural formula. The structural formula of the most common monosacchirdes; glucose, galactose and fructose are shown in Figure 3.6. Despite having the identical chemical formula (C6H12O6), glucose, galactose, and fructose differ structurally and chemically (and are known as isomers) due to different atom positions in the carbon chain.



Glucose *Galactose* *Fructose*

Figure 3.6 Structural formula of glucose, Galactose and Fructose

Activity 3.7 Write the formulas

The formula for a hexose sugar is C6H12O6 or (CH2O)6.

1. What is the formula of a:
   a. triose sugar?
   b. tetrose sugar?
   c. pentose sugar?

Roles of monosaccharides in living organisms

Monosaccharides are the simplest forms of sugar and the most basic units (monomers) from which all carbohydrates are built. They also play very important roles in living organisms. Major functions of monosaccharide in include:

1. as a source of energy in respiration: this is due to a large number of carbon-hydrogen bonds. These bonds can be broken to release a lot of energy, which is transferred to help make ATP (Adenosine triphosphate) from ADP (Adenosine diphosphate) and phosphate. The most important monosaccharide in energy metabolism is glucose.
2. as building blocks for larger molecules: for example, glucose is used to make the polysaccharides starch, glycogen, and cellulose. Ribose (a pentose sugar) is one of the molecules used to make RNA (ribonucleic acid) and ATP. Deoxyribose (also a pentose sugar) is one of the molecules used to make DNA.

b. Disaccharides (C12H22O11)

Disaccharides are formed of two monosaccharides. The three most common disaccharides are:

1) Maltose, which is composed of glucose + glucose,

2) Lactose, which is composed of glucose + galactose and

3) Sucrose, which is composed of glucose + fructose

Maltose or malt sugar is the product of breakdown of starch catalyzed by the enzyme amylase. Sucrose is the transport sugar in plants and the sugar that is commonly purchased in stores. Lactose is a sugar found in milk and is thus an important dietary component.

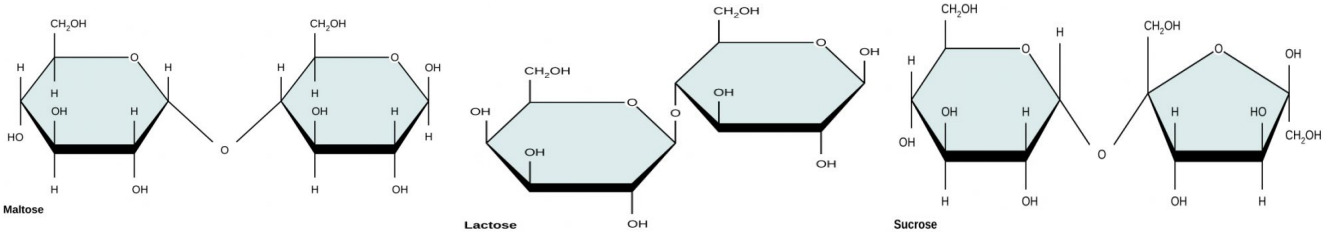


Figure 3.7 Disaccharides a) Maltose b) Lactose c) Sucrose

c. Polysaccharides -(C6H10O5)-n

The most important polysaccharides are starch, glycogen, and cellulose. Polysaccharides are made of polymers of monomer glucose. Because glucose is the primary source of energy for cells, living organisms must store it in the proper form. If glucose accumulated in cells, it would dissolve and cause the cell's contents to become overly

concentrated, compromising the cell's osmotic properties. Glucose is a reactive molecule that would disrupt normal cell chemistry. Condensation reactions convert glucose to a storage polysaccharide, which is a convenient, compact, inert (un-reactive), and insoluble molecule, avoiding these issues. The storage polysaccharide formed is starch in plants and glycogen in animals. Glucose can be made available again quickly by an enzyme-controlled reaction.

Activity 3.8 Group work

Form a group of 2-3 students and using diagrams/models, explore the contribution of carbohydrates (monosaccharide, disaccharides and polysaccharides) as structural components of cells and their functions for cells and the human body as a whole.

Laboratory Activity 3.9 Test for reducing sugars

Background

All monosaccharides, such as glucose, and some disaccharides, such as maltose, are considered reducing sugars. Sucrose is the only common non-reducing sugar. Reducing sugars get their name from the fact that they can carry out a reduction reaction. The Benedict's test, which uses Benedict's reagent, makes use of this. Benedict's reagent is a blue-coloured copper (II) sulphate solution in an alkaline solution. Sugars are used to convert soluble blue copper sulphate, which contains copper(II) ions, to insoluble brick red copper oxide, which contains copper (I). A brick-red precipitate of copper oxide can be seen.

Reducing sugar + Cu^{2+} *oxidized sugar* + Cu^{+} *blue red-brown*

Procedure

Add a 10 % glucose solution in a test tube

Add Benedict's reagent to the solution

Heat in a water bath.

Observe the colour change

Answer the following questions

1. How does the colour of your solution change as you continue heating?
2. Why do we heat in a water bath?
3. What is the reason for the colour change?

Perform the following activity about how Ethiopian traditional beverages are produced by malting seeds.

Laboratory Activity 3.10: Study of traditional beverages of Ethiopia

In Ethiopia traditional beverages are so delicious with mild alcoholic contents. There are typical procedures to prepare each of these traditional beverages. Being in groups of 3-4, study methods of preparation of one of the traditional beverages: Borde, Shameta, Tej or Tela

Methods of study:

Interview local producers

Observation

Using internet, books, or articles

a) What is the purpose of malting?

b) Do they use Gesho? If so why?

c) Discuss the content of the traditional beverage and the process of their preparation.

Starch [-(C6H10O5)-n]

Starch is the plant's stored form of sugar. Plants can produce glucose, and the surplus glucose is stored as starch in various plant components such as roots and seeds. Animals ingest starch, which is broken down into smaller molecules such as glucose. The glucose can subsequently be absorbed by the cells.

Glycogen [-(C6H10O5)-n]

Glycogen, which is made up of monomers of glucose, is the storage form of glucose in humans and other animals. Glycogen, the animal analogue of starch, is a highly branched polymer that is often stored in liver and muscle cells. Glycogen is broken down to release glucose if glucose levels fall.

Cellulose [-(C6H10O5)-n]

Cellulose is a naturally occurring biopolymer that is abundant. Plant cell walls are mostly made of cellulose, which provides structural support to the cell. Wood and paper are examples of cellulosic materials. Cellulose is made up of glucose monomers that are linked together in the glucose molecule by carbon atom bonds.

Every other glucose monomer in cellulose is densely packed as long extended chains. This is what gives cellulose its rigidity and high strength, which are critical for plant cells. Dietary fiber is cellulose that passes through our digestive system. While animal digestive enzymes cannot break down the glucose-glucose linkages in cellulose, herbivores such as cows, buffalos, and horses can digest cellulose-rich grass and use it as a food source. Certain bacteria live in these animals' rumens (part of herbivores' digestive systems) and secrete

the enzyme cellulase. Cellulases may degrade cellulose into glucose monomers, which the animal can utilize as an energy source.

What do you think about the structure of plant cell wall? Which biochemical molecules form a cell wall?

A cell wall often comprises numerous layers of fibers that run in different directions to boost strength. Other molecules aid in the cross-linking of the cellulose fibers, and some form a glue-like matrix around the fibers, which improves strength even further. The strength of cellulose fibers is roughly similar to that of steel. This implies that when pulled at both ends, they are extremely difficult to stretch or break, allowing a cell to endure the tremendous pressures that build within it due to osmosis.

Without a wall, the cell would explode in a dilute fluid. These pressures help the plant grow by hardening tissues and stimulating cell expansion. The shape of the cell as it grows is determined by the arrangement of fibers around it. Despite their strength, cellulose fibers are porous, allowing water and solutes to pass between the cell surface membrane and the surrounding environment.

Laboratory activity 3.11: Test for polysaccharides-starch and glycogen

This test is specific for polysaccharides. It is used to differentiate polysaccharides from the rest of carbohydrates. This test can be used to differentiate between glycogen, and starch.

Procedure

1. Take 2 ml of the given solution (starch, dextrin, or glycogen) in a test tube
2. Add 2-3 drops of iodine reagent in the above test tube
3. Wait for some time
4. Observe for the colour change

When the iodine reagent is added to the solution, the colour of the solution may change to Blue, Reddish-purple.

Answer the following questions

i. What colour change is observed in the food item that contains starch?

ii. What colour change is observed in the food item that contains dextrin?

iii. What colour change is observed in the food item that contains glycogen?

Major functions of carbohydrates

1. They serve as the primary source of energy for most organisms. Glucose in fruit juice, lactose in milk, starch in wheat, potato, rice etc is different forms of carbohydrate that we harvest energy from.

2. They act as a storage form of energy in the body (e.g. Starch and Glycogen).

- Starch stores energy for plants. In animals, it is catalyzed by the enzyme amylase (found in saliva) to fulfil the energy requirement.
- Glycogen is a polysaccharide food reserve of animals, bacteria, and fungi.

- In mammals, glycogen is stored in the liver and muscle as granules or particles (Up to 10% of liver mass and 1-2% muscle mass). Muscle glycogen supplies energy for muscle contraction during exercise.

3. They serve as cell membrane components that mediate some forms of intercellular communication.

4. They form the structural component of many organisms, including the cell walls of bacteria, fungi, and the exoskeleton of many insects. Chitin is involved in the formation of a fungal cell wall, whereas cellulose is an important component of ruminant diets.

Lipids

What are lipids?

Objectives

At the end of this section, the student will be able to:

- *discuss what lipids are,*
- *tell the importance of lipids for our cells,*
- *describe the structure of glycerol and fatty acids, and*
- *explain the importance of phospholipids in the cell membrane.*

Activity 3.12 Group work

After your study on saturated and unsaturated fatty acids, do the following activity.

Why are unsaturated fatty acids healthier than saturated fatty acids? Make a group of 5 students and collect full information about it from health officers in your area and present the report to the whole classmates.

Lipids are diverse groups of biomolecules that are insoluble in water but soluble in nonpolar solvents such as ether, chloroform, and acetone. Lipids are made of elements carbon, hydrogen and oxygen. It includes fats and oils and cholestrols. Fats are solid at room temperature and oils are liquid at room temperature. Chemically, they are very similar. We could say those true lipids are organic compounds formed by fatty acids combining with alcohol. The butter, cooking oil, and the meat we eat are good examples of lipids. Lipids are polymers of fatty acids and glycerol molecules.

Fatty acids [CH3(CH2)nCOOH]

Fatty acids are a series of acids, some of which are found in fats (lipids). CH3(CH2)nCOOH is the general formula for fatty acids. The contain the acidic group –COOH, known as a carboxyl group. The larger molecules in the series have long hydrocarbon tails attached to the acid 'head' of the molecule. As the name suggests, the hydrocarbon tails consist of a chain of carbon atoms combined with hydrogen. The chain is often 15 or 17 carbon atoms long.

Based on the presence or absence of double bonds (–C=C–) in their structure, there are two types of fatty acids:

Unsaturated fatty acids consist of one or more double bonds in their structure so that they do not contain the maximum possible amount of hydrogen. Double bonds make fatty acids and lipids melt more easily – for example, most oils are unsaturated. If there is more than

one double bond in their structure, the fatty acids or lipids can be described as polyunsaturated; if there is only one double bond, they are called monounsaturated. Plant lipids are often unsaturated and occur as oils, e.g. olive oil and sunflower oil.

Saturated fatty acids have no double bonds in their carbon-carbon chain. All saturated fatty acids are solid at room temperature. Animal lipids are often saturated and occur as animal fat.

Where in our body do we encounter fats?

Fat is stored in several places in the human body, particularly just below the dermis of the skin and around the kidneys. Below the skin, it also acts as an insulator against loss of heat.

Phospholipids

Phospholipids are a subset of lipids. Each molecule has the unusual property of having one water-soluble end. This is because one of the three fatty acid molecules is replaced by a phosphate group, which is polar and thus dissolves in water.

The phosphate group is hydrophilic (water-loving) and makes the head of a phospholipid molecule hydrophilic, although the two remaining tails are still hydrophobic (water-hating). This allows the molecules to form a membrane around a cell, where the hydrophilic heads lie in the watery solutions on the outside of the membrane, and the hydrophobic tails form a layer that is impermeable to hydrophilic substances.

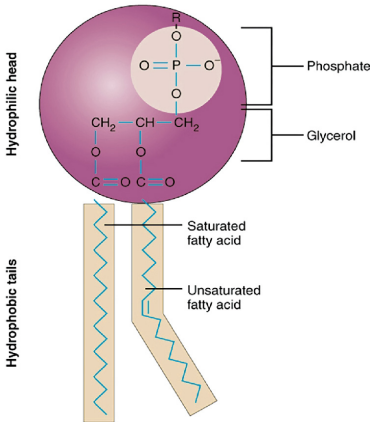


Figure 3.8 A phospholipid molecule

Major of functions of lipids

1. Fatty acids serve as the foundation for other types of lipids and serve as stored energy.
2. Serve as major fuel store and major dietary lipid in plants (oil) and animals (Fat). Fats are stored in specialized cells called adipose cells (fat cells), serve as poor conductors of heat and provide insulation at low temperatures.
3. They serve as structural components in cell membranes (e.g., phospholipids); precursors for the synthesis of Vitamin D, Bile acids, hormones of adrenal cortex such as cortisol, and aldosterone; female sex hormones such as progesterone and estrogen and male sex hormones such as testosterone (Cholesterol).
4. Some serve as protective coatings on skin, fur and feathers of animals, birds and fruit and leaves of plants (Example, Wax). The shiny appearance of fruits and leaves is due to waxes. Waxes also serve as a water barrier for animals, birds and insects; and also protects against cold.

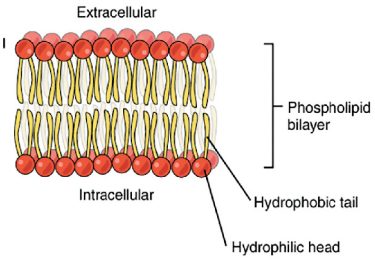


Figure 3.9 Phospholipid bilayer

Proteins

Activity 3.16 THINK-PAIR-SHARE

In a group, discuss what you know about the structure and function of proteins. Before starting the discussion, write individually what you know about proteins. Finally, share what you know to your group members, discuss to consolidate and present your findings to the whole class.

Objectives

At the end of this section, the student will be able to:

- *mention the importance of proteins to cells and the body of living things,*
- *elaborate formation of proteins by amino acids,*
- *differentiate proteins according to their structure,*
- *difine what are amino acides, and*
- *group proteins according to their function.*

What are proteins?

Proteins are biological molecules composed of carbon, hydrogen, oxygen, and nitrogen and sometimes contain phosphorus and sulphur. Although amino acids may have other formulas, those in protein invariably have the general formula RCH(NH2)COOH, where C is carbon, H is hydrogen, N is nitrogen, O is oxygen, and R is a group, varying in composition and structure, called a side chain.

Proteins are biological molecules made up of amino acids monomers. They are one of the most abundant organic molecules in living systems and have the widest range of functions of any macromolecule. Proteins can be structural, regulatory, contractile, or protective. They could be toxins or enzymes, or they could be used in transportation, storage, or membranes. Each cell in a living system may contain thousands of proteins, each with a distinct function. Their structures, like their functions, vary greatly. They are all, however, amino acid polymers arranged in a linear sequence (also referred to as a "peptide"). They are an extremely important class of macromolecule in living organisms. More than 50% of the dry mass of most cells is protein. Protein rich food items include; meat, cheese, milk, fish, beans, vegetables, etc.

Amino acids

What are amino acids?

Amino acids are the monomers that make up proteins. Amino acids have:

- a central carbon atom which is bonded to an amine group, –NH2,
- a carboxylic acid group, –COOH and
- a hydrogen atom

The only way in which amino acids differ from each other is in the remaining, fourth, group of atoms bonded to the central carbon. This is called the R group (Figure 3.10). 20 different amino acids occur in the proteins of living organisms, all with a different R group. Examples of some amino acids (Alanine, valine, lysine, and asparatic acid) are given in figure 3.11 below. In the process of protein synthesis amino acids join by covalent linkage forming a peptide bond that elongates further and form a polypeptide bond.

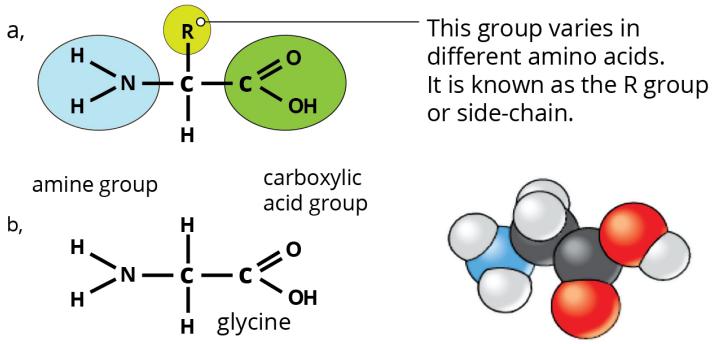


Figure 3.10 General formula of amino acids

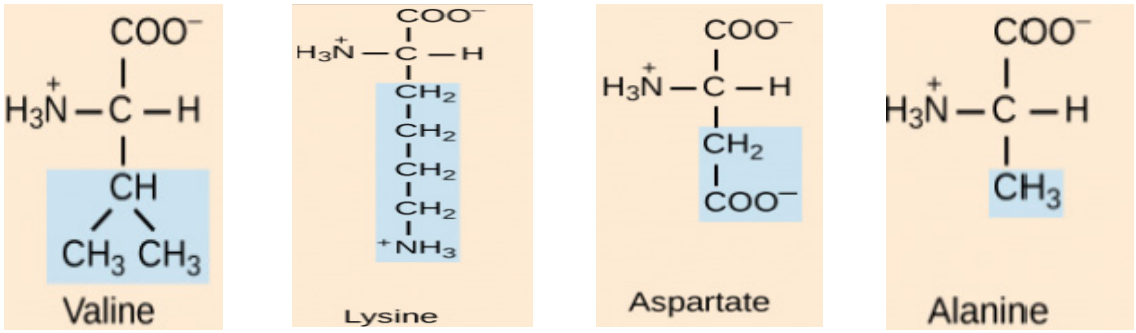


Figure 3.11 Examples of amino acids

The peptide bond

Each amino acid is attached to another amino acid by a covalent bond. One loses a hydroxyl (–OH) group from its carboxylic acid group, while the other loses a hydrogen atom from its amine group. This leaves a carbon atom of the first amino acid-free to bond with the nitrogen atom of the second. The link is called a peptide bond. The oxygen and two hydrogen atoms removed from the amino acids form a water molecule.

Do you have any idea about the structure of proteins?

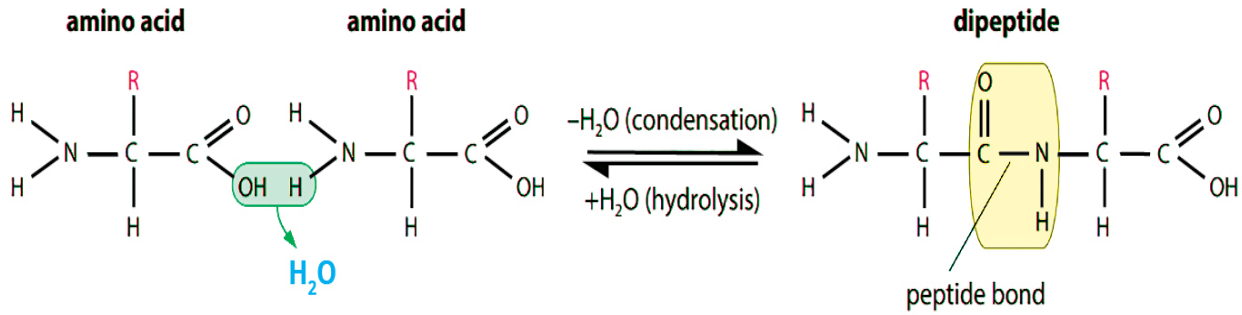


Figure 3.12 Amino acids link together by the loss of a molecule of water to form a peptide bond.

Activity 3.17 Group work

Form a group of 2-3 students and using diagrams/models, explore the contribution of proteins (globular and fibrous/functional and structural) as structural components of cells, and their functions for cells and the human body as a whole.

The new molecule which has been formed is made up of two linked amino acids, and is called a dipeptide. Any number of extra amino acids could be added to the chain in a series of condensation reactions. A molecule made up of many amino acids linked together by peptide bonds is called a polypeptide. A complete protein molecule may contain just one polypeptide chain, or it may have two or more chains that interact with each other.

In living cells, ribosomes are the sites where amino acids are joined together to form polypeptides. The reaction is controlled by enzymes. Polypeptides can be broken down into amino acids by breaking the peptide bonds. This is a hydrolysis reaction, involving the addition of water, and happens naturally in the stomach and small intestine during digestion. Here, protein molecules in food are hydrolyzed into amino acids before being absorbed into the blood.

According to their shape, proteins can also be classified into:

Globular proteins area protein whose molecules curl up into a 'ball' shape, such as myoglobin or haemoglobin. In a living organism, proteins may be found in cells and other aqueous environments such as blood, tissue fluid, and in the phloem of plants. Globular proteins usually curl up so that their non-polar, hydrophobic R groups point into the center of the molecule, away from their watery surroundings. Water molecules are excluded from the center of the folded protein molecule. Many globular proteins have roles in metabolic reactions. Their precise shape is the key to their functioning. Enzymes, haemoglobin, antibodies are examples of globular proteins.

Fibrous proteins are protein molecules that do not coil up into a ball but form long strands. Fibrous proteins are not usually soluble in water and most have structural roles. For example, keratin forms hair, nails, and the outer layers of the skin making these structures waterproof. Another example of a fibrous protein is collagen which is found in skin, tendons, cartilage, bones, teeth, and the walls of blood vessels.

Major functions of proteins

1. Structural proteins: are fibrous and tough, as well as insoluble in water. They are structural elements of connective tissues, bones, tendons, cartilages, nails, hair, and horns. Collagen, elastin, and keratin are examples of structural proteins.

2. Enzymes: are globular proteins that serve as biological catalysts. They catalyze metabolic reactions by lowering the activation energy, which increases the reaction rate. Protein enzymes include DNA polymerase, lysozyme, nitrogenase, and lipase.

3. Hormones: are polypeptides that are made up of long chains of linked amino acids. They play critical roles in the regulation of the body›s physiological processes, which include reproduction, growth and development, electrolyte balance, sleep, and so on. Growth hormone (GH) and follicle-stimulating hormone are two examples of these hormones (FSH).

4. Respiratory pigments: are globular protein pigments that are typically water-soluble. Myoglobin, which provides oxygen to working muscles; and haemoglobin, which transports blood to all tissues and organs via the blood, is the two examples.

5. Transport proteins: are cell membrane structural components. They create channels in the plasma membrane to transport specific molecules within the cells. Some of them are also found in animal blood and lymph. Serum albumin (which transports hemin and fatty acids), channel proteins, and carrier proteins are examples of transport proteins.

6. Motor proteins: are involved in muscle contraction and relaxation (muscle movement). Actin, myosin, kinesin, and dynein are all components.

7. Storage proteins: In cells, these proteins serve as a storage reserve for amino acids and metal ions. They can be found in eggs, seeds, and pulses. Ferritin, ovalbumin, and casein are examples of storage proteins.

8. Toxins: Bacteria are the most common producers of these proteins. Diphtheria toxin, Pseudomonas exotoxin, and ribosome-inactivating proteins are among them. By causing cytotoxicity, they aid bacteria in attacking and killing their host organism.

Laboratory Activity 3.18: The Biuret test for proteins

Background

In this test, a protein in an alkaline solution reacts with copper ions to produce a mauve/purple colour.

There are two ways of carrying out the test:

Method 1

Procedure

Mix the food or 2 cm3 of the test solution with Sodium hydroxide solution in a test tube

Add a few drops of 1% copper (II) sulphate solution.

Allow the mixture to stand for a few minutes (to allow the colour to develop fully).

Method 2

Procedure

1. Mix the food or 2 cm3 of the test solution with Biuret solution (which contains copper ions in an alkaline solution).
2. Allow the mixture to stand for a few

Answer the following questions

1. Which food items can be tested for proteins?
2. What is the reason for the colour change?
3. Why do you add a copper (II) sulphate solution?

Laboratory Activity 3.19: Xanthoproteic Test

Background: Proteins are polymers of amino acids. They are complex organic compounds containing nitrogen, hydrogen, carbon and oxygen. Proteins are abundant in our everyday food e.g. egg, soya bean, pulses, fish, milk etc. The presence of proteins can be confirmed qualitatively by using several tests, Xanthoproteic test is one of them. Xanthoproteic test is a biochemical method, which is used for the identification of amino acids containing phenolic or indolic groups like phenylalanine, tyrosine, and tryptophan (aromatic amino acids).

Procedures

1. Take a clean test tube and add 1 ml of the sample solution within it.
2. After that add 1 ml of concentrated nitric acid to it.
3. Keep the test tube at room temperature and allow it to cool down.
4. After that add 1 ml of 40% NaOH solution to the test tube.

Answer the following questions

1. What colour change do you observe after adding nitric acid and cooling at room temperature?
2. Why do we add sodium hydroxide?
3. What is the colour observed at the end of the experiment?

Nucleic acids

What are nucleic acids?

Objectives

At the end of this section, the student will be able to:

- *describe the structures of nucleotides and nucleic acids,*
- *differentiate between DNA and RNA, and*
- *explain the importance of DNA and RNA.*

Nucleic acids are chemical molecules made up of phosphoric acid, sugars, and organic bases that exist naturally. Nucleic acids are the cell's principal information-carrying molecules, and they determine every living thing's inherited features by directing the process of protein synthesis. Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are the two main types of nucleic acids (RNA).

The structure of DNA and RNA

If you were asked to design a molecule that could act as a genetic material in living things, where would you start?

DNA stands for deoxyribonucleic acid and RNA for ribonucleic acid. Nucleic acids such as DNA and RNA, like proteins and polysaccharides, are macromolecules. They are also polymers, made up of many similar, smaller molecules joined into a long chain. The smaller molecules that form DNA and RNA are called nucleotides. DNA and RNA are therefore polynucleotides. They are often referred as nucleic acids.

Most organisms carry their genetic information in the nucleotide sequences of DNA, but a few viruses carry it in RNA. Along the length of the DNA is a series of chemical structures called genes. Genes are stretches of DNA that code for RNA and amino acids and, therefore, proteins.

Nucleotides

Figure 3.8 shows the structure of nucleotides. Nucleotides are made up of three smaller components. These are:

- a nitrogen-containing base
- a pentose sugar
- a phosphate group

There are five different nitrogen containing bases in DNA and RNA. The four nitrogenous bases in the DNA molecule are adenine, thymine, guanine, and cytosine. An RNA molecule also contains four bases, but have Uracil instead of thymine. These bases are often denoted by their first letters: A, T, C, G, and U. The order and composition of the different nucleotides sequences determines the hereditary function of the nucleic acids.

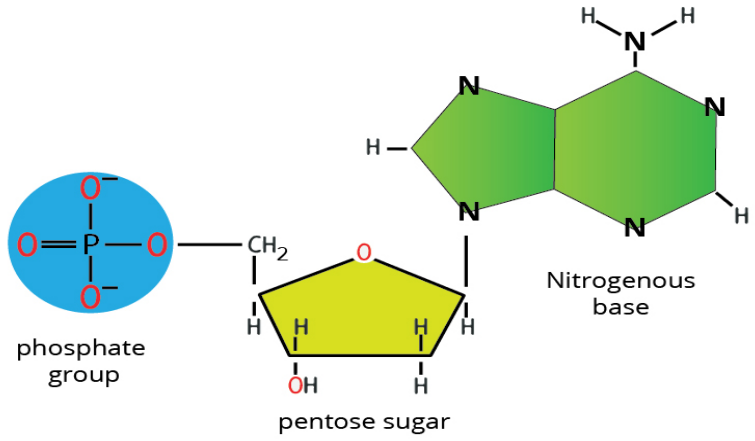


Figure 3.13 The components of nucleotides.

The pentose (5-carbon) sugar can be either ribose (C5H10O5) (in RNA) or deoxyribose (C5H10O4) (in DNA) Figure 3.9. As their names suggest, deoxyribose is almost the same as ribose, except that it has no oxygen atom on its second carbon atom.

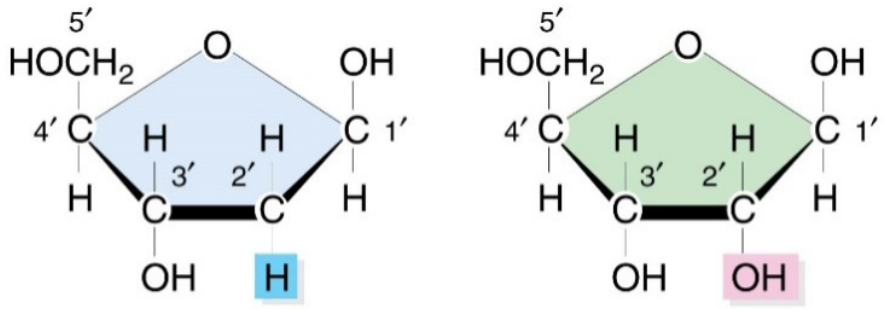


Figure 3.14 Structures of deoxyribose and ribose sugars

DNA is a large molecule made up of two strands (made of two chains) of nucleotides wounded into a double helix. RNA is much smaller and is single-stranded (made of a single chain). There are three types of RNA: mRNA (messenger RNA), rRNA(ribosomal RNA), and tRNA(transfer RNA).

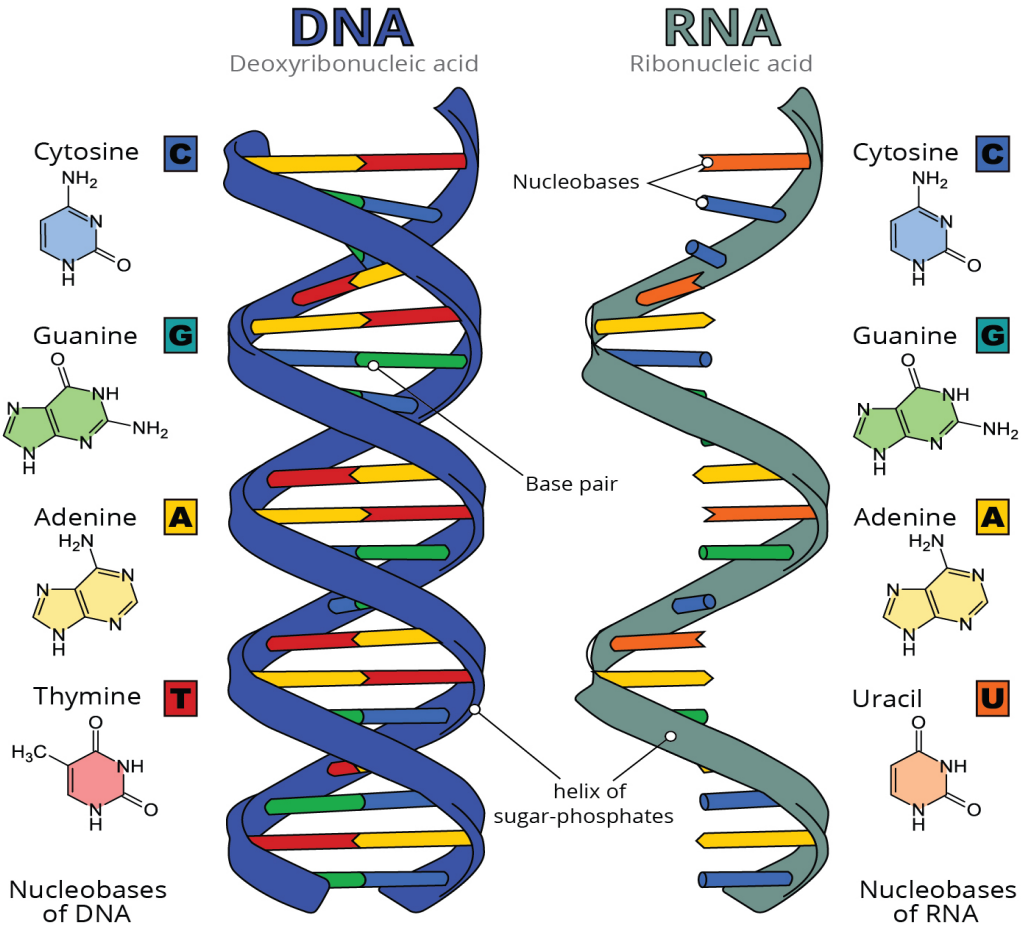


Figure 3.15 The structure of nucleic acids

Table 3.4 Similarities and differences in function and structure of the nucleic acids

Features	DNA	RNA
Nitrogenous bases	Adenine, Guanine, Cytosine, Thymine	Adenine, Guanine, Cytosine, Uracil
Pentose sugar	Deoxyribose sugar	Ribose sugar
Phosphate	Phosphate group	Phosphate group
Size	Huge-allows the molecule to carry the code for many different proteins in the genes	Much smaller-need code for only one protein; small size allows RNA to move out of the nucleus
Stability	Very stable – ensures that the genes remain the same over the generation	Less stable- is degraded quite quickly so does not carry on coding for a protein
Number of strands	Two strands- allow coding of genes and replication during cell division.	Single-stranded- does not replicate

Major functions of Nucleic Acids: DNA and RNA

Deoxyribonucleic acids (DNA)

It is the genetic material that stores all the information required to be transferred to the next generation. The genetic information is stored in its nucleotide sequences. DNA has a unique property of replication or production of its copy that can be transferred to a daughter cell during cell reproduction.

It specifies the biological development of all living organisms and viruses. It carries the genetic code (instructions for protein synthesis). Information coded in the nucleotide sequence of DNA for a particular protein is first copied to mRNA (by the process of transcription). The code in the mRNA is then translated into amino acid sequences of protein. Proteins are required to build an organism and catalyze all of its biochemical reactions thereby controlling all of the functions of the cell or organism.

Ribonucleic acids (RNA)

RNA has different roles to play in different organisms.

It acts as genetic material in some viruses and has enzymatic activity in other organisms

(where it is called ribozyme).

Three types of RNA are present among organisms: mRNA, tRNA and rRNA. All three have essential roles in the development and maintenance of life.

mRNA moves the genetic code (information for protein synthesis) from DNA to ribosomes (protein-synthesizing machinery in the cell).

tRNA helps the proteins synthesis by providing a source of amino acids (the building blocks of proteins).

rRNA form a complex with proteins making the structure the ribosome.

Activity 3.21 Group work

In a group of 3-4 students and using diagrams/models, explore the contribution of Nucleic acids (DNA and RNA) as components of cells and their functions (inheritance) for cells and the human body as a whole.

Unit Review

- Water is made of hydrogen and oxygen atoms and is important for plants and animals, where it forms a large part of the mass of each cell.
- Extensive hydrogen bonding gives water unusual properties.
- Water is liquid at most temperatures on the Earth's surface. It has a high specific heat capacity, which makes liquid water relatively resistant to changes in temperature.
- Water acts as a solvent for ions and polar molecules, and causes non-polar molecules to group together.
- Water has a relatively high latent heat of vaporization, meaning that evaporation has a strong cooling effect. It also has high cohesion and surface tension which affects the way it moves through narrow tubes such as xylem and allows it to form a surface on which some organisms can live.
- Cells of any living organism are composed of organic and inorganic molecules, and each of these molecules is composed of atoms
- In living organisms, inorganic molecules such as water and salts frequently lack carbon atoms
- Organic molecules such as carbohydrates, lipids, proteins, and nucleic acids are large molecules containing carbon and hydrogen and are referred to as biological macromolecules.
- Polymers are the most common type of biological macromolecule. Polymers are formed by combining smaller molecules known as monomers through a process known as polymerization.
- carbohydrates are biological macromolecules made of carbon, hydrogen and oxygen atoms and that are composed of smaller molecules known as monomers.
- Glucose is one of the monomers.
- Monomers are regarded as the simplest and quickest source of energy.
- carbohydrates are used to store energy in the bodies of living organisms until it is needed; as starch in plants and glycogen in human and animal liver and muscles.
- carbohydrates are a basic component of some cell parts, such as plant cell wall. They are also be found in cell membranes and protoplasm.
- lipids are biochemical macromolecules composed of carbon, hydrogen, and oxygen atoms.
- lipids are made up of a diverse range of compounds such as fats, oils, waxes, phospholipids, and derived lipids such as steroids.
- lipids are compounds are insoluble in water but soluble in nonpolar solvents such as benzene and carbon tetrachloride.
- energy obtained from lipids is greater than the energy obtained from the same amount of carbohydrates.
- lipids account for approximately 5% of the organic materials found in the composition of a living cell. Lipids are also important in the structure of cell membranes.

- lipids act as a thermal insulator in animals and humans, allowing organisms to keep their body temperatures stable in cold and harsh environments.
- lipids serve as a protective coating for the surfaces of many plants and animals, and some of them can act like hormones.
- proteins are the structural building blocks of all living organisms. They are made up of carbon, hydrogen, oxygen and nitrogen atoms. There are also proteins that contain sulfur.
- proteins make up the majority of all living organisms, from the largest animals to the smallest microscopic organisms.
- proteins play a role in the biochemical processes that keep life alive.
- proteins play an important role in the structure and function of living cells.
- proteins from muscles, ligaments, tendons, organs, glands, nails, hair, and many of the body's vital fluids, such as blood and lymph, are required for bone growth.
- proteins also include enzymes and hormones, which stimulate and regulate all vital processes in the body.
- nucleic acids are biological macromolecules that contain the elements oxygen, hydrogen, carbon, nitrogen, and phosphorus.
- nucleic acids are classified into two types: ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) (DNA).
- nucleic acids are composed of basic units known as nucleotides that bind together via covalent bonds to form a polynucleotide or nucleic acid.
- nucleic acids are in charge of passing on genetic traits from one generation to the next during cell division.
- DNA carries the genetic information responsible for a living organism's distinct characteristics and organizes all of the cell's vital activities.
- RNA is transcribed from the DNA. It then translated into the proteins responsible for genetic traits, and those responsible for organizing the vital activities.

Review Questions

I. True false Items: Say "True" or "False" for the following statements on your exercise book.

1. A deficiency disease caused by lack of iron in our food is called goiter.
2. DNA is termed as a genetic material.
3. All proteins are made up of fatty acids and glycerol molecules.
4. Phospholids are molecules that are used for a dipeptide bond. Formation.
5. Maltose is a disaccharide made of two glucose units.
6. DNA is made of 5- Carbone sugar ribose, phosphate and a nitrogenous base
7. Calcium is one of the inorganic ions that are used for bone and teeth formation.
8. Water is a universal solvent.
9. Proteins are made up of beta glucose molecules.
10. Glycogen is a storage form of polysaccharide in animals.

II. Multiple-choice Items

Choose the correct answer from A – D and write your answer on your exercise book.

1. Disaccharides consist of:-

   A. Two molecules of monosaccharides C. Four molecules of monosaccharides

   B. Three molecules of monosaccharides D. Five molecules of monosaccharides

2. The basic unit of a protein molecule is .....

   A. Peptides B. Amino acid C. Allanylglycine D. Albumins

3. Which of the following is not a macromolecule?

   A. RNA B. DNA C. Salt D. Protein

4. The bonds that form between the atoms of polymeric macromolecules are ..... bonds.

   A. hydrogen B. peptide C. disulfide D. covalent

5. Which of the following does not represent a correct monomer/polymer pairing?

   A. Monosaccharide/polysaccharide C. Triglyceride/cellulose

   B. Amino acid/protein D. Nucleotide/nucleic acid

6. Polymerization reactions in which polysaccharides are synthesized from monosaccharides

   A. require the formation of phosphodiester bonds between the amino acids.

   B. are hydrolysis reactions.

   C. depends upon van der Waals forces to hold the amino acids together.

   D. result in the formation of water

7. During the formation of a peptide linkage, a (n) ..... is formed.

A. molecule of water C. hydrophobic bond

B. disulfide bridge D. hydrophilic bond

8. Which of the following is responsible for making every amino acid unique?

A. Amino group C. Carboxyl group

B. Hydrogen D. "R" group

9. Enzymes are:

A. DNA B. Lipids C. carbohydrates D. proteins

10. A protein molecule is made of .....

A. amino acids C. Glucose monomers

B. Glycerol and fatty acids monomers D. only fatty acids

11. The monomers that make up polymeric carbohydrates like starch are called

A. nucleotides B. trisaccharides C. monosaccharides D. nucleosides

12. A simple sugar with the formula C5H10O5 can be classified as a

A. hexose B. polysaccharide C. disaccharide D. pentose

13. DNA and RNA both include

A. pentoses B. hexoses C. fructoses D. maltoses

14. Lactose, or milk sugar, which is composed of one glucose unit and one galactose unit, can be classified as a

A. disaccharide B. hexose C. pentose D. polysaccharide

15. Which of the following is not a function of calcium?

A. formation of Bone and teeth C. development of muscle cells

B. formation of ligaments D. all of them are not functions

16. Which property of water allows the insect called Raft Spider to walk on the surface of water?

A. surface tension C. Liquidity

B. High specific heat D. changing state

III. Fill-in the blank Items

Copy and complete the following table. Place a cross mark (X) in each box as appropriate.

	Globular protein e.g. Haemoglo-bin	Fibrous protein e.g. Collagen	Monosaccharide	Disaccharide	glycogen	Starch	Cellulose	Lipid
Monomer								
Polymer								
Macromolecule								
Polysaccharide								
Contain subunits that form branched chain								
Contains amino acids								
Made from organic acids and glycerol								
Contain glycosidic bonds								
Contain peptide bond								
One of its main functions is to act as an energy store								
Usually insoluble in water								
Usually has a structural function								
Contain the elements Carbon, Hydrogen and Oxygen only								

Short Answer Items

1. Why are biological macromolecules considered as organic?
2. Describe the similarities and differences between glycogen and starch.
3. Explain at least three functions that lipids serve in plants and/or animals.
4. Mention food items that contain calcium.
5. What is the importance of high latent heat of vaporization of water?
6. How are cohesion and adhesion different?
7. Plants must get water from their roots to their branches. Explain how cohesion and adhesion might help plant get water from the ground to its upper leaves?
8. Why do phospholipids form lipid bilayers in aqueous conditions?
9. Unlike glycogen storage in human body, fat storage is unlimited. Why?

Unit 4: Cell Cycle

Content	Learning objectives
4.1 What is a cell cycle 4.2 Cell division 4.2.1 Mitosis 4.2.2 Meiosis 4.3 Renowned Geneticist in Ethiopia	4.1 Outline the series of events taking place in the cell cycle 4.2 Identify the two types of cell division 4.3 Compare and contrast Mitosis and Meiosis 4.4 Explain the importance of cell division 4.5 Recognize the occurrence of cancer cells due to failure to control the cell cycle 4.6 Appreciate the works of renowned Ethiopian Geneticist

4.1 What is a cell cycle?

Objectives

At the end of this section, the student will be able to:

- *define cell cycle,*
- *outline the different stages of cell cycle and*
- *collect information on cancer*

What are the main divisions of a cell cycle ?

Before dealing with cell cycle, it is important to refresh your memory about cell structure and function, particularly the nucleus where key processes of cell reproduction takes place. The next activity (Activity 4.1) gives you opportunity to construct at least two dimensional (2D) cell model to show an animal cell and arrangement of cell organelles using a cardboard or stiff paper. You can follow the same procedure to prepare a model of plant cell, where chloroplasts and cell wall are included as additional structures. The presence of cell wall in your model creates difference in the cytoplasmic division of plant cells and animal cells, which you will learn in the next lesson of cell division.

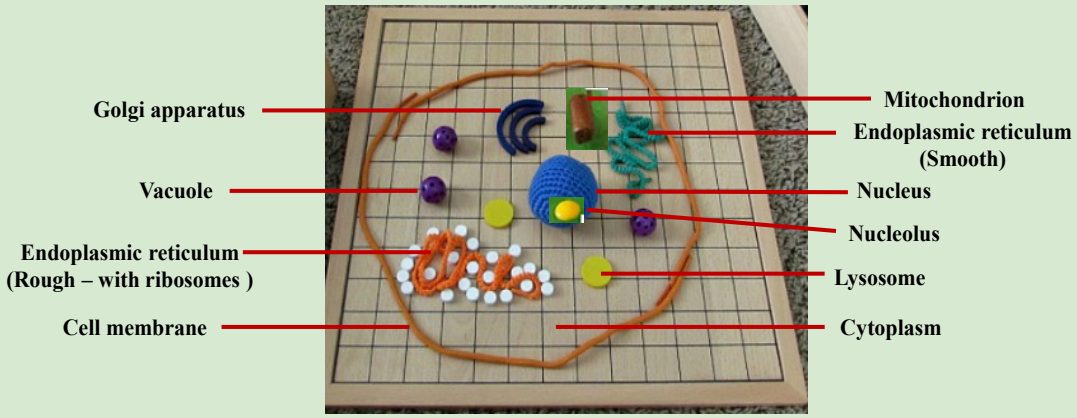
Why not a cell diminishes in size through repeated cell division? What should happen before and after cell division to maintain cell size?

ACTIVITY 4. 1 MODELING

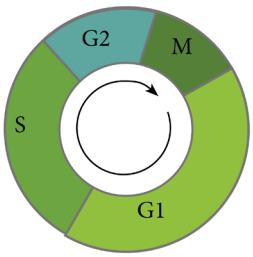
Materials required: Card board or stiff paper. Glue, threads (with different colours), puncher, coloured paper, small beads or . small seeds (e. g. pea , chickpea, lentils), wool or cotton , Scissor

Direction: Perform the activity in small group of two students sharing a seat or a table.

- ✓ First create a round boundary by colour thread to represent the shape and the cell membrane
- ✓ Fix the piece of rolled wool or cotton and the colour bead with glue at the centre to show the position of the nucleus and nucleolus
- ✓ Then , fix small coloured paper (punched out), beads (seeds of similar size or shape) and thin colour threads with glue to represent the different organelles as shown in the figure below
- ✓ Draw the diagram on a paper and label the parts without looking the Figure. Exchange your paper with your neighbor and make corrections to the parts labeled wrong.
- ✓ Discuss why nucleus is important for cell division. Identify the difference between nucleus and nucleolus.



A cell cycle is a sequence of events that takes place in the parent cell as a means of distributing genetic materials thereby forming daughter cells (Figure 4.1). There are two main divisions of the cell cycle: Interphase and cell division.



G1 - growth

S - DNA synthesis

G2 - Growth and preparation for mitosis

M - Mitosis

Figure 4.1 Stages of the cell cycle

Interphase is divided into three phases called G1, S, and G2.

G1 Phase (First Gap): is the first stage of interphase. During this stage, cells are quite active metabolically. They accumulate the building blocks of chromosomal DNA and the associated proteins as well as store sufficient energy reserves to complete the task of replicating each chromosome in the nucleus.

S Phase (Synthesis of DNA): is the stage of DNA replication (Synthesis).

G2 Phase (second gap): is the stage where the cell replenishes its energy stores and synthesizes proteins necessary for chromosome manipulation and movement. Some cell organelles are duplicated during this stage. Cells may continue growing during the G2 phase. Cells make the final preparations before entering into the mitotic phase.

The cell division, on the other hand, includes nuclear division – Karyokinesis (mitosis, or, M - stage) followed by cytoplasmic division (Cytokinesis). This ultimately results in two identical daughter cells. Each daughter cell grows and starts the cycle the mother cell has undergone.

In the next group activity you will have an opportunity to combine skills in computation with geometry to estimate time spent or determine the proportion (percentage) of each stage or phase of cell cycle using Figure 4.1. This can help you to create paper time clock taking one round cell cycle as 360 degree and assuming the whole cell cycle is completed within 24 hrs.

ACTIVITY 4. 2 CRITICAL THINKING

Direction:

Form a small group of 2 or 3 students. Use Figure 4.1 while measuring degree of angles for each stage with corresponding time from the 24 hr (Hint: 150 = 1 hr)

For efficient way to accomplish your task , first divide the circle representing cell cycle into two halves down in the middle with a ruler , and then in half again horizontally. You will get four quarters of 900. This can easily divide your cell cycle into 6 hrs of 150 each.

Once the cell cycle is divided into four segments and the hours will be labelled (24 hr at the top) with one hr (150) interval clock wise

Measure the degree bounding each stage of the cell cycle and calculate the exact time spent for each stage/phase of cell cycle

Use the formula : (Degree measured / 3600) X 24 hr. . Then summarize you results as shown in the next table

Variable	Interphase			Cell division (mitosis + cytokinesis)	Total
	G1	S	G2		
Measured degree					
Time spent (hr)					
Percentage					

Questions

What is the proportion of time spent in interphase as compared to cell division (mitosis & cytokinesis)

Why does a cell spend most of its time in the interphase?

Each stage of cell cycle is not static. What does this mean?

What will happen if cell cycle is not controlled?

The cell cycle in general and cell division has an internal controlling system that enables it to follow regular pattern. If such regulatory system fails to work properly, the cells excessively divide, and this may be called "cell madness". Cancer will occur as a result of failure

Attention

Cancer can start when the controlling factors over cell division and cell growth fail.

Cancer occurs in the absence of growth factors allowing a cell to divide continuously at very high density at the expense of other normal cells

Cancer cells can have a number of problems:

- They might not be able to communicate with healthy cells
- They may not be able to carry out normal cells
- They may not securely anchor themselves like other cells do, which can make them more likely to travel somewhere and spread to other parts of the body

Imagine scraping your elbow. In addition to being uncomfortable, you will lose bunch of skin cells. How does your body make new cells to replace cells that are damaged or lost as a result of injury or accident?

of controlling cell division, Cancer cells do not respond normally to the cell cycle controlling system; they divide in unregulated manner and may invade other tissues of the body

ACTIVITY 4. 3 INTERVIEWING KEY INFORMANTS

Direction:

Go to the nearby health centre around your school or your home and gather information by interviewing health workers about cancer

Your interview should include the following key questions

1. What is cancer?
2. How does cancer affect a person?
3. What should be done to prevent cancer?
4. How can cancer patients be treated?

The Cell division

Objectives

At the end of this section, the student will be able to:

- *recognize the causes of cell division and*
- *explain the importance of cell division*

In grade 9, you have learned that a cell is the basic structural and functional unit of life. It is their ability to reproduce that distinguishes living organisms from non-living organisms. This ability has a cellular basis. There must be at least a single cell to have an organism, such as the unicellular organism amoeba. There are also multicellular organisms with a huge number of cells, which initially start with a single cell or few cells and become multicellular by repeated cell division. As it is stated in cell theory, new cells arise from pre-existing cells by cell division. This fundamental principle, known as the cell doctrine, was originally postulated by Rudolf Virchow in 1858, and it provides the basis for the continuity of life.

Cell division is a basic process in all living things where a parent or mother cell, divides into two daughter cells. An ordered series of events involving cell growth and cell division that produces two new daughter cells are termed the cell cycle. Cells on the path to cell division proceed through a series of precisely timed and carefully regulated stages of growth, DNA replication, and nuclear and cytoplasmic division that ultimately produces two identical (clone) cells.

As the cell grows the volume of cytoplasm relative to the cell membrane will be small that it will have .low surface area to volume

ratio. As a result material transport across the cell membrane by simple diffusion will be inadequate for the cell to survive. Moreover, as the size of the cell increases the controlling power of the nucleus is highly minimized. Thus to solve these problems cell employs a mechanism called cell division by which one cell become two or more.

What causes a cell to divide?

What is the importance of cell division to organisms ?

You already know the cause of cell division, but it should also be noted that the cell is increasing its number as it divides repeatedly. The increase in cell number in turn is important for many reasons. In unicellular organisms, cell division is a means of reproduction or getting new offspring. For instance, Amoeba is unicellular. When a single cell Amoeba divides, it has increased its population, i.e. Number of Amoebae (offspring). In multicellular organisms, cell division is a means of increasing cell number either for growth or to replace damaged/dead cells and repair the body. In sexually reproducing organisms it occurs around reproductive organs as a means of getting gametes or sex cells. .

From your previous lesson on cell cycle (Refer to Figure 4.1) cell division continues after G_2 stage of the interphase. Cell division consists of two sub divisions

i) Nuclear division (Karyokinesis) – results in the separation and distribution of duplicated genetic materials of mother cell (dividing cell) to daughter cells by mitosis or meiosis.

ii) Cytokinesis (cytoplasmic division) - is the separation of the cytoplasmic components into the daughter cells.

Hereafter, you will learn the pattern of arrangement and redistribution of the duplicated genetic material during mitosis and meiosis.

ACTIVITY 4.4: PEER DISCUSSION

Direction:

Carefully read the questions asked below. Think about cell division taking place in human body. Discuss with a friend sitting next to you. Compare your answers with your classmates

- Where does cell division occurs mainly for tissue renewal rather than growth – Is it in a child or in adult human body?
- Mention our body part where cells are undergoing continuous replacement. Why is this so?

4.2.1 Mitosis

Objectives

At the end of this section, the student will be able to:

- *outline the pattern of mitotic cell division,*
- *tell how mitosis produces daughter cells as an exact copy of mother cell and point out the importance of mitosis*

What is mitosis?

Mitosis is a type of nuclear division where duplicated chromosomes of a single mother cell are distributed between two identical daughter cells, having the same number and kind of hereditary materials (chromosomes) as the parent nucleus. As a result, a diploid (2n) mother cell gives rise to two diploid (2n) identical daughter cells.

How does a cell divides by mitosis?

As illustrated in Figure 4.2, apart from cytokinesis (cytoplasmic division), mitosis as nuclear division (Karyokinesis) is divided into a series of phases namely; prophase, metaphase, anaphase, and telophase.

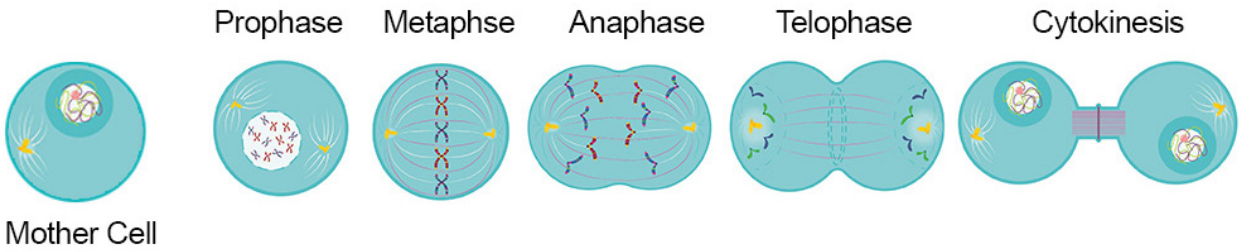


Figure 4.2 Illustration of cell division by mitosis

Attention

- The term mitosis was first coined by Walther Flemming in 1882 when he discovered that chromosomes during cell division split longitudinally to distribute themselves equally between two daughter cells.
- The end result of mitosis is growth of the eukaryotic organism and replacement of damaged or dead cells
- After fertilization (union of sperm cell and egg cell), the growth of the zygote occurs by cell division through mitosis into the 2 – cell stage, then 4 – cell stage, 8 – cell stage, 16 – cell stage, and so. This is called **Cleavage.**

What happens in the different phases while a cell undergoes mitosis?

Detailed description of what actually happens at different phases of mitosis is presented as follows:

1. **Prophase (the "first phase"):** During this phase

- each duplicated chromosome, composed of two sister chromatids and, containing identical genetic material pairs up.
- the nuclear membrane breaks down, the nucleolus disappears.
- chromosomes shorten, thicken and become visible.
- the centrosomes begin to move to opposite poles of the cell, and spindle fibres emerge from the centrosomes (two in numbers and located outside the nucleus) - Figure 4.2

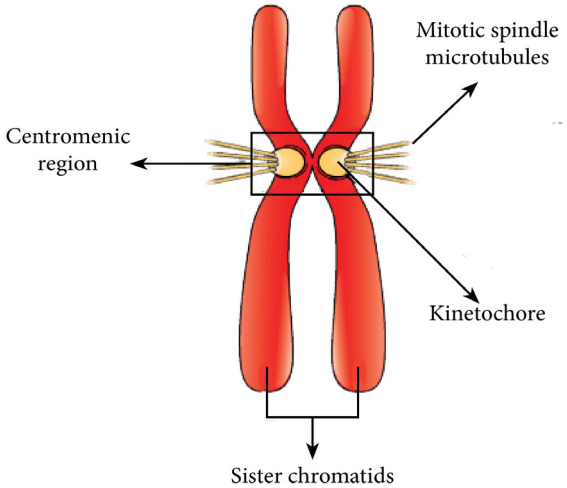


Figure 4.3 Sister chromatids: Mitotic spindle emerging from the centrosomes

What is the significance of cell division through mitosis?

2. Metaphase (arrangement phase)

During this phase

- mitotic spindles are fully developed with centrosomes at the opposite poles.
- chromosomes line up (arrange themselves) end–to–end along the centre or metaphase plate (equatorial plane) of the cell.
- each sister chromatids are attached to a spindle fibre originating from opposite poles.

3. Anaphase (migrating phase)

- During this phase cohesion proteins binding the sister chromatids together known as centromere, breakdown.
- separated sister chromatids are pulled apart by the mitotic spindle which drags one chromatid to one pole and the other chromatid to the opposite pole. This will ensure daughter cells receive chromosomes that are the same in number and kind.

4. Telophase (a reverse of prophase)

This phase is also known as a reversed prophase because what has disappeared during the interphase will reappear during the telophase and vice versa. Accordingly,

- nuclear membrane reappears and surrounds each set of chromosomes to create two new nuclei arriving at opposite poles.
- The mitotic spindle breaks down and disappears.

Cytokinesis, also known as cytoplasmic division, will take place after the four stages of mitosis (nuclear division) are completed. However, its completion in animal cell is different from plant cell. As animal cell is surrounded only by cell membrane, cytokinesis enables the cytoplasm of the mother cell to pinch or constrict in the middle. As a result the two daughter cells entirely separate. However, as plant cell is surround by hard cell wall in addition to the cell membrane , the cytoplasm cannot simply pinch off and fully separate; instead a new wall will be laid down between the two daughter cells, Thus, the two adjacent cells remained joined together by the middle wall – called **middle lamella**

The redistribution of duplicated chromosomes through mitosis is important to get two daughter cells from single diploid mother cell that are identical in quality and quantity of chromosomes.. The process of mitosis is important to increase cell number, which in turn is essential for growth. We, human beings, after the union of

haploid (n) sperm and haploid (n) egg started as a zygote, which is diploid (2n). Then the zygote by repeated cell division through mitosis develops into multicellular organism. This is how we human beings are made up of million cells.

Cells have a finite life span; they wear out or become damaged; so they need to be replaced continuously. The process of growth, repair and replacement of dead cells all rely on cell division through mitosis. Unicellular organisms like Amoeba also use cell division through mitosis to increase their number or population.

http://www.differencebetween.net/science/difference-between-homologous-chromosomes-and-sister-chromatids/#ixzz72kDLiFk2

Key terms

Spindle fiber – is long protein fiber extending from structures called centrioles. It starts from the pole of the cell and extends up to the centre, where it is linked to duplicated chromosomes arranged for distribution. It is necessary to pull chromosomes separated towards the pole during the anaphase stage of cell division

Homologous chromosomes – are couples of one maternal and one paternal chromosome paired up during fertilization. They are paired chromosomes, each of which represents a parent for a unit character such as height, body colour, sex etc. The best analogy for homologus chromosomes, is paired shoe with the same number . Every person like the unit character has same number , say shoe size 41, two in number and fit to the right and left feet of Mr/Mrs "X" or "Y". Likewise, in humans each diploid (2n) body (somatic) cell has 23 pairs of homologous chromosomes, giving a total of 46 (2 X 23) chromosomes.

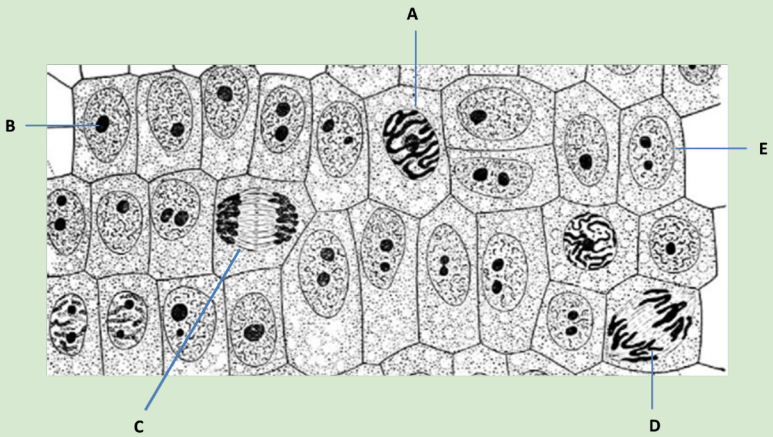
Sister chromatids: Two copies of one maternal or paternal chromosome linked together by cohesive protein on the centromere.

ACTIVITY 4.5 GROUP WORK

Direction:

The figure below shows different phases of mitosis in onion cells as seen under the microscope

Form a small group and carefully look at the figure, and based on your lesson about mitosis, identify the phases represented by letters "A" to "E". Compare your answer with other groups and defend yourself if there is any difference.



4.2.2 Meiosis

Objectives

At the end of this section, the student will be able to:

- *outline the pattern of cell division by meiosis,*
- *tell the importance of meiosis and*
- *point out the difference between mitosis and meiosis*

What is meiosis? How does it differ from mitosis?

The process of meiosis is a characteristic feature of organisms that reproduce sexually. It occurs in reproductive organs such as ovaries of female animals, testes of male animals, anther and ovules of flowering plants. Meiosis involves two fissions of the nucleus giving rise to four gametes or sex cells, each possessing half the number of chromosomes (n) present in the mother cell. Meiosis is called **reduction division,** as the final daughter cells are haploid (n) as compared to the diploid (2n) mother division.

What would happen if the human gametes (sperm cell and egg cell), had 46 chromosomes like the other body cells? The answer is simple that there will be 92 chromosomes in the zygote, which will not be normal. Thus, during gametogenesis (gamete formation) in human ovaries and testes, the 46 chromosomes in the initial mother will be reduced by half to 23 chromosomes by meiosis. As a result, the sperm or egg cells nuclei will have 23 chromosomes (haploid, abbreviated as n). So, when sperm and egg join together at fertilization, a zygote that contains the normal number of 46 chromosomes (23 pairs, Diploid abbreviated as 2n) will be formed.

Why is meiosis so important?

Figure 4.4 depicts the different phases of meiosis I and II. A short description of each phase is presented in Table 4.1

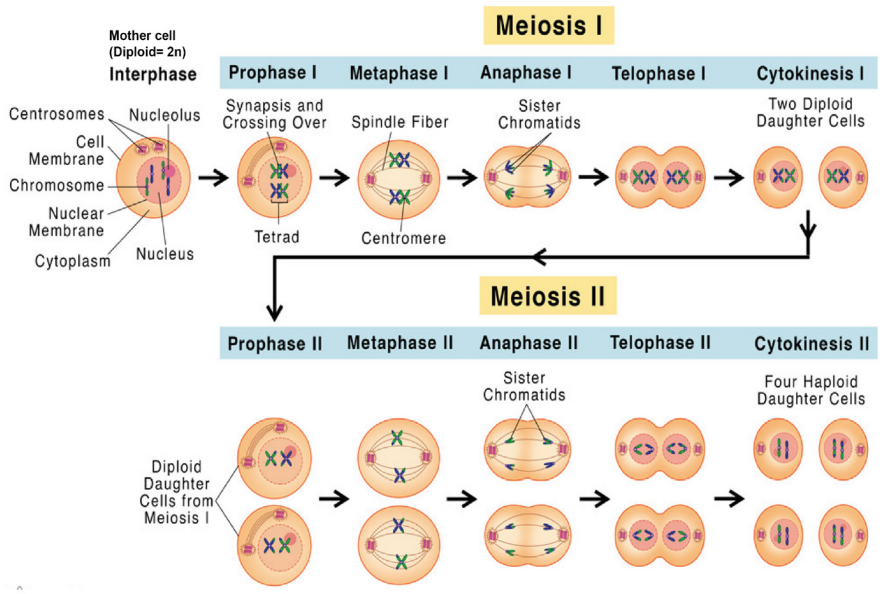


Figure 4.4 Illustration of meiosis I and Meiosis II

Table 4.1 Description of the different stages of Meiosis I and Meiosis II

Stage	Description
Prophase I	Each chromosome appears shortened and thickened form two chromatids Homologous chromosomes pair up
Metaphase I	Chromosomes align on spindle fiber; lining up in the middle or metaphase plate
Anaphase I	The centromere joining sister chromatids do not separate The pair of chromatids from each homologous pair moves to the end (pole) of the cell. Reduction to haploid (n) will take place because homologous chromosomes of male and female parents separate
Telophase I	The nuclear membrane reforms and the cells begin to divide. In some cells, the cell continues to full cytokinesis while in other cells there may be prolonged interphase but with no further DNA duplication
Prophase II	New spindles are formed and the chromosome, still made up of paired chromatids moves toward the middle of the cell.
Metaphase II	The chromosomes line up in the metaphase plate , with the spindle attached to the sister chromatids of each chromosome coming from the opposite poles.
Anaphase II	The centromeres divide and sister chromatids separate and pulled to the opposite ends of each cell
Telophase II	Nuclear membrane reappears, the chromosomes return to the interphase state Cytokinesis follows giving four daughter cells each with half the chromosome number of the initial parent (mother) cell

ACTIVITY 4.6 DEMONSTRATION

Direction

- With your small group (two pairs of neighbouring students) discuss and attempt the following questions/task

  Is it Meiosis I or Meiosis II that is similar to mitosis? Why so?

  What are the basic similarities between Mitosis and meiosis)?
- Prepare a table of comparison that shows difference between Mitosis and meiosis
- Let students bring threads with different colours (red and green). Show them how they start with homologus chromosomes (paternal and maternal chromosomes represented by red and green threads). Demonstrate the different stages of nuclear division with small pieces of the colour threads and show the result of chromosomal duplication and redistribution that occur first in mitosis and then in meiosis
- Ask students to repeat what has been demonstrated and identify the difference in mitosis and meiosis .

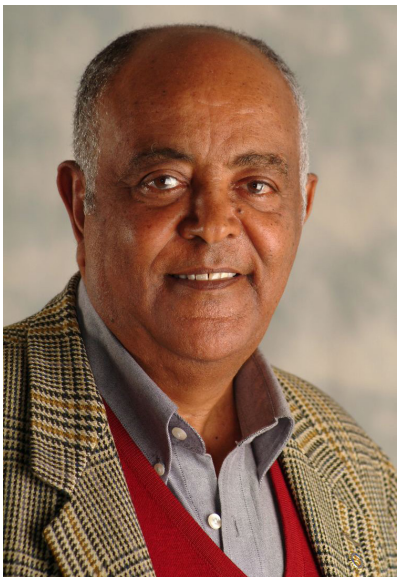
4.3 Renowned Ethiopian Geneticist

Objectives

At the end of this section, the student will be able to:

- *appreciate the work of a renowned geneticist and*
- *look for more Ethiopian Geneticist who contributed a lot to their field*

Dr. Melaku Worede



Dr. Melaku Worede, a geneticist and agronomist, is renowned for employing science to benefit poor farmers and saving Africa's seeds from extinction. He was awarded the "Right livelihood Award" in 1989" for preserving Ethiopia's genetic wealth by building one of the finest seed conservation centres in the world." He played key role in the establishment of the Plant Genetic Resource centre in Addis Ababa, where he became Director in 1979 and served for more than 14 years – until retirement

After retirement, Dr. Melaku developed his pioneer work on a framing based native seed (landrace) conservation, enhancement and utilization. He was able to develop and grow locally adapted native seeds (e.g durum wheat) without commercial fertilizers or other chemicals. He was able to show that his native seeds exceeded their high in put counterparts on the average by 10 – 15% and the original farmers' cultivars by 20 – 25% in yield.

ACTIVITY 4.6 PEER DISCUSSION

Direction

- Carefully read the work of Dr Melaku and share your impression with a friend sitting
- with you
- Form a group of four students and look for more renowned Ethiopian Genetists from books and /or the internet. Organize a report to share with your classmates.

Unit Summary

- A cell cycle is a sequence of events that takes place in the parent cell as a means of distributing genetic materials thereby forming daughter cells. There are two main divisions of the cell cycle: Interphase and Cell division.
- Interphase is the stage of preparation where a cell exhibits growth and DNA (genetic material synthesis)
- Cell division is nuclear division either by mitosis or meiosis followed by cytoplasmic division (cytokinesis).
- Cell division is a basic process in all living things where a parent **or mother cell**, divides into two cells, called **daughter cells**.
- Cell division is a means of growth and replacing damaged or dead cells in multicellular organisms. It is equivalent to reproduction in unicellular organisms.
- Mitosis is a division of the somatic (body) cells to form identical daughter cells. It has four stages namely prophase, metaphase, anaphase, and telophase.
- Meiosis is a division of reproductive cells, resulting in daughter cells sex cells (gametes) with half of the chromosomes in the initial or mother cell.
- In meiosis a cell divides twice, Meiosis I and Meiosis II, resulting in four daughter cells.
- In meiosis I, homologous chromosomes separate and move to opposite cells. This is a reduction by half, going from diploid (2n) to haploid (n).
- In meiosis II, sister chromatids separate and move to opposite poles of the cell.
- Meiosis occurs only in reproductive organs such as testes and ovaries while mitosis occurs in body (somatic) cells.

Review Questions

True – False items: Say "**True**" or "**False**" for the following statements on your exercise book.

1. It is meiosis I that resembles mitosis.

2. Homologus chromosomes are duplicated one parent chromosomes.

3. Meiosis results in four haploid daughter cells.

4. DNA duplication is the longest phase of the interphase.

5. Prokaryotic organisms like Bacteria do not divide by mitosis.

Matching items: Match the terms under **"Column B"** with the descriptions under **"Column A"**

Column A	Column B
1. known as cytoplasmic division	Anaphase
2. paired maternal and paternal chromosomes	Cytokinesis
3. pull chromosomes to opposite ends of a cell	Homologous chromosomes
4. arrangement of chromosomes at the metaphase plate	Interphase
5. separation of sister chromatids	Metaphase
6. duplicated one parent chromosmes	Sister chromatids
	Spindle fiber
	Telophase

Short answers

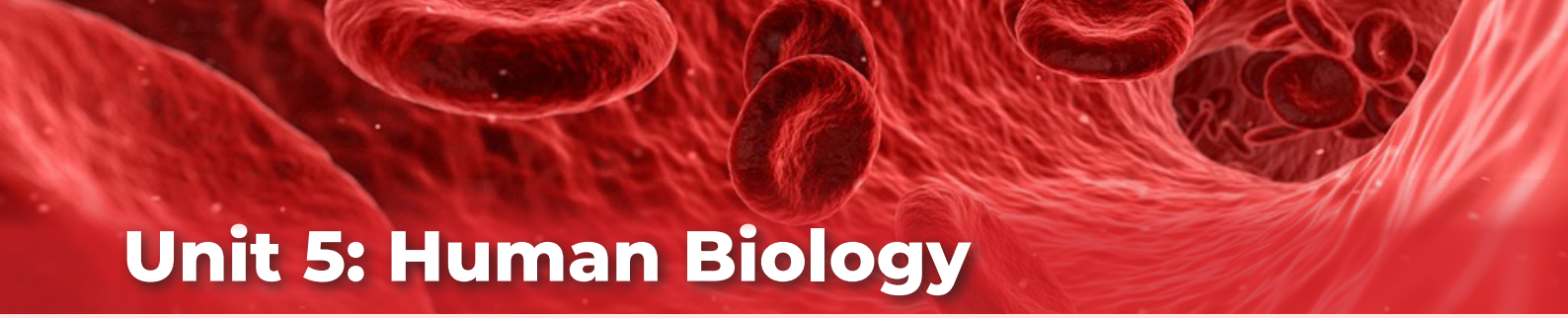
1. What is the importance of meiosis to sexually reproducing organisms?
2. Mention at least two important features of cancer cells.
3. What is the difference between interphase and prophase?
4. What would happen if there is no cytoplasmic division at the end of telophase?

If a cell is having 2n=40 divide by meiosis

A. How many cells are formed at the end of meiosis i? meiosis ii?

B. How many chromosomes are there in each daughter cells at the end of meiosis i? meiosis ii?

C .How many set of chromosome(s)/is/ are there at the end of meiosis i? meiosis II?



Unit 5: Human Biology

Content	Learning objectives
5.1. Digestive system 5.2. Circulatory and Lymphatic system 5.2.1. Blood donation 5.2.2. Diseases of the circulatory and lymphatic systems (leukemia, varicose vein, elephantiasis, cardiovascular diseases) 5.3. Breathing system 5.4. The excretory system 5.5. The immune system 5.6. Renowned Physicians in Ethiopia	• Discuss the structure and function of the digestive system (alimentary canal and accessory organs). • Classify the types of digestion along the alimentary canal • List the end products of carbohydrates, proteins, and fats after complete digestion • Express the site of absorption of digested food, minerals, vitamins, and water • Explore structural adaptations of the small intestine for the absorption • Differentiate the absorption routs of different end products of digestion (hint: lacteals, capillaries) • Group enzymes of the digestive system based on their roles and pH • Demonstrate the structure of the heart using a heart model/ diagram • Differentiate between pulmonary and systemic circulations. • Compare and contrast arteries and veins based on their structures and functions • Debate on the importance of blood donation and its health implications on the donors and recipients. • Discuss the key functions and components of the lymphatic system. • Define the immune system • Discuss the types of immunity (innate and acquired). • Relate the lymphatic system with the immune system • Discuss the diseases of the circulatory and lymphatic systems (leukemia, varicose vein, elephantiasis, cardiovascular diseases) • Draw and label the human breathing and excretory systems • Show the link between the human breathing system and the circulatory system • Demonstrate the mechanism of breathing using locally available materials • Design a model of one of the systems (excretory, circulatory, digestive systems) using locally available materials • Examine the effects of smoking and cannabis on the normal functioning of the breathing systems.

5.1 The Digestive System

Objectives

At the end of this section, the student will be able to:

- *discuss the structure and function of the digestive system (alimentary canal and accessory organs),*
- *classify the types of digestion along the alimentary canal,*
- *list the end products of carbohydrates, proteins, and fats after complete digestion,*
- *express the site of absorption of digested food, minerals, vitamins, and water,*
- *explore structural adaptations of the small intestine for the absorption,*
- *differentiate the absorption routs of different end products of digestion (hint: lacteals, capillaries), and*
- *group enzymes of the digestive system based on their roles and pH.*

What do you know about the digestive system?

All living organisms need nutrients to survive, plants can obtain nutrients from their roots and the energy molecules required for cellular function through the process of photosynthesis. Animals, however, obtain their nutrients through the consumption of other organisms. At the cellular level, the biological molecules necessary for animal function are amino acids, lipid molecules, nucleotides, and simple sugars. However, the food consumed consists of protein, fat, and complex carbohydrates. Animals must convert these macromolecules into the simple molecules required for maintaining cellular function. The conversion of the food consumed to the nutrients required is a multistep process involving digestion and absorption. During digestion, food particles are broken down into smaller components, which are later absorbed by the body. This happens by both physical means, such as chewing and by chemical means, via enzyme-catalyzed reactions. These processes take place in the human digestive system step-wise.

Activity 5.1 THINK-PAIR-SHARE

In your previous grades, you have studied about the digestive system of human beings. Now, be in groups of 2-3 students on the same desk and discuss what you know about the digestive system and the process that takes place beginning from the mouth to the anus and let one of you share it to the whole class.

The human digestive system is composed of four digestive processes:

1. **Ingestion** - the taking in of nutrients, in the mouth,
2. **Digestion** - the breakdown of complex organic molecules into smaller components by enzymes step-wise, physical, and chemical processes that begins in the oral cavity and extends to the small intestine,
3. **Absorption** - the transport of digested nutrients from the small intestine to the cells of the body though finger like projection called villi in the small intestine, and

What are the components and processes of the digestive system?

Do you have any idea about the relationship between biology and other sciences?

4. **Egesting** - the removal of food waste from the body. The distinction between excretion and egestion is based on the type of wastes excreted by an organism. Undigested food that remains after digestion is expelled in animals during the egestion process. Excretion is the process through which metabolic wastes are expelled in both plants and animals.

The digestive tract of adult humans is normally 6.5 m to 9m long. It stores and breaks down organic molecules into simpler components. Physical (mechanical) digestion begins in the mouth, where food is chewed and formed a **bolus** (the Greek word for the ball) by the tongue. Physical digestion breaks food into smaller pieces, increasing the surface area for chemical digestion.

Where in the alimentary canal does the chemical digestion begin?

Activity 5.2 Group work

Form a group of 3-4 students and:

1. discuss the structure and functions of the digestive system;
2. draw, label and study the route of the alimentary canal and the types of digestion (mechanical and chemical) along the alimentary canal;
3. discuss digestion end products; and
4. support your activity using virtual lab (digestive system animation) using internet and other resources.

The chemical digestion of carbohydrate (starch) starts in the oral cavity by an enzyme called salivary amylase or ptyalin. The food is then swallowed and enters the **esophagus** a long tube that connects the mouth to the stomach. Using **peristalsis**, wave-like smooth-muscle contractions, the muscles of the esophagus push the food toward the stomach. The stomach contents are extremely acidic, with a **pH** between 1.5 and 2.5. This acidity kills microorganisms, breaks down food tissues, and activates digestive enzymes. The chemical digestion of protein starts in the stomach by the enzyme pepsin.

Further breakdown of food takes place in the **small intestine** where bile is produced by the liver, and enzymes produced by the small intestine and the pancreas, continue the process of digestion. The smaller molecules are absorbed into the bloodstream through the epithelial cells lining the walls of the small intestine. The waste material travels onto the **large intestine** where water is absorbed and the drier waste material is compacted into **feces;** it is stored in the **rectum** until it is excreted through the **anus.**

The Oral Cavity

What is the process of digestion that takes place in the mouth?

In the oral cavity, both physical and chemical digestion begins. It is the point of entry (ingestion) of food into the digestive system. The process that takes place in the mouth includes:

1. the food is broken into smaller particles by mastication, the chewing action of the teeth.
2. saliva, the watery fluid produced by the salivary glands contains

If one ingests glucose where will it be digested?

amylase enzyme, and breaks down starches into simpler molecules.

3. saliva dissolves food particles and makes it possible to taste what is being eaten.

4. saliva lubricates the food so that it can be swallowed.

5. we detect the flavour when food particles dissolved in saliva penetrate the cells of the taste buds located on the tongue and cheeks.

6. the tongue, positions and mixes food and forms a ball of food called bolus ready to be swallowed.

Activity 5.3 Individual work

Dry your tongue and distribute a small amount of salt on it to dissolve in saliva.

What do you feel? Have you detected any test? Why?

The teeth

What is the importance of teeth in digestion? Can you mention the different types of teeth?

The teeth are important structures for physical digestion (**Figure 5.1**). There are 4 types of teeth:

Incisors: are eight chisel-shaped teeth at the front of your mouth specialized for cutting.

Canine: teeth that are sharp, dagger-shaped specialized for tearing.

Premolar: teeth that are broad flattened specialized for grinding.

Molars: teeth tend to be even broader and have cusps that are even more flattened. They are designed for crushing and grinding food. The last set of molars is the **wisdom teeth**, so-called because they usually do not emerge until we reach about 16 to 20 years of age. Each tooth is covered with enamel, which is the hardest substance in the human body.

Activity 5.4 Group work

In group of 2-3 students, answer the following questions:

- Draw and label parts of a single teeth.
- Classify your teeth according to their functions.
- What are the reasons for the teeth decay?

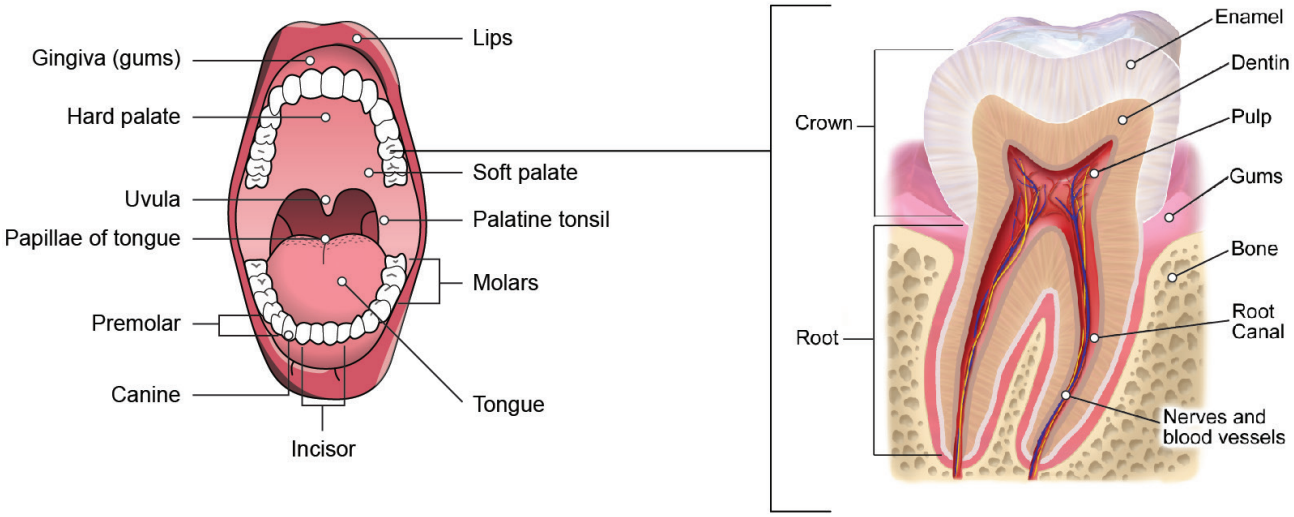


Figure 5.1 The structure and types of teeth

External and internal structures of teeth

The teeth are the hardest substances in the human body. Besides being essential for chewing, the teeth play an important role in speech. Parts of the teeth include:

Enamel: the hardest, white outer part of the tooth. Enamel is mostly made of calcium phosphate, a rock-hard mineral.

Dentin: a layer underlying the enamel. It is a hard tissue that contains microscopic tubes. When the enamel is damaged, heat or cold can enter the tooth through these paths and cause sensitivity or pain.

Pulp: the softer, living inner structure of teeth. Blood vessels and nerves run through the pulp of the teeth.

Periodontal ligament- tissue that helps to hold the teeth tightly against the jaw.

Roots- is the part of the tooth that extends into the bone and holds the tooth in place. It makes up approximately two-thirds of the tooth

Gums. Gums, also called gingiva, are the fleshy, pink connective tissue that's attached to the neck of the tooth and the cementum.

Crown: the crown of a tooth is the top portion of the tooth that is visible.

Human dentition

The conventional way of expressing the total number of teeth in the human beings are represented: incisor(I), canines(C), molars(M) and premolars(P). It gives a set like I:C:P:M. For example, if it is given 2:1:2:3 for upper teeth then, it indicates 2 incisors, 1 canine, 2 premolars and 3 molars of the upper mouth on one side. Include the dental formula

The dental formula of human beings (adults):

$(2123/2123) \times 2 = 32(2123/2123) \times 2 = 32$

There are 2 incisors, 1 canine, 2 premolars and 3 molars. In adults, dentition pertains to all types of teeth development. In a normal adult there are 32 teeth. There are two types of dentition: **temporary and permanent**. There are 20 teeth in the temporary dentition and 32 teeth in the permanent dentition. In a child, there are 20 teeth present which are called **milk teeth** or **deciduous teeth**. These teeth grow at the age of 6 years. i. e.

$(2102/2102) \times 2 = 20(2102/2102) \times 2 = 20$. These are two incisors, 1 canine and 2 molars.

In order to represent the total number of the teeth in the jaw or

mouth, the whole formula is multiplied by two as the formula for one side of the mouth. Both monkeys and human beings have the same set of teeth and the same dental formula.

Keeping teeth health

Adult teeth should last you all through your life. However, this doesn't always happen, because your teeth can be affected by bacteria that cause dental caries. There are many different bacteria that are found naturally in your mouth. These bacteria, combined with food and saliva, form a thin film known as plaque on your teeth. If these bacteria are given a sugar-rich diet (in other words, if you eat a lot of sweet, sugary food) they produce a lot of acid waste. This acid attacks and dissolves the tough enamel coating of your teeth. Once through the enamel, the acid also dissolves away some of the dentine and then the bacteria can get into the inside of your tooth. The bacteria will then reproduce and feed, eating away at your tooth until they reach the nerves of the pulp cavity causing toothache. The same bacteria can affect your gums, causing **periodontal disease**. The symptoms include tender gums, bleeding when you clean your teeth and eventually the possible loss of all your teeth, not from tooth decay but from gum disease. Taking in lots of acidic food and drink, such as fruits and cola, can also weaken the enamel on your teeth. This is particularly the case if you clean your teeth straight after an acidic drink such as fruit juice or cola, when the softening effect on the enamel is strongest and brushing your teeth can actually wear the enamel away.

Tooth and gum disease are extremely common all over the world. They cause pain, bad breath, loss of teeth and difficulty eating. The good news is that they can both be avoided, especially if you have good dental care available. Ways to avoid tooth decay include:

- Regular brushing of your teeth and gums twice a day. This removes the plaque from the teeth, preventing the build-up of a sticky, acidic film over the enamel.
- Avoiding sweet, sugary foods – if the bacteria in your teeth are deprived of sugar, they cannot make acidic waste and your teeth are safe.
- Have regular dental check-ups. A dentist can clean your teeth more thoroughly than you can, and any early signs of decay can be treated. Your teeth won't heal themselves, but any tooth decay can be removed and replaced by a filling.

The Esophagus

The swallowed food travels from the mouth to the stomach by way of the esophagus. The bolus of food stretches the walls of the esophagus,

Activity 5.5 Answer to the questions

After studying the digestive system in the mouth, answer the following questions:

1. Discuss the structure and function of the teeth.
2. What are the functions of saliva?
3. How does chewing assist in the digestion of food?
4. What are amylase enzymes, and why are they necessary?
5. How is food moved along the esophagus?

activating muscles that set up waves of rhythmic contractions called peristalsis. Peristaltic contractions, which are involuntary, move food along the gastrointestinal tract (Figure 5. 2). Peristaltic action will move food or fluid from the esophagus to the stomach. Look at the process of peristalsis in figure 5.2.

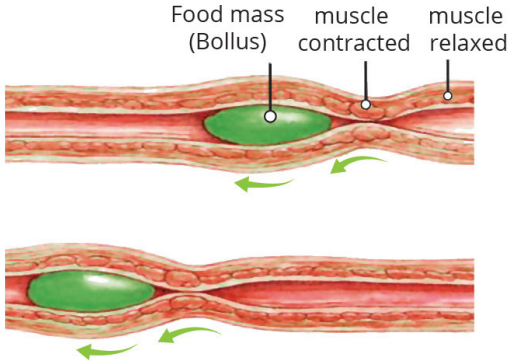


Figure 5.2 Rhythmic contractions of muscle move food along the digestive tract

What are the processes of digestion that take place in the stomach?

The stomach

The stomach is the site of food storage and initial protein digestion. The stomach contains three layers of muscle, which run in different directions so that the muscle contractions can churn the food (Figure 5.3 (a)). The movement of food to and from the stomach is regulated by circular muscles called sphincters. Sphincters act like the draw strings on a bag. Contraction of the lower esophageal sphincter (LES) closes the opening to the stomach, while its relaxation allows food to enter. The lower esophageal sphincter prevents food and acid from being regurgitated up into the esophagus. A second sphincter, the pyloric sphincter, regulates the movement of food and stomach acids into the small intestine (Figure 5.3(b)).

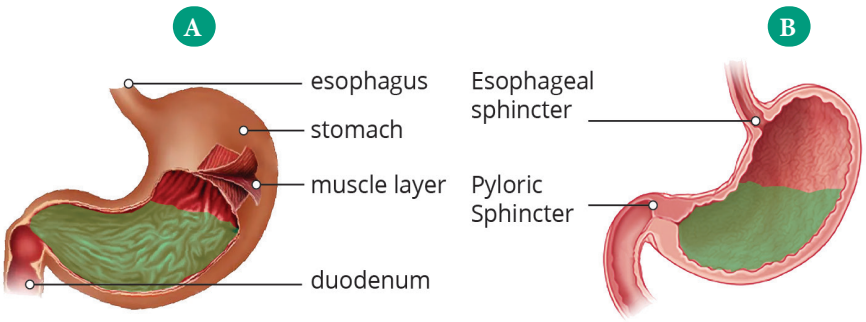


Figure 5.3 a) Muscle is responsible for the contractions of the stomach b) Sphincters regulate the movement of food.

The J-shaped stomach has numerous ridges that allow it to expand so that it can store about1.5L of food. Millions of cells line the inner wall of the stomach. Activities in the stomach:

1. the cells secrete the various stomach fluids, called **gastric fluids or gastric juice**, that aid digestion,
2. contractions of the stomach mix the food with the gastric fluids, and
3. it is involved in both physical (churning action if stomach wall) and chemical digestion(e.g. digestion of proteins by the action of enzyme pepsin).

Approximately 500mL of the fluids in the stomach are produced following a large meal.

What is the composition of gastric juice?

Gastric fluid includes:

1. mucus,
2. hydrochloric acid (Hydrochloric acid (HCl)),
3. pepsinogens, and other substances.

Hydrochloric acid kills many harmful substances that are ingested with food. It also converts pepsinogen into its active form, pepsin, which is a protein-digesting enzyme. Pepsin breaks the long amino acid chains in proteins into shorter chains, called polypeptides.

The pH inside the stomach normally ranges between 2.0 and 3.0 but may approach pH 1.0. Acids with a pH of 2.0 can dissolve fibers in a rug. It is the high acidity of hydrochloric acid that makes it effective at killing pathogens and allows pepsin to do its work.

How does the stomach safely store these strong chemicals, both of which dissolve the proteins that makeup cells?

A layer of alkaline mucus protects the stomach lining from being digested. Pepsinogen passes across the cell membrane and is activated by Hydrochloric acid (HCl) to become pepsin. The pepsin breaks down the proteins in the food, but not the proteins of the stomach's cells because these proteins are protected by the mucous layer. The esophagus does not have a protective mucous layer, so if the lower esophageal sphincter (LES) is weak, stomach acid may enter the esophagus and damage its lining. This causes pain known as heartburn.

The partially digested food and gastric juice mixture are called **chyme.** Gastric emptying occurs within two to six hours after a meal. Only a small amount of chyme is released into the small intestine at a time. The movement of chyme from the stomach into the small intestine is regulated by hormones, stomach distension, and muscular reflexes that influence the **pyloric sphincter.** The low pH of the stomach will denature the **amylase and lipase** that were secreted in the mouth. Therefore, over time, the chemical digestion of starches and fats will decrease in the stomach and their further digestion will take place in the small intestine.

What do we call the partially digested food in the stomach?

What is the reason for the release of small amount of chyme in to the small intestine at a time?

Absorption in the stomach

Although the stomach absorbs few of the products of digestion, it can absorb many other substances, including glucose and other simple sugars, amino acids, and some fat soluble substances, water, specific vitamins, and alcohol, etc.

The small intestine

The small intestine is up to 7 m in length, but only 2.5 cm in diameter (**Figure 5.4a**). Most chemical digestion takes place in the small intestine. Parts of the small intestine:

1. **duodenum** the first 25 cm to 30 cm of the small intestine where the majority of digestion occurs,
2. **jejunum** is the second component of the small intestine **and**
3. **ileum** the third component

The small intestine secretes digestive enzymes and moves its contents along by peristalsis. The stomach absorbs some water, specific vitamins, some medicines, and alcohol, but most absorption takes place within the small intestine. Long finger like projections called villi (singular: villus) greatly increase the surface area of the small intestine (**Figure 5.4(b)**). One estimate suggests that villi account for a tenfold increase in surface area for absorption. The cells that make up the lining of each villus have microvilli, which are fine, threadlike extensions of the membrane that further increase the surface for absorption.

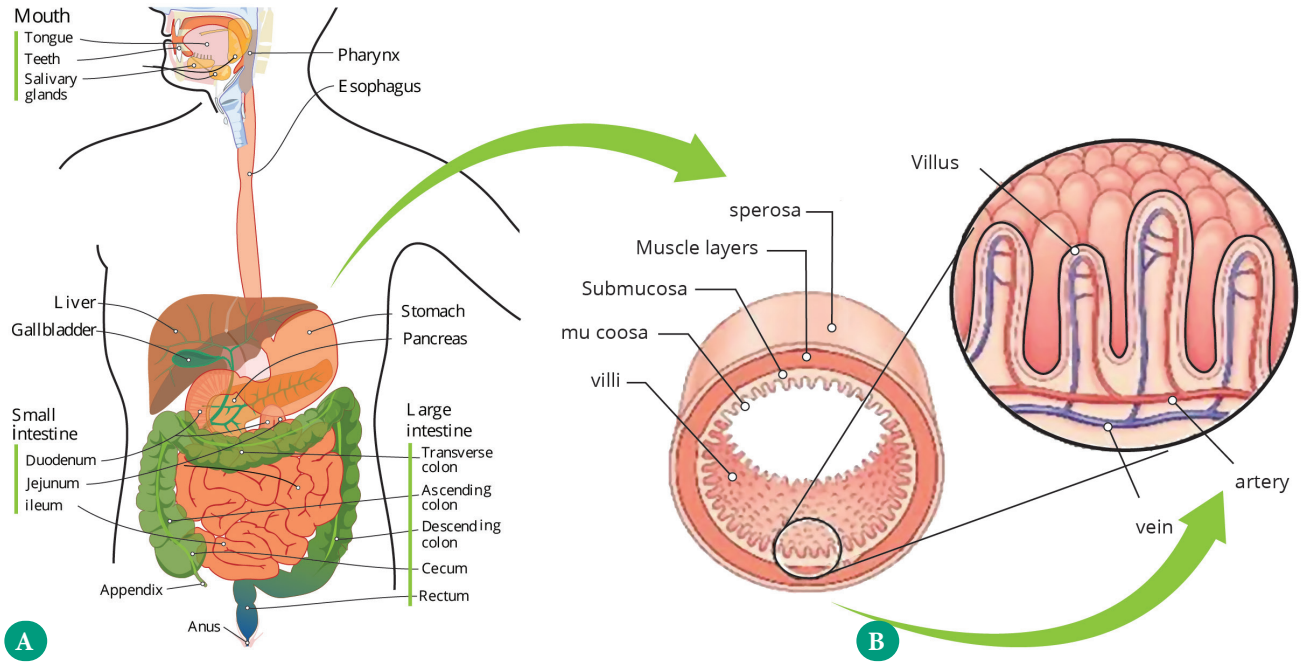


Figure 5.4 Parts of the digestive system and the absorption villi

Each villus is supplied with a capillary network that intertwines with **lymph vessels called lacteals** that transport materials. Some nutrients are absorbed by diffusion, but some nutrients are actively transported from the digestive tract. Monosaccharides and amino acids are absorbed into the capillary networks; **fats** are absorbed into the **lacteals**(Figure 5.5).

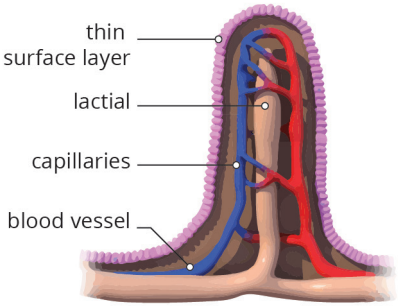


Figure 5.5Anatomy of a villus, with the lacteal

Activity 5.6 Group work

In a group of 2-3 students, discuss:

1. the sites of absorption of digested foods, minerals, vitamins, water;
2. the structural adaptation of the small intestine (villi with lacteals and capillaries) for absorption.
3. Present you work to the class.

Finally, your teacher will summarize the sites of absorption; adaptations of the small intestine for absorption and the roles of lacteals and capillaries.

The accessory organs

What are accessory organs?

The organs discussed above are the organs of the digestive tract through which food passes. Accessory organs add secretions and enzymes that break down food into nutrients. Accessory organs include:

- the salivary glands,
- the pancreas,
- the liver, and
- the gall bladder.

The secretions of the pancreas, liver, and gallbladder are regulated by hormones in response to food consumption. The liver is the **largest internal organ** in humans and it plays an important role in the digestion of fats and detoxifying blood. The liver produces bile, which is a digestive juice that is required for the breakdown of fats in the duodenum. The liver also processes the absorbed vitamins and fatty acids and synthesizes many plasma proteins. The gallbladder is a small organ that aids the liver by storing bile and concentrating bile salts. The pancreas secretes bicarbonate that neutralizes the **acidic chyme** and a variety of enzymes (**trypsin, amylase, and lipase**) for the digestion of proteins, carbohydrates, and fats, respectively. The details of the accessory organs are given below.

Activity 5.7 Discussion

As you already know, food moves from the stomach to the small intestine. Partially digested food reaches the small intestine already soaked in HCl and pepsin. How are the cells of the small intestine protected from the effects of HCl and pepsin? Discuss this issue with your classmates after collecting information from the internet or books.

Pancreas

The pancreatic secretions contain enzymes that promote the breakdown of the three major components of food: **proteins, carbohydrates, and lipids**. Pancreatic secretions contain the following digestive enzymes:

Trypsin- a protein-digesting enzyme called **trypsinogen** is released from the pancreas. Once trypsinogen reaches the small intestine, an enzyme called **enterokinase** converts the inactive trypsinogen into **trypsin,** which acts on the partially digested proteins. Trypsin breaks down **long-chain polypeptides** into shorter-chain peptides.

Erepsins- are released from the pancreas and small intestine. They complete protein digestion by breaking the bonds between short-chain peptides, releasing individual amino acids.

Amylase- continue the digestion of carbohydrates that begun in the mouth by salivary amylase. The intermediate-size chains are broken down into disaccharides. The small intestine releases disaccharide enzymes, called **disaccharidases**, which complete the digestion of carbohydrates

Lipases-enzymes released from the pancreas that breaks down lipids (fats). There are two different types of lipid-digesting enzymes:

Pancreatic lipase, the most common lipase, breaks down fats into fatty acids and glycerol.

Phospholipase acts on phospholipids.

The summary of the enzymes found in the small intestine, where they are produced, and their actions that take place are given in **Table 5.1** below.

Table 5.1 Digestion in the Small Intestine

Enzyme	Produced by	Reaction
lipase	pancreas	fat droplets + H_2O → glycerol + fatty acids
trypsin	pancreas	protein + H_2O → peptides
erepsin	pancreas, small intestine	peptides + H_2O → amino acids
pancreatic amylases	pancreas	starch + H_2O → maltose
maltase	small intestine	maltose + H_2O → glucose

Liver and Gallbladder

What is the importance of liver?

The liver continually produces fluid called **bile.** Bile contains bile salts, which aid fat digestion. When the stomach is empty, bile is stored and concentrated in the gallbladder. When there are fats in the small intestine, the hormones trigger the gall bladder to release bile salts.

Once inside the small intestine, the bile salts:

Emulsify or breakdown, large fat globules. The breakdown of fat globules into smaller droplets is physical digestion, not chemical digestion since chemical bonds are not broken. Physical digestion prepares the fat for chemical digestion by increasing the exposed surface area on which fat-digesting enzymes, such as pancreatic lipase, can work.

Why liver is said to be unusual organ with regard to blood circulation?

Bile also contains pigments. The liver breaks down haemoglobin from red blood cells and stores the products in the gallbladder for removal. The characteristic brown colour of feces results from haemoglobin breakdown.

Stores glycogen and vitamins A, B_{12}, and D.

Detoxify many harmful substances in the body. Harmful chemicals are made soluble and can be dissolved in the blood and eliminated in the urine. One of the more common poisons is alcohol.

Large Intestine

The human large intestine is much smaller in length compared to the small intestine but larger in diameter. It has three parts: the **cecum, the colon, and the rectum**. The cecum joins the ileum to the colon and is the receiving pouch for the waste matter. The colon is home to many bacteria or intestinal flora that aid in the digestive processes. The colon has four regions, **the ascending colon, the transverse colon, the descending colon and the sigmoid colon** (**Figure 5.4a**). The main functions of the colon are to extract the water and mineral salts from undigested food, and to store waste material.

Activity 5.8 Library/ Internet search

Conduct library/internet search on groups of enzymes associated with digestion of different food staffs, the sites of their action and the required environment (pH) for each group. Finally, present your findings to the class. for discussion.

Chemical digestion is complete by the time food reaches the large intestine (**Figure 5.4a**). The colon, the largest part of the large intestine, must store waste long enough to reabsorb water from it. During this time, some inorganic salts, minerals, and vitamins are also absorbed with the water.

The large intestine houses bacteria, such as *Escherichia coli (E. coli),* which are essential to life and use waste materials to synthesize vitamins B and K. Cellulose, the long-chain carbohydrate characteristic of plant cell walls, reaches the large intestine undigested. Although cellulose cannot be broken down by humans, it serves an important function: cellulose provides bulk. As wastes build up in the large intestine, receptors in the wall of the intestine provide information to the **central nervous system**, which, in turn, prompts a bowel movement. The bowel movement ensures the removal of potentially toxic wastes from the body. Individuals who do not eat sufficient amounts of cellulose (roughage or fiber) have fewer bowel movements. This means that wastes and toxins remain in their bodies for longer periods. Scientists have determined that cancer of the colon

can be related to diet. Individuals who eat mostly processed, highly refined foods are more likely to develop cancer of the colon.

The rectum (**Figure 5.4a**) stores feces until defecation. The feces are propelled using peristaltic movements during elimination. The anus is an opening at the far-end of the digestive tract and is the exit point for the waste material. Two sphincters regulate the exit of feces, the inner sphincter is involuntary and the outer sphincter is voluntary.

Table 5.2 Summary of digestion in human alimentary canal

Region of gut	Glands and secretion	Enzymes and optimum pH	Food digested, products and other activity
Mouth: mastication by jaws and tongue	Salivary glands :saliva 1-2 liters/daily	1. pH-7, slightly acid in adults, slightly alkali to neutral in children 2. amylase	1.mucin lubricates food bolus 2.(A) starch(amylase)----dextrins (B) cooked starch ----maltose
Oesophagus	None	None	Food bolus moves by peristalsis
Stomach churning action. Temporary storage 1 to3 hrs	Gastric gland, stomach wall-gastric juice 2-4L; stores daily	1. pH 1, strongly acidic 2. rennin(in young children) 3. lipase(in young children) 4. pepsin	1. Hydrochloric acid (HCl) is bacteriocidal 2. clots milk protein-caesin 3. lipids---fatty acids and glycerine 4. proteins—amino acids Absorption: water, salts, vitamins and ethanol
Duodenum(Accessory organ secretions)	1.liver- bile juice, 700CM3-1.2 litres daily 2 pancreas-pancreatic juices, 700Cm3 daily	1. pH 7-8, slightly alkaline 2. no enzyme	1. alters pH of stomach contents 2. bile salts emulsify or cream lipids
		1. pH 7-8,slightly alkaline 2. amylase 3. lipase 4. Trypsin 5.nuclease	1.food as chime propelled by peristalsis 2. starch(amylase)------maltose 3. lipids---- fatty acids and glycerol 4. peptones---- short peptides 5. nucleic acids----nucleotides
Small intestine and duodenum	Glands in intestine and duodenum wall-intestinal juice, 200cm3	1. pH 7-8 2. entrokinase changes trypsinogen into trypsin 3.lipase 4.glycosidases-maltase, lactase, sucrase	1---------- 2. dipeptides, peptides-------amino acids 3. lipids---fatty acids and glycerol(propanetriol) 4. maltase----maltose into glucose molecules Lactase-----lactose into glucose and galactose Sucrose---sucrose into glucose and fructose Absorption: large surface area, villi, and microvilli, main region of absorption of vitamins, minerals, amino acids, glucose, fatty acids and glycerol
Large intestine	Lining with mucous glands	pH 6-8 no enzymes	1. mucous lubricates faces 2. water absorbed from faces 3. bacteria synthesis vitamin B groups 4. faces mainly water 75%, bacteria, 8%, lipids, 6%, dietary fiber cellulose, 2% etc

5.2 The circulatory and lymphatic system

Objectives

At the end of this section, the student will be able to:

- *Demonstrate the structure of the heart using a heart model/ diagram*
- *Differentiate between pulmonary and systemic circulations.*
- *Compare and contrast arteries and veins based on their structures and functions*
- *Discuss types of blood*
- *Debate on the importance of blood donation and its health implications on the donors and recipients.*
- *Discuss the key functions and components of the lymphatic system.*

What do you know about the movement of blood in your body?

The circulatory system is a means by which blood moves throughout your body. The circulatory system:

- carries nutrients to cells,
- remove wastes away from cells,
- carry chemical messages from cells in one part of the body to distant target tissues,
- distributes heat throughout the body and, along with the kidneys,
- maintain levels of body fluid,
- provide oxygen for the cellular respiration and
- transport of immune cells throughout the body to defend against invading organisms

Moreover, your circulatory system has 96 000 km of blood vessels to sustain your 100 trillion cells. Your heart is about the size of your fist and with a mass of about 300g. The heart beats about 70 times/min from the beginning of your life until death. Every minute, 5L of blood cycles from the heart to the lungs, picks up oxygen, and returns to the heart. The structure of the heart and the activities of its parts are given in the figure (**Figure5.6**).

Activity 5.9 Group work

In groups of 4-6 students, prepare diagrams /models of the heart and study each part with its functions and present for the whole-class.

Have you ever heard about a live pump?

In this section, you will explore the remarkable live pump - the heart that propels the blood into the vessels. There is no single better word

What are the chambers of the heart?

to describe the function of the heart other than "pump" since its contraction develops the pressure that ejects blood into the major vessels: the aorta and pulmonary trunk. From these vessels, the blood is distributed to the other parts of the body. A field of study about the heart is called cardiology and the scientists, cardiologists.

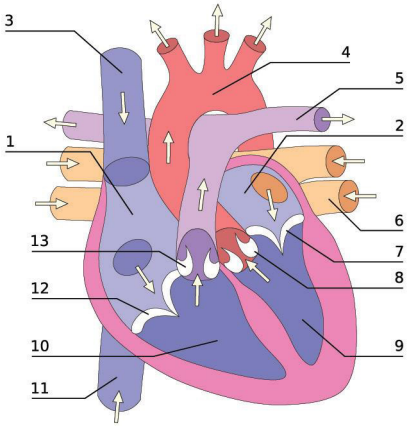


Figure 5.6 The heart anatomy

Description

1. Right atrium (Atrium dextra)
2. Left atrium (Atrium sinistrum)
3. Superior Vena Cave (Venea cava Superior)
4. Aorta
5. Pulmonary artery
6. Pulmonary vein
7. Bicuspide (Mitral) valve
8. Semilunar (Aortic) valve
9. Left ventricle
10. Right ventricle
11. Inferior Vena Cave (Venea cava Inferior)
12. Tricuspid valve
13. Semilunar (Pulmonary) valve

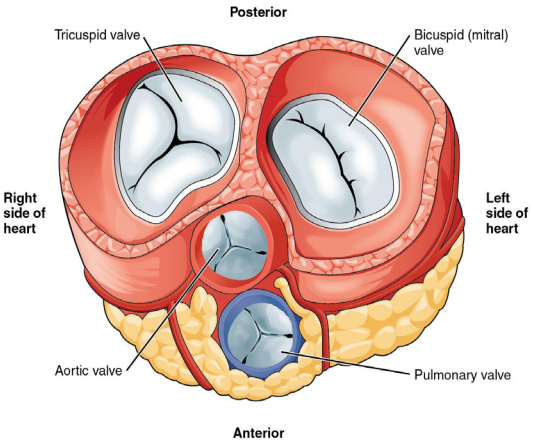


Figure 5.7 The valves of the heart

The heart is a muscular organ that pumps blood to circulate throughout the body. The heart wall consists of three layers: the **endocardium, myocardium, and epicardium**.

The **endocardium** is the thin membrane that lines the interior of the heart,

The **myocardium** is the middle layer of the heart. It is the heart muscle and is the thickest layer of the heart, and

The **epicardium** is a thin layer on the surface of the heart in which the coronary arteries lie.

The **pericardium** is a thin sac the heart sits in, often filled with a small amount of fluid, which separates the heart from the other structures in the chest such as the lungs.

Activity 5.10 Group discussion

In group of 2-3 students:

1. Discuss the 4 chambers of the heart.
2. Explain the process of movement of blood though the chambers.
3. Which chamber is the strongest?
4. Which chamber carries deoxygenated blood?

What types of valves are there between the heart chambers?

Valves

In the cardiovascular system of the heart four valves prohibit the backflow of blood:

a. Tri-cuspid valve (Right atrioventricular RAV) - valve separates the right atria from the right ventricle.

b. Bi-cuspid valve (Left atrioventricular LAV) -valve separates the left atria from the left ventricle

Semi-lunar valves

a. Valve that separate the right ventricle from the pulmonary artery and

b. Valve that separate the left ventricle from the aorta. The semi-lunar valves are half-moon-shaped (hence, the name *semi-lunar*), and they prevent blood that has entered the arteries from flowing back into the ventricles (**Figure 5.6**).

Attention

The heart consists of two (right & left) parallel pumps separated by the septum (Figure 5.6). The four-chambered human heart is composed of two thin-walled atria (singular: atrium) and two thick-walled ventricles. Blood from the systemic system enters the right atrium, and blood from the pulmonary system enters the left atrium. The stronger and more muscular ventricles pump the blood to the lungs and distant tissues.

Laboratory Activity 5.11: Dissection of mammalian heart (cow or sheep)

The human heart is a pump. It pumps blood around the body at different speeds and at different pressures according to the body's needs. It can do this because the wall of the heart is made from cardiac muscle. Cardiac muscles are unlike any other muscle. It never gets fatigued like skeletal muscles. On average, cardiac muscle fibres contract and relax about 70 times a minute. In a lifetime, this muscle will contract over two billion times. The objective of this activity, therefore, is to study the external and internal structure of this amazing mammalian heart.

Procedures:

1. Collect a freshly slaughtered sheep or cow heart from the butcheries
2. Carefully handle and observe:
   - the external structures (the outlets and inlets of the pulmonary artery and pulmonary veins)
   - the inlets (superior and inferior vena cava)
   - the epicardium
3. Using a dissecting knife carefully cut open the heart vertically and observe the following structures:
   - the right and left ventricles
   - the septum
   - the tricuspid and bicuspid valves and
   - the semi-lunar valves

Answer the following questions

1. What do you deduce from your study of the structure of the mammalian heart structure
2. Now, can you associate what you have studied in the classroom with your practical activity in the laboratory?
3. Write a short report on your activity in the laboratory

Activity 5.12 THINK-PAIR-SHARE

Recall what you have studied about the 4 chambers of the heart and movement of blood. Then, share ideas about the movement of blood in our body. Finally, your teacher will help you to classify the two types of circulations. Try to support your activity using virtual lab (circulatory system animation, video).

What are the two types of blood circulation?

The human circulatory systems are a double circulatory system. It has two separate circuits and blood passes through the heart twice: **pulmonary and systemic circulation**.

Pulmonary circulation - the movement of blood from the heart to the lungs for oxygenation, then back to the heart again. Oxygen-depleted blood from the body leaves the systemic circulation when it enters the right atrium through the **superior and inferior venae cavae**. The blood is then pumped through the tricuspid valve into the right ventricle. From the right ventricle, blood is pumped through the pulmonary valve and into the pulmonary artery. The pulmonary artery splits into the right and left pulmonary arteries and the blood in the arteries travel to each lung (Figure 5.8).

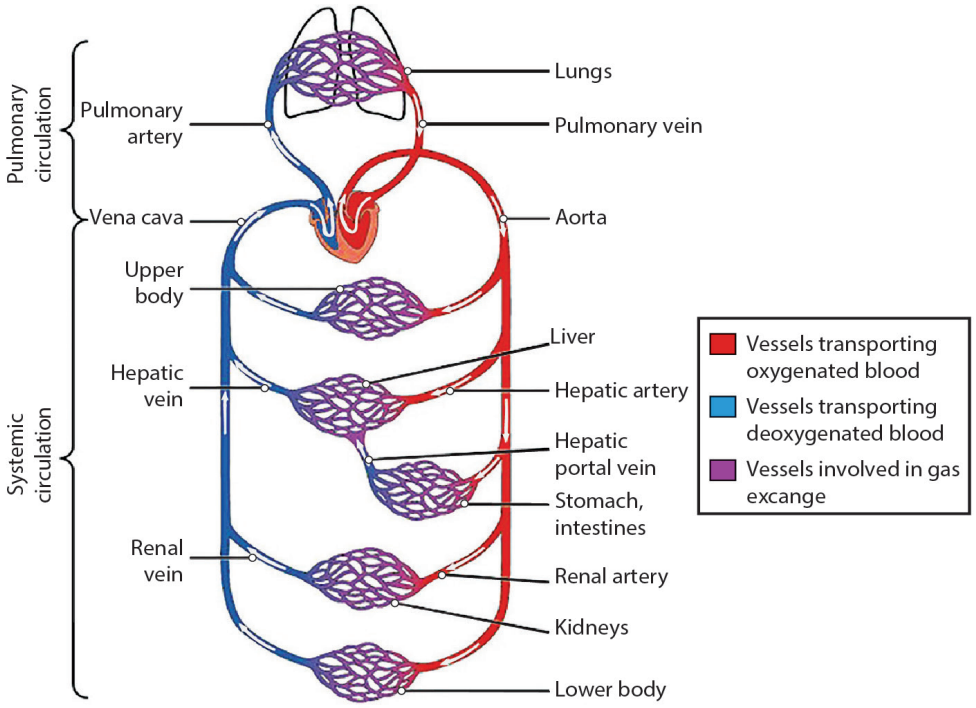


Figure 5.8 Pulmonary and systemic circulation

Systemic circulation - is the movement of blood from the heart through the body to provide oxygen and nutrients to the tissues of the body while bringing deoxygenated blood back to the heart. Oxygenated blood enters the left atrium from the pulmonary veins (Figure 5.8). The blood is then pumped through the mitral valve into the left ventricle. From the left ventricle, blood is pumped through the aortic valve and into the **aorta, the body's largest artery**. The aorta arches and branches into major arteries to the upper body before passing through the diaphragm, where it branches further into the **iliac, renal, and suprarenal** arteries which supply the lower parts of the body.

The arteries branch into smaller **arteries, arterioles, and finally capillaries.** Gas and nutrient exchange with the tissues occurs within the capillaries that run through the tissues. Metabolic waste and carbon dioxide diffuse out of the cell into the blood, while oxygen and glucose in the blood diffuse out of the blood and into the cell. Systemic circulation keeps the metabolism of every organ and every tissue in the body alive, except the parenchyma of the lungs, which are supplied by pulmonary circulation.

Activity 5.13 Pulse rate

Walking or mild exercise will increase your heart rate by 20 to 30%. For those in good health, increased energy demands during extreme exercise can raise the heart rate to an incredible 200 beats per minute. Although few individuals can sustain such a rapid heart rate, it indicates the capacity of the heart to adjust to changing situations.

1. While sitting still, place your index and middle finger near your wrist. The pulse you feel is blood rushing through the brachial artery in your arm. Count the number of heartbeats in 30 s. Record your pulse at rest and then calculate the heart rate as beats per min.
2. Remain sitting quietly and place your index finger and middle finger on the side of your neck just to the side of your trachea. You will feel blood pulse through the carotid artery, which is an artery that carries blood to the head. Take your pulse for 30 s and then calculate the heart rate for 1 min.
3. Run on the spot for approximately 2 min.
4. Take your pulse immediately after exercise using either the carotid artery or the brachial artery.
5. Record your heart rate.

    a. Compare the strength of the pulse in the carotid artery with that in your arm.

    b. Compare your heart rate before and after exercise.

    c. Do you think the difference between resting heart rate and the heart rate after exercise would be greater for athletes? Explain your answer.

Cardiac Cycle

The period of time that begins with contraction of the atria and ends with ventricular relaxation is known as the cardiac cycle. The period of contraction that the heart undergoes while it pumps blood into circulation is called systole. The period of relaxation that occurs as the chambers filled with blood is called diastole. Both the atria and ventricles undergo systole and diastole, and it is essential that these components be carefully regulated and coordinated to ensure blood is pumped efficiently to the body.

Heart Sounds

One of the simplest, yet effective, diagnostic techniques applied to assess the state of a patient's heart is auscultation (listening to various internal sounds) using a stethoscope. In a normal, healthy heart, there are only two audible heart sounds: Lub and Dup (or Dub). Lub, or rest heart sound is the sound created by the closing of the atrioventricular valves during ventricular contraction. The second heart sound, "Dup" (or "Dub") is the sound of the closing of the semilunar valves during ventricular diastole.

The term murmur is used to describe an unusual sound coming from the heart that is caused by the turbulent flow of blood. Murmurs are graded on a scale of 1 to 6, with 1 being the most common, the most difficult sound to detect, and the least serious. The most severe is a scale of 6. Specialized electronic stethoscopes are used to record both normal and abnormal sounds.

When using a stethoscope to listen to the heart sounds, called asculation, it is common practice for the clinician to ask the patient to breathe deeply. This procedure not only allows for listening to air flow, but it may also amplify heart murmurs. Inhalation increases blood flow into the right side of the heart and may increase the amplitude of right-sided heart murmurs. Expiration partially restricts blood flow into the left side of the heart and may amplify left-sided heart murmurs.

Activity 5.14 Heart sound

Medical workers use stethoscopes to measure blood pressure and to listen to the heart, lungs, and intestines. You will use a stethoscope to listen to your heart. Disinfect the earpieces of the stethoscope with rubbing alcohol before and after use.

i. Place a stethoscope on your own chest and listen for a heart sound. Locate the area where the heart sounds are loudest and clearest.
ii. After 1 min of moderate exercise (e.g., walking on the spot), listen for your heart sounds again.

a) Draw a diagram of a chest showing where you located the clearest sound.

b) Did the sound of your heart beat change after exercise? Describe what differences you heard.

Blood Pressure

Blood pressure is the force of the blood on the walls of the arteries. It can be measured indirectly with an instrument called a

sphygmomanometer. A cuff with an air bladder is wrapped around the arm. A small pump is used to inflate the air bladder, thereby closing off blood flow through the brachial artery, one of the major arteries of the arm. A stethoscope is placed below the cuff and air is slowly released from the bladder until a low-pitched sound can be detected. The sound is caused by blood entering the previously closed artery.

Each time the heart contracts, the sound are heard. A gauge on the sphygmomanometer measures the pressure exerted by the blood during ventricular contraction. This pressure is called systolic blood pressure. Normal systolic blood pressure is less than 120 mmHg. Blood pressure is measured in the non-SI units of millimeters of mercury, or mmHg. The cuff is then deflated even more, until the sound disappears. At this point, blood flows into the artery during ventricular relaxation, or filling. This pressure is called diastolic blood pressure. Normal diastolic blood pressure is less than 80 mmHg. A systolic pressure of 120 mmHg and a diastolic pressure of 80 mmHg would be reported as 120/80 (120 over 80). Reduced filling, such as that caused by an internal hemorrhage, will cause diastolic blood pressure to fall.

Do you have any idea about the lines of movement of blood in the body?

Blood Vessels

Blood vessels are the channels or conduits through which blood is distributed to body tissues. The vessels make up two closed systems of tubes that begin and end at the heart. One system, the pulmonary vessels, transports blood from the right ventricle to the lungs and back to the left atrium. The other system, the systemic vessels, carries blood from the left ventricle to the tissues in all parts of the body and then returns the blood to the right atrium. Based on their structure and function, blood vessels are classified as arteries, capillaries, and veins.

Activity 5.15 Compare and contrast

In a pair, compare and contrast arteries, veins and capillaries based on their structures and functions by using diagrams and models, and then prepare your own summarized notes.

In small groups, answer the following questions.

- *What is blood?*
- *What components of blood do you know?*
- *What types of cells are there in blood?*
- *Why do you think your white blood cells could be higher than the normal?*
- *What are platelets?*

Blood

Blood is a constantly circulating fluid providing the body with nutrition, oxygen, and waste removal. Blood is mostly liquid, with numerous cells and proteins suspended in it, making blood "thicker" than pure water. The average person has about 5 liters of blood.

Liquid called plasma makes up about half of the content of the blood. Plasma contains proteins that help the blood to clot, transport substances through the blood, and perform other functions. Blood plasma also contains glucose and other dissolved nutrients. About half of blood volume is composed of blood cells.

Blood Components

Normally, 7-8% of human body weight comes from blood. This essential fluid carries out the critical functions of transporting oxygen and nutrients to our cells and getting rid of carbon dioxide, ammonia, and other waste products. In addition, it plays a vital role in our immune system and in maintaining a relatively constant body temperature. Blood is a highly specialized tissue composed of more than 4,000 different kinds of components. Three of the most important ones are:

- Red blood cells, which carry oxygen to the tissues
- White blood cells, which fight infections
- Platelets, smaller cells that help blood clot
- Red blood cells (erythrocytes)

Red blood cells, or erythrocytes, are relatively large microscopic cells without nuclei. Red blood cells normally make up 40-50% of the total blood volume. They transport oxygen from the lungs to all of the living tissues of the body and carry away carbon dioxide. The red cells are produced continuously in our bone marrow from stem cells at a rate of about 2-3 million cells per second. Hemoglobin (containing iron) is the gas transporting protein molecule that makes up 95% of a red cell. People who are anemic generally have a deficiency in red cells, and subsequently feel fatigued due to a shortage of oxygen. The red colour of blood is primarily due to oxygenated red cells. Human fetal hemoglobin molecules differ from those produced by adults in the number of amino acid chains. Fetal hemoglobin has three chains, while adults produce only two. As a consequence, fetal hemoglobin molecules attract and transport relatively more oxygen to the cells of the body.

Red blood cell adaptation for efficient oxygen transportation:

What are adaptations of a red blood cell that equip it for efficient oxygen transport?

RBC have nucleus at the young stage and lose its nucleus when matured. Not having a **nucleus** means that there is more space inside for hemoglobin, so each red blood cell can carry more oxygen.

Biconcave shape gives it a larger surface area for gaseous diffusion than a flat disc of the same volume.

Very thin cell surface membrane enables oxygen and carbon dioxide can diffuse in and out rapidly.

Flexible cell surface membrane allows it to squeeze along the narrowest blood capillaries.

White blood cells (leukocytes)

White blood cells, or leukocytes, exist in variable numbers and types but make up a very small part of blood's volume; in normally exists among only about 1% in healthy people. Leukocytes are not limited to blood. They occur elsewhere in the body as well, most notably in the **spleen, liver, and lymph** glands. Most are produced in our bone marrow from the same kind of stem cells that produce red blood cells. Others are produced in the thymus gland, which is at the base of the neck. White blood cells (called lymphocytes) are:

the first responders to our immune system. They seek out, identify, and bind to alien proteins on bacteria, viruses, and fungi so that they can be removed. Other white blood cells (called granulocytes and macrophages) then arrive to surround and destroy the alien cells.

have the function of getting rid of dead or dying blood cells as well as foreign matter.

Individual white blood cells usually only last for 18-36 hours before they are removed, though some types live as much as a year. There are several different kinds of white blood cells (Table 5.3). The two important types are:

neutrophils white blood cells that have a lobed nucleus, and

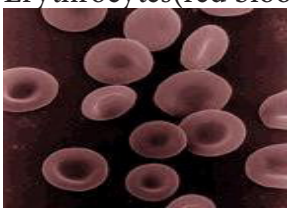
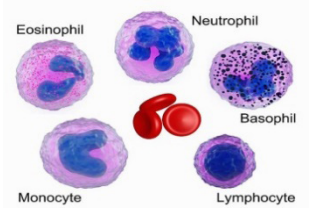
lymphocytes white blood cells that are smaller than neutrophils and which have a large nucleus that takes up most of the cell.

Platelets or thrombocytes that are tiny cell fragments **without nuclei** enclosed in a membrane. Platelets play an essential role in blood clotting. Clotting has two important functions:

What are platelets?

- it helps to stop blood from flowing out of the damaged vessel, and
- it prevents disease-causing pathogenic microorganisms (viruses, bacteria) from getting into the body.
- they collect where a damaged blood vessel is leaking blood and form a temporary plug by combining with fibers of collagen, a protein of the blood vessel wall.
- they release an enzyme that sets off a chain of chemical reactions in the blood. The result of these reactions is to change **fibrinogen**, a soluble plasma protein into a network of insoluble **fibrin threads**. These networks of fibrin threads, then plug in the cut and clot the blood.

Table 5.3 Red blood cells, white blood cells and platelets

Cell types	Number	Life span	Functions
Erythrocytes(red blood cells) 	5-6million	120 days	Transport oxygen and help transport carbon-dioxide
Leukocytes(White blood cells) 	5000-10000	18-36 hours, some can survive as long as a year	Defense and immunity
Platelets 	250000-400,000	9-10 days	Blood clotting

Plasma

Plasma is a yellow-tinted water, sugar, fat, protein, and salt fluid that transports red blood cells, white blood cells, and platelets.

Plasma makes up 55 percent of our blood volume.

What is plasma?

- provides nutrients to cells while also removing metabolic waste.
- blood clotting factors, carbohydrates, lipids, vitamins, minerals, hormones, enzymes, antibodies, and other proteins are all found in it.
- includes some of every protein generated by the body; so far, only about 500 proteins have been discovered in human plasma.

Activity 5.16 Answer to the questions

1. Have you ever heard about A, B, AB & O blood groups?
2. If yes, do you know what your blood group is?
3. What are the bases for blood grouping?

Blood groups

The blood grouping depends on which antigens are on the surface of the red blood cells. Antigens are molecules. They can be either proteins or sugars. The types and features of antigens can vary between individuals due to small genetic differences. The antigens in blood have various functions, including:

- transporting other molecules into and out of the cell,
- maintaining the structure of red blood cells, and

- detecting unwanted cells that could cause illness.

Scientists use two types of antigens to classify blood types:

- ABO antigens and
- Rh antigens.

Antigens and antibodies play a role in the immune system's defence mechanism. White blood cells produce antibodies. These antibodies will target an antigen if they consider it a foreign object. This is why it is essential to match blood types when a person needs a transfusion. If a person receives red blood cells with antigens that are not already present in their system, their body will reject and attack the new red blood cells. This can cause a severe and possibly life-threatening reaction.

The ABO blood group system classifies blood types according to the different types of antigens in the red blood cells and antibodies in the plasma. They use the ABO system alongside the Rh antigen status to determine which blood type or types will match for a safe red blood cell transfusion.

There are four ABO groups:

Group A: The surface of the red blood cells contains A antigen, and the plasma has anti-B antibody. Anti-B antibodies would attack blood cells that contain B antigens.

Group B: The surface of the red blood cells contains B antigen, and the plasma has anti-A antibody. Anti-A antibody would attack blood cells that contain A antigen.

Group AB: The red blood cells have both A and B antigens, but the plasma does not contain anti-A or anti-B antibodies. Individuals with type AB can receive any ABO blood type.

Group O: The plasma contains both anti-A and anti-B antibodies, but the surface of the red blood cells does not contain A or B antigens. Since these antigens are not present, a person with any ABO blood type can receive this type of blood.

Do you have any idea about the relationship between biology and other sciences?

Rhesus factor

During the 1940s scientists discovered another antigen on the red blood cell, **the Rhesus factor**. Like the ABO blood groups, the Rhesus

factor is inherited. Individuals who have this antigen are said to be Rhesus positive (Rh^+). Approximately 85 % of the populations have the antigen. The remaining 15% of individuals who do not have the antigen are said to be Rhesus negative (Rh^-). Individuals who are Rh^- may donate blood to Rh^+ individuals, but should not receive Rh^+ blood. The human body has no natural antibodies against Rh factors, but antibodies can be produced following a transfusion. Although Rh antibodies are produced in response to antigens, it should be pointed out that the immune reaction is subdued compared with that of the ABO group.

How does Rh+ blood differ from Rh– blood and what happens if the Rh factor of the blood transfused is incompatible?

Rhesus-factor incompatibilities become important for Rh^+ babies of Rh^- mothers. If the baby inherits the Rh^+ factor from the father, a condition called erythroblastosis fetalis (*a medical condition where an Rh negative mother's antibodies attack the red blood cells of an Rh positive fetus)* can occur with these condition and subsequent pregnancies. The first child is spared because the blood of the mother and baby are separated by the placenta (a membrane inside the uterus that exchanges materials between mother and baby). During birth, the placenta is shed from the uterus. Capillary beds rupture, and, for the first time, the blood of the baby comes into contact with the blood of the mother.

Why does a fetus with erythroblastosis fetalis develop anemia?

The mother's immune system recognizes the Rh^+ antigens and triggers the production of antibodies. But, by the time the antibodies are produced, the first baby is no longer connected to the placenta and has escaped the potentially dangerous situation. However, a second pregnancy presents problems if the fetus is Rh^+. The mother retains many of the antibodies from her first encounter with Rh^+ blood. If antibodies cross the placenta, they attach to the antigen on the red blood cells of the fetus, causing them to be destroyed. Symptoms *when an Rh negative mother's antibodies attack the red blood cells of an Rh positive fetus* include **anemia, jaundice, and an enlarged liver**.

5.2.1 Blood Donation

Objectives

At the end of this section, the student will be able to:

- *Discuss the reason for blood donation,*
- *Outline the conditions for blood transfusion, and*
- *Discuss blood type and Rh factor compatibility.*

Blood is a very vital component of the human body. In case of an injury, severe sickness, or during operations, loss of a large quantity of blood may result in death. In such cases, blood from a healthy person called the donor is given to the sick or a person that lost blood under some other unexpected condition. The sick person who receives blood is called the recipient. The process of transferring blood from a healthy person (donor) to a person deficient in blood (recipient) is called blood transfusion. Great care has to be taken by the doctors while transfusing blood from the donor to the recipient.

Activity 1.5: THINK-PAIR-SHARE

In a group of 4-5 students, go to the nearby blood bank, hospital, health centers or posts, and gather information on the importance of blood donation and its health implication (if any) on the donor and/or the recipients. Finally, report your findings to the classroom discussion.

Blood group compatibility

If the blood from two different blood groups is mixed and if it is not compatible, there may be a reaction between the antigen and the complementary antibody which makes the red blood cells stick together, a phenomenon known as **agglutination**. The agglutins block the capillaries and even larger blood vessels. But if someone loses a lot of blood in an accident, an injury, during giving birth or an operation, then they may need a blood transfusion. This is when blood taken from one person is given to another to save their life. Before a transfusion it is vital to know the blood groups of both the person giving the blood (the donor) and the person receiving the blood (the recipient).

This means the right type of blood can be given to prevent agglutination. The blood groups must be compatible. It is not usually the case that only one type of blood can be given, simply that blood containing a particular antigen must not be mixed with blood containing the matching antibody (summarized in table 5.4). For example, blood group O has no antigens so it can be given to anyone, but someone who has blood group O has both antibodies so they can only receive group O blood. On the other hand someone with blood group AB which has no antibodies can receive any type of blood. Figure 5.9 summarizes the compatibilities of the different blood groups.

Form group of 2-3 students and do a library search about the lymphatic system and present your findings to the class.

Table 5.4 Antigens and antibodies

Blood group	Antigen on red blood cells	Antibody in plasma
A	A	B
B	B	A
AB	AB	None
O	None	AB

The O blood groups is termed "Universal Donor" while the AB blood group is termed as a "Universal recipient"

Key: x-shows coagulation

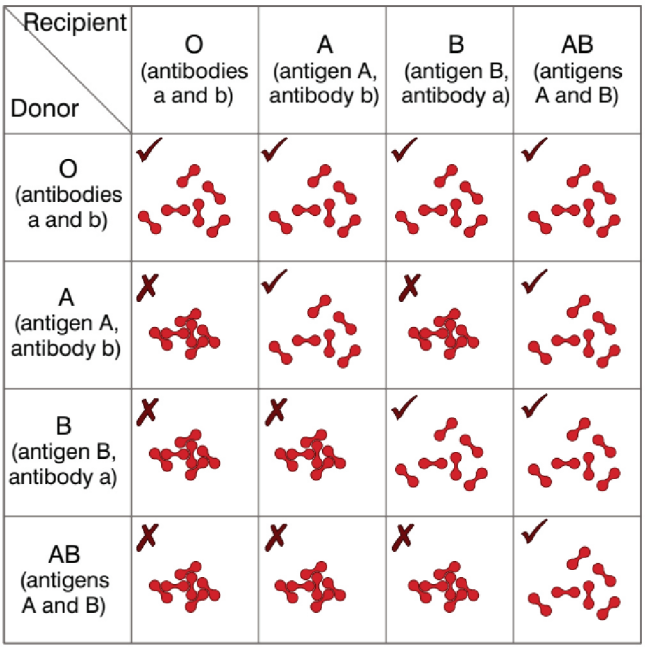


Figure 5.9 Blood compatibility chart

The Lymphatic System

What is the lymphatic system?

A little amount of protein spills from capillaries into tissue voids on a regular basis. Even if the leak is modest, the buildup of proteins in the extracellular fluid (ECF) would be a significant problem; osmotic pressure would drop and tissues would enlarge.

The proteins are emptied from the ECF and return to the circulatory system via the **lymphatic system**, a collection of vessels (Figure 5.10). Lymph, a fluid similar to blood plasma, is transported through lymph vessels that are open-ended like veins. This low-pressure return system is driven by slow muscle contractions against the arteries, which are equipped with flap-like valves to prevent fluid backflow. Through the right and left subclavian veins, the lymphatic system returns lymph to the venous system.

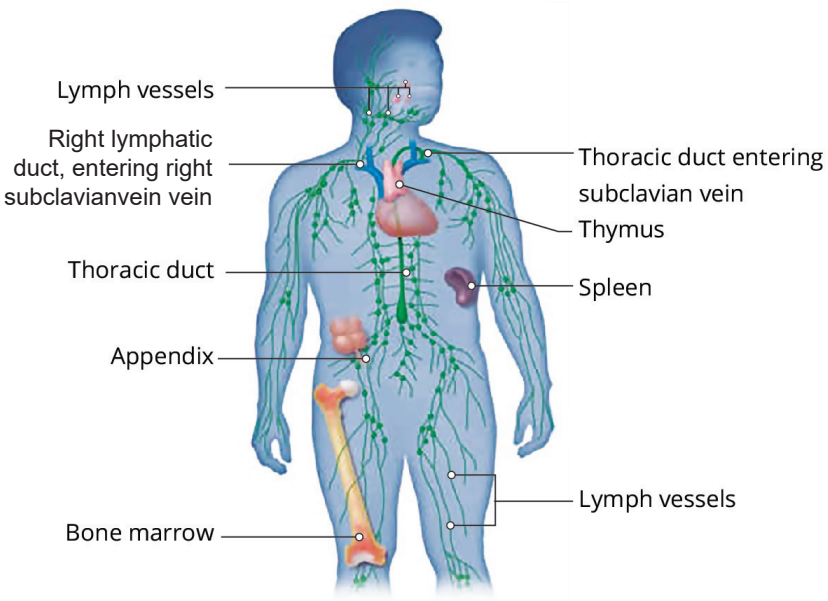


Figure 5.10 The lymphatic system

Lymph nodes are enlargements that appear in the lymph channel at regular intervals (Figure 5.10). These contain white blood cells that, through the process of phagocytosis, filter out any bacteria present. Lymph nodes store lymphocytes in addition to screening damaged cells and debris from the lymph. The lymph nodes in your neck can expand when you have a sore throat.

What are the functions of the lymphatic system?

The key functions of the lymphatic system:

- returns excess interstitial fluid to the blood
- the absorption of fats and fat-soluble vitamins from the digestive system and the subsequent transport of these substances to the venous circulation. The blood capillaries absorb most nutrients, but the fats and fat-soluble vitamins are absorbed by the lacteals. The lymph in the lacteals has a milky appearance due to its high fat content and is called **chyle.**
- defence against invading microorganisms and disease. Lymph nodes and other lymphatic organs filter the lymph to remove microorganisms and other foreign particles. Lymphatic organs contain **lymphocytes** that destroy invading organisms.

Activity 5.18 Outline the relationship

Based on your studies above and using internet and books a source of information, outline the relationship between the lymphatic and the immune systems.

Components of the Lymphatic System

The lymphatic system consists of a fluid (lymph), vessels that transport the lymph and organs that contain lymphoid tissue.

Which components of the lymphatic system do you know?

Lymph

Lymph is a fluid substance made up of lymphocytes and white blood cells that is clear to white in colour. Lymph is a component of the lymphatic system that is present in lymphatic veins and other cavities throughout the body. It transports white blood cells within lymph nodes and bones, removes interstitial fluid from organs, and fights disease-causing and infectious bacteria invading blood cells. Lymph serves a variety of purposes:

- Removes metabolic wastes from tissue cells,
- Provides the body with nutrition,
- Aids in the invasion of microbe-caused pathogenic diseases,
- Through lymphatic vessels, absorbs fat-soluble vitamins and other digested fat molecules from the small intestine, and
- Maintain the composition of tissue fluid.

Lymphatic vessels

Unlike blood vessels, lymphatic vessels transport only fluid away from tissues (Figure 5.11). The lymph capillaries are the smallest lymphatic vessels, beginning in the tissue spaces as blind-ended sacs. Lymph capillaries can be found in every part of the body except the bone marrow, the central nervous system, and tissues that lack blood vessels, such as the epidermis. The wall of the lymph capillary is made up of endothelium, which is made up of simple squamous cells that overlap to form a simple one-way valve. This configuration allows fluid to enter the capillary but prevents lymph from exiting the vessel.

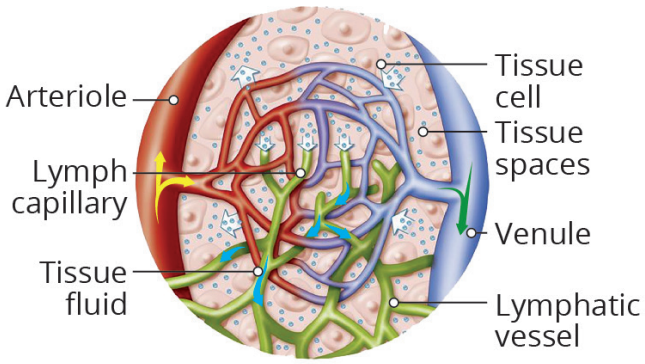


Figure 5.11 Lymphatic vessels

Lymphatic vessels are formed when microscopic lymph capillaries are connected. Small lymphatic vessels connect to form larger tributaries known as lymphatic trunks, which drain large areas. The lymphatic trunks join together until lymph enters the two lymphatic ducts. The right lymphatic duct drains lymph from the upper right quadrant of the body. The thoracic duct drains the remainder.

Lymphatic tributaries, like veins, have thin walls and valves to prevent blood backflow. The lymphatic system lacks a pump like in cardiovascular system. The pressure gradients that move lymph through the vessels are caused by skeletal muscle action, respiratory movement, and smooth muscle contraction in vessel walls.

Why the lymphatic system is an open system?

Organs of the lymphatic system

Clusters of lymphocytes and other cells, such as macrophages, are enmeshed in a framework of short, branching tissue fibres that distinguish lymphatic organs. Lymphocytes are formed alongside other types of blood cells in the red bone marrow and are transported in the blood from the bone marrow to the lymphatic organs. When the body is exposed to microorganisms and other foreign substances, lymphocytes proliferate within the lymphatic organs and are transported to the site of the invasion via the blood. This is a component of the immune response that seeks to eliminate the invading agent. Among the lymphatic organs are:

Which types of lymphatic organs do you know?

- Lymph nodes
- Tonsils
- Spleen, and
- Thymus.

Have you ever encountered injury on your hands, legs or somewhere on your limbs and felt tenderness, pain, and uncomfortable at your groin area and armpits? What do you think is the reason?

i. Lymph nodes

Lymph fluid flows in the lymph nodes throughout the body before finally making its way back to the blood stream. While doing so, it collects and traps harmful matter, such as bacteria, viruses, and bodily waste products. The lymph nodes filter the fluid and release it back into the bloodstream. Lymph nodes also contain immune cells that help fight infection by attacking the germs that the body's lymph fluid has collected. The lymph nodes may swell when a person has a temporary infection. The swelling occurs as a result of immune cell activity in the lymph nodes. The location of the swelling often relates to the affected area. For example, an ear injury/infection may cause swollen lymph nodes near the ear, while someone with an upper respiratory tract infection may notice swollen lymph nodes in their neck.

You may have experienced tonsillitis in your early child hood with red swollen tonsils. Do you know why the tonsils are swollen? What are the causative agents for this ?

ii. Tonsils

Tonsils are lymphatic tissue clusters located just beneath the mucous membranes that line the nose, mouth, and throat (pharynx) (Figure 5.12). The tonsils' lymphocytes and macrophages protect us from harmful substances and pathogens such as bacteria and viruses that enter the body through the nose or mouth.

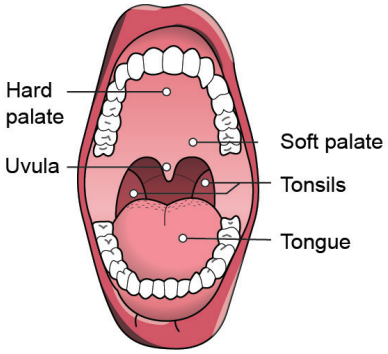


Figure 5.12 Locations of Tonsils

Spleen

The spleen is found in the upper left abdominal cavity, just below the diaphragm and posterior to the stomach (Figure 5.10). Its shape and structure are similar to that of a lymph node, but it is much larger. The spleen performs the following functions:

- filters blood in the same way that lymph nodes filter lymph;
- lymphocytes in the spleen react to pathogens in the blood and attempt to destroy them;
- macrophages engulf debris, damaged cells, and other large particles;
- removes old and damaged erythrocytes from the circulating blood; and
- it produces lymphocytes, particularly in response to infection.

Thymus

The thymus is a soft organ with two lobes anterior to the ascending aorta and posterior to the sternum (Figure 5.10). It is relatively large in infants and children, but after puberty, it begins to shrink in size until it is quite small in older adults. The thymus' primary function is to process and mature special lymphocytes known as T-lymphocytes or T-cells. Pathogens and foreign agents are not recognized by lymphocytes while they are in the thymus. After maturing, lymphocytes enter the bloodstream and travel to other lymphatic organs, where they aid in disease defense. Thymosin, a hormone produced by the thymus, stimulates the maturation of lymphocytes in other lymphatic organs.

Activity 5.19 THINK-PAIR-SHARE

Nowadays, with the modernization of human life style, feeding habits and environmental pollution, people all over the world are suffering from severe cardiovascular diseases of different types. Being in groups of 2-3 students, write down the types of circulatory and lymphatic system diseases and discuss causes and symptoms of such diseases. Finally, report your finding to your classmates. Some of them are described below.

5.2.2. Diseases of the circulatory and lymphatic systems

Objectives

At the end of this section, the student will be able to:

- *Discuss the diseases of the circulatory and lymphatic systems (leukemia, varicose vein, elephantiasis, cardiovascular diseases).*

Leukemia

Leukemia is a type of cancer that affects blood-forming tissues, including bone marrow (Figure 5.13). There are several types of leukemia, including acute lymphoblastic leukemia, acute myeloid leukemia, and chronic lymphocytic leukemia. For example, many patients with slow-growing leukemia are asymptomatic, and rapidly progressing types of leukemia can cause fatigue, weight loss, frequent infections, and easy bleeding or bruising. Also, the treatment varies greatly. Treatment for slow-growing leukemia may include

monitoring. Chemotherapy, sometimes followed by radiation and stem-cell transplant, is used to treat aggressive leukemia.

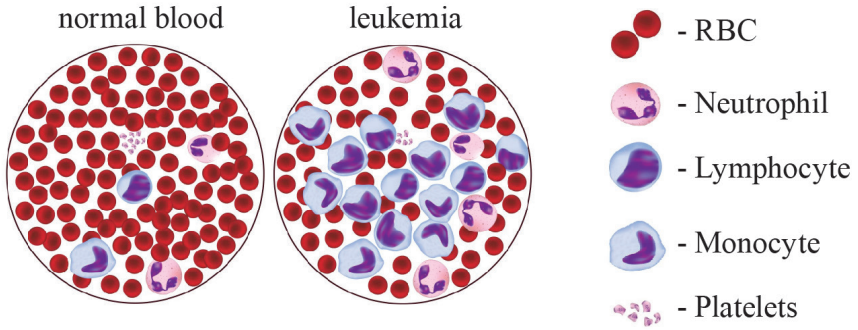


Figure 5.13 Leukemia

Varicose veins

Varicose veins are enlarged, swollen, and twisting veins that often have blue or dark purple colour (**Figure 5.14**). They occur when faulty vein valves allow blood to flow in the wrong direction or pool. Varicose veins are thought to affect more than 23% of all adults. It is common in:

- pregnant women are more prone to varicose veins, and
- overweight people are more prone to varicose veins

Aching legs, swollen ankles, and spider veins are some of the symptoms. It occurs when the valves in the veins fail to function properly, allowing blood to flow inefficiently. Treatment for varicose veins is rarely necessary for health reasons; however, if swelling, aching, and painful legs occur, and there is significant discomfort, treatment is available. There are several options, including some home remedies. In severe cases, a varicose vein may rupture or develop into varicose ulcers on the skin.

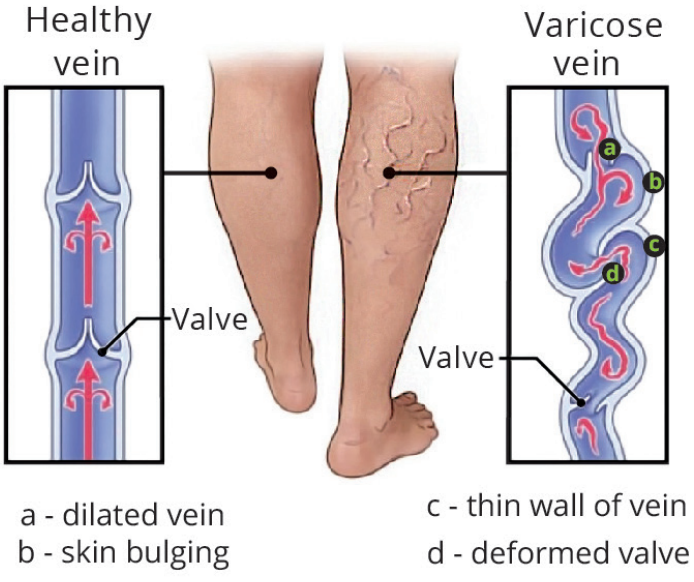


Figure 5.14 *Figure A, shows a normal vein with a properly working valve. In Figure B, the varicose vein has a faulty valve; the walls of the vein are thin and stretched*

Activity 5.20 Reflection

Based on your studies in the previous lessons, reflect on diseases of the circulatory and lymphatic system, and explain why some people are easily susceptible to infection while others are resistant to many infections. Use virtual lab (animation and video) to reflect.

Elephantiasis

Elephantiasis is a condition that causes a large enlargement of a part of the body, usually the limbs (Figure 5.15). External genitals are another area that is frequently affected. Elephantiasis is caused by a blockage in the lymphatic system, resulting in an accumulation of a fluid known as lymph in the affected areas. Elephantiasis is caused by parasitic worms transmitted by mosquitoes. *Wuchereria bancrofti*, *Brugia malayi*, and *Brugia timori* are the three worms involved.

Figure 5.15 Elephantiasis

Worms have an impact on the body's lymphatic system. The lymphatic system is in charge of eliminating waste and toxins. If it becomes clogged, it is unable to properly remove waste. This causes a buildup of lymphatic fluid, resulting in swelling.

Cardiovascular diseases

What are cardiovascular diseases?

Cardiovascular diseases are classified into several types. Among them are:

- Abnormal heart rhythms, also known as arrhythmias;
- Aorta disease and Marfan syndrome are two examples,
- Congenital heart disease is a condition that occurs at birth,
- Coronary artery disease is a condition that affects the arteries in the heart (narrowing of the arteries),
- Deep vein thrombosis (DVT) and pulmonary embolism (PE),
- A heart attack,
- Heart failure, and
- Muscle disease of the heart (cardiomyopathy).

Have you heard about any type of heart disease? If yes, mention and share your classmates.

Heart disease

Heart and blood vessel disease (also known as heart disease) encompasses a wide range of issues, many of which are linked to a process known as atherosclerosis. Atherosclerosis is a condition that occurs when a substance called plaque accumulates in the artery walls. This buildup narrows the arteries, making blood flow more difficult. When a blood clot forms, it can obstruct blood flow. This can result in a heart attack or a stroke.

Heart attack

A heart attack occurs when a blood clot blocks blood flow to a portion of the heart. If the clot completely obstructs blood flow, the part of the heart muscle supplied by that artery begins to die. Most people recover from their first heart attack and go on to live normal lives, gaining many more years of productive activity. However, having a heart attack means that you must make some changes. The medications and lifestyle changes recommended by your doctor may differ depending on how badly your heart was damaged and the degree of heart disease that caused the heart attack.

Stroke

What is the reason for stroke?

Stroke is a cerebrovascular disease. It occurs when a blockage or bleed of the blood vessels either interrupts or reduces the supply of blood to the brain. When this happens, the brain does not receive enough oxygen or nutrients, and brain cells start to die.

There are 2 types of stroke:

1. An ischemic stroke (the most common type of stroke) occurs when a blood vessel that supplies the brain becomes blocked, typically due to a blood clot. When a part of the brain's blood supply is cut off, some brain cells begin to die. This can lead to the loss of functions controlled by that part of the brain, such as walking or speaking.

2. When a blood vessel in the brain bursts, it causes a hemorrhagic stroke. Uncontrolled hypertension is the most common cause of this (high blood pressure). Some stroke effects are permanent if too many brain cells die as a result of oxygen deprivation. This population of cells is never replenished.

The good news is that brain cells do not always die during a stroke; instead, the damage is only temporary. As injured cells repair themselves, previously impaired function improves over time. In

Activity 5.21 Group work

Here in this section are mentioned some cardiovascular and lymphatic system diseases. Yet there are too much of them to mention. Therefore, in groups of 3-4 students and reading books and browsing internet resources, list cardiovascular and lymphatic system diseases as much as you can and discuss among your classmates. Two of them are given below.

1. Endocarditis?
2. Rheumatic fever?

other cases, nearby undamaged brain cells may take over for the injured areas of the brain. In any case, strength may return, speech may improve, and memory may improve.

Heart failure

Heart failure, also known as congestive heart failure, occurs when the heart does not pump blood as efficiently as it should. Heart failure does not imply that the heart ceases to beat; this is a common misconception. Instead, the heart continues to beat, but the body's need for blood and oxygen is unsatisfied. If left untreated, heart failure can worsen. It is critical to follow the doctor's orders if your loved one has heart failure.

Arrhythmia

An abnormal heart rhythm is referred to as **arrhythmia**. Arrhythmias come in a variety of forms. The heart can beat too slowly, too quickly, or in an irregular pattern. Bradycardia or a slow heart rate, occurs when the heart rate is less than 60 beats per minute. Tachycardia, or an abnormally fast heart rate, is defined as a heart rate of more than 100 beats per minute. An arrhythmia can impair the function of your heart. Your heart may not be able to pump enough blood to meet your body's needs if it has an irregular heartbeat.

5.3 The breathing system

Hold your breath and see how long you can hold your breath as you continue reading. How long can you do it? May be you are feeling uncomfortable already. Why do you feel uncomfortable? Then, individually, write down the reasons why this happens. Share your list and discuss in groups on your reasons.

Objectives

At the end of this section, the student will be able to:

- *Draw and label the human breathing systems,*
- *Show the link between the human breathing system and the circulatory system, and*
- *Demonstrate the mechanism of breathing using locally available materials*

You can't go more than 3 minutes without breathing, and even if you tried, your autonomic nervous system would take over. This is because every cell in the body needs to run the oxidative stages of cellular respiration, the process by which energy is produced in the form of adenosine triphosphate (ATP). Oxygen is used as a reactant, and carbon dioxide is released as a waste product, in order for oxidative phosphorylation to take place. Although cells require oxygen, your need to breathe is primarily driven by the accumulation of carbon dioxide.

The respiratory system, which includes muscles to move air into and out of the lungs, passageways through which air moves, and microscopic gas exchange surfaces covered by capillaries, allows

carbon dioxide to be exhaled and oxygen to be inhaled. Gases are transported from the lungs to tissues throughout the body via the circulatory system. If your breathing is disrupted by a variety of conditions, such as what you did in your activity above, or diseases of the respiratory system, such as asthma, emphysema, chronic obstructive pulmonary disorder (COPD), and lung cancer, you will experience difficulties in the normal functioning of your breathing system, which can be quite severe at times.

What is the primary function of the breathing system in human body?

The breathing system organs' primary functions are to:

- provide oxygen to body tissues for cellular respiration,
- remove the waste product, carbon dioxide,
- help to maintain acid-base balance, and
- portions of the breathing system are also used for non-vital functions such as sensing odors, producing speech, and coughing.

The nose, larynx, pharynx, trachea, bronchi, bronchios, and alveoli are the major structures of the breathing system. The following sections go over these structures and their functions one by one.

Activity 5.22 Individual work

Students, you will be provided with prepared diagram/model of the human breathing systems. Observing your diagram/ model draw, label and study the breathing system. During your activity use virtual lab (simulation software, animation and video). Then, answer the following question given below.

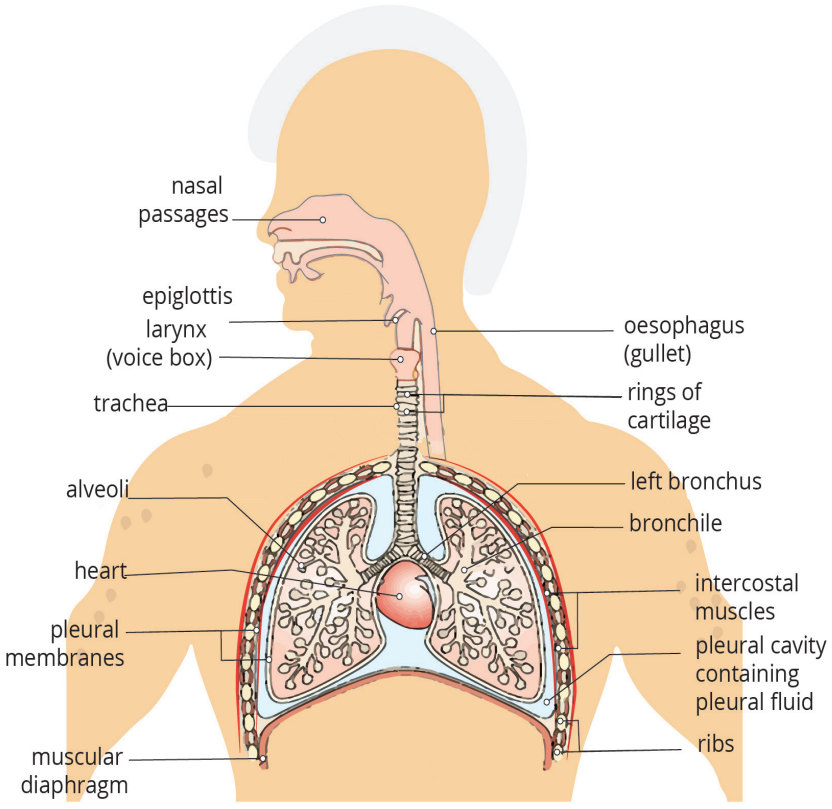


Figure 5.16. The human breathing system

Activity 5.23 Individual work

When you are sick of common cold or influenza, you may lose your smelling sense for some time and regain it back when you get better of the common cold.

1. Explain this phenomenon
2. What is the reason for the loss of you sense of smell?

In humans, air enters the breathing system through the two nasal cavities or the mouth (Figure 5.18). The tiny hairs that line the nasal cavities act as a filter, keeping foreign particles out of the lower breathing tract. The nasal cavity contains mucus, which warms and moistens the incoming air, traps foreign particles and keeps the cells that line the cavity moist.

Major breathing structures and their functions

The Nose

The nostrils are the main entry and exit points of breathing system, which are located in the nose. The nasal cavity, which is divided into left and right sections by the nasal septum, receives the inhaled air. The air moves from the nasal cavities to the pharynx. Mucous membranes line portions of the nasal cavities, which contain sebaceous glands and hair follicles that prevent large debris, such as dirt, from passing through the nasal cavity.

Why nasal cavity is considered as a good air conditioner?

Goblet cells, a type of specialized columnar epithelial cell that produces mucus to trap debris, are found in the nasal epithelium. With a constant beating motion, the cilia of the breathing epithelium help remove mucus and debris from the nasal cavity, sweeping materials towards the throat to be swallowed. Cold air, on the other hand, slows the movement of the cilia, resulting in the accumulation of mucus, which can lead to a runny nose in the winter. This moist epithelium warms and humidifies the incoming air. The incoming air is warmed by capillaries just beneath the nasal epithelium. Because the thick mucus produced to defend you from pathogens blocks the surface of the receptors on the nasal epithelium, you lose your ability to smell during a common cold or influenza.

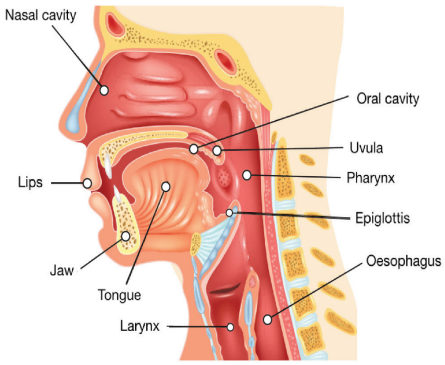


Figure 5.17. The pharynx

Pharynx

The pharynx is a tube made up of skeletal muscle and mucous membrane that runs parallel to the nasal cavities. The pharynx, also known **as the throat**, is a tube that runs from the base of the skull to the sixth cervical vertebra. It receives air from the nasal cavity and air, food, and water from the oral cavity, serving the breathing and digestive systems. It opens into the larynx and esophagus from the back.

Only air can pass through the upper part of the pharynx (throat). Air, food, and fluids can pass through the lower parts. The pharynx

contains the pharyngeal, palatine, and lingual tonsils. Sometimes the pharynx can be infected by microorganisms. The pharyngeal tonsil has a large number of lymphocytes (a type of white blood cell) and is covered with ciliated epithelium that traps and destroys pathogens that enter through inhalation.

Larynx

The larynx is a structure that connects the pharynx to the trachea and helps regulate the amount of air that enters and leaves the lungs (Figure 5.18). Several pieces of cartilage make up the structure of larynx.

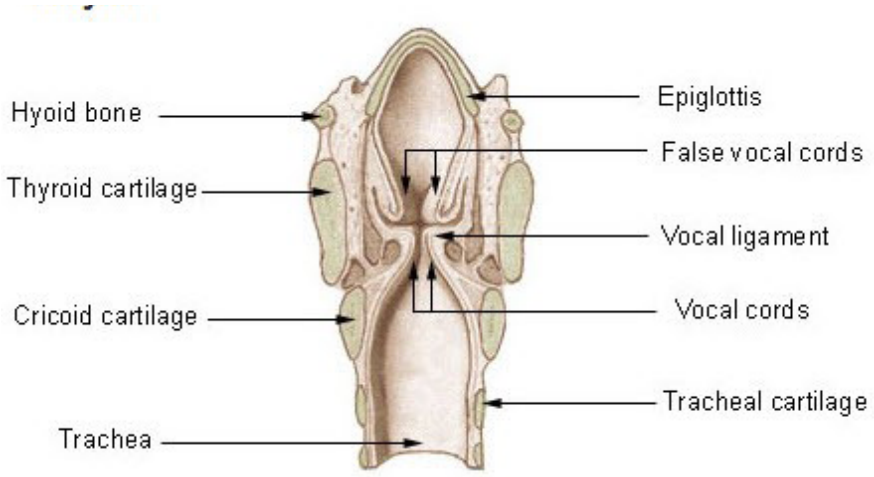


Figure 5.18. The larynx extends to the trachea.

The epiglottis is a thin, elastic cartilage that covers the trachea's opening and is attached to the thyroid cartilage. When the epiglottis is closed, the unattached end of it rests on the glottis. The glottis is made up of the vestibular folds, true vocal cords, and space between them (Figure 5.19).

Do you know how sound is formed in the voice box?

The inner borders of the real vocal cords (Figure 5.19) are free, allowing oscillation to make sound. The size of true vocal cord membranous folds varies from person to person, resulting in voices with various pitch ranges. Males have greater folds than females, which gives them a deeper voice.

What happens if pieces of food or fluid you swallow-in wrongly entered into your trachea? Which structure of your laryngeal area prevents you from such drop-ins?

During swallowing, the pharynx and larynx lift upward, allowing the pharynx to expand and the laryngeal epiglottis to swing downward,

closing the trachea opening. Because of these movements, food and liquids cannot enter the trachea, which creates a bigger region for food to travel through.

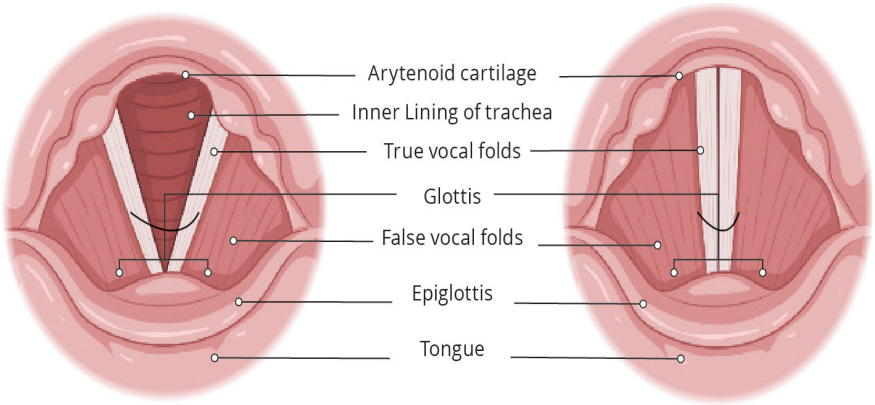


Figure 5.19 The vocal cords

Trachea

The trachea (windpipe) extends from the larynx toward the lungs (Figure 5.20). The trachea is formed by 16 to 20 stacked pieces of cartilage that are connected by connective tissue. The elastic membrane of the trachea allows it to stretch and expand slightly during inhalation and exhalation, whereas the rings of cartilage provide structural support and prevent the trachea from collapsing.

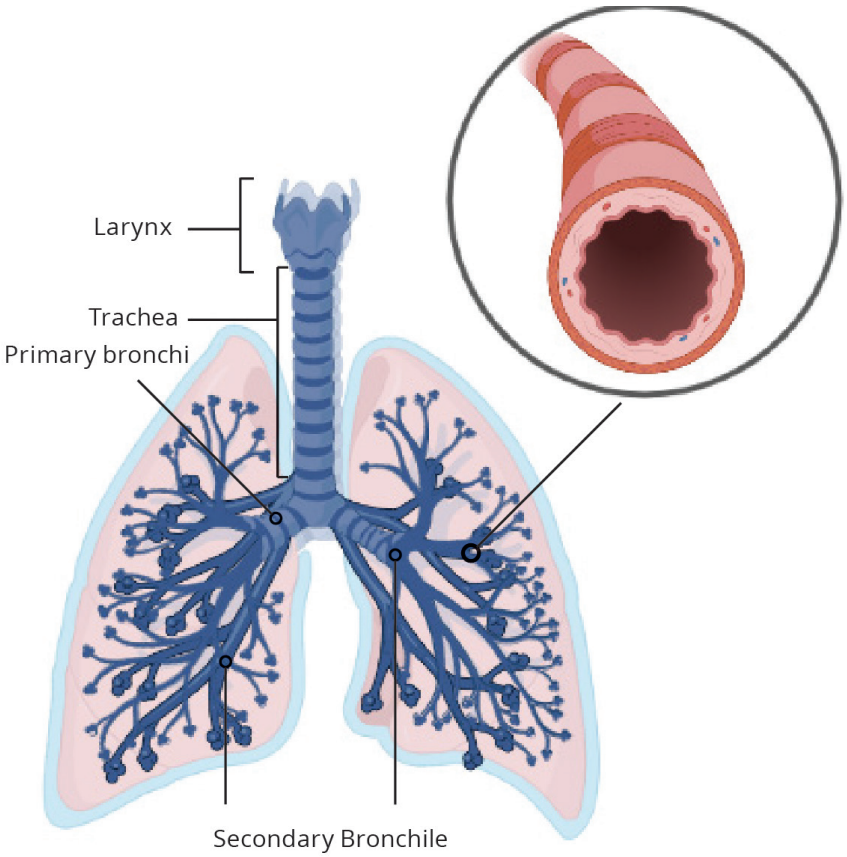


Figure 5.20 The trachea

Bronchi and Bronchioles

The right and left primary **bronchi** branch of the trachea towards the right and left lungs. The primary bronchi further branch into the secondary and tertiary bronchi. A **bronchiole** branches from the tertiary bronchi. Bronchioles, which are about 1 mm in diameter, further branch until they become the tiny terminal bronchioles, which lead to the structures of **gas exchange**. There are more than 1000 terminal bronchioles in each lung. The muscular walls of the bronchioles do not contain cartilage-like those of the bronchi. However, smooth muscle can change the size of the tubing to increase or decrease airflow through it.

Activity 5.24 Group work

Before you move to the next topic, in groups of 2-3 students, identify the interplay between the circulatory and the breathing systems. How is the breathing system interrelated to the circulatory system? Explain.

Breathing Gas Exchange

Where in the breathing system does the actual gas exchange take place?

Structures involved directly in gas exchange are found in the breathing zone. The breathing zone begins when the terminal bronchioles join a breathing bronchiole (Figure 5.21), the smallest type of bronchiole which leads to an alveolar duct and opens into a cluster of alveoli.

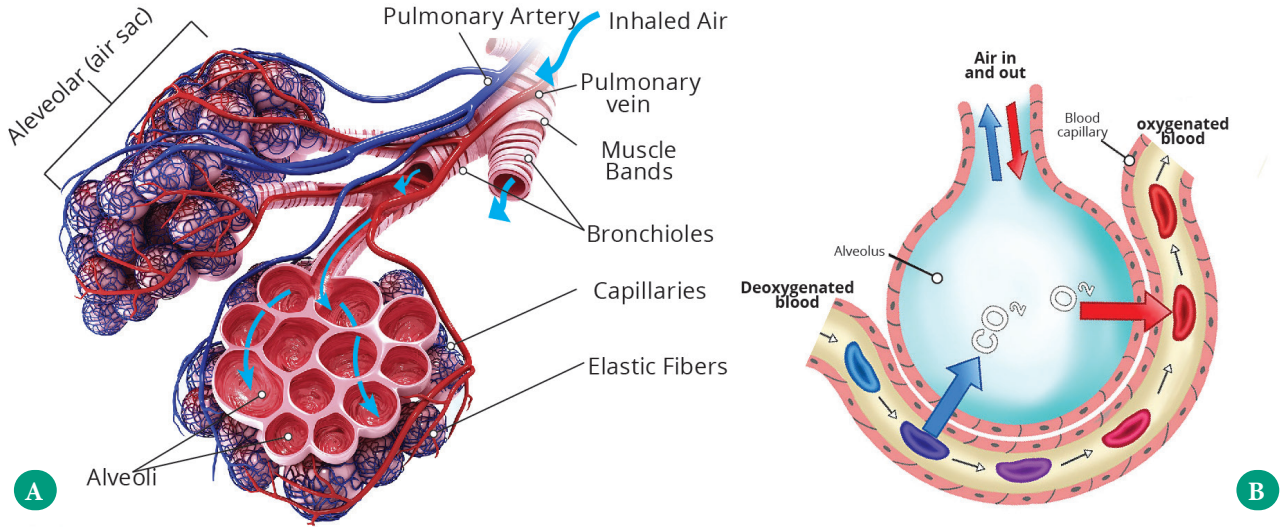


Figure 5.21 Bronchioles (a) lead to alveolar sacs (b) in the breathing zone, where gas exchange occurs.

Alveoli

An alveolar sac is a cluster of many individual alveoli that are responsible for gas exchange. An alveolus with elastic walls, stretch during air intake which greatly increases the surface area available

Activity 5.25 Individual work

Now individually, do the following: (the teacher will help you in this activity)

1. Put your pointing figure in between two of your ribs.
2. Inhale air to the maximum. What happens with your ribs?
3. Now, exhale the volume of air you inhaled. What happens to your ribs?
4. What happens with your chest cavity as you inhales and exhale air from your lungs?

for gas exchange. Alveoli are connected to their neighbors by alveolar pores, which help maintain equal air pressure throughout the alveoli and lung (Figure 5.21).

In the following table is shown the composition of atmospheric and exhaled air.

Table 5.5 Comparison of atmospheric and exhaled air

Component	Atmospheric air	Exhaled air
oxygen	21%	16%
Nitrogen	78%	78%
Carbon dioxide	0.04%	4%
Temperature	37 degree centigrade	variable
Moisture	saturated	variable

Breathing Movements

Pressure differences between the atmosphere and the chest, or thoracic cavity determine the movement of air into and out of the lungs. Atmospheric pressure remains relatively constant, but the pressure in the chest cavity may vary. An understanding of breathing hinges on an understanding of gas pressures. The mechanism of breathing is shown in Figure 5.22.

Gases move from an area of high pressure to an area of low pressure:

- Inspiration occurs when the pressure inside the lungs is less than that of the atmosphere , and
- expiration occurs when the pressure inside the lungs is greater than that of the atmosphere.

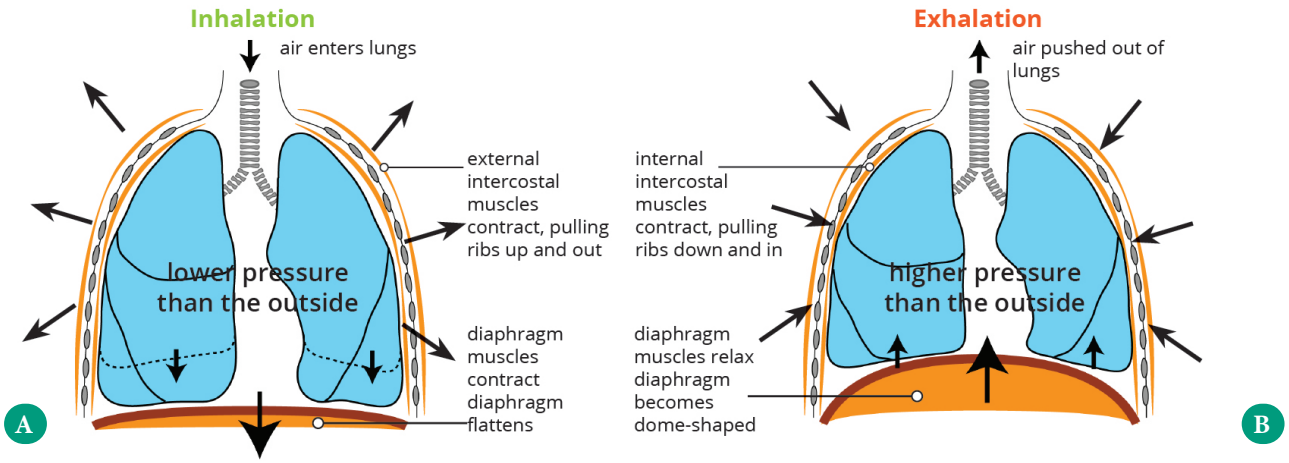


Figure 5.22 Breathing movements: a) Inspiration b) Expiration

The **diaphragm**, a dome-shaped sheet of muscle that separates the thoracic, or chest cavity from the abdominal cavity, can regulate the pressure in the chest cavity.

During inspiration, the diaphragm muscle contracts, or shortens, pulling downward. The chest volume increases and pressure in the lungs decreases. The atmospheric pressure is now greater than the pressure in the chest cavity, and air moves into the lungs.

During expiration, the diaphragm relaxes and returns to its dome shape due to the force exerted by the organs in the abdomen. The chest volume decreases and pressure increases. The pressure in the chest cavity is now greater than the atmospheric pressure, and air moves out of the lungs (Figure 5.22).

Changes in chest volume during inspiration and expiration:

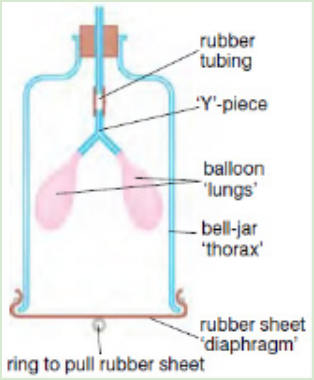
A. The intercostals muscles contract and the rib cage pull upward. Because the pressure in the chest cavity is lower than the atmospheric pressure, air moves into the lungs.

B. The intercostals muscles relax and the rib cage falls. Because the pressure in the chest cavity is higher than the atmospheric pressure, air moves out of the lungs.

Activity 5.26 Observing the mechanism of breathing

In order to observe the breathing movement of your lungs, prepare a lung model from locally available materials as indicated in the left hand corner. Materials you may need for this activity: 1. A bell jar 2. Plastic tubing (like juice straw) 3. Threads 4. The stopper and rubber tubing

Finally, produce the model and observe how your lungs move during inhalation and exhalation.



The respiratory and circulatory systems work together to provide oxygen to the body and remove carbon dioxide from the body. While the former deals with air and the latter with blood, they work together to coordinate the operations of each system's components. Other body systems, such as the digestive and neurological systems, are crucial as well, but the circulatory and respiratory systems must work continually even without a few minutes of rest.

How a blood circulatory system does interact with the respiratory system?

The circulatory and respiratory systems take oxygen from the air and transport it throughout the body while the digestive and respiratory systems take carbon dioxide from the body and release it into the atmosphere. The lungs expand and fill with fresh air as a person inhales. The respiratory system works in collaboration with the circulatory system to transport oxygen from fresh air to red blood cells in the arteries of the lungs, as well as to release carbon dioxide from the blood into the lungs' air. This used air leaves the body when a person

exhales. The heart circulates blood from the lungs, carrying oxygenated red blood cells, down the arteries to the cells, where oxygen is released and carbon dioxide is absorbed. Then the used blood is sent back through the veins to the lungs, and the cycle begins again.

Table 5.6 Summary: Comparison of inspiration and expiration

Parts of respiratory system	Inspiration	Expiration
1. Diaphram	Contracts and flattens downwards	Relaxes and moves upwards to dome shape
2. External Intercostal Muscles	Muscles contract	Muscles relaxes
3. Internal Intercostal Muscles	Muscles relax	Muscles contract
4. Ribcage And Sternum	Move upwards and out wards	Moves downwards and inwards
5. Thorax Volumes	Increases	Decreases
Air Pressure	Decrease in pressure inside thorax and lung	Increases in pressure inside thorax and lung
Air Movement	External air pressure drives air into lungs at low pressure	Air forced out of lungs by thorax compression and elastic recoil of lungs

Activity 5.27 Individual presentation

Conduct internet searches / consult health professionals/ users about the effects of smoking and cannabis on the normal functioning of the breathing system and present your findings to your classmates. During your presentation, use virtual lab (simulation software, animation and video) as available.

Disorders of the Breathing System

All breathing disorders share one common characteristic: they all decrease oxygen delivery to the tissues. The following activity will help you to explore the different types of breathing disorders.

Some of the breathing disorders are:

Bronchitis

Breathing difficulties can be caused by bacteria or viral illnesses, as well as reactions to environmental pollutants. Bronchitis is a condition in which the airways narrow and the mucous lining of the bronchial tubes becomes inflamed. Excess mucus production, tissue swelling, constriction of the airways, and restricted airflow through the bronchi are all symptoms of this condition. In the bronchioles, the situation becomes even more acute. The bronchioles, unlike the trachea and bronchi, are not maintained by cartilage bands to keep them open.

Emphysema

The alveolar walls become irritated in emphysema. The air sacs lose their flexibility, stretch, and eventually rupture as a result of this. As a result, exhaling becomes difficult, and air is trapped in the lungs. Because there are fewer alveoli, the surface area available for gas exchange is reduced, resulting in lower oxygen levels. Emphysema is caused by smoking, which is by far the most common cause. Chronic bronchitis has been linked to emphysema. COPD (chronic

obstructive pulmonary disease) is the name given to both of these conditions. COPD, like bronchitis, causes the bronchioles to become more resist[pant to air movement. Although air moves freely into the alveoli, the smaller diameter of the bronchioles increases barrier to air movement out of the lungs, making exhalation difficult. The breathing rate increases as the body attempts to maintain homeostasis. The circulatory system responds by speeding up the heartbeat.

Bronchial Asthma

The inflammation of the bronchioles is linked to bronchial asthma. Exhaling requires more work than inhaling in asthma. The imbalance between the amount of air entering and leaving the lungs must be addressed by increasing the exertion of expiration. Common causes for asthma are tobacco smoking, pollution, and allergens such as pollen, mold, dust, etc.

5.4 The Human Urinary system

Objectives

At the end of this section, the student will be able to:

- *discuss the structure and function of the kidney,*
- *identify the process of urine formation, and*
- *tell the role of the excretory system in the homeostatic process.*

What do you know about the excretory system of human beings?

You will be provided with diagrams or models of the human excretory system(kidney) and you should draw, label, and study the structure and function of the excretory system(Kidney). Finally, present your diagram to your classmates. Support your activity using virtual lab (simulation software, animation and video). You can browse from internet, books and school digital libraries.

You may be familiar with the functions of the excretory system, which include blood purification and waste removal. The system, on the other hand, performs additional equally vital functions. Consider pH control, which is shared by the lungs and blood buffers such as carbonic acid (H_2CO_3) and bicarbonate anion (HCO_3^-) in order to maintain blood pH between 7.35 and 7.45 as the value higher than 7.8 or lower than 6.8 can lead to death.

What do you know about regulating the concentration of solutes in the blood? Did you know that the kidney is important in determining the concentration of red blood cells?

The kidneys produce 85% of the erythropoietin (EPO) needed to drive red blood cell formation. The kidneys also undertake the final synthesis step in the creation of vitamin D. When the kidneys fail, these functions are weakened or removed entirely, causing

Activity 5.28 Group work

Being in groups of 3-4 students and using locally available resources construct a model of the kidney and discuss its structure and functions.

homeostasis to be disrupted. Weakness, fatigue, shortness of breath, anemia, generalized edema (swelling), metabolic acidosis, increased potassium levels, heart arrhythmias, and other symptoms may occur in the affected person. Each of these functions is critical to your survival and well-being.

The section explains the anatomy of the excretory system and how it facilitates the physiologic tasks required for equilibrium. The kidney should be thought of as a plasma regulator rather than a urine maker. As you read through each section, consider the following scenario: What if this doesn't work? This inquiry will assist you in comprehending how the urinary system maintains homeostasis and influences all other bodily systems as well as one's quality of life.

External structure of kidney

The kidneys are a pair of bean-shaped organs in the abdominal cavity that are placed directly below the liver. The endocrine system includes the adrenal glands, which are located on top of each kidney. Blood is purified and filtered by the kidneys. The kidneys filter all of the blood in the human body on a daily basis, consuming over 25% of the oxygen taken by the lungs in the process. Through aerobic respiration, oxygen enables kidney cells to produce chemical energy in the form of ATP.

What do we call the filtrate that leaves the human urinary system?

Urine is the filtrate that comes out of the kidneys. The ureters, which are around 30 cm long, transport urine from the kidneys to the urinary bladder. Urine is driven through the ureters by waves of peristalsis, rather than passively draining into the bladder (smooth muscle contractions). Urine from both ureters is collected in the bladder. Its capacity is diminished during late pregnancy because to compression by the increasing uterus, resulting in increased urination frequency. Urine is transported from the bladder to the exterior of the body via the urethra.

The only urologic organ that differs significantly between males and girls is the urethra; all other urine transport systems are identical. Female urethras are shorter than male urethras, measuring around 4 cm in length, and provide less protection against fecal germs (approximately 20 cm). The increased frequency of urinary tract infections (UTIs) in women can be explained by this length disparity. In males, the urethra also serves as a reproductive organ, transporting sperm (sperm and accessory fluids).

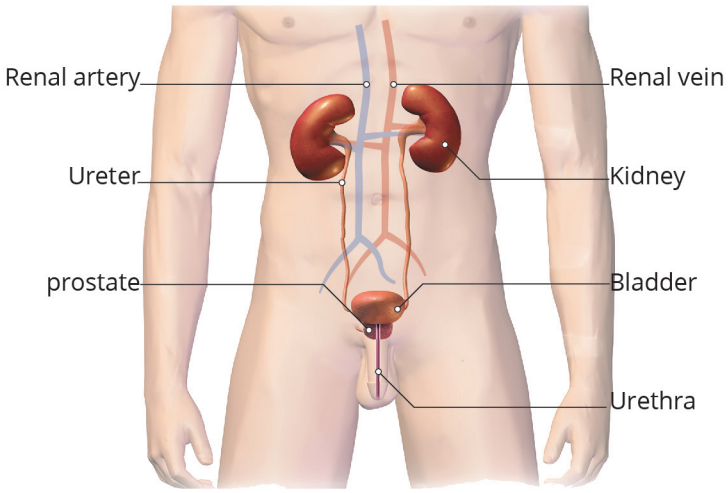


Figure 5.23 Kidneys filter the blood and produce urine that is stored in the bladder before removal

Internal structure of kidney

The kidney is divided into three sections on the inside: an outer cortex, a medulla in the middle, and the renal pelvis in the hilum of the kidney. The hilum is the concave portion of the bean form where blood arteries and nerves enter and exit the kidney, as well as where the ureters exit. The presence of renal corpuscles causes the renal cortex to be granular, and nephron tubules can be observed throughout the renal cortex and renal pyramids, which make up the majority of the renal medulla. Each kidney has an average of eight renal pyramids. The urine produced by the nephrons passes via the renal pelvis and into the ureters, which transport it to the bladder (5.24).

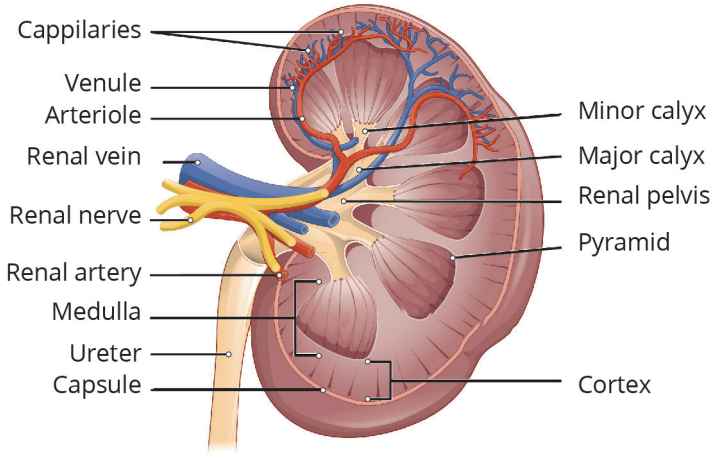


Figure 5.24.The internal structure of the kidney

The network of blood arteries in the kidney is an important part of its anatomy and function because it filters blood. The renal hilum is where the arteries, veins, and nerves that supply the kidney enter and exit. Renal blood flow begins with the aorta branching into renal arteries and finishes with the renal veins exiting to join the inferior vena cava, which takes blood back to the heart's right atrium. Before branching into several afferent arterioles and entering the capillaries supplying the nephrons, the renal arteries split multiple times to form

additional blood vessels. As mentioned previously, the functional unit of the kidney is the **nephron,** illustrated in figure 5.25. Each kidney is made up of over **one million nephrons** that dot the renal cortex. A nephron consists of three parts:

- a renal corpuscle,
- a renal tubule, and
- the associated capillary network.

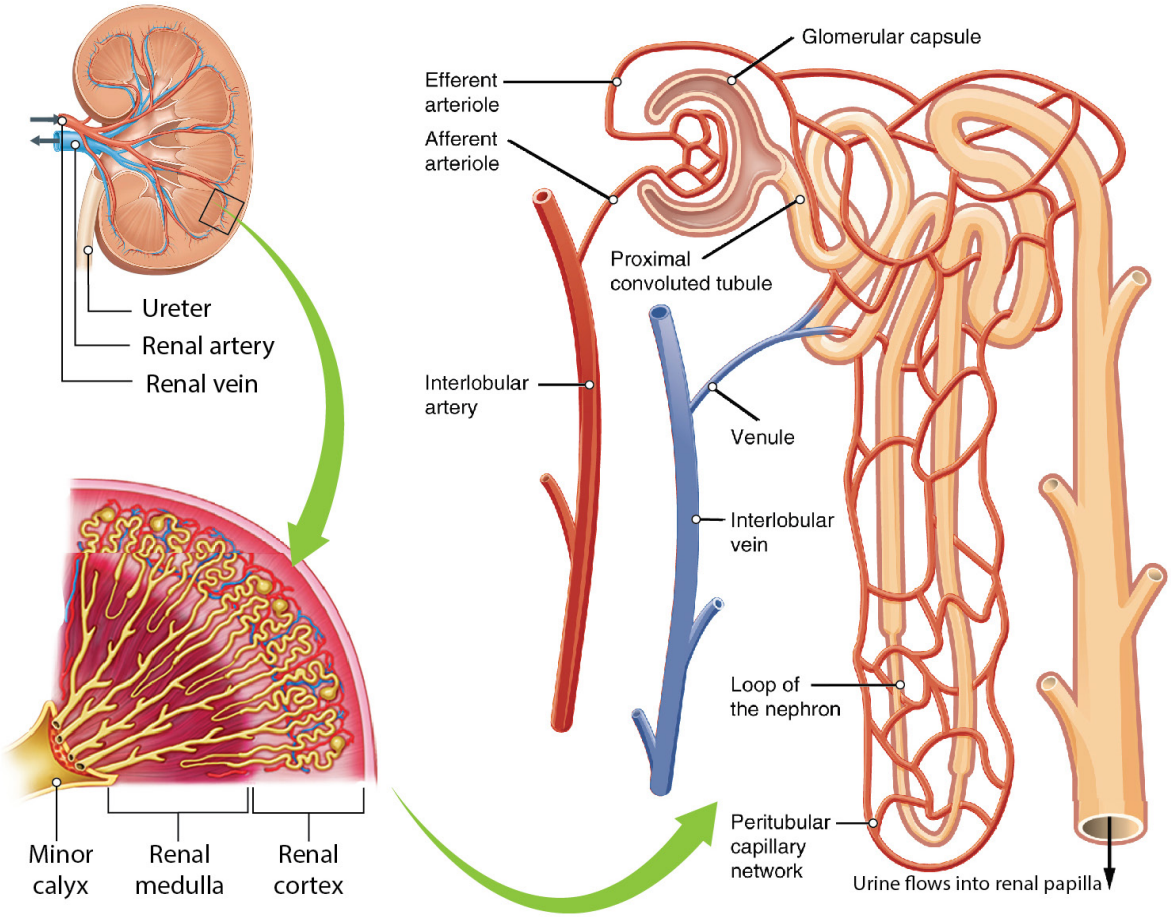


Figure 5.25. The Structure of a nephron.

Renal corpuscle

The glomerulus, a network of capillaries that surrounds the renal corpuscle in the renal cortex, is made up of the glomerular or Bowman's capsule, a cup-shaped chamber that surrounds it (Figure 5.25).

Renal Tubule

The renal tubule is a long, convoluted structure that emerges from the glomerulus and can be split into three segments based on function:

1. the Proximal Convoluted Tubule (PCT),
2. the loop of Henle, which forms a loop (with descending and ascending limbs), and

3. the Distal Convoluted Tubule (DCT). The DCT, or distal collecting duct, joins and discharges the nephron's contents into collecting ducts. Urine will eventually pass via the renal pelvis and into the ureters.

Capillary Network within the Nephron

The nephron receives blood that needs to be filtered via a capillary network that branches off from the renal arteries. Afferent arterioles are the branches that enter the glomerulus. Efferent arteriole refers to the branch that leaves the glomerulus. The glomerular capillary bed is the capillary network that runs through the glomerulus. The peritubular capillary network surrounds and interacts with portions of the renal tubule after the efferent arteriole exits the glomerulus.

What are the functions of the kidney?

The formation of urine

Kidneys filter blood in a three-step process:

The nephrons filter blood as it passes through the glomerulus' capillary network. Except for proteins, almost all solutes are filtered out into the glomerulus by a process known as glomerular filtration.

The filtrate is collected in the tubules of the kidneys. Tubular reabsorption is the process by which most of the solutes are reabsorbed in the PCT. The filtrate continues to exchange solutes and water with the peritubular capillary network in the Henle loop. During this phase, water is also reabsorbed.

Tubular secretion, which is essentially the inverse of tubular reabsorption, secretes extra solutes and wastes into the renal tubules. The collecting ducts collect filtrate from the nephrons, which are then carried into the renal pelvis and eventually to the ureters as urine. The full procedure is depicted in Figure 5.26.

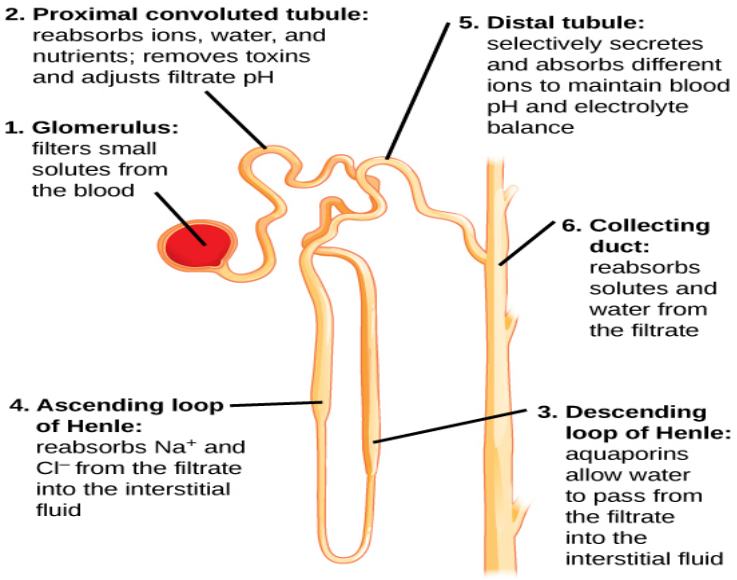


Figure 5.26. The process of urine formation in the kidney

Activity 5.29 Group work

In group of 3-4 students answer the following questions with examples.

1. Do you find any relationship between circulatory system and excretory system? What are they?
2. Nowadays our society is affected by kidney diseases. What could be the reason?

Each part of the nephron performs a different function in filtering waste and maintaining

Homeostatic balance:

1. The glomerulus forces small solutes out of the blood by pressure.
2. The proximal convoluted tubule actively transfers toxins and medications from the interstitial fluid into the filtrate, reabsorbing ions, water, and nutrients from the filtrate. By selectively secreting ammonia (NH_3) into the filtrate, where it interacts with H+ to generate NH_4^+, the proximal convoluted tubule also regulates blood pH. More ammonia is secreted when the filtrate is acidic.
3. Aquaporin-containing cells border the descending loop of Henle, allowing water to flow from the filtrate into the interstitial fluid.
4. Na^+ and Cl^- ions diffuse into the interstitial fluid in the thin section of the ascending loop of Henle. These same ions are actively transferred into the interstitial fluid in the thick region. The filtrate becomes increasingly dilute as it passes up the leg because salt but not water is lost.
5. K^+ and H^+ ions are selectively secreted into the filtrate in the distal convoluted tubule, while Na^+, Cl^-, and HCO_3^- ions are reabsorbed to maintain blood pH and electrolyte balance.
6. Solutes and water from the filtrate are reabsorbed by the collecting duct, resulting in dilute urine.

5. 5 The immune system

In a group of 3 students, discuss the immune system and types of immunity, and present your findings to the class with the guidance of your teacher.

Objectives

At the end of this section, the student will be able to:

- *define what is immunity,*
- *mention types of immunity, and*
- *discuss what is innate and acquired immunity.*

The Immunity system

Immunity is defined as the body's ability to prevent the invasion of pathogens. The immune system includes varieties of defences against viruses, bacteria, fungal infections, and parasites (such as threadworms). The lymphatic system is part of the broader immune system. The types of immune systems include innate and adaptive (Acquired) immune systems.

Mothers are recommended to breastfeed their kids immediately after delivery. Do you know why?

a) Innate immune system

The body's initial line of defense against invading microbial diseases is innate immunity. Pattern recognition receptors (PRRs), which are produced by innate immune cells, help to maintain homeostasis by regulating endogenous processes including inflammation and cell death.

These are the non-specific, unchanging lines of defenses which include:

- Physical and chemical barriers to pathogens.
- To attract immune cells to infection locations, cytokines and other chemical agents are produced.
- To recognize bacteria, stimulate cells, and facilitate the clearance of dead cells or antibody complexes, the complement cascade is activated.
- Specialized white blood cells identify and remove foreign compounds found in organs, tissues, blood, and lymph.

What do you know about the vaccines against certain diseases e.g. vaccine against COVID-19?

ii) Adaptive (Acquired) immune system

After an initial reaction to a new pathogen, adaptive (or acquired) immunity is formed, resulting in an increased response to future exposure to the same disease. Vaccination is based on this acquired immunity process. Because bacteria and viruses are always changing and evolving in an 'arms war' with our immune systems, this is critical. The adaptive immune system has the following characteristics:

- During the antigen presentation process, particular "non-self" antigens are recognized.
- The development of targeted responses to eradicate specific infections or pathogen-infected cells.
- Immunological memory is the process through which signature antibodies or T cell receptors "remember" each infection. If another infection arises, these memory cells can be summoned to eliminate the invader swiftly.

Do you have any idea about the cells of the immune system? What types of cells of the immune system do you know?

Cells of the immune system

The immune system is made up of numerous different cell types and subtypes. The following are some of the most common types:

Lymphocytes: White blood cells that travel between the bloodstream and the lymphatic system. They are crucial in the battle against infection. T cells, B cells, and natural killer cells are the three most common types of lymphocytes. Lymphocytes are formed in the bone marrow. Some move to the thymus and mature into T cells, while others mature into B cells in the bone marrow.

Neutrophils: The most common form of white blood cell, neutrophils play a vital role in the innate immune system. A type of phagocyte is neutrophils (cells that engulf and then digest cellular debris and pathogens). They are ordinarily located in the bloodstream, but chemical signals like Interleukin-8 cause them to be promptly recruited to the site of injury or infection.

Macrophages: phagocytes that play a role in both the innate and adaptive immune systems are another form of phagocyte. Foreign chemicals, pathogenic bacteria, and cancer cells are all targets for them. Lymphocytes and other immune cells are also stimulated by macrophages to respond to infections.

Dendritic cells: Antigen-presenting cells serve as intermediaries between the innate and adaptive immune systems. They are frequently found in tissues that come into contact with the outside world, such as the skin, nose, lungs, stomach, and gut linings. They travel to lymph nodes in response to infections, where they interact with T cells and B cells to start the adaptive immune response.

Antigens and antibodies

Antibodies (also called immunoglobulins) are Y-shaped proteins produced by B-cells that bind to antigens on the surface of foreign substances like bacteria and viruses. This recognizes and identifies the foreign thing as "non-self," prompting other immune cells to attack it.

Hormones and the immune system

The immune system produces a wide range of hormones. Lymphokines are the common name for these hormones. The immune system is suppressed by steroids and corticosteroids (adrenaline components).

5.6 Renowned Physicians in Ethiopia

Objectives

At the end of this section, the student will be able to:

- *mention renowned Ethiopian physicians,*
- *discuss contributions of renowned Ethiopian physicians, and*
- *appreciate the contributions of Ethiopian physicians.*

Prof. Asrat Woldeyes

1. Prof. Asrat Woldeyes (1928-1999) was the first distinguished Ethiopian surgeon and professor of medicine in Addis Ababa University. He was the first Ethiopian to qualify in this field of medicine in the West after medical studies at Edinburgh University. He devoted the majority of his working life to surgery at Addis Adaba's two main hospitals, as well as the deanship of medicine at the university.

Dr. Widad Kidane Mariam

2. Dr. Widad KidaneMariam was born to an Ethiopian emigrant family in Palestine during the Italian occupation of her country of origin. She studied medicine at the American University of Beirut and became the "first female" medical practitioner and topmost physician administrator in charge of the medical services division in the Ministry of Health in the 1960s-1970s. When she was asked to be the first Ethiopian gynecologist to volunteer for the Swedish Save the Children Fund project in Addis Abeba, she also became a founding organizer responsible for the establishment of the first Ethiopian Family Planning Association as well as Maternal and Child services for the homeless in Addis Abeba Municipality.

Activity 5.30 THINK-PAIR-SHARE

In Ethiopia, as it is true in all countries of the world, the history of medicine begins much earlier and the number of physicians that contributed to their country has increased time to time. Here are mentioned two of the most renowned pioneer Ethiopian physicians. Now, being in groups of 3-4 students and using books, internet and interviewing as a source of information:

1. List down names of the renowned Ethiopian physicians.
2. Write a report on their contributions to Ethiopian society and the world.
3. Finally, share your findings to the whole classroom.

Unit Review

- The digestive tract is made up of the alimentary canal and its auxiliary organs, which break down food into molecules that may be absorbed and used by the body's cells.
- In the body, food travels through four different processes: ingestion, digestion, absorption, and excretion.
- The digestive system has six actions or tasks that prepare nutrients for use by body cells: ingestion, mechanical digestion, chemical digestion, motions, absorption, and elimination. The wall of the digestive tract has four layers or tunics: mucosa, submucosa, muscular layer, and serous layer or serosa.
- The alimentary tract and accessory organs are the two primary components of the digestive system.
- The mouth, pharynx, esophagus, stomach, small and large intestines, rectum, and anus are all parts of the digestive system's alimentary tract.
- The salivary glands, liver, gallbladder, and pancreas are all accessory organs that are connected to the alimentary system.
- Secretions of organs and glands in the digestive system

Organ/gland of secretion	Secretion(s)	Function
Salivary glands	Salivary amylase	Initiates the breakdown of polysaccharides to simpler carbohydrates
Stomach	Hydrochloric acid	Converts pepsinogen to pepsin; kills microbes
	Pepsinogen	when converted to pepsin, initiates the digestion of proteins
	Mucus	protects the stomach from pepsin and Hydrochloric acid (HCl)
Pancreas	Pancreatic Amylase	Continues the breakdown of carbohydrates into disaccharides
	Bicarbonate ions	neutralize Hydrochloric acid (HCl) from the stomach
	Trypsinogen	when activated to trypsin, converts long-chain peptides into short-chain peptides
	Lipase	Breaks down fats to glycerol and fatty acids
Small intestine	Erepsin	Completes the breakdown of proteins
	Disaccharidases (e.g., maltase)	breakdown disaccharides (e.g., maltose) into monosaccharide
Liver	Bile	Emulsifies fat
Gallbladder	Bile	Stores and secretes concentrated bile from the liver
Large intestine	Mucus	Helps the movement of food waste

- The cardiovascular system is made up of a muscle pumping apparatus called the heart, as well as a closed system of vessels called arteries, veins, and capillaries.
- The heart is a muscle pump that provides the required force to circulate blood throughout the body's tissues.
- The epicardium, myocardium, and endocardium are the three layers of the heart.
- The right atrium, right ventricle, left atrium, and left ventricle is the four chambers of the heart.

- Atrioventricular valves and semi-lunar valves are two types of heart valves.
- The right atrium pumps blood to the right ventricle, which then pumps it to the lungs, where it receives oxygen. Blood goes from the lungs to the left atrium and subsequently to the left ventricle. It is then injected into the systemic circulatory system.
- The conduction system of the heart is made up of specialized cardiac muscle cells that coordinate the contraction of the chambers.
- Blood travels from the right ventricle to the lungs and returns to the left atrium via the pulmonary arteries.
- The systemic vessels transport blood from the left ventricle to all regions of the body's tissues before returning it to the right atrium.
- Diffusion, filtration, and osmosis are all ways for substances to flow past the capillary wall.
- Ventilation, external respiration, gas transfer, internal respiration, and cellular respiration are all part of the respiration process.
- The pharynx also referred to as the throat, is a tract that runs from the base of the skull to the sixth cervical vertebra.
- The larynx, often known as the voice box, is an airway that connects the pharynx above and the trachea below.
- The major airway to the lungs is the trachea, sometimes known as the windpipe.
- The trachea is divided into the right and left principal bronchi, which branch off into smaller and smaller passages until they reach alveoli, which are tiny air sacs.
- Beyond the major bronchi, the two lungs contain all of the bronchial tree's components.
- The right lung is narrower, wider, and divided into three lobes than the left lung.
- The left lung is longer, narrower, and divided into two lobes than the right lung.
- The urinary system eliminates waste products from the body, controls fluid volume, maintains electrolyte concentrations in body fluids, regulates blood pH, and secretes erythropoietin and renin.
- The kidneys, ureters, urinary bladder, and urethra are all parts of the urinary system.
- The parenchyma of the kidney is made up of the cortex and medulla.
- The renal pelvis is located in the center of the kidney and collects urine as it is produced.
- A nephron, which is made up of a renal corpuscle and a renal tubule, is the functional unit of the kidney.
- Urine is transported from the kidney to the urinary bladder via the ureters.
- The urinary bladder serves as a temporary urine storage reservoir.
- The urethra is the last tube through which urine flows.
- An involuntary internal urethral sphincter and a voluntary external urethral sphincter govern the passage of urine through the urethra.

Review Questions

I. True False Items: Say "**True**" or "**False**" for the following statements on your exercise book.

1. Blood pressure is highest in veins.
2. Atherosclerosis is the build-up of plaque inside arteries.
3. Platelets are blood cells that fight infections.
4. Food travels from the mouth to the stomach because of gravity.
5. Most absorption of nutrients takes place in the stomach.
6. For good health, you should never eat lipids.
7. The kidneys are the main organs of the excretory system.
8. Nephrons carry urine out of the body.

II. Multiple Choice Items: Choose the correct answer from A - E and write on your exercise book.

1. Part of the alimentary canal where mechanical digestion and the chemical digestion of polysaccharides begin.

   A. Mouth B. Stomach C. Liver D. Small Intestine E. None of the above

2. The 1st location in the digestive system where peristalsis occurs:

   A. Mouth B. Esophagous C. Stomach D. Small Intestine E. Large Intestine

3. Where in the alimentary canal does pepsinogens are activated into pepsin to aid in the digestion of proteins.

   A. Mouth B. Esophagous C. Stomach D. Small Intestine E. Pancreas

4. The organ that releases many enzymes that aid in the breakdown of all types of organic molecules:-

   A. Mouth B. Gall Bladder C. Stomach D. Liver E. Pancreas

5. The tube though which food and air (that you breathe) passes:-

   A. Esophagous B. Larynx C. Trachea D. Pharynx E. Rectum.

6. Bile is produced in _____.

   A. Salivary Glands B. Pancreas C. Stomach D. Liver E. Gall Bladder

7. Which of the following organs produce insulin, required for glucose uptake into body cells?

   A. Liver B. Gall Bladder C. Pancreas D. Stomach E. None of the above

8. Which of the following <u>is not</u> a major task of the digestive system?

   A. Secretion B. Digestion C. Absorption D. Elimination E. Circulation

9. Which of the following is not considered an accessory gland to the digestive system?

   A. Wall of the gastrointestinal tract GI) C. Liver

   B. Salivary Glands D. Pancreas

   E. All of the above

10. Rank the following blood vessels in order of their average pressure, from highest to lowest:

artery, vein, arteriole, venule, aorta, capillary.

A. Capillary > vein >venule> arteriole > artery > aorta

B. Aorta > arteriole >venule> artery > vein > capillary

C. Aorta > artery > arteriole > capillary >venule> vein

D. Capillary > arteriole >venule> artery > vein > aorta

E. None of the above

11. Which of the following statement about circulatory systems is false?

A. In closed circulatory systems, blood flows through vessels that are separate from the interstitial fluid of the body.

B. The earthworm has a closed circulatory system.

C. In an open circulatory system, the hemolymph empties into the body cavity.

D. Lobsters are organisms that have closed circulatory systems.

12. Red blood cells are also known as:-

A. Lymphocytes B. monocytes C. erythrocytes D. basophils

13. How does the structure of red blood cells allow them to deliver oxygen to the cells of the body?

A. Their size and shape allow them to carry and transfer oxygen.

B. Their disc shape contains many small vesicles that allow them to carry and transfer oxygen.

C. They have nuclei and do not contain haemoglobin.

D. They contain coagulation factors and antibodies.

E. All of the above

14. Which of the following best describes plasma?

A. It is a protein synthesized in the liver.

B. It is a liquid that contains only lipids and antibodies.

C. It is a blood component that is separated by spinning blood.

D. It is an antibody produced in the mucosal lining.

E. All of the above except A

15. Which of the following is a function of the breathing system?

A. gas exchange C. transport of oxygen

B. absorption of nutrients D. structural support E. A and D

16. The trachea leads to the____.

A. bronchioles B. Bronchii C. oesophagus D. pulmonary vessel E. Nasal cavity

17. The space at the back of the mouth, which leads either to the airway or the esophagus is the:

A. larynx B. nasal cavity C. Pharynx D. None of the above

18. Oxygen from the air enters the bloodstream through:-

A. cardiac notch B. pulmonary vein C. alveoli D. paranasal sinuses E. larynx

19. When the diaphragm contracts (is pulled downward), _____ occurs.

A. inhalation C. hiccup

B. exhalation D. Lung collapse E. Both exhalation and inhalation

20. Which one of the following is the correct path urine takes as it moves through the urinary system?

A. kidneys - ureters - bladder – urethra C. bladder - kidneys -urethra – ureters

B. ureters - kidneys - bladder - urethra D. Uretra – kidneys – Ureters – badder

E. None of the above

21. The _____ is the functional unit of the kidney.

A. Villus C. Lymph node

B. Alveoli D. Nephron E. All of the above

22. Which of the following substances <u>are not</u> filtered out of the blood in the nephrons?

A. Blood cells and proteins C. Urea and water

B. Glucose and amino acids D. Salts and hormones E. A and C

23. All of the substances that are removed from the blood via the Bowman's capsule are called __.

A. Plasma B. Filtrate C. Urine D. Lymph W E. C and D

24. What substances must be reabsorbed back into the blood from the convoluted tubule and loop of Henle?

A. Water B. Salts C. Glucose D. All of the above E. None of the above

25. Urine is primarily composed of:

A. Lymph B. Red blood cells C. Carbon dioxide D. Water E. Oxygen

26. What is the role of liver in the maintenance of homeostasis?

A. Stores extra carbohydrates in the form of glycogen

B. Produces bile to aid in fat digestion

C. Produces clotting proteins D. All of the above E. Only A and B

III. Fill in the Blanks: ***Fill in the blank with the term that best completes the sentence.***

1. Blood pressure that is higher than normal termed _____.
2. The liquid part of blood is referred to as _____.
3. Blood type is determined by the presence or absence of _____ on blood cells.

4. Tiny sacs in the lungs where gas exchange takes place are called _____.

5. The disease in which air passages of the lungs periodically become too narrow is _____.

6. A wave of involuntary muscle contractions that moves food through the digestive system is called _____.

7. The physical breakdown of chunks of food into smaller pieces is referred to as _____ digestion.

8. The small intestine is lined with tiny finger-like projections named _____.

9. Solid waste that leaves the large intestine is known as _____.

10. Nutrients needed in small amounts for the body to function properly are_____.

IV. Short Answer Items

1. Which enzymes secreted by the pancreas promote digestion?

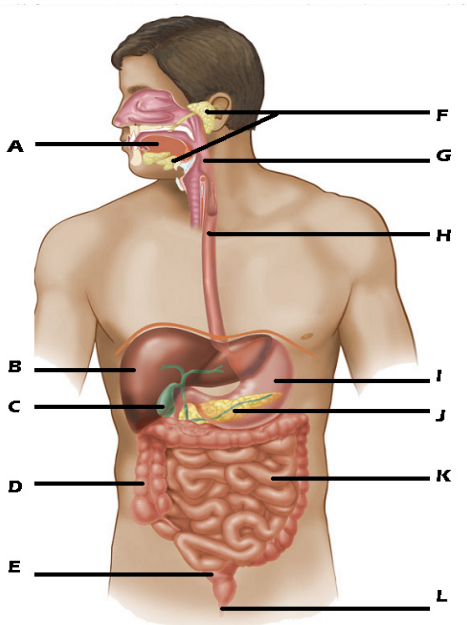
2. Explain the chemicals and processes involved in protein and carbohydrate digestion. Why are carbohydrates not digested in the stomach?

3. List the lipid-digesting enzymes secreted from the pancreas. Do these enzymes allow for acomplete breakdown of lipids?

4. How is the duodenum protected against stomach acid? Why does pepsin remain inactive in the duodenum?

5. In cases of extreme obesity, a section of the small intestine may be removed. What effect do you think does this procedure have on the patient?

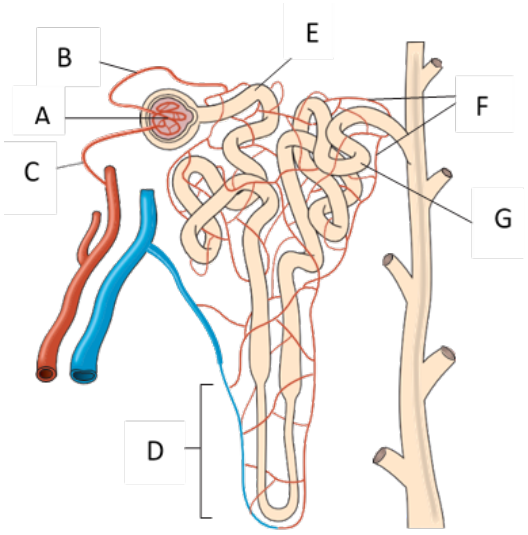
6. Describe what the inside of the small intestine looks like and how this organ increases thethe efficiency of its operation.



Write the structures A-L

1. ----------
2. ----------
3. ----------
4. ----------
5. ----------
6. ----------
7. ----------
8. ----------
9. ----------
10. ----------
11. ----------
12. ----------

7. Discuss functions of the circulatory system?
8. Mention types of blood circulation in human body?
9. Define pulmonary Circulation.
10. What is the difference between pulmonary and Systemic Circulation?
11. Discuss the effect of fat deposits on the artery walls.
12. State functions of the right atrium.
13. What is the function of the right ventricle?
14. Why muscles of the heart on the left side are thicker?
15. Label the following kidney diagram following the letters pointed at each structure



Write the structures A-F

1. ----------
2. ----------
3. ----------
4. ----------
5. ----------
6. ----------
7. ----------

Unit 6: Ecological Interactions

Contents	Learning Competency
1.1 Trophic levels 1.1.1 Food chains & Food webs 1.1.2 Flow energy and matter through ecosystems 1.2 Cycling of materials in the ecosystem 1.2.1 Water cycle 1.2.2 Carbon cycle 1.2.3 Nitrogen cycle 1.2.4 Phosphorus cycle	1.1 outline with examples the trophic levels in an ecosystem 1.2 elaborate food chain and food web with examples 1.3 show the flow of energy and matter in an ecosystem 1.4 discuss ecological pyramid 1.5 draw and label the water, carbon, nitrogen and phosphorus cycles 1.6 relate the carbon cycle with global warming 1.7 associate nitrogen cycle with soil fertility and agriculture 1.8 appreciate the role of soil organisms in soil fertility 1.9 investigate why farmers in their locality use crop rotation in cultivation

6.1 Trophic Levels

Objectives

At the end of this section, the student will be able to:

- *Define trophic level, food chain, and food web ,*
- *construct food chain and food web-based on observed feeding relationship among common organisms in their locality and*
- *outline the flow of energy from the sun to plants than to a higher trophic level.*

A cat always hunts a rat. You know what will happen if a hyena and dog come together. What does this remind you about feeding relationship in your environment?

6.1.1 Food chain and food web

What is the ultimate source of energy in life? How is energy transferred from organism to organism?

Have you observed solar panels used to collect energy from the sun, which transform solar energy to electrical energy for different purposes? Your answer might be yes, however, the best way to trap and store energy from sunlight is to grow plants and use the food they synthesize. This stored energy is transferred to other living organisms that eat plants and themselves have been eaten by another organism. Thus, the ultimate source of energy in living organisms is the sun.

How does energy flow in food chain?

In this lesson, you will learn how energy is transferred from plants through a series of organisms. Plants are the first to trap energy and produce their food. They are called producers, also known as autotrophs (self – feeding). Animals feed on either plants or other animals as a source of energy. They are known as consumers or heterotrophs, feeding on plants (herbivores) or other animals (carnivores) or feed on both plants and animals (omnivores). Thus, energy is transferred from plants through a chain of organisms, employing the "to eat or to be eaten"process. This process is known as the food chain or food web.

The following are characteristic features of a food chain

- There is repeated process of "to eat or to be eaten", so the food chain represent nutritive interaction among biotic component of the ecosystem.
- Plants (producers) are at the base or beginning of the food chain.
- There is the unidirectional flow of energy from the sun to the producers and then to series of consumers.

Is it the unidirectional flow of energy that is commonly observed in an ecosystem?

Omnivorous (animals that feed both on plants and other animals) occupy more than one position in the food chain.

You daily observe that one organism does not eat one organism only. Every organism eats different organisms and it can be eaten by other different organisms. Therefore, ecosystems normally exhibit multidirectional energy flow, which is more than a direct chain of who – eats – what. What is occurring in the ecosystem is a complex web structure, called the food web. A food web is an interconnected food chain that makes interwoven or web-like structures. As shown in Figure 6.1 food chain follows a single path whereas the food web follows multiple paths.

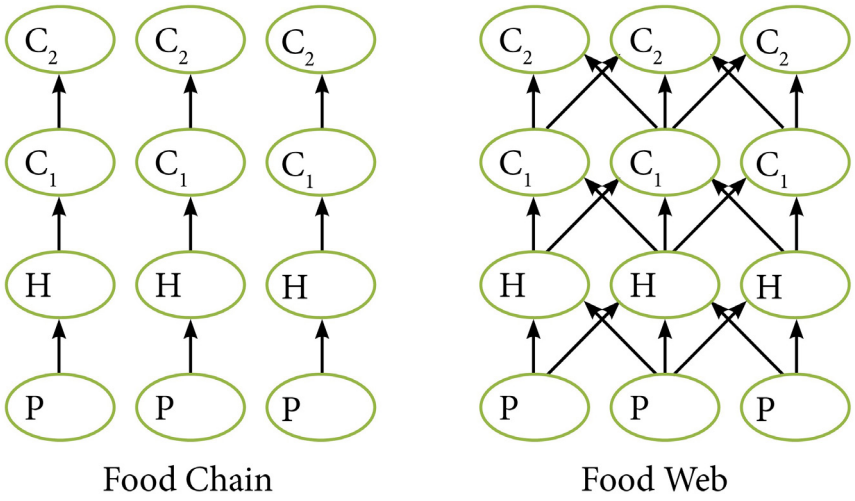


Figure 6.1 Schematic illustrations of the food chain and food web (P = producer, H= Herbivore, C_1= Primary carnivore, C_2 = Secondary carnivore).

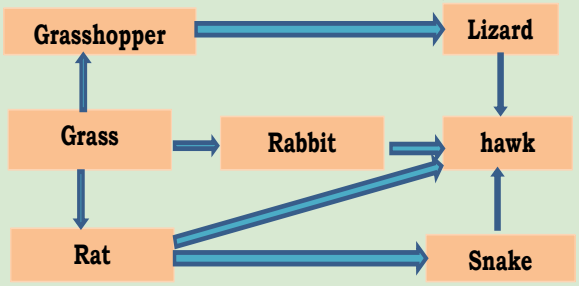
ACTIVITY 6.1 Think – Pair – Share

Direction:

Think of a possible feeding relationship of organisms commonly observed in your locality.

Share your ideas with your classmates. Discuss whether it is a food chain or food web that is observed on the ground and anticipate why this is so.

Based on the food web illustrated below, construct different short food chains and share your work with other groups.



What is a trophic level? How is it different from feeding level?

Each organism occupies a specific position in the food chain, called trophic level. Basically, a trophic level indicates the position of the organism in an order of receiving energy and usually ranges from 1 to 3 or 4 trophic levels. Plants, which are the first to trap solar energy, stand at the first trophic level; herbivores that eat plants stand at the second trophic level and carnivores that eat herbivores stand at the third trophic level (Figure 6.2).

The feeding level is the order of consuming or eating one another. Herbivores are at the first feeding level consuming plants also known as primary consumers. Carnivores that eat herbivores stand at the second feeding level and so on.

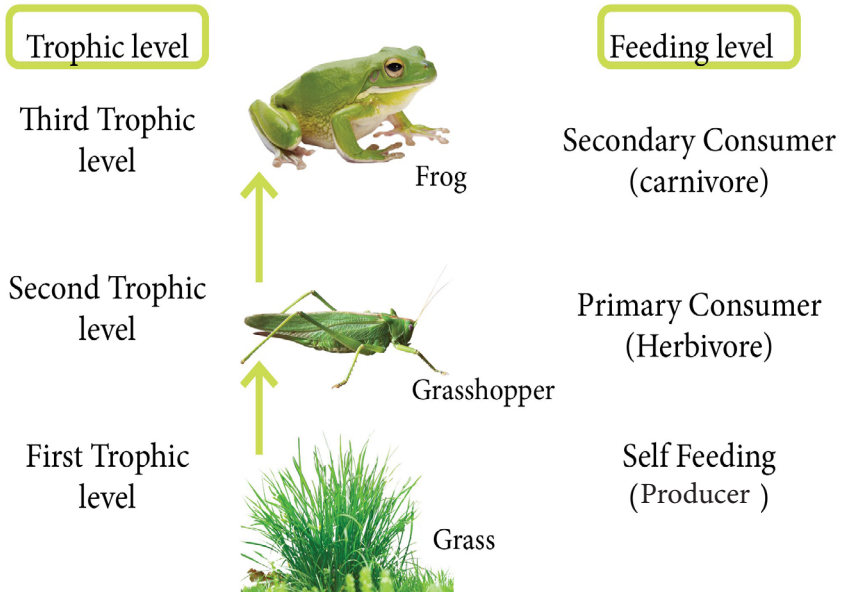


Figure 6.2 Illustration of Trophic level

ACTIVITY 6.2 Field Visit

- Your teacher will arrange a short visit to your school garden or corner with grass for you to observe feeding relationship among organisms
- You may encounter insects like grasshopper. Observe what these insects feed on and which organisms are hunting grasshoppers. Take field note on the different feeding relationships that you observed
- After coming to class, discuss with your small group on what you observed and construct a food chain and /or food web to show feeding relationship among organisms.
- Prepare a report and submit it to your teacher as an input for class discussion.

6.1. 2 Flow of energy and matter through ecosystem

How does energy flow in an ecosystem during a nutrient recycle?

You already know that the ultimate source of energy in life is the sun. You have also learned that it is solar energy trapped by the producer during photosynthesis that flows through a series of organisms by a food chain or food web. As shown in Figure 6.3, the energy from the sun flows through organisms, but this energy cannot go back to the sun. This is why we say energy cannot be recycled - it flows through the ecosystem. However, nutrients in food (organic matter) recycle within an ecosystem and are reused over and over again. This is the result of composition (synthesis) and decomposition (breakdown), which take place in the ecosystem.

Plants synthesize food (organic matter) from simple inorganic matter. When producers or consumers die, fungi and other decomposers obtain energy by breaking down the organic matter and in the process; they return key nutrients like nitrogen to the soil so that producers can use them as raw materials for photosynthesis.

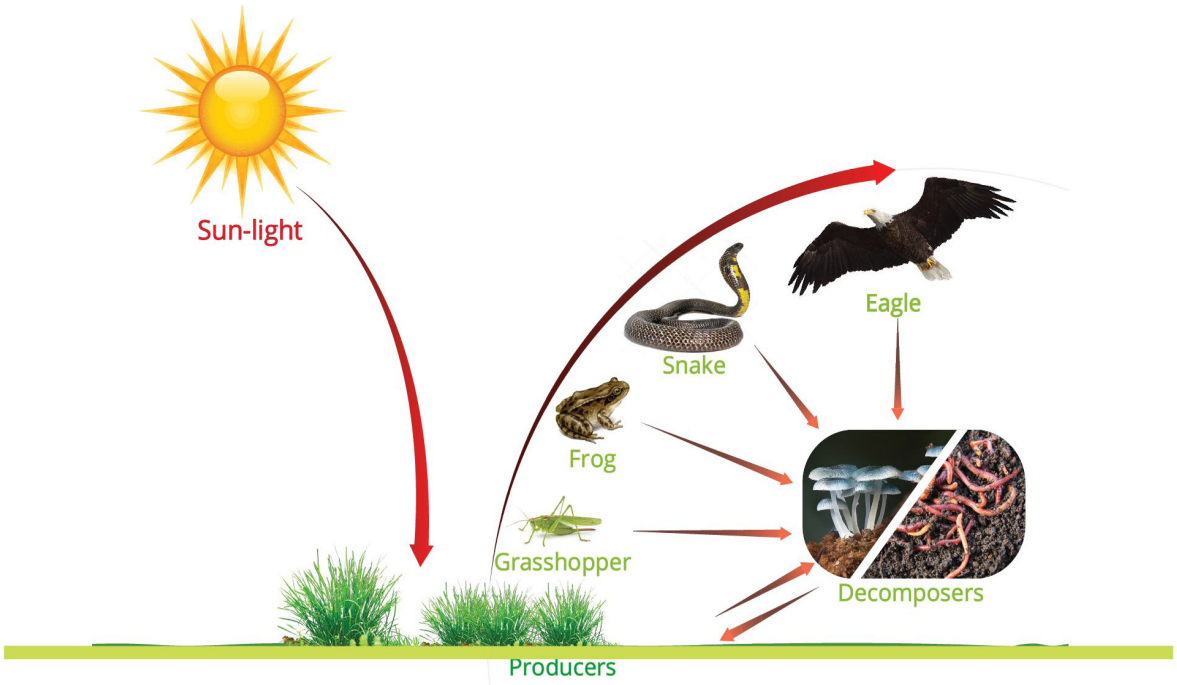


Figure 6.3 Flow of energy and matter (inorganic and organic) in an ecosystem

What happens to energy as it is transferred from one trophic level to the next trophic level?

As energy flows from one trophic level to the next it successively declines in amount. Fig 6.4 demonstrates how energy contained in the grass is not fully transferred to a cow that feeds on the grass. It is only about 10% of the energy in grass that will turn to biomass (living organic mass) in the body of the cow. The rest (90% of the total energy) is lost as heat or used for different activities of the cow

or removed from the cow's digestive system as an undigested and indigestible food item.

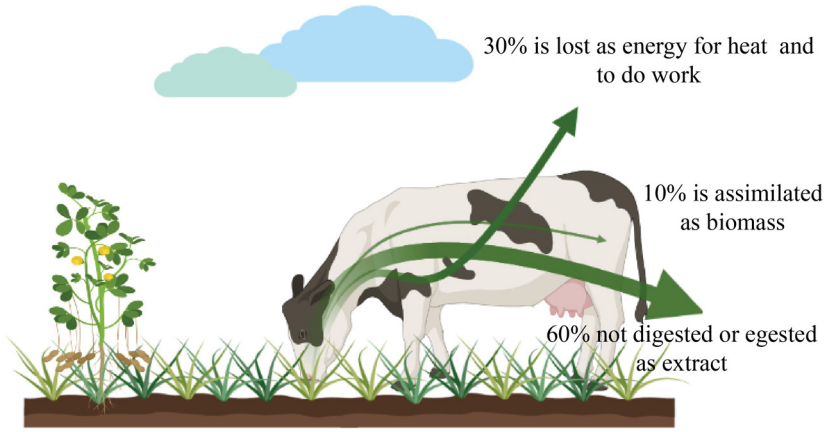


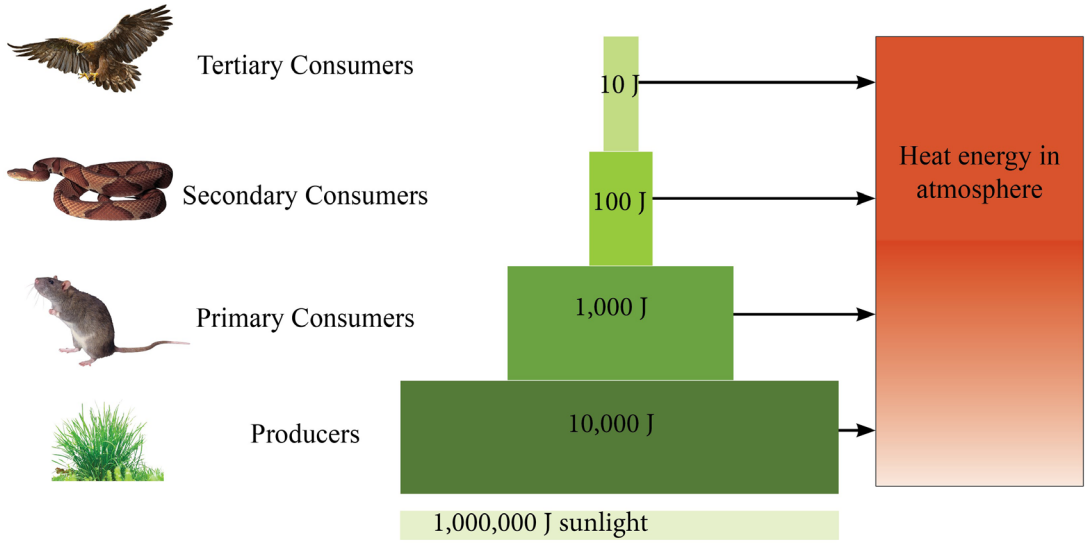
Figure 6.4 Energy transfer from grass (producer) to cow (herbivore)

The flow of energy at each trophic level in a particular ecosystem can be shown using an ecological pyramid (Figure 6.5). It is constructed using horizontal bars, where each bar represents organisms of specific trophic levels and their order, which is based on who eats whom. The ecological pyramid primarily represents the flow of energy with the producers (first trophic level) at the very bottom, followed by the primary consumers (Herbivores), then secondary consumers (carnivores), and so on, with the highest trophic level being on the top of the pyramid.

What is an ecological pyramid ? How is it constructed ?

The ecological pyramid can also be constructed to represent the biomass or number of organisms at each trophic level. Accordingly, there are three types of ecological pyramids namely: the pyramid of energy, the pyramid of number and the pyramid of biomass. The pyramid of energy is always upright and narrowing sharply from the base to the top-level carnivore because there is commonly 90% energy loss at each trophic level (Figure 6. 5).

Figure 6.5 An Idealized pyramid of energy.



Key terms

Biomass. is the weight of living organic matter contained or assimilated to the body of an organism per unit time

Ecological pyramid. This is a graphical representation of the feeding relationship of a group of organisms in the form of a pyramid. A horizontal bar is constructed to represent the different trophic level or feeding level. The bars at the base of the pyramid always represent plants (producers). The length of the bar shows the amount of energy (pyramid of energy), biomass (pyramid of biomass) or number of organisms (pyramid of number) present at each trophic level.

transfer of energy for each link in the food chain. Notice that the producer - Grass, is capable of converting only 1% of solar energy by photosynthesis.

ACTIVITY 6.3 Think – Pair – Share

Direction:

Discuss with a friend sitting next to you and answer the following questions

- Why is trophic level usually limited to 3 or 4? Why not more?
- What is the trophic level of a human being? Explain

As opposed to pyramid of energy, pyramids of biomass or number can be upright (with the long bar at the base and shorter bar at the apex) or inverted depending on the type of ecosystem and the particular food chain (Figure 6.6)

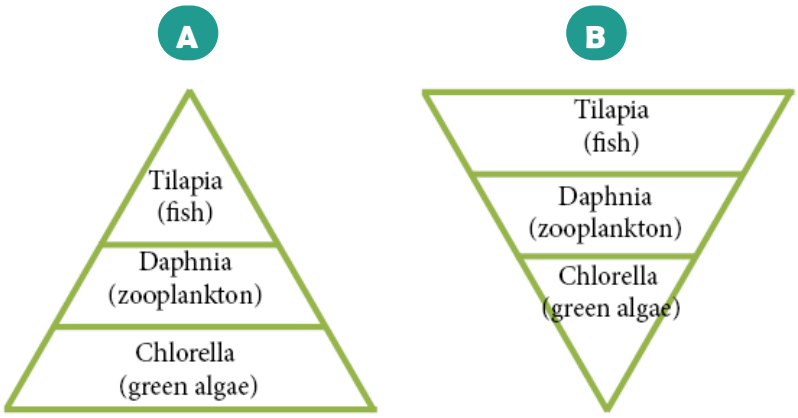


Figure 6.6 Illustration of the pyramid of number (A) and pyramid of biomass (B) in the aquatic food chain

ACTIVITY 6.4 Homework

Direction:

Based on the food chain: Tree –bird–bird flea

1. Construct pyramid of number and pyramid of biomass for the given food chain
2. Compare your pyramid with Figure 6.5 and comment on the difference
3. What do you conclude about the pyramid of number and pyramid of biomass?

6.2 Cycling of Materials in an Ecosystem

Objectives

At the end of this section, the student will be able to:

- *draw and label the water, carbon, nitrogen, and phosphorous cycle,*
- *relate the carbon cycle with global warming,*
- *associate nitrogen with soil fertility and agriculture,*
- *appreciate the role of soil organisms in soil fertility and*
- *identify why crop rotation is important to farmers*

Self Test

What is the advantage of being vegetarian (feeding on plants and plant products)?

What is meant by cycling of materials in an ecosystem?

An ecosystem refers to the complex of living organisms (biotic component), their physical and chemical environment (abiotic component), and all their interaction and interrelationship in a particular unit of space. As materials in an ecosystem are found in a limited amount, it is essential that the same nutrients materials should continuously be reused, over and over again. The cycling occurs between the biotic (living) and the abiotic (non-living) components of the ecosystem. The biotic component consists of plants, animals, and microorganisms while the abiotic comprises the atmosphere (air), hydrosphere (Aquatic/water), and lithosphere (soil). Materials always move around within an ecosystem when organisms feed, breathe, respire, and excrete. Nutrients are released when the waste product or dead bodies are decomposed. What is a waste product to one organism becomes a vital nutrient to another. For example, animal excreta (a waste product) will be broken down by decomposers, release nitrogen and phosphorous (vital nutrients) which will be used for plant growth, thereby increasing agricultural yield. Note that the waste product, instead of polluting the environment, can be a rich source of organic fertilizer.

Attention

Decomposers are bacteria and fungi, commonly found in soil. They play key role in returning nutrient to the ecosystem.

Unlike ingesters, animals that swallow food (organic matter) and digest inside their gut, digestion in decomposers takes place outside the living body in the soil, or wherever the dead matter happens to be.

Decomposers exhibit extracellular digestion by releasing enzymes on to the dead matter, digesting the complex organic matter into simpler and smaller ones and absorb these products of decomposition. Since the products released are accumulated in the external environment (soil), they serve as "nutrient pool" and increase soil fertility as well as plant productivity.

What are the important materials that cycle through the ecosystem?

ACTIVITY 6.5 Peer discussion

Direction: In pairs, discuss and answer the following questions

- Why is the cycling of materials in an ecosystem so important?
- What will happen to organisms or life if decomposers are absent from the ecosystem?

In addition to water, there are 4 elements (nutrients) that cycle through the ecosystem: oxygen, carbon, nitrogen, and phosphorous. These elements take the path from the non - living environment to living organisms, such as trees, and then back to the non – living environment. The paths that include biological, geological, and chemical processes form cycles, known as the biogeochemical cycle.

In this, subsection you will learn about the aforementioned major cycles in detail, discuss and share ideas in class.

6.2.1 Water cycle

What happens during the water cycle?

Water on earth does not stay still. It is always on move. Rain that falls at a particular place can be the result of evaporation that occurred at a distant ocean days before. Likewise, water in a river may have been rainfall somewhere at a distance or melting ice or snow from the top of high mountains. It is the water cycle that is responsible for water movement in the ocean, on the land, and in the atmosphere.

The earth has a limited amount of water. When examining the water on Earth, 97.5 percent of it is non-potable saltwater. Of the remaining water, 99 percent is locked underground as ground water or as icecap in the polar areas. Thus, less than 1 percent of freshwater is easily accessible from lakes and rivers. This water keeps going around and around in what we call the water cycle or the hydrologic cycle. Water continuously cycles between the oceans, atmosphere, land, and organisms, as illustrated in Figure 6.7. A change in temperature, heating, and cooling, is the main driving force in the water cycle, causing a change in the state of water as water vapour (gas), ice or snow (solid), and liquid water. Among the many processes involved in the water cycle, the most important are: evaporation, transpiration, condensation, precipitation, and runoff.

The water cycle is sun driven process. It is solar heating that helps the cycle to start with evaporation. Evaporation of water from the earth and surface of the leaf by transpiration rises in the atmosphere in the form of water vapor. Then, the water vapor cools and condenses in the atmosphere into rain or snow, and falls again to the earth's surface as precipitation (Rainfall or snowfall). The water falling on earth through surface run off collects in rivers, lakes, soil, and soft rocks, where some water is taken up by plant roots and much of it flows into oceans and also infiltrate the soil and accumulated as ground water. The surface water by evaporation and evapotranspiration will restart the cycle.

Water accumulated in the ground can come to the surface as a spring or stream. Groundwater can also be pumped out for different purposes such as drinking and irrigation and join the water cycle by surface evaporation.

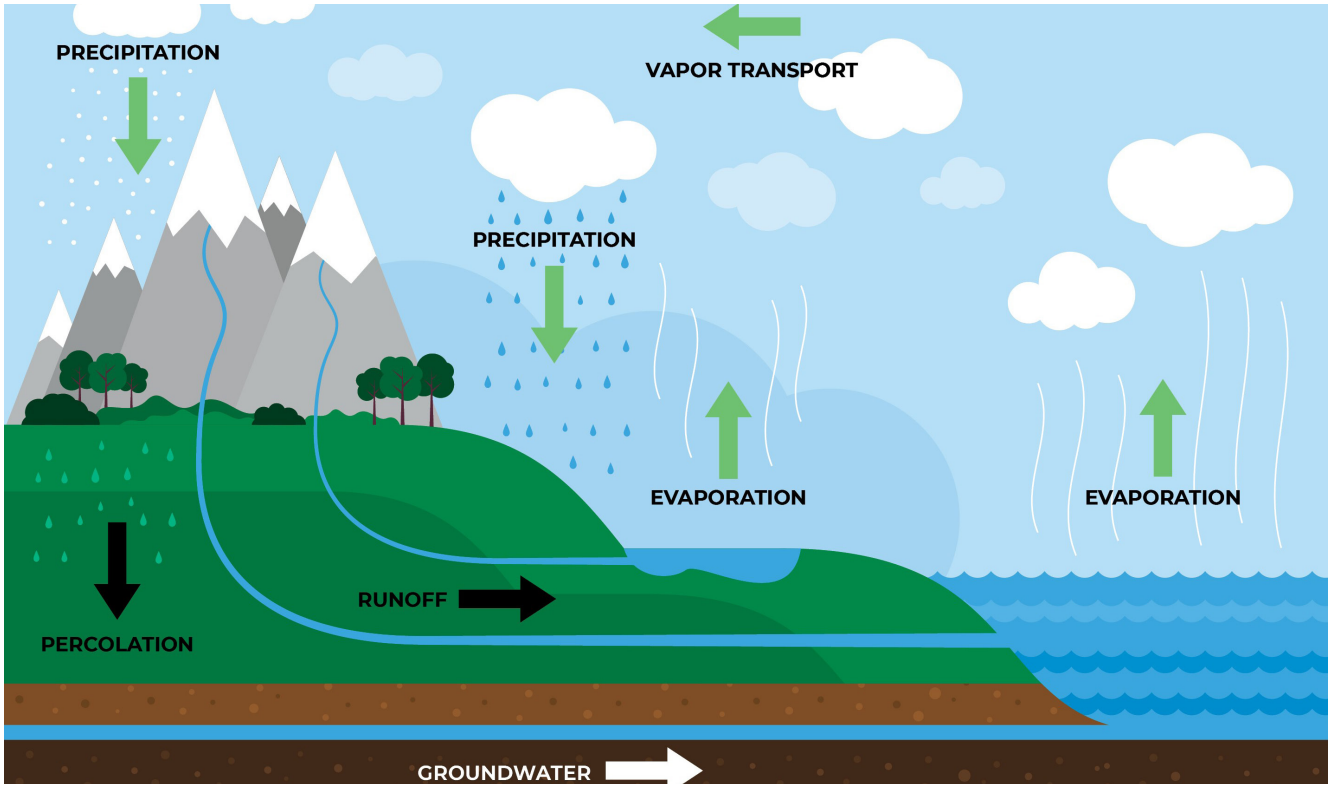


Figure 6.7 Water cycle

Activity 6.6. Group Work

Title: How does the water cycle work?

Materials Needed: Large glass beaker (100ml), Smaller glass beaker (50ml), Water, Plastic cover, string or Large rubber-band

Procedure:

- Place the small glass beaker at the centre of the larger glass beaker.
- Fill the large glass beaker with water about 2/3rd of the way up the small beaker (do not put water inside the small beaker).
- Cover the large glass beaker with a plastic cover and either tie it with string or put a large rubber band around it to secure the plastic cover.
- Place the set up outside in a sunny area for a few hours.

After a few hours observe what happens to the plastic cover and look if there is water inside the small beaker. **Key questions:**

1. What did you observe on the plastic cover?
2. What is the process that enabled water particles to move up towards the plastic cover?
3. What process is demonstrated when the water drops are getting too heavy and falling back to small glass beaker?

6.2.2 Carbon cycle

What happens during carbon cycle?

The air around us is composed of many different gases including oxygen, carbon dioxide, nitrogen and inert gases. Oxygen and carbon dioxide, in particular are important for the survival of living organisms. The amount of these gases is maintained in the atmosphere by photosynthesis and cellular respiration.

As depicted in Figure 6.8, the amount of carbon in the atmosphere is maintained by process that continuously takes it from the atmosphere and various processes that release it back to the atmosphere. When green plants undergo the process of photosynthesis to make their food they absorb carbon dioxide from the air. The carbon element stored in the plant is transferred to animals that eat the plant. When plants and animals die their dead bodies are decomposed and release carbon dioxide back to the air due to the action of bacteria and fungi in the soil. In addition all living organisms including plants and animals release carbon dioxide through respiration in their entire life time. Over a period of long time dead bodies of organisms become fossil fuel which can be used by factories, power stations and vehicles. The combustion or burning of fossil fuel also releases carbon dioxide into the air.

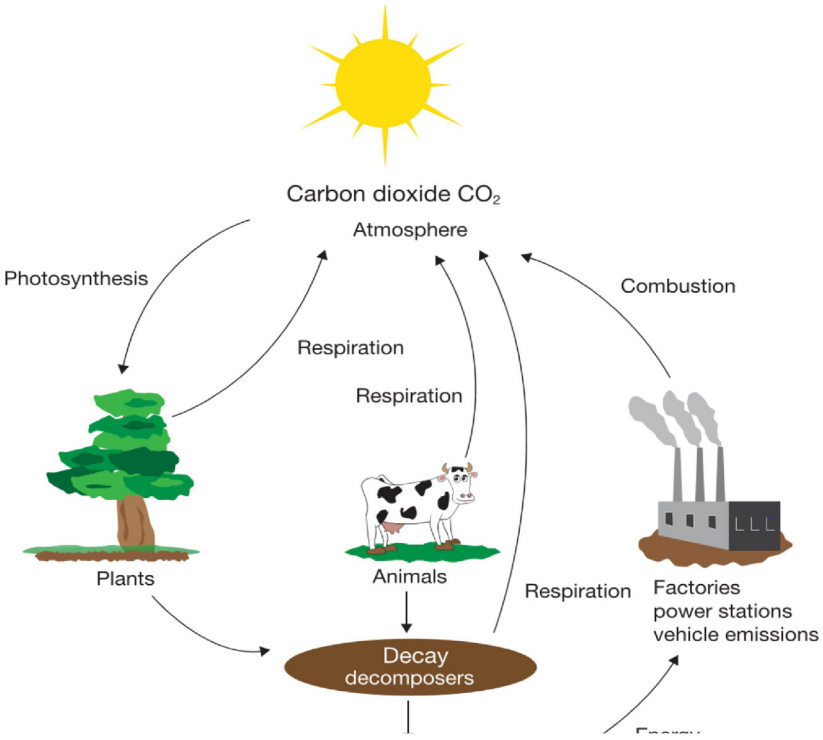


Figure 6.8. The carbon cycle

How do you link carbondioxide to climate change?

Though CO_2 is a natural part of Earth's atmosphere, humans produce more of it every year, and that's changing our climate. Its atmospheric concentrations has significantly increased since the Industrial Revolution (late 18th centuary). Burning of the fossil fuels (coal, oil,

natural gas) and wood for energy are the major sources. Atmospheric CO_2 acts like a heat-trapping blanket, absorbing the heat and holding it in, causing global warming. Global warming is a rise in the overall temperature of the earth's surface. There are also other heat-trapping gases (Greenhouse gases) in the atmosphere (methane and nitrous oxide), but CO_2 is the most important one. Thus, adition of excessive CO_2 in to the atmosphere due to human activity is the root cause of climate change.

Attention

Photosynthesis and cellular respiration are the major processes that maintain the balance of oxygen and carbon dioxide in the atmosphere

Photosynthesis is the exact reverse of aerobic respiration. The reactant for photosynthesis is the product of respiration and vice versa as shown below

$$CO_2 + H_2O \underset{\text{Respiration}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + O_2$$
(Food)

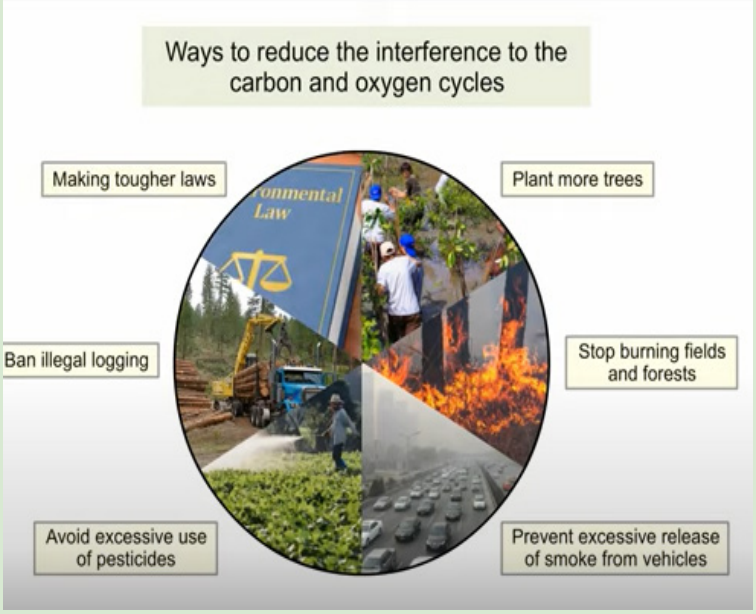
While photosynthesis occurs in the chloroplast of the leaf cell, aerobic cellular respiration takes place in the mitochondrion of a cell of aerobic organisms.

ACTIVITY 6.7 Group Discussion

Direction

In a group of four students (two pairs of neighbouring students) discuss and attempt the question below.

- How do illegal logging (cutting trees) and forest burning interferes in the carbon-oxygen cycle? How can this be related to climate change such as global warming? Why do we say the water cycle is a sun driven process?
- In small group , carefully look at the summary chart below . Discuss the ways suggested to human interference with the carbon – oxygen cycle. Select at least two ways mentioned in the chart , elaborate and write a short group report to present in class



6.2.3 Nitrogen cycle

What is nitrogen cycle?

You have learned that proteins are made up of the elements C, H, O, N and S. You also know that the immediate result of photosynthesis is carbohydrate (glucose), which consists of C, H, and O which is transformed to protein upon the addition of nitrogen. Nitrogen is available to the plant from the soil through the nitrogen cycle.

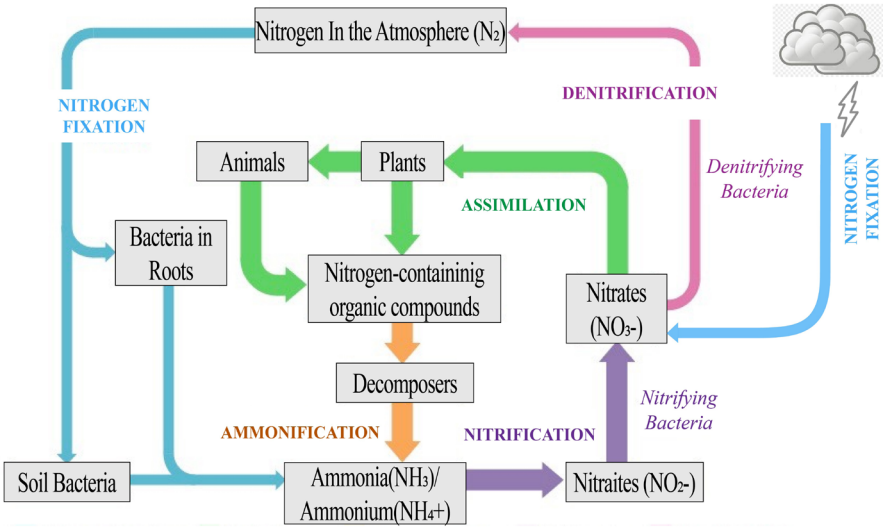


Figure 6.9. The Nitrogen cycle

As shown in Figure 6.9 the nitrogen cycle is a repeating pathway of processes during which nitrogen in different forms moves through both biotic (plants, animals, bacteria and fungi) and abiotic (atmosphere, soil, water) components of the ecosystem. The major processes involved in cycling nitrogen are: nitrogen fixation, ammonification, nitrification, assimilation and denitrification. A brief description of these processes is given hereafter

1. Nitrogen fixation

Nitrogen accounts for about 78% of the atmosphere. Most living organisms are unable to incorporate atmospheric nitrogen, N_2, into their systems. To be usable, the N_2 should be fixed into usable forms such as ammonia or nitrate. Nitrogen fixation is the conversion of N_2 into ammonia either biologically (mediated by bacteria) or non-biologically (atmospheric fixation by lightning and industrial fixation in the laboratory). In this lesson, we will focus on the biological fixation of nitrogen.

Based on the group of bacteria involved, the biological N_2 fixation may be categorized into two:

i) Symbiotic nitrogen fixation and
ii) Non – symbiotic fixation

i. Symbiotic Nitrogen Fixation

This form of biological nitrogen fixation is carried out in the root nodules of leguminous plants (such as peas, beans, and peanuts) by the group of soil bacteria known as rhizobia. Rhizobia form a symbiotic association with leguminous plants and form the root nodules where N_2 is reduced into ammonia (Figure 6.10). The nitrogen fixation reaction (conversion of N_2) is catalyzed by an enzyme known as nitrogenase.

How are rhizobia linked to global climate?

The ammonium ions produced by this process are passed to the legume plant (assimilated) and used to synthesize amino acids-building units of protein.

$$N_2 + 8e^- + 8H^+ + 16ATP \qquad 2NH_3 + H_2 + 16ADP + 16Pi$$

Figure 6.10. Root nodules of legume plant

It is well known that concentrations of carbon dioxide and other greenhouse gases in the atmosphere have increased since the beginning of the industrial era due to human activities. Among these gasses is nitrous oxide (N_2O), an intermediate product of microbial denitrification in the nitrogen cycle. The emission of N_2O is one risk to global climate change because of its global warming potential (over 300 times than carbon dioxide) and long atmospheric residence time. Excessive use of synthetic N fertilizer in the agricultural system is the major source of N_2O emissions. Biological N_2 fixation by rhizobia could be an alternative source of fixed N to synthetic N fertilizer to improve or sustain agricultural productivity and at the same time mitigate emission of N_2O to the atmosphere.

ii. Non - symbiotic nitrogen fixation

This form of biological nitrogen fixation is carried out by free living soil bacteria (belonging to the genera Azotobacter and Klebsiella). These bacteria reduce nitrogen gas into ammonium ions, which can

either be used by plants or oxidized immediately into nitrates by nitrifying bacteria.

2. Nitrification

This is a microbial process by which ammonia is sequentially oxidized - converted first to nitrite and then to nitrate.

In the first step of nitrification, ammonia-oxidizing bacteria (belonging mainly to the genus Nitrosomonas) oxidize ammonia to nitrite according to the following equation:

$$NH_3 + O_2 \qquad NO_2^- + 3H^+ + 2\,e^-$$

In the second step of nitrification, nitrite-oxidizing bacteria (mainly belonging to the genus Nitrobacter) oxidize nitrite to nitrate according to the following equation

$$NO_2^- + O_2 \qquad NO_3^- + 2H^+ + 2\,e^-$$

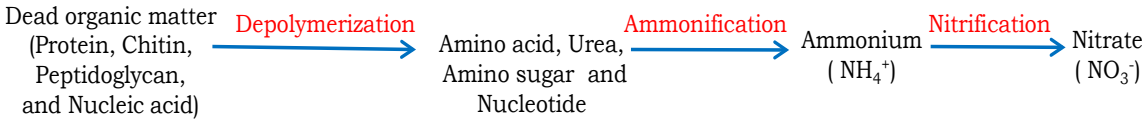
3. Assimilation of ammonium and nitrate by plant

Plants commonly absorb nitrogen in inorganic forms either as nitrate (NO_3^-) or as ammonium (NH_4^+). Plants preferentially take up the reduced ammonium (NH_4^+) rather than the oxidized nitrate (NO_3^-), because the energy expenditure for the NH_4^+ assimilation is much lower than for NO_3^-.

The mechanism of absorption of ionic forms of nitrogen is essentially similar to the mechanism involved in the uptake of other ions. Like other nutrients, they can be absorbed by the root actively or passively, reach the root xylem and then transported to the stem and leaves of the plant. Both ammonium and nitrate assimilated by plants are used in the synthesis of several amino acids which in turn are polymerized into different proteins.

4. Ammonification

This is an essential step that converts reduced organic matter having amine group (of general formula R – NH_2) present in the soil to reduced inorganic nitrogen (NH_4^+) through the action of microorganisms. Ammonification is the last step of the nitrogen cycle involving an organic compound and is an intermediary step between depolymerization of large organic molecules and the nitrification process as presented hereunder.



5. Denitrification

The flow of atmospheric nitrogen (N_2) and its various forms through soil, microorganism, plants and animals should involve a process of returning nitrogen (N_2) to the atmosphere to maintain balance. This process, called denitrification, converts nitrate to nitrogen gas (N_2), thus removing bioavailable nitrogen and returning it to the atmosphere. Unlike nitrification, denitrification is an anaerobic process, occurring mostly in waterlogged soils that are anoxic (without oxygen), layers of sediments in lakes and oceans.

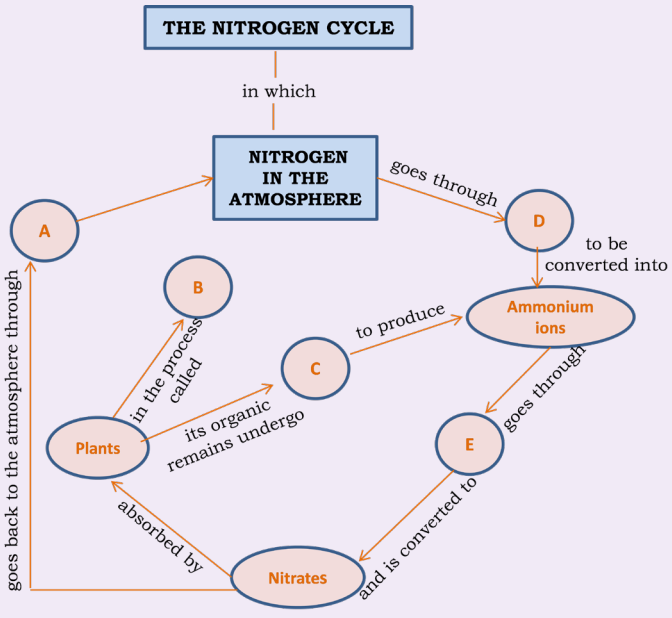
$$NO_3^- \longrightarrow NO_2^- \longrightarrow NO + N_2O \longrightarrow N_2$$

It is important to know that the biological processes of the nitrogen cycle is largely mediated by different microorganisms , mainly bacteria . This is summarized in the following table. epidermis

Biological process	Microorganisms involved
1. Nitrogen Fixation	Nitrogen fixing bacteria living in legume root nodule (Rhizobium) Nitrogen fixing bacteria living in soil (Azotobacter and Klebsella)
2.Nitrification	Nitrifying bacteria (Nirtrosomonas, Nitrobacter)
3.Ammonification	Ammonifying bacteria (Aerobic and anaerobic bacteria, fungi)
4.Denitrification	Denitrifying bacteria (Pseudomonas, Thiobacillus, Micrococcus)

Self Test

After studying the brief description of major steps in the nitrogen cycle as illustrated with Figure 6.9, complete the following mental map and label the processes represented by letters (A to E).



Why is cycling nitrogen important?

Nitrogen is the most important component in an organism in the form of DNA, RNA and proteins. You know that DNA contains a unique genetic code to guide all activities in living organisms. Like a recipe book, it holds the instruction for making all the proteins, both structural and functional, in our bodies.

Key terms

DNA (deoxyribonucleic acid) is an organic compound of complex structure that is found in all prokaryotic and eukaryotic cells. DNA codes genetic information for the transmission of inherited traits. DNA is key to life because it determines how a cell replicates and performs its various activities.

A DNA molecule is composed of a long chain of monomers, the nucleotides. Each nucleotide consists of a five carbon sugar (deoxyribose) to which is attached a phosphate group and a nitrogenous base (contains nitrogen)

Functional proteins perform different functions that play key role to life. These key roles can be : catalytic (Eg. enzymes), Storage (E.g albumin in egg, casein in milk) , transport (E.g haemoglobin transport oxygen), protective (Eg. antibodies, blood clotting factors) .. etc

Structural protein, unlike functional proteins, are involved in producing structures such as bones and muscles as well as cell membrane and skin that covers the cell and the external body respectively.

ACTIVITY 6.8 Think–Pair–Share

Direction: With a friend sitting next to you

- anticipate and point out what will happen to life or living things if there was no nitrogen in the atmosphere
- discuss the importance of soil bacteria in cycling nitrogen and comment on the misconception that bacteria are commonly taken as harmful and dangerous to human beings.

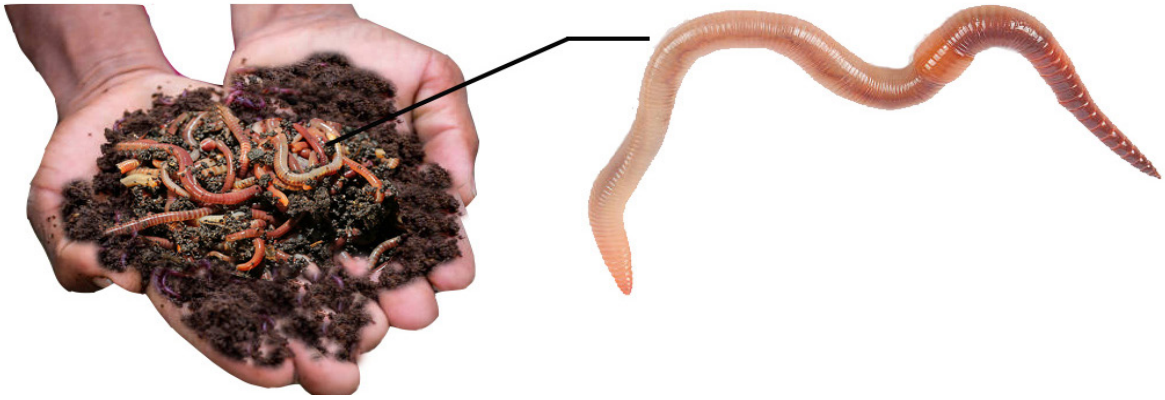
How do you relate nitrogen cycle, soil bacteria and soil fertility?

You already know that atmospheric nitrogen (N_2) cannot be directly used by both plants and animals. Plants use nitrogen in the inorganic form as ammonium and nitrate and convert it to organic forms such as amino acids and proteins. It is, thereafter, animals that feed on plants get the organic form and transform, use and store the organic form of nitrogen in their body. Here, the different soil bacteria, like the nitrogen bacteria and nitrifying bacteria are absolutely essential to providing plants with ammonium and nitrate. Moreover, the ammonifying bacteria, decomposing dead organic matter, liberate ammonium. Thus, soil bacteria that plays a key role in cycling nitrogen increase soil fertility, which in turn results in increased plant growth and agricultural productivity. For instance, the nitrogen-fixing bacteria can be used as biofertilizers due to their big capacity for fixing a huge amount of nitrogen increasing soil fertility without causing any harmful effect on aerial and soil environment. They help improve soil structure and serve as a continuous source of natural fertilizer without being leached easily.

What is the role of larger soil organisms such as earthworms ?

Earthworms are soil organisms that are visible to the naked eye (Figure 6.11). They are one of the major decomposers of organic matter. The mutual action of earthworms and microbes brings faster decomposition of organic matter, and enhance cycling of nutrients thereby facilitating plant growth and crop productivity. Having an abundance of earthworm is a good indicator of fertile soil and ensure higher agricultural yield As a result, earthworms are nicknamed as "Friends of farmers".

When earthworms move through the soil, they form tubular channel or burrows. These burrows improves soil structure, particularly soil porosity which increases the amount of air and water holding capacity. From your lesson on seed germination, you have learned that air and water are essential for seed to break dormancy (resting stage) and start growth and development of seedling. .



Key terms

Bio-fertilizers are microbial preparations containing living cells of different microorganisms which have the ability to mobilize essential plant nutrients such as nitrogen and phosphorus in soil from unusable to usable form through biological processes.

Biofertilizers, being cost effective, non-toxic, and eco-friendly, serve as good substitute for expensive and harmful chemical fertilizers. They increase crop yield, ensure food security and sustainable agriculture.

Vermicompost or worm compost is organic fertilizer obtained by using worms. These are commonly earthworms that decompose food scraps, dungs, other wastes and dead organic matter and facilitate nutrient recycling

Farmers that use **organic fertilizers** (Organic farmers) usually grow legumes such as peas and beans for dual purpose. First, they harvest the legumes as a crop as these plants are freely supplied with nitrogen fertilizer due to the nitrogen fixing bacteria in their root nodules. After harvesting yield, the organic farmers grow a non-legume crops to take an advantage of all nitrogen fixed and accumulated in the soil and root of the legumes: none is lost in a crop.

ACTIVITY 6. 9 Homework

Direction

Collect information from books about crop rotation. Then, prepare brief note and show why farmers use crop rotation and how they practice it.

6.2.4. Phosphorus cycle

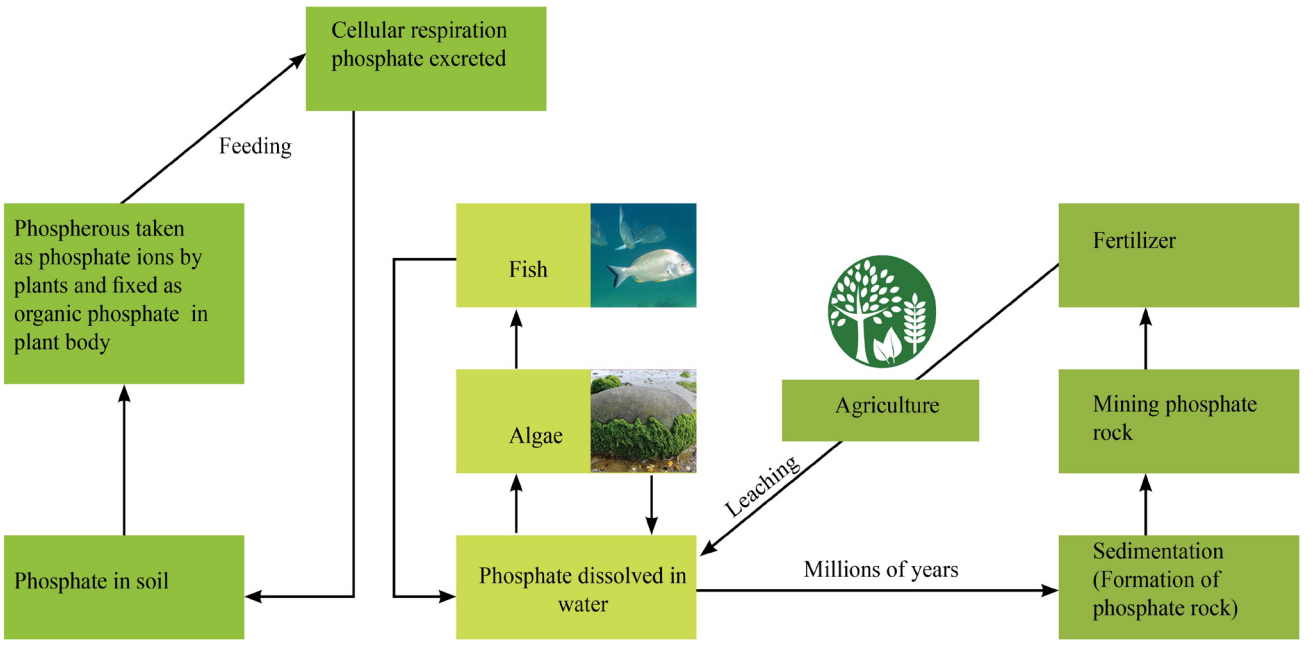
How is phosphorus recycled?

Phosphorus, like nitrogen, is needed by organisms to build proteins. Moreover, it is an essential component of the nucleotides of DNA, which is key for life. Phosphorous is also needed in the synthesis of ATP, known as the energy currency of a cell. Phosphorus is usually present in the form of phosphate ions in soil and rock.

As illustrated in Figure 6.12 cycling of phosphorus can be summarized as follows

- phosphate ions present in soil or water are taken up by plants and aquatic algae are converted to organic phosphate
- organic phosphate synthesized by the producers is passed along food chains to various consumers or feeders.
- dead bodies of plants and animals are decomposed by bacteria and fungi and phosphate ions are released from different compounds like phospholipids, ATP, DNA and returned to the soil and water bodies. Phosphate is also excreted from animals and aquatic organisms.
- phosphate will enter the soil in the form of fertilizers obtained by mining phosphate rocks and applying them in agricultural lands to boost crop yield. Phosphate fertilizer from farmlands can be leached by rainfall, reach the nearby water bodies and cause eutrophication.

Figure 6.12. Phosphorous cycle



ACTIVITY 6.10 Group work

Direction

Discuss in a small group and prepare a short report on the danger of agrochemicals (fertilizers and pesticides) released from farmlands to the nearby water body, such as lakes or reservoirs.

Key terms

ATP, abbreviation for Adenosine, is the immediate source of energy (instantly liberates energy) needed for various activities of a cell. Energy released during cellular respiration is harvested and stored as ATP.

Eutrophication is undesirable excessive growth of aquatic plants (hydrophytes or macrophysics) and massive growth of algae (algal bloom). It is induced by leaching of fertilizers (rich in nitrogen and phosphorus from nearby farmlands or water loaded

Biofertilizers, being cost effective, non toxic , and eco – friendly , serve as good substitute for expensive and harmful chemical fertilizers. They increase crop yield , ensure food security and sustainable agriculture.

Unit Summary

- The Earth obtains energy which is trapped by plants for photosynthesis and transferred to animals that feed on them.
- A food chain is a unidirectional energy flow from the sun to producer and then to a series of consumers.
- Food web is interconnected food chains that make interwoven or web-like structures where energy flows in different directions (multidirectional) from producers to different consumers.
- The order of receiving solar energy is known as trophic level in that plants (producers) are at the First trophic level and animals that feed on plants will be at the Second trophic level or First feeding level and so on.
- The flow of energy at each trophic level in a particular ecosystem can be shown using an ecological pyramid.
- The ecological pyramid can be a pyramid of energy, number and biomass.
- As energy is successively decreasing as it is transferred from one level to another level the pyramid of energy is always upright. As a result, the number of trophic where energy transferred is sufficient to sustain life will be limited from 4 to 5.

- Ecological pyramid of number and biomass, depending on the particular ecosystem and food chain, pyramid of number and biomass can be upright or inverted.
- Materials in an ecosystem are found in a limited amount and the same nutrients are continuously re-used, over and over again. This is what we call the cycle of materials.
- The most important cycle of materials in an ecosystem include: water, carbon -oxygen cycle, nitrogen and phosphorus cycles
- Water (hydrologic) cycle is a change in the state of water as water vapour (gas), ice or snow (solid) and liquid water is driven by solar heating and mainly due to change in temperature.
- Among the many processes involved in the water cycle, the most important are: evaporation, transpiration, condensation, precipitation and runoff
- The carbon cycle maintains the amount of carbon in the atmosphere by process (es) that continuously take it from the atmosphere and release it back to the atmosphere.
- In cycling carbon, atmospheric carbon dioxide is continuously taken by plants as raw material for photosynthesis and the uptake is balanced by respiration, decomposition and combustion, all of which release carbon dioxide back to the atmosphere.
- As opposed to the carbon cycle, in the oxygen cycle, where oxygen is continuously taken from the atmosphere by processes like respiration, decomposition, combustion and rusting is balanced by photosynthesis which releases it back to the air
- The nitrogen cycle is a repeating pathway of processes during which nitrogen in different forms moves through both biotic (plants, animals, bacteria and fungi) and abiotic (atmosphere, soil, water) components of the ecosystem.
- The major processes involved in cycling nitrogen are nitrogen fixation, ammonification, nitrification, assimilation, denitrification.
- The phosphorus cycle is mainly the transfer of phosphate ions from the soil, water and rock to plants and aquatic algae, first converted to organic phosphate in the producers and transferred to consumers through the food chain. Phosphate ions are released from consumers through their excreta and as their dead bodies are decomposed by soil bacteria and fungi.

Review Questions

I. True – False items: Say "True" or "False" for the following statements on your exercise book.

1. There is more energy at the third trophic level than at the second trophic level.
2. Ammonium is more preferred by plants than nitrate
3. Plants can release as well as take carbon to and from the atmosphere
4. Denitrifying bacteria are aerobic
5. It is food web, not food chain that actually exists in ecosystem

II. Multiple-choice items: Choose the correct answer from A – D and write on you exercise book.

1. In the food chain: Grass – rat – snake – Eagle, the position of Snake is at ..... feeding level and ..... trophic level

A) 3, 2 B) 3, 4 C) 4, 3 D) 2, 3

2. If the producers in the ecological pyramid have a total of 70, 000 Kcal of energy, which of the following will be true

A) The secondary consumers would have a total of 7 Kcal energy

B) The primary consumers would have a total of 7000 Kcal energy

C) The secondary consumers would have a total of 70 Kcal energy

D) The tertiary consumers would have a total of 700 Kcal energy

3. The biomass of an ecosystem is

A) The total energy of living and non – living organisms in an ecosystem

B) The total mass of living organisms in an ecosystem

C) The total energy of living organisms in an ecosystem

D) The total mass of living and non – living matter in an ecosystem

4. In nitrogen fixation, nitrogen combines with

A) Carbon B) Hydrogen C) Oxygen D) Water

5. What is the correct term for rising water vapour meeting colder air and turning back in to water droplets?

A) Condensation B) Dehydration C) Evaporation D) Precipitation

III. Matching items: Match the terms under "Column B" with description under "Column A"

Column A	Column B
1. Is the process by which the protein in the waste matter, dead plants or animals is converted to ammonia	Ammonification
2. Carbon dioxide is the by-product of this biological process	Condensation
3. The position of an organism in an order of receiving solar energy	Denitrification
4. This process converts atmospheric nitrogen into usable form.	Evaporation
5. The position of an organism in an order of who eats whom	Feeding level
6. This contributes to the return of vapour to the atmosphere	Nitrogen fixation
	Photosynthesis
	Respiration Trophic level

IV. Short Answer Items

1. Why is it unusual for a large number of organisms to be present at the top of an ecological pyramid?
2. How do plants get nitrogen?
3. List down the advantages of organic fertilizers such as dead bodies and waste products of animals as compared to chemical fertilizers.
4. What is the difference between forest clearing (cutting trees) and forest burning in terms of:
   a) carbon dioxide concentration in the atmosphere
   b) effect on global warming