بِسۡمِ اللّٰہِ الرَّحۡمٰنِ الرَّحِیۡمِ

(In the Name of Allah, the Most Compassionate, the Most Merciful.)

BIOLOGY

9

Based on Revised National Curriculum of Pakistan 2023

PUNJAB CURRICULUM AND
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Experimental Edition

Authors

- Dr. Raheela Nadeem
- Dr. Robeela Shabbir
- Dr. Adnan Ahmad Rana
- Mr. Zunnorain Ahmed
- Muhammad Naveed Asghar

Editor

- Dr. Atif Yaqub
- Dr. Robeela Shabbir
- Mr. Zunnorain Ahmed

Director Manuscript

Ms. Rehana Farhat

Supervision

- Dr. Robeela Shabbir
- Mr. Zunnorain Ahmed

Coordinator

Ms. Farida Sadiq

Dy.Director(Art&Design)

Ms. Aisha Sadiq

Dy. Director(Sciences)

Mr. Imtiaz Hussain

Design & layout

Ms.Sameira Ismail

BIOLOGY 9

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Chapter 1

THE SCIENCE OF BIOLOGY

After studying this chapter, students will be able to:

- Define Biology.
- State that the Holy Quran instructs to reveal the study of Life.
- Define major fields of Biology as Botany, Zoology and Microbiology.
- Define the sub-fields of Biology.
- Relate that Biology connects with other natural sciences.
- Distinguish in terms of the broad subject matter the fields (Biophysics, Biochemistry, Computational Biology, Biogeography, Biostatistics, Biotechnology, Bio-economics).
- Identify the careers in Biology.
- Explain with examples how Biology is a subset of the natural sciences and of the life sciences.
- Justify with examples that science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas.
- Describe the steps of the scientific method.
- Evaluate the terms 'hypothesis', 'theory' and 'law' in the context of research in the natural sciences.

Ever wondered how plants grow or why animals behave the way they do? **Science** is all about exploring these mysteries! It's a systematic way of studying the natural world through observation and experimentation. To make it easier to learn, science is divided into different branches like Biology, Physics, Chemistry, and Mathematics. In this chapter, we will dive into the fascinating world of Biology that's the study of living things. We will see how biologists use scientific method to solve biological problems.

1.1 - BIOLOGY AND ITS BRANCHES

Biology is the science of life. The word "Biology" comes from two Greek words i.e., "bios" (life) and "logos" (study). It explores the structures, functions, and interactions of living organisms. Understanding Biology helps us to address issues related to health, food, and the environment. Biology offers a fascinating journey of discovery from the microscopic world of bacteria to the vast ecosystems of our planet.

Major Fields of Biology

Biology is a vast field that explores the incredible diversity of life on Earth. To better understand this complexity, scientists have divided Biology into three main fields:

Zoology: It is the study of animals, including their structure, function, behaviour, and diversity.

Botany: It is the study of plants, including their structure, growth, reproduction, and interactions with their environment.

Microbiology: The study of microorganisms, such as bacteria and microscopic fungi is called microbiology. It includes the study of the structures, functions, habitats and reproduction of microorganisms, and their impacts on health and environment.

Branches or Sub-Fields of Biology

Biology is divided into different branches to better understand the aspects of life.

Morphology is the study of the form and structure of organisms. Morphology studies the outward appearance (shape, colour, pattern, etc.) as well as internal structures, like organs.

Anatomy is the branch of Biology that explores the internal physical structure of organisms, particularly humans. It helps in disease diagnosis, medical device development, and improving quality of life e.g., the study of the organs of the digestive system.

Physiology is the branch of Biology that deals with the functioning of body parts. For example, how the blood circulatory system transports vital substances throughout the body.

Histology is the microscopic study of tissues. Tissues are groups of cells that have similar functions. Tissue examination helps in disease diagnosis, drug studies, and understanding organ structure and function.

Cytology is the study of cells i.e., the building blocks of life. Cytologists unravel the fundamental structures of cells and their organelles. They also study the mechanisms of cell division.

The human body contains over 30 trillion cells. Various types of cells possess unique structures.

Molecular Biology deals with the study of biological molecules like carbohydrates, proteins, lipids, and nucleic acids. Molecular biologists also study fundamental life processes, develop drugs, and create genetically modified organisms.

Embryology is the study of the process of development of organism from fertilized egg. In this branch, scientists study tissue and organ formation, identify birth defects, and develop medical treatments.

Genetics is the branch of Biology that deals with the study of transfer of characteristics from parents to offspring. In Genetics, scientists also study the causes of genetic diseases, and develop better varieties of plants and animals.

Palaeontology is the branch of Biology that deals with the study of fossils. The examination of fossils helps scientists to know the evolutionary history of organisms. For example, dinosaur fossils provide evidence of giant reptiles that roamed the Earth millions of years ago.

Fossils are the remains of plants and animals that were preserved in rocks and other geological formations.

The oldest known fossil is a Cyanobacterium, estimated to be 3.5 billion years old.

Taxonomy is the branch of Biology that deals with the classification of organisms into groups on the basis of similarities and differences. Classification of organisms helps to organize and understand the diversity of life, identify new species, and study evolutionary relationships.

Ecology is the branch of Biology that deals with the relationships between organisms and their environment. Ecology helps to conserve biodiversity and address environmental problems. The food chain, for instance, illustrates the interconnectedness of organisms for energy and nutrients.

Marine Biology is the branch of Biology that deals with the study of life in oceans. It helps to understand ocean biodiversity, discover new species, and address marine conservation issues. For example, coral reefs support a wide variety of marine life.

Pathology is the study of diseases, their causes, and effects. Pathology helps in disease diagnosis, prevention, and treatment. For example, pathologist studies how the uncontrolled division and spread of cells causes cancer.

Immunology is the branch in which we study the components of the immune system and their role against diseases. Immunologists study to develop vaccines, treat autoimmune diseases, and improve immune responses to infections.

Pharmacology is the branch in which we study drugs and their effects on the body. This helps in the development of new drugs. For example, new antibiotics are developed that are used to kill bacteria and treat bacterial infections.

These are just a few of the many branches of Biology. Each branch offers unique insights into the fascinating world of life, contributing to our understanding of the complexity and beauty of our planet.

1.2- RELATION OF BIOLOGY WITH OTHER SCIENCES

Biology is closely linked with other natural sciences such as Chemistry, Physics, and Earth Sciences. These connections help us understand life processes, environmental interactions, and the complexities of living organisms.

The following are a few examples of how Biology is connected with other sciences.

1. Biochemistry

Biochemistry is the study of the structure and reactions of different chemical substances present in living systems. The study of the chemical reactions of photosynthesis and respiration are examples of Biochemistry.

2. Biophysics

It deals with the study of the principles of Physics, which apply to biological processes. For example, in Biophysics we study the rules of lever and motion for understanding the function of muscles, bones and joints.

3. Computational Biology

In Computational Biology, scientists use Mathematical models, algorithms, and computer simulations to understand biological systems and relationships. It involves analysing biological data, such as sequence of amino acids in a protein.

4. Biogeography

It deals with the study of the distribution of living organisms in different geographical regions of the world. The influence of climate change on the distribution of organisms is also studied in Biogeography.

5. Biostatistics

It deals with the principles of statistics to analyse and interpret data related to living organisms. Biostatistics plays a crucial role in biological research, healthcare, and public health etc.

6. Biotechnology

It deals with the use of living organisms or their components to develop beneficial products or processes for various fields, including healthcare, agriculture, and environmental management. For example, Biotechnologists use bacteria for the production of insulin to treat diabetic patients.

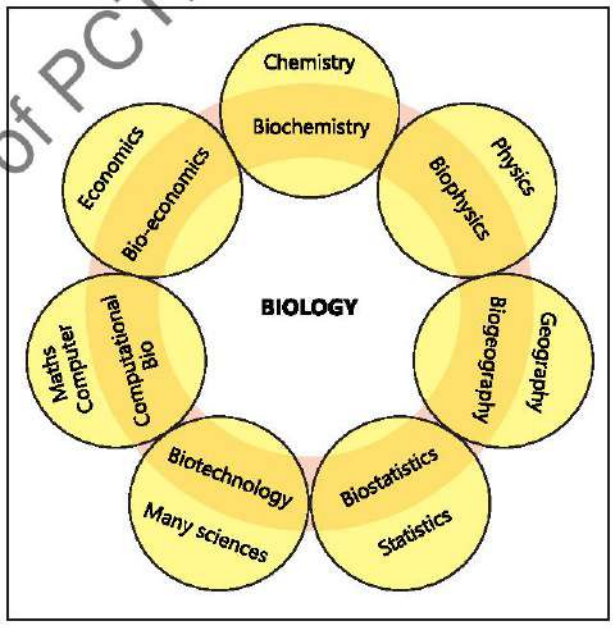


FIGURE 1.1: Relation of Biology with other sciences

7. Bio-economics

It deals with the study of organisms from economical point of view. In bio-economics, scientists calculate the cost and profit of the biological projects e.g. production of new variety of crops.

1.3- CAREERS IN BIOLOGY

The students of Biology get a comprehension of the various phenomena of life. After their FSc with Biology, they can select further studies for diverse careers, for example:

1. Medicine and Surgery

The profession medicine deals with the diagnosis and treatment of diseases. In surgery the defective parts of the body are repaired, replaced or removed. For this profession, students need to complete a 5-year Bachelor of Medicine, Bachelor of Surgery (MBBS) degree.

2. Dentistry

Dentists specialize in oral health. They diagnose and treat dental diseases and perform surgeries. For this profession, students get a 4-year Bachelor of Dental Surgery (BDS) degree.

3. Pharmacology

Pharmacologists study the effects of drugs on human body and develop new medications. For this career,

More Careers in Biology

Career	Major Jobs
Veterinary Medicine	Diagnosis and treatment of diseases in animals and surgeries in animals
Environmental Science	Solving issues related to pollution and natural resources
Microbiology	Research on microorganisms to understand their impact
Genetic Counselling	Providing support to people on genetic conditions and testing
Nutrition and Dietetics	Advising on proper dietary habits to promote health.
Public Health	Improving the health of communities through education, policy-making, and research.
Biomedical Engineering	Designing and making medical equipment to improve patient care.
Bioinformatics	Analysis of biological data by using computational tools

a Bachelor of Studies (BS) degree in Pharmacy or Doctor of Pharmacy (D. Pharm) degree is required.

4. Physiotherapy

It is the therapy that is used to restore movement and physical function of body that has been impaired by disease or injury. Physiotherapists use physical exercise and physical modalities (such as massage) to improve patient's physical movement. To become a physiotherapist, a 4-year BS degree in Physical Therapy or Physiotherapy is needed.

5. Fisheries and Wildlife

Fisheries and wildlife departments also offer jobs to the biologists after a BS and Master of Studies (MS) degree in Zoology, Fisheries or Aquaculture.

6. Agriculture

Agricultural scientists improve farming practices, crop production, and sustainable agriculture techniques. A 4-year BS degree in Agriculture is required.

7. Animal Husbandry

This field involves breeding and caring for livestock to improve their quality and productivity. For it, students can pursue a 4-year BS degree in Animal Husbandry.

8. Horticulture

Horticulturists cultivate fruits, vegetables, flowers, and ornamental plants. A 4-year BS degree in Horticulture is required for it.

9. Forestry

Foresters manage and conserve forests and wildlife. For this profession, 4-year BS degree in Forestry is necessary.

10. Farming

The professionals of farming prepare farms e.g., animals farms, poultry farms, fruit farms. In such farms, they grow crops and raise animals for food and other products. A 4-year BS degree in Agriculture or specific farming courses is required for this profession.

11. Biotechnology

Biotechnologists use biological processes to develop products and technologies in medicine, agriculture, and more. A 4-year BS degree in Biotechnology is required for this.

12. Forensics

Forensic scientists analyse physical evidence from crime scenes in criminal investigations. A 4-year BS degree in Forensic Science is needed for this.

1.4- Quranic Instructions to Reveal the Study of Life

In the Holy Quran, there are several verses that highlight the study of life. Here are a few Quranic guidelines that encourage exploring and reflecting on the study of life:

وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ ۖ

"We made every living thing from water." (Sura: Al-Ambia, Verse: 30)

The Quran mentions in multiple verses that all living things were created from water.

Water is described as a divine blessing from *Allah*.The average water content in different organisms ranges between 60% to 90%. The above Verse hints at the common origin of all living things in the water.

خَلَقَ الْإِنسَانَ مِن صَلْصَالٍ كَالْفَخَّارِ ۝

"He made man from clay like the potter." (Sura: Al-Rehman, Verse: 14)

By the hints given in both these Verses, we can find the events that occurred in the creation of human beings. We are advised to think over the possible ways through which such events might have occurred. *Allah* also hints at the method of the development of animals including human beings.

ثُمَّ خَلَقْنَا النُّطْفَةَ عَلَقَةً فَخَلَقْنَا الْعَلَقَةَ مُضْغَةً
فَخَلَقْنَا الْمُضْغَةَ عِظَامًا فَكَسَوْنَا الْعِظَامَ لَحْمًا ۝

"Then fashioned We the drop a clot, then fashioned We the clot a little lump, then fashioned We the little lump bones, then clothed the bones with flesh."
(Sura: Al-Mominoon, Verse: 14)

Quran also describes the common origin and modification of animals.

وَاللّٰهُ خَلَقَ كُلَّ دَآبَّةٍ مِّنْ مَّآءٍ ۚ فَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰى بَطْنِهٖ ۚ وَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰى رِجْلَيْنِ ۚ
وَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰٓى اَرْبَعٍ ۚ يَخْلُقُ اللّٰهُ مَا يَشَآءُ ۚ اِنَّ اللّٰهَ عَلٰى كُلِّ شَيْءٍ قَدِيْرٌ ۝

"Allah hath created every animal from water. Then some of them creep up over their bellies, others walk on two legs, and others on four. Allah creates what He pleases. Surely, Allah is most capable of everything." (Sura: Al-Nur, Verse: 45)

This verse explains that *Allah* created early life in water (fishes) and then animals with limbs were evolved. Among such animals some were created who creep over their bellies and then some were created who walk on two and some on four legs.

1.5- SCIENCE AS A COLLABORATIVE FIELD

Science is a collaborative field in which researchers from various disciplines (fields) work together to solve complex problems. Interdisciplinary teams can tackle problems more efficiently by leveraging the strengths and expertise of each discipline. It often leads to quicker and sustainable solutions. Let's discuss a few examples of interdisciplinary collaboration in science:

Human Genome Project

The Human Genome Project aimed to sequence and map the entire human genome. This project was completed in 2003. It involved researchers from various disciplines, including molecular biology, genetics, informatics, and computer science.

FIGURE 1.2: The Human Genome Project

Climate Change Research

Climate change requires collaboration among many disciplines, such as atmospheric science, ecology, economics, and sociology.

Medical Research

Medical research often depends on interdisciplinary collaboration. For example, cancer research involves oncologists (cancer consultants), biologists, biochemists, geneticists, pharmacologists, and statisticians.

Robotics and Artificial Intelligence (AI)

The field of robotics and AI is highly interdisciplinary. It involves computer science, engineering, mathematics, neuroscience, and psychology. This collaboration has led to significant advancements in robotic systems, autonomous vehicles, machine learning and natural language processing.

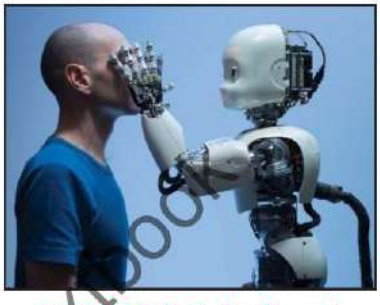


FIGURE 1.3: Robotic and artificial intelligence

Space Exploration

Organizations like NASA and the International Space Station (ISS) involve scientists from various fields, including astrophysics, planetary science, engineering, Biology, and medicine. These collaborations enable scientists to investigate the cosmos.

1.6- SCIENTIFIC METHOD

Scientists take specific steps for doing scientific work or research. These steps are called the scientific method. For biological research, these steps are called biological method. The following steps are involved in scientific method:

1. Recognition of a scientific problem
2. Observation
3. Hypothesis
4. Deduction
5. Experiments
6. Results

In all branches of science, new things are being discovered and old theories are modified or replaced with better ones.

1. Recognition of a Problem

The first step involves identifying and defining a scientific problem (specific issue or phenomenon) that scientist wants to investigate. Such problem is either asked by someone or comes in biologist's mind by himself. For

example, a biologist notices that plants in an area are growing taller than usual. He develops a scientific problem: "What factors are responsible for the increased growth of these plants?" This problem becomes the starting point for a scientific inquiry.

2. Observations

Scientists make observations about the problem. They use five senses for making observation. They also read and study the previous researches on the same or related problems. Observations may be qualitative or quantitative.

Qualitative observations involve observations that cannot be measured with numbers. For example, the colour and texture of a flower.

Quantitative observations involve measurements or numerical data that can be expressed in terms of quantity. For example, the number of birds in a tree. Quantitative observations are more accurate than qualitative because quantitative observations are invariable, measurable and can be recorded in terms of numbers.

3. Hypothesis

On the basis of observations, scientists develop a statement that may prove the answer of the scientific problem under study. Such tentative answer of scientific problem is called hypothesis. Scientists make many hypotheses for a single problem. A hypothesis has the following characteristics:

Information is also gathered by reading books. It helps to understand existing knowledge and formulate a hypothesis.

- It is a proposed statement to answer the problem.
- It always matches with the available observations.
- It can be tested through experiments.
- There is always a way to disprove the hypothesis.

4. Deduction

Scientists develop logical results from their hypotheses. Such logical results of hypotheses are called deductions. Usually, deductions follow the pattern of "if-then" statements. Scientists assume that 'if' hypothesis is true 'then' what might be the results. For example:

- **Hypothesis:** "Leaf discoloration and stunted growth in a plant are caused by a deficiency of iron in the soil".
- **Deduction:** "If iron deficiency is causing the symptoms, then adding iron to the soil will improve the colours of leaves and promote plant growth".

5. Experiments

It is the most basic step of scientific method. Scientists perform experiments to test all hypotheses. In a successful experiment, one hypothesis is proved correct and the alternate hypotheses are proved incorrect. The incorrect hypotheses are rejected and the proved one is accepted. Scientists make new deductions from the accepted hypothesis. Then they perform further experiments and confirm the correctness of hypothesis.

Experimental Group and Control group

When scientists do experiments, they arrange two settings. One is called **"experimental group"** and the other is called **"control group"**.

For example, you want to do experiment to test the necessity of carbon dioxide for photosynthesis. You will arrange two similar plants. You will not provide carbon dioxide to one plant (experimental group). While you will provide carbon dioxide to the other plant (control group). The necessity of carbon dioxide will be proved when photosynthesis does not occur in the experimental group but occurs in the control group.

6. Results

Scientists gather data from their experiments. They use statistical analyses and graphs etc. to summarize the results. Scientists also include a list of all the references in the summary to acknowledge the sources of information. Scientists publish their findings in scientific journals and books. They also share the findings with other scientists. For this purpose, they create a scientific report and give presentation in National and International meetings and seminars.

1.7- Theory and Law (Principle)

When experiments prove a hypothesis correct, scientists use such hypothesis for making further hypotheses. When new hypotheses are again proved by

experiments, the original hypothesis becomes a theory. A theory is supported by extensive evidence and is repeatedly validated by multiple researchers. For example, the theory of evolution explains how species change over time through natural selection.

Scientists keep on testing the theories by doing experiments. They try their best to disprove the theory. If a theory is proved again and again by experiments, it becomes a law or principle. A scientific law is a uniform or constant fact of nature. The examples of biological laws are Hardy-Weinberg law and Mendel's laws of inheritance.

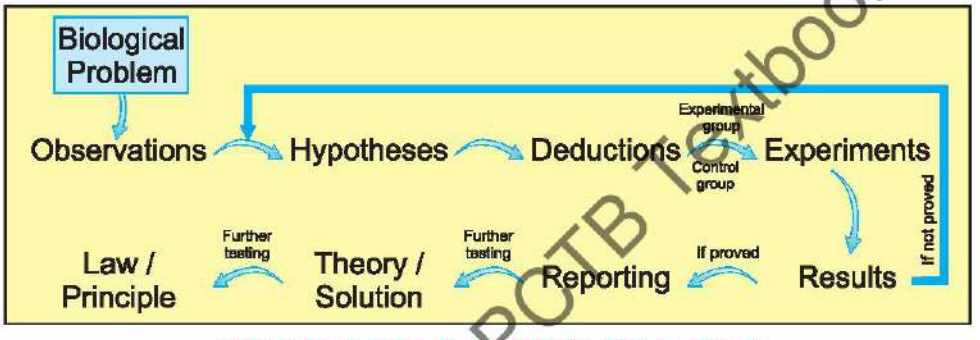


FIGURE 1.4: Flowchart of Scientific method

1.8- MALARIA -AN EXAMPLE OF BIOLOGICAL METHOD

Malaria is a common disease in many countries including Pakistan. You will know how biologists solved the biological problem concerning malaria.

In human history, malaria has killed more people than any other disease.

Biological Problem 1: What is the cause of malaria?

1. Observations

This disease was known to physicians of the ancient times (more than 2000 years ago). In the last part of 19th century, there were four major observations about malaria.

Quinine was the only remedy for malaria from the 17th to the 20th century.

- Malaria and marshy areas have some relation.
- Quinine is an effective drug for treating malaria.
- Drinking the water of marshy areas does not cause malaria.

- *Plasmodium* was seen in the blood of malarial patients.

In 1878, a French army physician **Laveran** did research on the "cause of malaria". He took the blood from a malarial patient and examined it under microscope. He noticed some microorganisms in the blood. The microorganism was given a name – ***Plasmodium***.

2. Hypothesis

Biologists thought on these observations and discoveries and developed a hypothesis i.e. "*Plasmodium is the cause of malaria*"

3. Deduction

They developed a logical result (deduction) by taking this hypothesis as true. The deduction was; *"If Plasmodium is the cause of malaria, then all malarial patients should have Plasmodium in their blood."*

3. Experiment and Results

In order to test the deduction, biologists performed experiments. They examined the blood samples of 100 malarial patients and 100 healthy persons under microscope. The following was the result of these experiments;

In these experiments, the malarial patients were the experimental group while the healthy persons were the control group.

- Most of the malarial patients had *Plasmodium* in their blood.

The result proved that the hypothesis "*Plasmodium is the cause of malaria*" was true.

Biological Problem 2: How Plasmodium gets into the blood of man?

The next biological problem was to learn about "*how Plasmodium gets into the blood of man*". Biologists were having following observations;

- Malaria is associated with marshes.
- Drinking water of marshes did not cause malaria.

When biologists considered these observations, they thought that *Plasmodium* was not in the marsh water.

1. Observations

In 1883, a physician, A. F. A. King, listed 20 observations. Some important observations of King were:

- People who slept outdoors had more chances to get malaria than those who slept indoors;
- People who slept under fine mosquito nets had less chances for getting malaria than those who did not use such nets;
- Individuals who slept near a smoky fire usually did not get malaria.

2. Hypothesis

On the basis of these observations King suggested a hypothesis: "*Mosquitoes transmit Plasmodium and so are involved in the spread of malaria.*"

3. Deduction

Following deduction was made from this hypothesis.

"If mosquitoes are involved in the spread of malaria, then Plasmodium should be present in mosquitoes."

3. Experiment and Results

In order to test the above deduction, Ronald Ross performed important experiments in 1880s. He was a British army physician who was working in India.

FIGURE 1.5: Ronald Ross with his experimental set-up

He allowed a female *Anopheles* mosquito to bite a malarial patient. He killed this mosquito and found *Plasmodium* multiplying in its stomach. As the next experiment, he thought to allow an infected mosquito (having *Plasmodium)* to bite a healthy person. If the hypothesis was true, the healthy person would have got malaria. But he did not use human beings for such risky experiment.

Ross performed his experiment again but used sparrows instead of man. He allowed female *Culex* mosquitoes to bite a sparrow suffering from malaria. Then he studied some of these mosquitoes at different times. He found that

Plasmodium multiplied in the walls of the mosquito's stomach and then moved into its salivary glands. He allowed some infected mosquitoes to bite healthy sparrows. Ross found that these healthy sparrows got malaria. When he examined the blood of these sparrows, he found many *Plasmodia* in it. So, it proved the hypothesis; *Mosquitoes transmit Plasmodium. So, mosquitoes are involved in the spread of malaria.*

***Aedes* mosquito transmits dengue fever.**

Experiments on Human Beings

In the end, experiments were performed on human beings to test this hypothesis. In 1898, Italian biologists allowed an *Anopheles* mosquito to bite a malarial patient. The infected mosquito was then allowed to bite a healthy man. This person later became ill with malaria. In this way, it was confirmed that mosquitoes transmit *Plasmodium* and so are involved in the spread of malaria.

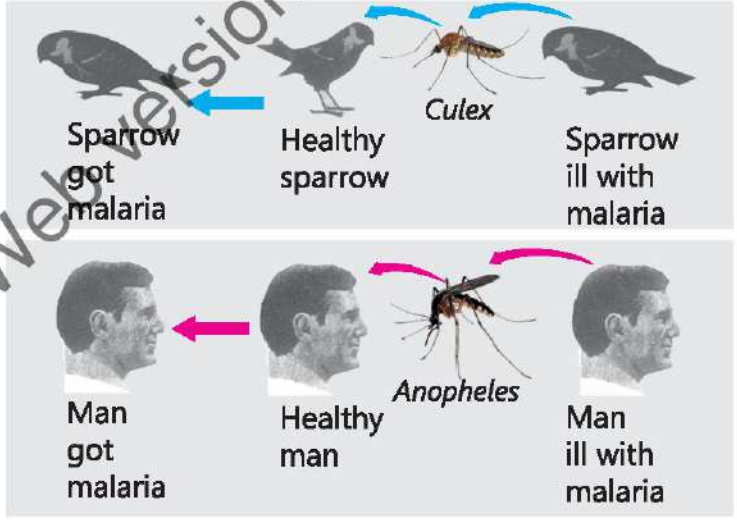


FIGURE 1.6: Malaria in sparrow and man is transmitted by Culex and Anopheles mosquitoes respectively

KEY POINTS

- Biology is the study of life. It deals with the structure of living things and the processes that occur in them.
- Major fields of Biology are Zoology (study of animals), Botany (study of plants) and Microbiology (study of microorganisms).
- The main sub-fields or branches of Biology include:

Branch	Study of;
Cytology	Cells
Histology	Tissues
Morphology	Form and structure of organisms
Anatomy	Internal physical structure of organisms
Physiology	Functioning of body parts
Embryology	Development of organism from fertilized egg
Genetics	Transfer of characteristics from parents to offspring
Molecular Biology	Biological molecules like carbohydrates, proteins, lipids, and nucleic acids
Palaeontology	Fossils
Taxonomy	Classification of organisms
Ecology	relationships between organisms and their environment
Marine Biology	Life in oceans
Pathology	Diseases, their causes, and effects
Immunology	Components of immune system and their role against diseases
Pharmacology	Drugs and their effects on the body

- Students of Biology can adopt careers like medicine and surgery, fisheries, agriculture, animal husbandry, biotechnology, horticulture, forestry and forensics.
- The scientific method involves basic steps like recognition of scientific problem, taking observations, making hypothesis, making deductions, performing experiments and summarizing and reporting results.
- A hypothesis is a tentative answer to the scientific problem.
- Deduction is the logical result of hypothesis.

- A scientific theory is an explanation based on the facts that have been repeatedly confirmed through experiments.
- If a theory is proved again and again by experiments, it becomes a law or principle.
- A scientific law is a uniform or constant fact of nature.

EXERCISE

A. Select the correct answers for the following questions.

1. Which branch of Biology focuses on the study of the structure and function of cells?
   a) Cytology b) Microbiology
   c) Histology d) Ecology
2. The study of the processes of heredity and variation in living organisms is known as:
   a) Ecology b) Genetics
   c) Anatomy d) Embryology
3. Insulin made through bacteria is an example of the technique of:
   a) Parasitology b) Biotechnology
   c) Biochemistry d) Histology
4. Heart pumps blood, stomach digests food, and kidneys excrete wastes. The statement comes from.
   a) Physiology b) Anatomy
   c) Morphology d) Histology
5. Which branch of Biology involves the study of the classification of organisms?
   a) Taxonomy b) Physiology
   c) Palaeontology d) Biogeography
6. Which step comes between making hypothesis and doing experiments?
   a) Making deductions b) Making observations
   c) Summarizing results d) Analysing data

7. Which of the following is NOT a characteristic of the scientific method?
   a) It relies on evidence
   b) It involves formulating hypotheses
   c) Hypothesis will always be correct
   d) It requires rigorous testing
8. Choose the correct sequence of steps of scientific method?
   a) Observations – hypothesis – deduction – experiments
   b) Observations – hypothesis – law – theory
   c) Hypothesis – observations – deduction – experiments
   d) Law – theory – deduction – observations
9. People who slept near smoky fire had less chance to suffer from malaria. Why?
   a) Smoke kills *Plasmodium* in their blood
   b) Fire increases temperature and *Plasmodium* are killed in air
   c) Mosquitoes cannot tolerate smoke and are repelled
   d) Smoke kills *Plasmodium* present in mosquitoes
10. Experiments are very important in scientific method because a researcher:
    a) Always gets correct results
    b) Disproves many hypotheses and gets some hypothesis proved
    c) Is sure that he will prove the hypotheses
    d) Gets a chance to work in the laboratory

B. Write short answers.

1. Define the following branches of Biology.

   Genetics, Anatomy, Palaeontology, Marine Biology, Pathology
2. Which branch of Biology involves the study of the development of organisms from fertilization to birth or hatching?
3. How is the profession of medicine and surgery different from animal husbandry?
4. Differentiate between Morphology and Physiology
5. What is Computational Biology?
6. What is the role of observation and experimentation in the scientific method?

1. Link the study of Biology with that of Physics, Chemistry, Statistics, Geography, Economics and Computer Science.
2. Explain how the study of Biology can lead to different professional studies.
3. Science is a collaborative field in which scientists work together to share knowledge. Prove this statement by giving examples.
4. How a hypothesis is converted to theory, law and principle?
5. What are the basic steps a scientist adopts in order to solve a scientific problem?
6. Describe the work of different scientists in discovering the cause of malaria.
7. Write a descriptive note on the experiments performed by Ross.

D. Inquisitive questions.

1. Why is it important to classify biology into different branches such as botany, zoology, and microbiology? How does specialization benefit scientific research?
2. How can a scientist apply the scientific method to confirm an observation that a certain plant species grows more quickly in shady places than in direct sunlight?

Chapter 2
BIODIVERSITY

After studying this chapter, students will be able to:

- Define biodiversity and classification.
- Describe advantages of classification.
- List the taxonomic ranks of classification.
- Discuss the history of classification schemes.
- List the three distinct domains into which living organisms are broadly classified into.
- Describe the complications of classifying viruses.
- Outline the binomial nomenclature system.

Our planet is home to a vast variety of organisms, from tiny insects to towering trees. This variety is essential for the health and balance of our world. It provides us with food, medicine, and clean air. In this chapter, we will explore the variety of organisms and the method of classifying them into groups.

2.1 - Biodiversity

Biodiversity means the variety of organisms in a particular area. Biodiversity of an area is measured by considering the number of different kinds of organisms and the variation within each kind.

Biologists have discovered and classified almost two million kinds of organisms. However, they estimate that the total kinds of organisms on Earth is much greater. Biodiversity is not evenly spread out. The biodiversity in a place depends on factors like climate, altitude, and soil type. Tropical regions have more biodiversity than polar regions.

Importance of Biodiversity

Biodiversity provides many essential services for humans and the planet. Here are some key benefits of biodiversity:

Ecosystem stability: Biodiversity helps to maintain the balance of ecosystems. It plays important role in biogeochemical cycles such as carbon cycle, and nitrogen cycle.

Climate regulation: Plants and algae absorb carbon dioxide. It helps to keep the climate balanced.

Natural resources: Biodiversity provides a vast array of resources, from food and medicine to building materials and fuel.

"The United Nations has designated May 22nd as International Biodiversity Day. It is celebrated to promote the protection of biodiversity.

Economic benefits: Biodiversity supports different industries, including agriculture, tourism, and pharmaceuticals.

2.2- CLASSIFICATION

Biologists have identified about 02 million kinds of organisms. Out of these, 0.5 million are the kinds of plants and 1.5 million are the kinds of animals. It is only a small percentage of the total kinds, which live on Earth. Every year, biologists discover thousands of new kinds of organisms. To better study such a large collection of organisms, biologists classify them. Classification is the process in which organisms are divided into groups and subgroups on the basis of similarities and differences found in them.

Some people don't respect biodiversity on the grounds that it is useful for humans. Rather, they respect biodiversity on aesthetic and moral grounds.

Aims and Principles of Classification

The main aims of classification are;

a. To determine similarities and differences among organisms so that they can be studied easily

b. To find the evolutionary relationships among organisms

Biologists classify organisms into groups and subgroups on the basis of similar physical characteristics. In recent times, they also take help from genetics. They find the genetic similarities and differences among organisms. Then they use this information to know similarities and differences in their structures and functions.

Advantages of Classification

- Classification allows biologists to group similar organisms together, making it easier to identify and understand their characteristics, relationships, and evolutionary history. It helps us understand the vast diversity of living organisms on Earth.
- Classification provides a framework for studying and comparing different species.
- It explains the inter-relationship amongst various organisms.
- It helps in the identification of new species and in understanding their evolutionary relationships.
- Classification provides a common language for biologists around the world, enabling effective communication in the study of organisms.

Overall, classification is crucial for our understanding of the natural world and for the conservation and management of biological diversity.

2.3- Taxonomic Ranks

The groups into which organisms are classified are known as taxonomic ranks or taxa (singular "taxon"). The Swedish botanist **Carl Linnaeus** devised the Linnaean system of taxonomic ranks in 1735. In this system, Linnaeus suggested seven taxonomic ranks i.e., kingdom, phylum (division), class, order, family, genus and species. In 1977, the rank of domain was added to this system. The taxonomic ranks are defined as below:

Domain: The highest taxonomic rank is domain. All organisms are divided into three domains: Archaea, Bacteria, and Eukarya.

Kingdom: Domain is further divided into kingdoms. For example, the domain Eukarya is divided into four kingdoms i.e., Animalia, Plantae, Fungi, Protista.

Phylum (Division: for plants and fungi): Each kingdom is subdivided into related phyla or divisions.

Class: Each phylum/division is divided into related classes.

Order: Each class is further divided into related orders.

Family: Each order is broken down into related families.

Genus: Each family is divided into related genera (singular genus).

Species: It is the lowest level of classification. A species is a group of similar organisms that can interbreed and produce fertile (capable of reproduction) offspring.

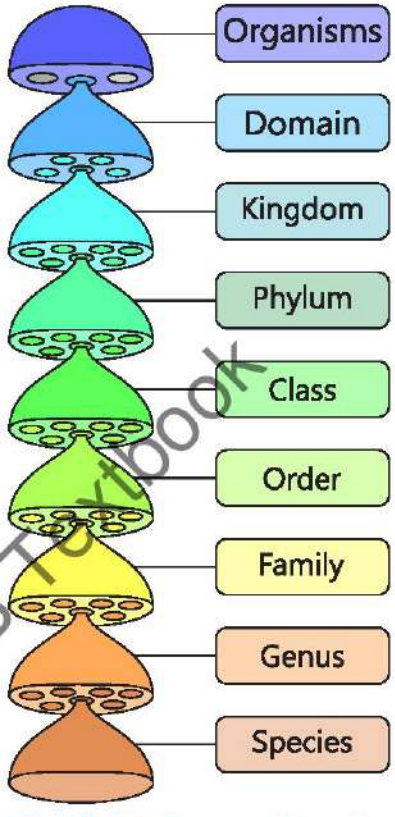


FIGURE 2.1: Taxonomic ranks

Table : Classification of fruit fly, human and pea

Taxonomic Rank	Fruit fly	Human	Pea
Domain	Eukarya	Eukarya	Eukarya
Kingdom	Animalia	Animalia	Plantae
Phylum or Division	Arthropoda	Chordata	Magnoliophyta
Class	Insecta	Mammalia	Magnoliopsida
Order	Diptera	Primates	Fabales
Family	Drosophilidae	Hominidae	Fabaceae
Genus	*Drosophila*	*Homo*	*Pisum*
Species	*Drosophila melanogaster*	*Homo sapiens*	*Pisum sativum*

2.4- HISTORY OF CLASSIFICATION

The history of the classification system can be traced back to ancient times.

- The Greek philosopher **Aristotle** (384-322 BC) was the first who classified organisms into two groups i.e., plants and animals.
- The Arab scholar **Abu Usman Umer Al-Jahiz** (781-869 AD) described the characteristics of 350 species of animals. He wrote a lot about the life of ants.
- The Italian botanist **Andrea Caesalpinia**(1519-1603 AD) divided plants into fifteen groups and called them genera.
- The French botanist **Tournefort** (1656-1708 AD) introduced the taxa of class and species.
- The Swedish biologist **Carl Linnaeus** (1707-1778 AD) created a taxonomic hierarchy of organisms with seven taxa i.e., kingdom, phylum, class, order, family, genus, and species.

In 1172 Ibn Rushd (Averroes) translated Aristotle's book "de Anima" into Arabic.

(a) Two-Kingdom Classification System

It was the earliest classification system in which all organisms were classified into two kingdoms i.e., Plantae and Animalia. The organisms that can prepare their own food (autotrophs) were classified in the kingdom plantae. On the other hand, the organisms that cannot make their own food (heterotrophs) were classified in kingdom animalia. According to this system, prokaryotes (bacteria, archaea) and fungi were members of kingdom plantae.

Taxonomists found this system unworkable because many unicellular organisms like Euglena have both plant-like (presence of chlorophyll) and animal-like (heterotrophic mode of nutrition in darkness and lack of cell wall) characteristics. So, a separate kingdom was proposed for such organisms. This system also did not clear the difference between prokaryotes (bacteria and archaea) and eukaryotes.

(b) Three-Kingdom Classification System

In 1866, the German zoologist **Ernst Hackel** proposed a third kingdom i.e., Protista for Euglena-like organisms. He also included prokaryotes (bacteria and archaea) in the kingdom Protista. In this system, fungi were still included in the kingdom Plantae. Some taxonomists disagreed about the position of fungi in kingdom Plantae. Fungi resemble plants in many ways but are heterotrophs which get their food by absorption. They do not have cellulose in their cell walls but possess chitin.

(c) Five-Kingdom Classification System

In 1937, French biologist **E-Chatton** suggested the terms, "Prokaryotic" to describe bacteria and "Eukaryotic" to describe protista, fungi, animals and plants. In 1969, American ecologist **Robert Whittaker** introduced the five-kingdom classification system. This system is based on;

- The levels of cellular organization i.e. prokaryotic (bacteria, archaea), unicellular eukaryotic (Protista) and multicellular eukaryotic (fungi, plants and animals)
- The modes of nutrition i.e. photosynthesis, absorption, and ingestion.

On this basis, organisms were classified into five kingdoms: Monera, Protista, Fungi, Plantae and Animalia. In 1988, American biologists Margulis and Schwartz modified the five-kingdom classification of Whittaker. They considered genetics along with cellular organization and mode of nutrition in classification. They classified the organisms into the same five kingdoms as proposed by Whittaker.

(d) Three-Domain Classification System

In 1977, American microbiologist **Carl Woese** (1928-2012) added a taxon i.e., **domain** above kingdom. He classified organisms into three domains i.e., Archaea, Bacteria, and Eukarya. It was actually a division of the prokaryotes in two domains i.e., Archaea and Bacteria. While all eukaryotes were placed in a single domain i.e., Eukarya. This classification is based on the differences between Archaea and Bacteria.

(a) 2-Kingdom System

Kingdom Plantae	Kingdom Animalia

(b) 3-Kingdom System

Kingdom Protista	Kingdom Plantae	Kingdom Animalia

(c) 5-Kingdom System

Kingdom Monera	Kingdom Protista	Kingdom Plantae	Kingdom Fungi	Kingdom Animalia

(d) 3-Domain System

Archaea	*Bacteria*	*Eukarya*			
Kingdom Archaebacteria	Kingdom Eubacteria	Kingdom Protista	Kingdom Plantae	Kingdom Fungi	Kingdom Animalia

FIGURE 2.2: Different Classification Systems

2.5- DOMAINS OF LIVING ORGANISMS

The following are the main characteristics of the three domains of organisms.

1- Domain Archaea

These are the most primitive organisms on Earth. They are prokaryotes but their cell wall does not contain peptidoglycan but is made of various polypeptides and proteins. Their rRNA (ribosomal RNA) resembles more to eukaryotes than to bacteria. Their cell membrane contains unique lipids which enable them to live in extreme environments e.g., hot springs, salt lakes, and acidic or alkaline waters. However, they also exist in more common environments like soil and oceans. Some archaea obtain energy from inorganic compounds such as sulphur or ammonia. Their other groups perform photosynthesis but do not produce oxygen.

FIGURE 2.3: Diversity in domain Archaea

There is one kingdom in domain Archaea i.e., kingdom Archaebacteria (ancient bacteria). Examples of archaebacteria include Methanogens (produce methane as a by-product of their metabolism), Halophiles (found in extremely salty environments), Thermophiles (found in hot springs), Acidophiles (found in extremely acidic environments).

2- Domain Bacteria

This domain contains bacteria and cyanobacteria. They are also prokaryotes. The cell wall is made of peptidoglycan. They are found in all environments including soil, water, air, and in the bodies of organisms. They are unicellular. Many live solitary although some form chains, clusters, or colonies of cells. Most are heterotrophic but some have chlorophyll and carry out photosynthesis. This domain contains kingdom Eubacteria (true bacteria). Some bacteria cause diseases. Many bacteria are beneficial e.g., decomposer bacteria play important role in nutrient recycling.

3. Domain Eukarya

The domain includes all unicellular and multicellular eukaryotes. They have complex eukaryotic cells with nucleus and other membrane-bound organelles. This domain contains kingdoms protista, fungi, plantae and animalia.

FIGURE 2.4: Three Domains

2.6- CLASSIFICATION OF DOMAIN EUKARYA

(a) Kingdom Protista

Kingdom Protista includes eukaryotes which are unicellular or colonial or filamentous or simple multicellular. Simple multicellular means that they do not have multicellular sex organs. There are three types of protists.

Certain protists are parasitic and cause diseases. For example, *Plasmodium* causes malaria and *Entamoeba* causes a type of dysentery called amoebic dysentery.

Plant-like protists (called algae) have cell walls made of cellulose. They have chlorophyll in chloroplasts and are autotrophs. *Euglena* and diatoms are common examples. **Animal-like protists** (called protozoans) are heterotrophs and ingest food. Their cells have no cell wall. *Amoeba* and *Paramecium* are common examples. **Fungus-like protists** absorb nutrients from decaying organic matter. Their cell walls are made of cellulose instead of chitin. Slime molds and water molds are examples.

FIGURE 2.5: Common protists

(b) Kingdom Fungi

This kingdom consists of fungi. They are heterotrophic. Fungi get nutrients in a unique way. They do not ingest food like animals and some protists. They absorb food from decaying matter present in their surroundings. Fungi are eukaryotic and have cell wall around their cells. Their cell wall is made of chitin (a polysaccharide). Most of the fungi are multicellular e.g., mushrooms, rusts, smuts and molds while a few are unicellular e.g., yeast.

Some fungi are used in the production of bread, cheese and beer. An antibiotic, called penicillin, is derived from the fungus *Penicillium*.

FIGURE 2.6: Common fungi

(c) Kingdom Plantae

It includes plants which are eukaryotic, multicellular organisms with cell walls made of cellulose. They are autotrophic and prepare food through photosynthesis. All plants have multicellular sex organs. During sexual reproduction, they form embryos. Asexual reproduction through vegetative parts is also common. Examples are mosses, ferns, conifers and flowering plants.

FIGURE 2.7: Common plants

(d) Kingdom Animalia

This kingdom includes animals which are eukaryotic, multicellular and heterotrophic. They develop from embryos. They ingest food and digest it within their bodies. Vertebrates and invertebrates are included in kingdom Animalia.

2.7- Status of Virus in Classification

Viruses are ultramicroscopic creatures that are at the borderline of living and non-living. They are acellular i.e., they are not made of cells and do not have organelles. A virus consists of nucleic acid (DNA or RNA) surrounded by a protein coat. They cannot run metabolism. For the synthesis of their proteins and to increase in number, viruses become parasites in organisms (plants,

animals, and bacteria). Viruses are not included in the classification system because they lack any of the characteristics of the three domains of life.

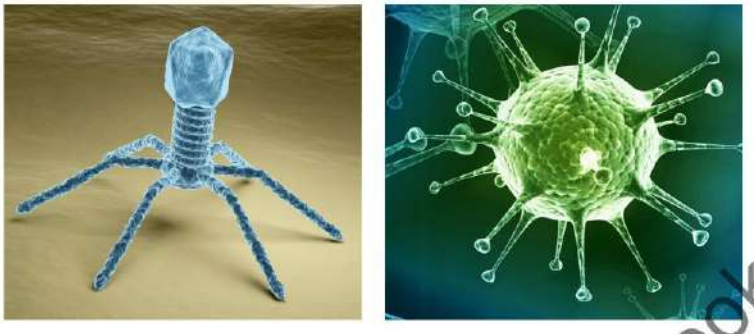


FIGURE 2.8: Two common viruses – Left; A bacteriophage (virus which attacks bacteria) and Right; Influenza virus

Prions and viroids are also acellular particles and are also not included in classification system. Prions are composed of protein only and Viroids are composed of circular RNA only. Both these particles cause infectious diseases in certain plants. They are also a cause of cancer.

Table : Characteristics of the Domains and Kingdoms of Life

Domain	Archaea	Bacteria	Eukarya			
Kingdom	Archaebacteria	Eubacteria	Protista	Fungi	Plantae	Animalia
Cell Type	Prokaryotic		Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Nuclear Envelope	Absent		Present	Present	Present	Present
Cell Wall	Archaebacteria: polypeptides and proteins Eubacteria: peptidoglycan		Present in some, various types	Chitin	Cellulose and other polysaccharides	Absent
Mode of Nutrition	Autotroph or heterotroph		Autotroph or heterotroph, or combination	Absorptive heterotroph	Autotroph	Ingestive heterotroph
Multi - cellularity	Absent in all		Absent in most	Present in most	Present in all	Present in all

Coronavirus is a virus, identified in late 2019 in Wuhan, China. It caused a pandemic of respiratory illness, called COVID-19. The virus primarily spreads through respiratory droplets when an infected person coughs, sneezes, talks, or breathes. It can also spread by touching surfaces contaminated with the virus. Wearing a mask over nose and mouth can help to prevent the spread of disease. Common symptoms of this disease include fever, cough, shortness of breath, fatigue, body aches, loss of taste or smell, sore throat, and headache. In some cases, it can lead to severe respiratory problems, especially in older adults and people with underlying health conditions. Washing hands frequently with soap for at least 20 seconds or use of hand sanitizer with at least 60% alcohol can also prevent the spread of disease. Vaccination plays a crucial role in protecting from COVID-19. Vaccines help immune system to recognize and fight the virus, reducing the severity of the disease.

2.8- BINOMIAL NOMENCLATURE

The great Swedish biologist Carl Linnaeus was the founder of the system of giving scientific names to organisms. The scientific name of an organism consists of two parts. The first part is the name of the genus to which the organism belongs. The second part is the name of the species. The system of scientific naming of organisms is termed as binomial nomenclature.

Common Name	Scientific Names
Onion	*Allium cepa*
Potato	*Solanum tuberosum*
Tomato	*Solanum esculentum*
Honeybee	*Apis cerana*
Tiger	*Panthera tigris*
Human being	*Homo sapiens*

Significance of Binomial nomenclature

- In binomial nomenclature, two organisms cannot have the same name. The words of scientific name are taken from Latin language (spoken by no country) so that no country is favoured. The scientific name of an organism is same anywhere in the world. This system provides a standard way of communication, whether the language of a particular biologist is Chinese, Arabic, Spanish, or English.

- Various regions have different names for the same organism e.g. the common name of onion in Urdu is 'Piyaz' but in different regions of Pakistan it is also known as 'ganda' or 'bassal' or 'vassal'. In other countries it has other sets of names.
- In some cases, several different organisms are called by the same common name, e.g. 'blue bell' is used for dozens of plants with bell shaped flowers. Similarly, 'black bird' is used for crow as well as for raven.
- Common names have no scientific basis. For example; a fish is a vertebrate animal with a backbone, fins and gills. But several common names of 'silver fish', 'cray fish', 'jellyfish', and 'star fish' do not fit to the true definition of fish.

Rules of Binomial nomenclature

The scientific naming of an organism is done in accordance with some international rules. Some important rules of binomial nomenclature are:

1. For scientific naming, words are taken from Latin language.
2. Every scientific name has two parts. The genus name always comes first followed by the species name.
3. Every scientific name should have to be unique because the same name cannot be used for naming two different organisms.
4. The first part of the name i.e. genus name should begin with a capital letter. The second part of the name i.e. species name should begin with small letter.
5. At the time of printing of a scientific name, it should be typed in Italics.
6. When a scientific name would be hand written, two parts of it should be separately underlined.

KEY POINTS

- Biodiversity is a measure of the variety of living organisms present in different ecosystems including terrestrial, marine and desert ecosystems.
- Classification is the process in which organisms are divided into groups and subgroups on the basis of similarities and differences found in them.
- The groups into which organisms are classified are known as taxonomic ranks or taxa (singular "taxon").
- The highest level of classification is the domain.
- Living organisms are broadly classified into three domains: Archaea, Bacteria, and Eukarya.
- The members of kingdom protista are unicellular or simple multicellular organisms and have eukaryotic cells.
- Fungi are eukaryotic heterotrophic organisms which absorb food.
- Plants are eukaryotic multicellular autotrophs and have multicellular sex organs.
- Animals are eukaryotic multicellular heterotrophs which ingest food and digest it in specialized cavities.
- Viruses lack any of the characteristics of the three domains or six kingdoms of life; therefore, they are not included in the classification system.
- The scientific name of every organism consists of two parts; first is the name of the genus and second is the name of its species.

EXERCISE

A. Select the correct answers for the following questions.

1. Which of the following taxonomic ranks represents the broadest rank?
   a) Species
   b) Genus
   c) Kingdom
   d) Domain
2. Which characteristics is unique to organisms in the domain Archaea?
   a) Cell walls made of peptidoglycan
   b) Presence of a nucleus
   c) Ability to live in extreme environments

d) Lack of ribosomes

3. Which of these statements is NOT related to bacteria?
   a) Do not have a nucleus.
   b) Cell wall made of peptidoglycan
   c) Most are heterotrophic
   d) Have chlorophyll in their chloroplast.
4. Which of these organisms belongs to the domain Eukarya?
   a) *Escherichia coli*
   b) Yeast
   c) Coronavirus
   d) None of these
5. Which of the following is a key characteristic that distinguishes eukaryotic cells from prokaryotic cells?
   a) Lack of a cell wall
   b) Presence of a nucleus
   c) Absence of ribosomes
   d) Smaller size
6. Which kingdom includes organisms that are primarily unicellular, eukaryotic, and often heterotrophic?
   a) Archaea
   b) Protista
   c) Fungi
   d) Plantae
7. Why are fungi included in heterotrophic organisms?
   a) Have chitin in cell wall
   b) Absorb nutrients
   c) Reproduce by spores
   d) Cannot prepare food
8. Why it is impossible to classify viruses within traditional biological kingdoms?
   a) They lack cellular structure and organelles.
   b) They cannot perform photosynthesis.
   c) They are smaller in size than bacteria.
   d) They are parasites.
9. Which of the following is the correct way for writing the scientific name of humans?
   a) *Homo sapiens*
   b) Homo sapiens
   c) Homo Sapiens
   d) homo sapiens
10. Which information you can get if you know the scientific name of an organism?
   a) Kingdom and phylum
   b) Phylum and genus
   c) Genus and species
   d) Class and species

B. Write short answers.

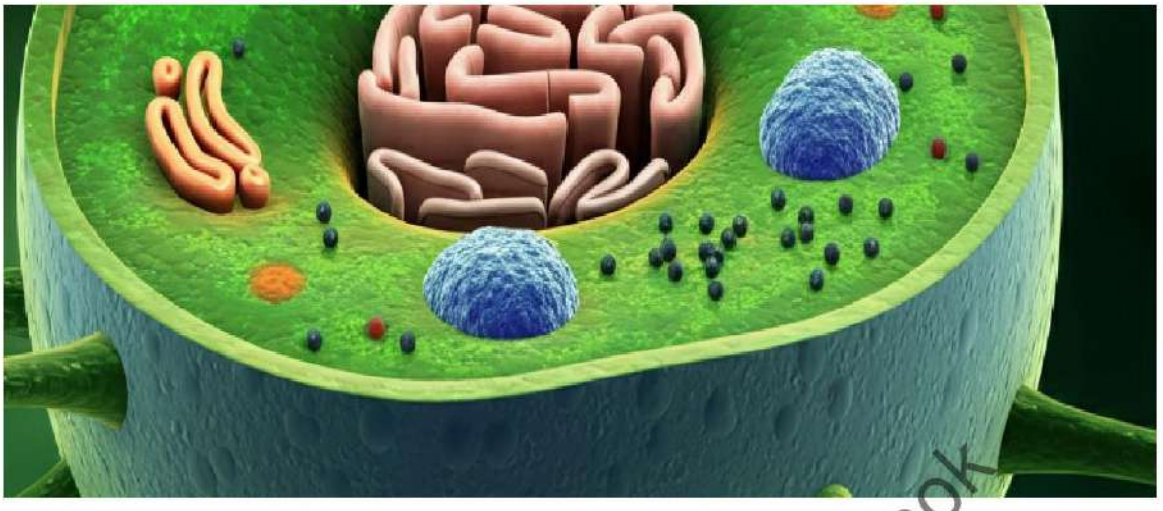
1. What is the term used to describe the variety of organisms in ecosystems?
2. How is the biodiversity crucial for humans and for the planet Earth?
3. What are the seven taxonomic ranks used in the Linnaean system?
4. Write the taxonomic ranks of lion and corn?
5. What are the basic differences between archaea and bacteria?
6. What are the shortcomings of the three-kingdom classification system?
7. Which kingdom includes organisms that are multicellular and heterotrophic, and lack cell walls?
8. Enlist the distinguishing characteristics of fungi.
9. List the three domains that encompass all living organisms.
10. Why cannot we classify viruses in any kingdom?
11. How does binomial nomenclature facilitate clear communication about organisms across different languages?

C. Write answers in detail.

1. Discuss biodiversity and its significance in maintaining the health of ecosystems.
2. Explain the importance of classification in biology and how it helps us understand the relationships between different organisms.
3. Describe the Linnaean system of classification in detail, stating the seven taxonomic ranks and their relationships.
4. Compare and contrast the domains Archaea and Bacteria, focusing on their key characteristics.
5. Describe the diagnostic characteristics of the four kingdoms within the domain Eukarya.
6. Discuss the challenges of classifying viruses within the traditional three domains of life.
7. Explain the rules and guidelines for suggesting scientific names to organisms.

D. Inquisitive questions.

1. How might placing an organism in the incorrect taxonomic group affect conservation or scientific studies?
2. Imagine you discover a new organism. What steps would you take to classify and name it according to the principles of binomial nomenclature?



Chapter 3

THE CELL

After studying this chapter, students will be able to:

- Describe cell as the basic unit of life.
- Compare with diagrams the structure of animal and plant cells.
- Sketch different sub-cellular organelles and outline their roles.
- Identify different types of cells (mesophyll cell, epidermal cell, neurons, muscle, red blood cell, liver cell) and sketch their structures.
- Describe the concept of division of labour and how it applies within cells (across organelles) and in multicellular organisms (across cells)
- Describe cell specialization.
- Define stem cells as unspecialized cells.

Have you ever wondered which tiny building blocks make up all living things? Cells are the microscopic structures that form the foundation of life. Cells are the units that carry out all the functions necessary for life. In this chapter, we will explore the fascinating world of cells, uncovering their intricate structures and vital roles in the living world.

Cell is like a City

A cell is like a busy city. For example, in a cell there are structures that produce energy (like power plants of the city), some structures process and transport materials (like roads and delivery services), and other structure remove or break wastes (like waste disposal units). Finally, just like a city has a government, a cell has a nucleus that directs its activities, by giving instructions for every function of the cell.

3.1- CELL

The cell is the basic unit of life. Just as bricks are the building blocks of a house, cells are the building blocks of living organisms, including plants, animals, and humans. Every living thing, from the smallest bacterium to the largest whale, is made of cells.

Most of the cells are very small, and cannot be seen with the naked eye. Despite their size, cells are very complex and carry out all essential functions to keep living things alive and functioning.

Some cells are large enough to be seen with naked eye e.g., the egg cell of ostrich, a unicellular green algae *Acetabularia*, and a unicellular giant *Amoeba*.

3.2- STRUCTURE OF CELL

The basic structure of a cell was discovered by an English scientist Robert Hooke. In 1665, using a simple microscope, Hooke examined a thin slice of cork and discovered tiny, box-like structures that he called "cells." He could not study the details of the internal structure of cell. However, in the 19th century the quality of microscope improved. In 1831, while studying plant cells under a microscope, a Scottish scientist, Robert Brown observed the "nucleus". After that, many organelles were discovered in coming years. In the following paragraphs we will study the structures present in cells and their functions.

There are two basic types of cells: prokaryotic and eukaryotic. Prokaryotic cells are simple and do not have membrane-bound organelles. Eukaryotic cells are more complex and have membrane-bound organelles.

Cell Wall

The cells of bacteria, fungi, plants and some protists (algae) have a rigid non-living wall around cell membrane. It is called cell wall. It provides shape, strength, protection and support to the inner living matter (protoplasm) of the cell. The plant cell wall is made of three layers i.e., middle lamella, primary wall, and secondary wall.

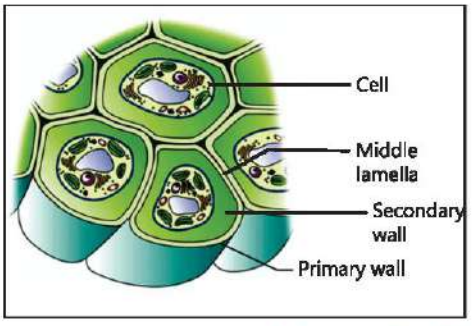


FIGURE 3.1: Layers of plant cell wall

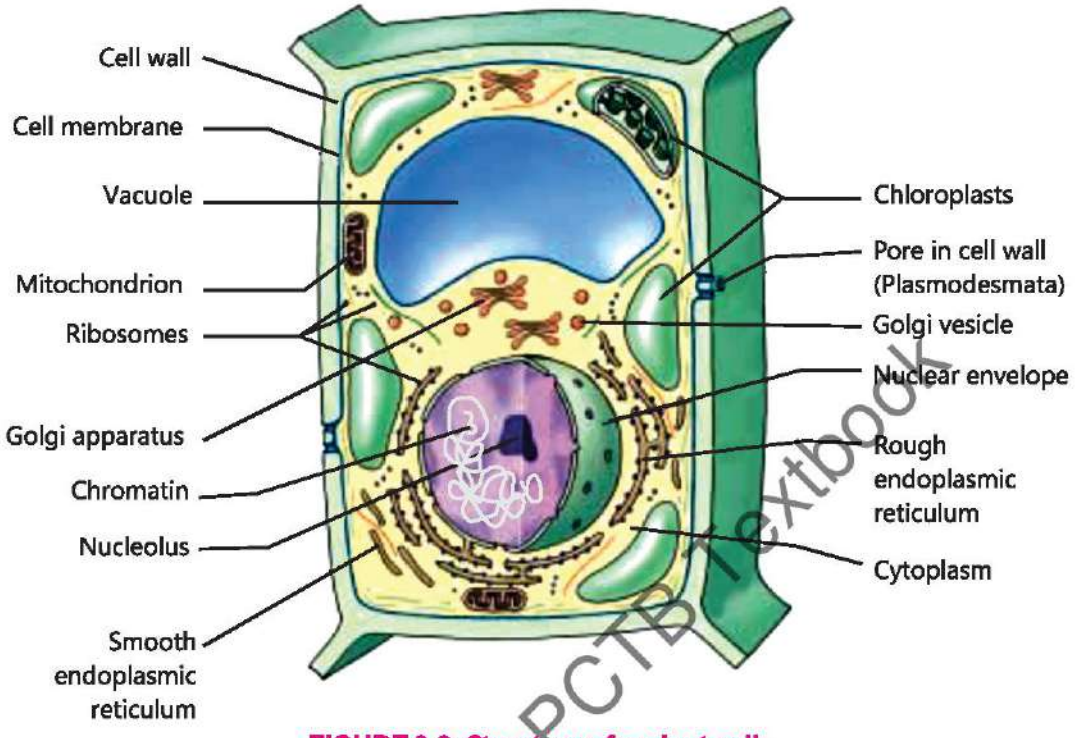


FIGURE 3.2: Structure of a plant cell

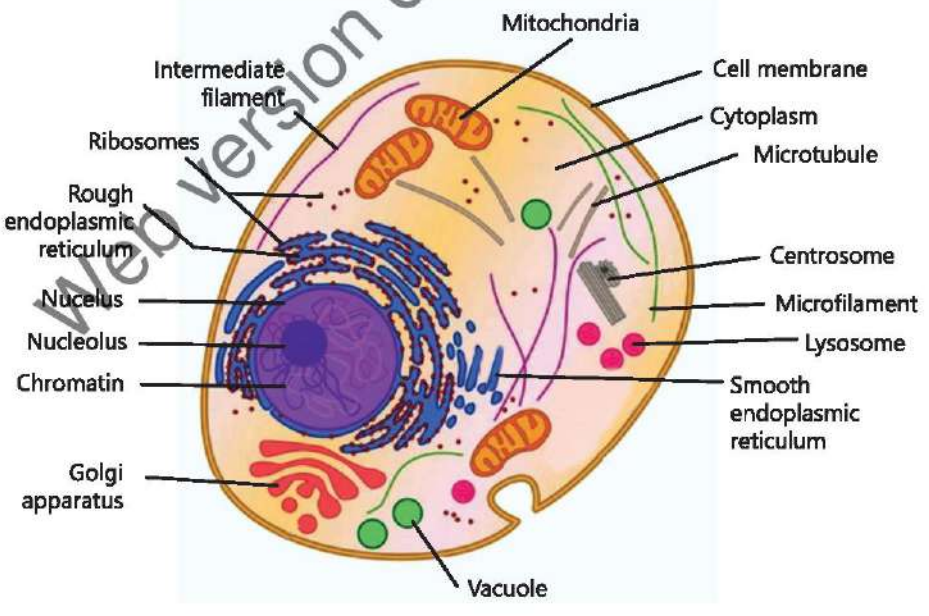


FIGURE 3.3: Structure of an animal cell

The **primary wall** is present just above the cell membrane. It is mainly composed of cellulose, hemicellulose, and pectin. Cellulose forms fibres that crisscross over one another to form strong primary wall. **Middle lamella** holds together the primary walls of adjacent cells. It contains magnesium, calcium and pectin. Some plant cells e.g., xylem cells make **secondary wall** on the inner side of primary wall. It is mainly made of cellulose, lignin and other chemicals.

FIGURE 3.4: Cellulose fibresin primary wall

The cell wall of algae is also composed of cellulose. The cell wall of prokaryotes is made of peptidoglycan (a single molecule made of amino acids and sugars). The cell wall of fungi is made of chitin.

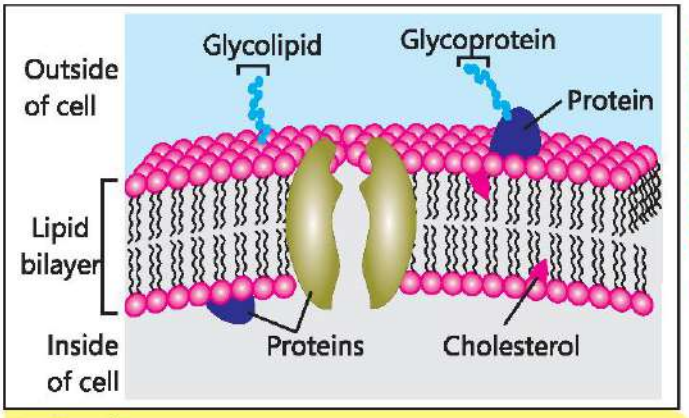
Plasmodesmata (singular plasmodesma) are the channels in cell walls that allow the exchange of molecules between adjacent cells.

Cell Membrane

All cells have a thin and elastic cell membrane around the cytoplasm. It is selectively-permeable. It allows very few molecules to pass through it while blocks many other molecules.

Cell membrane is composed of proteins and lipids and small quantities of carbohydrates. The structure of cell membrane is described as fluid-mosaic model. According to this model the lipids make a fluid-like bilayer in which protein molecules are submerged. The lipids and proteins can move laterally. Due to these movements, the pattern or "mosaic," of lipids and proteins constantly changes. Carbohydrates are joined with proteins (in the form of glycoproteins) or with lipids (in the form of glycolipids).

In eukaryotic cells, many organelles e.g., mitochondria, chloroplasts, Golgi apparatus, endoplasmic reticulum, and lysosomes are also bounded by membranes.



Another lipid, cholesterol, is attached with the inner sides of the lipid bilayer. Cholesterol is absent in the membranes of most bacteria.

FIGURE 3.5: The fluid- mosaic model of cell membrane

Cytoplasm

It is the jelly-like substance that fills the inside of a cell. It is a complex mixture of water, proteins, enzymes, salts, and other substances. Cytoplasm provides a medium for organelles to move and function. It also helps in the transport of materials throughout the cell. It acts as the site for various metabolic reactions e.g., Glycolysis (breakdown of glucose). It also stores food and wastes of the cell.

Cytosol is a liquid part of the cytoplasm that includes molecules and small particles, such as ribosomes, but not membrane-bound organelles.

Nucleus

All eukaryotic cells have a prominent nucleus. In animal cells, it is present in the center. In mature plant cells, it is pushed to side due to a large central vacuole. The nucleus is bounded by a double membrane known as **nuclear envelope.** It is semi-permeable and has many small pores called **nuclear pores.** The inner jelly-like material of nucleus is called **nucleoplasm.** In nucleoplasm, there are one or more small bodies called **nucleoli** (singular; nucleolus). Here, ribosomes are assembled. Nucleoplasm contains fine thread-like material known as **chromatin**. It is composed of deoxyribonucleic acid (DNA) and proteins. When a cell starts dividing, its chromatin condenses and takes the shape of thick **chromosomes.** DNA contains genes which control all the activities of the cell. DNA is also responsible for the transmission of characteristics to the next generation. That is why it is called the hereditary material.

The nucleus serves as the cell's "control center". It oversees cellular activities by directing the production of proteins.

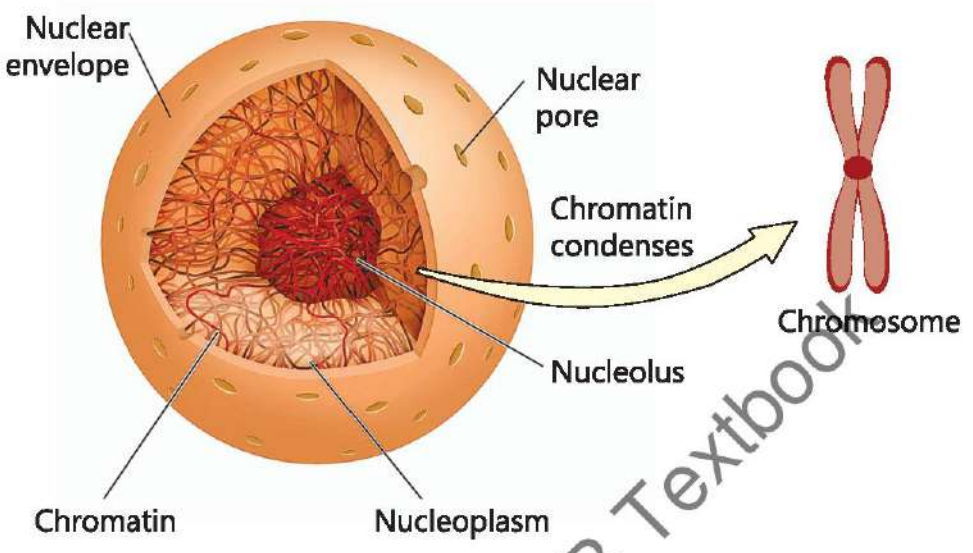


FIGURE 3.6: Structure of Nucleus and chromosome

The prokaryotic cells do not contain a prominent nucleus. Their chromosome is made of DNA only and floats in cytoplasm.

Cytoskeleton

It is a network of thin tubes and filaments present throughout the cytoplasm. It consists of three parts i.e., microtubules, microfilaments, and intermediate filaments.

Microtubules are hollow tubes made up *tubulin* protein. This part holds organelles in place, maintains a cell's shape, and act as tracks for organelles. Microtubules also make mitotic spindle, cilia and flagella.

Microfilaments are finer than microtubules. These are made up of contractile proteins mainly *actin*. They help in cell movement e.g., the crawling of white blood cells and the contraction of muscle cells.

Intermediate filaments are rods made of variety of proteins, mainly *keratin* and *vimentin*. They anchor the nucleus and some other organelles in the cell. They also make cell-to-cell junctions.

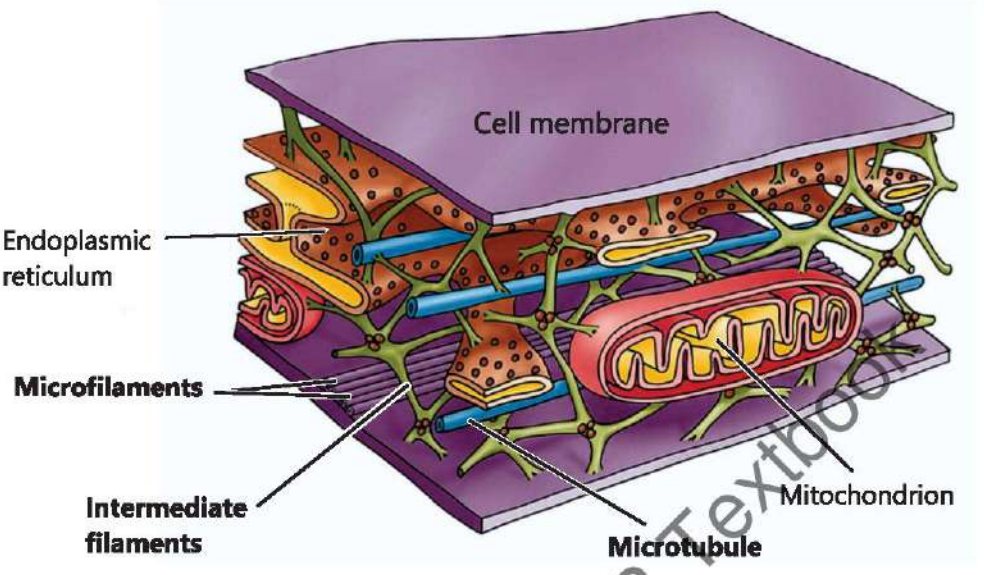


FIGURE 3.7: Cytoskeleton

Ribosome

Ribosomes are tiny granular structures. They are the sites of protein synthesis. Ribosomes float freely in the cytoplasm and are also attached on the surface of rough endoplasmic reticulum. They are composed of almost equal amounts of proteins and ribosomal RNA (rRNA). Ribosomes are not bounded by membranes and so are also found in prokaryotes. Eukaryotic ribosomes are slightly larger than prokaryotic ones. Each ribosome consists of two subunits. The two subunits of a ribosome unite during the process of protein synthesis. When a ribosome has finished its work, its subunits get separated again.

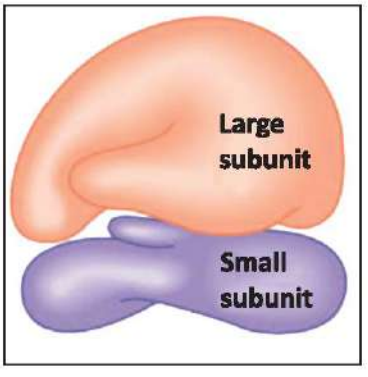


FIGURE 3.8: Ribosome

Endoplasmic Reticulum

It is a network of membrane-bounded channels present throughout the cytoplasm of eukaryotic cell. There are two types of endoplasmic reticulum.

Rough Endoplasmic Reticulum (RER): Numerous ribosomes are attached on its surface. RER serves the function in protein synthesis.

Smooth Endoplasmic Reticulum (SER): It lacks ribosomes. It is involved in lipid metabolism and in the transport of materials from one part of the cell to the other. It also detoxifies the harmful chemicals that have entered the cell. In muscle cells, the SER is also involved in contraction process.

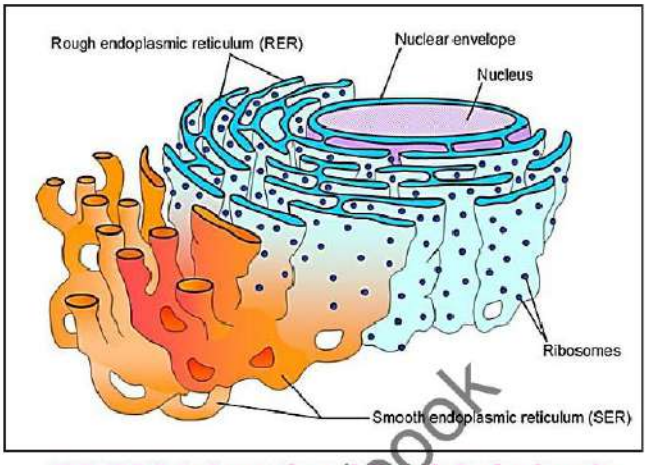


FIGURE 3.9: Smooth and Rough Endoplasmic Reticulum

Golgi Apparatus

In 1898, an Italian physician Camillo Golgi discovered a set of flattened sacs in the cytoplasm. These flattened sacs, called **cisternae**, are stacked over each other and make a structure known as Golgi apparatus. It is found in both plant and animal cells. It modifies proteins coming from rough ER and packs them into small membrane-bound sacs called **Golgi vesicles**.These sacs are kept in cell or are transported to exterior in the form of secretions.

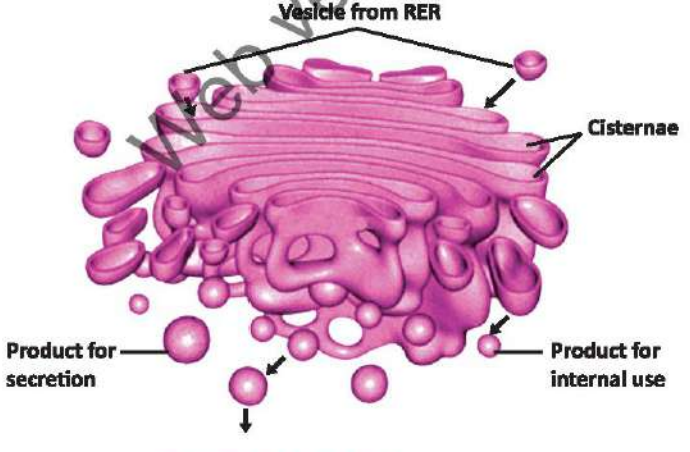


FIGURE 3.10: Golgi apparatus

In 1906, Golgi was awarded Nobel Prize for physiology and medicine.

Lysosome

Lysosomes were discovered by Belgian scientist Christian René de Duve. These are small membrane-bound vesicles that contain digestive enzymes. Lysosomes are predominantly found in animal cells.

Lysosomes bud off from Golgi apparatus. Cell engulfs the food material in the form of food vacuole. Lysosome fuses with food vacuole and its digestive enzymes break down the food present in vacuole. Lysosomes also have enzymes for breaking cellular wastes. They also engulf the damaged organelles and break them. Lysosomes can store certain molecules for later use.

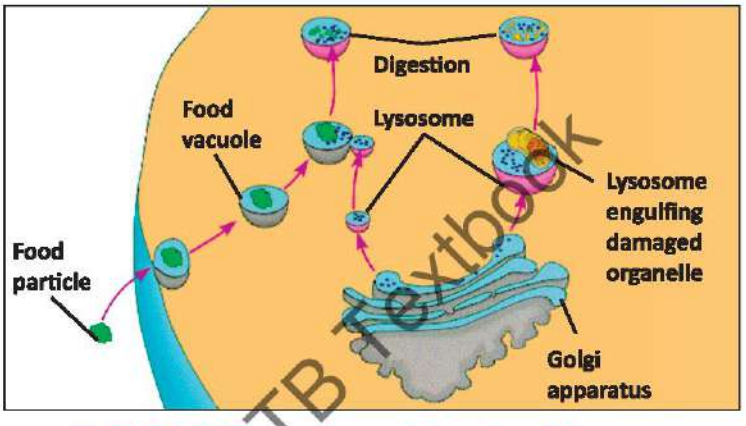


FIGURE 3.11: Formation and function of Lysosome

Mitochondria

Mitochondria (singular: mitochondrion) are the **"powerhouse"** of the cell because they produce energy. They perform the reactions of aerobic respiration in which oxygen is used to break food (glucose) to release energy in the form of ATP.

Mitochondria are double membrane-bounded organelles present only in eukaryotes. The outer membrane of mitochondria is smooth but the inner membrane forms many folds. These folds are called **cristae** (singular crista). They increase the surface area for respiration. The inner fluid-like material is called **matrix**. Mitochondria contain

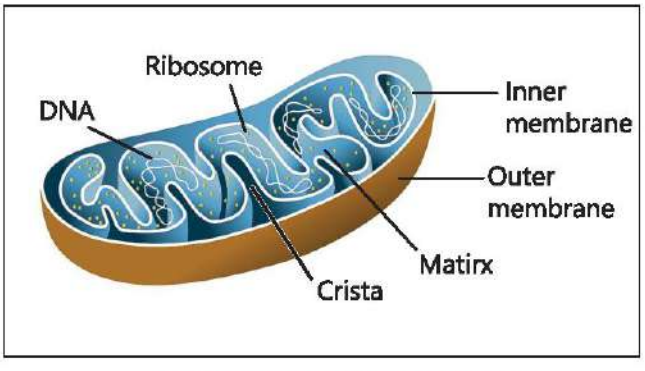


FIGURE 3.12: A Mitochondrion

their own DNA and ribosomes. The ribosomes of mitochondria are more similar to prokaryotic ribosomes than to eukaryotic ribosomes.

Plastids

Plastids are membrane-bounded organelles present in the cells of plants and photosynthetic protists (algae). There are three main types of plastids: chloroplasts, chromoplasts, and leucoplasts.

Chloroplasts are green plastids. They are present in the cells of green parts of plants and in algae. They contain photosynthetic pigments e.g., the green chlorophyll. They carry out photosynthesis. With the help of their pigments, they capture light energy and convert it into chemical energy. They use this energy to prepare glucose.

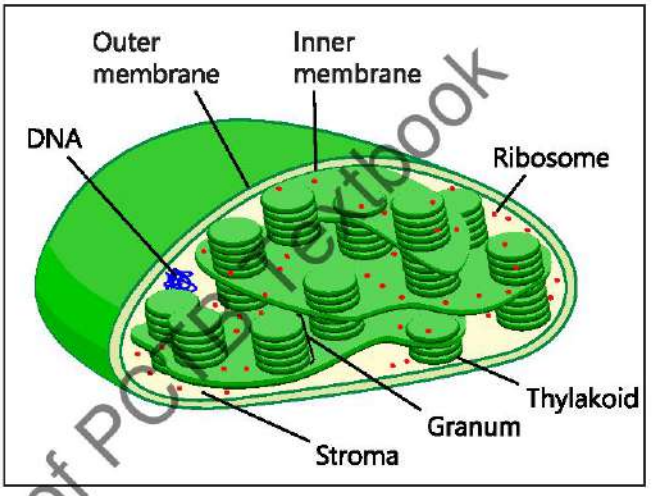


FIGURE 3.13: A Chloroplast

Like mitochondria, chloroplasts are enclosed by double membrane. On the internal side of inner membrane, there are many sets of stacked membranes. These stacks are called **grana** (singular, granum). The sac-like structures which make a granum are called **thylakoids**. Photosynthetic pigments are present on the surface of thylakoids. A fluid called **stroma** surrounds the thylakoids. Like mitochondria, chloroplasts also contain DNA and ribosomes.

Chromoplasts are the plastids that contain pigments such as carotenoids. These pigments are of bright colours. Chromoplasts are present in the cells of flower petals and fruits. Chromoplasts give colours to these parts, thus help in pollination and dispersal of fruit and seeds.

Leucoplasts are plastids that have no pigments. They are involved in the storage of starches, lipids, and proteins. They are present in the cells of those parts of plants where food is stored e.g., underground stems, seeds, roots etc.

Vacuoles

These are single membrane-bound sacs filled with fluid. Animal cell may have many small temporary vacuoles. They contain water and food substances. Some freshwater organisms like amoeba and sponges have contractile vacuoles which collect and pump out extra water and other wastes. Some cells ingest food by forming food vacuoles. Food vacuoles also store food.

Point to ponder!

Why are the vacuoles called the wastebins of the cells?

Most mature plant cells have a single, large, central vacuole. It is formed by the fusion of many small vacuoles. The membrane of plant vacuole is called tonoplast and the sap inside plant vacuole is called cell sap. It is a watery solution of salts. Due to this large central vacuole, the nucleus is pushed to a side. This outward pressure of the vacuole on the cytoplasm and cell wall makes plant cells turgid. This pressure is called **turgor pressure** and the process is called **turgor**. The turgor pressure helps in maintaining the shape of cells.

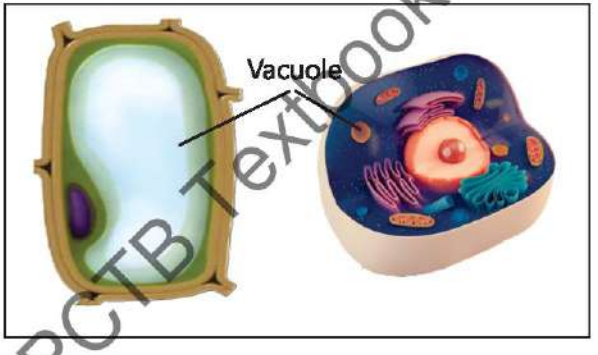


FIGURE 3.14: Vacuole in plant and animal cell

Centrioles

Centrioles are barrel-shaped organelles found in the cells of animals and most protists. They are absent in prokaryotes, higher plants and fungi. There is a pair of centrioles in which both centrioles are at right angles to each other. In animal cells, the pair is called a **centrosome** and it is located near the nuclear envelope. Each centriole is formed of 9 triplets of microtubule (made up of tubulin protein). At the start of cell division, the pair of centrioles duplicates. The new pairs move to the opposite pole of the cell. There, they form spindle fibres, which are responsible for the separation of chromosomes during cell division. The cells which have cilia or flagella contain centriole near cell membranes. These centrioles are called **basal bodies**. Basal bodies are responsible for the formation of cilia and flagella.

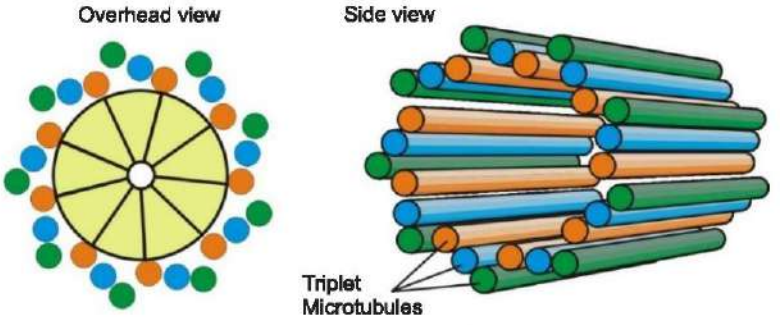


FIGURE 3.15: Structure of Centriole

Cilia and Flagella

Some cells have thin, tail-like projections called cilia (singular *cilium*) and flagella (singular *flagellum*). Cilia are short in length and are usually numerous in number; while flagella are longer but less in number. Eukaryotic cilia and flagella consist of nine pairs of microtubules which surround a single central pair of microtubules. Cilia and flagella are connected to the basal body. Prokaryotic cells also have flagella but their structure is completely different. Prokaryotic flagella are made of a protein called flagellin. The function of cilia and flagella is movement.

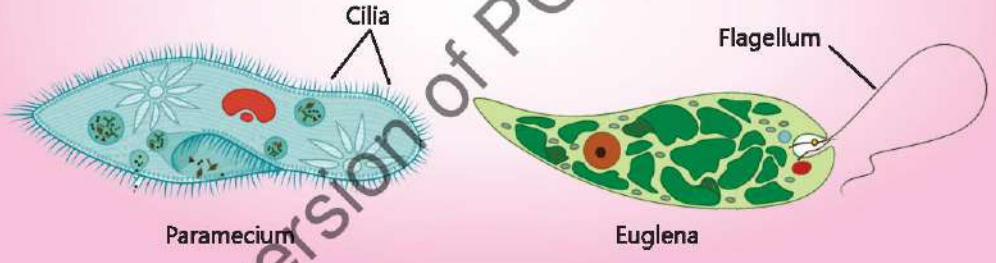


Table : Brief Comparison between Plant and Animal Cells

Component		Description	Where found	Function
Animal and Plant Cells	Cytoplasm	Jelly-like, with organelles in it	Between plasma membrane and nuclear envelope	Provides the site to cell organelles, site of metabolic reactions
	Cell membrane	A partially permeable membrane that forms a boundary around the cytoplasm	Around cytoplasm	Prevents cell contents; controls what substances enter and leave the cell
	Nucleus	A spherical or oval organelle containing DNA	In the centre in animal cells, on a side in plant cells	Controls cell division; controls cell activities

Component		Description	Where found	Function
Plant Cells Only	Cell wall	A tough, non-living outer layer made of cellulose	Around the outside of plant cells	Prevents mechanical support; allows water and salts to pass
	Large Vacuole	A fluid-filled space surrounded by a membrane	Inside the cytoplasm of plant cells	Contains salts and water; helps to keep plant cells turgid
	Chloroplast	An organelle containing chlorophyll	Inside the cytoplasm of some plant cells	Traps light energy for photosynthesis

3.3- Structural Advantages of Plant and Animal Cells

We have studied plant and animal cells. They have distinct structural differences that reflect their specialized functions and adaptations. Here are some structural advantages of both plant and animal cells.

Advantages of Plant Cell Structures

- Plant cells have a rigid cell wall made of cellulose. It provides structural support and protection.
- They contain chloroplasts, which are responsible for photosynthesis. Chloroplasts convert light energy into chemical energy, allowing plants to produce food.
- The large central vacuole stores water, nutrients, and waste products. It provides turgor pressure that maintains cell shape.
- Plant cells are interconnected by plasmodesmata, channels that allow direct communication and transport of substances between cells.

Advantages of Animal Cell Structures

- Animal cells have centrioles which make spindle fibres. This ensures the accurate distribution of chromosomes during cell division.
- They contain lysosomes, filled with enzymes that break down waste materials. Lysosomes contribute to cellular cleanup and recycling.
- Some animal cells have structures called flagella and cilia, which are involved in movement. For example, sperm cells have a flagellum that propels them toward the egg for fertilization.

- They lack a rigid cell wall, allowing them to change shape easily. This flexibility is crucial for cell movements, such as white blood cells moving to sites of infection or injury.

3.4- CELL SPECIALIZATION

In multicellular organisms, there are different types of cells. Each type has a special structure and performs special function. When cells are formed by cell division, they are all similar. After their formation, cells undergo the process of specialization or differentiation. During this process, they get special sizes, structures, and metabolic features. As a result, they become specialized. Here we will discuss some specialized cells of plants and animals.

Mesophyll Cells: These are green cells present in leaves. They are specialized for photosynthesis. They contain large number of chloroplasts, which contain the green pigment chlorophyll necessary for capturing light energy. Their shape and arrangement in leaves is suitable for maximum absorption of light.

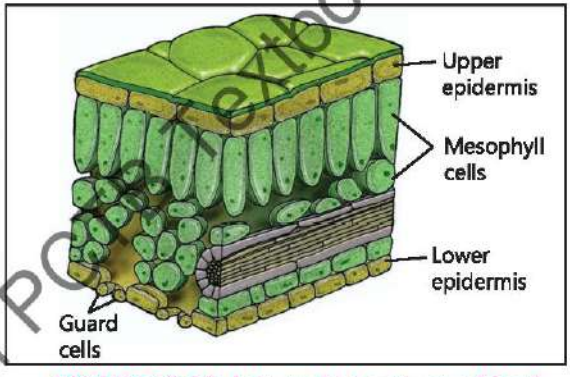


FIGURE 3.16: Internal structure of leaf showing mesophyll cells

Epidermal Cells: They are flat and tightly packed cells that make the outer layer (epidermis) of plant organs. Epidermis protects the internal tissues. Modified cells of epidermis also perform other functions. For example, the epidermis of root contains root hair cells. These cells make extensions called root hairs. Root hairs increase surface area to absorb water and minerals from soil. The lower epidermis of leaves contains guard cells which regulate the opening and closing of stomata.

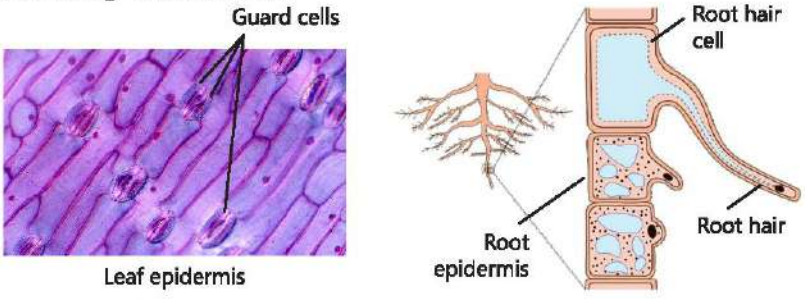


FIGURE 3.17: Epidermis of leaf and root

Muscle Cells: Muscle cells are specialized animal cells that can contract. They are elongated cells filled with actin and other contractile proteins. Skeletal muscle cells are long, striated. They are attached to bones. They are voluntary in action and their contractions move the skeleton for body movements and locomotion. Cardiac muscle cells are branched and striated. They are found in the heart walls. They are involuntary in action and their contractions result in the pumping action of heart. Smooth muscle cells are spindle shaped and non-striated. They are involuntary in action and present in the walls of many internal organs. For example, smooth muscles in the alimentary canal contract to move food forward, while those in blood vessels regulate blood flow.

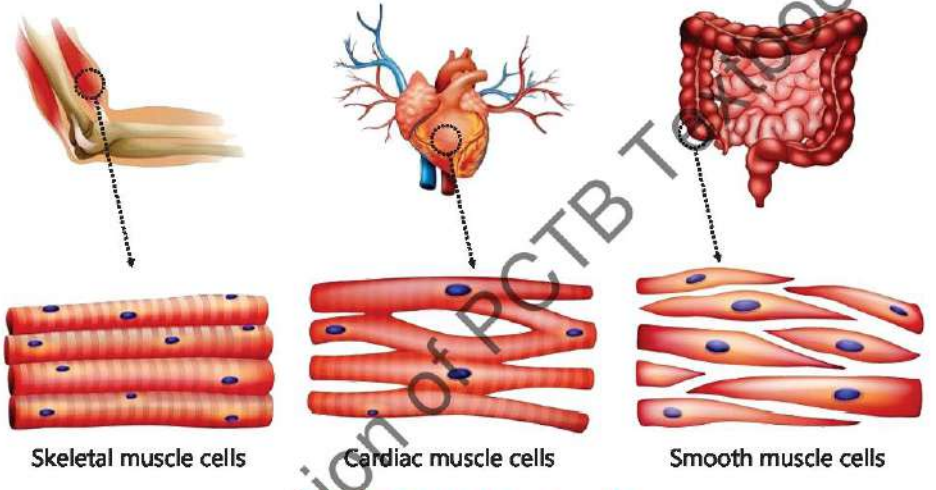


FIGURE 3.18: Muscle cells

Neurons: These are the specialized cells of the nervous system. They are responsible for transmitting messages (nerve impulses) throughout the body. To perform this function, they have a unique structure. A neuron consists of a cell body and two types of cytoplasmic extensions. Dendrites, the shorter extensions, receive nerve impulses and transmit them to the cell body. Axons, the longer extensions, carry nerve impulses away from the cell body.

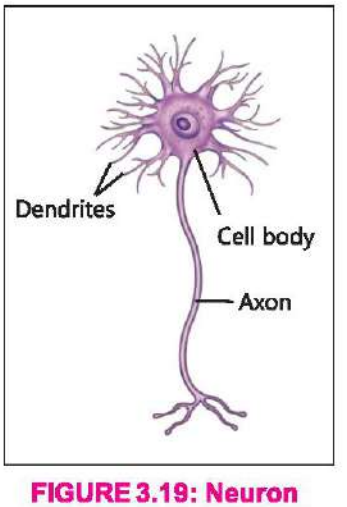


FIGURE 3.19: Neuron

Red Blood Cell (Erythrocyte): These blood cells are specialized to carry oxygen from the lungs to the body's tissues. They are biconcave disk-shaped cells. This shape provides more surface area to absorb and release oxygen. They are

filled with haemoglobin that actually carries oxygen. In mammals, the mature red blood cells do not contain nucleus, mitochondria, and endoplasmic reticulum etc. It helps to accommodate more haemoglobin.

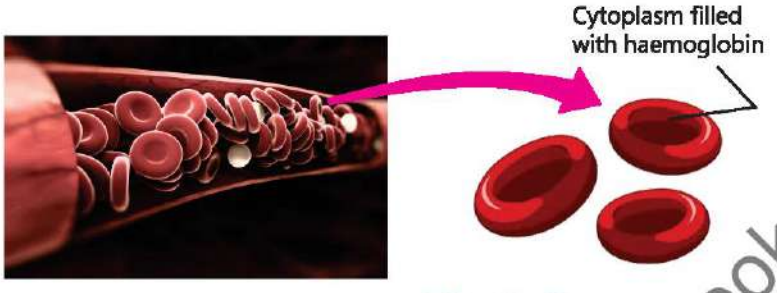


FIGURE 3.20: Red blood cells

Liver Cell: They are also called hepatocytes. They are specialized for a lot of important functions like storage of glycogen, iron and some vitamins; detoxification of toxic substances; production of clotting proteins of blood, recycling of old red blood cells etc. They have prominent nuclei for maximum activities required for making enzymes and other proteins. Large number of mitochondria provide the necessary ATP for energy-intensive processes. Expansive network of SER helps for extensive detoxification and lipid synthesis. There are large number of peroxisomes which contain enzymes to neutralize toxic substances. Small ducts are present between liver cells which collect and transport their secretion (bile) to the bile ducts.

Toxic ammonia is converted into less toxic form urea in liver; hence it assists kidney function.

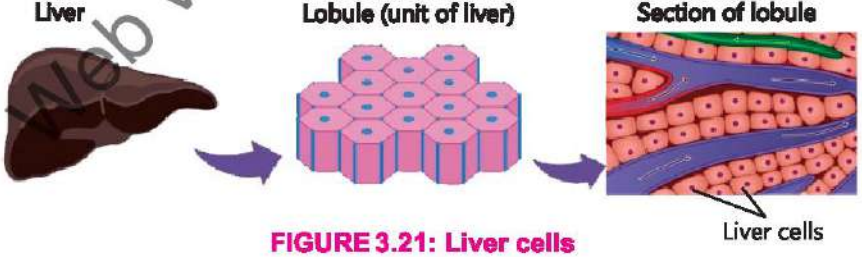


FIGURE 3.21: Liver cells

Division of Labour within and across Cells

Division of labour refers to the specialization of different parts of a system to perform specific tasks more efficiently. It is a fundamental principle that enhances efficiency and functionality in biological systems (both within and across cells).

Within Cells: Within a cell, this concept is exemplified by the various organelles that each carry out distinct functions necessary for the cell's survival. For instance, mitochondria generate energy, endoplasmic reticulum synthesizes proteins and lipids, and lysosomes break down waste materials. In this way, the function of each organelle contributes to the cell's overall survival, growth, and functioning.

Across Cells: In multicellular organisms, the division of labour extends across cells. Each type of cell performs a specific role and contributes to the overall functions of the organism. For example, muscle cells are specialized for contraction and movement, nerve cells for transmitting messages, and red blood cells for carrying oxygen. This intercellular specialization allows complex organisms to perform a wide range of functions.

3.5- STEM CELLS

In sexually reproducing organisms, all different types of cells arise from a single cell (zygote). The zygote is an unspecialized cell but it has the ability to make new cells which can differentiate into specialized cells. Such unspecialized cell that has the ability to make a variety of specialized cell types is called **stem cell**.

During development, when the earliest stem cell (zygote) divides, it makes different cell lines. The cells of each line differentiate into specific type like skin cells, muscle cells, nerve cells, blood cells etc.

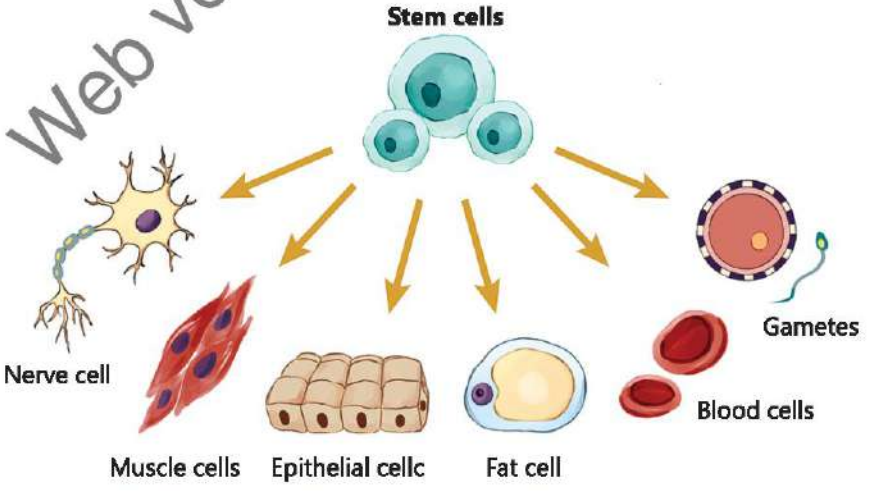
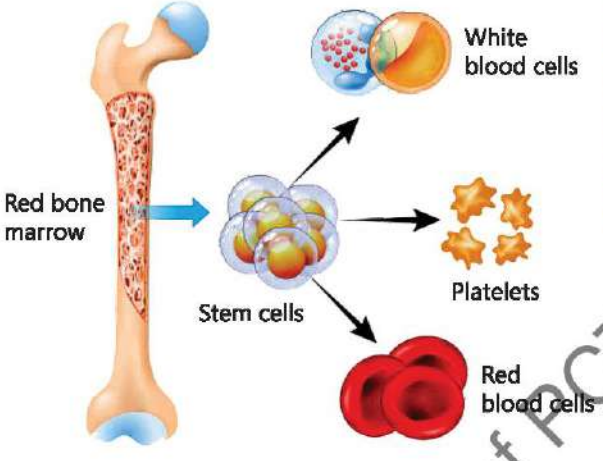


FIGURE 3.22: Differentiation of stem cell into specialized cells

Stem cells also remain in different parts of the body throughout life. These stem cells can divide and differentiate into specific cells as the body needs them. They can also regenerate damaged tissue under the right conditions. For example, stem cells present in skin help in wound healing. Stem cells present in liver also help it to repair after damage. Stem cells present in the bone marrow differentiate to make different types of blood cells and immune cells.



In some parts of the body, such as the gut and bone marrow, adult stem cells regularly divide to produce new tissues for maintenance and repair.

FIGURE 3.23: Stem cell of blood cells

KEY POINTS

- The cell is the fundamental building block of life.
- The primary wall of the cell wall is made up of cellulose and hemicellulose.
- The secondary cell wall is made of lignin.
- The cell membrane is made of a lipid bilayer with embedded proteins.
- Cytoskeleton is a network of microfilaments, microtubules and intermediate filaments.
- Ribosomes are made of ribosomal RNA (rRNA) and proteins.
- The Golgi apparatus is a set of many flattened sacs (cisternae) stacked over each other.
- Lysosomes have strong digestive enzymes which are responsible for breaking down various biomolecules into simpler compounds that can be used by the cell.
- Mitochondria are the "powerhouses" of the cell because they produce energy by cellular respiration.
- Chloroplasts are responsible for photosynthesis.
- Centriole is formed of 9 groups of microtubule triplets (made up of tubulin protein).
- Nucleus is spherical or oval in shape and is surrounded by a double membrane called the nuclear envelope.
- Chromosomes are composed of Deoxyribonucleic acid (DNA) and proteins.
- Mesophyll cells are found in the leaves of plants and are responsible for photosynthesis.
- Epidermal cells make up the outermost layer of plant tissues, forming a protective barrier against the environment.
- Neurons are specialized cells of the nervous system that transmit nerve impulses throughout the body.
- Muscle cells are responsible for movement.
- Red blood cells are a type of blood cell that carries oxygen from the lungs to the body's tissues and transport carbon dioxide back to the lungs for exhalation.
- Stem cells are undifferentiated or unspecialized cells that can differentiate into specific cells.

EXERCISE

A. Select the correct answers for the following questions.

1. The process of cellular respiration occurs in:

a) Nucleus
b) Mitochondria
c) Ribosomes
d) Golgi apparatus

2. The smooth endoplasmic reticulum (SER) is primarily involved in the synthesis of:

a) Proteins
b) Lipids
c) Carbohydrates
d) Nucleic acids

3. Ribosomes are composed of:

a) RNA and protein
b) DNA and protein
c) Carbohydrates and lipids
d) RNA and carbohydrates

4. What is the primary function of ribosomes?

a).Energy production
b) Protein synthesis
c) Lipid synthesis
d) DNA synthesis

5. Which cell organelle is involved in packaging and modifying proteins?

a) Nucleus
b) Mitochondria
c) Golgi apparatus
d) Endoplasmic reticulum

6. Which cell organelle is responsible for breaking down waste materials?

a) Golgi apparatus
b) Nucleus
c) Mitochondria
d) Lysosome

7. Which of the following cell structures is involved in maintaining cell shape?

a) Cytoskeleton
b) Centrioles
c) Nucleus
d) Lysosome

8. Which specialized region of the nucleus is responsible for ribosome assembly?

a) Nucleoplasm
b) Nucleolus
c) Chromatin
d) Chromatin

9. What is the main function of the nuclear pores?

a) Regulation of cell division
c) Protein synthesis
b) Control of pH of the cell
d) Control of transport of molecules

10. Which of the following cellular structures is found in animal cells and helps in cell division?

a) Cell membrane
b) Centriole
c) Plasmodesma
d) Vacuole

11. Which sub-cellular organelle plays a crucial role in energy production within the cell?

a) Endoplasmic reticulum
b) Golgi apparatus
c) Mitochondria
d) Lysosomes

12. In a multicellular plant, which cell type is responsible for the production of glucose?

a) Xylem
b) Phloem
c) Epidermal
d) Mesophyll

13. Which organelle can double its number by itself?

a) Ribosomes
b) Lysosomes
c) Mitochondria
d) Golgi apparatus

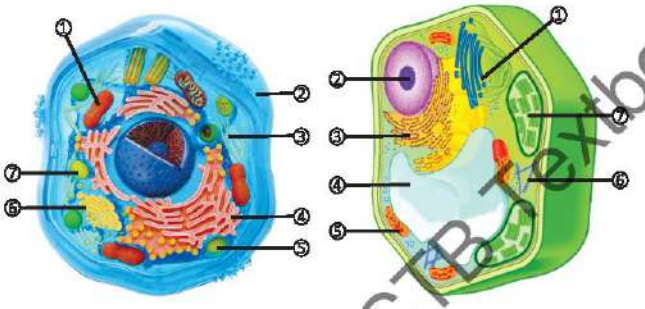
14. Which of these are present on the surface of rough endoplasmic reticulum?

a) Ribosomes
b) Lysosomes
c) Mitochondria
d) Vacuoles

B. Write short answers.

1. What are the main functions of cell membrane?
2. What key role does the Golgi apparatus play in eukaryotic cells?
3. How do lysosomes contribute to the cell's functioning?
4. Which organelle detoxifies harmful substances and breaks down lipids?
5. What is the smooth endoplasmic reticulum responsible for?
6. How do the vacuoles in plant cells differ from vacuoles in animal cells?
7. What could happen if lysosomal enzymes stop working properly?
8. Why are the cristae important for cellular respiration?
9. How are chromatin and chromosomes related?
10. Which type of cell is responsible for sending nerve signals?

11. What do mesophyll cells do in plant leaves?
12. How would you define a stem cell?
13. Name the chemical compounds that make up:
    a. Cell membrane
    b. Fungal cell wall
    c. Plant cell wall
    d. Bacterial cell wall
    e. Ribosomes
    f. Chromosomes
14. Label the parts of these cell diagrams?

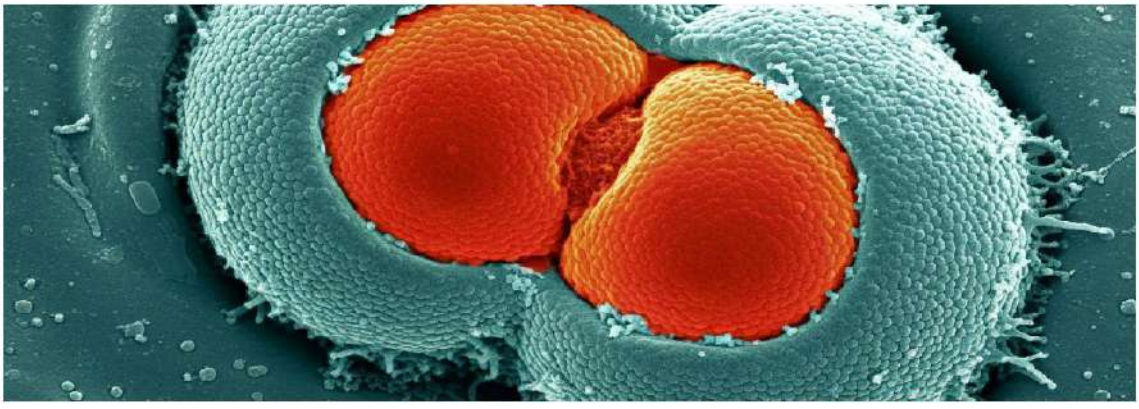


C. Write answers in detail.

1. Explain the fluid mosaic model of the cell membrane.
2. Describe the structure and functions of the cell wall.
3. Discuss the components of the nucleus.
4. Describe the structure and function of lysosome and endoplasmic reticulum.
5. Describe the formation and function of the Golgi complex.
6. Describe the structure and functions of the chloroplast.
7. How does turgor pressure develop in a plant cell?
8. Write any four differences between a plant cell and an animal cell.
9. Describe the concept of division of labour and how it applies in multicellular organisms. Give at least three examples.
10. Write a note on cell specialization.

D. Inquisitive questions.

1. What impact might mitochondrial dysfunction or absence have on other organelles' ability to operate in a cell?
2. What may happen if the coordination between the ribosomes and the nucleus were to fail, and why is it so important?



Chapter 4

CELL CYCLE

After studying this chapter, students will be able to:

- Describe cell cycle.
- Explain mitosis and stages of mitosis (by use of sketch and diagrams).
- Explain meiosis and stages of meiosis (by use of sketch and diagrams).
- Compare the processes of mitosis and meiosis.
- Outline the significance of mitosis and meiosis.

The cell follows a regular series of events called the "cell cycle" during its life. This series includes stages of growth, preparation, and cell division. The process of cell division may happen in two way i.e., mitosis (cells make identical copies of themselves) or meiosis (cells produce special cells with half the genetic material, needed for reproduction). Mitosis is essential for growth and repair in the body, while meiosis is vital for creating reproductive cells like eggs and sperm. Together, these processes keep living organisms growing, healing, and passing on traits to the next generation. In this chapter, we will explore the events of the cell cycle and cell divisions i.e., mitosis and meiosis.

4.1- CELL CYCLE

It is the series of events that take place in a eukaryotic cell from its formation to its division into two daughter cells. The cell cycle can be divided in two main phases i.e. interphase and the mitosis phase.

Interphase

This phase lasts for about 90% of the total time of cell cycle. During interphase, the cell performs the life functions according to its specialty and

prepares itself for next division. Interphase consists of the following three phases:

G1 Phase (First Gap Phase): It starts from the end of the Mitosis phase. It is also called the growth phase. During this phase cell makes proteins and organelles and so grows in size. Cell also makes enzymes that are required in S phase for the replication of DNA.

S Phase (Synthesis Phase): During this phase, the DNA of each chromosome is replicated (copied). It results in the duplication of chromosomes (each chromosome consists of two sister chromatids). The total number of chromosomes in cell remains the same.

G2 Phase (Second Gap Phase): In this phase, the cell continues to grow and produces proteins necessary for cell division. The cell checks for any DNA damage that may have occurred during replication and makes necessary repairs. It also begins to reorganize its contents in preparation for mitosis.

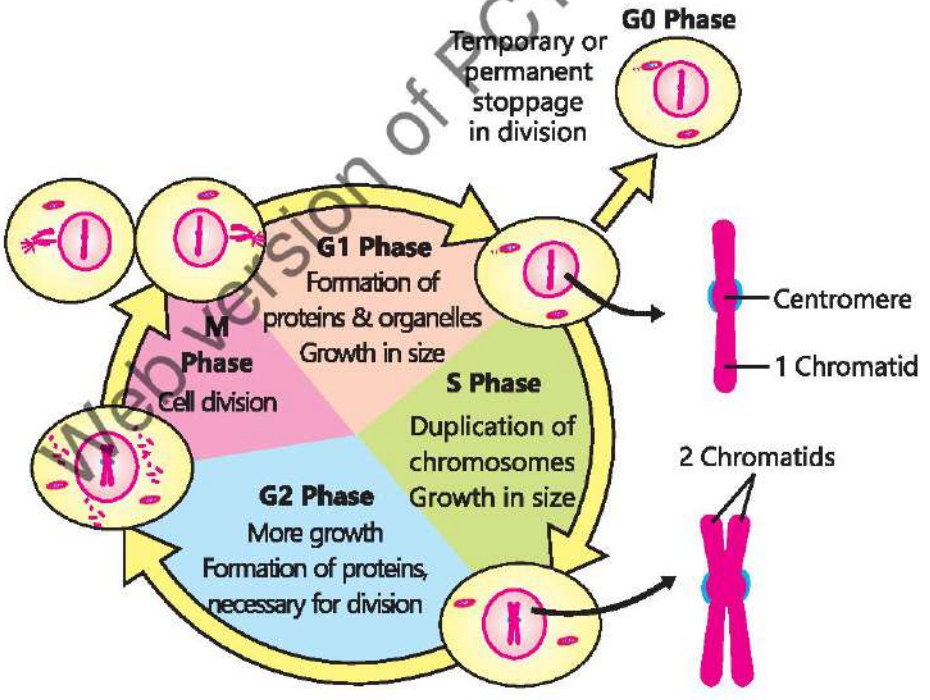


FIGURE 4.1: Eukaryotic Cell cycle

After interphase, the cell enters the division phase and divides into the two daughter cells. The events of cell cycle are controlled by special genes. All phases occur in a sequence.

G0 Phase:

Many cells stop dividing and start performing their specific functions. This phase is called G0 phase. Many cells (e.g. neurons) remain in G0 for indefinite periods. Some cell (e.g. cells of liver and kidney) remain in G0 phase temporarily. Other cells (e.g. epithelial cells) do not enter G0 and continue to divide throughout life.

Table: Main Phases in Eukaryotic Cell Cyle

Phase	Description
Interphase	The cell prepares for division and goes through growth in size and DNA replication.
Gap 1 (G1) Phase	The cell grows in size and carries out normal functions. It prepares for DNA replication.
Synthesis (S) Phase	The cell replicates its DNA, making an exact copy of its genetic material.
Gap 2 (G2) Phase	The cell grows further. Cell ensures that all preparations are complete for division.
Gap 0 (G0) Phase	The cell exits the cycle and stops dividing, often to carry out specialized functions (not all cells enter this phase).
M Phase	The cell divides its genetic material equally into two new, identical cells.

4.2- MITOSIS

Mitosis is the type of cell division in which a cell divides into two daughter cells, each with the **same number of chromosomes** as were present in the parent cell. Mitosis occurs in the somatic cells of eukaryotes. Prokaryotes also divide to make identical cells. But the events of their division are different from mitosis. That is why we call it **binary fission.**

Phases of Mitosis

The German biologist, Walther Flemming discovered the events of mitosis in 1880s. There are two major phases of mitosis i.e. karyokinesis and cytokinesis.

A. Karyokinesis: Karyokinesis means the division of the nucleus. it is further divided into four phases.

i. Prophase

During prophase, the thread-like **chromatin** material condenses and makes thick visible **chromosomes**. Each chromosome consists of two sister chromatids attached with a single centromere. The nuclear envelope and nucleolus break down during prophase.

The centrosome of cell duplicates into two. The two centrosomes migrate to opposite side of the nucleus. When they are migrating, they make a network of microtubules called **spindle fibres** (complete set is called **mitotic spindle**). In plant cells, there is no centrosome. Their mitotic spindle is formed by the aggregation of spindle fibres present in cytoplasm.

ii. Metaphase

During this phase, some spindle fibres bind with chromosomes. They attach at the point of centromere where special kinetochore proteins are present.

Two spindle fibres from both sides bind with one chromosome. The chromosomes attached with spindle fibres arrange themselves along the equator of the cell. In this way a plate is formed called **metaphase plate.**

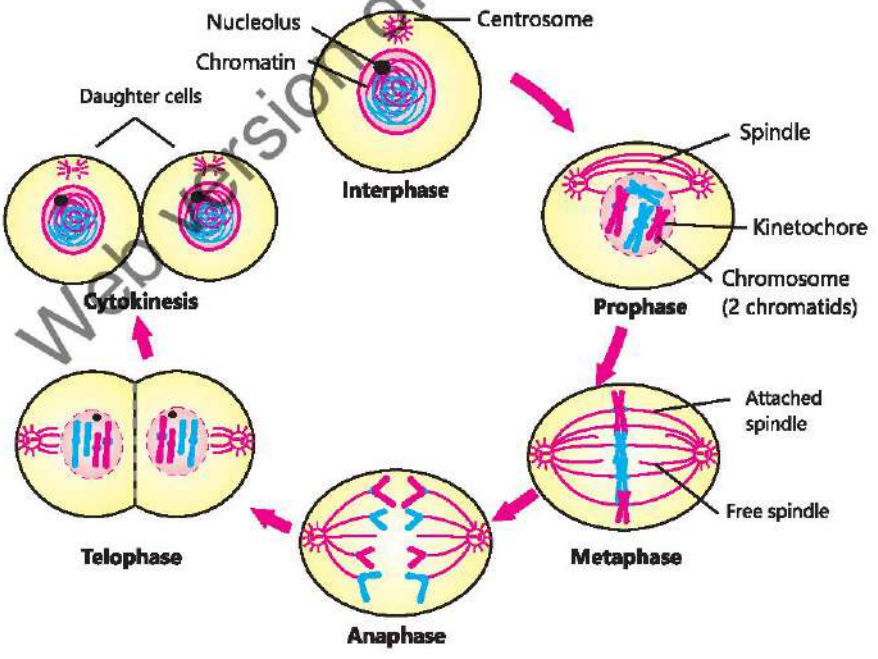


FIGURE 4.2: Phases of mitosis

iii. Anaphase

The spindle fibres attached with chromosomes pull toward the poles. Due to this pulling, the chromosome's sister chromatids separate. In this way, there are two similar sets of chromatids, which move towards the poles of the cell.

iv. Telophase

In this phase, new nuclear envelope forms around each set of separated chromosomes and nucleolus reforms. Both sets of chromosomes unfold back into chromatin.

B. Cytokinesis: It is the division of cytoplasm. In animal cells, a furrow develops in the cell membrane at the equator. At this furrow, the cytoplasm has a **ring of microfilaments.** The ring contracts and the furrow moves inward. In this way parent cell is pinched into two.

In plant cells, Golgi apparatus makes vesicles. These vesicles move to the middle and fuse to form a plate called **phragmoplast.** The plate grows outward and its membranes fuse with the cell membrane. The result is two daughter cells.

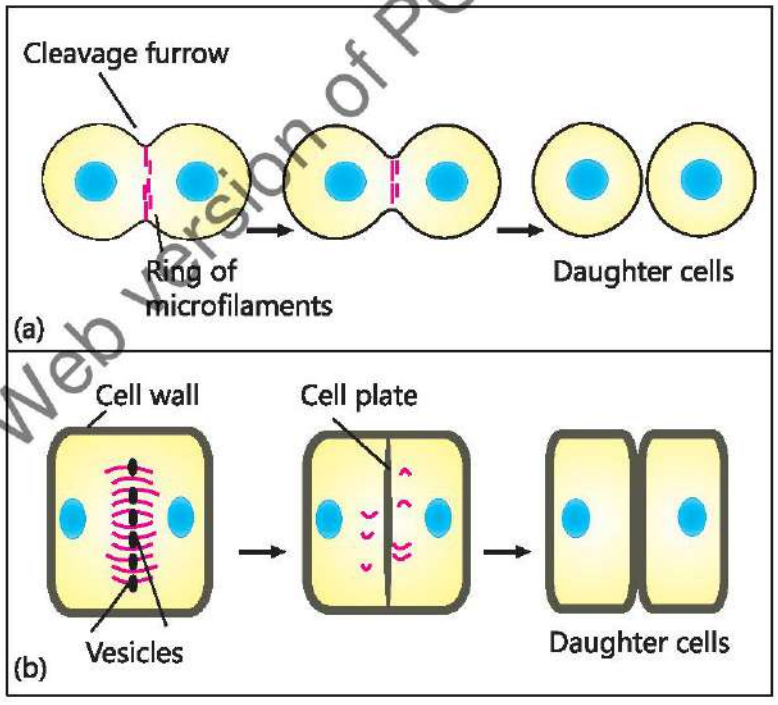


FIGURE 4.3: Cytokinesis; (a) in animal cell, (b) in plant cell

Significance of Mitosis

Growth: Growth in organisms means an increase in size. It occurs due to increase in the number of cells. Mitosis plays a crucial role in growth by producing new cells that are identical to the original cells.

Your body consists of about 200 trillion cells. All these cells were formed from a single cell (zygote) at the start of your life. Millions of cell divisions occurred while your body was reaching its present form. In each of these divisions the genetic material was equally distributed between the daughter cells. It happened through mitosis.

Cell Replacement: Many cells are constantly dying in our bodies. For example, the red blood cells and the cells of the walls of intestine and skin etc. These are replaced by new ones which are exact copies of the older cells. The new cells are formed by mitosis.

Regeneration: Some animals can regenerate parts of the body. For this purpose, they form new cells by carrying out mitosis in the cells of remaining parts.

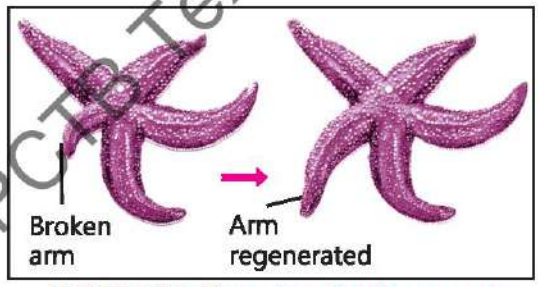


FIGURE 4.4: Regeneration in sea star

Asexual reproduction: Mitosis is a means for asexual reproduction. For example, Hydra reproduces asexually by budding. During this process mitosis forms a mass of cells called bud on the surface of Hydra. Mitosis continues in the cells of the bud and it grows into a new individual.

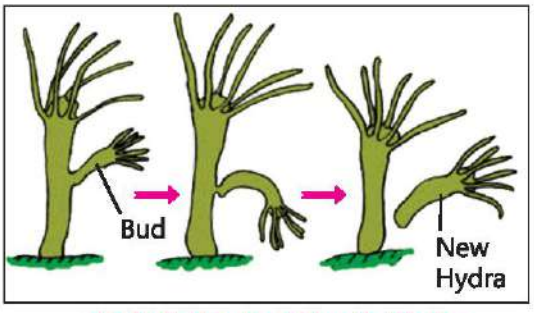


FIGURE 4.5: Budding in Hydra

Errors in Mitosis

Sometimes the process of mitosis goes wrong. For example, during the anaphase of mitosis, the sister chromatids of a chromosome may fail to separate. As a result, one daughter cell receives both sister chromosomes and the other will receive none. Chromosomes may also be damaged during mitosis.

If the genes that regulate mitosis are mutated (changed), the cells continue to divide. Due to this uncontrolled division, masses of cells are formed. These

masses are called **tumors**. If the tumors remain in their original location, they are called **benign**. If they migrate and invade other tissues, they are called **malignant** tumors (cancer). It is called **metastasis**(spreading of disease).

4.3- MEIOSIS

It is the type of cell division in which each daughter cell receives half the number of chromosomes as compared to the parent cell. In meiosis, a diploid parent cell divides to produce four haploid daughter cells. **Diploid** means the cells in which chromosomes are in pairs (homologous pairs) while **haploid** means the cells with half number of chromosomes i.e., cells with no pairs of chromosomes.

Phases of Meiosis

Meiosis was discovered in 1876 by a German biologist Oscar Hertwig. Meiosis consists of two divisions i.e., Meiosis-I and Meiosis-II.

Meiosis-I

In meiosis-I, the homologous chromosomes in a diploid cell separate and so two haploid daughter cells are produced. It is subdivided into prophase-I, metaphase-I, anaphase-I and telophase-I.

Prophase-I

During this stage, chromatin condenses and takes the shape of chromosomes. Each chromosome consists of two sister chromatids, because the DNA has already replicated before meiosis.

Homologous chromosomes move close together. They pair up in a process called **synapsis**. Each pair of homologous chromosomes is called **tetrad**. Non-sister chromatids of homologous chromosomes become "zipped" together, forming X-shaped structures called **chiasmata**. Each chiasma is the site for crossing over i.e., exchange of portions of chromosomes between non-sister chromatids. Crossing over leads to recombination of genetic material.

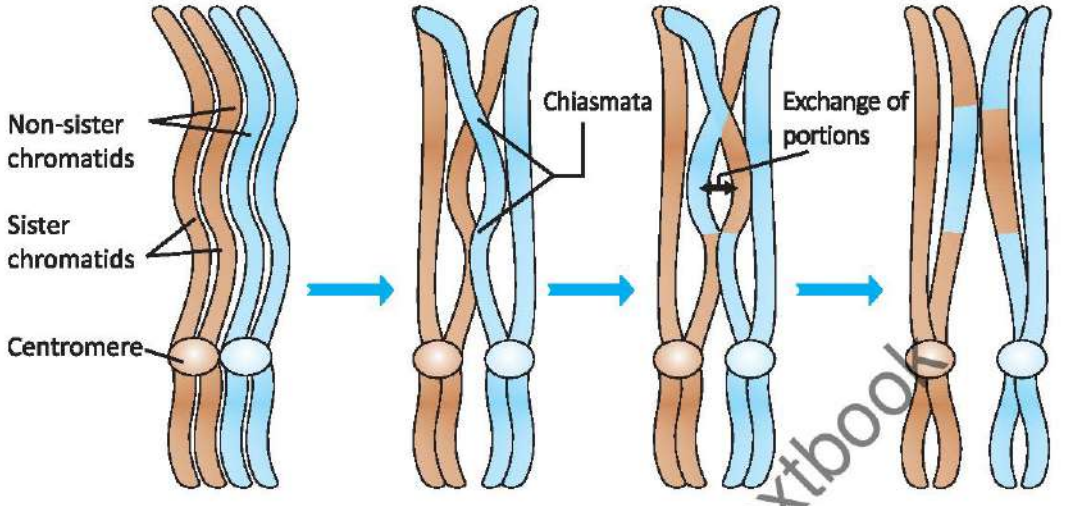


FIGURE 4.6: Crossing over

Other events of prophase-I are similar to prophase of mitosis. The nucleoli disappear and nuclear envelope breaks. Centrioles migrate to opposite poles and make spindle fibres to which chromosomes attach.

Metaphase-I

The tetrads attached with spindle fibres align along the equator. In this way, they form metaphase plate. In the metaphase plate of meiosis-I, two spindle fibres from both poles attach with one pair of homologous chromosomes.

Anaphase-I

Each spindle fibre attached with a single chromosome pulls towards the pole. In this way, the paired chromosomes are separated. One chromosome of each pair is pulled toward one pole and the other towards opposite pole. So, two haploid sets of chromosomes are formed. Each chromosome still contains two sister chromatids.

Telophase-I

Spindles disappear and a new nuclear envelope is made around each haploid set. Nucleolus also reforms during Telophase-I. The chromosomes uncoil into chromatin. Cytokinesis occurs and two daughter cells are made.

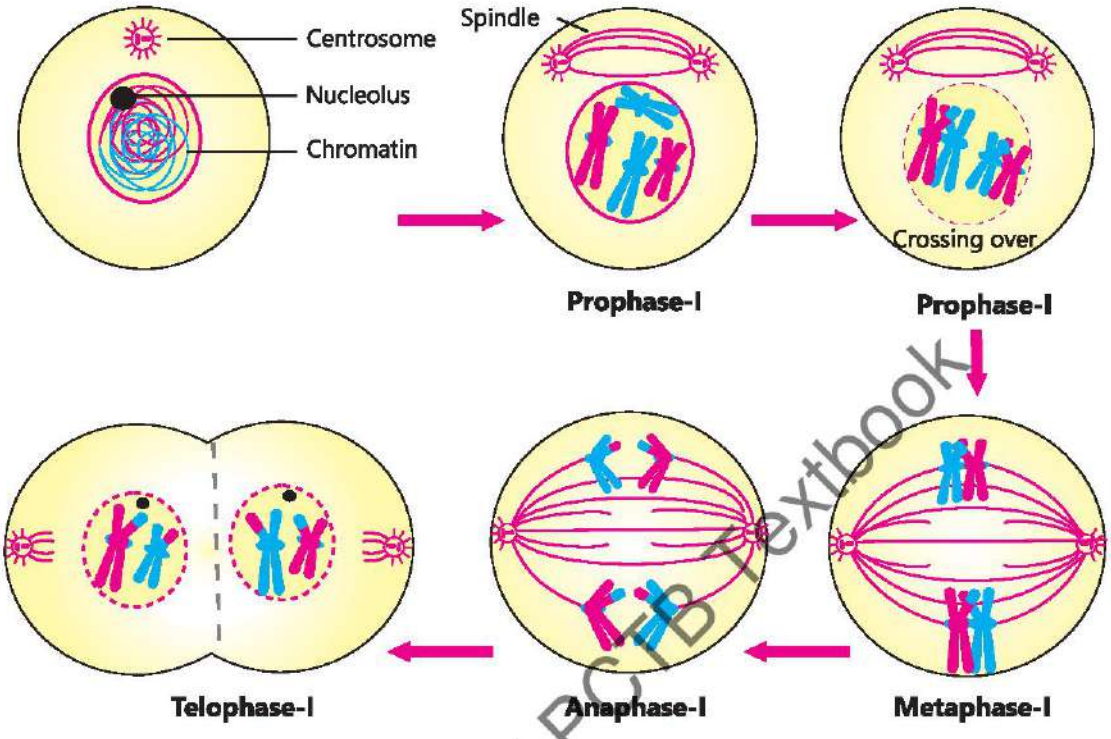


FIGURE 4.7: Phases of meiosis-I

Meiosis-II

Meiosis-II closely resembles mitosis and consists of four phases: prophase-II, metaphase-II, anaphase-II, and telophase-II.

In prophase-II, the nucleoli and nuclear envelope disappear, and the chromatin condenses. Centrioles move to the poles, forming spindle fibres. During metaphase-II, spindle fibres attach to the kinetochores of chromosomes, aligning them at the cell's equator. In anaphase-II, spindle fibres pull sister chromatids apart toward opposite poles. Finally, in telophase-II, chromosomes uncoil back into chromatin, nuclear envelopes and nucleolus reform, and cytokinesis occurs. This results in the formation of four daughter cells, each with half number of chromosomes.

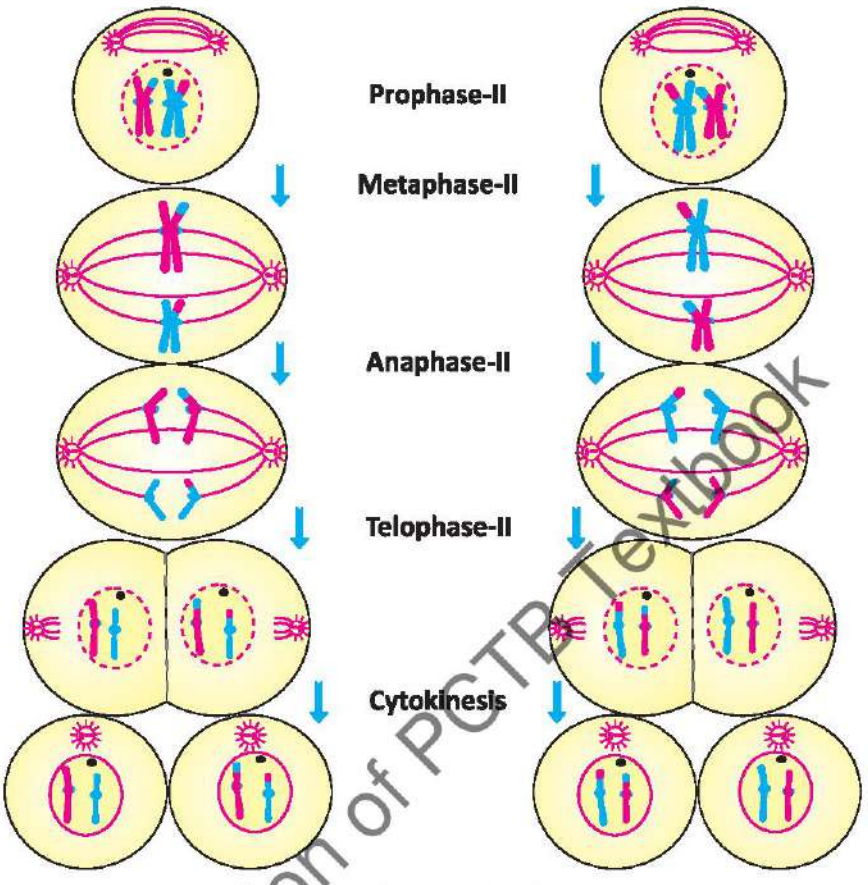


FIGURE 4.8: Phases of Meiosis-II

Significance of Meiosis

1. Meiosis maintains the number of chromosomes

In animals, special cells in reproductive organs undergo meiosis. The daughter cells, called **gametes**, have half the number of chromosomes (with no pairs). During sexual reproduction, male and female gametes join to make the first cell (zygote) of new generation. The original number of chromosomes is restored in zygote. It undergoes mitosis many times and develops into the new animal.

In flowering plants, specialized cells in flowers undergo meiosis. The daughter cells, called **spores** have half number of chromosomes. These spores grow into new generation inside the flowers. This generation produces gametes by mitosis. The gametes join to make zygote with full set of chromosomes. The zygote undergoes mitosis and develops into new plant.

2. Meiosis brings genetic diversity

Crossing over creates new combinations of genes on chromosomes. Each chromosome in the gametes carries a unique set of genes. When diverse gametes from two parents combine, the resulting zygote is genetically different from both parents. In this way, meiosis contributes to genetic diversity in populations.

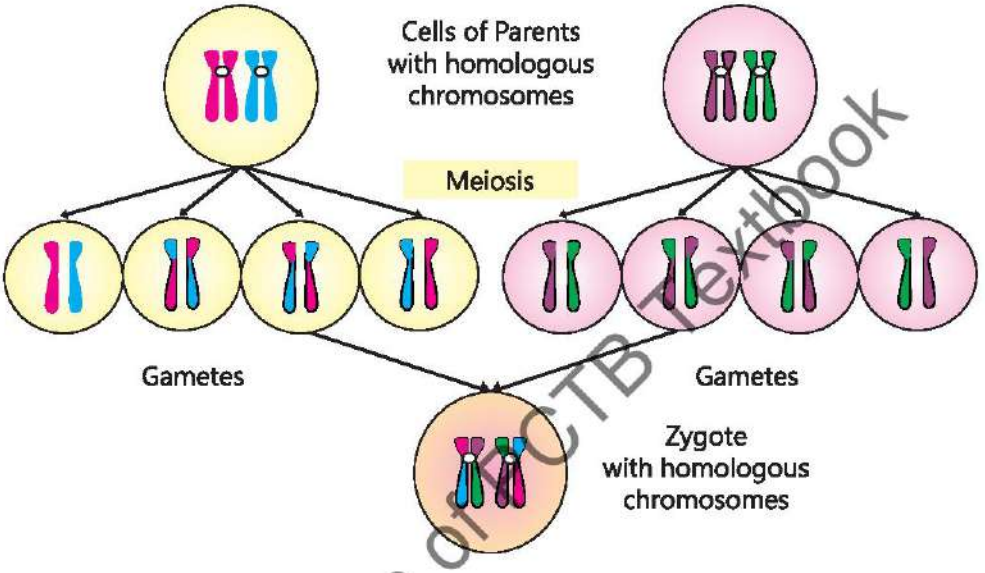


FIGURE: 4.9: Meiosis creates cells with new combinations of genes

Errors in Meiosis

During meiosis-I, chromosomes separate while during meiosis-II sister chromatids separate. It is called **disjunction**. Sometimes **non-disjunction** occurs. Due to it, the daughter cells (gametes) receive more or less than the normal number of chromosomes. If such gametes fuse, the zygote receives abnormal number of chromosomes. If such zygote develops, the resulting offspring suffers from severe medical problems.

4.4- COMPARISON BETWEEN MEIOSIS AND MITOSIS

Similarities

1. DNA replication occurs during interphase (S phase) before both divisions.
2. Both divisions begin with a parent cell that has chromosomes in pairs.

3. In both divisions, chromatin condenses and chromosomes become visible during prophase.
4. Both mitosis and meiosis involve the formation of a spindle apparatus.
5. Both involve prophase, metaphase, anaphase, and telophase. However, meiosis has two rounds i.e., meiosis-I and meiosis-II.
6. In both divisions, sister chromatids separate. In mitosis, it happens during anaphase. In meiosis, it happens in anaphase II.
7. Cytokinesis occurs at the end of both divisions. During cytokinesis, the cytoplasm divides and two new cells are formed.

Differences

Table: Difference between mitosis and meiosis

Mitosis	Meiosis
A parent cell divides only once; two daughter cells are produced.	A parent cell undergoes two divisions; four daughter cells are produced.
Chromosome number in daughter cells remains the same as the parent cell.	The chromosome number is reduced by half in daughter cells.
Variations are not generated	Variations occur due to crossing-over
Occurs in somatic cells.	Occurs in germ line cells.
Homologous chromosomes do not form pairs.	Homologous chromosomes form pair.
No crossing over occurs during prophase.	Crossing over occurs during prophase.
Single chromosome aligns to form a metaphase plate.	Homologous pairs align to form a metaphase plate.
During anaphase, chromosomes break and individual chromatids are pulled towards poles.	During anaphase-I, individual chromosomes are pulled towards poles.
Occurs for growth, development, and maintenance of multicellular organisms.	Occurs for producing gametes in animals and spores in plants for sexual reproduction.

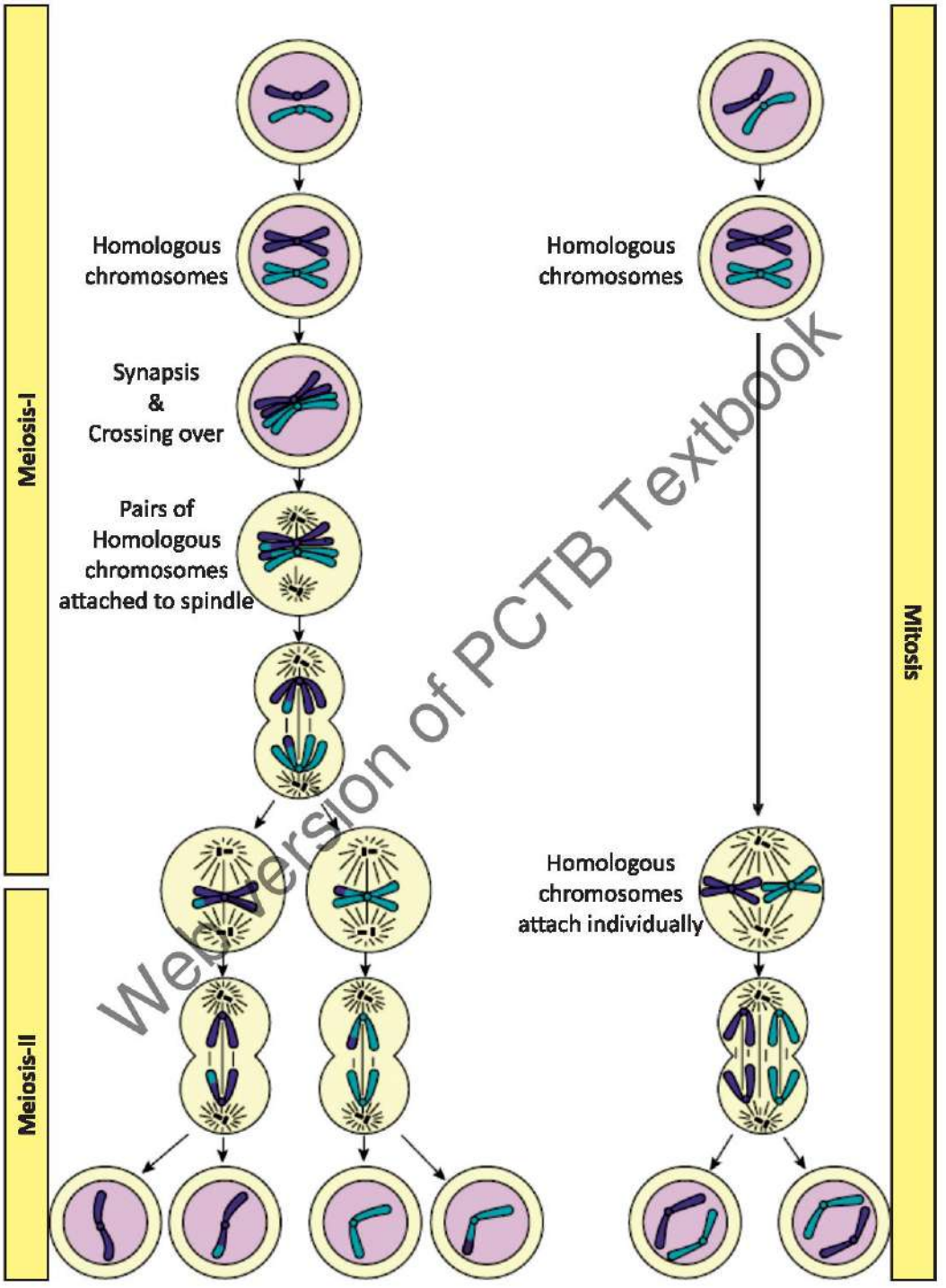


FIGURE 4.10: Comparison between meiosis and mitosis

KEY POINTS

- Cell cycle is series of events starting after cell division to the next division.
- By mitosis a cell divides into two daughter cells and each daughter cell receives the same number of chromosomes as were present in the parent cell.
- During prophase of mitosis chromatin condenses and takes the shape of chromosomes. Centrioles duplicate and make spindle fibres.
- During metaphase of mitosis one chromosome is attached with two spindle fibres from opposite poles.
- During anaphase of mitosis centromeres of chromosomes divide and sister chromatids separate.
- During telophase of mitosis new nuclear envelope forms around each set of chromosomes.
- Mitosis occurs during development, growth, cell replacement, regeneration and asexual reproduction.
- Meiosis is the type of cell division, in which each daughter cell receives half the number of chromosomes as compared to parental cell.
- During prophase I of meiosis, homologous chromosomes form pairs. The non-sister chromatids of homologous chromosomes exchange their segments in crossing over.
- During metaphase I of meiosis, one pair of homologous chromosomes is attached with two spindle fibres from opposite poles.
- During anaphase I of meiosis, homologous chromosomes are pulled apart forming two diploid sets at opposite poles.
- During telophase I of meiosis, spindle fibres disappear, and new nuclear envelope surrounds each haploid set.
- Meiosis maintains the chromosome number in next generation by making haploid gametes. Meiosis produces variations in next generations.

EXERCISE

A. Select the correct answers for the following questions.

1. In which phase of cell cycle, maximum growth occurs in cell?
   a) M phase
   b) S phase
   c) G1 phase
   d) G2 phase
2. In which phase of cell cycle, the chromosomes duplicate?
   a) Mitosis
   b) G1 phase
   c) G2 phase
   d) S phase
3. Which of the following is NOT a characteristic of mitosis?
   a) It occurs in somatic cells.
   b) It results in genetically identical daughter cells.
   c) The chromosome number is halved in daughter cells.
   d) It results in the formation of two daughter cells.
4. At which stage of mitosis chromosomes line up in the centre?
   a) Prophase
   b) Metaphase
   c) Anaphase
   d) Telophase
5. If you observe a cell in which nuclear membrane is reforming around two sets of chromosomes, what stage of cell cycle is this?
   a) Anaphase
   b) Telophase
   c) Prophase
   d) Metaphase
6. How does the centrosome contribute to mitosis?
   a) Initiates DNA replication
   b) Makes mitotic spindle
   c) Forms the nuclear envelope
   d) Duplicates organelles
7. Centrosomes make mitotic spindle in;
   a) Animal cells
   b) Plant cells
   c) Prokaryotic cells
   d) All of these
8. An organism has 4 pairs of chromosomes. After meiosis-I, how many chromosomes and chromatids will be present in each daughter cell?
   a) 8 chromosomes and 16 chromatids
   b) 4 chromosomes and 8 chromatids
   c) 4 chromosomes and 4 chromatids
   d) 8 chromosomes and 8 chromatids
9. Which event is unique to meiosis but not mitosis?
   a) DNA replication
   b) Chromosome alignment
   c) Crossing over
   d) Nuclear division

10. Why is meiosis-II necessary after meiosis-I?
    a) To replicate chromosomes
    b) To reduce chromosome number
    c) To separate sister chromatids
    d) To ensure genetic recombination

B. Write short answers.

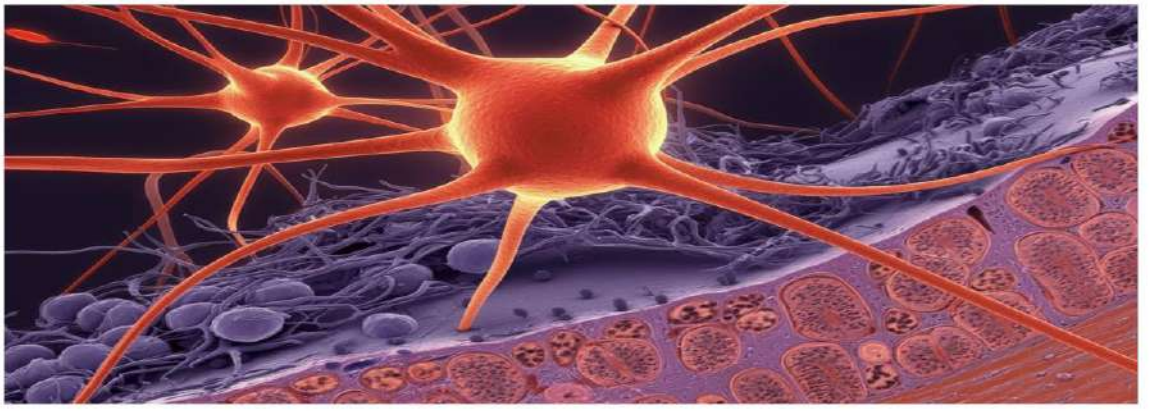
1. Enlist the events that occur during the G1 phase of interphase?
2. What is the main purpose of the S phase in the cell cycle?
3. During which phase of mitosis sister chromatids separate?
4. How does crossing over contribute to genetic variation in meiosis?
5. What is the role of spindle fibres in mitosis?
6. How is cytokinesis in animal cell different from plant cell?
7. What is the difference between prophase of mitosis and prophase-I of meiosis-I?
8. How does meiosis differ from mitosis in terms of chromosome number?
9. What are the key events of anaphase in mitosis?
10. What is the function of the centrosome during cell division?
11. What are sister chromatids, and when do they separate in meiosis?
12. How is mitosis related to the process of regeneration?

C. Write answers in detail.

1. Describe the events that occur during the phases of mitosis.
2. Describe cytokinesis in animal and plant cells.
3. Describe the significance of mitosis.
4. Describe the events that occur during the phases of meiosis-I.
5. Describe the significance of meiosis.

D. Inquisitive questions.

1. What role might mistakes in the cell cycle checkpoints play in the emergence of cancer?
2. Why do skin cells divide continuously throughout an organism's existence, but nerve and muscle cells permanently exit the cell cycle?



Chapter 5

TISSUES, ORGANS, AND ORGAN SYSTEMS

After studying this chapter, students will be able to:

- Distinguish between tissues, organs and organ systems with examples from animals and plants.
- Enlist the different types of tissue that come together to form the stomach organ in the human body.
- Discuss the organ systems that come together to form the human body.
- Describe the advantages of homeostasis.
- Discuss how various organs and organ systems of the human body work to maintain homeostasis.
- Discuss the different types of tissue that come together to form the leaf.
- Explain plant physiology in terms of structures and roles of various plant organs.

Living organisms exhibit a complex organization of structures in which each level of structure is built upon the previous one. This chapter will explore the fundamental levels of biological organization: cells, tissues, organs, and organ systems. We will study the characteristics and examples of each level, understanding how they perform the functions of life.

5.1- Levels of Organization

Organisms are built on a pattern of increasing complexity. There are different levels of organization where lower levels are simpler and higher levels are increasingly complex. The levels of organization in multicellular organisms begin with the simplest and smallest level i.e., the atom, and progresses to the largest and most complex level i.e., the organism.

1- **Atom:** Atoms are the smallest unit of matter that maintain the property of an element. For example; carbon, hydrogen, oxygen.

2- **Molecule:** Atoms combine to form molecules which can have entirely different properties than the atoms they contain. For example; water, protein, nucleic acid.

3- **Organelle:** Molecules combine in specific ways and make the subcellular level i.e., organelle. Each organelle is specialized to do a particular function. For example; **mitochondria** are responsible for cellular respiration and **ribosomes** are specialized for protein synthesis.

4- **Cell:** When organelles assemble and interact with each other, they make cell – the smallest unit with characteristics of life. They can carry out life activities and can also reproduce. Unicellular organisms are made of only one cell while multicellular organisms are made of many cells.

5- **Tissue:** In multicellular organisms, cells make tissues. A tissue is a group of similar cells that work together to perform one or more specific functions. Examples of tissues include:

- In animals;
  - **Epithelial tissue** – covers body surfaces and lines cavities (e.g., skin)
  - **Muscle tissue** – enables movement (e.g., cardiac muscle in the heart).
- In plants;
  - **Epidermal tissue** – protects the underlying parts (e.g., epidermis of leaf)
  - **Vascular tissue** – transports water and nutrients (e.g., xylem and phloem).

6- **Organ:** An organ is a structure made up of related tissues working together to perform specific functions. Examples of organs include:

- In animals; Heart (pumps blood through the circulatory system), and lungs (facilitate gas exchange)
- In plants; Leaves (conduct photosynthesis), and roots (absorb water and nutrients from soil).

7- **Organ System:** An organ system consists of multiple organs that work together to perform related functions. Examples of organ system include:

- In animals - circulatory system (transports nutrients and oxygen throughout the body) and digestive system (breaks down food and absorbs nutrients).
- In plants - root system (anchors the plant and absorbs water and nutrients) and shoot system (supports the plant and conducts photosynthesis).

8- **Organism:** An organism is a living entity that can function independently on behalf of proper functioning of its organ systems. Examples include humans and trees.

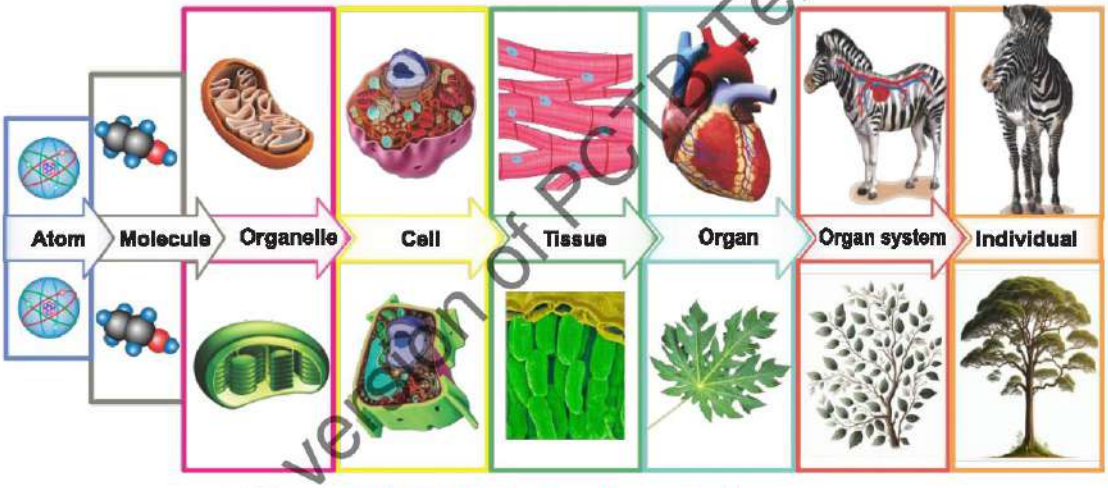


FIGURE 5.1: Levels of organization

Emergent Properties

In organisms, the components at each level do not work solely. Instead, they interact. Due to their interactions, they create new functions called **emergent properties**. These include the abilities that are present in higher level of organization but are not possible from the individual components. Following are the examples of emergent properties when lower levels make higher levels:

> The Greek philosopher Aristotle said; *"The whole is greater than the sum of its parts".*

1- From Organelles to Cells: Individual organelles have specific functions. However, when these organelles interact within a cell, they create a complex system capable of carrying out various cellular processes, such as cell division, protein synthesis, and energy production.

2- From Cells to Tissues: Individual cells do not have properties that are present in the tissue which they make. For example, muscle cells combine to form muscle tissue, which can contract and generate force.

3- From Tissues to Organs: An organ performs complex functions that its individual tissues cannot perform. For example, the heart is composed of various tissues, including muscle tissue, connective tissue, and epithelial tissue. The coordinated interaction of these tissues allows the heart to pump blood throughout the body.

4- From Organs to Organ Systems: Multiple organs working together form organ systems, which carry out vital functions. For example, the digestive system is composed of organs like the mouth, oesophagus, stomach, intestines, and liver. These individual organs cannot digest food but the coordinated actions of these organs enable the digestion and absorption of nutrients.

5- From Organ Systems to Organisms: In an individual, the interactions of various organ systems bring emergent properties such as consciousness, thinking, and the ability to adapt to environment. These complex behaviours are not present in individual organ systems but arise from their coordinated interactions.

5.2- Organs and Organ Systems in Plants

You know that organs are made of two or more types of tissues organized to serve a particular function. Organs which perform related functions work together and make an organ system. The following are examples of organs and organs systemin plants.

Organs in Plants

Roots: Roots are usually found underground anchor the plant in the soil and absorb water and essential minerals from the soil. Roots also store nutrients that the plant uses for their growth.

Roots: Roots anchor the plant in the soil and absorb water and essential minerals from the soil. Roots also store nutrients that the plant uses for their growth.

Stems: Stems support leaves, flowers, and fruits. Stems contain vascular tissues (xylem and phloem) that facilitate the movement of water, minerals, and nutrients between roots and leaves.

Leaves: Leaves are the primary sites of photosynthesis and transpiration. Transpiration in leaves is the loss of water vapour through small pores called stomata.

Flower: Flower is reproductive part of a plant. It plays a crucial role in plant's sexual reproduction.

Leaf as an Organ

In plants, leaf is a complex organ made of various related tissues. The major tissues that form a leaf are:

1- Epidermal Tissue: The outermost layer of leaf is made of epidermal tissue (epidermis). The upper epidermis is usually covered by waxy cuticle, which reduces water loss and provides protection. The lower epidermis also contains guard cells. Between two guard cells, there is a tiny pore called stoma (plural *stomata*). Stomata control gas exchange and the loss of water vapours.

2- Mesophyll Tissue: This tissue is present between the upper and lower epidermis. It consists of cells which are rich in chloroplasts. It is the site of photosynthesis. There are two types of mesophyll in the leaf.

- **Palisade mesophyll**: It is located just beneath the upper epidermis. It consists of tightly packed elongated cells.
- **Spongy Mesophyll:** It is present below the palisade mesophyll. It is composed of loosely arranged cells with air spaces between them. These air spaces facilitate the diffusion of gases throughout the leaf.

3- Vascular Tissue: This tissue is located in the midrib and veins of leaf. It is called a complex tissue because it consists of two tissues i.e., xylem tissue and phloem tissue. The xylem tissue of leaf conducts water and minerals from the xylem of stem to leaf cells. Phloem tissue transports the products of photosynthesis (sugars) from leaf cells to the phloem of stem.

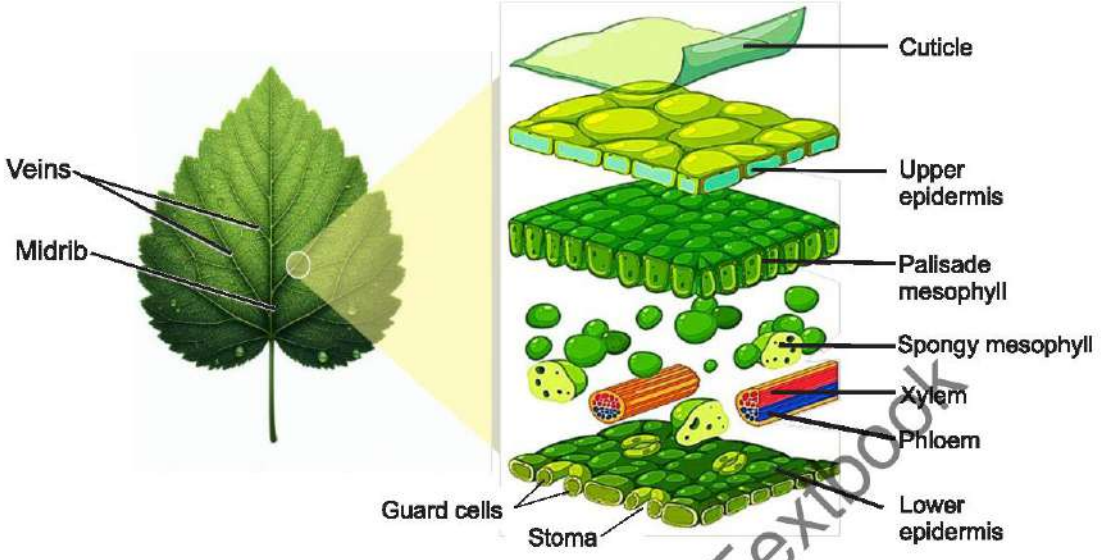


FIGURE 5.2: Tissues which make the leaf organ

Organ Systems in Plants

An organ system consists of organs that work together to perform essential functions. Unlike animals, plants are stationary organisms, so their organ systems are less complex. Plants have two main organ systems i.e., the root system and the shoot system. The **root system** consists of roots which anchor the plant in the soil. Roots also absorb water and salts needed from soil, and, in some cases, store food. The **shoot system** includes stems, branches, leaves, and flowers (and fruits formed from flowers). These organs work to enable processes like photosynthesis and reproduction.

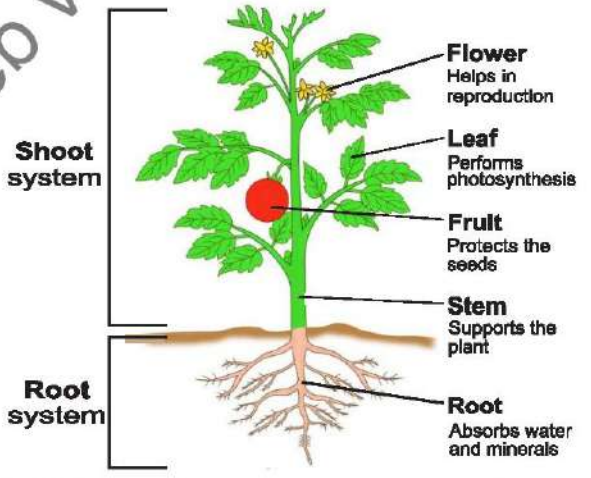


FIGURE 5.3: Organs and organ systems in Plants

5.3- Organs and Organ Systems in Humans

Organs in Human Body

Various organs are present in human body, each with specific functions. Here are a few of the most important organs:

Heart: The heart is a muscular organ that pumps blood throughout the body. It is essential for delivering oxygen and nutrients to cells and removing waste products.

Lungs: The lungs are responsible for breathing. It facilitates the exchange of oxygen and carbon dioxide between the body and environment.

Brain: The brain is the control center of the body. It is responsible for coordination among other organs, thinking, and decision-making.

Liver: The liver performs many vital functions, including filtering blood, producing bile, and storing glucose.

Kidneys: The kidneys are responsible for filtering waste products from the blood and producing urine.

Stomach: The stomach is a muscular organ that breaks down food using digestive enzymes.

Intestines: The intestines are long, tubular organs that digest food and absorb nutrients from the digested food.

Pancreas: The pancreas produces digestive enzymes. It also produces hormones such as insulin and glucagon.

Stomach as an Organ

Stomach is an important organ of the digestive system. It is responsible for the partial digestion of proteins. It also stores food. It is composed of the following tissues:

1- Epithelial Tissue: The inner wall is made up of epithelial tissue. It is glandular in nature and secretes mucus. The mucus lines the inner wall and protects it from acid. This tissue also secretes gastric juice that contains enzyme pepsinogen for protein digestion and hydrochloric acid for activating pepsinogen to pepsin enzyme.

2- Connective Tissue: It lies beneath epithelial tissue. It provides structural support and contains blood vessels, nerves, and lymphatics.

3- Muscle Tissue: There are three layers of smooth muscles: the outer longitudinal layer, the middle circular layer, and the inner oblique layer. These muscle contract and relax to mix food with the gastric juice.

4- Outer Connective Tissue: It is the outermost layer that encircles the stomach and supports it.

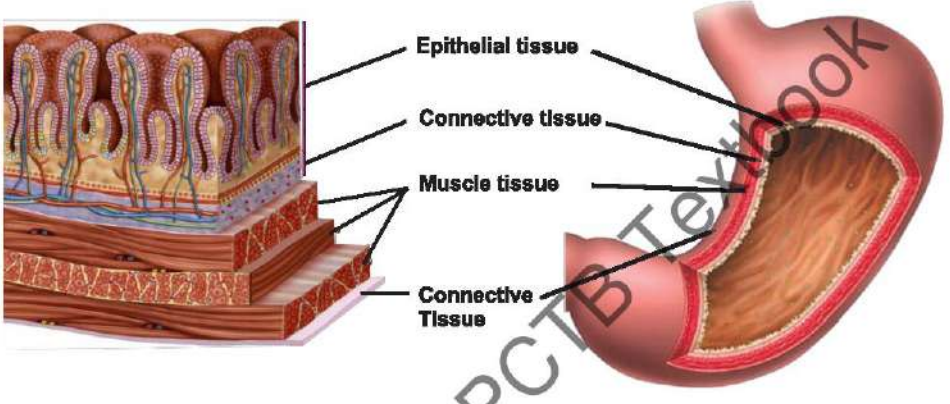


FIGURE 5.4: Tissues which make the stomach organ

Organ Systems in Human Body

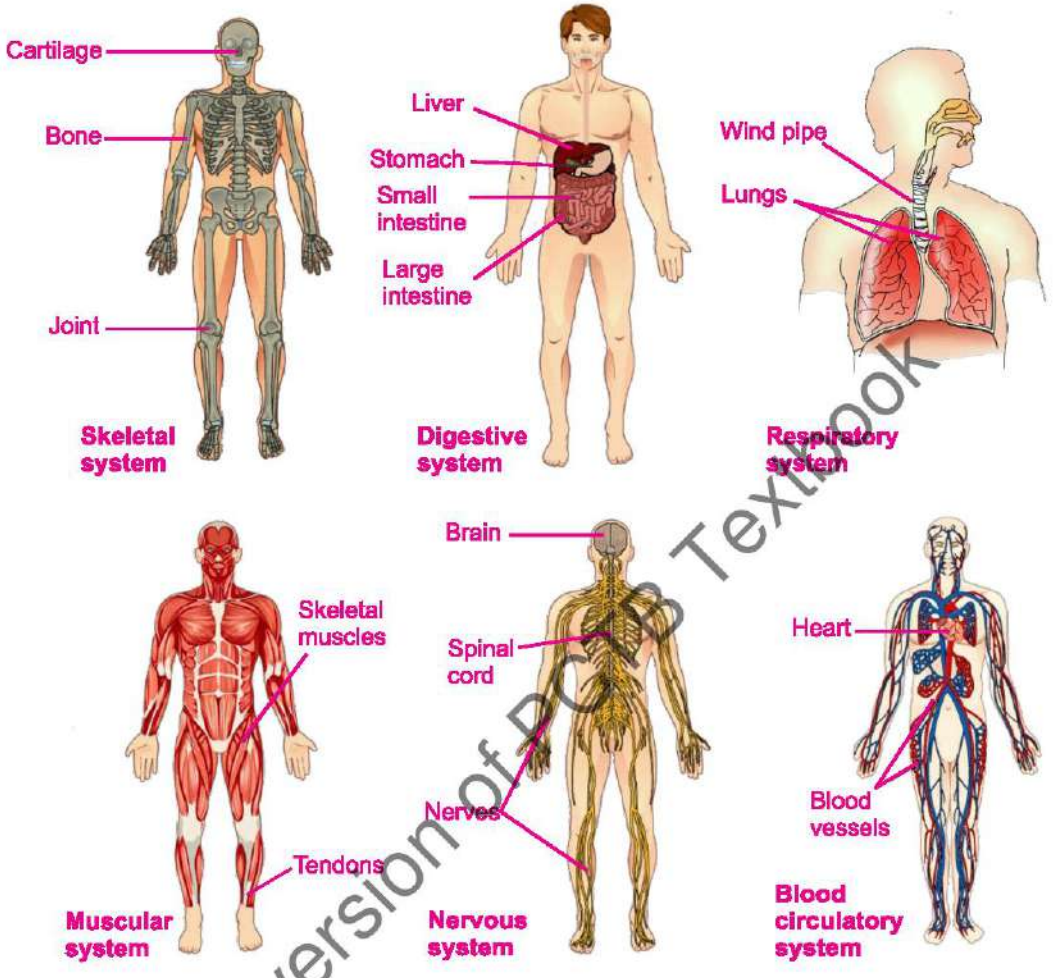
Here are a few examples of organ systems which form the human body.

Skeletal system: It consists of bones, cartilages and tendons. It provides structure, support, and protection to the body. It serves as a framework for muscles to attach, allowing movements. It also stores minerals and produces blood cells.

Digestive System: It consists of organs such as mouth, oesophagus, stomach, small intestine, and large intestine. This system is responsible for the digestion of food and the absorption of digested food.

Respiratory System: It includes the lungs, trachea (windpipe), and bronchi. This system is involved in the exchange of gases (oxygen and carbon dioxide) between the body and the environment.

Muscular System: It includes skeletal muscles, which attach to bones. These muscles contract to move bones. It allows movements and locomotion in the body.



Nervous System: It includes brain, spinal cord, and nerves. The nervous system coordinates and controls body functions through nerve impulses.

Blood Circulatory System: It includes heart, blood vessels (arteries, veins, and capillaries), and blood. This system transports oxygen, nutrients, hormones, and waste products throughout the body.

5.4- HOMEOSTASIS

The organs and organ systems of the body work in coordination to maintain a stable internal environment. It is called homeostasis. **Homeostasis** is defined as the ability of an organism to maintain a stable internal environment of the

body despite changes in the external environment. E xamples of homeostasis include regulating the temperature, blood pressure, blood sugar, and pH levels.

Importance of Homeostasis

Homeostasis plays a vital role in supporting overall health and well-being. For example;

- Each cell is a sophisticated machine that plays a precise role within the body. The proper functioning of cell is possible only when extracellular conditions such as temperature, pH, and the concentrations of salts, glucose and oxygen are kept in normal range.
- When we do hard work, our muscles produce heat that raises the body temperature. In such situation, the temperature regulating centre in the brain sends message to sweat glands. As a result, sweating occurs and the temperature of the body falls to normal.
- When the body temperature falls, the temperature regulatory centre sends message to muscles. As a result, shivering occurs to generate heat.

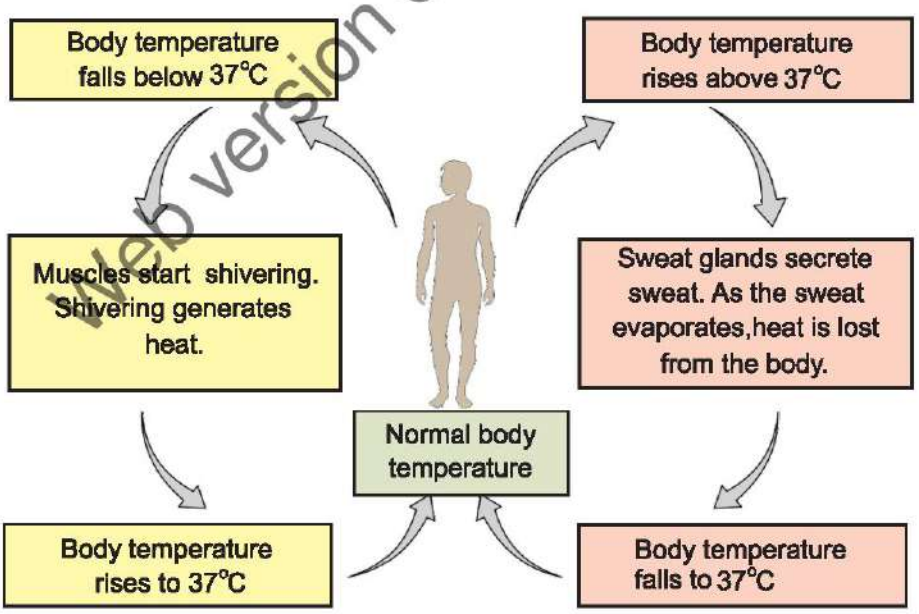


FIGURE 5.6: Homeostasis of body temperature

- When we drink juice, blood glucose level rises. In this situation, pancreas releases a hormone insulin in blood. This hormone lowers the blood glucose level to normal.
- When we do hard exercise, our muscles need more oxygen. In such condition, the rate of breathing and heartbeat are increased. Accelerated breathing and heartbeat supply more oxygen and food to the muscles for continuous work.

Role of Organ Systems in Homeostasis

Several organ systems work together for homeostasis. For example;

- Nervous system and endocrine system regulate and coordinate activities such as heart rate, respiration, and metabolism. They also respond to changes in the environment.
- Respiratory system ensures that the body receives enough oxygen for cellular respiration. It also expels excess carbon dioxide from the body.
- Cardiovascular system plays role in the regulating body temperature and pH levels. It also ensures that all cells receive the necessary substances for proper functions.
- Digestive system works for proper distribution of nutrients to cells for energy, growth, and repair.
- Muscular and skeletal systems help to maintain body posture, support and movement.
- Urinary system eliminates waste materials from the body. It also regulates water and salt balance in body tissues. In this way, it maintains blood volume, blood pressure, and pH levels.
- Integumentary system acts as a barrier to protect the body from external factors. It also helps to regulate temperature through sweating.

KEY POINTS

- Organelles are the subunits of a cell that perform distinct functions.
- A tissue is a group of similar cells that work together to perform a specific function.
- Organs are structures made up of more than one type of tissues having related function that work together.
- An organ system is a collection of different organs that work together to perform a related function.
- The epithelial tissue of the stomach secretes gastric juice, which contains mucus, HCl and pepsinogen. Mucus protects the stomach lining.
- The smooth muscles of stomach help in the breakdown of food.
- Mesophyll tissue is present in leaf. Its cells contain chloroplasts. It is the site of photosynthesis.
- Xylem and Phloem are the vascular tissues responsible for transporting water and nutrients.
- Homeostasis is defined as the body's ability to maintain a relatively stable internal environment despite the changes in the external environment.
- Organ systems work together for homeostasis.

EXERCISE

A. Select the correct answers for the following questions.

1. A higher level of organization exhibits emergent properties when:
   a) Its parts function independently.
   b) The sum of its parts is greater than the whole.
   c) The individual parts are more important than the whole.
   d) Its parts interact to perform more functions.
2. Which of the following demonstrates the levels of organization of the body, from simplest to most complex?
   a) Cell → Organ → Tissue → Organelle → Organ system
   b) Organelle → Cell → Tissue → Organ → Organ system

c) Tissue → Cell → Organelle → Organ → Organ system
d) Organ system → Tissue → Cell → Organelle → Organ

3. At which level of organization gas exchange occurs between body and environment?
   a) Organelle level in mitochondria
   b) Cellular level in alveolar cells
   c) Tissue level in epithelial tissues
   d) Organ system level in the respiratory system
4. The epithelial tissue in the stomach wall is responsible for producing:
   a) Mucus
   b) Pepsinogen
   c) Hydrochloric acid
   d) All of these
5. In the wall of stomach, which tissue also contains blood vessels and nerves?
   a) Epithelial
   b) Muscle
   c) Inner connective
   d) Outer connective
6. In a leaf, which tissue is responsible for photosynthesis?
   a) Xylem
   b) Mesophyll
   c) Epidermis
   d) Phloem
7. What is the primary function of the xylem tissue in a leaf?
   a) To transport sugars to other parts
   b) To transport water to parts of leaf
   c) To synthesize chlorophyll
   d) To control the opening and closing of stomata
8. Which of these is a function of the human skeletal system?
   a) Storing minerals and producing blood cells
   b) Removing carbon dioxide from blood
   c) Filtering blood to remove waste products
   d) Breaking down food for energy
9. Which structures are responsible for the transport of food in plant body?
   a) Xylem tissue
   b) Palisade mesophyll
   c) Phloem tissue
   d) Spongy mesophyll
10. In a plant, which of the following is the primary function of the flower?
    a) Transporting water and minerals
    b) Supporting leaf growth
    c) Facilitating reproduction through pollination
    d) Regulating gas exchange

B. Write short answers.

1. Enlist the levels of organization from cells to organ systems.
2. What are the major roles of the epithelial tissue present in the stomach?
3. How do the smooth muscles contribute to the stomach's function?
4. What is the function of the palisade mesophyll in the leaf?
5. What is the role of the shoot system in plants?
6. What is homeostasis, and why is it important for organisms?
7. How does the human body maintain a stable internal temperature?
8. Differentiate between the following:
   i. Tissue and organ
   ii. Root system and shoot system
   iii. Epidermal and mesophyll tissue
   iv. Palisade and spongy mesophyll

C. Write answers in detail.

1. Explain the levels of organization in multicellular organism. How does each level contribute to the overall functioning of an organism?
2. What is a tissue level? Explain plant and animal tissues.
3. Describe the tissue composition of the stomach. How does each tissue contribute to the digestive function of the stomach?
4. Describe the tissue composition of the leaf. How does each tissue contribute to the functions of the leaf?
5. How do the organ systems come together to form the human body?
6. Describe the roles of the digestive system and the excretory system in homeostasis.
7. Explain the functions of various plant organs.
8. Describe the structure and function of the plant root system.
9. Define homeostasis and explain its importance. Discuss how different organ systems work together to maintain homeostasis.
10. Describe how the respiratory and circulatory systems work together to maintain homeostasis of oxygen and carbon dioxide levels in the body.

D. Inquisitive questions.

1. How does the structure of epithelial tissue relate to its function in different parts of the body?
2. Evaluate the importance of organ systems working in harmony and predict the consequences of a failure in one system on the others.

Chapter 6
BIOMOLECULES

After studying this chapter, students will be able to:

- Define biochemistry/ molecular biology.
- Outline the various types of common biomolecules (Carbohydrates, Proteins, Lipids, DNA, RNA) including their locations inside the cell and main roles.
- Define carbohydrates and outline the structure, function and sources of carbohydrates.
- Identify carbohydrates as monosaccharides, disaccharides and polysaccharides.
- Outline the structure and function and sources of proteins with structure of amino acids.
- Outline the structure, function and sources of lipids.
- Describe briefly the structure of DNA.
- Outline the function of DNA as carrier of hereditary information.
- Describe briefly the structure of RNA.
- Outline the function of RNA as aid in converting hereditary information into proteins.
- Outline how information in the DNA is converted to information on RNA and then into proteins.

Biochemistry is the study of the chemical processes that occur within living organisms (e.g., photosynthesis, cellular respiration). Molecular biology is the study of the structure and function of the biomolecules (e.g., carbohydrates, proteins, nucleic acids). This chapter digs into the fascinating world of biomolecules.

6.1- BIOMOLECULES

The molecules produced by organisms are called biomolecules or biological molecules. They include carbohydrates, lipids, proteins, and nucleic acids (DNA and RNA). They are mostly large in size and are called macromolecules. Biomolecules play crucial roles in the structure and functions in organisms. The following table mentions important biomolecules and their functions.

Table: Major Biomolecules and their Functions

Biomolecule	Location in the cell	Main Functions
Carbohydrates	• Cytoplasm • Cell membrane	• Act as source of energy • Act as energy storage molecules
Proteins	• Cell membrane • Cytoplasm • Endoplasmic reticulum • Golgi apparatus • Lysosome, mitochondria	• Many proteins act as enzymes • Some hormones are proteins • Make membranes and many other structures in cells • Control cellular traffic
Lipids	• Cell membrane • Cytoplasm	• Act as energy storage molecules • Act as heat insulators • Make structure of cell membrane
DNA (Deoxyribonucleic Acid)	• Nucleus (eukaryotes) • Nucleoid region (prokaryotes) • Mitochondria • Chloroplasts	• Carries genetic information for the development, functioning, and characteristics of organism
RNA (Ribonucleic Acid)	• Nucleus • Ribosomes • Cytoplasm	• Carries genetic information from DNA to ribosome for protein synthesis

Biomolecules make the 93% of the dry mass of protoplasm. The remaining 7% of dry mass comprises of vitamins and inorganic substances like carbon dioxide, acids, bases and salts.

Table: Percentage of Biomolecules in the Dry Mass of Protoplasm

Biomolecules	% Dry mass
Proteins	50
Nucleic acids	18
Carbohydrates	15
Lipids	10

All the chemical reactions that occur in an organism are collectively called **metabolism.** Metabolism can be divided into two main categories: anabolism and catabolism. **Anabolism** is the type of metabolism in which simpler substances are combined to form complex substances. Energy is used in these reactions. **Catabolism** is the type of metabolism in which complex molecules are broken down into simpler ones. Energy is released in these reactions.

6.2- CARBOHYDRATES

"Carbohydrate" means 'hydrated carbons'. They are the organic compounds in which the ratio of H and O is 2:1 (same as in water). They are also known as "Saccharides" (meaning sugar). They have the general formula $\mathbf{C_n(H_2O)_n}$ where *n* is the number of carbon atoms. There are three classes of carbohydrates: monosaccharides, disaccharides, and polysaccharides.

1. Monosaccharides

Monosaccharides (simple sugars) are made of single sugar molecule. They are easily soluble in water and have sweet taste. They may have 3 to 7 carbon atoms. Pentoses (5 C) and hexoses (6 C) are most common.

Examples:

- Ribose ($C_5H_{10}O_5$) and deoxyribose ($C_5H_{10}O_4$) are pentoses.
- Glucose, fructose, and galactose are hexoses ($C_6H_{12}O_6$).

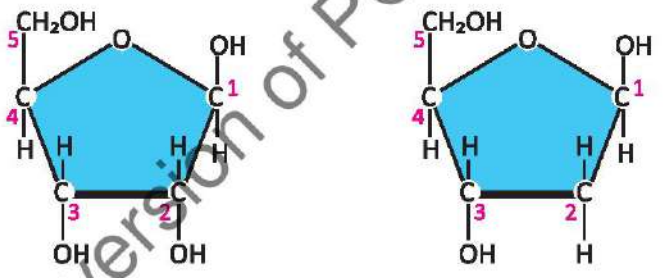


FIGURE 6.1: Common pentoses

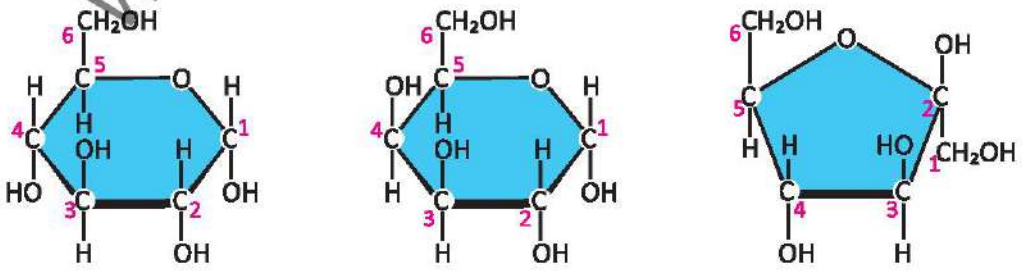


FIGURE 6.2: Common hexoses

2. Disaccharides

They are made of two monosaccharides units. They are less soluble in water and are less sweet in taste.

Examples:

- **Sucrose** (table sugar) is made of two monosaccharides i.e., glucose and fructose.
- **Maltose** is made of two glucose molecules.

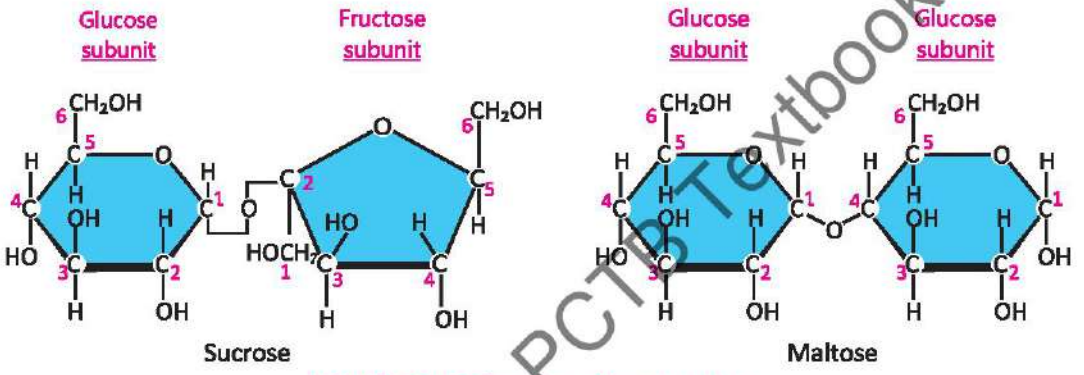


FIGURE6.3: Common disaccharides

3. Polysaccharides

Polysaccharides are large molecules composed of hundreds to thousands of monosaccharides units. They are insoluble in water and are tasteless.

Polysaccharides are the most abundant carbohydrates in nature.

Examples:

- **Starch** is a storage polysaccharide found in plants. It is composed of straight as well as branched chains of glucose units.
- **Glycogen** is the animal starch mainly stored in liver and muscles. It consists of highly branched chains of glucose which are broken down when energy is needed.
- **Cellulose** is a polysaccharide that also consists of straight chains of glucose units. It is found in the cell walls of plants.
- **Chitin** is a modified form of cellulose. It is found in the exoskeletons of crabs, lobsters and insects. It also makes the cell wall of fungi.

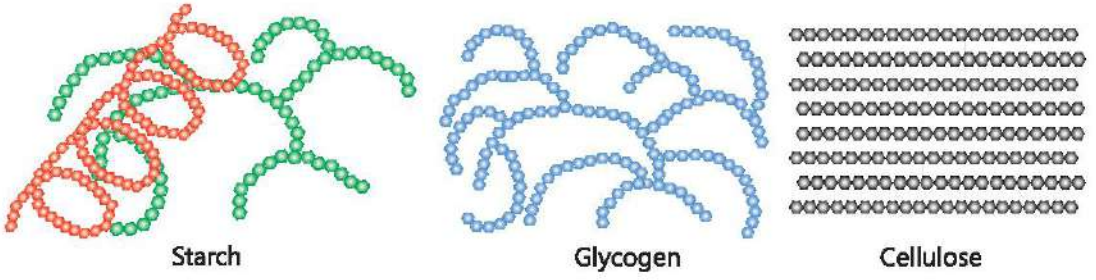


FIGURE 6.4: Polysaccharides

Sources and Functions of Carbohydrates

Sources:

- **Monosaccharides:**Glucose, fructose and galactose are found in fruits, vegetables, honey and cereals.
- **Disaccharides:**Sucrose is found in sugar beet, sugar cane and fruits. Lactose is found in milk and dairy products. Maltose is found in cereals.
- **Polysaccharides:**Starch is found in cereal crops; wheat, barley, maize, rice etc.

Functions:

- Carbohydrates are the primary source of energy. Glucose is used by cells to produce energy through cellular respiration.
- Dietary fibre contains undigestible carbohydrates e.g., cellulose. It helps for the proper bowel movements.
- Pentoses (ribose and deoxyribose) are essential parts of nucleic acids (RNA and DNA respectively).
- Plants convert their monosaccharides to disaccharides like sucrose to transport monosaccharides between body parts.
- Cellulose is the most abundant carbohydrate. It provides support to plant cells and ultimately to the whole plant.

6.3- PROTEINS

Proteins are the most abundant biomolecules in cell. They are defined as the polymers of amino acids. Proteins are important for the structures of cells. They also participate in everything organisms do.

Structure of Proteins

Proteins are made up of monomers called **amino acids**. Different proteins contain different numbers of amino acids. For example, insulin protein has 51 amino acids and haemoglobin has 574 amino acids.

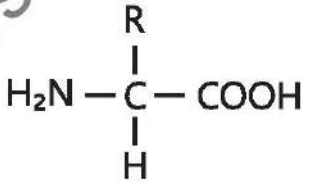
Amino acids

Amino acids are the organic molecules that join in specific number and sequence to make proteins. About 170 types of amino acids occur in organisms. However, 20 types of amino acids participate in making most of the proteins.

Essential amino acids: These are the 09 amino acids which cannot be synthesized by our body and are supplied by foods.

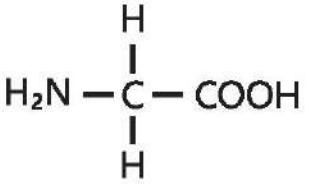
Non-essential amino acids: These are 11 amino acids that can be synthesised in our bodies.

An amino acid is an organic molecule made of an amino group (NH_2), a carboxyl group (COOH), a hydrogen group (H) and a side group (R) which are attached to a central carbon atom:

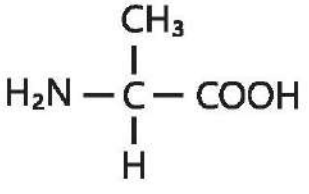


Amino acid - general structure

Different amino acids contain different side groups. For example, in amino acid glycine the side group is H and in amino acid alanine, the side group is CH_3.



Glycine



Alanine

Sources and Functions of Proteins

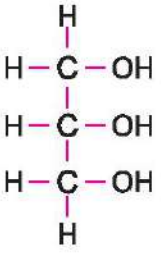
Good sources of protein include meat (mutton, beef, chicken), fish, eggs, milk, pulses, beans etc. Proteins perform various functions in our bodies, including:

- Proteins are an important part of all cell membranes.
- Some proteins e.g. collagen and keratin make almost whole structures of cartilage, hair, and nails.
- Enzymes are proteins that catalyse all biochemical reactions occurring in organisms.
- Some proteins are hormones. They regulate body processes.
- Haemoglobin protein transports oxygen in the blood.
- Actin and myosin proteins are the main components of muscle cells. They are responsible for muscular contractions.
- Fibrin is a blood clotting protein that makes blood clot to prevent the loss of blood after an injury.
- Some proteins called antibodies (part of our immune system) defend the body against harmful pathogens.

6.4- LIPIDS

Lipids are organic compounds that are insoluble in water but are soluble in organic solvents (e.g., alcohol, ether, benzene). They are composed of glycerol and fatty acids.

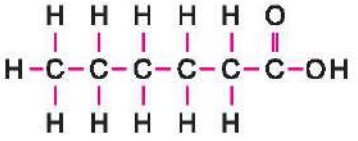
Glycerol is an alcohol having 3 carbon atoms. Each carbon has a hydroxyl group.



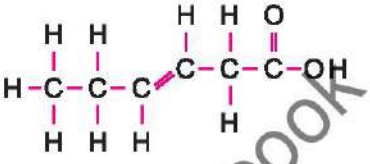
Glycerol

Fatty acids are long hydrocarbon chains with carboxyl group (COOH) at the end. There are two types of fatty acids:

- **Saturated fatty acids** have internal carbon atoms bonded with maximum number of hydrogen atoms. They do not have double bonds between carbon atoms. Saturated fatty acids are solid at room temperature.
- **Unsaturated fatty acids** have one or more double bonds between carbon atoms. They are liquid at room temperature.



Saturated fatty acid

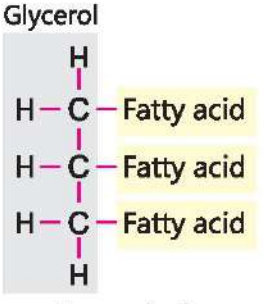


Unsaturated fatty acid

Main Groups of Lipids

1- Fats and Oils

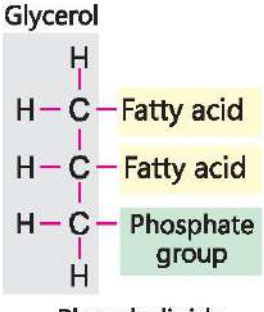
Fats and oils are the most familiar lipids. They contain one glycerol and three fatty acids. Fats contain saturated fatty acids and so are solid at room temperature e.g., animal fats. On the other hands, oils contain unsaturated fatty acids and so are liquid at room temperature e.g., plant oils such as olive oil, corn oil, and coconut oil.



Fats and oils
General structure

2- Phospholipids

These lipids make the core of all membranes. A phospholipid molecule consists of one glycerol, two fatty acids and a phosphate group.



Phospholipids
General structure

Sources and Functions of Lipids

Sources

Sources of lipids from animals are meat and dairy products, while the sources of lipids from plants are nuts, seeds, olive oil etc. Plants synthesize oils and

store them in seeds, such as sunflower oil, coconut oil, groundnut oil and corn oil.

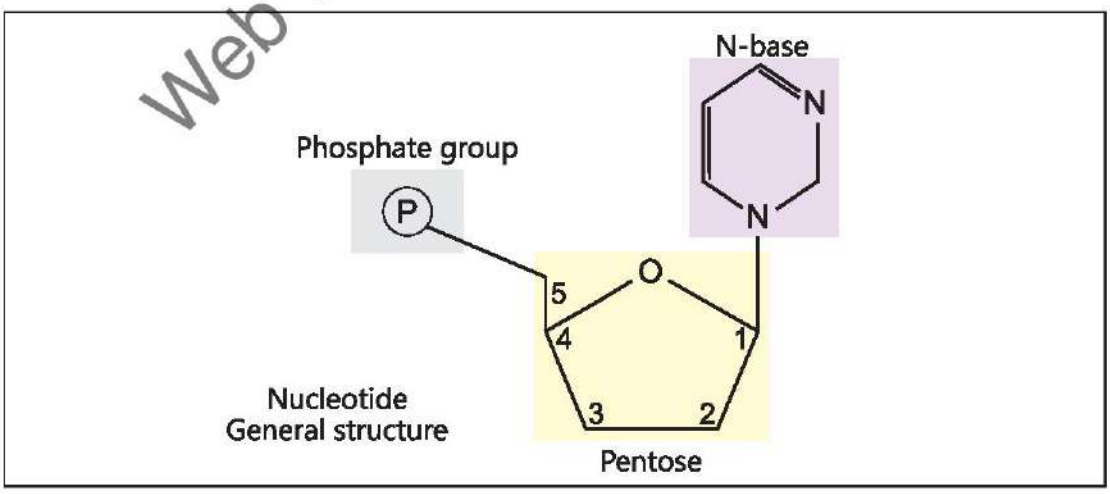
Functions

- Lipids are the most energy-rich biomolecules. They serve as a long-term energy reserve in the form of fats in adipose tissues. When the body requires energy, these stored lipids are broken down to release fatty acids and glycerol, which can be used as fuel for energy.
- Lipids are essential components of cell membranes.
- Lipids act as insulators and protect vital organs. For example, adipose tissue surrounding organs provides cushioning and heat insulation.
- Some lipids help in the synthesis of hormones. Steroid hormones are derived from a lipid i.e., cholesterol.
- Lipids help in the absorption of fat-soluble vitamins (A, D, E, and K) in the digestive system.

6.5- Nucleic Acids

Nucleic acids are the biomolecules that are composed of units called nucleotides. A nucleotide is made up of three components:

1. Pentose sugar (ribose or deoxyribose)
2. Nitrogenous base
3. Phosphate group (PO_4)



There are two types of nucleic acids:

1- Deoxyribonucleic Acid (DNA)

DNA is made of deoxyribonucleotides (de-oxy-ribo-nucleotides). In this nucleotide, the pentose sugar is deoxyribose while the nitrogenous base may be adenine (A), thymine (T), cytosine (C), or guanine (G).

In 1953, US biologist James Watson and British biologist Francis Crick proposed the double helix model of DNA. According to this model:

In 1962, James Watson and Francise Crick received Nobel prize for the discovery of the double helix structure of DNA.

- DNA is a double helix molecule. It is made of two strands of nucleotides.
- Both strands are coiled around each other.
- The nitrogenous bases of one strand make hydrogen bonds with the nitrogenous bases of the opposite strand.

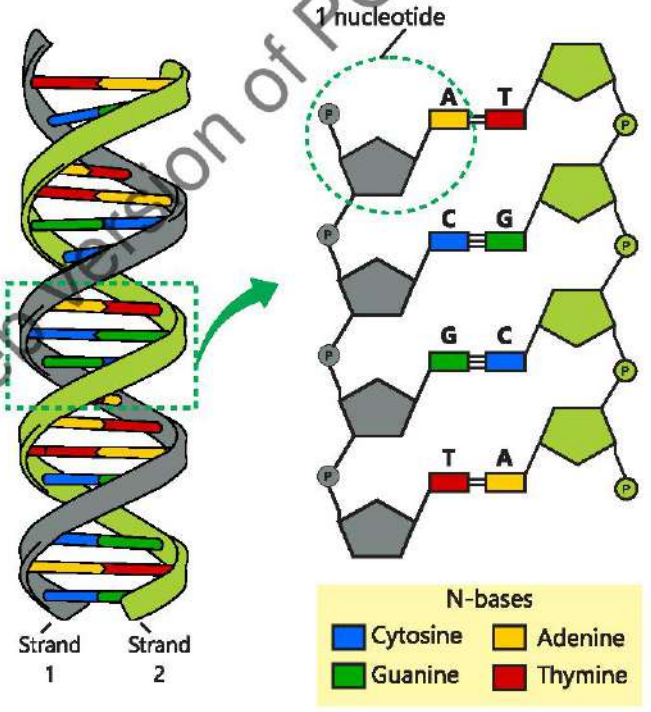


FIGURE 6.5: Double helix model of DNA

- The paring of nitrogenous bases is specific i.e., adenine of one strand forms a pair with thymine of opposing strand. Similarly, cytosine forms a pair with guanine.
- There are two hydrogen bonds between adenine and thymine and three hydrogen bonds between cytosine and guanine.

Function of DNA

DNA contains the hereditary information. This information is in the form of a sequence of nucleotides. This sequence determines the order of amino acids during protein synthesis. The segment of DNA in which the sequence of nucleotides determines the synthesis of a protein (polypeptide chain) is called a gene. During reproduction, DNA is passed from one generation to the next. In this way, DNA carries the heredity information to the next generation.

2- Ribonucleic Acid (RNA)

RNA is single-stranded. Its strand consists of ribonucleotides. A ribonucleotide contains ribose sugar instead of deoxyribose. In a ribonucleotide, the nitrogenous base may be adenine (A), uracil (U), cytosine (C), or guanine (G). There are three types of RNA:

a. Messenger RNA (mRNA): Carries the genetic information from DNA to the ribosomes during protein synthesis.

b. Transfer RNA (tRNA): Transfers specific amino acids to the ribosomes, ensuring the correct sequence during protein synthesis.

c. Ribosomal RNA (rRNA): Constitutes the structural and functional components of ribosomes, the cellular machinery for protein synthesis.

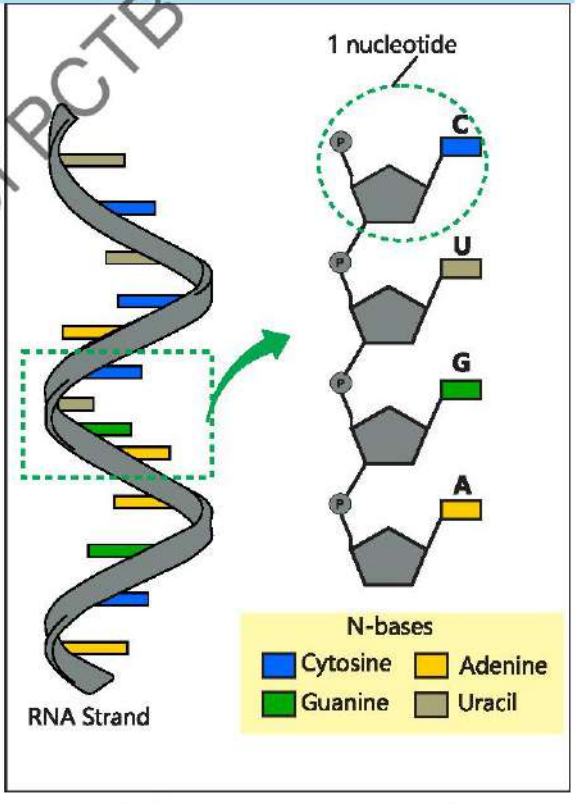


FIGURE 6.6: Structure of RNA

6.6- THE WORKING OF DNA AND RNA

The DNA molecule in a chromosome consists of thousands of nucleotides. Along the length of DNA molecule, there are specific segments called genes. Each gene consists of specific sequence of nucleotides that carries information for the synthesis of a specific protein.

During the working of a gene, the specific sequence of DNA nucleotides is copied. This copy is in the form of a molecule of messenger RNA (mRNA). The process of making mRNA copy of DNA is called **transcription**. The mRNA carries the sequence of its nucleotides to the ribosome. The ribosome reads this sequence and joins specific amino acids to form a protein. This step is known as **translation**.

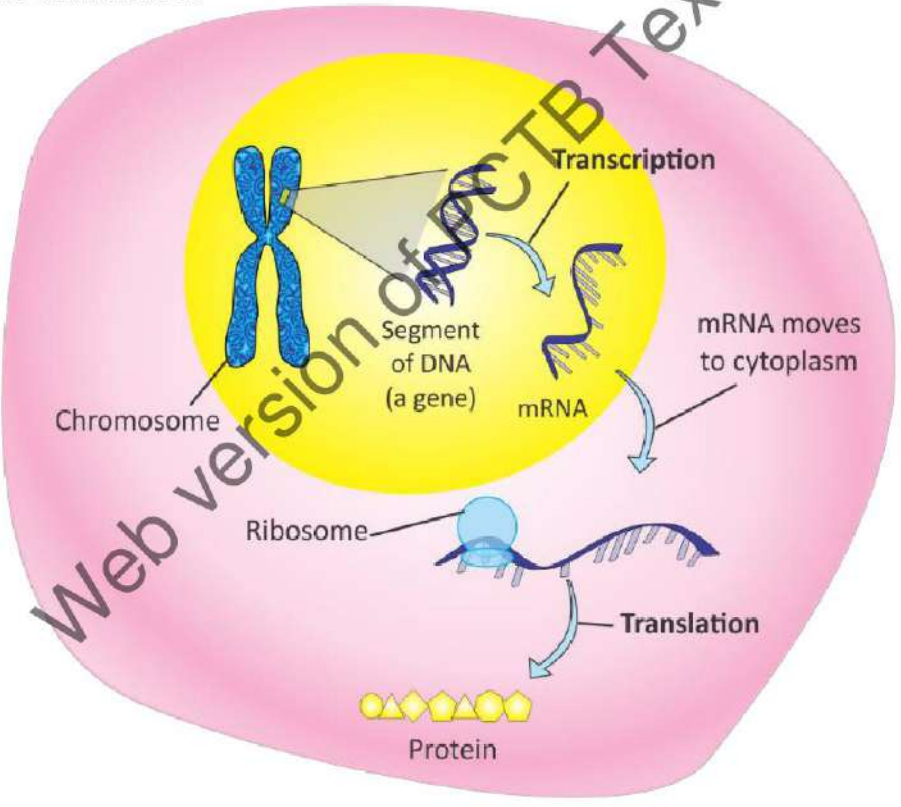


FIGURE 6.7: Working of DNA (also called the Central Dogma)

KEY POINTS

- Biochemistry is the study of the substances and chemical processes that occur within living organisms.
- Molecular biology is the study of the structure and function of the biomolecules.
- Biomolecules are the molecules produced by organisms. They include carbohydrates, lipids, proteins, and nucleic acids.
- Carbohydrates are organic compounds composed of carbon, hydrogen, and oxygen in which the ratio of H and O is 2:1 (same as in water).
- Monosaccharides are made of single sugar molecule. They are easily soluble in water and have sweet taste.
- Disaccharides are made of two monosaccharides. They are less soluble in water and are less sweet in taste.
- Polysaccharides are composed of hundreds to thousands of monosaccharides. They are insoluble in water and are tasteless.
- Starch is a storage polysaccharide found in plants. Glycogen is the animal starch mainly stored in liver and muscles.
- Cellulose is a polysaccharide found in the cell walls of plants.
- Chitin is a modified form of cellulose. It is found in the exoskeletons of crabs, lobsters and insects. It also makes the cell wall of fungi.
- Carbohydrates are the primary source of energy.
- Proteins are the most abundant macromolecules in a cell.
- Proteins are made of amino acids.
- Amino acids are the building blocks of proteins; an amino acid contains an amino group, a carboxyl group, a hydrogen group and a side group attached to a central carbon atom.
- Proteins are an important part of all cell membranes.
- Lipids are organic compounds that are insoluble in water but are soluble in organic solvents.
- Saturated fatty acids have single bond in carbon-to-carbon atoms

- Unsaturated fatty acids have one or more double bonds between carbon atoms.
- Lipids serve as a long-term energy reserve in the form of fats in adipose tissues.
- Lipids are essential components of cell membranes.
- DNA is a double-stranded molecule while RNA is a single-stranded molecule. Both DNA and RNA are composed of nucleotides.
- Each nucleotide of DNA consists of a deoxyribose sugar, a phosphate group, and one of four nitrogenous bases: adenine (A), thymine (T), cytosine (C), and guanine (G).
- Each nucleotide of RNA consists of a ribose sugar, a phosphate group, and one of four nitrogenous bases: adenine (A), Uracil (U), cytosine (C), and guanine (G).
- The copying of a specific sequence of DNA nucleotides in the form of messenger RNA (mRNA) is called transcription.
- Ribosome reads the nucleotide sequence of mRNA and joins specific amino acids according to it to form a protein. It is known as translation.

EXERCISE

A. Select the correct answers for the following questions.

1. What is the primary function of carbohydrates?
   a) Provide energy
   b) Act as enzymes
   c) Regulate processes
   d) Make membranes
2. How will you differentiate between monosaccharides and polysaccharides?
   a) Monosaccharides are single sugars.
   b) Polysaccharides are sweet in taste.

c) Monosaccharides are present in plant cell wall.
d) Polysaccharides dissolve easily.

3. What is true about cellulose?
   a) It is sweet in taste.
   b) It is digestible by human digestive system.
   c) It provides structural support in plants.
   d) It is soluble in water.
4. Which of the following proteins is involved in oxygen transport?
   a) Insulin
   b) Haemoglobin
   c) Collagen
   d) Keratin
5. Which component of an amino acid determines its unique properties?
   a) Amino group
   b) Carboxyl group
   c) R group (side group)
   d) Hydrogen group
6. Which proteins are involved in defence against pathogens?
   a) Antibodies
   b) Myosin
   c) Fibrinogen
   d) Haemoglobin
7. Which of the following are the units of most lipids?
   a) Amino acids
   b) Fatty acids and glycerol
   c) Nucleotides
   d) Simple sugars
8. How do unsaturated fatty acids differ from saturated fatty acids?
   a) They have more hydrogen atoms.
   b) They contain double bonds in their hydrocarbon chains.
   c) They are solid at room temperature.
   d) They are found only in animal fats.

9. Which of the following is NOT a function of proteins?
   a) Transport oxygen in the blood.
   b) Carry genetic information.
   c) Help in digesting food.
   d) Fight against pathogens.
10. Which components make up a nucleotide?
   a) Sugar, phosphate, nitrogenous base
   b) Amino acid, sugar, nitrogenous base
   c) Fatty acid, phosphate, nitrogenous base
   d) Protein, sugar, nitrogenous base

11. Which nitrogenous base is found in RNA but not in DNA?

a) Adenine b) Thymine

c) Uracil d) Guanine

B. Write short answers.

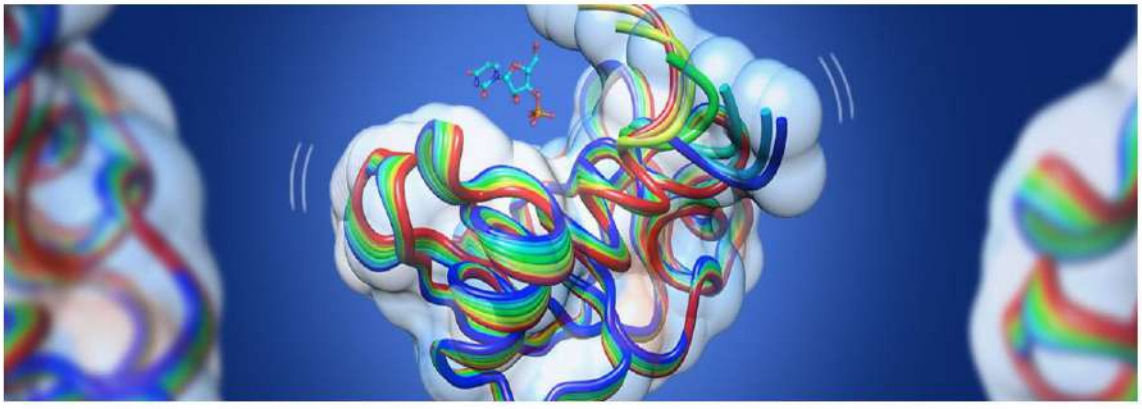
1. What are the main functions of carbohydrates in the body?
2. How do the three group of carbohydrates differ in taste?
3. Name two common monosaccharides and two disaccharides.
4. Which monosaccharides make a sucrose molecule?
5. Give an example of a storage polysaccharide in plants.
6. Define amino acid and draw its structure.
7. What are the basic components of lipids? Draw their structures.
8. What are the types of RNA? Write their functions.
9. Briefly describe the function of DNA.

C. Write answers in detail.

1. Write a comprehensive note on the structures and roles of the three classes of carbohydrates.
2. Discuss the functions of proteins.
3. What are fatty acids? Explain their types.
4. Describe the basic structure of fats and oils. Explain how lipids play role in energy storage.
5. Explain the double helix structure of DNA, and discuss the base pairing in this structure.
6. Explain how the information in DNA is converted to RNA and then to proteins.

D. Inquisitive questions.

1. Evaluate the importance of water in the functioning of biomolecules.
2. Find the amount/ percentage of carbohydrates, Proteins, Fats and water in the following food product and compare them with each other:
   Roti(40gm), Burger, Cucumber, Egg, Rice(100gm), Potato fries(100gm),Carrot



Chapter 7

ENZYMES

After studying this chapter, students will be able to:

- Define metabolism, catabolism and anabolism with examples.
- Define enzymes and describe their characteristics.
- Describe and depict the mechanism of enzyme action.
- Describe the factors which could influence enzyme activity.
- Describe competitive and non-competitive enzyme inhibition.

Enzymes are remarkable proteins which speed up biochemical reactions that would otherwise occur at very slow speed. In this chapter, we will study the unique characteristics of enzymes and uncover how they perform their work. We will also explore the various factors that influence their activity.

7.1- METABOLISM

Metabolism is the sum of all chemical reactions that occur within an organism to sustain life. There are two sub-sets of metabolism i.e., catabolism and anabolism.

Hummingbirds have one of the highest metabolic rates of any animal. They need to eat constantly to keep up their energy levels.

1. **Catabolism** involves the breakdown of complex molecules into simpler ones, releasing energy in the process. Examples include:
   - Cellular respiration in which food (glucose) molecule is broken into CO_2 and H_2O to get energy.

- Lipolysis in which lipid (fat) is broken into fatty acids and glycerol, which can be used for getting energy.

2. **Anabolism** involves building up complex molecules from simpler ones. This process consumes energy. Examples include:
   - Photosynthesis in which CO_2 and H_2O are joined to make glucose using sunlight. Oxygen is also produced as byproduct.
   - Protein synthesis in which proteins are formed by joining the amino acids.

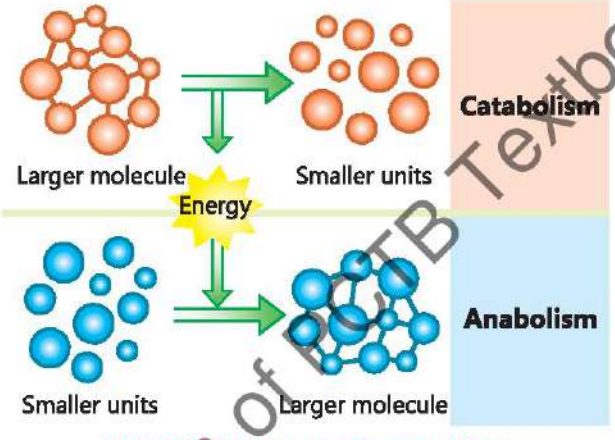


FIGURE 7.1: Types of metabolism

7.2- ENZYMES

Enzymes are biological catalysts that speed up chemical reactions in living organisms without being consumed in the process. They are primarily proteins and are highly specific to their substrates (the molecules that undergo enzyme-controlled reactions). Most enzymes can speed up reactions millions of times faster than uncatalyzed reactions.

Characteristics of Enzymes

Chemical nature of enzymes: Enzymes are predominantly proteins. Typically, they contain 100 to 1,000 amino acids.

Globular structure: Enzymes possess a three-dimensional globular structure. This structure

Some RNA molecules also act as enzymes. Such RNA is called **ribozyme**. Ribozymes are primarily found in ribosome. They are also found in specific viruses and bacteria.

allows them to form active sites that can bind specifically to substrates.

Specificity of enzymes: Enzymes are highly specific to the reactions they catalyse. They are also very specific for the nature of substrate. For example, the enzyme amylase specifically catalyses the breakdown of starch into simple sugars.

Intracellular and extracellular enzymes: Enzymes can be classified based on the location where they function. Intracellular enzymes operate within cells e.g., enzymes of cellular respiration. Extracellular enzymes are secreted outside the cells to catalyse reactions e.g., enzymes secreted by the cells of stomach walls into stomach cavity for the digestion of food.

Cofactors of enzymes: Many enzymes require additional non-protein molecules to be fully active. Such non-protein molecules are called cofactors. There are two main groups of cofactors. i.e., inorganic cofactors and organic cofactors. Inorganic cofactors include metal ions like iron and magnesium ions. The organic cofactors are of two types.

- **Prosthetic groups** tightly bind with the enzymes. Example are certain vitamins (e.g., biotin) and the haem group .
- **Coenzymes** loosely bind to the enzyme and may be released during the reaction. Examples include many vitamins and nucleotides (NAD and NADP).

Enzyme actions in complex metabolic reactions: Multiple enzymes work in a sequence to carry out a series of reactions. Each enzyme in the series catalyses a specific step. After speeding up the reaction, the product is passed on to the next enzyme for further reaction.

Use of enzymes in different industries: Enzymes have extensive applications in various industries. For example:

- **Food industry:** Enzymes that break starch into simple sugars are used in production of white bread, buns, and rolls. Enzymes are also used for the production of cheese.
- **Paper Industry:** Enzymes degrade starch to lower its viscosity that aid in making paper.

- **Biological detergent:** Protease enzymes are used for the removal of protein stains from clothes. Amylase enzymes are used in dish washing to remove resistant starch residues.
- **Fermentation industry:** Enzymes degrade starch and proteins to produce simple sugar, amino acids and peptides. These substances are used by microorganisms e.g., yeast in fermentation to produce different products of human use.

7.3- MECHANISM OF ENZYME ACTION

An enzyme has one or more pockets or clefts on its surface. These are called **active sites**. The active sites are directly involved in catalysis. Two models have been proposed to explain the mechanism of enzyme action.

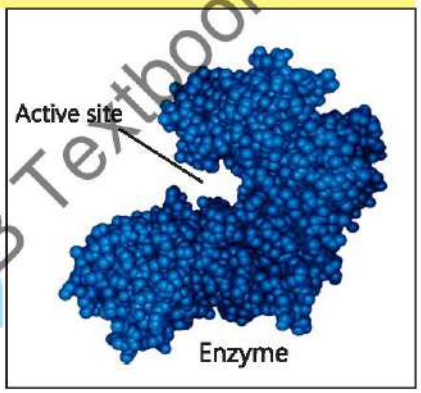


FIGURE 7.2: Active site of enzyme

1- Lock and Key Model of Enzyme Action

This model was proposed by a German chemist **Emil Fischer** in 1894. According to it, the active site of enzyme has a fixed structure. The substrate molecule fits precisely into it to form an **enzyme-substrate complex**. The enzyme catalyzes the reaction and substrate is transformed into product/s. Then, the product is released from the enzyme.

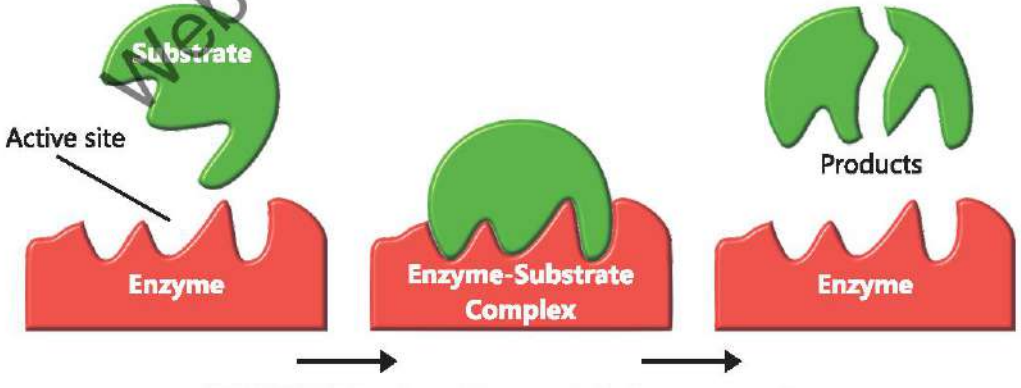


FIGURE 7.3: Lock and key model of enzyme action

2. Induced Fit Model

This model was proposed by an American biologist **Daniel Koshland** in 1958. According to this model, the active site of enzyme is not rigid. When substrate interacts with the enzyme, its active site is reshaped to perform its function.

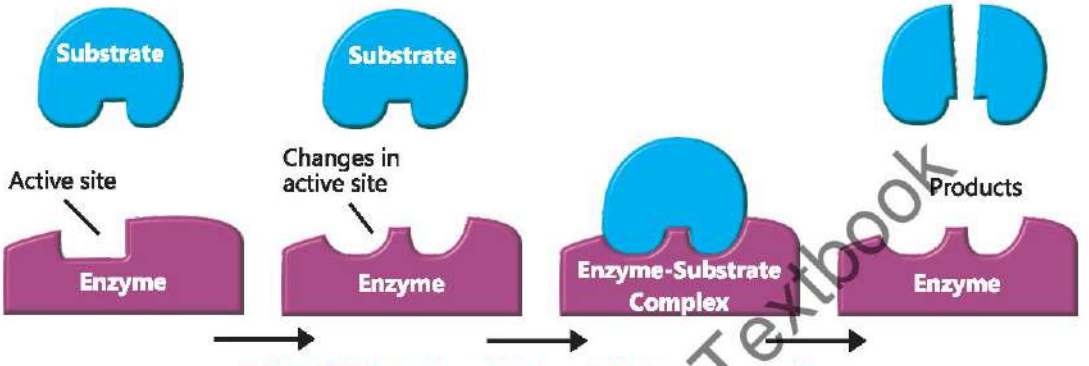


FIGURE 7.4: Induced fit model of enzyme action

7.4- Factors that Affect the Activity of Enzymes

Enzymes are sensitive to their environment. The activity of an enzyme is affected by the following factors:

1. Temperature

Each enzyme works at maximum rate at a specific temperature called optimum temperature. The optimum temperature for most of the human enzymes is 37°C. When temperature rises to a certain limit, the heat adds in the movement of molecules. So, the rate of enzyme action increases. But when temperature is raised well above the optimum temperature, heat breaks the bonds in enzyme molecule. In this way the globular structure of enzyme is lost. This is called

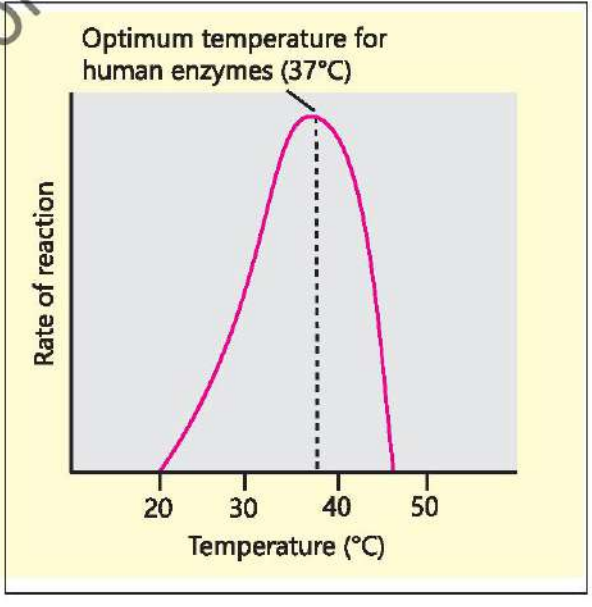


FIGURE 7.5: Effect of temperature on enzyme activity

denaturation of enzyme. It results in a rapid decrease in the rate of enzyme action.

2. pH

Enzymes are sensitive to hydrogen ion concentration (pH) of the fluid in which they work. They show maximum activity at a specific pH, called their **optimum pH**. Change in pH can affect the ionization of the amino acids at the active site of enzyme. It slows down enzyme activity or blocks it completely. Different enzymes have different optimum pH values. For example, **pepsin** in stomach works in acidic medium (pH 1.5 to 2.0) while **trypsin** in small intestine works in alkaline medium (pH 7 to 8).

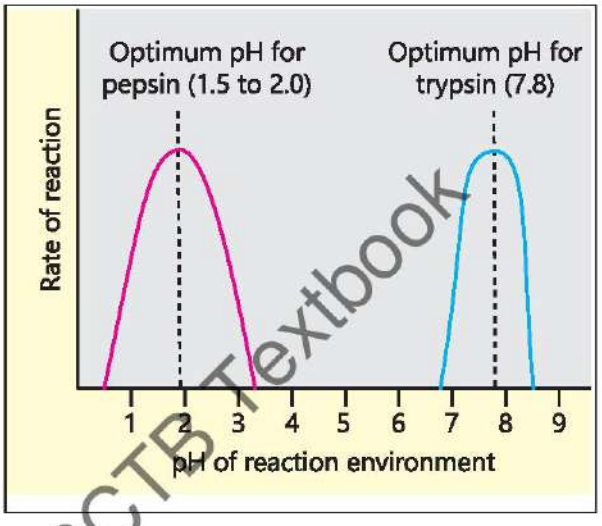


FIGURE 7.6: Effect of pH on enzyme activity

3. Substrate Concentration

An increase in substrate concentration increases the rate of reaction. At high substrate concentration, all active sites of the enzymes are occupied. In this condition, any more substrate molecules do not find free active sites. This state is called **saturation** of active sites and reaction rate does not increase.

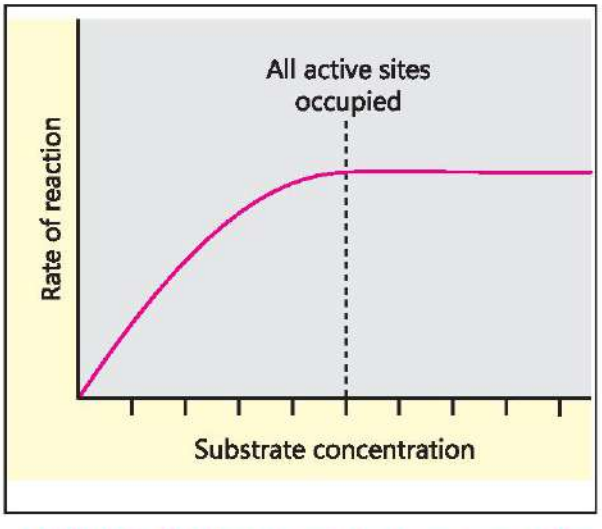


FIGURE 7.7: Effect of substrate concentration on enzyme activity

7.5- ENZYME INHIBITION

Certain substances, called enzyme inhibitors, bind to enzyme and decrease its activity. This phenomenon is known as enzyme inhibition.

1. Competitive Inhibition

Some inhibitors resemble the enzyme's substrate. They compete with the substrate to attach to the active site of enzyme. When the inhibitor is attached to the active site, it blocks it and does not allow the substrate to attach. Examples of competitive inhibitors are antibiotics. The antibiotic molecules compete with the substrates of bacterial enzymes. They attach to bacterial enzymes and inhibit them.

2. Non-Competitive Inhibition

Some enzyme inhibitors do not have similarity to the substrate. They do not attach to the active site of enzyme. Rather, they attach to some other location of enzyme. This attachment changes the overall shape of enzyme and also the shape of active site. So, this changed active site does not fit substrate and enzyme is inhibited. Examples include heavy metals like mercury and certain drugs used in cancer therapy.

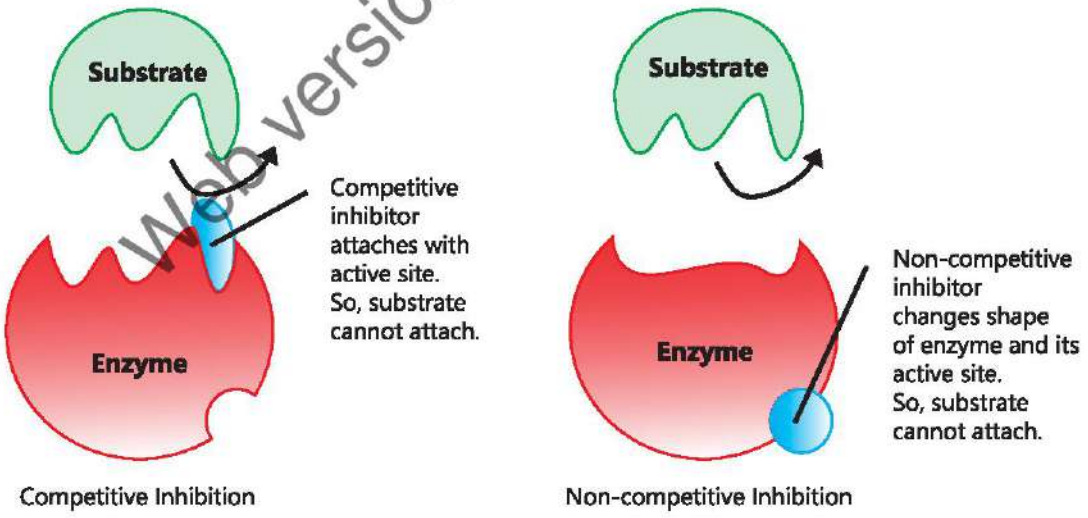


FIGURE 7.8: Types of enzyme inhibition

KEY POINTS

- The biochemical reactions occurring in living organisms are called metabolism.
- In anabolism, small molecules combine to form large molecules. In catabolism, larger molecules are broken down into smaller molecules.
- Enzymes are proteins that catalyze (i.e. speed up) biochemical reactions.
- Enzymes are highly specific to the reactions and also for the substrate.
- Intracellular enzymes operate within cells e.g., enzymes of cellular respiration.
- Extracellular enzymes are secreted outside the cells to catalyse reactions e.g., enzymes working in stomach cavity for the digestion of food.
- Cofactors are the non-protein molecules required by enzymes to be fully active.
- Inorganic cofactors include metal ions like iron and magnesium ions.
- The organic cofactors are of two types.
- Prosthetic groups are the organic cofactors which tightly bind with the enzymes e.g., certain vitamins (e.g., biotin) and the haem group .
- Coenzymes are the organic cofactors which loosely bind to the enzyme e.g., many vitamins and nucleotides (NAD and NADP).
- Enzymes work at their maximum rate at optimum temperature and pH.
- The catalytic region of enzyme molecule is known as active site.
- According to the lock and key model, the active site of enzyme has a fixed structure.
- According to induced fit model, when substrate interacts with the enzyme, active site of enzyme is reshaped to perform its function.
- Inhibitors are substances that interfere with and block an enzyme's activity.
- Competitive inhibitors resemble the substrate. They compete with the substrate for the same active site of an enzyme. Examples are antibiotics.
- A non-competitive inhibitor bind to a site on the enzyme other than the active site. Examples are heavy metals and certain drugs used in cancer therapy.

EXERCISE

A. Select the correct answers for the following questions.

1. Primarily, all enzymes are;
   a) Nucleic acids
   b) Proteins
   c) Carbohydrates
   d) Lipids
2. Which best defines an enzyme?
   a) A chemical that breaks down food.
   b) A hormone that regulates metabolism.
   c) A protein that speeds up reactions.
   d) A molecule that stores energy.
3. What can happen if an enzyme is exposed to temperature that is higher than its optimal temperature?
   a) Enzyme activity rate will increase.
   b) Enzyme's shape will change, potentially reducing its activity.
   c) Enzyme will speed up the reaction and remain stable.
   d) Enzyme will become a substrate itself.
4. Enzymes are specific in their action because:
   a) Their active sites fit specific substrates.
   b) They are always proteins.
   c) They are consumed in reactions.
   d) They work only at high temperatures.
5. Prosthetic groups are;
   a) Required by all enzymes.
   b) Proteins in nature.
   c) Loosely attached with enzymes.
   d) Tightly bound to enzyme.
6. How does increasing temperature affect enzyme activity?
   a) Increases activity to a point
   b) Always decreases activity
   c) Makes enzymes non-functional
   d) No effect on enzyme
7. How does competitive inhibitor affect enzyme action?
   a) Attaches with the substrate.
   b) Changes enzyme shape.
   c) Attaches and blocks the active site.
   d) Blocks the cofactors.
8. An enzyme works best at a pH of 7.4. It is placed in an acidic solution with a pH of 4.0. How will this affect the enzyme?
   a) The active site will be modified, reducing substrate binding.

b) The enzyme will catalyse reactions faster due to increased H ions.
c) The enzyme will gain additional active sites.
d) The substrate will become inactive in an acidic environment.

9. What is TRUE according to the induced fit model of enzyme action?
a) Enzyme's active site changes shape to bind the substrate.
b) Substrate changes shape to bind to active site.
c) No shape changes occur in active site or substrate.
d) Substrate attaches the enzyme at a site other that active site.

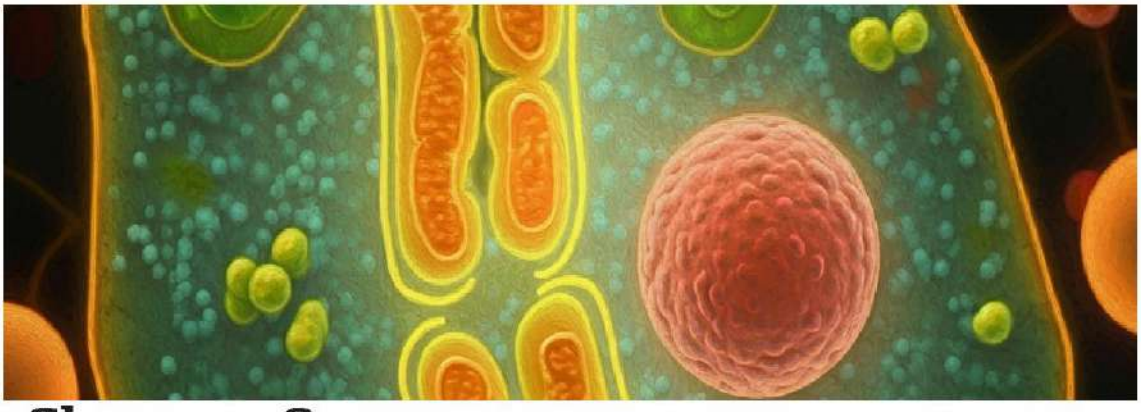
10. What is TRUE about the optimum pH values of the following enzymes of digestive system?
a) Pepsin works at low pH while trypsin works at high pH
b) Both work at high pH
c) Both work at low pH
d) Pepsin works at high pH while trypsin works at low pH

B. Write short answers.

1. Define metabolism. Differentiate between catabolism and anabolism.
2. Which type of metabolism demands input of energy? Give an example.
3. Define an enzyme. What is its role in metabolism?
4. What is the active site of enzyme? State its importance in enzyme specificity.
5. Provide an example of a specific enzyme-substrate pair.
6. What is the effect of substrate concentration on enzyme activity?
7. Provide two examples of enzymes that operate optimally at specific pH.
8. What do you mean by optimum temperature and pH?
9. Which type of enzyme inhibitors inhibit the enzymes without attaching to the active site?
10. Differentiate between competitive and non-competitive inhibition.

C. Write answers in detail.

1. Describe the characteristics of enzymes.
2. Describe how temperature extremes can inhibit enzyme activity and lead to enzyme denaturation.
3. How does pH affect enzyme activity?
4. Describe the factors that affect the activity of enzymes.
5. Compare the Lock-and-Key and Induced Fit models of enzyme action.



Chapter 8
BIOENERGETICS

After studying this chapter, students will be able to:

- Describe the importance of oxidation-reduction reactions.
- Explain ATP as a molecule that is the chief energy currency of all cells.
- Describe photosynthesis.
- State the role of chlorophyll found in chloroplast.
- State the equation (in words or symbols) for photosynthesis.
- Describe respiration.
- Describe anaerobic respiration and state its importance.
- State the equation (in words or symbols) for aerobic respiration.
- Compare aerobic and anaerobic respiration with reference to the amount of energy released.
- List ways in which respiratory energy is used in the body.
- Compare respiration and photosynthesis.

Bioenergetics is the study of how living organisms acquire, convert, store, and utilize energy to fuel their life processes. Organisms obtain energy primarily from their surroundings. Plants capture sunlight through photosynthesis, while animals and other organisms consume food. This energy is then converted into usable chemical energy, stored in molecules like ATP (adenosine triphosphate). ATP acts as a ready source of energy. Cells can use ATP whenever they need energy for processes such as growth, movement, repair, and reproduction.

Oxidation-reduction (redox) reactions are fundamental to the metabolism of organisms. In these reactions, electrons are transferred between molecules. In oxidation, molecule loses electrons and in reduction, it gains electrons. This electron flow is essential for generating energy in the form of ATP during

processes like cellular respiration and photosynthesis. **Bioenergetics** is the study of energy transformations in living organisms.

8.1- ATP: THE CELL'S ENERGY CURRENCY

Cells use a special energy currency for their reactions. This currency is a **nucleotide** called **adenosine triphosphate (ATP)**. When cells store energy, they make ATP. When cells need energy, they break ATP. ATP molecule has three subunits i.e. **adenine**, (a nitrogen containing base); **ribose** (a five-carbon sugar) and three **phosphate** groups.

In 1941, the Nobel prize winner, Fritz Lipmann proposed that ATP is the main energy-transfer molecule in the cell.

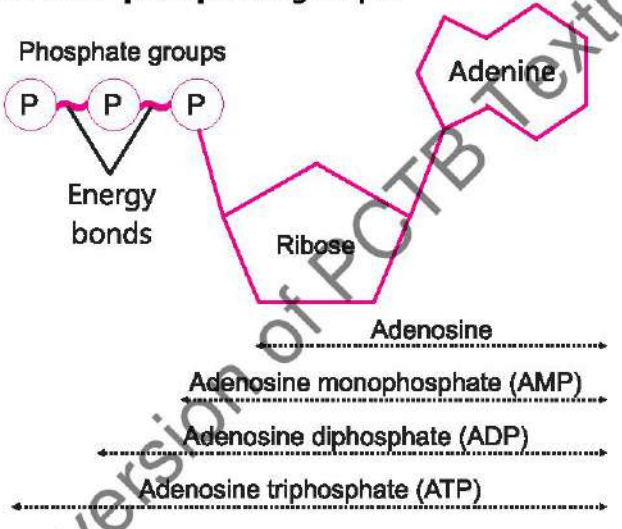


FIGURE 8.1: Molecular structure of ATP

In the molecule of ATP, the covalent bonds between **two phosphates** are high-energy bonds. When one of these bonds is broken, inorganic phosphate (Pi) separates and energy is released.

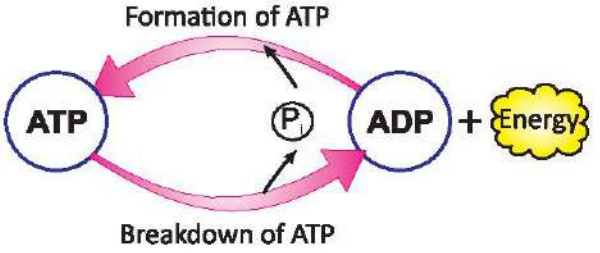


FIGURE 8.2: ATP-ADP Cycle

The breaking of one phosphate bond releases about 7.3 kcal (7,300 calories) per mole of ATP.

$$ATP + H_2O \rightarrow ADP + P_i + \text{energy (7.3 kcal/mole)}$$

In common energy reactions only the outer P-P high-energy bond breaks. When this happens, ATP becomes **ADP (adenosine diphosphate)** and one Pi is released. In some cases, ADP is further broken down to **AMP (adenosine monophosphate)** and Pi:

$$ADP + H_2O \rightarrow AMP + Pi + \text{energy (7.3 kcal/mole)}$$

Cells get energy from the oxidation of food. They store this energy by combining ADP with Pi to form ATP. So, we can summarize that ATP is made during energy-releasing processes and is broken down during energy-consuming processes. In this way ATP transfers energy between metabolic reactions.

8.2- PHOTOSYNTHESIS

Autotrophic organisms (plants, algae, some bacteria) use inorganic raw materials to prepare their organic food. The organic food is in the form of carbohydrates. The carbohydrates are used for getting energy and are also converted to other molecules like proteins, lipids etc.

Photosynthesis is the synthesis of glucose from carbon dioxide and water in the presence of sunlight (and chlorophyll), with oxygen as a by-product. It is the most important metabolic reaction and all life depends on it. A simple general equation for photosynthesis is as follows;

$$6\,CO_2 + 12\,H_2O + \text{photons} \rightarrow C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O$$

carbon dioxide + water + light energy → glucose + oxygen + water

Mechanism of Photosynthesis

Photosynthesis occurs in two phases i.e. light reactions and dark reactions. Light reactions take place on the thylakoid membranes of chloroplasts. Dark reactions take place in the stroma of the chloroplasts.

1- Light Reactions

During light reaction, light energy is used to make high-energy molecules (ATP and NADPH). Following are the key events of light reactions:

Nicotinamide adenine dinucleotide (NAD):
It is a coenzyme. One form of this coenzyme also carries phosphate. It is called NADP.

- When chlorophyll absorbs light, two of its electrons become high-energy electrons. These high energy electrons are released from **chlorophyll**.
- The high energy electrons are passed to an **electron transport chain**. In this chain, when electrons pass from higher to lower energy level, they release energy which is used to produce **ATP.**
- Light also breaks water molecule. **Oxygen** is released while hydrogen atoms give electrons to chlorophyll and become hydrogen ions.
- The electrons of chlorophyll, after the production of ATP, and the hydrogen ions of water are used to reduce a NADP into **NADPH** (Nicotinamide Adenine Dinucleotide Phosphate – reduced)..

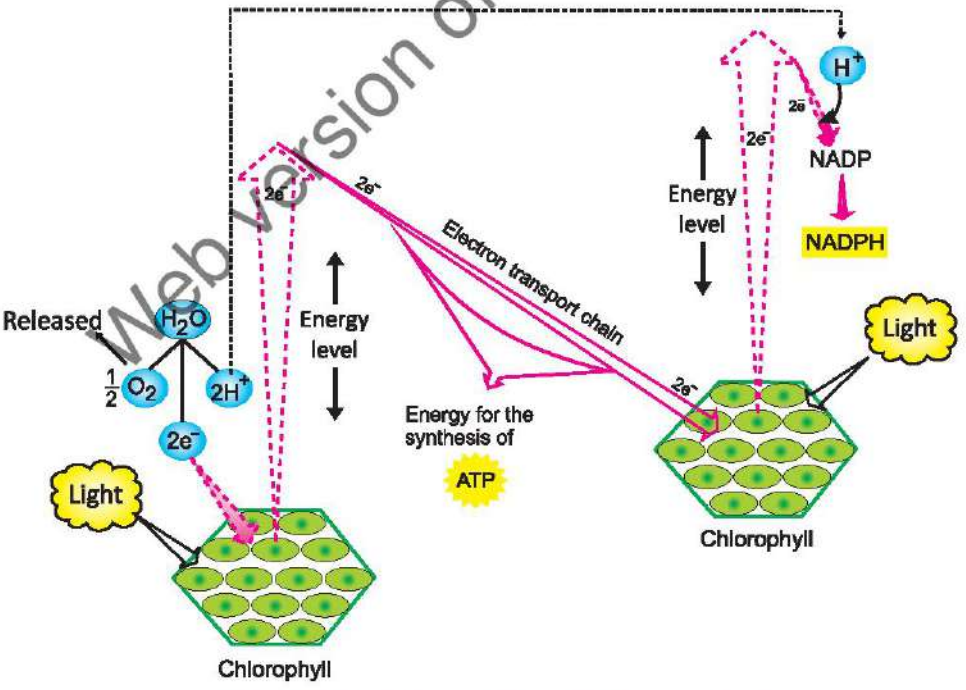


FIGURE 8.3: Light reactions of photosynthesis

2- Dark Reactions (Calvin Cycle)

During this phase, carbon dioxide is reduced to make glucose. The details of dark reactions were discovered by Melvin Calvin. Following is the summary of dark reactions:

- CO_2 molecules combine with 5-carbon compounds to form 6-carbon compounds. This 6-carbon compound is unstable and splits into two 3-carbon compounds.
- The 3-carbon compounds are reduced to 3-carbon carbohydrates by using ATP and hydrogen from NADPH (produced during light reactions). The 3-carbon carbohydrates are used to make glucose.
- The 3-carbon carbohydrates are also used to regenerate the original 5-carbon compounds. This step also utilizes ATP.

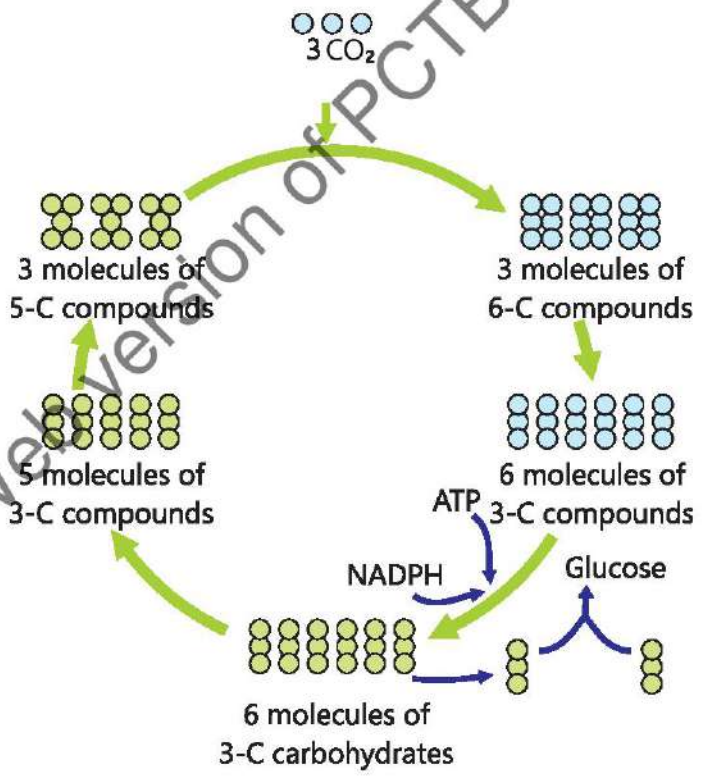


FIGURE 8.4: Dark reactions of photosynthesis

Role of Chlorophyll in Photosynthesis

The thylakoid membranes of chloroplasts contain pigments. **Chlorophyll-a** is the main pigment. Others are called **accessory pigments** and include chlorophyll-b and carotenoids.

Pigments absorb sunlight and convert it into chemical energy for photosynthesis. Only about 01% of the light falling on the leaf surface is absorbed, the rest is reflected or transmitted. The blue and red lights carry out more photosynthesis. Different pigments absorb different wavelengths of light. Chlorophyll-a absorbs light of **blue and red** wavelengths. The wavelengths which are not absorbed by chlorophyll-a are absorbed by accessory pigments.

Pigments are the substances that absorb visible light. Different pigments absorb light of different wavelengths (colours).

When a pigment absorbs light, reactions occur in it and its electrons are released. The high energy electrons pass through electron transport chain and their energy is used for the formation of ATP and for reducing NADP to NADPH.

8.3- Cellular Respiration

Organisms get energy by breaking the C-H bonds of food. For this purpose, they carry out the **oxidation** of food inside cells. This oxidation of food is called **cellular respiration.** The most common food used by cells to get energy is glucose.

Aerobic and Anaerobic Respiration

1- Aerobic respiration

Cellular respiration occurring in the presence of oxygen is called **aerobic respiration**. It is the complete oxidation of glucose with maximum release of energy. In its first phase, a molecule of glucose (6-C) is broken down into two molecules of pyruvic acid (3-C). In the second phase, the molecules of pyruvic acid are completely oxidized (all C-H bonds are broken) and all energy is released.

In anaerobic process, many C-H bonds of food are left unbroken.

2- Anaerobic Respiration (Fermentation)

Cellular respiration that occurs in the absence of oxygen is called **anaerobic respiration**. In anaerobic respiration, glucose is incompletely oxidized with less amount of energy released. Its first phase is exactly similar to that of aerobic respiration. A molecule of glucose is broken down into two molecules of pyruvic acid. In the second phase, pyruvic acid may be treated in two ways:

A. Alcoholic Fermentation:

During anaerobic respiration in bacteria and yeast etc. pyruvic acid is further broken down into alcohol (C_2H_5OH) and CO_2. This type of anaerobic respiration is called alcoholic fermentation.

Yeast and bacteria can ferment sugars of berries to alcohol. Birds eating these berries can become quite drunk, as is obvious from their flight pattern.

$$2(C_3H_4O_3) \longrightarrow 2(C_2H_5OH) + 2CO_2$$

Pyruvic acid — Ethyl Alcohol

B. Lactic Acid Fermentation:

During anaerobic respiration in the skeletal muscles of humans and other animals, pyruvic acid is converted into lactic acid ($C_2H_6O_3$). This type of anaerobic respiration is called lactic acid fermentation.

$$2(C_3H_4O_3) + 4H \longrightarrow 2(C_3H_6O_3)$$

Pyruvic acid — Lactic acid

Importance of Fermentation

The environment of Earth did not have free oxygen (O_2) in the early phases of life. The early organisms respired anaerobically and got energy for their life. Even today, some organisms including some bacteria and some fungi get energy from anaerobic respiration and are called anaerobes. When skeletal muscles of humans work hard (during exercise etc.) but oxygen supply is not sufficient to fulfil the demand, the skeletal muscles carry out anaerobic respiration to get energy.

Scientists have used fermentation in fungi and bacteria for making useful products for mankind. For examples, the fermentation in bacteria is used for making cheese and yogurt. Fermentation in yeasts is used in brewing and

baking industries. Similarly, the soy sauce is made through the fermentation by a fungus.

Mechanism of Cellular Respiration

For the study of all the reactions of cellular respiration, we will go into the mechanism of aerobic respiration. There are three main steps of aerobic respiration.

1- Glycolysis

In the first step, the glucose (6C) molecule is broken. It results in two molecules of pyruvic acid (3C), with two ATPs and two NADH. This process is called **glycolysis** and it occurs in cytoplasm. Oxygen is not required for glycolysis. That is why, it also occurs in anaerobic respiration.

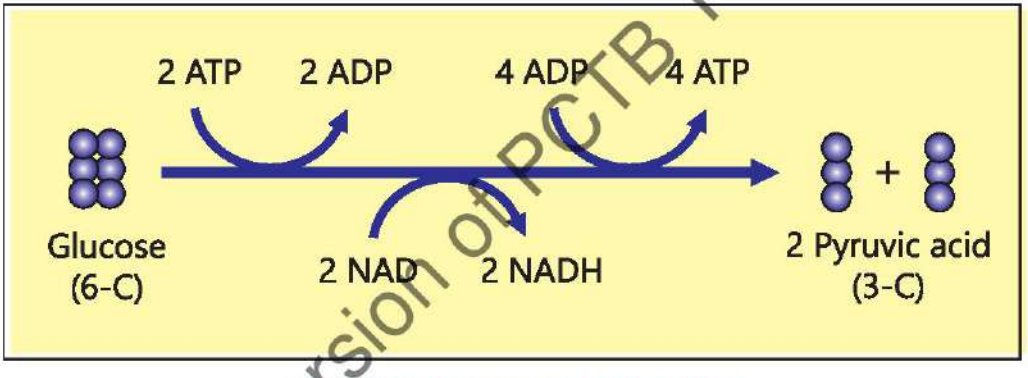


FIGURE 8.5: Summary of Glycolysis

2- Krebs Cycle

When oxygen is available, the molecules of pyruvic acid move from cytoplasm to the matrix of mitochondria. Here, a series of reaction called Krebs cycle (discovered by a British scientist Sir Hans Krebs) occurs. Before Krebs cycle, each pyruvic acid is converted into **acetyl coenzyme-A**, carbon dioxide and NADH.

In Krebs cycle, the acetyl coenzyme-A is completely oxidized to carbon dioxide. It results in the formation of ATP and energy-rich compounds i.e. NADH and $FADH_2$ (Flavin Adenine Dinucleotide – reduced).

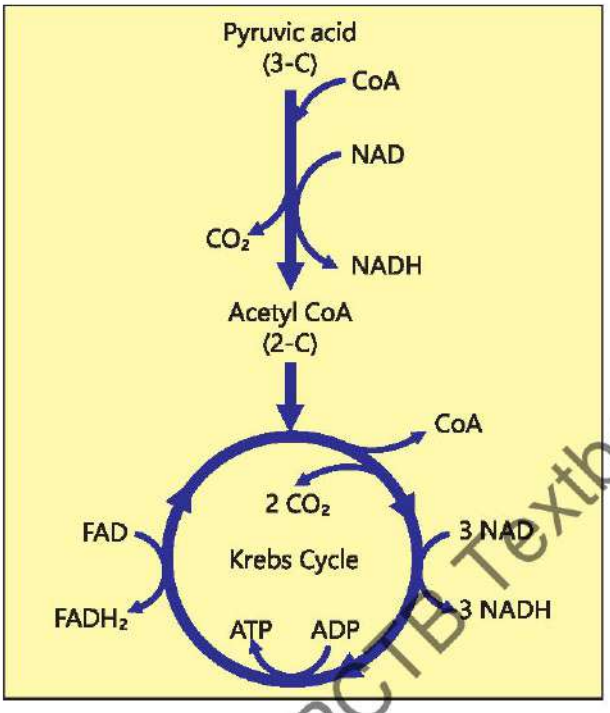


FIGURE 8.6: Summary of Krebs cycle

3- Electron Transport Chain

This step occurs on the inner membranes of mitochondria. During it, NADH and $FADH_2$ change back to NAD and FAD by releasing electrons and hydrogen ions. The released electrons pass through an electron transport chain and release energy. This energy is used to make ATP. At the end of chain, electrons and hydrogen ions combine with oxygen and form water.

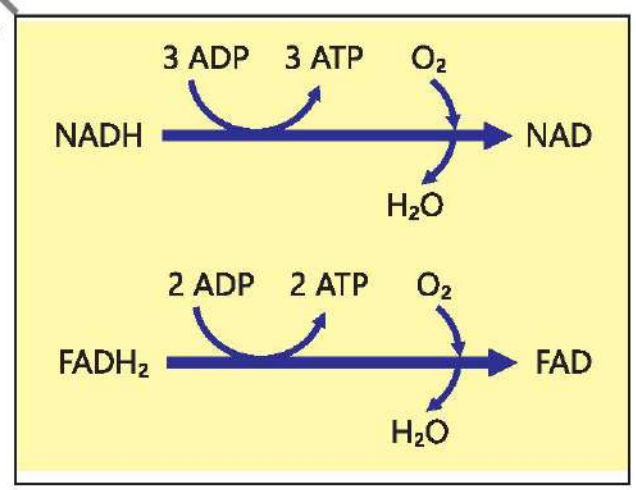


FIGURE 8.7: Electron transport chain

Use of Respiratory Energy in Body

Respiratory energy (ATP) produced during cellular respiration is used in various ways:

1. Muscle contractions and movement
2. Active transport of substances
3. Synthesis of biomolecules
4. Replication of DNA and mitosis
5. Transmission of nerve impulse
6. Maintenance of body temperature
7. Break down and elimination of toxins from the body.

Table: Difference between aerobic and anaerobic respiration

	Aerobic Respiration	Anaerobic Respiration
Presence of Oxygen	Yes	No
Number of ATP as net profit	36	02
Final products	CO_2, H_2O	Lactic acid or Ethanol + CO_2
occurrence	Cytoplasm and Mitochondria	Cytoplasm
Importance	Major source of energy for most organisms	• Source of energy for anaerobic organisms • Source of energy for aerobic organisms in short supply of O_2 • Source of useful products (ethanol, cheese etc.)

Table: Difference between photosynthesis and respiration		
Characteristics	**Photosynthesis**	**Respiration**
Type of metabolism	Anabolic process	Catabolic process
Energy investment / production	Energy is stored in the form of bond energy	Bond energy of food is transformed into ATP
Organisms capable of performing this process	Some bacteria, all algae, and all plants	All organisms
Site of occurrence	Chloroplasts In green parts only	In cytoplasm and mitochondria In all cells
Time of occurrence	In daytime only, in the presence of light	All the time

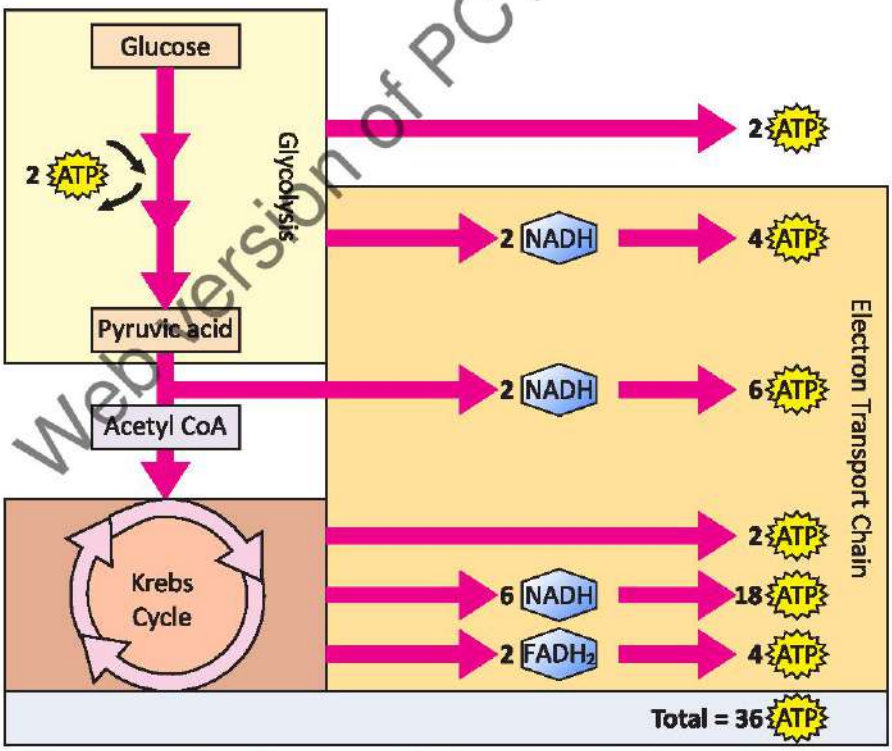


FIGURE 8.8: An overview of number of ATPs reduced by the aerobic oxidation of glucose

KEY POINTS

- In oxidation-reduction (redox) reactions, electrons are transferred between molecules.
- In oxidation, molecule loses electrons.
- In reduction, it gains electrons.
- Electron flow (oxidation-reduction) is essential for generating energy.
- ATP is the energy currency of the cells.
- In photosynthesis, water and carbon dioxide combine in the presence of light and chlorophyll and carbohydrates and oxygen are produced.
- During light reactions of photosynthesis chlorophyll captures sunlight and makes ATP.
- During dark reactions carbon dioxide is reduced to make glucose.
- Anaerobic respiration is the incomplete oxidation of glucose in the absence of oxygen while aerobic respiration is the complete oxidation of glucose in the presence of oxygen.
- During glycolysis, glucose is broken down into two molecules of pyruvic acid.
- During Krebs cycle, pyruvic acid molecule is completely broken down into hydrogen ions, high energy electrons and carbon dioxide.
- During electron transport chain, electrons travel on a series of electron carriers and emit energy, which is utilized to convert ADP into ATP.

EXERCISE

A. Select the correct answers for the following questions.

1. When we get energy from ATP, which bonds are broken?
   a) P-P bonds
   b) C-H bonds
   c) C-N bonds
   d) C-O bonds
2. Light reactions of photosynthesis occur in;
   a) Plasma membrane of cell
   b) Cytoplasm of cell
   c) Stroma of chloroplasts
   d) Thylakoids of chloroplasts
3. Which type of chlorophyll is most common in plants?
   a) Chlorophyll a
   b) Chlorophyll b
   c) Chlorophyll c
   d) Chlorophyll d
4. Which wavelengths of light are absorbed to maximum by chlorophylls?
   a) Green and blue
   b) Green and red
   c) Red and blue
   d) Only green
5. When yeast ferments glucose, the products are;
   a) Alcohol and CO_2
   b) Alcohol and water
   c) Lactic acid
   d) CO_2 and H_2O
6. Where do the dark reactions of photosynthesis occur?
   a) Stroma of chloroplast
   b) Thylakoids of chloroplast
   c) Outer membrane
   d) Cytoplasm
7. Which molecule donates electrons in the light-dependent reactions of photosynthesis?
   a) NADPH
   b) Water
   c) Oxygen
   d) Carbon dioxide
8. Which process in aerobic respiration produces the most ATP?
   a) Glycolysis
   b) Krebs cycle
   c) Electron transport chain
   d) Fermentation
9. How many ATP molecules are the net profit from one glucose molecule during anaerobic respiration?
   a) 2
   b) 4
   c) 12
   d) 36

10. What is a common byproduct of anaerobic respiration in animal cells?

a) Oxygen b) Water

c) Lactic acid d) Carbon dioxide

B. Write short answers.

1. Write the importance of oxidation-reduction reactions.
2. What do ATP and ADP mean? What are the roles of these molecules for the cellular metabolism?
3. Write down the word equation for photosynthesis.
4. Why is chlorophyll important for photosynthesis?
5. How is oxygen produced during photosynthesis?
6. Which organisms carry out photosynthesis? Which cell organelle is responsible for the absorption of light for photosynthesis?
7. State the main purpose of cellular respiration?
8. State the equation (in words or symbols) for aerobic respiration.
9. Write a brief note on the role of oxygen in aerobic respiration.
10. Define anaerobic and aerobic respiration.
11. What are the end products of anaerobic respiration in animals and yeast?
12. How do muscles respond to oxygen deficiency during intense exercise?
13. List ways in which respiratory energy is used in the body.

C. Write answers in detail.

1. Explain ATP as a molecule that is the chief energy currency of all cells.
2. Outline the processes involved in photosynthesis?
3. Write a note on the intake of carbon dioxide and water by plants
4. Explain the types and importance of anaerobic respiration.
5. Outline the mechanism of aerobic respiration.
6. Compare the processes of respiration and photosynthesis.

D. Inquisitive questions.

1. How does the structure of ATP enable it to store and release energy efficiently?

Chapter 9
PLANT PHYSIOLOGY

After studying this chapter, students will be able to:

- Define mineral nutrition in plants.
- Categorize minerals nutrients of plants into macronutrients and micronutrients.
- State that nitrogen is important in protein synthesis and magnesium for chlorophyll formation.
- Conceptualize transport and its needs.
- Explain the internal structure of root and root hair.
- Describe how roots take up water and mineral salts by active and passive absorption.
- Describe transpiration and relate this process with cell surface and stomatal opening and closing.
- Describe temperature, wind and humidity as the factors affecting the rate of transpiration.
- Describe the mechanism of transport of water and salt in plants.
- Explain the mechanism of food translocation by the theory of Pressure Flow Mechanism.
- Describe the process of gaseous exchange in plants
- Describe the mechanisms/adaptations in plants for excretion of wastes.
- Explain osmotic adjustments in plants.

Plants exhibit remarkable efficiency in carrying out essential life processes. This chapter will explore the world of plant physiology. We will study the mechanisms that enable plants to nourish themselves, transport water and nutrients, exchange gases with the environment, and maintain a stable internal environment.

Autotrophic organisms obtain water, carbon dioxide and minerals from their environment and prepare their food e.g., some bacteria, all algae, and all plants.

Heterotrophic organisms obtain their food from other organisms e.g., most bacteria, and all protozoans, fungi and animals.

9.1- NUTRITION IN PLANTS

Nutrition means the processes in which food is prepared or obtained and converted into body substances for growth and energy. **Nutrients** are the substances required by organism for energy, growth, repair, and maintenance.

Mineral Nutrition in Plants

We know that plants get their food from a process called photosynthesis. They use sunlight to turn carbon dioxide and water into sugar. But for the synthesis of other biomolecules, they need other materials from soil. Such materials are called mineral nutrients. These are special chemical elements absorbed from soil that are essential for the plants to grow. The minerals which are required in larger quantities are called **macronutrients** e.g. carbon, hydrogen, oxygen, phosphorus, potassium, nitrogen, sulphur, calcium, and magnesium. While, the minerals which are required in lower quantities are called **micronutrients** e.g. iron, molybdenum, boron, copper, manganese, zinc, chlorine, and nickel.

Following table describes the roles of important macro and micronutrients in plants.

Table: Role of Mineral Nutrients in Plant Life	
Macronutrients	**Role in Plant Life**
Carbon	Major component of all biomolecules
Hydrogen	Major component of all biomolecules
Oxygen	Major component of biomolecules, necessary for cellular respiration
Phosphorus	Component of ATP, nucleic acids, and coenzymes, necessary for seed germination, photosynthesis etc.
Potassium	Regulates the opening and closing of the stoma
Nitrogen	Component of proteins, chlorophyll and enzymes
Sulphur	Component of proteins, vitamins and enzymes
Calcium	Activates enzymes, is a structural component of cell walls, influences water movement in cells
Magnesium	Component of chlorophyll, activates many enzymes

Micronutrients	Role in Plant Life
Iron	Necessary for photosynthesis, activates many enzymes
Molybdenum	Component of the enzyme that coverts nitrates to ammonia
Boron	For sugar transport, cell division, and certain enzymes
Copper	Component of several enzymes
Manganese	Involved in the activities of enzymes of photosynthesis and respiration
Zinc	Required in a large number of enzymes
Chlorine	Involved in osmosis of water
Nickel	Required in a nitrogen metabolism

Roles of Nitrogen and Magnesium

Nitrogen is a necessary part of all proteins, enzymes and nucleic acids. It is also a part of chlorophyll. Nitrogen helps plants for rapid growth, increasing seed and fruit production and improving the quality of leaf. Plant roots absorb nitrogen in the form of **nitrates**. Nitrogen deficiency slows down the growth of plant. It also results in insufficient production of chlorophyll and so leaves begin to turn yellow. It is called chlorosis.

Carnivorous plants trap and digest small animals. Such plants fulfil their needs of nitrogen from the prey animals.

Magnesium is part of the chlorophyll. It also activates many plant enzymes needed for growth. It also helps in fruit formation and germination of seeds. Plant roots absorb Magnesium in ionic form (Mg^{2+}). If sufficient amounts of magnesium are not available, plants begin to break the chlorophyll in leaves. This causes the yellowing of leaves i.e., chlorosis. After prolonged magnesium deficiency leaves may also drop.

When a plant faces N or Mg deficiency, it transports these elements from older to younger leaves. So, the yellowing of leaves is seen in old leaves first. If deficiency continues, this symptom progresses to the young leaves.

FIGURE 9.1: (a) Chlorosis due to Nitrogen deficiency, (b) Chlorosis due to magnesium deficiency

9.2- TRANSPORT IN PLANTS

Transport means the movement of substances such as water, nutrients, hormones, and waste products within an organism. This movement is essential for cellular functions, growth, and responses to environmental changes.

Plants get water and mineral nutrients (salts) from the soil. These materials are transported to the aerial parts of the body. Similarly, the food prepared by leaves is transported to other parts of the body. In all land plants (except mosses and liverworts), the transport of water, salts and food is carried out by xylem and phloem tissues. **Xylem** is responsible for the transport of water and salts while **phloem** is responsible for the transport of food. Before studying the mechanism of transport of water and salts in plants, let us see how plants absorb water and salts from the soil.

Recalling

- **Passive Transport:** It is the movement of ions or molecules across cell membrane from a region of higher concentration to a region of lower concentration. This movement does not require energy. Diffusion and osmosis are examples of passive transport.
- **Active Transport:** It is the movement of ions or molecules across cell membrane from a region of lower concentration to a region of higher concentration, using energy.
- **Osmosis:** It is the movement of water molecules through a semi-permeable membrane from a region of lower solute concentration to a region of higher solute concentration. This movement does not require energy.

Internal Structure of Root and Uptake of Water and Salts

We know that roots are the organs which absorb water and salts from the soil. The internal structure of a root shows the following features that help the roots to perform this function.

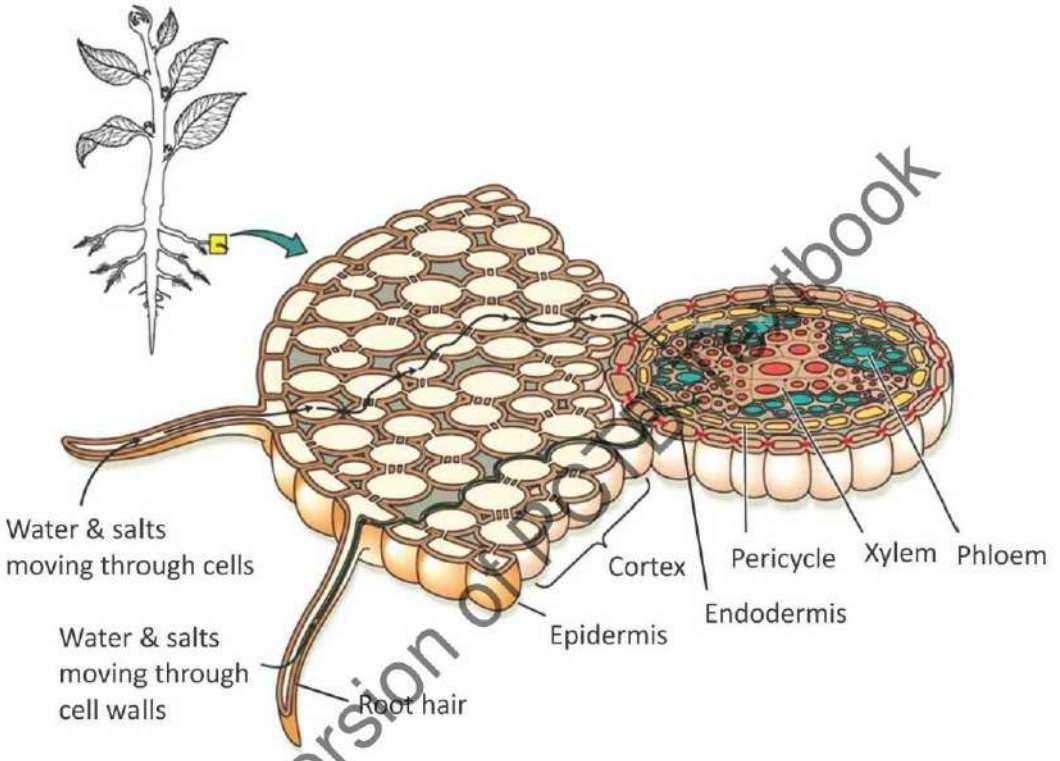


FIGURE 9.2: Uptake of water and salts by root

Epidermis and Root Hairs: The outermost covering of the root i.e. epidermis is a single layer of cells. Many cells of epidermis have tiny hair-like extensions into the spaces among soil particles. These extensions called root hairs are in direct contact with soil water. Root hairs have large surface area. The soil water has a lower concentration of salts as compared to root hairs. Root hairs take in more salts by **active transport**. Due to the difference in the concentration of salts in soil and root hair, water moves by **osmosis** (passive transport) from soil to the root hairs. From root hairs, the water with dissolved salts moves to the other cells of epidermis.

Cortex: It is broad zone of cells just inside the epidermis. Water moves from epidermis to cortex.

Endodermis: It is the innermost boundary of cortex that receive water from cortex.

Pericycle: It is a narrow layer of cells present on the inner side of endodermis.

Inside the root, water and salts take two pathways to reach the center.
(i)- through the cells
(ii)- through cell walls and intercellular spaces.

Vascular tissues: Xylem and phloem (collectively called vascular bundle) are present in the innermost region of the root. They are in the form of a pipe which is connected to the similar pipe in the stem. Water from pericycle moves into the xylem of root from where it will be transported to the xylem of the stem.

9.3- TRANSPIRATION

The loss of water in the form of vapours from plant surface is called transpiration. This loss may occur through **stomata** in leaves, through the cuticle present on leaf epidermis, or through special openings called **lenticels** present in the stems of some plants.

Most of the transpiration occurs through stomata and is called **stomatal transpiration**. In leaves, water moves from the xylem into the cell walls of mesophyll cells. From the moist walls of mesophyll cells, water evaporates into the air spaces of the leaf. These water vapours then move towards the stomata and then pass to the outside air.

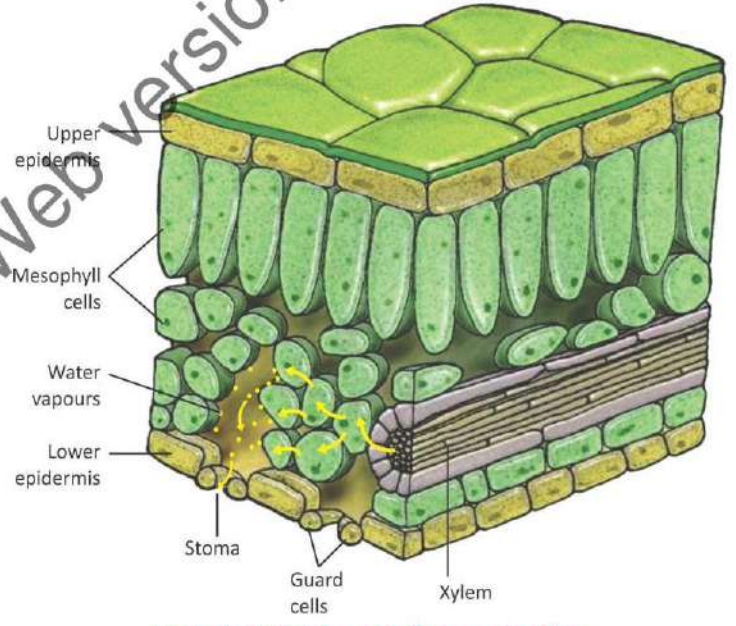


FIGURE 9.3: Events of transpiration

Mechanism of the opening and Closing of Stomata

Stomata open and close because of changes in the turgor pressure of their guard cells. The sausage-shaped guard cells are the only epidermal cells which contain **chloroplasts**. Their cell wall is thicker on the inside and thinner elsewhere. When guard cells become turgid, they become bean-shaped. In this condition, the inner sides of cell walls of both guard cells move away from each other. So, the stoma between them opens.

Transpiration is a necessary evil. Although transpiration is the loss of water from plant but, yet it creates a pull on the water columns in the xylem tissue of leaves, stem and root. This pull is responsible for the transport of water and salts from root to leaves.

Events during daytime: The guard cells take in potassium ions from the surrounding cells by active transport. As a result, the solute concentration of guard cells increases as compared to the other cells of epidermis. So, water moves from epidermal cells to guard cells by osmosis. The guard cells become turgid and their inner sides move away from each other. In this way, the stoma between them opens. The solute concentration remains high in guard cells because they are do photosynthesis and prepare glucose in them. So, water stays in them and they remain turgid.

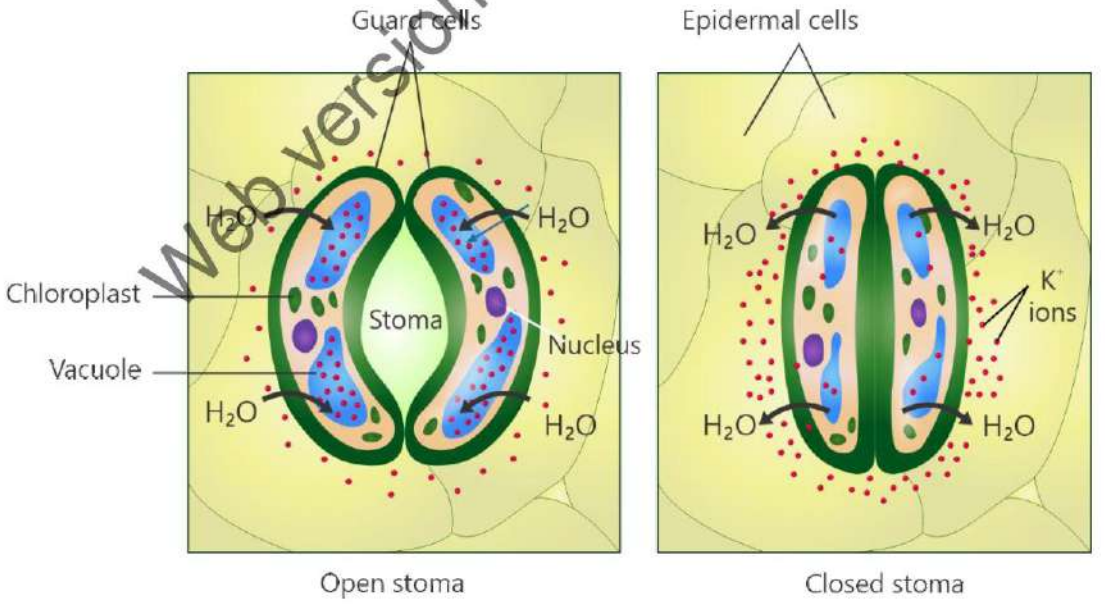


FIGURE 9.4: Opening and closing of stoma

Events during evening: At evening, the glucose concentration falls in guard cells and potassium ions also move back to epidermal cells. As a result, water moves out from guard cells and they lose turgor. Their inner sides touch each other and the stoma closes.

Factors Affecting the Rate of Transpiration

Transpiration is affected by several factors. For example:

- **Temperature:** Increase in temperature results in an increase in the rate of transpiration. It is due to the fact that at higher temperature, water evaporates more quickly.
- **Wind:** Wind speeds up transpiration by carrying away humid air surrounding the leaves, allowing for more water to evaporate.
- **Humidity:** The higher is humidity (the percentage of water vapour in the atmosphere); the lower is the rate of transpiration.
- **Surface area and distribution of stomata:** Leaves with more surface area transpire more than the leaves with narrow blades. In most plants the number of stomata on the lower leaf surface is greater than on the upper surface. Therefore, the rate of transpiration from the lower surface is greater than from the upper surface.

9.4- Transport of Water in Plants

Roots cannot push the absorbed water to the leaves of the plant. Instead, the leaves apply a pulling force on water present in roots. The pulling force in leaves is created by the transpiration of water from their surfaces. Therefore, it is called **transpirational pull**.

When mesophyll cells of leaf lose water, more water enters in them from xylem vessels. Inside xylem vessels, there is a continuous water column. This water column extends from leaves to stem and to the roots. The continuous water column is created due to three reasons: (i) the forces of attraction among water molecules, (ii) the narrow diameter of xylem vessels, and (iii) the force by which water molecules are adhered to the walls of xylem vessels.

When one water molecule moves up by the xylem of the leaf, it produces a tension on the entire water column in the xylem of leaves, stem and root. As a result, the entire water column is pulled upwards.

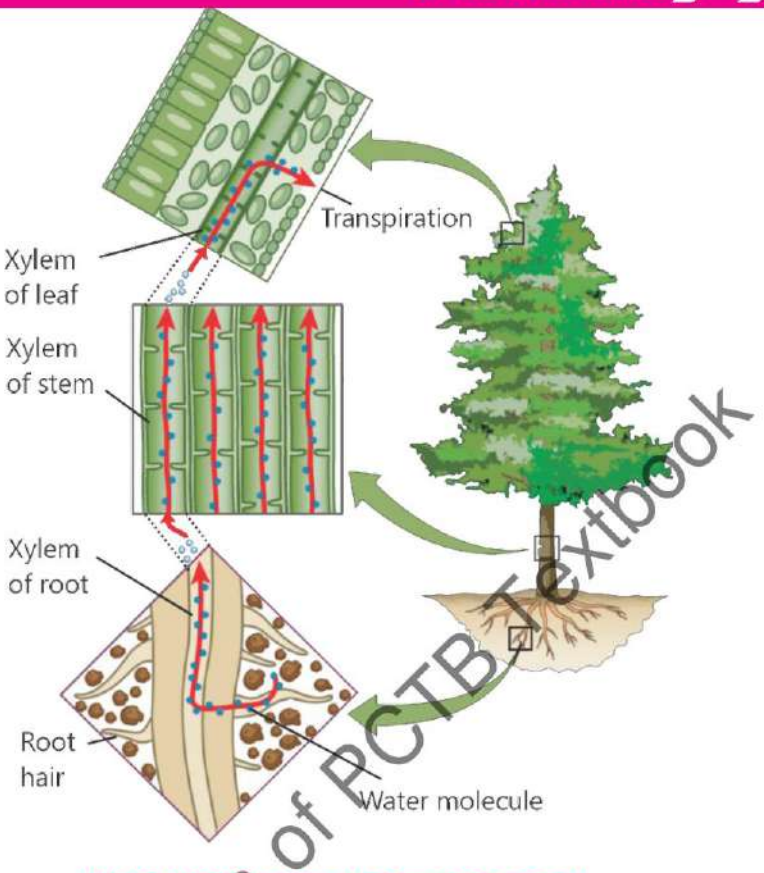


FIGURE 9.5: Transport of water in plants

9.5- TRANSLOCATION OF FOOD IN PLANTS

Xylem is a one-way passage for water and salts (from roots to leaves). Phloem is a two-way passage for food. The direction of food movement is decided by supply and demand in the sources and sinks.

We know that inside the plant body, food is transported from one part to the other through phloem tissue. For transportation in most plants, glucose is converted into sucrose. The mechanism of the transport of food in plants is called **pressure flow mechanism**. According to pressure flow mechanism, dissolved food flows from a **source to a sink**. The sources include photosynthetic tissues (e.g. mesophyll of leaves) and storage tissues (e.g. roots). Sinks include the sites of food utilization (e.g. growing tips of roots and stems) and the storage tissues.

At the source site, food (sucrose) enters the sieve tubes of phloem by active transport. Companion cells of phloem provide energy for this active transport. Due to higher solute concentration in sieve tubes than the nearby xylem tissue, water flows into sieve tubes by osmosis. In this way, the fluid pressure in sieve tubes increases and the solution of food flows towards the sink.

At the sink, sucrose is actively unloaded from sieve tubes into the sink tissues. Water also moves by osmosis from sieve tubes into the xylem. It reduces fluid pressure in sieve tubes. Due to higher fluid pressure at the source than the sink, food flows in bulk towards the sink.

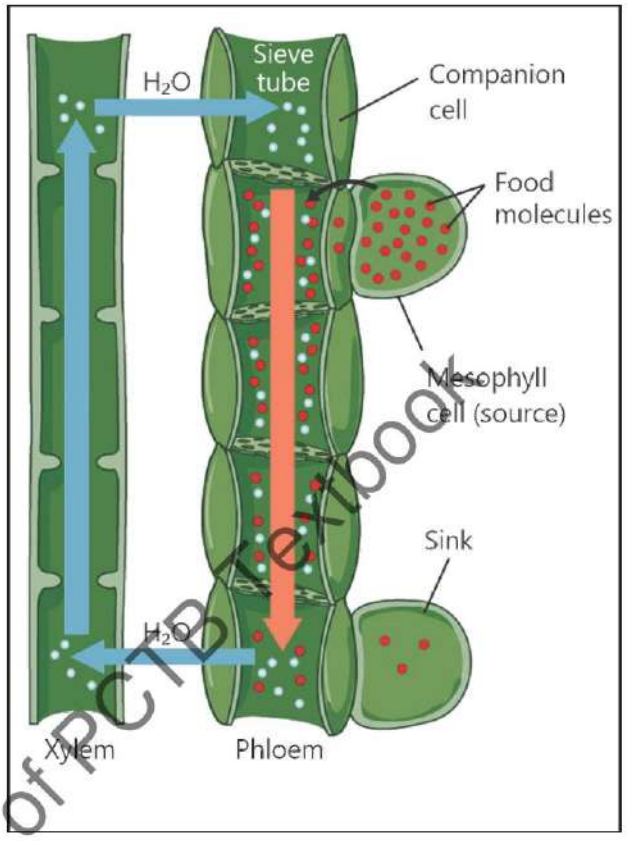


FIGURE 9.6: Transport of food

9.6- GASEOUS EXCHANGE IN PLANTS

During the daytime, all plant cells are carrying out cellular respiration while their green parts are carrying out photosynthesis.

- In photosynthesis, they use carbon dioxide and release oxygen. They take carbon dioxide which they produce in respiration. They also take carbon dioxide from the environment.
- In respiration, they use oxygen produced during photosynthesis. They release carbon dioxide to the environment.

So, during daytime leaves are releasing oxygen and taking carbon dioxide from the environment. During night, all cells are carrying out respiration while there is no photosynthesis. So, the plant is taking in oxygen from environment and releasing carbon dioxide.

Process of Gaseous Exchange

In plants, the gaseous exchange between body and the environment occurs through the surface. The epidermis of root, stem and leaves allows the exchange of gases between the inner cells and environment. At some parts a thick **cuticle** is present over epidermis. It also allows the exchange of gases.

In leaves and young stems, the air moves in and out through the stomata present in epidermis. Inside body, gaseous exchange occurs between cells and air.

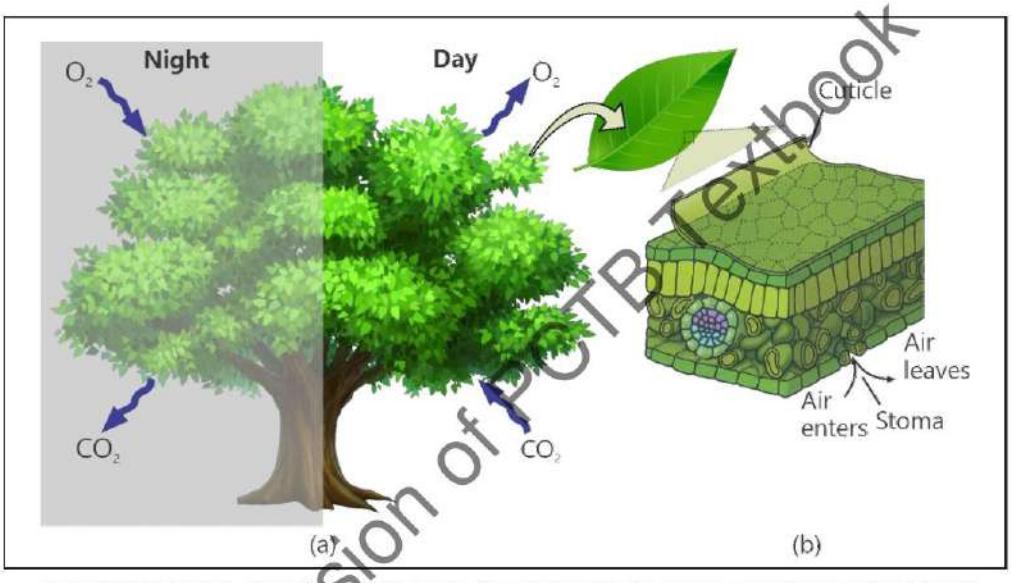


FIGURE 9.7: (a)- Gaseous exchange in plant; (b) Gaseous exchange in a leaf

In woody stems, the entire surface is covered by bark. Gaseous exchange cannot occur through bark. The bark contains special pores called **lenticels**, which allow the gaseous exchange with the environment.

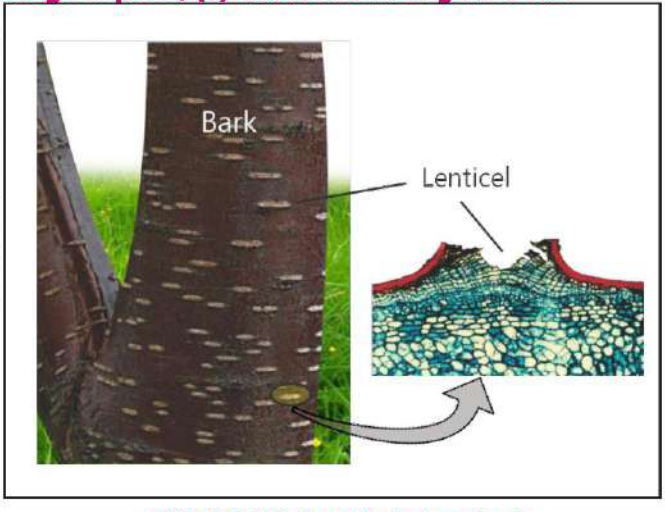


FIGURE 9.8: Lenticels in a bark

9.7 MECHANISMS FOR EXCRETION IN PLANTS

a- Excretion of Extra Carbon dioxide and Oxygen

During the day, plants use the carbon dioxide produced in cellular respiration for photosynthesis. However, at night, when photosynthesis is not occurring, carbon dioxide becomes a waste product. Plants release this excess carbon dioxide through their general surfaces and stomata.

Similarly, the oxygen produced during photosynthesis is used for cellular respiration during the day. Excess of oxygen is released into the atmosphere through the stomata.

b- Excretion of Extra Water

Plants store large amounts of water in the vacuoles of their cells. It results in turgor, which provides support to the soft parts of the body. If plants have extra water, they remove it in two ways.

1. Transpiration: During the day, plants remove their extra water by transpiration. You know that there are three types of transpiration: stomatal transpiration, cuticular transpiration, and lenticular transpiration.

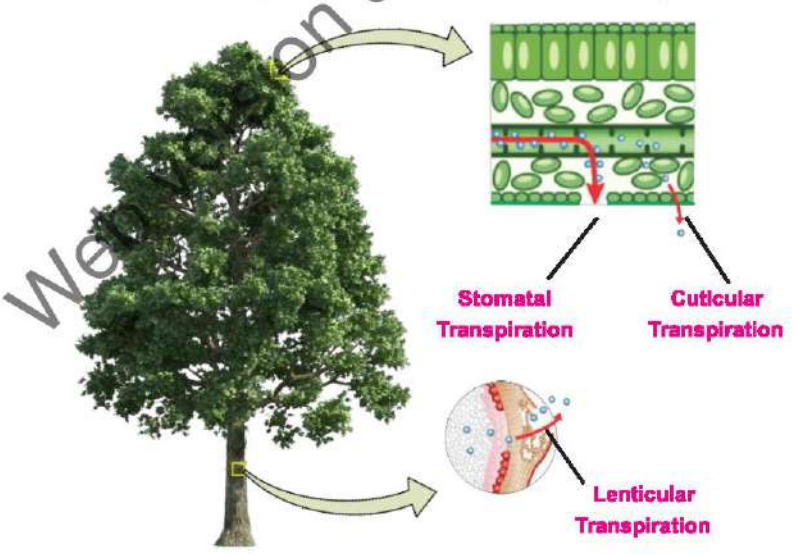


FIGURE 9.9: Types of transpiration

2. Guttation: At night, when stomata are closed, many plants store excess water in their xylem tissue. This water is removed during the day. Some plants, such as grasses, have a specialized mechanism called guttation to remove excess water at night. Guttation involves the release of water droplets through small pores located at the tips or edges of leaves. This process helps to regulate the plant's water content.

Guttation is different from dew formation. Dew means the water drops on the surface of leaves formed by the condensation of water vapours present in the air.

FIGURE 9.10: Guttation in different leaves

c-Excretion of other Metabolic Wastes

Plants adopt different methods to remove other metabolic wastes from their bodies. Some plants can store wastes in the form of harmless crystals. Some plants keep their wastes in their leaves. When their leaves fall, plant body also gets rid of these wastes. Some plants excrete their wastes through special pores by applying force. For example, rubber plant excretes latexes, Acacia (keekar) tree excretes gums, coniferous trees excrete resins, and ladyfinger excretes mucilage.

FIGURE9.11: Excretion in Plants

9.8- OSMOTIC ADJUSTMENTS IN PLANTS

On the basis of habitats, there are four types of plants.

1. **Mesophytes** are the terrestrial plants which are adapted to survive in moderate environment that are neither too dry nor too wet **They have** well-developed root system that efficiently absorbs water. A cuticle on their surfaces minimizes water loss during hot and dry periods. Moreover, they keep their stomata closed to reduce transpiration. Examples of mesophytes include maize (corn), clover, and rose.
2. **Hydrophytes** live in freshwater (ponds, and lakes etc.) or in wet soil. In these plants, the absorption of water occurs through the whole surface. They use different ways to remove extra water from their bodies. For example, many hydrophytes have broad leaves which float on the surface of water. These leaves have large number of stomata on their upper surfaces. Water moves out through these stomata. The most common example of such plants is water lily.
3. **Xerophytes** live in extremely dry environments (deserts). They have deep roots to absorb water from almost dry soil. Their body surface has very few stomata. It is also covered with thick waxy cuticle to reduce the loss of water. Some xerophytes e.g. *Cacti* (*singular: Cactus*) store water in their specialized stems or roots. Such stems or roots are soft and juicy and are called **succulent organs**.
4. **Halophytes** live in habitats with salty waters (e.g. sea or salty marshes). Water tries to move out from their hypotonic bodies into the hypertonic environment. Such plants absorb salts from outside and make their

bodies hypertonic. In this way, water does not move out of cells. The excess salt can be stored in cells or excreted out from salt glands on leaves. Many sea grasses are included in this group.

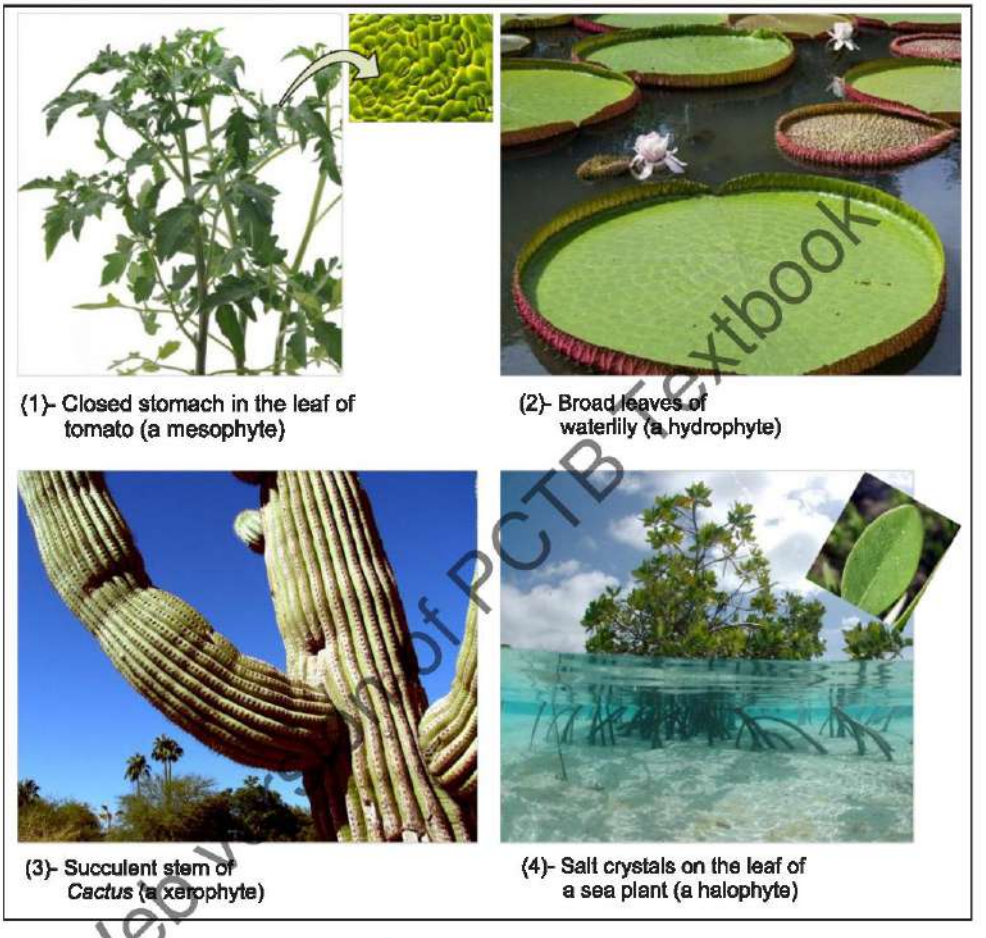


FIGURE 9.12: Osmotic adjustments in Plants

KEY POINTS

- Nutrition means the processes in which nutrients are obtained or prepared and converted into body substances for growth and energy.
- Plants need nitrogen for protein synthesis and Magnesium for chlorophyll formation.
- Roots have tiny root hairs, which are actually the extensions of epidermal cells of roots.
- Roots absorb water from the soil through root hairs using osmosis, moving water into the plant's vascular system.
- Transpiration is the loss of water from plant surface through evaporation.
- Water moves up the plant through xylem vessels, reaching leaves and other parts. This process is driven by transpiration pull.
- Water molecules stick together (cohesion) and to the walls of xylem vessels (adhesion) It allows them to form a continuous column from roots to leaves.
- As water transpires from leaves, it generates a pull in the xylem, drawing water upward from the roots.
- Transport of food occurs from the areas of supply (sources) to the areas of metabolism or storage (sinks).
- In leaves, sugar molecules are actively loaded into phloem sieve tubes.
- The high concentration of sugars in phloem draws water from xylem into the phloem by osmosis. It increases pressure at the source (leaves).
- At the sink, sugars are water move out of phloem. It reduces fluid pressure in sieve tubes. So, food flows in bulk from source towards the sink.
- At the sink, sugars are removed from the phloem. It reduces pressure and allows water to return to the xylem.
- Stomata in leaves regulate water loss and gas exchange, balancing the needs of the plant.
- On the basis of habitat (availability of water), there are four types of plants i.e., mesophytes, hydrophytes, xerophytes, and halophytes.

EXERCISE

A. Select the correct answers for the following questions.

1. Which of the following plant nutrients is required in large amount?
   a) Iron b) Zinc
   c) Potassium d) Boron
2. Which element is required by plants for the formation of chlorophyll?
   a) Phosphorus b) Calcium
   c) Magnesium d) Sulphur
3. The primary function of root hairs is:
   a) Transport of nutrients b) Storage of food
   c) Increase surface area for absorption d) Synthesis of proteins
4. Root hairs absorb salts from soil by;
   a) Diffusion b) Osmosis
   c) Active transport d) Filtration
5. Water moves from the soil into root cells by:
   a) Osmosis b) Active transport
   c) Diffusion d) Bulk flow
6. The transpiration is regulated by;
   a) Mesophyll b) Guard cells
   c) Xylem d) Phloem
7. Under which condition, there will be high rate of transpiration?
   a) High humidity b) Low light intensity
   c) Wind d) Waterlogged soil
8. Which ion plays a role in the opening of stomata?
   a) Sodium (Na^+) b) Potassium (K^+)
   c) Calcium (Ca^{2+}) d) Magnesium (Mg^{2+})
9. In most plants the food is transported in the form of:
   a) Glucose b) Sucrose c) Starch d) Maltose
10. What is TRUE according to the pressure flow mechanism of food transport?
    a) Water enters the source, creating pressure
    b) Water is pulled from the sink
    c) Movement of food in phloem is due to gravity
    d) Solutes move from low to high concentration

11. Succulent organs are present in:

a) Xerophytes
b) Hydrophytes
c) Mesophytes
d) Halophytes

B. Write short answers.

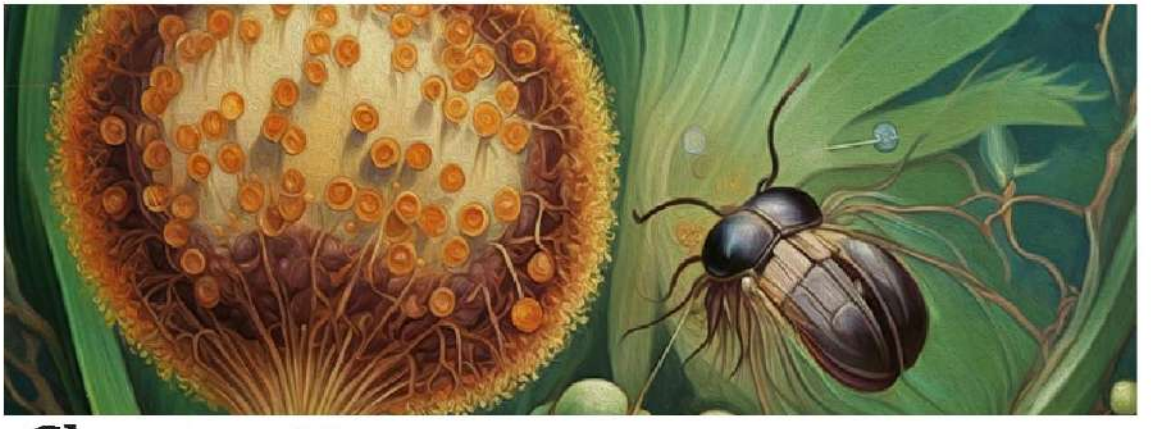
1. Define mineral nutrition in plants.
2. Define macronutrients and micronutrients and give examples.
3. State the roles of nitrogen and magnesium in plants.
4. Define transpiration and its types.
5. How is the transpirational pull important in plants?
6. Transpiration is the loss of water from plants. Is it a harmful phenomenon? If no, what is its importance?
7. Differentiate between:
   i. Xylem and phloem
   ii. Transpiration and guttation
   iii. Hydrophytes and halophytes
   iv. Hydrophytes and xerophytes
   v. Lenticular transpiration and stomatal transpiration
8. How do the plants of rubber and keekar excrete their wastes?

C. Write answers in detail.

1. Describe the events involved in the opening and closing of stomata.
2. Explain the internal structure of root and describe the uptake of salt and water by root.
3. Describe temperature, wind and humidity as the factors affecting the rate of transpiration.
4. Describe the mechanism of transport of water and salt in plants.
5. Explain the mechanism of food translocation by Pressure Flow Mechanism.
6. How do the plants excrete extra water and salts from their bodies?
7. Describe the process of gaseous exchange in plants
8. Describe the mechanisms/adaptations in plants for excretion of wastes.
9. Explain osmotic adjustments in in hydrophytes, xerophytes and halophytes.

D. Inquisitive questions.

1. Why do plants transpire more on a windy day compared to a humid one?



Chapter 10
REPRODUCTION IN PLANTS

After studying this chapter, students will be able to:

- Describe different types of asexual reproduction i.e. binary fission, budding, spore formation and vegetative propagation.
- Distinguish between vegetative propagation and artificial propagation.
- Explain vegetative propagation in plants (through stem, suckers and leaves).
- Describe the two methods of artificial vegetative propagation (stem cuttings and grafting).
- Explain sexual reproduction in Plants.

You know that reproduction is the process in which organism produce new organisms of their own kind. There are two main kinds of reproduction. The reproduction that does not involve the fusion of gametes is called **asexual reproduction**. The offspring produced by asexual reproduction are genetically identical to the parents. On the other hand, the reproduction that involves the fusion of male and female gametes is called **sexual reproduction**. In sexual reproduction, the offspring have variations among themselves and with the parents.

This chapter explores the methods of reproduction in plants, both asexual and sexual reproduction. We will study the vegetative and artificial propagation methods. Artificial propagation techniques like stem cuttings and grafting will also be discussed.

10.1 - Types of Asexual Reproduction

Some common methods of asexual reproduction in different organisms are given next.

1. Binary Fission

Binary fission means division in to two. It is the usual method of reproduction in **bacteria**. During binary fission, the bacterial DNA replicates and the daughter DNA molecules move to opposite sides. Then, the cell membrane pinches in. New cells wall is synthesized in the middle and so two identical daughter cells bacteria are produced.

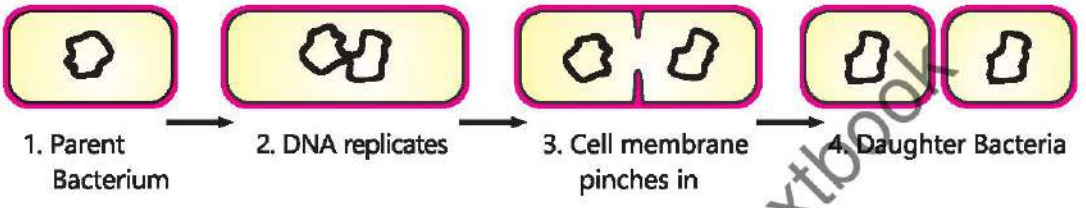


FIGURE 10.1: Binary fission in bacteria

Many **protists** (unicellular eukaryotes e.g. *Amoeba*, *Euglena* etc.) also reproduce by binary fission. In protists, the nucleus of parent organism divides into two. This is followed by the division of cytoplasm. So, two daughter protists are formed.

Some animals e.g. Planarians also reproduce asexually by binary fission.

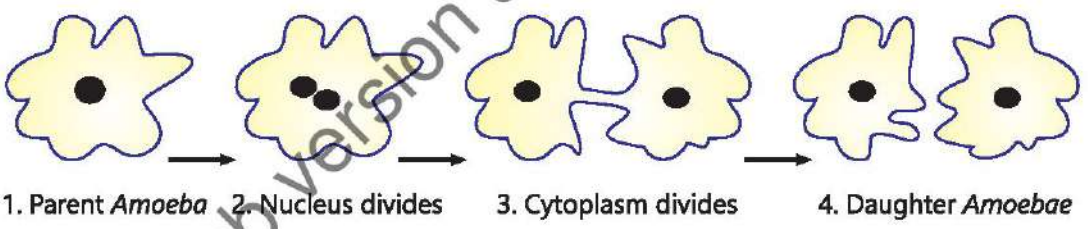


FIGURE 10.2: Binary fission in Amoeba

2. Budding

This method is very common in yeast (a unicellular fungus). During budding, a part of the parent organism grows out from its body. This part is called a **bud**. When the bud has grown big, it may separate from parent body or may remain attached.

Some animals e.g. hydra also reproduce asexually by budding.

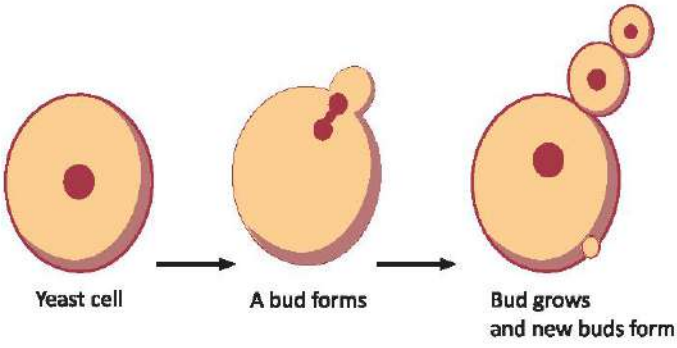


FIGURE 10.3: Budding in Yeast

3. Spore Formation

Spores are thick-walled asexual reproductive cells. Most fungi (e.g. *Rhizopus:* bread mold) produce spores in special sac-like structures called **sporangia** (*Singular:* sporangium). When spores are mature, the sporangium bursts and spores are released.

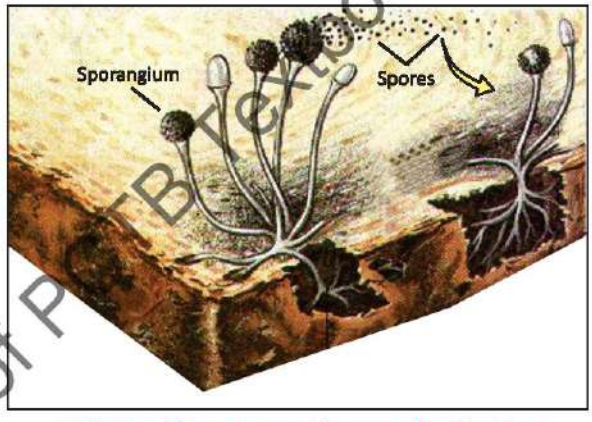


FIGURE 10.4: Asexual reproduction by spores (in Rhizopus)

Spores can tolerate unfavourable conditions due to their thick walls. When favourable conditions are available, the spores germinate to produce new fungus.

Some bacteria reproduce by forming **endospores** (spores produced inside the cell). They form endospores in unfavourable environmental conditions. Even if the original cell dies, the endospore survives. When conditions improve, the endospore grows into a new bacterium.

The improperly sterilized canned foods may contain endospores of bacteria. When endospores germinate, new bacteria make toxins.

4: Vegetative Propagation

It is a methods of asexual reproduction in plants. In this method, new plant is produced from the vegetative part (root, stem or leaf) of the parent plant.

Vegetative propagation takes much less time to produce new generation as compared to the sexual method. Secondly, the offspring are genetically identical to the parent plant. Vegetative propagation may be natural or artificial.

- Natural vegetative propagation is a process where plants reproduce on their own, using structures like stems, roots, or leaves.
- Artificial vegetative propagation means the processes in which humans use the vegetative parts of plants for their reproduction by methods like cuttings, grafting, or layering.

In the natural vegetative propagation, plants use the following vegetative parts for producing new plant.

(a)- Stem

The following types of stems take part in vegetative propagation in plants:

1. Stolon (runner): It is a horizontal stem that grows above the ground. A stolon has nodes where new leaves and roots grow. The leaves grow upwards and roots grow down. In this way, a new plant is formed at the node. Strawberry reproduces by using its stolon.

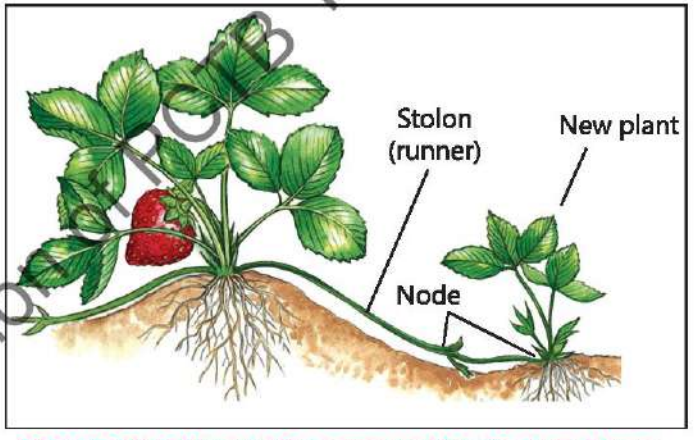


FIGURE 10.5: Vegetative propagation in strawberry (through runner)

2. Tuber: It is fleshy stem that grows underground. It has "eyes" which are actually its buds. Eyes can grow into new plants. Potatoes reproduce by tubers.

3. Rhizome: It is a horizontal stem that grows below the ground. It has nodes where new leaves and roots grow. In this way, a new plant grows from each node. Ferns, ginger, and sugar cane reproduce by using rhizome.

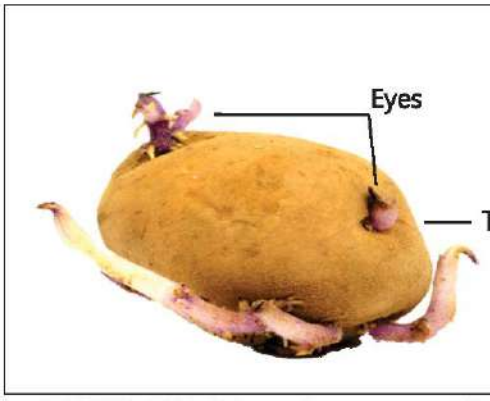


FIGURE 10.6: Vegetative propagation in potato (through tuber)

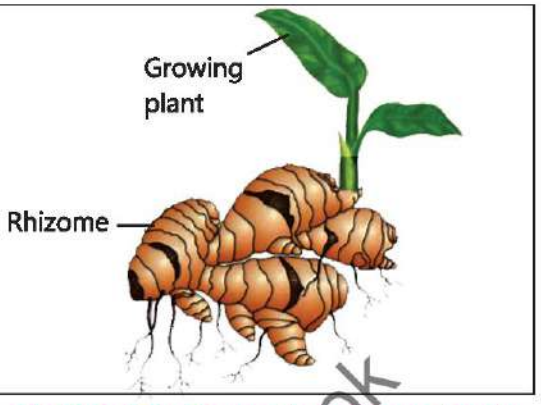


FIGURE 10.7: Vegetative propagation in ginger (through rhizome)

4. Bulb: It is a very short stem that grows underground. It has bud and fleshy leaves. Bulbs grows naturally to produce new plants. Tulips, onions and lilies reproduce by bulbs.

5. Corm: It resembles the bulb but does not have fleshy leaves. Almost all of a corm consists of stem, with a few brown non-functional leaves on the outside. Dasheen and garlic reproduce by corms.

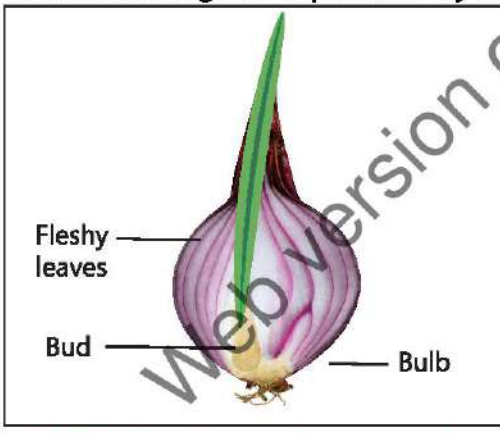


FIGURE 10.8: Vegetative propagation in onion (through bulb)

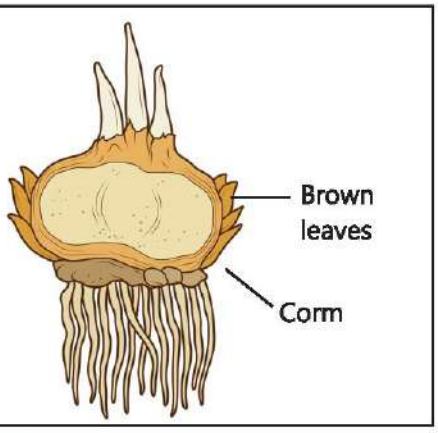


FIGURE 10.9: Vegetative propagation in garlic (through corm)

(b)- Suckers

Suckers are new shoots that emerge from the base of the parent plant or from its underground roots. These shoots grow into new plants while still attached to the parent. When suckers develop their own root system, they become independent. Examples are banana and raspberry plants.

(b)- Modified Leaves

The leaves of some plants (e.g. *Bryophyllum)* are modified for vegetative propagation. Such leaves have buds at their margins. When leaf falls on ground, the buds grow into new plants.

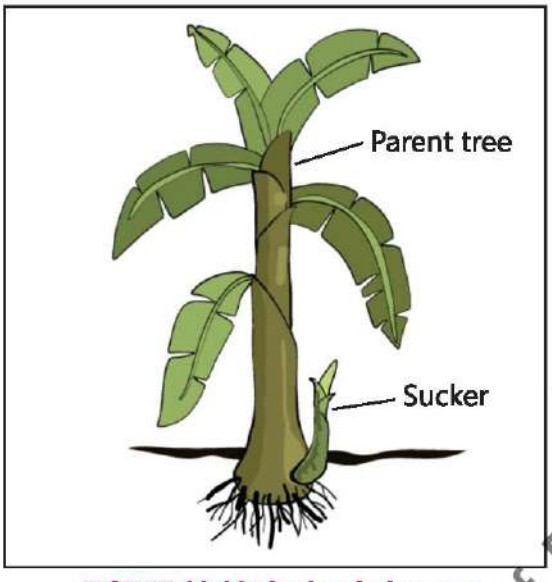


FIGURE 10.10: Sucker in banana

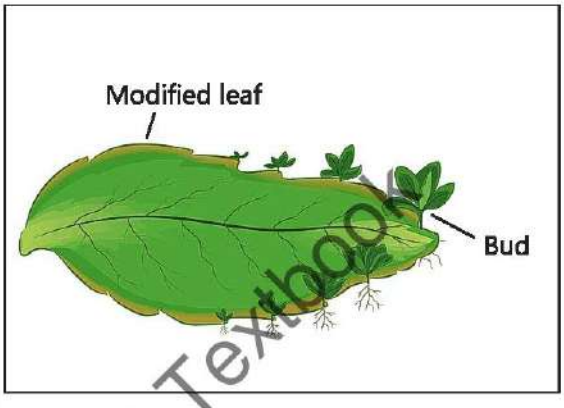


FIGURE 10.11: Modified leaf of bryophyllum

10.2- Artificial Propagation

Artificial propagation includes the methods in which humans produce new plants by using the vegetative parts of plants. It includes techniques such as cutting, grafting, or tissue culture. Artificial propagation is used to cultivate plants with desirable characteristics or to increase crop production. The following two are the most common methods of artificial propagation.

1. Cutting

In some plants, a piece of stem or a piece of root can form a new plant. Such a piece of stem or root that are cut from a plant and used to grow new plant is called **cutting.** Cuttings are widely used to propagate houseplants, ornamental trees and shrubs, and some fruit crops. Roses and grapevines are grown from stem cuttings. Sweet potato is grown from root cuttings.

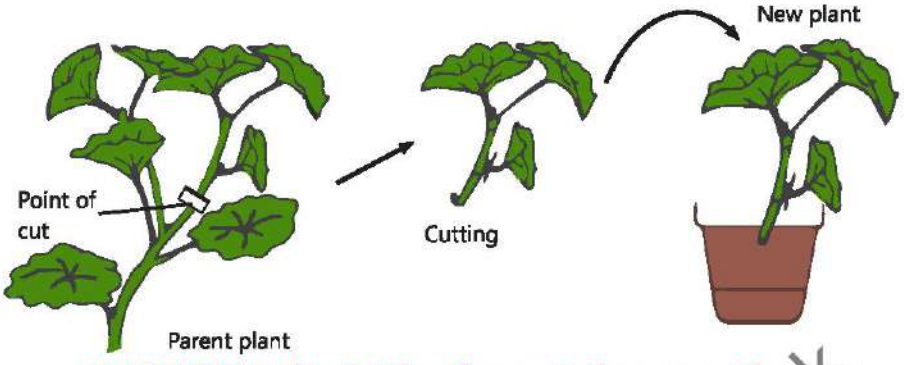


FIGURE 10.12: Using Cuttings for vegetative propagation

2. Grafting

Grafting is the joining of two or more plant parts of the same type to form a single plant. In grafting, a bud or small stem of one plant is attached to the roots or stems of a second plant. Grafting enables to combine the beneficial characteristics of two plants. This method is used to propagate almost all commercial fruit trees and (e.g. almond, plum, cherries etc.), many ornamental trees and shrubs.

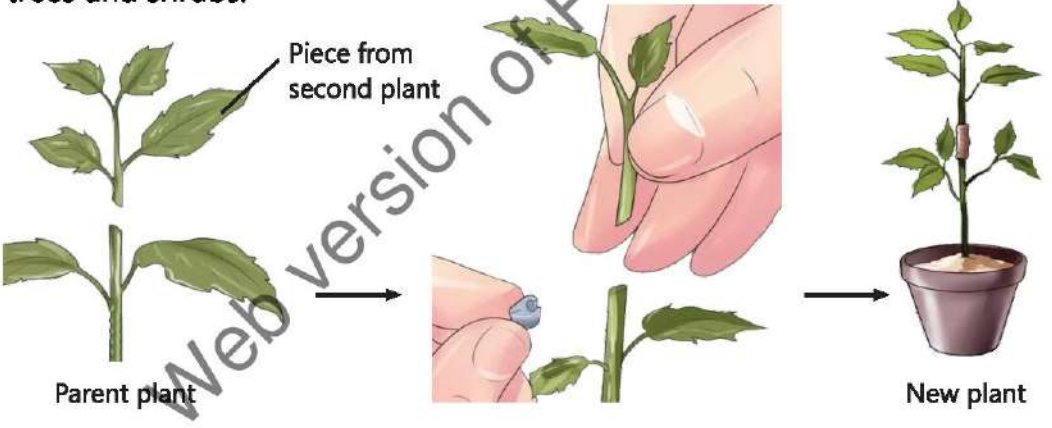


FIGURE 10.13: Grafting

Advantages and Disadvantages of Vegetative Propagation

Advantages: Vegetative propagation allows to produce many new plants in a short time. The new plants are exactly like the parent plant, so they all have the same good characteristics. This means useful qualities, like good fruit or strong growth, are passed on to the next generation.

Disadvantage: Plants produced through vegetative propagation do not have genetic differences. In other words, all the offspring are identical. Due to it, they are equally sensitive to environmental changes and prone to the same diseases or pests.

10.3- Sexual Reproduction in Plants

The major groups of plants have two type generations during sexual reproduction which come one after the other. These are sporophyte generation and gametophyte generation. The sporophyte generation produces spores which grow and make the new **gametophyte** generation. The gametophyte generation produces gametes which unite and make the new sporophyte generation. This phenomenon is called **alternation of generations**.

The sporophyte generation is diploid (2n) and produces haploid (1n) spores by meiosis. The spores develop into haploid gametophyte generation. The gametophyte produces haploid gametes by mitosis. The haploid gametes fuse to form diploid zygote, which develops into the next sporophyte stage.

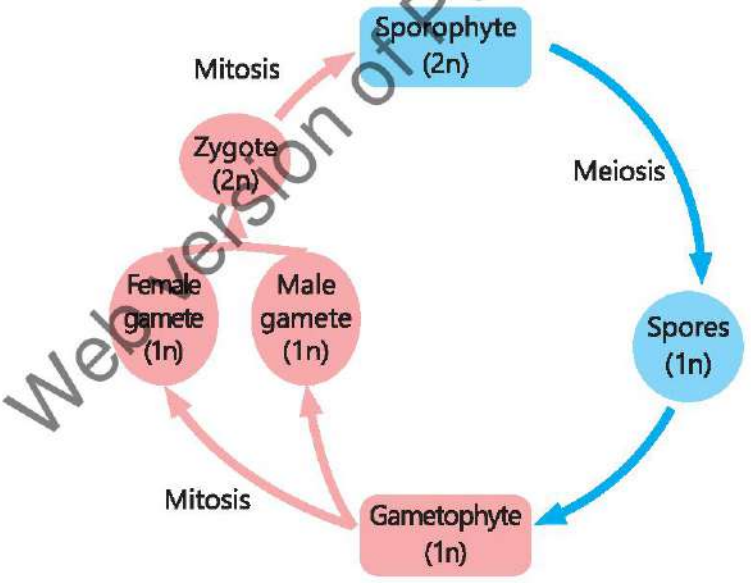


FIGURE 10.14: Alternation of generations in plants

Life Cycle of Angiosperms (Flowering Plants)

In angiosperms, flowers are the organs for sexual reproduction.

Parts of a Flower

The **receptacle** is the swollen tip of a flower stalk where all the floral parts (are attached. It serves as the base that supports the flower's structure.

Floral parts are in the form of the following four concentric whorls, or rings:

1. **Calyx:** It is the outermost whorl. It is made of green leaf-like **sepals.** Sepals protect the inner parts of a developing flower before it opens.
2. **Corolla:** It is the second whorl and made of **petals**. Most flowers have coloured petals.
3. **Androecium:** It is the third whorl and is made of male reproductive structures called **stamens**. Each stamen consists of an anther and a filament. Anther contains pollen sacs (microsporangia), which produce microspores. The stalk-like filament supports the anther.
4. **Gynoecium**: It is the innermost whorl made of the female reproductive structures called **carpels**. A carpel consists of three parts.
   i. The enlarged base of carpel is called ovary. It is the part where ovules are produced. Ovules produce megaspores during reproduction.
   ii. The stalk-like part attached to ovary is called style.
   iii. The tip of style is called stigma.

In some flowers, one or more carpels are fused to form a structure called **pistil.**

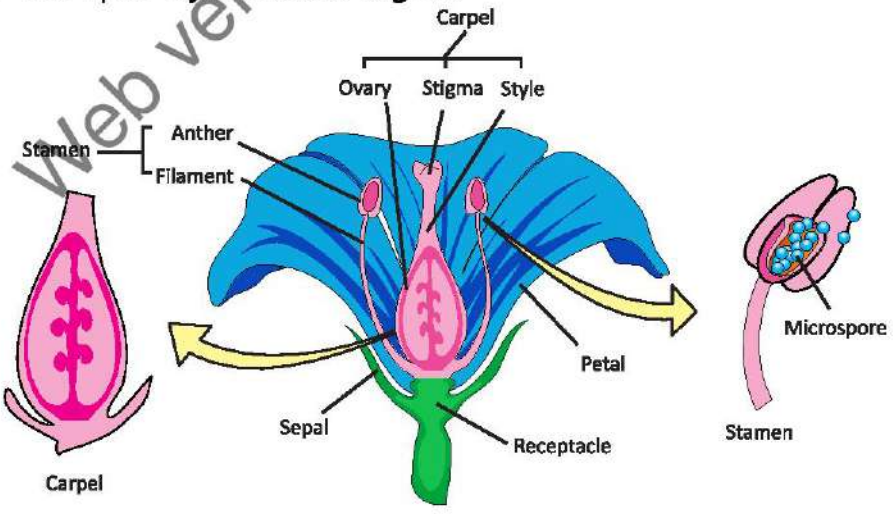


FIGURE 10.15: Parts of a flower

Stages of the Life Cycle

An angiosperm plant represents the sporophyte generation. When a flower matures, it produces spores. The spores germinate and make female and male gametophytes. The gametophytes are small structures consisting of few cells only. They make gametes which combine to form zygote that develops into new sporophyte.

Following are the main stages in the life cycle of an angiosperm.

1- Development of Female Gametophyte (Embryo Sac)

The ovule acts as megasporangium. It contains a diploid **megaspore mother cell** which undergoes meiosis and produces four haploid **megaspores**. Only one megaspore remains alive. Inside megaspore, eight haploid nuclei are formed by mitosis. Two nuclei migrate to the center and fuse to form a **fusion nucleus**. One nucleus out of the remaining six forms the female gamete i.e., egg cell.

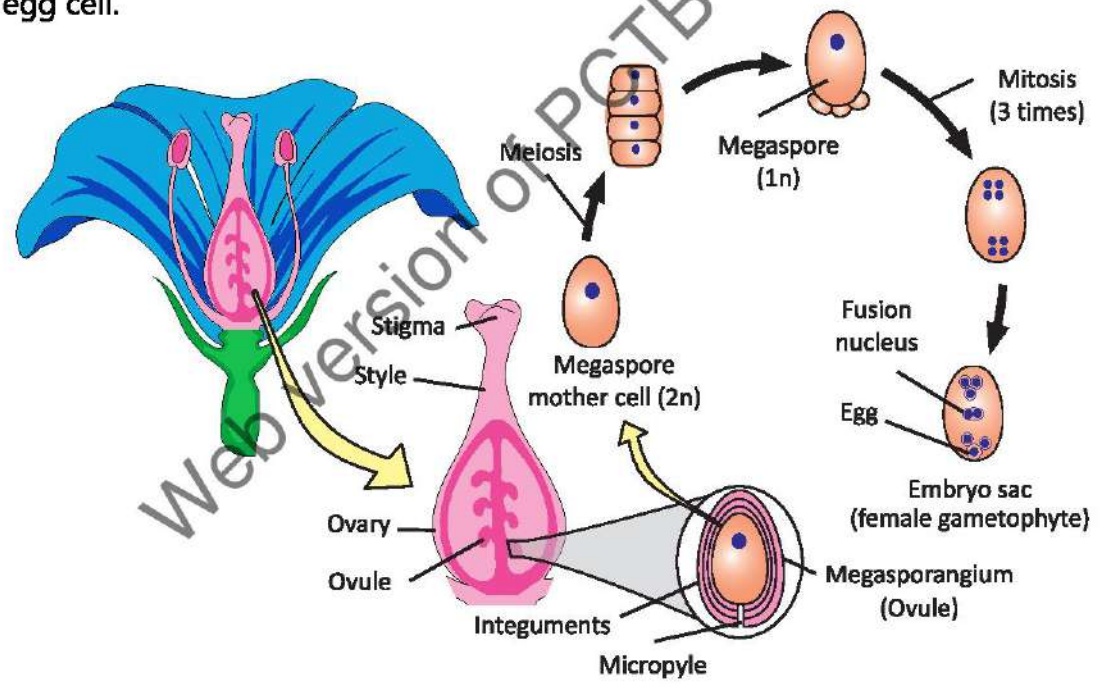


FIGURE 10.16: Development of female gametophyte (embryo sac)

The resulting structure, which contains seven cells (one egg cell, one fusion nucleus, and five non-functional cells), is the female gametophyte or embryo sac.

2- Development of Male Gametophyte (Pollen Grain)

The pollen sacs present in anther act as microsporangia. Each pollen sac contains many diploid **microspore mother cells**. Each microspore mother cell undergoes meiosis and produces four haploid **microspores** A microspore undergoes mitosis. The resulting two-celled structure is a pollen grain, which is the male gametophyte. One cell in pollen grain is the **tube cell**, which will form the pollen tube. The other cell is the **generative cell**, which will form two sperms.

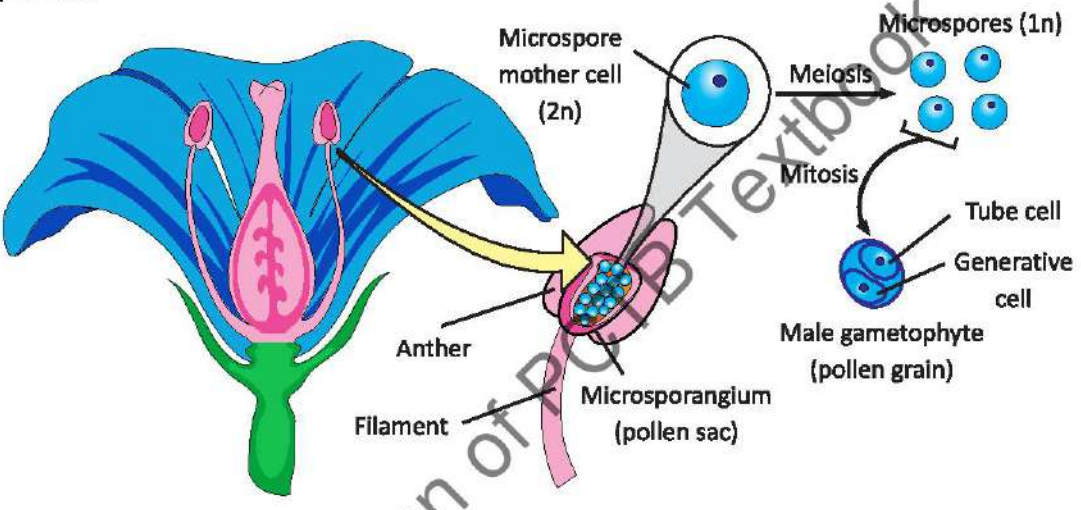


FIGURE 10.17: Development of male gametophyte (pollen grain)

3- Pollination

The male gametophyte (pollen grain) contains sperms while the female gametophyte (embryo sac) contains egg. The pollen grains are transferred from the anther to the stigma so that the sperms can fertilize the egg. It is called **pollination** i.e. the transfer of pollen grains from an anther to a stigma.

The transfer of pollens from the anther to the stigma of the same flower or another flower on the same plant is called **self-pollination.**

The transfer of pollens from the anther of one plant to the stigma of a flower on a different plant of the same species. is called **cross-pollination.**

4- Fertilization

When pollen grain reaches stigma, its tube cell forms a pollen tube. This tube grows through the stigma and style towards the ovary. The pollen tube reaches

the ovule and enters in it through the micropyle. The generative cell of pollen grain forms two sperms, which enter the embryo sac to reach the egg.

One sperm fuses with the egg, forming a diploid **zygote**. The zygote eventually develops into an embryo. The second sperm fuses with the fusion nucleus, producing a **triploid (3n) nucleus**. This nucleus then develops into tissue called **endosperm**. The endosperm provides nourishment for the embryo. This process of the fusion of two sperms (one with the egg and the other with the fusion nucleus) is called **double fertilization**. It is a unique characteristic of angiosperms.

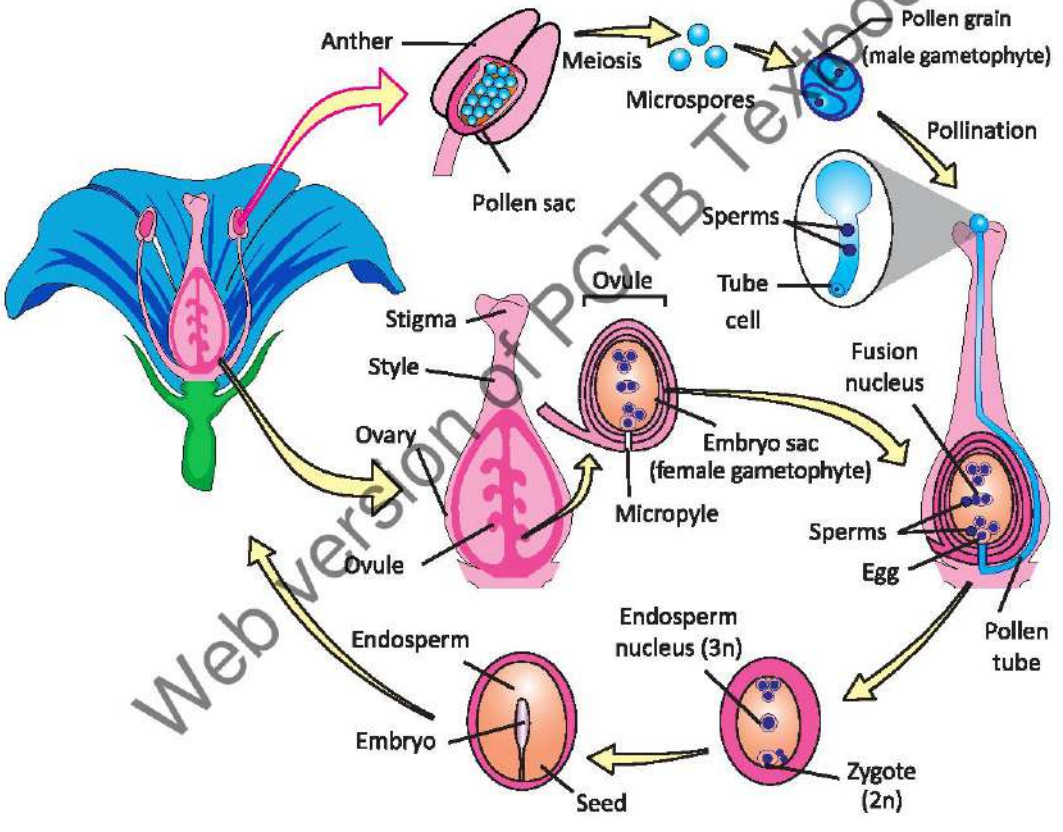


FIGURE 10.18: Life cycle of a flowering plant

5-Seed and Fruit Formation

After fertilization, the zygote develops into embryo and the triploid nucleus develops into endosperm tissue. After these developments, the ovule is said to be matured and is now called **seed**. The ovary changes into **fruit**.

6- Development of Sporophytes

When seeds mature, they are dispersed. If seeds get suitable conditions, their embryos develop into new plants (the sporophytes of the next generation).

In some plants, ovaries develop into fruits without fertilization of egg in ovule. So, there is no seed in fruit. This process is known as **parthenocarpy**. It results in seedless fruits e.g. bananas and seedless varieties of grapes.

KEY POINTS

- Binary fission is the division in which the parent cell simply divides into two daughter cells, each genetically identical to the parent.
- In budding, the offspring develops from a small outgrowth or "bud" on the parent organism.
- Vegetative propagation is a method of plant reproduction where new plants are produced from vegetative structures like stems, roots or leaves.
- Cloning is the technique of producing identical offsprings from small pieces of tissue taken from shoot tips or other suitable parts of the plant.
- Plants have two different generations. The diploid generation produces spores and is called sporophyte generation, while haploid generation produces gametes and is called gametophyte generation.
- The microspore undergoes mitosis and produces two haploid cells i.e., a tube cell which form pollen tube and a generative cell which divides to produce two sperms.
- A germinated microspore has a tube nucleus and two sperms is male gametophyte generation of plant.
- Ovule contains one megaspore mother cell which undergoes meiosis and produces four haploid megaspores. In one ovule, only one megaspore remains functional. Here it germinates into haploid female gametophyte, called embryo sac.
- Embryo sac consists of seven cells. There is one egg and two other cells at one end. There are three cells at the other end. There is a large cell in the centre which contains two polar nuclei (fusion nucleus 1n + 1n).

EXERCISE

A. Select the correct answers for the following questions.

1. Which of the following organisms commonly reproduce by binary fission?
   a) Yeast
   b) Bacteria
   c) Rhizopus
   d) Plants
2. What is the primary method of reproduction in yeast?
   a) Binary fission
   b) Spore formation
   c) Budding
   d) Fragmentation
3. Which of the following statements is true about spore formation in fungi?
   a) They produce spores during sexual reproduction
   b) They produce two kinds of spores
   c) Spores can only grow into new fungi in dry environments
   d) Spores are produced to withstand harsh conditions
4. What happens in some bacteria during harsh conditions?
   a) Creation of a bud that detaches from the cell
   b) Formation of thick-walled endospores
   c) Splitting the cell into two identical daughter cells
   d) Fusion of two bacterial cells
5. Which of the following is an example of vegetative propagation through runners?
   a) Potato
   b) Strawberry
   c) Onion
   d) Ginger
6. Which plant propagates through tubers?
   a) Onion
   b) Potato
   c) Ginger
   d) Garlic
7. The horizontal aboveground stem, which produces leaves and roots at its nodes;
   a) Stolon
   b) Bulb
   c) Rhizome
   d) Corm
8. Which of these does NOT help a plant for vegetative propagation?
   a) Rhizome
   b) Corm
   c) Runner
   d) Flower
9. Which part of the flower is responsible for producing pollen?
   a) Stigma
   b) Anther
   c) Ovary
   d) Petal

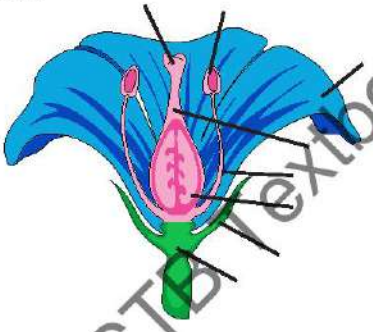
10. Which of the following is NOT a part of carpel?
    a) Filament b) Style
    c) Stigma d) Ovary
11. Which structure forms the female gametophyte in flowering plants?
    a) Pollen grain b) Ovule
    c) Anther d) Sepal
12. The male gametophyte in flowering plants is known as:
    a) Pollen grain b) Embryo sac
    c) Ovary d) Carpel
13. In the life cycle of flowering plants, which structure is triploid (3n)?
    a) Egg b) Fusion nucleus
    c) Endosperm nucleus d) Sperm
14. Embryo sac is formed inside;
    a) Filament b) Anther
    c) Style d) Ovule
15. Double fertilization involves;
    a) Fertilization of the egg by two male gametes
    b) Fertilization of two eggs in the same embryo sac by two sperms
    c) Fertilization of the egg and the fusion nucleus by two sperms
    d) Fertilization of the egg and the tube cell by two sperms

B. Write short answers.

1. Write a short note on budding in yeast.
2. Write a short note on spore formation in fungi.
3. What are the advantages of spore formation in fungi and bacteria?
4. Describe how vegetative propagation occurs through runners.
5. State how potatoes reproduce through tubers.
6. Describe the advantages and disadvantages of vegetative propagation.
7. Name the four whorls present in a flower and also tell the components of each whorl.
8. Briefly describe the formation of egg cell and polar nuclei within embryo sac of a flower.
9. Differentiate between:
    i. Asexual and sexual reproduction
    ii. Binary fission in bacteria and amoeba

iii. Stolon and rhizome
iv. Bulb and corm
v. Cutting and grafting
vi. Vegetative propagation and artificial propagation
vii. Male and female gametophytes
viii. Calyx and corolla
ix. Stamen and carpel

10. Label the given diagram of flower.



C. Write answers in detail.

1. Explain the process of binary fission in bacteria and describe how it leads to the formation of two daughter bacteria.
2. What do you mean by vegetative propagation? Differentiate among different plant structures modified for vegetative propagation.
3. Describe the ways by which humans can grow new plants by using the vegetative parts of the parent plants?
4. Define sporophyte and gametophyte. State their roles in the life cycle of plants.
5. Explain the lifecycle of flowering plants, focusing on the alternation between the gametophyte and sporophyte generations.
6. Describe how the female gametophyte (embryo sac) develops within the ovule of a flower.

D. Inquisitive questions.

1. Why are spores considered an adaptation for survival n harsh environmental conditions?
2. How do asexual and sexual reproduction contribute differently to genetic diversity of plant populations?
3. How does the pollen tube facilitate the process of fertilization in flowering plants?

Chapter 11
BIOSTATISTICS

After studying this chapter, students will be able to:

- Define biostatistics and its uses.
- Define and calculate mean, median and mode.
- Sketch a bar chart for a given set of biological data.

You know that the scientific work often involves statistical methods. In the field of biology, scientist collect, analyse, and interpret data for getting results and for understanding various phenomena. In this chapter, we will study the main uses and principles of biostatistics.

11.1- Introduction of Biostatistics

Biostatistics is a branch of statistics that applies statistical methods to biological sciences. Biostatistics is essential for designing biological experiments, clinical trials, and epidemiological studies.

Uses of Biostatistics

The major uses of biostatistics include:

1- Designing Experiments and Studies

Biostatistics helps in planning and structuring experiments to ensure that the data collected will be relevant and sufficient to answer the research questions. For instance, in a clinical trial testing a new drug, biostatisticians determine the sample size needed to detect a significant effect.

2- Analysing Biological Data

Biostatistics involves applying statistical techniques to analyse data. This analysis can uncover trends, correlations, and patterns. For example, analysing the growth rates of plants under different environmental conditions can reveal how factors like light and water affect growth.

3- Interpreting Results

After analysing data, biostatistics helps to interpret the results in a meaningful way. For example, interpreting the results of a survey on the prevalence of a disease in a population can guide public health interventions.

4- Predicting Outcomes

Biostatistics can be used to create models that predict future outcomes based on current data. For instance, predicting the spread of an infectious disease within a population helps in planning vaccination campaigns and allocating resources.

5- Public Health and Policy Making

In public health, biostatistics provides evidence-based insights that guide policy decisions and health guidelines. For example, statistical analysis of data on COVID-19 rates can lead to the implementation of COVID-19 vaccination campaign.

Examples of the Uses of Biostatistics

1- Epidemiology

Epidemiologists use biostatistics to study the distribution and determinants of health and diseases in populations. For example, analysing data on COVID-19 infection rates, recovery rates, and the effectiveness of vaccines involves biostatistical methods.

2- Genetics

Biostatistics is used in genetic research to analyse the inheritance of traits and the association of genetic variations with diseases. For instance, genetic studies use biostatistics to identify genetic markers linked to diseases like diabetes and cancer.

3- Agriculture

In agricultural research, biostatistics helps in analysing crop yields, the effectiveness of fertilizers, and the resistance of plants to pests and diseases. For example, comparing the yield of different wheat varieties under various farming practices involves statistical analysis.

4- Clinical Trials

Biostatistics is crucial in the design and analysis of clinical trials that test new treatments and drugs. For instance, determining whether a new medication is more effective than a placebo requires rigorous statistical testing to ensure the results are statistically significant.

11.2- MEAN, MEDIAN, AND MODE

The mean, median, and mode are the measures that help summarize and understand data sets. The mean provides an overall average, the median gives the middle value, and the mode highlights the most frequent value.

Mean

The mean, also known as the average, is the sum of all the values in a data set divided by the number of values. It represents the central value of a data set.

Formula

$$\text{Mean} = \frac{\text{Sum of All Data Points}}{\text{Number of Data Points}}$$

Example

Consider the following data set representing the heights (in cm) of five students:

150, 160, 165, 155, 170.

$$\text{Mean} = \frac{150 + 160 + 165 + 155 + 170}{5} = \frac{800}{5} = 160$$

So, the mean height is 160 cm.

2- Median

The median is the middle value of a data set when the values are arranged in ascending or descending order. If the number of values is odd, the median is the middle value. If the number of values is even, the median is the average of the two middle values.

Steps to Calculate Median

1. Arrange the data in ascending order.
2. If the number of values (n) is odd, the median is the value at the position $\frac{n+1}{2}$.
3. If the number of values (n) is even, the median is the average of the values at positions $\left(\frac{n}{2}\right)$ and $\left(\frac{n}{2}+1\right)$.

Example

Consider the data set: 150, 160, 165, 155, 170.

1. Arrange in ascending order: 150, 155, 160, 165, 170.
2. Number of values (n) = 5 (odd).
3. Median is the value at position $\left(\frac{5+1}{2}\right) = 3$.

So, the median height is 160 cm.

For an even number of values, consider the data set: 150, 160, 165, 155.

1. Arrange in ascending order: 150, 155, 160, 165.
2. Number of values (n) = 4 (even).
3. Median is the average of the values at positions $\left(\frac{4}{2}\right) = 2$ and $\left(\frac{4}{2}+1\right) = 3$.

$$\text{Median} = \frac{155+160}{2} = \frac{315}{2} = 157.5$$

So, the median height is 157.5 cm.

3- Mode

The mode is the value that appears most frequently in a data set. A data set may have one mode, more than one mode, or no mode at all.

Steps to Calculate Mode

1. Count the frequency of each value in the data set.
2. The value with the highest frequency is the mode.

Example 1

Consider the data set: 150, 160, 165, 155, 160.

- Frequencies: 150 (1), 160 (2), 165 (1), 155 (1).
- The value with the highest frequency is 160.

So, the mode of the data set is 160.

Example 2

Consider the data set: 150, 160, 160, 155, 155.

- Frequencies: 150 (1), 160 (2), 155 (2).
- The values with the highest frequency are 160 and 155.

So, the data set is bimodal with modes 160 and 155.

Example 3

Consider the data set: 150, 160, 165, 155, 170.

- Frequencies: 150 (1), 160 (1), 165 (1), 155 (1), 170 (1).
- All values have the same frequency.

So, this data set has no mode.

11.3- BAR CHART

A bar chart is a graphical representation of data using bars of different heights or lengths. It is used to compare the quantities of different categories. Bar charts are effective for comparing different categories and visually representing the distribution of data.

Steps to Create a Bar Chart:

1. Gather the data to be represented in the bar chart.
2. Arrange the data into categories and their corresponding values.
3. Draw a horizontal axis (x-axis) and a vertical axis (y-axis).
4. Label the x-axis with the categories and the y-axis with the values.

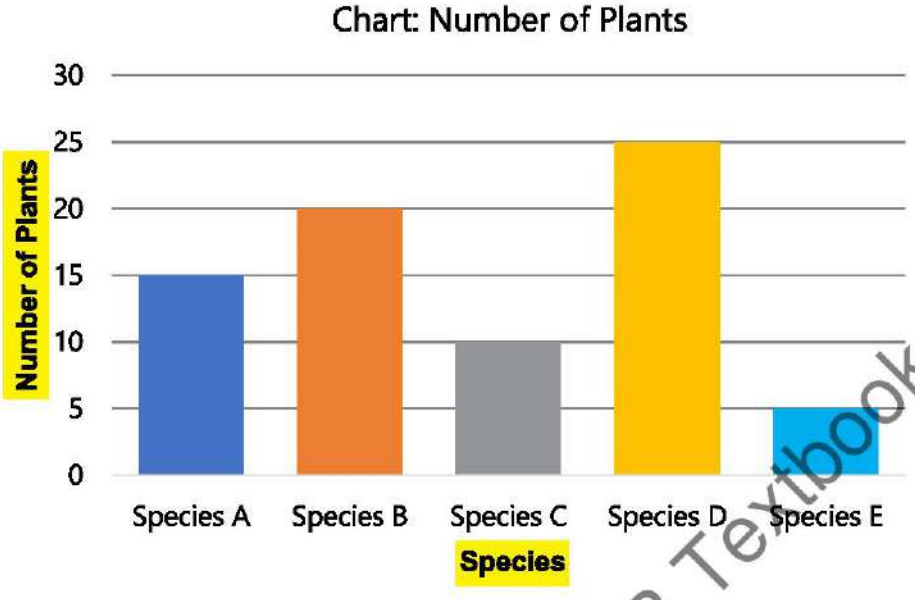
5. Determine the scale for the y-axis based on the range of values in the data set. Divide the axis into equal intervals.
6. For each category, draw a bar with a height corresponding to its value. Ensure the bars are of equal width and are spaced evenly.
7. Label each bar with its category name and value.

Example

Consider the following data representing the number of plants belonging to different species found in a field survey:

Species	Number of Plants
Species A	15
Species B	20
Species C	10
Species D	25
Species E	5

1. Collect Data: The data is already collected in the table above.
2. Organize Data: Data is organized in the table with species and their corresponding number of plants.
3. Draw Axes: Draw the x-axis and y-axis.
4. Label the x-axis with the species: A, B, C, D, E. Label the y-axis with the values i.e., number of plants.
5. Scale the Axes: The highest value is 25. Use a scale with intervals of 5 i.e., 0, 5, 10, 15, 20, 25.
6. Draw Bars: For each species, draw a bar up to the corresponding number of plants.
7. Label the Bars: Label each bar with the species name and its value.



KEY POINTS

- Biostatistics is the application of statistical methods to biological sciences.
- Biostatistics helps in designing experiments, analysing data, interpreting results, predicting outcomes, and informing public health policy.
- Mean is the sum of all values divided by the number of values.
- Means provides an overall average, useful for understanding general trends.
- Median is the middle value when data is ordered. If even number of values, the median is the average of the two middle values.
- Median is useful for understanding the middle value, especially with skewed data.
- Mode is the value that appears most frequently.
- Mode highlights the most common value, useful for categorical data analysis.
- Bar charts help compare different categories.

EXERCISE

A. Select the correct answers for the following questions.

1. What is the primary purpose of biostatistics?
   a) To analyse financial data
   b) To apply statistical methods to biological sciences
   c) To design engineering models
   d) To study historical events
2. In biostatistics, which method is used to predict future outcomes based on current data?
   a) Designing experiments
   b) Drawing charts
   c) Taking average
   d) Analysing data
3. Which of the following best describes the mean of a data set?
   a) The most frequently occurring value
   b) The middle value when data is ordered
   c) The sum of all values divided by the number of values
   d) The difference between the highest and lowest values
4. If the data set is 5, 8, 12, 15, 20, what is the median?
   a) 8
   b) 12
   c) 15
   d) 20
5. What is the mean of the data set: 7, 8, 9, 10, 11?
   a) 7
   b) 8
   c) 9
   d) 10
6. When the number of values in a data set is even, how is the median calculated?
   a) By choosing the middle value
   b) By taking the average of the two middle values
   c) By selecting the most frequent value
   d) By adding all values and dividing by the total number of values
7. In a data set with values 3, 3, 6, 7, 8, 9, 9, what is the mode?
   a) 3
   b) 6
   c) 7
   d) Both 3 and 9
8. If a data set has no repeated values, what is the mode?
   a) The highest value
   b) The average of the data set
   c) There is no mode
   d) The median value

9. In a bar chart, what does the height or length of each bar represent?
   a) The total number of categories
   b) The value of the corresponding category
   c) The average of all values
   d) The difference between the highest and lowest values
10. When constructing a bar chart, which axis usually represents the categories?
   a) Vertical axis (y-axis)
   b) Horizontal axis (x-axis)
   c) Both axes equally represent the categories
   d) Neither axis represents the categories

B. Write short answers.

1. Define biostatistics.
2. What is the median of a data set?
3. How is the mean calculated?
4. What does the height of a bar in a bar chart represent?
5. What is the mode of a data set?

C. Write answers in detail.

1. Explain the importance of biostatistics in the field of public health. Provide examples of how it is used to inform public health decisions.
2. Discuss the differences between mean, median, and mode. Include examples where each measure is most appropriate to use.
3. Describe the steps involved in creating a bar chart using Excel. Include a discussion on how to customize the chart for better visualization and interpretation of data.
4. Provide a detailed example of how to calculate the mean, median, and mode of a data set. Use the following data set for your calculations: 12, 15, 22, 8, 19, 25, 15.
5. You are given the following data set, create a bar chart to represent the number of different types of fruits sold at a market in one week:
   - Apples: 30
   - Bananas: 45
   - Oranges: 20
   - Grapes: 25
   - Mangoes: 15

   Ensure to label the axes and provide a title for the chart.

Glossary

A

Active site: A small cleft or depression on the surface of enzyme molecule; location at which catalysis occurs.

Adhesion: The sticking together of molecules of different kinds.

Aerobic respiration: Type of cellular respiration; complete breakdown of glucose molecule in the presence of oxygen.

Alcoholic fermentation: The type of anaerobic respiration in which pyruvic acid is further broken down into ethanol and carbon dioxide.

Anabolism: The set of metabolic processes that involve the synthesis of larger molecules from smaller ones.

Anaerobic respiration: Type of cellular respiration that does not require oxygen.

Anaphase: A phase of mitosis during which the spindle fibres contract and shorten and exert pulling the sister chromatids apart towards opposite poles of the cell.

Anatomy: The branch of biology deals with the internal structure and organization of living organisms.

Amino acids: The building blocks of proteins. 20 different amino acids are commonly found in proteins, each with a unique chemical structure.

Animal husbandry: It concerns with the care, management, and breeding of domestic animals e.g., cattle, sheep etc. for various purposes, such as agriculture, research or conservation.

Animalia: Kingdom that includes eukaryotic multicellular organisms without cell walls. They are heterotroph consumers.

Asexual reproduction: Reproduction that does not involve fusion of gametes; requires a single parent which gives rise to offspring.

ATP, adenosine triphosphate: A nucleotide and a crucial molecule that serves as the primary energy carrier in cells.

B

Binary fission: Method of asexual reproduction in which parent simply divides into two identical offspring; happens in bacteria, some protists, some lower animals.

Binomial nomenclature: The way of giving scientific names to organisms; consists of two names (species name and genus name).

Biochemistry: Branch that deals with the study of chemical processes occurring in living organisms.

Biodiversity: All kinds of organisms found in an area.

Bio-economics: The study of organisms from economical point of view.

Bioenergetics: Study of the energy relationships and energy transformations in biological systems.

Biogeography: The study of the distribution of living organisms in different geographical regions of the world.

Biology: The scientific study of living organisms and their interactions with the environment.

Biomolecules: The molecules produced by organisms; e.g., carbohydrates, lipids, proteins, and nucleic acids (DNA and RNA).

Biostatistics: The study of the principles of statistics which are applicable to biology to analyse and interpret data related to living organisms.

Biophysics: The study of principles and techniques of physics which are applicable to biological phenomena.

Biotechnology: The use of living organisms or their components to produce useful products.

Botany: The field of biology that deals with the study of plants.

Budding: A type of asexual reproduction in which a new organism develops from a small outgrowth or "bud" on the parent.

Bulbs: Modified short underground stems with stored food.

C

Catabolism: The metabolic processes that involve the breakdown of larger molecules into smaller ones.

Cell: The fundamental unit of life.

Cell cycle: The series of events that a cell grows, replicates its DNA, and divides into two daughter cells.

Cell wall: The protective and rigid structure that surrounds the cell membrane of many types of cells, including plant cells, bacterial cells, and fungal cells.

Cell membrane: The coat of lipids and proteins, surrounds and encloses a cell.

Cellular respiration: The oxidation of food (glucose) that occurs in cells to get energy (ATP).

Centriole: Cylindrical (tube-like organelles) composed of microtubules: present in the cells of animals and most protists.

Chiasmata: The complexes formed by the joining (attachment) of two non-sister chromatids of homologous chromosomes during meiosis-I.

Chloroplast: Organelle in the cells of plants and algae where photosynthesis takes place.

Chromatin: The complex of DNA and proteins that makes up a eukaryotic chromosome.

Chromosome: Coiled structure made of DNA and proteins.

Chromoplasts: The plastids that store pigments other than chlorophyll, such as carotenoids.

Class: The taxonomic rank; formed by dividing a phylum/division; consists of a group of related orders.

Classification: The process of organizing and classifying living organisms based on their similarities and differences.

Coenzymes: Cofactors, which are non-protein organic molecules, loosely attached with enzyme; participate in enzyme catalysed reactions.

Cofactor: Non-protein component of enzyme; participate in enzyme catalysed reactions.

Cohesion: The sticking together of molecules of the same kind.

Companion cells: Cells of phloem tissue that provide energy to sieve elements.

Competitive inhibitor: Inhibitor that resembles the substrate and competes with it for the same binding site on enzyme.

Crossing over: The exchange of genetic material between non-sister chromatids during prophase-I of meiosis-I.

Cytokinesis: The division of the cytoplasm.

Cytology: The study of the structure of cells and cell division.

Cytoplasm: The material inside the cell membrane of a cell (excluding organelles).

Cytoskeleton: Filaments and tubules in the cytoplasm that make the internal framework of cell.

D

Dark reactions: Reactions in which carbon from CO_2, energy from ATP, and hydrogen ions from NADPH are used to make sugar molecules.

Deduction: The logical result from a hypothesis; involves using logical reasoning to derive specific consequences from a hypothesis.

Deoxyribonucleic Acid (DNA): The hereditary material present in almost all organisms; a double-stranded molecule composed of nucleotides.

Disaccharides: Carbohydrates that are made from two monosaccharide units; less sweet in tases and less soluble in water.

Domain: The highest level of classification; there are three domains: Bacteria, Archaea, and Eukarya.

Double helix: The form of DNA, referring to its two polynucleotide strands wound into a spiral shape.

E

Ecology: The study of how organisms interact with their environment.

Electron Transport Chain (ETC): Series of electron-transport molecules that pass high-energy electrons from molecule to molecule and capture their energy.

Endodermis: A single layer of cells surrounds the pericycle.

Embryology: The study of the developmental stages of an organism.

Embryo sac: The female gametophyte of angiosperms; consists of eight haploid nuclei; formed from megaspore.

Emergent properties: The properties that arise when the interaction of individual component produce new functions.

Endoplasmic reticulum: A network of interconnected channels that extends from the cell membrane to the nuclear envelope.

Enzymes: Biological catalysts made of proteins that catalyse (i.e. speed up) biochemical reactions without themselves being changed.

Epidermis: The outermost plant tissue; form a protective barrier against the environment.

Erythrocytes (Red blood cells): Blood cells that carry oxygen from the lungs to the body's tissues and transport carbon dioxide back to the lungs for exhalation.

Evolution: The process through which populations and species of organisms change over time.

Excretion: The disposal of nitrogen-containing waste products from the body.

F

Family: Taxonomic rank formed by the division of an order.

Fatty acids: Building blocks of lipids; consist of a long hydrocarbon chain with a carboxyl group at one end.

Fertilization: The union of haploid gametes to produce a diploid zygote.

Fungi: Eukaryotic, multicellular (mushrooms and molds) or unicellular (yeasts) heterotrophs which obtain nutrients by absorbing organic matter from environment.

G

Gamete: A haploid cell, such as an egg or sperm. Gametes unite during sexual reproduction to produce a diploid zygote.

Gap 1 (G1) Phase: The first phase of the interphase; phase of extensive metabolic activity and growth, increases in number of organelles.

Gap 2 (G2) Phase: The phase of interphase in which cell continues to grow and prepares proteins essential for mitosis.

Genetics: The study of genes, heredity and variation in living organisms.

Gene: A discrete unit of hereditary information consisting of a specific nucleotide sequence in DNA (or RNA, in some viruses).

Genus: The taxonomic rank formed by the division of a family; a genus is a group of related species.

Glycerol: An alcohol having 3 carbon atoms. Each carbon has a hydroxyl group.

Glycolysis: First stage of cellular respiration in which glucose is split into two molecules of pyruvate (pyruvic acid).

Golgi apparatus: Organelle in eukaryotic cells that processes proteins and prepares them for use both inside and outside cell.

Grana (singular, granum): Structures in chloroplast, consist of sac-like membranes, known as thylakoids.

Guard cells: Bean-shaped cells in the epidermis of leaves; two guard cells surround a stoma.

H

Histology: The microscopic study of tissues of living organisms.

Homeostasis: The ability to maintain the internal conditions constant.

Homologous chromosomes: Chromosome pairs of the same length and centromere position that possess genes for the same characters.

Horticulture: Science that deals with gardening.

Human Genome Project: An international collaborative effort to map and sequence the DNA of the entire human genome.

Hydrophytes: The plants which live in freshwater.

Hypothesis: Tentative statement that may be the answer of the scientific problem.

I

Immunology: The study of the immune system of animals, which protects the body against infections, diseases, and other harmful substances.

Inhibitor: Chemical that interferes and blocks an enzyme's activity.

interphase: The phase of cell cycle during which the cell is not dividing but it carries out its normal functions like it grows in size, and prepares for cell division.

K

Karyokinesis: The division of a nucleus.

Kingdom: Taxonomic rank formed by the dividing a domain; e.g., Animalia, Plantae, Fungi, Protista.

Kreb's cycle: Second stage of aerobic respiration in which two pyruvic acid molecules are broken to make ATP, NADH and $FADH_2$.

L

Lactic acid fermentation: The type of anaerobic respiration in which pyruvic acid is converted into lactic acid.

Leucoplasts: Plastids that have no pigments; involved in the storage of starches, lipids, and proteins.

Light reactions: First stage of photosynthesis in which light energy from the sun is captured and changed into chemical energy that is stored in ATP and NADPH.

Lysosome: Spherical membrane-bounded organelle: contain digestive enzymes.

M

Macronutrients: Mineral nutrients that plants need in relatively large amounts.

Marine biology: The study of organisms, ecosystems, and processes in oceans.

Mesophyll cells: Cells in leaves; responsible for photosynthesis.

Messenger RNA (mRNA): A type of RNA, synthesized from DNA; attaches to ribosomes and specifies the primary structure of a protein.

Mesophytes: The plants that live in land habitats with moderate supply of water.

Meiosis: The type of cell division in which the number of chromosomes in daughter cells is reduced to half as compared to the parent cell.

Metabolism: The sum of all chemical reactions taking place within a cell in order to maintain life.

Microbiology: The study of microorganisms such as bacteria and microscopic fungi etc.

Microfilament: Part of cytoskeleton, solid rods made of actin protein.

Micronutrients: The nutrients that are needed by plants in very small amounts.

Microtubule: Part of cytoskeleton, hollow cylinder made of tubulin protein.

Mitochondria: Organelles in eukaryotic cell that makes energy available to the cell in the form of ATP.

Mitosis: The type of cell division in which the daughter cells have the same number of chromosomes as were present in the parent cell.

Molecular biology: The study of the structure and function of macromolecules (e.g., carbohydrates, proteins, nucleic acids).

Monosaccharides: The simplest carbohydrates and consist of a single sugar molecule.

Morphology: The study of the size, shape, and structure of living organisms.

N

Neuron: A nerve cell; the fundamental unit of the nervous system, having structure and properties that allow it to conduct signals.

Non-competitive Inhibitor: Inhibitor that has no structural similarity to substrate; it binds the enzyme outside the active site and alters the shape of enzyme.

Non-disjunction: The failure of chromosome pairs or sister chromatids to separate properly during cell division; results in an abnormal number of chromosomes (aneuploidy)l daughter cells.

Nuclear envelope: Double membrane that encloses the contents of the nucleus.

Nucleoid: A dense region of DNA in a prokaryotic cell.

Nucleolus: Darkly stained structure in nucleoplasm; manufactures the subunits of ribosomes.

Nucleoplasm: Semi-fluid matrix found inside the nucleus.

Nucleus: Organelle inside eukaryotic cells that contains acts as a control centre of the cell.

O

Organ: Structure made up of more than one type of tissues having related functions that work together.

Organ system: A collection of different organs that work together to perform a related function.

Organelles: Components of a cell e.g., mitochondria, ribosomes, lysosomes.

Ovary: (1) In flowers, the portion of a carpel in which the egg-containing ovules develop. (2) In animals, the structure that produces female gametes.

P

Palaeontology: The study of fossils.

Palisade mesophyll: The mesophyll located just beneath the upper epidermis; consists of tightly packed cells, is rich in chloroplasts; primary site of photosynthesis.

Pathology: The study of diseases caused by microorganisms such as bacteria, viruses, fungi etc.

Pharmacology: The study of drugs and their effects on the body.

Phloem: Vascular tissue in higher plants; transport food from where it is produced or stored to other parts of the plant.

Photosynthesis: The process in which carbon dioxide and water combine to make glucose in the presence of sunlight and chlorophyll.

Phragmoplast (cell plate): The dividing plate formed during cytokinesis in plant cells; formed by the fusion of small vesicles from Golgi apparatus.

R

Rhizomes: Underground stems that grow horizontally; have scale leaves.

Ribonucleic Acid (RNA): Type of nucleic acid that serves as a messenger between DNA and ribosomes during protein synthesis.

Ribosomal RNA (rRNA): A type RNA; makes the structure of ribosomes.

Rough Endoplasmic Reticulum: Endoplasmic Reticulum covered with ribosomes, involved in the production and processing of proteins.

S

Saturated fatty acids: fatty acids which have no double bonds between carbon atoms.

Scientific method: A systematic approach used by scientists to investigate and understand nature.

Sexual reproduction: Type of reproduction that involves the fusion of gametes.

Sieve elements: Cells of phloem tissue that transport food.

Smooth Endoplasmic Reticulum: Endoplasmic reticulum that lacks ribosomes; involved in production of lipids, carbohydrate metabolism, and detoxification.

Species: A group whose members possess similar anatomical characteristics and have the ability to interbreed.

Speciation: The process by which new species arise from existing ones.

Sperm: The male gamete.

Spongy mesophyll: Mesophyll present below the palisade layer; consists of loosely arranged cells with air spaces between them.

Substrates: The molecules that undergo a chemical reactions catalysed by enzymes.

Synapsis: The pairing of homologous chromosomes during meiosis-I.

Synthesis phase or S phase: Phase of interphase of cell cycle in which DNA replication occurs.

Sympatric Speciation: A type of speciation that occurs when a new species arises within the same geographical area without geographic isolation.

T

Taxonomy: The study of the naming and classification of organisms into groups and subgroups based on their similarities and differences.

Telophase Phase of mitosis; marks the completion of the separation of the duplicated chromosomes.

Tetrad: The bivalent made of two homologous chromosomes (four chromatids).

Theory: The hypotheses that stand the test of time (often tested and never rejected).

Thylakoid: The inner membrane in a chloroplast where the light reactions of photosynthesis occur.

Tissue: A group of similar cells that work together to perform a specific function.

Transcription: The synthesis of RNA on a DNA template.

Transfer RNA (tRNA): A type of RNA that transfers specific amino acids to the ribosomes during protein synthesis.

Translation: The synthesis of a polypeptide using the genetic information present on mRNA molecule.

Transpiration: The loss of water from plant surface through evaporation.

U

Unsaturated fatty acids: The fatty acids which have one or more double bonds between carbon atoms.

V

Vacuole: Sac-like organelle that stores and transports materials inside a cell.

X

Xerophytes: The plants that live in dry conditions

Xylem: Vascular tissue responsible for transporting water and minerals absorbed by the roots from the soil to the rest of the plant.

Z

Zoology: The field of biology deals with the study of animals.

Zygote: The diploid product of the union of haploid gametes; a fertilized egg.