Based on National Curriculum of Pakistan 2022-23

Model Textbook of

Biology

Arfah Nadeem
9A
APS Murree Rd RWP

Grade

9

National Curriculum Council
Ministry of Federal Education and Professional Training





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A Model Textbook of Biology for Grade 9

based on National Curriculum of Pakistan (NCP) 2022-23

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Preface

This Model Textbook for Biology Grade 9 has been developed by NBF according to the National Curriculum of Pakistan 2022-2023. The aim of this textbook is to enhance learning abilities through inculcation of logical thinking in learners, and to develop higher order thinking processes by systematically building the foundation of learning from the previous grades. A key emphasis of the present textbook is creating real life linkage of the concepts and methods introduced. This approach was devised with the intent of enabling students to solve daily life problems as they grow up in the learning curve and also to fully grasp the conceptual basis that will be built in subsequent grades.

After amalgamation of the efforts of experts and experienced authors, this book was reviewed and finalized after extensive reviews by professional educationists. Efforts were made to make the contents student friendly and to develop the concepts in interesting ways.

The National Book Foundation is always striving for improvement in the quality of its textbooks. The present textbook features an improved design, better illustration and interesting activities relating to real life to make it attractive for young learners. However, there is always room for improvement, the suggestions and feedback of students, teachers and the community are most welcome for further enriching the subsequent editions of this textbook.

May Allah guide and help us (Ameen).

Murad Ali Mohmand
Managing Director

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UTILITY OR PRACTICAL APPLICATIONS OF THE SUBJECT

1.The Science of Biology: This field studies science's underlying assumptions and its methodologies. This involves some integrated study of history, philosophy and sociology of science. The science of biology promotes curiosity, inquiry, creativity, inquiry, critical discussion and collaboration.

2. Biological Molecules: like proteins, carbohydrates, lipids and nucleic acids form the foundation of life sciences and are essential in understanding the body structure (anatomy) and functions (Physiology). Knowledge of biological molecules help the students to understand the role of nutrients, leading to better awareness of healthy eating habits, nutrition and their impact on physical and mental health. Biological molecules help bridge the gap between chemistry and biology. Exposure to biological molecules inspire students to pursue their careers in medicine, biochemistry, biotechnology, and related fields.

3. Cell: Studying the cell is foundational for biology students because cells are the basic structural, functional, and biological units of all living organisms. Understanding cells helps students grasp how life operates at a molecular and biochemical level.

Cells contain various organelles and structures, each with a specific role, like the nucleus for genetic material, mitochondria for energy production, and ribosomes for protein synthesis. By studying cells, students learn how these structures work together to sustain life. Cell biology is the gateway to more specialized areas like genetics, immunology, molecular biology, and physiology. A strong understanding of cell function equips students to tackle complex biological questions in advanced studies and research. Knowledge of cell biology is critical for biotechnological applications, such as developing vaccines, gene therapy, stem cell therapy, and other biomedical innovations. By studying cells, biology students build a foundation that is crucial for any further study of life sciences, medicine, and biotechnology.

4. Tissue, Organ and Organ System: Learning about tissues, organs and organ systems is necessary to grasp the concept of emergent properties at each level of organization. All these organ systems work together to maintain a constant suitable environment in the body.

5. Cell Cycle: Cells undergo division (mitosis and meiosis), which is crucial for growth, development, and reproduction. Learning these processes helps students understand organismal development and genetic inheritance.

6.Biodiversity: The application of biodiversity is that humans depend upon biodiversity for survival, such as for, medicines we use to stay healthy, and materials we wear or use to build our homes. Without a wide range of animals, plants and microorganisms, we cannot have the healthy ecosystems that we rely on to provide us with the air we breathe and the food we eat.

7. Metabolism: Enzymes are important because they are biological catalysts and are essential for understanding how reactions occur in living organisms. Enzyme play a central role in all biochemical reactions. Enzymes lower the activation energy needed for reactions thus guide us how organisms conserve energy and survive with even lower energy. Understanding enzymes is the basis for learning about metabolic diseases, drug actions and diagnostics. Study of enzymes

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includes experiments to see enzyme activity in practical lab measuring reaction rates and understanding variables. Why enzyme are inhibited and factors affecting enzyme activity help the students understand the control complex biochemical pathways.

Bioenergetics explains how energy flows through living systems, especially in processes like photosynthesis and cellular respiration. Bioenergetics involves understanding that how organisms transform energy from food or sunlight into usable forms, linking biology with chemistry and physics. Photosynthesis is important for survival of life as it provides food ad oxygen to all life forms. Cellular respiration is important for production of useable energy currency ATP for all cell activities.

8. Plant Physiology: The study of plant physiology has numerous practical applications in agriculture, horticulture, and environmental management. It helps in selecting appropriate fertilizers to promote healthy growth and maximize crop yield. It helps with effective irrigation practices, reducing water waste and optimizing plant health. It allows for improved crop management, especially in challenging climates or during dry seasons. Additionally, insights into plant adaptations for gaseous exchange and excretion aid in maintaining soil quality and enhancing air quality indoors. Overall, plant physiology knowledge supports sustainable farming, effective gardening, and resource conservation, contributing to food security and environmental management.

9.Plant Reproduction: Understanding various reproduction methods, including natural and artificial asexual reproduction and sexual reproduction in plants, has valuable applications in agriculture, horticulture, and biotechnology. Techniques like vegetative propagation, parthenogenesis, and cloning enable efficient crop production, plant breeding, and preservation of desirable traits. This knowledge supports sustainable practices, enhances food security, and contributes to advancements in genetic research

10: Evolution: Learning evolution prepares students for careers in science, medicine, and conservation, and helps them make informed decisions about health, environment, and technology. It's like unlocking a secret to understanding life itself.

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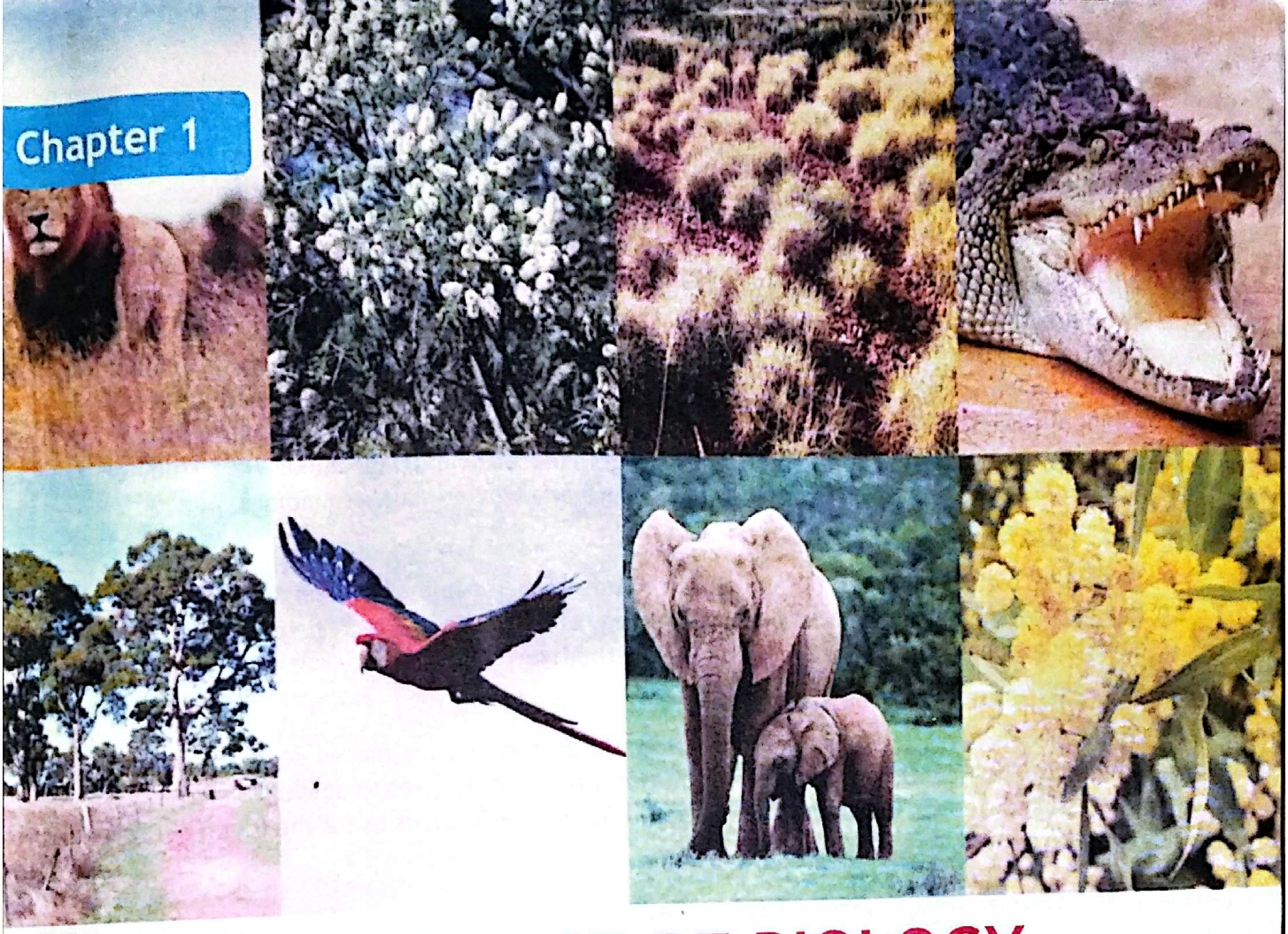
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Chapter 1



THE SCIENCE OF BIOLOGY

SLOs: After completing this lesson, the student will be able to:

1. Define biology
2. State Quran instructs to reveal the study of life.
3. Define major fields of biology as Botany, Zoology and Microbiology
4. Define with examples that biology has many sub-fields: Morphology, Anatomy, Physiology, Histology, Cytology, Genetics, Molecular biology, Embryology, Paleontology, Taxonomy, Ecology, Marine biology, Pathology, Immunology, Pharmacology.
5. Relate that biology connects with other natural sciences. Students should be able to distinguish in terms of the broad subject matter of the given fields: Biophysics, Biochemistry, Computational biology, Biogeography, Biostatistics, Biotechnology, Bio-economics.
6. Identify the careers in biology and explain with examples how biology is a subset of the natural sciences.
7. Justify with examples that science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas.
8. Describe the steps of the scientific method: Recognition, Observation, Hypothesis, Deduction, Experiments, and Results.
9. Evaluate the terms 'hypothesis', 'theory' and 'law' in the context of research in natural sciences.

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Among all the living organisms human beings are the most intelligent ones. By using their intelligence human beings started learning and this learning lead to development of science.

1.1 INTRODUCTION TO BIOLOGY

What is science? When you look at the plants you observe leaves and flowers. You wonder 'why are the leaves green? Why are the flowers of various colours? Asking this type of question is the first step to ask science. Science is a process of collecting information about the world around us. Much of the time, the first step in collecting information is asking a question. Why do I feel pain when I touch a hot object? Making observations, asking questions and trying to find the answers is what science all about. The study of science helps us to answer the how, what, where and why of our surroundings.

1.1.1 Definition of Biology

The word biology consists of two Greek words *bios* meaning life and *logos* meaning thought, reasoning and study. Biology is the study of living organisms. It helps us to explain how living things relate to one another and to their surroundings.

1.1.2 Quranic Instructions to Reveal the Study of Life

What science is discovering today, the Holy Quran has already hinted several hundred years ago, The Holy Quran is a book for all times to come. It gives us spiritual, moral and practical knowledge. There are many verses in Quran which tell us about the origin of life. Some are quoted here;

1. Origin of Life in Water

وَجَعَلْنَا مِنَ الْمَآءِ كُلَّ شَيْءٍ حَيٍّ

"We made every living thing from water"

(Sura Ambia 21, Ayat-30)

As we know that living things consists of 60 to 90 percent of water. So all living things have come out of water and thus they have a common origin.

2. Creation of Man

خَلَقَ الْإِنْسَانَ مِنْ صَلْصَالٍ كَالْفَخَّارِ

"He created man from clay like (that of) pottery"

(Sura Rehman 55, Ayat 14)

Creation of man consisted of two steps. The first step was the creation from water. The second step was to mix clay with water to create man. It can be said for all animals as man shares all characteristics of life with other animals.

3. Development

ثُمَّ خَلَقْنَا النُّطْفَةَ عَلَقَةً فَخَلَقْنَا الْعَلَقَةَ مُضْغَةً فَخَلَقْنَا الْمُضْغَةَ عِظٰمًا

فَكَسَوْنَا الْعِظٰمَ لَحْمًا

"Then fashioned we the drop a clot, then fashioned we the clot a little lump, then fashioned we the little lump bones, then clotted the bones with flesh,"

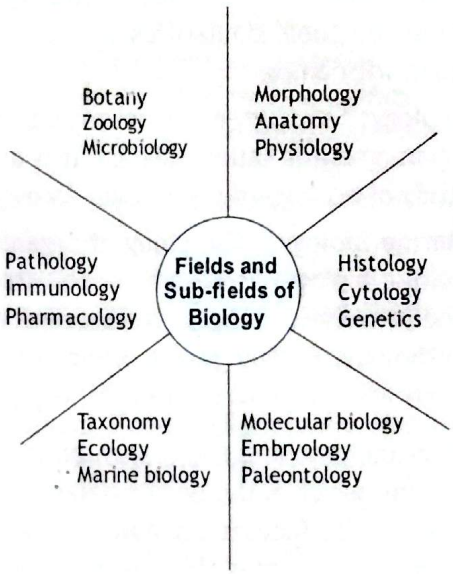
(Sura Al-mominoon 23, Ayat 14)

The sequence of developmental stages is described in Quran many times.

Muslim Scientists have made great contribution to the field of biology. The knowledge of Jabir Bin Hayyan, Abdul Malik Asmai and Bu Ali Sina have contributed a lot in the development of present-day knowledge of plants and animals.

1.2 MAJOR FIELDS OF BIOLOGY

Biology has three main divisions: Botany, Zoology and Microbiology. **Botany** is the study of plants, e.g., fern, pine, apple, rose, and mango etc. **Zoology** is the study of animals, e.g., fish, frog, lizard, parrot and cat etc. **Microbiology** is the study of micro-organisms e.g., viruses, bacteria etc.



By dividing biology into a number of sub-fields its study becomes convenient. Some of the sub-fields of biology are:

1. **Morphology:** The study of the size, shape, and structure of animals, plants, and microorganisms is called morphology. For example, the morphology of a flowering plant includes the roots, stem, leaves, flowers, and fruits. Dental structure in humans is an example of human morphology.
2. **Anatomy:** The study of the internal structure of organisms is called anatomy. It is also called internal morphology. The examples of anatomy include human body parts such as muscles, heart, brain, and kidneys etc.
3. **Physiology:** The branch that deals with the study of functioning of different parts of living organisms is called physiology. The examples of physiology are digestion, respiration, excretion, photosynthesis etc.
4. **Histology:** The microscopic study of tissues of organisms is called histology. The example is epithelial tissue that form a continuous layer covering the entire body surface.
5. **Cytology:** The study of the structure and functions of the cell and cell organelles is called cytology. It is also called cell biology. For example, the study of plant and animal cells.
6. **Genetics:** The study of genes and their role in inheritance means transmission of characteristics from one generation to another. For example. The plants having red flowers produces red flowers the white cats produce white kittens.

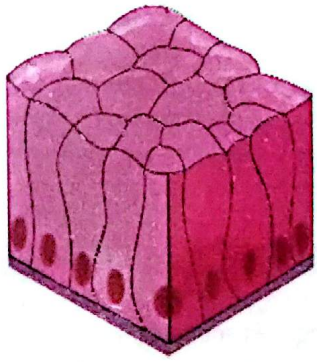


Fig 1.1. Epithelial tissue

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7. **Molecular biology:** Molecular biology is a branch of biology that focuses on understanding the structure and function of molecules that make up living organisms. It mainly studies how DNA, RNA, and proteins work together to control the activities of cells e.g., protein synthesis.
8. **Embryology:** Embryology is the branch of biology that studies the development of an organism from the fertilization of the egg to the formation of a fully developed organism.
9. **Palaeontology:** Paleontology is the study of fossils and ancient life forms that lived on Earth millions of years ago.
10. **Taxonomy:** It is the study of classifying living things into groups based on their similarities and differences and assigning them scientific names.
11. **Ecology:** The study of the interrelationship of organisms and their environment is called ecology. It is also known as environmental biology. For example the study of ecology of pond, lake, forest, desert etc.
12. **Marine biology:** The study of organisms that live in sea is called marine biology. For example, the study of fish, whales, dolphins, and porpoises, sponges, crustaceans, and molluscs etc.
13. **Pathology:** Pathology is a branch of science which deals with the study and diagnosis of diseases, e.g., study of malaria, COVID-19.
14. **Immunology:** It is the branch of science that studies the immune system, which is the body's defence system against infections and diseases. It focuses on how the body recognizes and fights off harmful substances, like bacteria and viruses, and how vaccines work to protect against illnesses e.g., prevention of polio through vaccination.
15. **Pharmacology:** The branch of science that deals with study of drugs, its interaction with the body and how they can be used to treat diseases. It involves understanding the effects of medications, their mechanisms of action and how they are absorbed, distributed, and eliminated in the body.

Fossils are the preserved remains or traces of ancient plants and animals that lived long ago shown in figure 1. 2; They can be bones, teeth, shells, or even imprints like footprints. Which have turned into rock over millions of years. Fossils help scientists learn about life in the past.



Fig 1.2: Fossils

The word pharmacology is derived from Greek word, pharmakon, meaning "drug" or "poison", together with other Greek word logos with the meaning of "study of" or "knowledge of"

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1.3 RELATIONSHIP OF BIOLOGY WITH OTHER SCIENCES

Biology is considered an interdisciplinary science, which is related to other sciences. Therefore, it is a multidimensional subject. The best example to support this is, the movement of animals that follows the laws of motion in physics. So biology is not an isolated science and is associated with other branches of science such as biophysics, biochemistry, biometry, computational biology, biogeography, biotechnology and bio-economics.

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Table 1.1 Relationship of Biology with Other Sciences	
Biophysics	The interrelationship among different branches of science cannot be denied. Biology gives information on various aspects of living things but this information relates to other branches of science as well. For example, when studying the process of movement in animals, the biologists have to refer to the laws of motion in physics.
Biochemistry	This branch of science that explores the chemical processes and substance that occur within living organisms. It combines principles from both biology and chemistry to understand how molecular structure such as proteins, lipids, carbohydrates, and nucleic acids function and interact to support life. It covers topics such as metabolism, enzyme function, genetic expression, cell signaling, and energy production, providing a molecular understanding of biological system.
Biostatistics/biometry	Statistics deals with the collection, analysis, interpretation, presentation, and organization of data. The application of statistical methods to analyze and interpret data in biological, medical, and public health contexts is biostatistics. It involves designing experiments, collecting data, and using statistical techniques to draw inference and make decisions about biological phenomena.
Computational biology	The study of the use of data analysis, mathematical modeling, and computational technique to understand biological system is called computational biology. For example, the process of locating fragments of DNA on chromosomes.
Biogeography	The study of distribution of plants and animals in different geographical regions of the world is called biogeography. For example, camel originated in North America and migrated to other parts of the world.
Biotechnology	The study of use of different techniques to manipulate the living organisms for the benefit of mankind is called biotechnology for example genetic engineering to manipulate DNA for forensics,
Bio-economics	The study of biology from economic point of view is called bio-economics. Production of wheat, fish, rice and studying their export value etc., are the examples of bio-economics.

Reading topic

1.4. CAREERS THAT REQUIRE A BACKGROUND IN BIOLOGY

After studying biology at secondary and higher secondary level a person has to select a career or profession. Pursuing a career in biology can be immensely rewarding and exciting. There are several applied fields in biology that you can select as a career e.g., medicine, surgery, fisheries, agriculture, animal husbandry, biotechnology, horticulture, farming and forestry etc.

Table 1.2 Careers That Require a Background in Biology	
Medicine and surgery	MBBS stand for bachelor of medicine and bachelor of surgery. Medicine is the diagnosis and treatment of different diseases. Surgery is the branch which treats diseases by removal, or replacement of the defective parts or organs. After MBBS a student can specialize in various fields of medicine and surgery.
Fisheries	Fisheries is the professional study of fish production. It makes a significant contribution to the economy of Pakistan. Careers associated with it are fish farming, fishery management and related research.

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Farming and Agriculture	Agriculture is the practice of growing crops and raising animals to provide food, materials, and other resources for people. It also uses technology to improves crop, livestock production. Farming is the specific activity within agriculture where people plant crops and care for animals on farms. It involves planting seeds, taking care of plants, and managing livestock. Careers associated with agriculture and farming are food sciences, agricultural engineering, agricultural entomology etc.
Animal Husbandry	Animal husbandry is the care and breeding of domestic animals. The careers associated with animal husbandry are veterinary science, animal breeding, animal training etc.
Biotechnology	Biotechnology is the use of living organisms, cell, or biological processes to develop products and technologies that benefit people. The careers associated with biotechnology are bacteriology, virology, molecular genetics etc.
Horticulture	Horticulture means the art of gardening. The careers involved are plant breeding, horticulture etc.
Forestry	It is the science of planting, managing and caring for forests. The careers related to forestry are forest ecology, environmental engineering etc.

Reading topic

1.5 SCIENCE IS A COLLABORATIVE FIELD

Science is profoundly a collaborative field as it allows researchers to combine knowledge from various fields, such as biology, physics, and chemistry, to solve complex problems.

Interdisciplinary collaboration involves the partnership of individuals or teams from different academic disciplines working together to address complex problems. For example, climate change research often involves meteorologists, biologists, chemists, and social scientists working together to understand its impacts and develop solutions.

Scientists often share tools, equipment, and data to enhance research efficiency and outcomes. Scientific process includes peer review, where researchers evaluate each other's work to ensure quality and validity. This process encourages constructive feedback and collaboration, leading to improved research methodologies and findings.

Bioinformatics is a combination of biology and information technology. It helps to understand complex biological data. The new emerging careers of biology are bioinformaticians (apply their computer skills in solving problems in life science), biomedical engineers (develop new devices and equipment for improving human health), Astrobiologists (study effects of outer spaces on living organisms), Cryobiologists (study of effects of low temperature on living organisms) etc.

Many scientific breakthroughs are achieved through teamwork to bring together diverse skills and perspectives, leading to innovative approaches and solutions. For example, large-scale projects like the Human Genome Project involved thousands of scientists from multiple institutions working together to map human DNA. Researchers from different countries work together to share knowledge, resources, and expertise, making collective progress possible for global collaboration.

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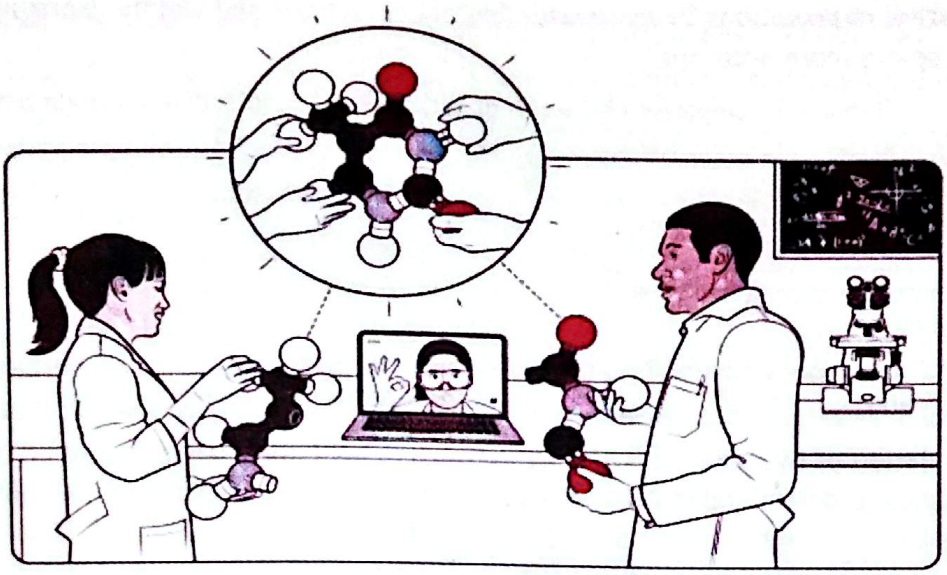


Fig.1.3. Collaboration in science

STEAM ACTIVITY 1.1

Topic: CLIMATE CHANGE

The teacher will divide the students into three groups. Each group may comprise of 3-5 students, and give each group different subtopics related to climate change. The students will investigate and research on the topics given.

Group 1: Causes of climate change.

Group 2. Effects of climate change.

Group 3. To overcome the problem of climate change.

The students will be given five days to prepare their research work.

Each group will read their research paper in the classroom before the students.

Then the teacher will ask each group to work together and prepare a joint research paper on 'Climate change' and submit.

1.6 SCIENTIFIC METHOD

The scientific method is a process for establishing facts through experimentation and testing. It involves making observations, forming a hypothesis, conducting an experiment, and analysing the results. Here are the steps of the scientific method:

1. Recognition of a problem
2. Observation
3. Building up hypothesis
4. Drawing deductions
5. Devising experiment
6. Inferring result

1. Recognition of problem: Biological problem is a question related to living organisms. This question is either asked by someone or comes in mind of a researcher.

2. Observations: Observations are very important step in solving a scientific problem. Observations are made with five senses i.e., vision, hearing, smell, taste and touch. Observations are of two types:

Qualitative observations are based on some quality or characteristic.

Quantitative observations are based on measurable value.

Quantitative observations being measurable are invariable and can be expressed in terms of number, so are more accurate.

Table 1.3 Comparison between qualitative and quantitative observations	
Qualitative observations	**Quantitative observations**
1. Subjective method.	1. Objective method.
2. Characteristics of things.	2. Quantify things.
3. Not accurate and not measurable kind of observations.	3. Accurate and measurable kind of observation.
4. Use of five senses such as sight, smell, touch and hearing.	4. Use of measuring instruments such as rulers, balance, scale etc.

3. Formulation of hypothesis: Hypothesis is a statement that may prove to be the answer of the biological problem under study. Hypothesis is a tentative explanation of the observations that might be true. A hypothesis should have following characteristics;

a. It should be a general statement.
b. It should be tentative idea.
c. It should agree with the available observations.
d. It should be testable and potentially falsifiable.

4. Deductions: Deductions are the logical consequences of the hypothesis. To draw deductions hypothesis is taken as true. Deductions involve "if" and "then" logic.

5. Experimentation: It is the most important step of biological method. Experiments are performed to prove if hypothesis is true or not. The deductions drawn from the hypothesis are subjected to accurate testing. Through experimentation, biologist learns which hypothesis is correct.

6. Summarization of the results: The biologist gathers actual quantitative data from experiments. This data arranged to draw results.

1.7 HYPOTHESIS, THEORY AND LAW

A hypothesis is a tentative answer to a question. It is based on past experience and the available data. A scientific hypothesis makes prediction that can be tested by recording additional observations. In deduction-based science, deduction usually takes the form of predictions about what outcomes of experiments or observations. We should expect if a particular hypothesis is correct, we then test the hypothesis by performing the experiment to see whether or not the results are predicted. This deduction reasoning takes the form of 'if...then' logic.

Theory

What is a scientific theory and how it is different from a hypothesis? A scientific theory is much broader in scope than a hypothesis. Compared to any one hypothesis, a theory is generally supported by more evidence.

In spite of the body of evidence supporting a widely accepted theory, scientists must sometimes modify or even reject theories when a new research method produce results that do not fit.

A theory that has been verified and appears to have wide application may become biological law for example, Mendel's law of inheritance.

The collection of facts or information is called data. First data is collected then data is organized by using techniques such as tables and graphs. To predict on the basis of data is called **analysis**. Analysis of data is done by means of ratio and proportion.

What is theory? When hypothesis tested again and again never rejected then it became theory.

1.8 MALARIA AN EXAMPLE OF BIOLOGICAL METHOD OF STUDY

Malaria has killed more people than any other disease. The malaria is an example of a biological problem. How such problems can be solved?

Symptoms of Malaria: The patient of malaria feels very chill and cold. His temperature rises above normal value of 98.6°F. The patient suffers from headache and has feeling of nausea. After some time, the person begins to sweat, feels better. The whole series of events are repeated after every 24, 48 or 72 hours depending upon the species of *Plasmodium*.

1. Cause of malaria

By adopting the steps of biological method, it was proved that malaria is caused by *Plasmodium*.

Recognition of the problem: Malaria was a problem since ancient times, but its cause was not known.

Observations: In 19th century, many different causes of malaria were being suggested. By that time, there were four major observations about malaria.

a. Malaria and marshy areas have some relation.
b. Quinine is an effective drug for treating malaria.
c. Drinking the water of marshes does not cause malaria.
d. *Plasmodium* is seen in the blood of a malarial patient.

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Hypothesis: Based on these observations and other information, following hypothesis was formulated by a French physician Laveran in 1882.

"*Plasmodium* is the cause of malaria".

Deduction: Although hypothesis is a tentative idea, to draw deductions it is accepted to be true. One of the deductions from the above hypothesis was;

"If *Plasmodium* is the cause of malaria, then all persons ill with malaria should have *Plasmodium* in their blood"

Experiments: This deduction was tested through experiment. Experiment was designed as;

Blood of 100 patients was examined under microscope. For the purpose of having control group, the blood of 100 healthy persons was also examined under microscope.

Results: The results of experiments showed that almost all malarial patients had *Plasmodium* in their blood. Only 07 out of 100 healthy persons had *Plasmodium* in their blood. Other 93 healthy persons were without any trace of *Plasmodium* in their blood.

In the 07 healthy persons with *Plasmodium* in their blood, *Plasmodium* was in incubation period. The incubation period is time between the entry of parasite in the host and the appearance of the symptoms of disease. After few days those 07 healthy persons became ill with malaria.

Results were quite convincing to prove the hypothesis that "*Plasmodium* is the cause of malaria"

Reporting the results: Results of these experiments were announced worldwide which helped to control malaria.

2. Spread of malaria

Biological method helped to find that mosquitoes spread malaria.

Recognition of the problem: Malaria is a fatal disease since ancient times. After the confirmation that malaria is caused by *Plasmodium*, it was important to find how *Plasmodium* gets into the blood of man. This disease was more common in areas near stagnant water ponds where mosquitoes breed. It was found that;

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a. Malaria is associated with marshes.
b. Drinking water of marshes does not cause malaria.

From these points, it can be concluded that *Plasmodium* was not present in the marshy water. So *Plasmodium* must be carried by something that comes to marshy water. Problem in this study was to find that agent.

Observations: An American scientist A. F. A. King listed 20 observations in 1883 about spread of malaria. Some important observations were;

a. People who slept outdoors were more likely to get malaria than those who slept indoors.
b. People who slept under fine nets were less likely to get malaria than those who did not use such nets.
c. People who slept near smoky fire usually did not get malaria.

Hypothesis: On the basis of these observations King suggested a hypothesis;

"Mosquitoes transmit *Plasmodium* so are involved in the spread of malaria"

Deductions: Following deductions were made considering the hypothesis true.

Deduction I: "*Plasmodium* should be present in mosquito".

Deduction II: "A mosquito can get *Plasmodium* by biting a malarial patient".

Experiments: In order to test the above deductions, many experiments were performed.

Experiments of Ronald Ross: Ross, a British army physician working in India performed an important experiment in 1897.

He allowed a female *Anopheles* mosquito to bite a malarial patient. He killed the mosquito some days later and found *Plasmodium* multiplying in mosquito's stomach.

Next Ross used sparrows in his experiments. He allowed female *Culex* mosquitos to bite the sparrows suffering from malaria. He then allowed these mosquitoes to bite healthy sparrows. After few days these sparrows became ill with malaria.

In the end, the hypothesis was tested by direct experimentation on human beings. An Italian biologist allowed an *Anopheles* mosquito to bite a malarial patient. The mosquito was kept for few days and then it was allowed to bite a healthy man. The person later became ill with malaria.

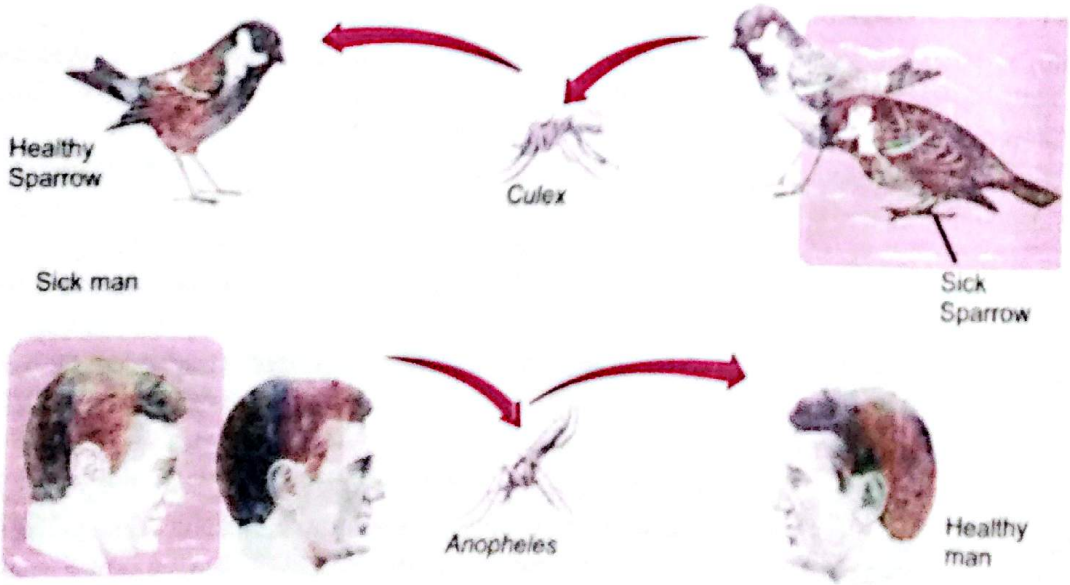


Fig. 1.4: Malaria in man is transmitted by *Anopheles* and in birds by *Culex*

Results: All these experiments confirmed that mosquito transmit *Plasmodium* and spread malaria.

When a female mosquito pierces the skin with the mouthparts, a small amount of saliva is injected into the wound before drawing blood. The saliva prevents the blood from clotting in the food canal of the mosquito.

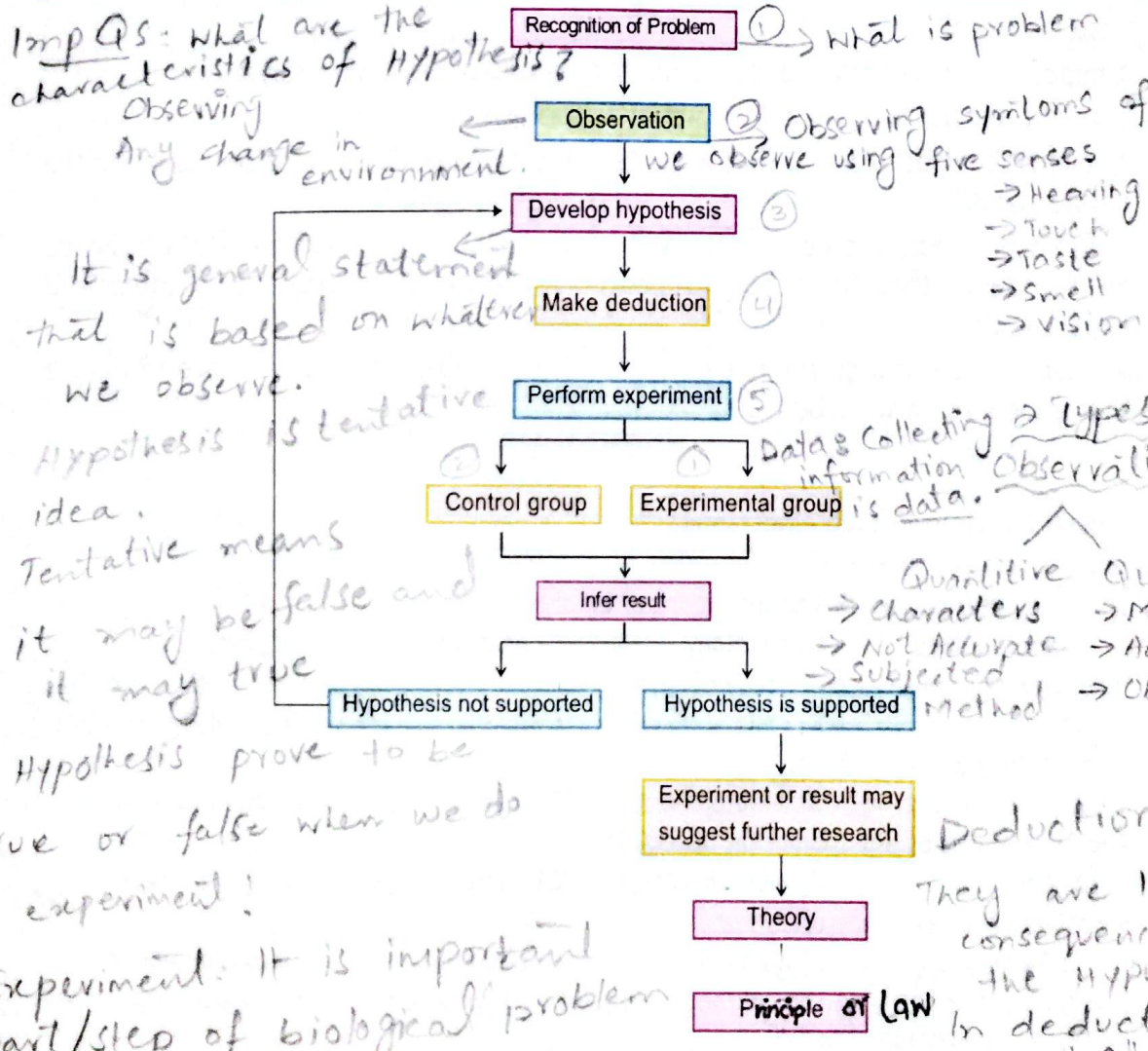
The word vector means transmitter. Any organism which carries a parasite and transfers it from one organism to another is called vector.

Dengue Fever



It is caused by a Dengue virus and is transmitted by mosquito *Aedes aegypti*, which has zebra like white and black stripes on its body. Typical case of Dengue haemorrhage fever is characterized by high grade fever, bleeding from nose, blood in urine and enlarged liver etc. There is no specific antiviral drug available for the treatment of patients suffering from Dengue fever. The second attack can be more serious and dangerous. The best prevention is personal protection from mosquito bite and measures to prevent mosquito breeding.

Imp Qs: What are the characteristics of Hypothesis?



Observing → Any change in environment.

Observation → Observing symptoms of problems. we observe using five senses → Hearing → Touch → Taste → Smell → vision

Recognition of Problem → What is problem

It is general statement that is based on whatever we observe.

Hypothesis is tentative idea.

Tentative means it may be false and it may true

Hypothesis prove to be true or false when we do experiment!

Data & Collecting information is data. → Types → Observations

Quantitive → characters → Not Accurate → Subjected method

Qualitive → Measurable → Accurate → Objective method

Deductions: They are logical consequences of the hypothesis. In deduction we use "if" and "then"

Experiment: It is important part/step of biological problem we use tools and equipment to prove hypothesis true or false

Fig 1.5: Scientific method of study

SUMMARY

1. Science is the study of world around us.
2. Biology is the study of living organisms.
3. The Holy Quran instructs us to study life.
4. Biology has many divisions and subfields. Biology is related to physics, chemistry, statistics, geography, technology and economics.
5. Medicine, surgery, fisheries, agriculture, animal husbandry, biotechnology, horticulture and forestry are dependent directly or indirectly on the study of biology.
6. Science is a collaborative field.
7. Scientific method is a system of observing and recognizing problem, developing hypothesis, making a prediction that can be tested, performing experiments and drawing conclusions from the result that support or testify the hypothesis.
8. Data is the collection of facts.
9. A hypothesis is a possible explanation for a group of related observations.
10. Deduction is the logical explanation of hypothesis.
11. A scientific hypothesis is a tentative, testable explanation for a phenomenon in the natural world.
12. A scientific theory is an explanation of some aspect of the natural world. It is based on the facts that have been repeatedly confirmed through observation and experiments.
13. A scientific law is a statement that describes an observable occurrence in nature that appears to always be true.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. The study of functions of various organs of an organism is:
   A) morphology B) histology C) anatomy D) physiology
2. Histology is the microscopic study of:
   A) tissues B) cells C) fossils D) plants
3. Paleontology is the study of:
   A) environment B) development C) fossils D) animals
4. The other name of environmental biology is:
   A) ecology B) biotechnology C) microbiology D) cell biology
5. Microbiology is the study of:
   A) fungi B) animals C) plants D) microorganism
6. If a scientist is studying the methods of inserting human insulin gene in bacteria, which branch of biology may this be?
   A) anatomy B) physiology C) biotechnology D) pharmacy
7. The starting point of scientific investigation is:
   A) hypothesis B) theory C) observation D) data

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Plasmodium
↓
Protesta

8. Information that is gathered as a result of an experiment is called:
   A) hypothesis B) data C) theory D) observation
9. Which of the following represents the correct sequence of different steps of scientific study?
   A) observation, → hypothesis → experiment → deduction → theory
   B) observation, → deduction → hypothesis → theory → experiment
   C) hypothesis → observation → deduction → experiment → theory
   D) observation → hypothesis → deduction → experiment → theory
10. Which of the following statements best distinguishes hypothesis from theories in science?
   A) theories are hypothesis that have been proven true
   B) theories are based on limited data while hypothesis are based on wide range of data
   C) theories are uncertain while hypothesis are certain
   D) theories are educated guess while hypothesis are widely accepted explanation of natural phenomenon
11. Malaria is caused by:
   A) mosquito B) stagnant water C) swamp D) *Plasmodium*
12. Malarial patient has *Plasmodium* in his blood. What would be the possible explanation if a healthy person who is not having any malarial symptoms shows *Plasmodium* in his blood?
   A) *Plasmodium* are dead B) *Plasmodium* are in incubation period
   C) *Plasmodium* are not mature D) *Plasmodium* are inactive
13. You are doing a control experiment which
   A) proceeds slowly enough that a scientist can record the results
   B) may include experimental groups and control groups tested in parallel
   C) is repeated many times to make sure the results are accurate
   D) proceed slowly enough that a scientist can test predictions
14. Which option has correctly matched disease and vector mosquito?

	Malaria in humans	Malaria in birds	Dengue fever
A	*Anopheles*	*Aedes*	*Culex*
B	*Aedes*	*Culex*	*Anopheles*
C	*Anopheles*	*Culex*	*Aedes*
D	*Culex*	*Anopheles*	*Aedes*

Section II: Short Answer Questions

1. Define the following branches of biology and give at least one significance of studying these branches
   a) Molecular biology b) Physiology
   c) Palaeontology d) Pharmacology
2. Can you distinguish between?
   a) Anatomy and Morphology b) Cytology and Genetics
   c) Biotechnology and Immunology d) Marine Biology and Ecology
3. Healthy life of a person depends on healthy life choices. How study of biology is going to help you to live a healthy life.
4. What is the contribution of the following scientists?
   a) A.F.A King b) Ronald Ross c) Laveran

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5. Observations are mainly of two types i.e., qualitative and quantitative. Sort the following observation according to these two types. Colour of cat, Height of giraffe, Weight of mango fruits, Body temperature of birds, Volume of blood in humans, Shape of leaves, Climate of desert, Speed of tiger, Song of a bird.
6. A Noble prize winner gave a hypothesis about effects of COVID-19 vaccine. Can it be wrong? Why? Develop deduction from this hypothesis, "Vaccination of COVID-19 can reduce the severity of complications in case of infection."
7. Why it is impossible to eradicate malaria?
8. The diagram shows one insect. Answer the following questions related to it.



i. Why do we use word vector for mosquito?

ii. What is name of organism which transmit malaria disease in man and birds?

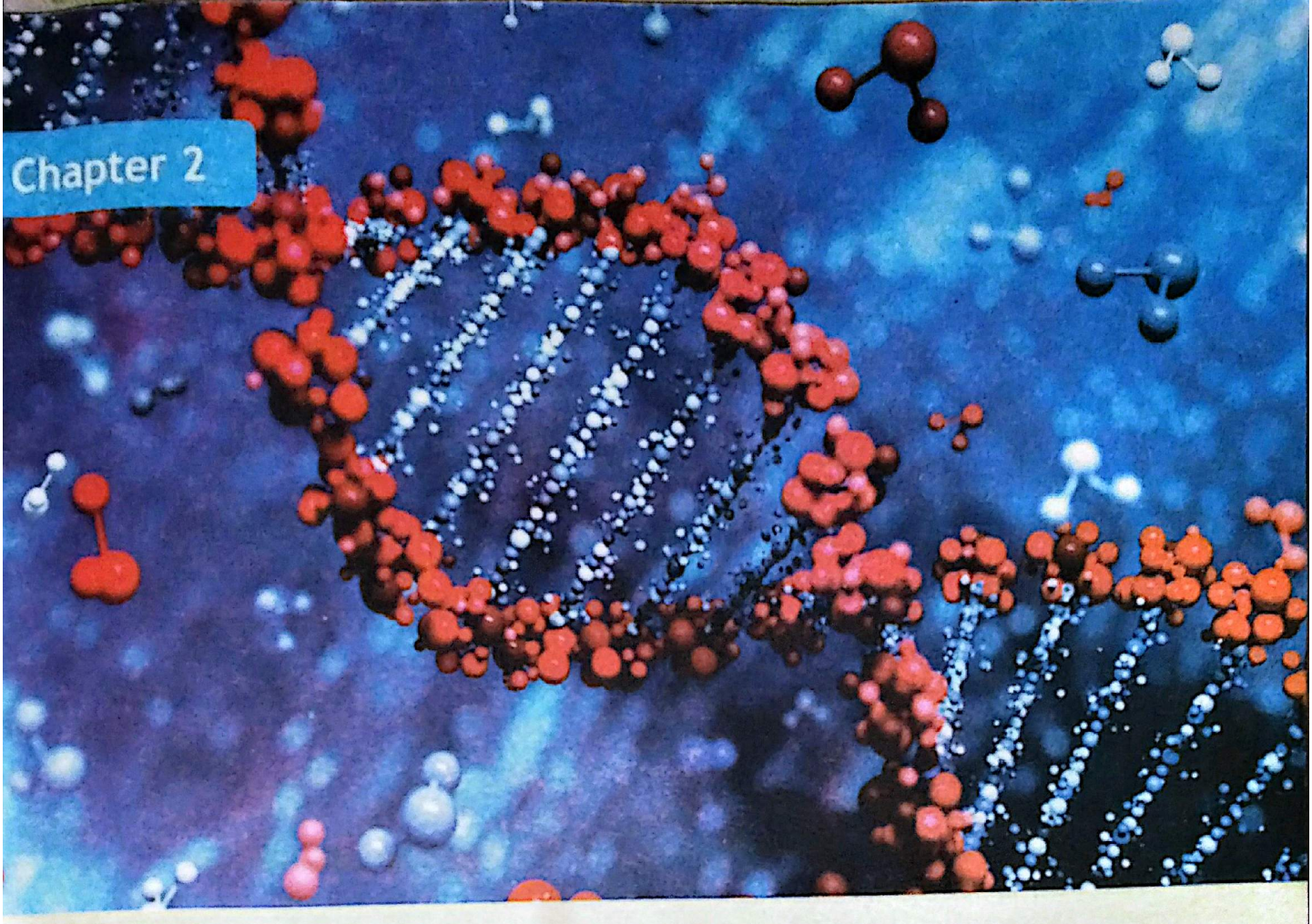
iii. What was the main purpose of experiment by Ronald Ross?

9. Why Ross did not allow the infected mosquitoes to bite a healthy person?
10. A student wants to investigate the effect of different factors on the activity of salivary amylase. He will design an experiment in order to reach conclusion. What would be the most appropriate first step to initiate?
11. Hepatitis B virus was found in blood of 10 persons. Only 6 of them were suffering from Hepatitis B disease. Why?

Section III: Extensive Answer Questions

1. How biology is related with other sciences? Show and explain the link.
2. How biology can lead to career of medicine, surgery, fisheries, agriculture, animal husbandry, biotechnology, horticulture, farming, forestry.
3. Explain that science is a collaborative field.
4. Why is biology important for the welfare of human beings? Give reasons.
5. Give at least ten examples of farming of animals which can improve economy of Pakistan. Describe the products and benefits of each example as well.
6. Discuss biological method of study and its application.
7. How biological method is applied to find the cause of malaria?
8. Explain use of biological method to understand the spread of malaria.

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MOLECULAR BIOLOGY

SLOs: After completing this lesson, the student will be able to:

1. Define Biochemistry/molecular biology
2. Outline the various types of common biomolecules (DNA, RNA, Proteins, Lipids, and Carbohydrates) including their locations inside the cell and main roles.
3. Outline the structure and function and sources of proteins with structure of amino acids
4. Outline the structure, function and sources of lipids
5. Define Carbohydrates and Outline the structure, function and sources of Carbohydrates.
6. Identify carbohydrates as monosaccharides, disaccharides and polysaccharides.
7. Describe briefly the structure of DNA as a double helix macromolecule made of nucleotides with base pairing in between the two helices through complementary base pairing.
8. Outline function of DNA as carrier of hereditary information
9. Describe briefly the structure of RNA as single stranded macromolecule made of nucleotides with nitrogenous base overhangs
10. Outline the function of RNA as aid in converting hereditary information into useful proteins.
11. Outline how information in the DNA is converted to information on RNA and then into proteins.

Biochemistry and molecular biology are essential for life. Biomolecules are made up proplasm. Protoplasm is combination of cytoplasm and nucleus. There are two types of Bio elements. Major and minor.

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2.1 BIOCHEMISTRY/ MOLECULAR BIOLOGY

Biochemistry is the study of different chemical compounds and the chemical processes taking place within the living organisms. Biochemistry is related to both biology and chemistry. Therefore, biochemistry solves the problems faced by living organisms by using the knowledge and techniques of chemistry.

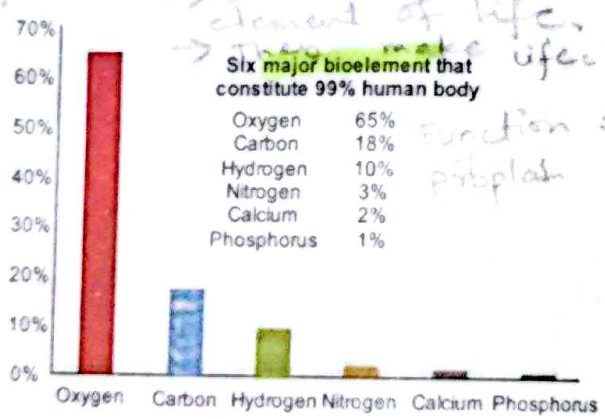
Sometimes biochemistry and molecular biology are taken as same but molecular biology is the specialized branch of biochemistry that is mainly concern with the interaction of bio-molecules with in the cells and biochemical processes like DNA replication, transcription and translation.

2.1.1 Importance of biochemistry

Study of biochemistry is greatly helpful to explore the cell biology and anatomy as all the structures of the living organisms (cells, tissues and organs etc.) have specific biochemical organization. Similarly, knowledge of biochemistry is essential to study the physiology of organisms because life processes such as photosynthesis, respiration, digestion, inheritance, are explained in biochemical terms.

2.1.2 Bioelements

Bodies of living organisms is made up of cells which are composed of protoplasm. Protoplasm is made of specific elements called **bioelements**. Out of 92 naturally occurring elements of earth, 16 act as bioelements as they form the protoplasm. On the basis of their proportions in the living organisms, bioelements are further classified into **Major** and **Minor bioelements**. Six most common bioelements constitute 99% of protoplasm so called major bioelements. Remaining ten bioelements constitute only 1% of the biomolecules so called Minor bioelements. The proportions of these bioelements are given in the fig: 2.1.



Minor bioelements: potassium, sulphur, chlorine, sodium, magnesium, iron, copper, manganese, zinc and iodine.

Fig. 2.1 Proportions of bio-elements in human body

2.2 BIOLOGICAL MOLECULES

Molecules produced and utilized in the metabolic processes within the living organisms are called biological molecules. Bio-molecules are the building blocks of life and perform important functions in living organisms like growth, development, energy production reproduction. Different bio-elements combine with each other to form biomolecules. Biomolecules may be **inorganic** (water and salts) and **organic** (carbohydrates, lipids, proteins and nucleic acids). Complex organic biomolecules are polymers of their building blocks called monomers. Major organic bio-molecules, their locations inside the cell and main roles are given in table 2.1.

Table 2.1: Biomolecules, their location in the cell and roles

Biomolecules	Location in cell	Main roles
Carbohydrates e.g. Glucose, lactose, sucrose, starch, cellulose, chitin	Cell wall, cell membrane, Smooth endoplasmic reticulum, Golgi bodies	Used as food, energy source, components of plant and fungi cell walls, component of DNA and RNA as 5-carbon sugar, cell surface markers (molecules present at the surface of specific cells due to which these cells are identified and distinguished from other types of cells).
Proteins e.g. Hemoglobin, Actin, myosin, hormones, enzymes, antibodies	Cytoplasm, Rough Endoplasmic reticulum, Golgi bodies,	Energy source, components of cell membrane, gaseous transport, chemical messenger, Speed-up chemical reactions, immunity, Component of chromosomes
Lipids e.g. Fats, phospholipids, waxes, oils, vitamin D	Cell membrane, smooth endoplasmic reticulum,	Provide cells with long-term energy, component of cell membranes.
DNA	Nucleus (Chromosomes)	Component of chromosomes, store and pass on genetic information to next generation.
RNA (mRNA, tRNA, rRNA)	Nucleolus, cytoplasm	Tools for translation, protein synthesis,

2.3 PROTEINS

Proteins are main structural and functional components of the cell, which make up around 55% of the dry weight of cell. They are present in all types of cells and contribute in the variety of cell functioning. Proteins are synthesized in the cells by ribosomes.

2.3.1 Chemical composition of Proteins

Proteins molecules mainly composed of C, H, O, N and sometimes P, S, Fe etc. Chemically proteins are **polypeptide chains** which are **polymers of amino acids**.

2.3.2 Amino acids

Amino acids are the building blocks or monomers of proteins. There are about 20-25 different types of amino acids commonly found in proteins. Each amino acid contains a central carbon atom called α (alpha) carbon. Four different groups are attached to α-carbon, including a hydrogen atom (-H), an amino group (-NH_2), a carboxyl group (-COOH) and an alkyl group labelled as -R. Each amino acid has a different -R group which determines its chemical properties.

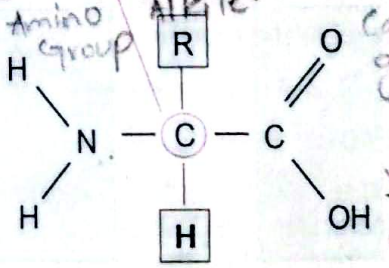


Fig: 2.2 General structure of an amino acid

2.3.3 Structure of proteins

Structure of protein may consist of a single polypeptide or more than one polypeptide. Number of amino acids and polypeptide chain varies in different proteins. Bond between two amino acids is called **peptide bond** as shown in figure given.

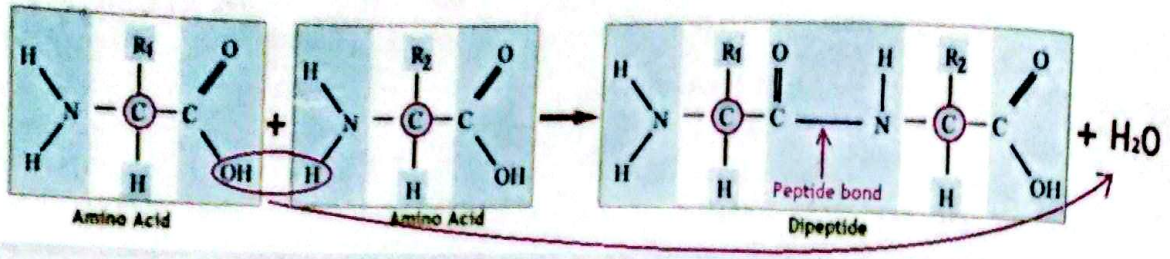


Fig: 2.3 Formation of peptide bond to form dipeptide

Structural conformation of Proteins

The structure of proteins is classified as primary, secondary, tertiary and in some cases quaternary. These structures are based on the level of complexity of the folding of a polypeptide chain. A linear polypeptide with a specific number, type and sequence of amino acids is called **primary structure**.

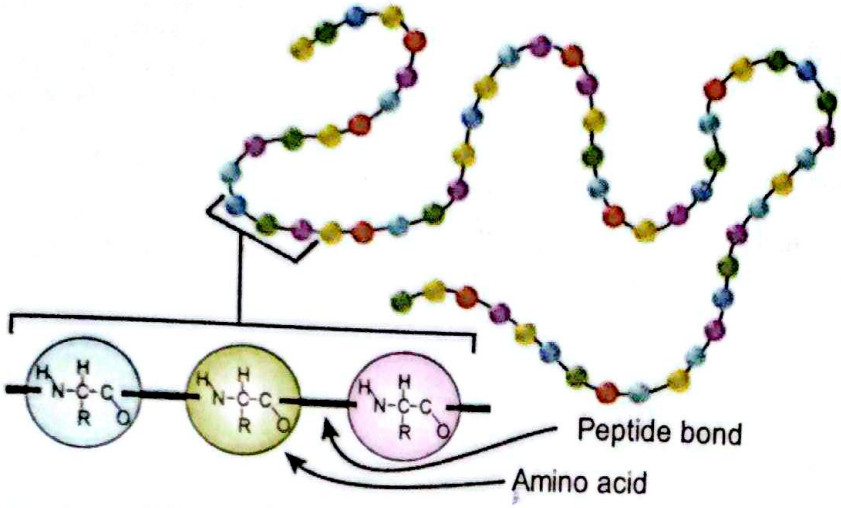


Fig: 2.4 Polypeptide chain and peptide bond

After synthesis a protein does not remain in its primary structure. Polypeptide folds upon itself due to additional bonds to form some higher structural level (secondary, tertiary or quaternary) to perform its specific role. Shape of the proteins (fibrous or globular) also depends upon the structural level in the protein.

2.3.4 Functions of Proteins

Proteins are very important molecules in our cells. Each protein within the body has a specific function. They are involved in the formation of many structures of body. They also play many important roles with in body. One gram of protein has 4 kcal of energy. A list of important proteins and their roles is given in table 2.2.

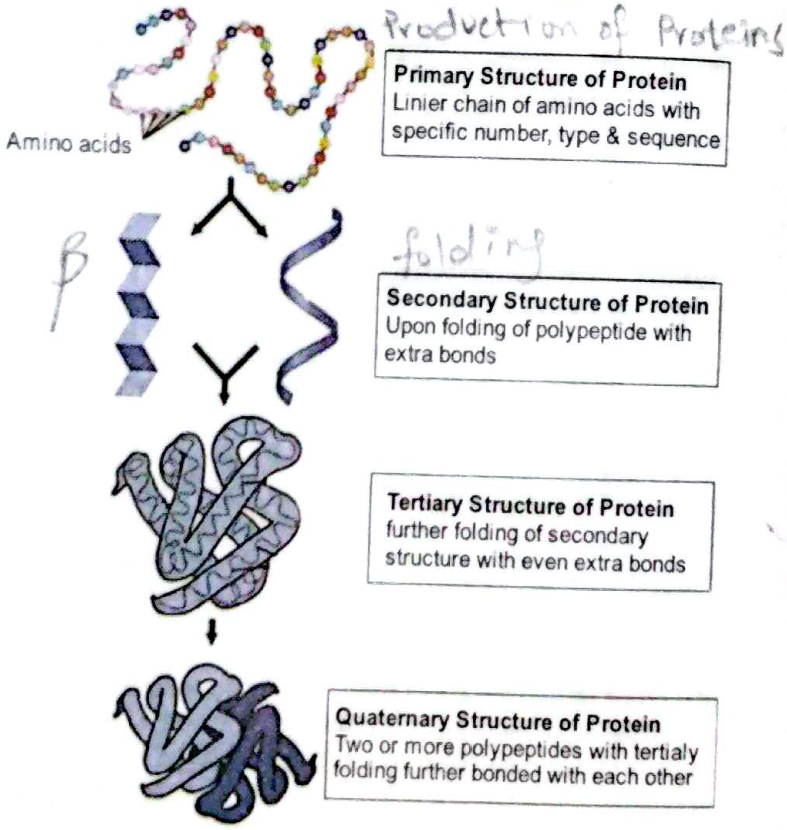


Fig: 2.5 Structure of protein

Central Dogma:
DNA — RNA — Proteins
Transcription

Table 2.2: Examples and Functions of Proteins	
Examples	**Functions**
Plasma membrane protein	Many proteins in plasma membrane act as channel and carrier proteins. Some proteins at the surface of cell act as antigen.
Enzymes	Most of the enzymes are protein which conrol biochemical reactions.
Hormones	Protein hormones act as chemical messengers and regulate different functions in body e.g. growth, reproduction, digestion, glucose level etc.
Antibodies	Antibody proteins produced by WBCs provide immunity against germs.
Haemoglobin	RBCs have red pigment haemoglobin protein that is involved in the transport of oxygen and carbon dioxide in the body via blood.
Fibrinogen	Blood plasma contains a blood clotting protein to stop bleeding at injuries.
Actin and Myosin	These proteins are present in muscle cells. These are involved in contraction and relaxation of muscles during movement.
Collagen	It is major component in structure of skin, bones, cartilage, muscles, tendons and ligaments. It provides support and strength.
Keratin	It is the component of hair, nails, feathers, horns and beaks to make them hard and protective.
Histone	It is attached to DNA to form chromosome.

2.3.5 Sources of proteins

Proteins may be obtained from plants fungi and animals. Plant seeds are most common source of proteins like beans, lentils, peas, nuts. Animal products are sources of high protein contents e.g. Milk, beef, mutton, poultry meat, egg, fish, sea food. Some proteins are obtained from mushrooms.

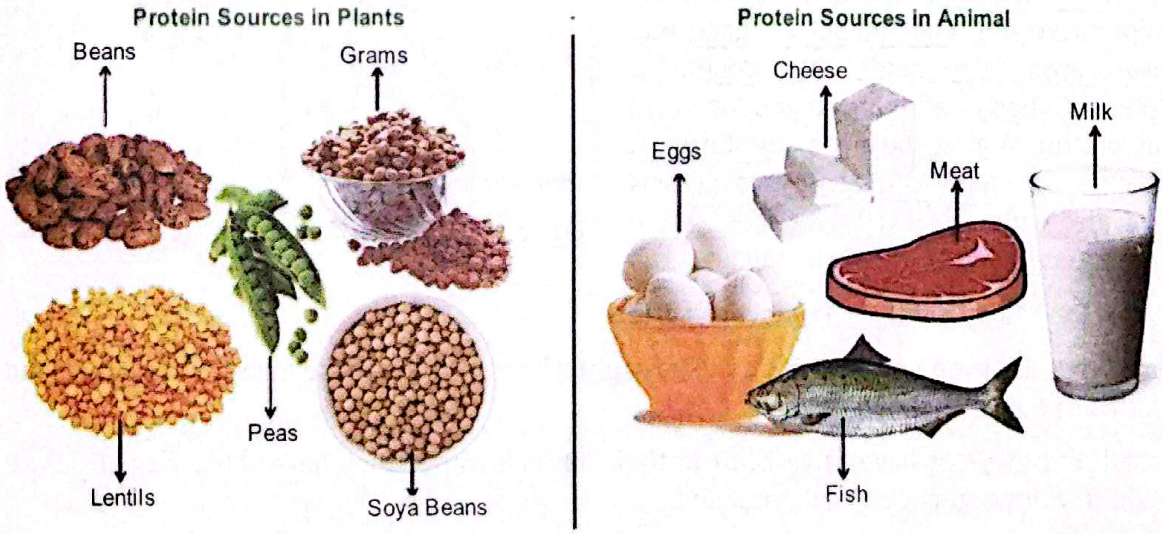


Fig: 2.6 Sources of proteins

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STEAM ACTIVITY 2.1

The presence or absence of protein in a given sample can be confirmed by biochemical tests.

Experiment	Observations	Inference
Biuret Test: Take 2 ml of test solution (Protein solution) add 2 ml of concentrated solution of NaOH and two to three drops of 1% copper sulphate solution and then Shake well	Pink or Violet coloration is produced in test tube.	Protein is present in the solution

Glycerol/Lipid
Head → hydrophilic
Tail → hydrophobic

2.4 LIPIDS

def of Lipids

A group of different types of organic compounds which are all hydrophobic in nature, collectively called lipids. Hence, lipids are a heterogeneous group of organic compounds which are insoluble in water but soluble in organic solvent such as alcohol, ether etc. Lipids found in living organisms include fats, oils, waxes and steroids.

Molecules of lipids are composed of C, H and O like carbohydrates. However one gram of lipids contain double amount of energy than carbohydrates because they have relatively more carbon-hydrogen ratio than carbohydrates.

Fatty Acid
Saturated (C-C) (Solid)
Unsaturated (C=C/C≡C) (Liquid)

2.4.1 Structure of Lipids

Lipids which are mainly made up of fatty acids and glycerol (an Alcohol) are called Acyl glycerides. Fatty acids may be saturated or unsaturated. **Saturated fatty acids** have all C-C single bonds and are solid at room temperature e.g. cheese, butter, ghee etc. **Unsaturated fatty acids** have double or triple C-C bonds and are liquid at room temperature e.g. soybean oil, mustard oil, olive oil etc. Most common types of acyl glycerides are tri-acyl glycerides which contains one glycerol and three fatty acids.

Imp equation

Glycerol + 3 fatty acids → Tri-acyl glyceride

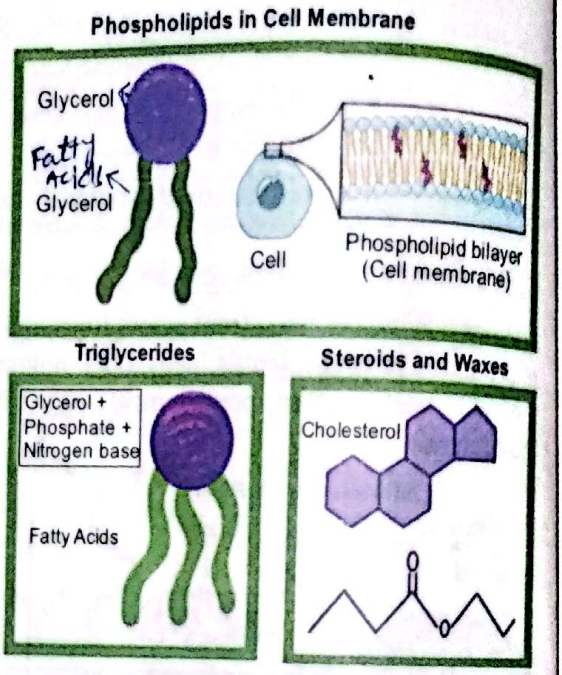


Fig: 2.7 Structure of different types of lipids

Some lipids are even more complex and have phosphate, nitrogen base along with glycerol and fatty acids e.g. phospholipids and waxes.

Some lipids may not have fatty acids in their formula rather they have three ring structure called steroids e.g. cholesterol, vitamin D.

* fatty acid vary in the lipids.
* Glyceride always remain one in lipids.

2.4.2 Functions of Lipids

Lipids are very useful biological molecules and have many important roles in cells and as a whole in bodies of living organisms.

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1. Phospholipids and cholesterol are components of plasma membrane structure.
2. Lipids act as energy stores in fat cells, liver and in blood. One gram of lipids provides 9.1 kcal of energy which is double than carbohydrates or proteins.
3. Many lipids act as important steroid hormones e.g. testosterone, Aldosterone etc.
4. Some lipids act as insulators against atmospheric heat and cold.
5. Waxes are used by insects for constructing their hives.
6. Waxy cuticle of leaves act as protective and waterproof layer to avoid water loss.
7. Some vitamins are lipid in nature e.g. vitamin A, D, E and K. Vitamin D is derived from cholesterol.

2.4.3 Sources of Lipids

Variety of food are rich sources of lipids. Foods containing large amounts of saturated fat include red meat, butter, cheese, ghee, fish liver oil etc.

Some oils are obtained from plant seeds like sunflower oil, soybean oil, peanut oil, coconut and palm oil are also rich in unsaturated fats. Wax is obtained from comb of many insects.



Fig: 2.8 Sources of lipids

STEAM ACTIVITY 2.2

The presence or absence of lipids in a given sample can be confirmed by biochemical tests.

Experiment	Observations	Inference
A. **Spot test:** Put a drop of test solution (lipid solution) on a filter paper and allow it to dry	A clear or translucent greasy spot appears on paper	Lipid is present in the solution
B. Take a small amount of fat (butter or ghee) in a test tube and half fill the test tube with distilled water.	Fat and water remain separate	Fat is insoluble in water
C. Heat the water and fat in the test tube	Fat melts on heating but don't mix water and make clear upper layer over the lower water layer	Fat is insoluble in water and don't mix even in melted form
D. **Emulsion Test:** Take 2 ml of the test material (lipid) add 2 ml of absolute alcohol and shake well. Now add 4 ml of cold water and shake well again then allow to stand.	A cloudy white suspension (emulsion) is formed after shaking	Lipid is confirmed

2.5 CARBOHYDRATES

Carbohydrates are the important biological molecules present in all parts of cell. Carbohydrates are also called as sugars or saccharides due to their sweet taste. Word saccharide is derived from Greek word "Sakcharon" meaning sugar. Most common and simple carbohydrate, glucose is naturally produced in the green plants by the process of photosynthesis using CO_2 from air and H_2O from soil.

★ Balanced equation

★ Process of photosynthesis
★ Photosynthesis equation

$$6CO_2 \text{ Carbon Dioxide} + 6H_2O \text{ Water} \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 \text{ Glucose} + 6O_2 \text{ Oxygen}$$

پودے سورج کی روشنی استعمال کرتے ہیں کھانا تیار کرنے کے لیے

Plants use sunlight energy for food synthesis. This energy is stored as chemical energy in the bonds of glucose molecules and 4 kcal per gram of energy is released when glucose is broken down in the cell. Plants use glucose molecules to form complex molecule like starch and cellulose.

2.5.1 Structure of Carbohydrates

Carbohydrates are the compounds of carbon, hydrogen and oxygen with a ratio of 1:2:1 respectively. Literal meaning of word carbohydrate is **"hydrates of carbon"**. This name is given because number of carbon atoms is almost equal to the number of water molecules in the chemical formula of carbohydrates. The ratio of hydrogen and oxygen in the formula of carbohydrates is the same as in water (H:O = 2:1).

Thus, generalized formula of carbohydrates is $C_X(H_2O)_Y$ Where X is number of carbon atoms and Y is number of water molecules. For example, formula of most common sugar glucose is $C_6(H_2O)_6$ or $C_6H_{12}O_6$.

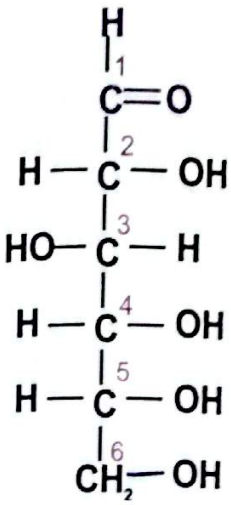


Fig: 2.9 Structure of Glucose

2.5.2 Functions of carbohydrates

Carbohydrates play following structural and functional role in living organisms

1. Carbohydrates are major source of useable and stored energy in the cells of living organisms.
2. Carbohydrates are structural material for cell wall of Plants (cellulose), Fungi (Chitin) and Bacteria (Peptidoglycan).
3. Cellulose present in the cell wall of plant fruit, vegetables, bran and whole grains is not digestible hence act as fiber or roughage in the human diet. It helps in the movement of food efficiently through the digestive tract and effective in avoiding constipation.
4. Cellulose fiber absorbs away toxic chemicals which might be present in food. It is used in paper industry. It also helps in lowering blood cholesterol and regulates blood pressure.
5. Sucrose is used as common table sugar and used as natural sweetener.
6. Extra glucose in plants is stored as starch in their root, stem, fruits or seeds used as animal and human food.
7. Extra blood glucose is stored in animal muscles and liver cells as glycogen which serves as energy bank. It can be converted back to glucose when needed for energy.
8. Chitin makes exoskeleton of arthropods

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2.5.3 Sources Carbohydrates

Carbohydrates are the most abundant class of organic biomolecules. They have various sources.

1. Monosaccharides such as glucose, fructose and galactose are obtained from fruits, vegetables and cereals. They are also present in honey.
2. Disaccharide such as sucrose is obtained in sugarcane, sugar beet and fruits. Maltose is found in cereals. Lactose is milk sugar and found in dairy products.
3. Cellulose is obtained from plants e.g. Cotton is pure cellulose.
4. Starch is present in cereals, wheat, barley, rice, maize, potato, sweet potato etc.

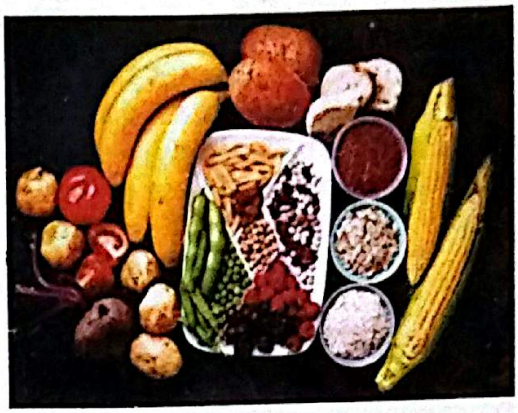


Fig: 2.10 Sources of Carbohydrates

2.6 CLASSIFICATION OF CARBOHYDRATES

Carbohydrates are classified on the basis of number of monomers i.e. saccharide units in the molecule. Carbohydrates are generally classified into three groups.

2.6.1 Monosaccharides

Monosaccharides are the simplest form of carbohydrates which are primarily produced during photosynthesis. They are white crystalline solids and are soluble in water. They are sweet in taste. Number of carbon atoms in different monosaccharides may range from 3 to 7. Monosaccharide are named on the basis of number of carbon atoms in their structure e.g. trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C) etc. Most common monosaccharides are pentoses and hexose. For example, ribose is a pentose ($C_5H_{10}O_5$), found in the nucleotides of nucleic acids. Glucose ($C_6H_{12}O_6$) is a familiar hexose. Monosaccharides are not further hydrolysed. If monosaccharides (mostly pentoses and hexoses) are in crystalline form they are found as open chain structure but when they are dissolved in water they are converted into ring structure.

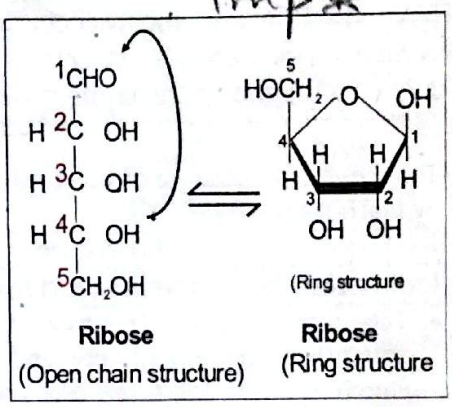


Fig: 2.11 Open chain and ring structure of pentose (ribose)

2.6.2 Disaccharides

Carbohydrates, which release two monosaccharides on their hydrolysis are called disaccharides because disaccharide are formed due to bonding of two monosaccharides. They are also white crystalline solids. They are comparatively less soluble in water and are less sweet in taste. The molecular formula of disaccharide is $C_{12}H_{22}O_{11}$. Examples of disaccharides are sucrose, maltose and lactose.

Sucrose is the most familiar disaccharide, commonly used sweetener and known as cane sugar. The sucrose is formed by the condensation of glucose and fructose releasing a water molecule.

Science titbits

Maltose is called malt sugar, because it is produced during the brewing the beer and related drinks by alcoholic fermentation of malted barley. Lactose is the only common sugar obtained from animals. Milk of all mammals is composed of 2-8% lactose. Lactose can be prepared from whey which is a by-product of the cheese-making process.

$$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$$

Glucose + Fructose → Sucrose + Water

Maltose is also produced during hydrolysis of starch and glycogen, as an intermediate disaccharide. It is slightly sweet, very soluble in water. The maltose is formed by the condensation of two glucose molecules releasing a water molecule.

$$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$$

Glucose + Glucose → Maltose + Water

Lactose is a naturally found in milk and milk products. The lactose is formed by the condensation of galactose and glucose.

$$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$$

Many Galactose + Glucose → Lactose + Water

2.6.3 Polysaccharides

Polysaccharides is largest group of carbohydrates. They are complex carbohydrates and polymers of more than ten monosaccharides. They are produced in the cells of plants and animals to store extra carbohydrate food and energy e.g., starch, glycogen. They are storage molecule of carbohydrates. Polysaccharides are not sweet in taste rather usually tasteless. They yield many monosaccharide units upon complete hydrolysis for energy use. Polysaccharides are also structural components of cell walls in the cells of plant (cellulose), fungi (chitin) and bacteria (peptidoglycan).

STEAM ACTIVITY 2.3

The presence or absence of starch, glycogen, cellulose and glucose in a given sample can be confirmed by biochemical tests.

Experiment	Observations	Inference
Iodine test for Starch in solution or food material		
A. Take 5 ml water in a test tube. Add a small amount of starch in water in test tube and then boil to prepare starch solution. Add a few drops of iodine solution into the clear starch solution in the test tube.	Dark blue black coloration is produced in test tube.	Starch is confirmed in solution
B. Take food material like potato, then cut a small slice of potato and add a few drops of iodine solution on the potato slice.	Dark blue black coloration is produced on potato slice.	Starch is confirmed in food
C. Take glycogen solution in test tube and add few drops of iodine solution	Red coloration is produced in test tube.	Glycogen is present in solution
D. Take cellulose solution in test tube and add few drops of iodine solution	No change in colour of iodine solution in test tube.	Starch and glycogen absent and Cellulose may be present
Test for Glucose		
A. Benedict's test for glucose: Take 5 ml of Benedict's solution in a test tube, add a few drops of the test solution (glucose solution) and boil for 2-3 minutes.	A dirty green, yellow or red precipitates are formed	Glucose is present
B. Fehling's solution test: Take 3 ml of Fehling's solution in a test tube, add 3 ml of test solution (glucose solution) and heat.	Red precipitates are formed	Glucose is present

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2.7 NUCLEIC ACIDS

Nucleic acids are the most important organic biomolecules which store and transfer hereditary information from one generation to next. There are two main types of nucleic acid.

i. Deoxyribonucleic Acid (DNA)
ii. Ribonucleic Acid (RNA)

Both types of nucleic acids (DNA and RNA) are made up of many units called nucleotides.

Science titbits

Swiss physician Friedrich Miescher isolated a whitish material from nucleus of human pus cells. He named this material as nuclein as it was isolated from nucleus. Later on, on the basis of its acidic properties, nuclein was called nucleic acid.

2.7.1 Structure of Nucleotide

Each nucleotide is made up of three components.

i. **Pentose** (5C Sugar)
ii. Nitrogen containing ring structure called **nitrogen base**, which is attached at the first carbon of pentose sugar
iii. **Phosphate group** from acid is attached with fifth carbon of pentose sugar

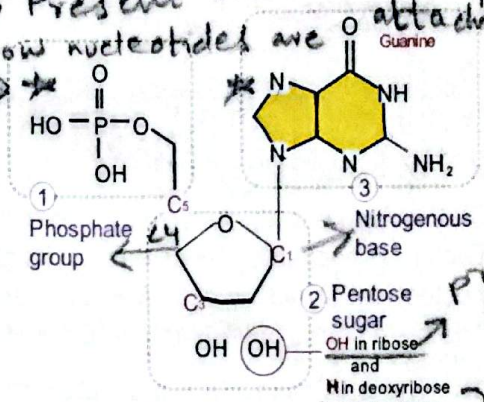


Fig: 2.12 Structure of a nucleotide

Pentose sugar in nucleic acid is of further two types:

a) Deoxyribose in DNA b) Ribose in RNA.

The nitrogen bases in nucleic acid are also of two main types.

a) **Purines**, which are nitrogen containing double ring structures i.e. Adenine and Guanine
b) **Pyrimidines** which are nitrogen containing single ring structures i.e. Cytosine, Thymine and Uracil

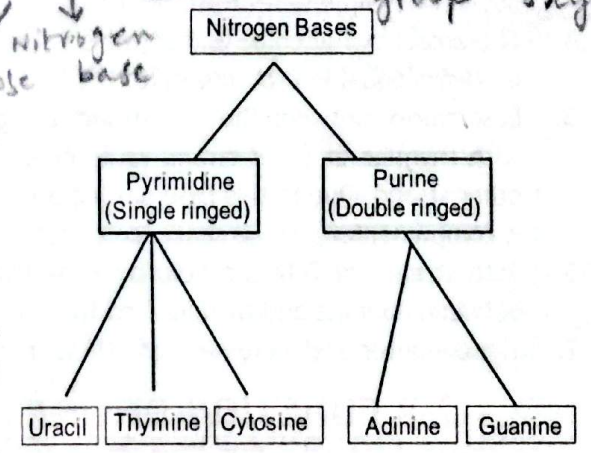


Fig: 2.13 Types of Nitrogen basis

Names of the nucleotides are given on the basis of the type of pentose sugar and nitrogen base they have. The DNA molecules consists of four different types of nucleotides called **deoxyribonucleotides**.

Each deoxyribonucleotides can have any one of the nitrogen base from Adenine, Cytosine, Guanine and Thymine. The RNA molecules also consists of four types of nucleotides called **ribonucleotide**, Each ribonucleotide can have any one of the nitrogen base from Adenine, Cytosine, Guanine and Uracil. So DNA nucleotides can have Thymine, while RNA nucleotides can have Uracil as nitrogen base.

Adenine = Thymine
Cytosine = Guanine

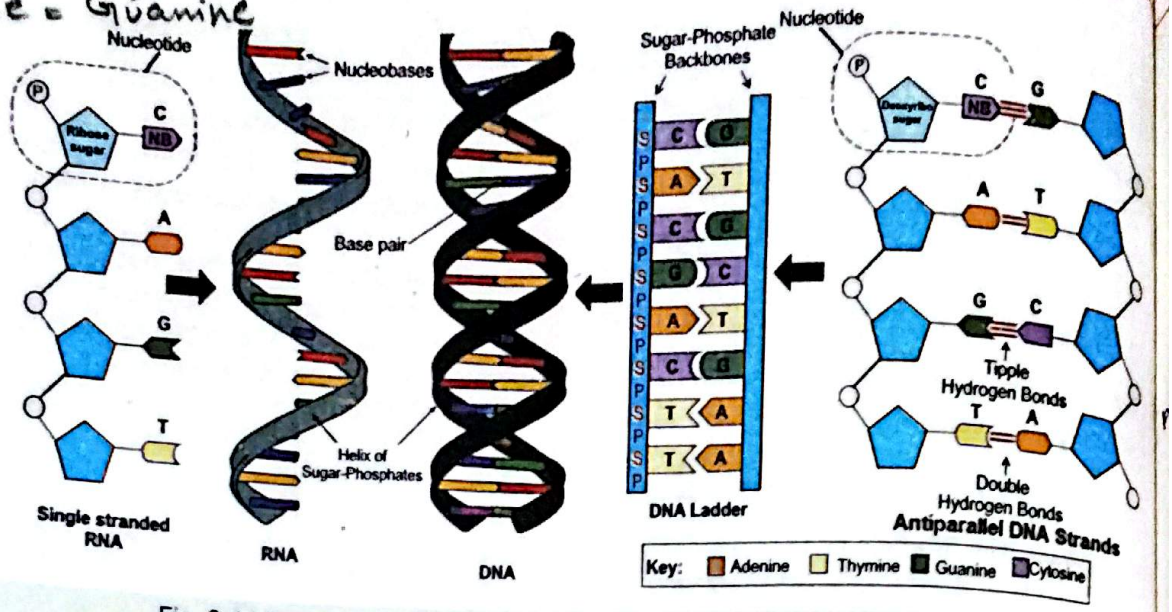


Fig. 2.14 Structure of RNA and Watson and Crick model for structure of DNA

2.7.2 Structure of DNA

DNA molecule is a polynucleotide as it is made up of many deoxyribonucleotides (Fig. 2.14). Each next nucleotide binds through its phosphate at the 3rd carbon of pentose sugar of previous nucleotide. Structure of DNA was explained by two scientists, James Watson and Francis Crick. The main points of **Watson and Crick Model of DNA** are:

1. The DNA molecule is a double stranded like a ladder and both strands are coiled around each other like a helix.
2. Both strands of DNA molecule are antiparallel (oppositely oriented to each other).
3. The back bone (uprights) of molecule are composed of sugar and phosphate part of nucleotide while bases form the rungs.
4. The amount of adenine and thymine is always equal and amount of cytosine and guanine is always equal in DNA molecule.
5. Base pairing between the both strands is highly specific. Adenine of one strand always pairs with thymine of other strand while cytosine of one strand always pairs with guanine of other strand. Due to this base pairing principle, the sequence of nucleotides in one strand is complimentary to the sequence of nucleotides in the other strand.
6. Both strands of DNA are held by weak hydrogen bonds. There are two hydrogen bonds between adenine and thymine and three hydrogen bonds between cytosine and guanine.
7. The diameter of double helix of DNA is thoroughly uniform and is about 2 nm.

2.8 FUNCTION OF DNA (GENES) AS CARRIER OF HEREDITARY INFORMATION

Heredity is the transmission of characters from one generation to the next and it is important for the continuity of all life forms. Although offsprings and parents may have different appearance but, they have a basic resemblance in many characters that runs from generation to generation. For the continuity of life forms, each generation transfer the hereditary instructions to the next generation.

These hereditary instructions are in the form of huge DNA molecules and are transferred from one generation to next. In a non-dividing cell, hereditary material (DNA) is found in nucleus in the form of thin fibres called **chromatin**. Chromatin is composed of **DNA** and a proteins called **histones**. Coiling of DNA around histones form bead like structures called **nucleosomes (Fig. 2.14)**.

2.8.1 Chromosomes contain units of heredity: The Genes

During cell division chromatin fibres condense and further fold to form thread-like structures called **chromosomes**. Small piece of huge DNA molecule in the chromosome is called **Gene.** Genes actually store and control the hereditary information. Each chromosome is made up of large number of genes. The total number of genes found in the complete set of chromosomes of an organism is called **genome** of that organism.

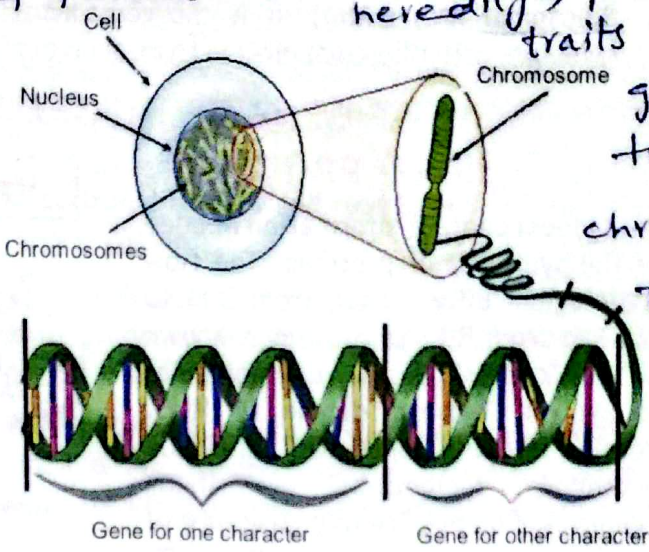


Fig. 2.15 DNA, Chromatin and condensed chromosome structure

2.8.2 Gametes act as vehicle for transfer of heredity information (genes) to next generation

During sexual reproduction, gametes or spores are produced by meiosis. Male and female gamete (sperm and egg) contain chromosomes (set of genes) of parent generation. At fertilization, male and female gametes fuse to form zygote, thus genes of both parents are transferred to zygote. Zygote develops into the offsprings which are the next generation. Thus, genes are transferred from one generation to next though gametes or spores. So therefore, DNA (genes) in the chromosomes carry the hereditary information from one generation to next.

2.9 STRUCTURE OF RIBONUCLEIC ACID (RNA)

The RNA is a polynucleotide helical chain like DNA but it is single stranded nucleic acid. (Fig.2.13) In RNA **pentose sugar ribose** is present instead of deoxyribose. RNA molecule also differs from DNA in having **uracil** nucleotide instead of thymine nucleotide. Nitrogen bases of RNA molecule are overhung because they are not bonded to nitrogen bases of other (complementary) strand like DNA. Sequence of nucleotides in RNA is synthesized by using the sequence of nucleotides in DNA by the process of transcription.

2.10 FUNCTION OF RNA IN CONVERTING HEREDITARY INFORMATION INTO USEFUL PROTEINS

After synthesis in the nucleus, RNA is transported to cytoplasm. RNA is an intermediate molecule for controlling the heredity. The primary function of RNA is to synthesize proteins by the process of translation. All three types of RNA are involved in translation of genetic information into various proteins necessary for cellular processes.

2.10:1 Types and functions of RNA

There are three types of RNA.

i. **Messenger RNA (mRNA)**: It carries message of DNA from nucleus to cytoplasm for protein synthesis so called mRNA.

ii. **Transfer RNA (tRNA)**: It transfer amino acids to ribosomes during protein synthesis hence called tRNA.

iii. **Ribosomal RNA (rRNA)**: It is the component of ribosome therefore, called rRNA. It combines with ribosomal protein to form units of ribosomes, which are factory of proteins.

2.11 FLOW OF GENETIC INFORMATION FROM DNA TO RNA AND THEN TO PROTEINS

DNA (genes) contain information needed for the synthesis of proteins. The flow of biological information, from DNA to RNA and from RNA to protein is known as the "central dogma of molecular biology" or **"central dogma of life"**. Proteins are the main structural and functional molecules of living organisms. Correct Primary structure of any protein is primarily determined by DNA. Protein synthesis takes place in two sequential steps i.e. transcription and translation. Together transcription and translation are known as **gene expression (Fig. 2.16).**

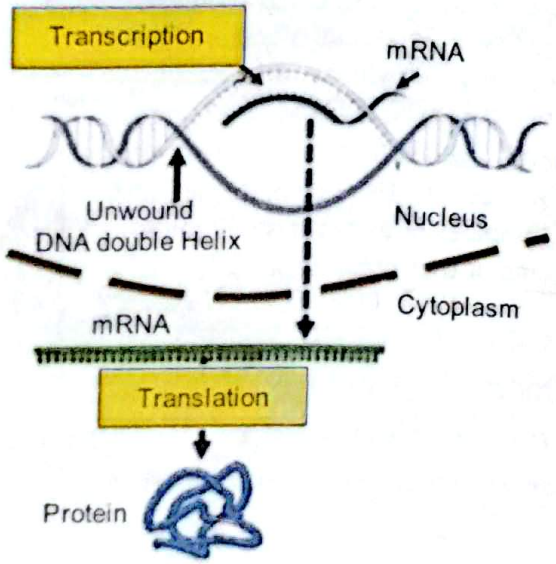


Fig. 2.16 Transcription and translation

2.11.1 Transcription

Transcription is the first step of gene expression that involves the formation of RNA molecule from DNA. Both DNA strands of a gene unwind from each other. Only one strand of DNA is copied. Nucleotide sequence of one DNA strand (coding strand) is copied in the form of mRNA. After the gene is copied to mRNA, both strands of DNA are again coiled together into its normal double stranded shape.

2.11.2 Translation

The mRNA synthesized in the nucleus of the cell moves into the cytoplasm where it binds to the ribosome. The message (codes) of mRNA is translated by ribosomes which link amino acids to form polypeptide chain with specific sequence of amino acids. Different types of tRNAs, transfer amino acids to ribosome as per sequence of codes in mRNA.

Summary

1. Biochemistry is the study of different chemical compounds and the chemical processes taking place within the living organisms.
2. Living organisms are composed of 16 out of 92 naturally occurring elements called bioelements out of which six are Major and ten are Minor bioelements.
3. Different bio-elements combine to form inorganic and organic biomolecules including water, carbohydrates, lipids, proteins and nucleic acids.

In reproductive cells there are [23] chromosomes!

4. Proteins are made up of a single or more polypeptide chains which are polymers of amino acids. Amino acids are composed of C, H, O, N and sometimes P, S, Fe etc. Number, type and sequence of amino acids in each polypeptide chain is specific. Proteins play multiple structural and functional roles.
5. A group of heterogeneous hydrophobic organic compounds including fats, oils, waxes and steroids found in the living organisms, is called lipids. One gram of lipids contain double amount of energy than carbohydrates due to higher carbon-hydrogen ratio.
6. Most common types of lipids are tri-acyl glycerides which contains one glycerol and three fatty acids. Saturated fatty acids are solid at room temperature whereas unsaturated fatty acids are liquid at room temperature.
7. Carbohydrates are the compounds of carbon, hydrogen and oxygen with a ratio of 1:2:1 respectively and literally called "hydrates of carbon".
8. Carbohydrates are the important biological molecules commonly called sugars or saccharides. Glucose is a monosaccharide, naturally produced in the green plants by the process of photosynthesis using CO_2 from air and H_2O from soil.
9. Polysaccharides are complex carbohydrates of plants and animals to store extra carbohydrate e.g., starch, glycogen and are usually tasteless. Cellulose, chitin and peptidoglycan are polysaccharides which are structural components of cell walls in the plant fungi and bacteria.
10. Nucleic acids are of two types; Deoxyribonucleic Acid (DNA) and Ribonucleic Acid (RNA) which store and transfer hereditary information from one generation to next.
11. DNA contain information for the synthesis of proteins. The flow of information, from DNA to RNA and from RNA to protein is known as the "central dogma of molecular biology" or "central dogma of life". Together transcription and translation are known as gene expression.

Human Gametes
↙ Egg (Mother) (chromoses) 23
↘ Sperm (Father) (23)
Fusion 46 chromosemes
↓ zygote
↓ Embroyo
↓ Fetus
↓ Developing baby

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Which of the following is major bio-element?
   A) sodium B) magnesium C) Phosphorous D) iron
2. Peptide bond is formed between two:
   A) Monosaccharides B) Amino acids C) Nucleotides D) Fatty acids
3. During translation, sequence of amino acids in the protein is decides on the basis of sequence of nucleotides in:
   A) mRNA B) rRNA C) tRNA D) DNA
4. Different amino acids differ from each other on the basis of their ---------- group:
   A) Alkyl B) Carboxylic C) Amino D) Phosphate

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5. Both strands of DNA are held together by hydrogen bonding, double hydrogen bonds are present between:
   A) Adenine and thymine
   B) Cytosine and guanine
   C) Cytosine and thymine
   D) Adenine and guanine
6. Transcription takes place in the
   A) Cytoplasm
   B) Nucleus
   C) Ribosomes
   D) Rough Endoplasmic reticulum
7. All the nucleotides of RNA differ from the nucleotides of DNA in having different:
   A) Nitrogen base B) Pentose sugar C) Phosphate group D) carboxylic group
8. Diameter of DNA is thoroughly uniform and is about:
   A) 34 nm B) 3.4 nm C) 2nm D) 1.1nm
9. Which of the disaccharide is also called transport sugar?
   A) Sucrose B) Maltose C) Fructose D) Lactose
10. Vitamin D belongs to:
   A) Carbohydrates B) Lipids C) Protein D) RNA

Section II: Short Answer Questions

Major / Minor
99% 1%

1. Compare ratios of bio-elements.
2. Compare the energy level of carbohydrates, proteins and lipids.
3. How biochemistry is important for study of physiology, cell biology and anatomy?
4. Define gene (a localized region of DNA that codes for a protein).
5. Name structural and energy producing nature of carbohydrates.
6. What are different plant sources of proteins?
7. How primary structure of protein is important?

Section III: Extensive Answer Questions

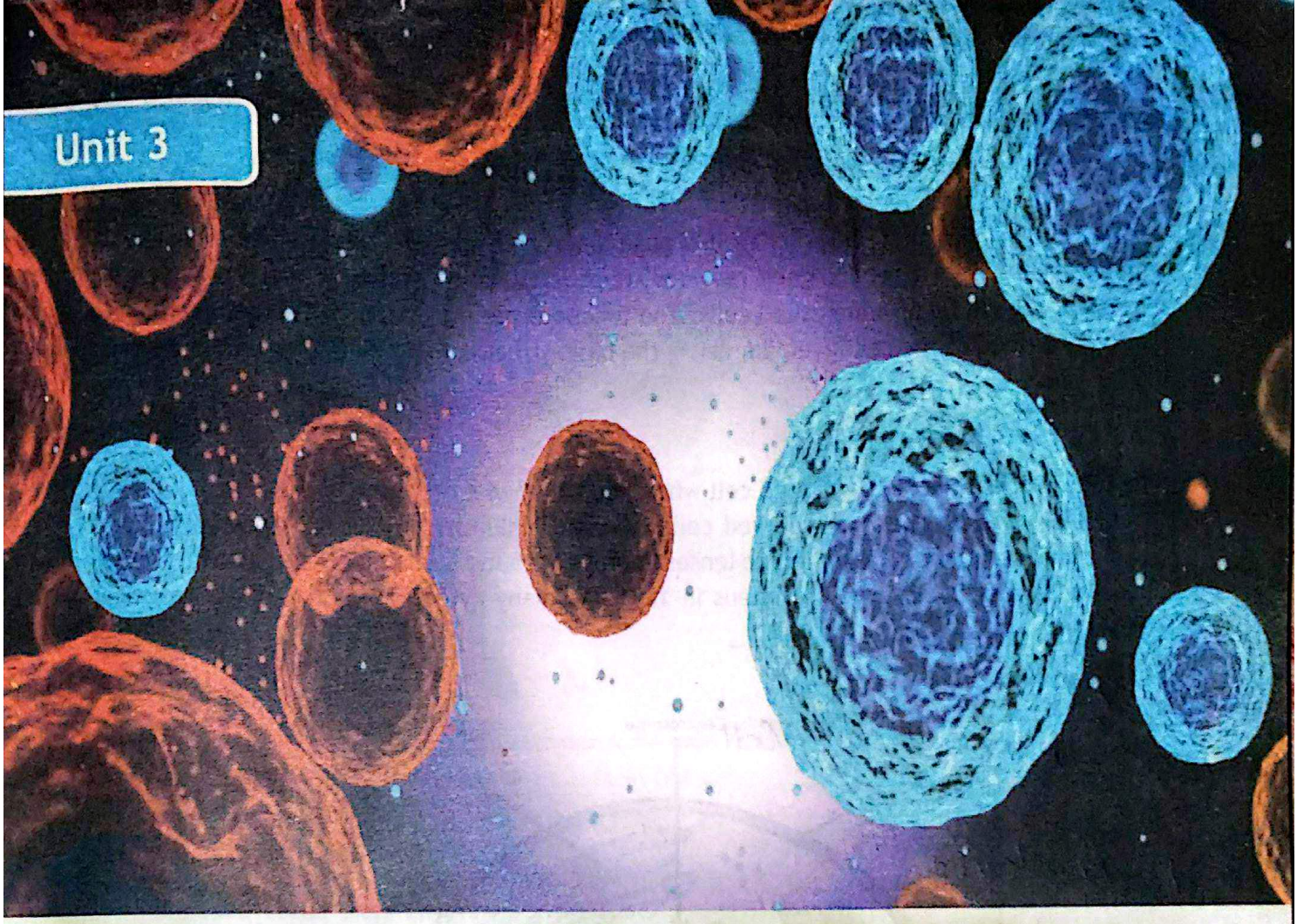
N/B

1. How lipids are important for living organisms?
2. Explain the composition of chromatin material?
3. What are different types of disaccharides? How are they produced? Mentions their sources. Marked on book at pg # 30/31
4. Give an account of genes on chromosomes.
5. Describe the role of gene in protein synthesis.
6. Explain how genes control inheritance of characters.
7. Describe the composition of chromatin material.

N/B

8. Explain that gene is a unit of inheritance and that it can be copied and passed on to the next generation.
9. Describe the central dogma stating the role of gene in protein synthesis.
10. Describe structure, sources and functions of lipids.

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Unit 3

The Cell

SLOs: After completing this lesson, the student will be able to:

1. Describe cell as the basic unit of life
2. Compare with diagram the structure of animal and plant cell.
3. Sketch different subceliular organelles nucleus, mitochondria, cell membrane etc. and outline their roles.
4. Outline structural advantages of plant and animal cells.
5. Identify different types of cells mesophyll, epidermal cells, neurons, muscles, red blood cells, liver cells and sketch their structures
6. Describe the concept of division of labour and how it applies to
7. Within cell across subcellular organelles
8. Multicellular organisms across cell
9. Describe cell specialization
10. Define stem cells as unspecialized cells

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* Structural and functional unit of unit of living organisms

* Size, shape, location, function. are different.

3.1 CELL

Earth is a living planet. It is home of a huge variety of life from microscopic organisms to magnificent blue whales and giant redwood trees. Irrespective of their size and shape all life forms are made up of units called cells. The functions performed by the living organisms are also performed at the cell level. So, cell is the basic structural and functional unit of all living organisms.

3.1.1 Structure of cell

In 1665, Robert Hooke discovered cell when he examined a thin slice of cork tissue under a compound microscope. He observed cells as empty chambers with thick outer coverings. However, the quality of microscope lenses improved greatly in the nineteenth century which lead to the discovery of cell nucleus in 1831 and many cytoplasmic organelles in coming years.

* Structure;

* 1665 – Robert Hooke – Cell

1831 – Nucleus + cytoplasm.

Muscle cell → shape → spindle

RBCs → concave shape

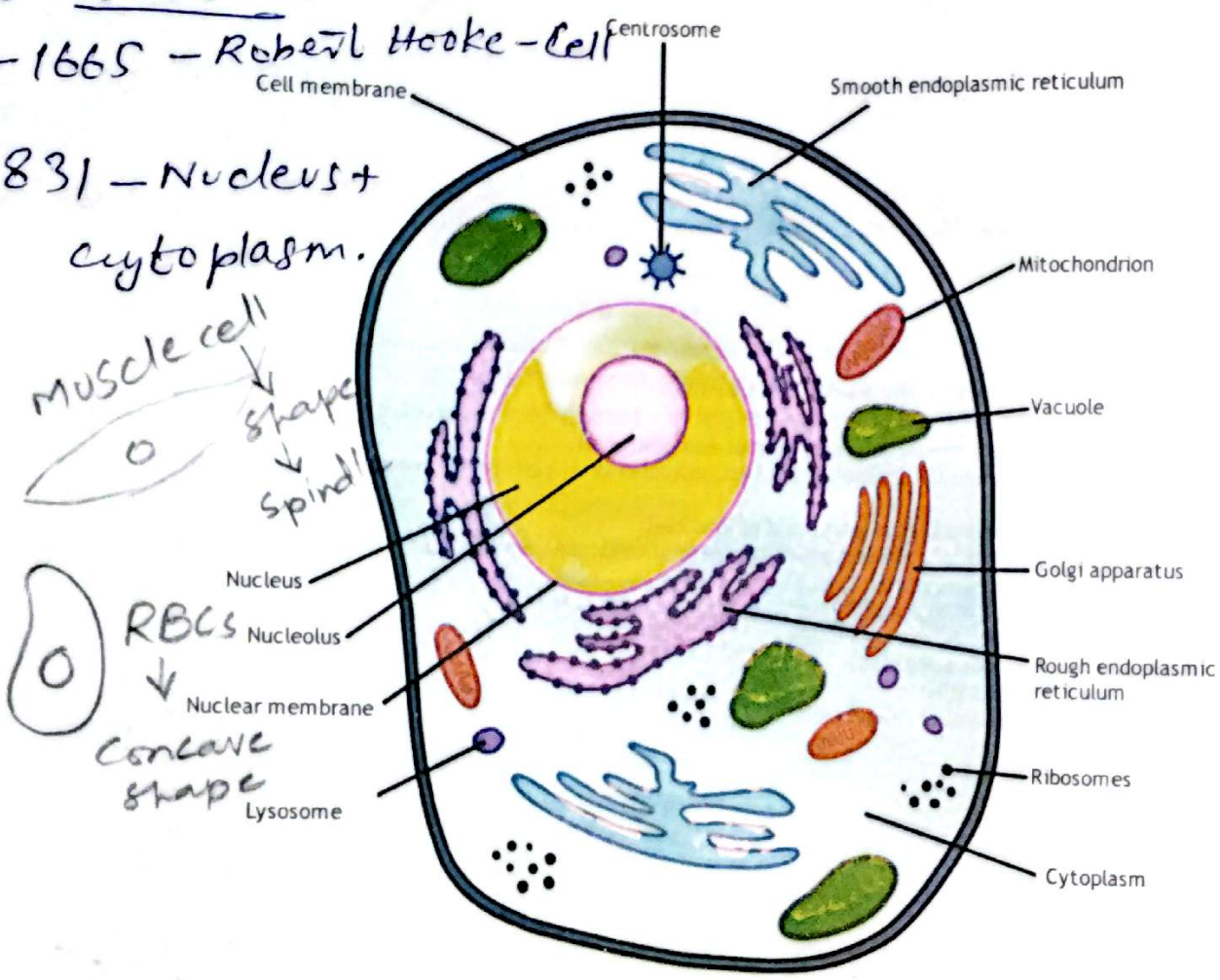
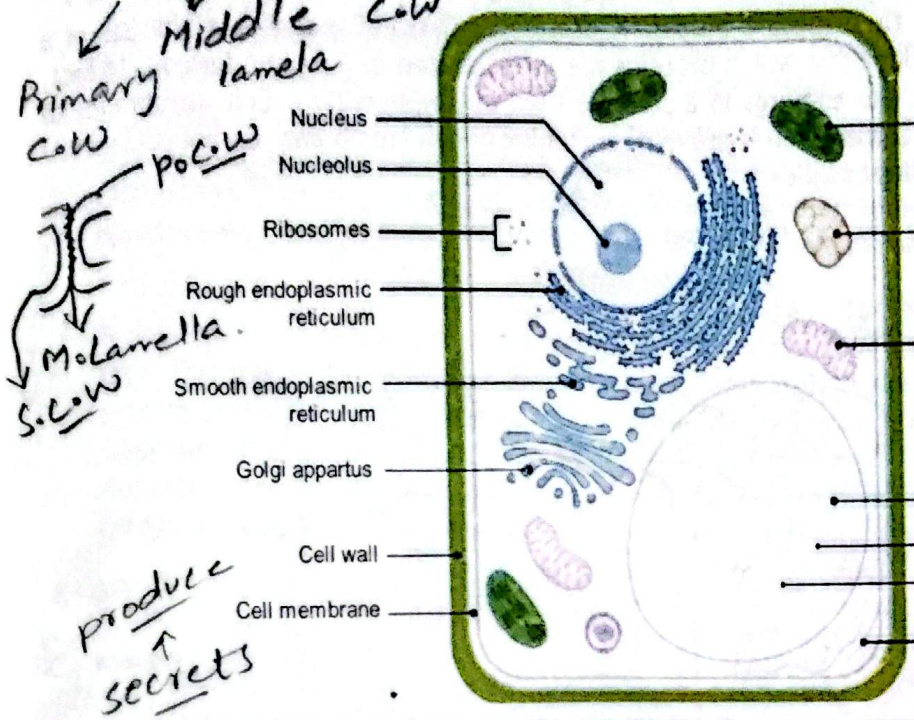


Fig 3.1: Animal cell

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cell wall → Secondary
↓ Middle c.w
Primary c.w
lamela

Bio online class start at 09:10 – 09:50



p.c.w
M.lamella
S.c.w

cell organelles
cell wall
structure:
Function:

produce
secrets

Fig 3.2: Plant cell

Cell wall (Present in plants, Absent in animals)

The cell wall surrounds the plasma membrane of plant cells. It is rigid, inert covering secreted and deposited outside the cell membrane. It consists of three layers namely middle lamella, primary wall and secondary wall.

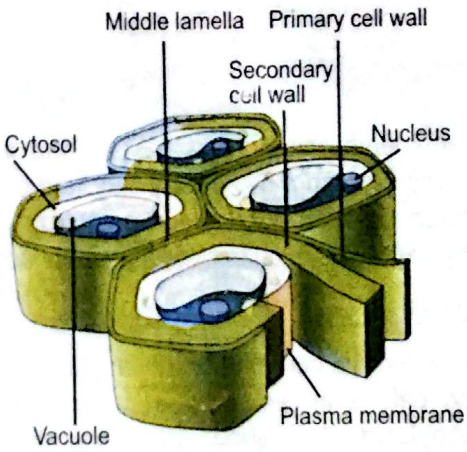


Fig 3.3: Plant cell wall

Middle lamella is a made up of magnesium and calcium salts of **pectin**. It is sticky in nature that holds the neighbouring (adjacent) cell walls together. **Primary wall** contains cellulose fibres arranged in a criss-cross fashion. It is thin and flexible. Some plant cells like xylem vessels form **secondary wall** inside the primary wall. It is very thick and rigid structure due to presence of lignin which cements the cellulose fibres together. Cell wall bears tiny pores through which neighbouring cells form cytoplasmic connections called plasmodesmata.



Algae have cellulose in their cell wall. Fungal cell wall is made up of chitin. Prokaryotes also possess cell wall made up of peptidoglycan. Cell wall is absent in animals and animal like protists (protozoa).

Cell wall supports the structure of individual cells and the plant as a whole. It protects and gives shape to the cell. Plant cells can develop turgor pressure due to presence of cell wall.

Cell membrane

Q: Why cell membrane is semi-permeable?

Cell membrane is a thin sheet like covering of the cell. Chemically it is composed of proteins 60-80 %, phospholipids 20-40 % and traces of carbohydrates. The structure of cell membrane is

→ invariable amount
→ different amount

explained according to **fluid mosaic model**. It postulates that cell membrane consists of a double layer of phospholipids in which proteins are incorporated in a mosaic fashion. In fact, protein molecules float like icebergs in a sea like fluid of phospholipids. Cell membranes of eukaryotes also contain cholesterol. It prevents stiffening of cell membrane. Carbohydrates are either linked with proteins or lipids.

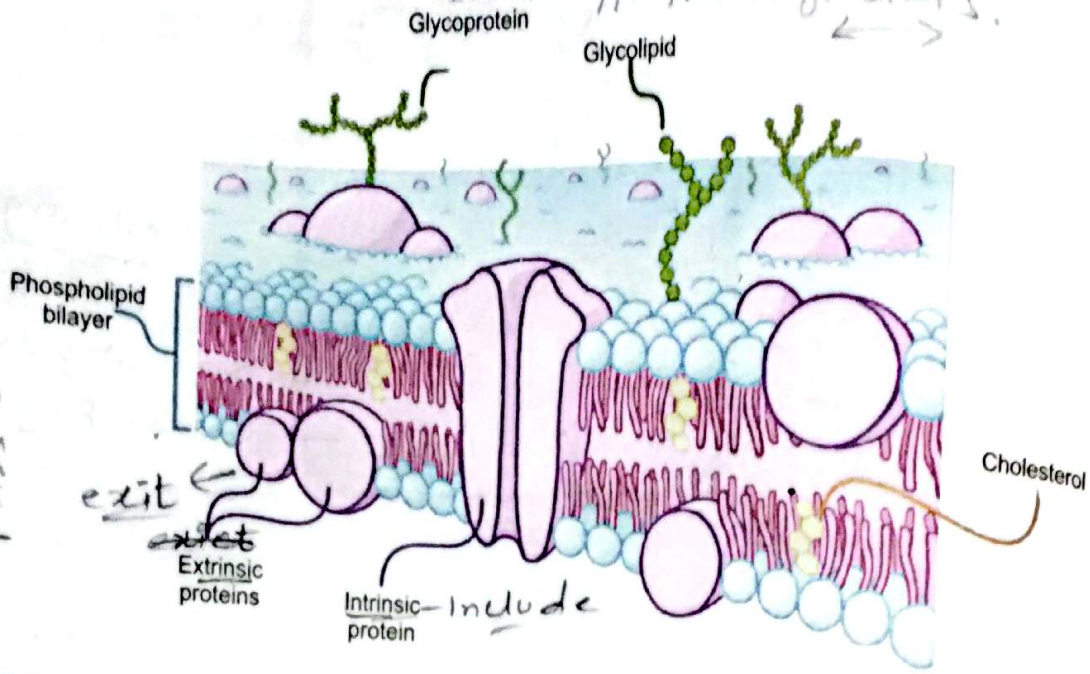


Fig 3.4. Fluid mosaic model of cell membrane

Cell membrane acts as barrier and gatekeeper for the cell. It is semipermeable so some molecules can move across the lipid bilayer but others cannot. It maintains fixed environment inside the cell. Cell membrane acts as a barrier between the cell and its environment. It regulates the exchange of materials between cell and its environment.

Cytoplasm

Between the cell membrane and nucleus of the cell is an aqueous substance called cytoplasm. It is about 90% water having many dissolved and suspended materials. It is the site for many biochemical processes. It stores food granules and waste materials. It is home for a variety of cell organelles which are discussed below.

Endoplasmic reticulum

It is a system of membranes present throughout the cytoplasm of eukaryotic cells. Flattened sacs of the endoplasmic reticulum are called **cisternae** which form a network of interconnected channels. There are two forms of endoplasmic reticulum. **Rough Endoplasmic Reticulum (RER)** have

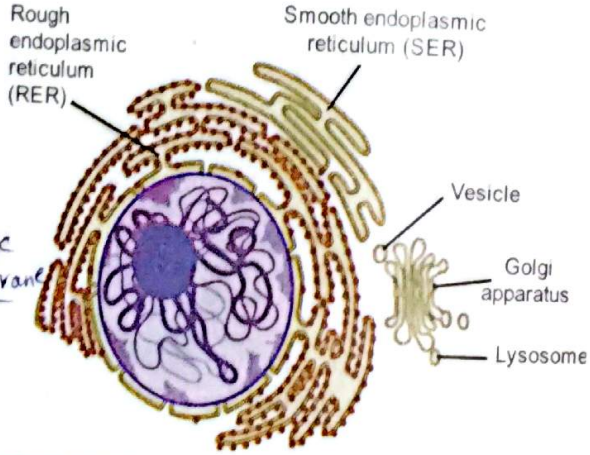


Fig 3.5: Structure of rough and smooth endoplasmic reticulum

rough appearance due to the attachment of numerous ribosomes on their surface. **Smooth Endoplasmic Reticulum (SER)** lack ribosomes on their surface.

A complex network of endoplasmic reticulum provides mechanical support to the cell. They are also involved in transport of substances within the cell. Due to attached ribosomes RER have role in the synthesis of some proteins. SER synthesize lipids including steroids. SER also detoxify harmful substances. In muscle cells SER have important role in contraction.

Ribosomes

Proteins make up to about 55 % dry weight of a cell. A cell thus needs protein synthesis at high rate. This role is performed by the ribosomes. Ribosomes are tiny granular structures found both in prokaryotic and eukaryotic cells. They are not bound by any membrane. They are composed of roughly equal amount of proteins and ribosomal RNA (rRNA). The prokaryotic ribosomes, however, are smaller in size. A large number of ribosomes are scattered in the cytoplasm. In eukaryotes many ribosomes are also attached on the surface of RER.

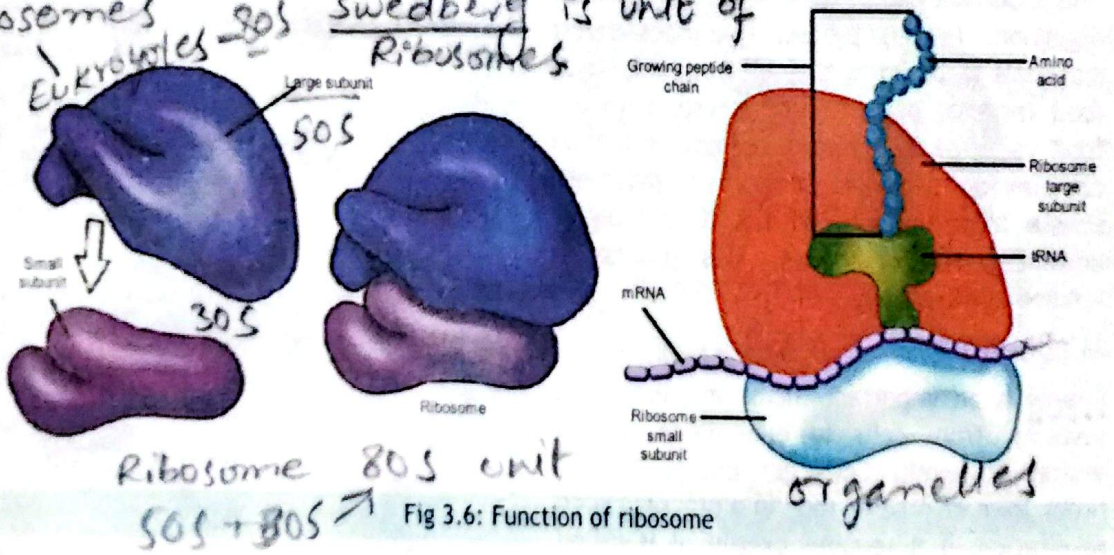


Fig 3.6: Function of ribosome

Each ribosome consists of two subunits, one small and one large. These two subunits join when ribosome has to perform its function of protein synthesis.

Golgi apparatus

Golgi apparatus was discovered by Camillo Golgi. It is present in all eukaryotic cells. Like endoplasmic reticulum, Golgi apparatus is also collection of flattened sacs called cisternae. However, in Golgi apparatus many cisternae are stacked over each other. They are constantly formed at one end and breakup into vesicles at the other end. Vesicles are tiny fluid-filled sacs which can store or transport materials.

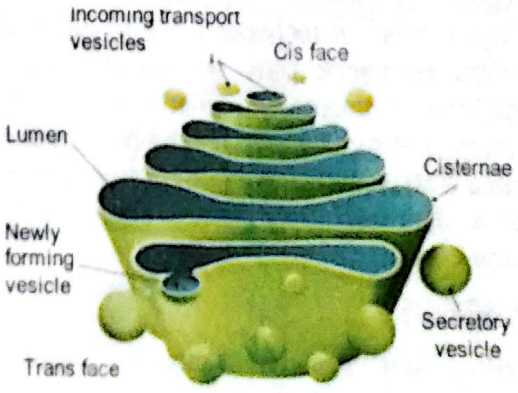


Fig 3.7: Structure of Golgi apparatus

Golgi apparatus store and modify materials into finished form before packing into vesicles. Some of these vesicles settle in cytoplasm as organelles like lysosomes. Others fuse with the cell membrane to release out packed material as cell secretion. Products of glands like

enzymes, hormones, mucus etc. are secreted in this way. In plant cell, it secretes cellulose fibres which arrange themselves to form cell wall.

Lysosomes

They are single membrane bound small sac like structures. They contain a variety of digestive enzymes. The enzymes contained in lysosomes are synthesized in RER and then transported to Golgi apparatus. Lysosomes then bud off from Golgi apparatus with their processed enzymes.

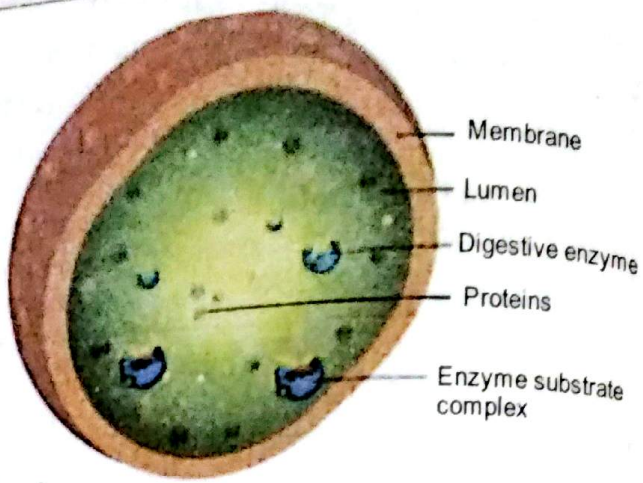


Fig 3.8: Structure of Lysosome

One important role of lysosome is **intracellular digestion**. In this process lysosomes digest materials taken up by the cell from outside as food vacuole. When lysosome fuses with the food vacuole, the lysosomal enzymes act on complex food substances and convert them into simple form. They also engulf and digest unwanted cell organelles. This process is termed as **autophagy**.

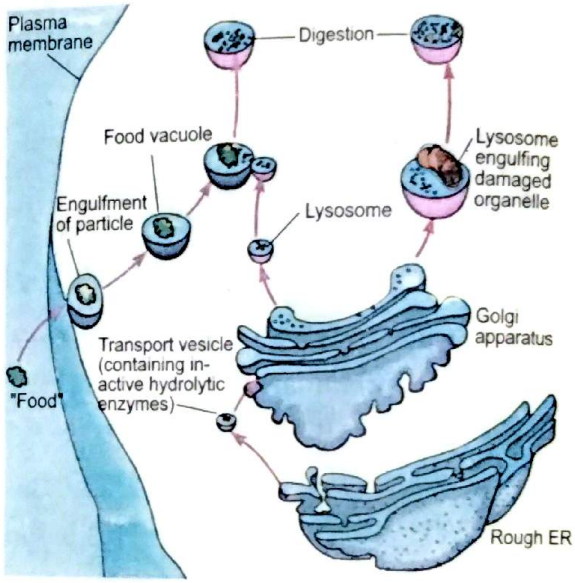


Fig 3.9: Formation and function of lysosome

Mitochondria

Energy is an important theme in biology. All systems, from cells to ecosystems require energy to work. Cells get energy by the breakdown of organic food in a process called respiration. If it requires oxygen, it is called **aerobic respiration**. It takes place in mitochondria. Mitochondria are found in all aerobic eukaryotic cells. Mitochondria are double membrane bound structures. The outer membrane is smooth and inner membrane forms finger like projections called **cristae**. They increase the surface area for the process of respiration. The fluid inside the mitochondrion is called **matrix**. Mitochondria have their own DNA and ribosomes. They can multiply within the cell at their own. They produce energy in the form of ATP that is why they are called power house of cell.

Q: why mitochondria is called "power house of cell"?

PLASTIDS

Plastids are double membrane bound organelles. They are found in plants and algae. There are three types of plastids i.e., chloroplast, chromoplast and leucoplast.

plant like protest

Chloroplast (Green)

Help in photosynthesis

Chloroplasts are usually oval in structure. Two membranes of the chloroplasts form chloroplast envelope. They have their own

Imp* Structure

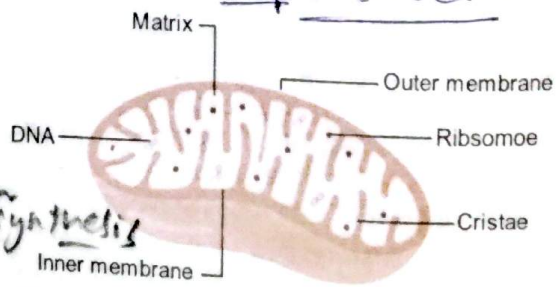


Fig 3.10: Structure of mitochondria

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DNA and ribosomes. They can multiply within the cell at their own. They have a system of membranes containing chlorophylls and other photosynthetic pigments. This system consists of hollow coin like membranous structures called **thylakoids**. Many thylakoids stack to form **granum**. Some thylakoids of adjacent grana fuse to from intergrana. The fluid part of chloroplast is called **stroma**. Chloroplasts synthesize food by photosynthesis process. It takes place in two phases;

a. Light-dependent phase which takes place in thylakoid membranes.
b. Light-independent phase which takes place in stroma.

Chromoplast

Chromoplasts are coloured pigments other than green. They may be red, pink, yellow, blue, purple etc. They are found in flower petals to attract insects. Insects help in pollination. They are also present in the wall of ripened fruits where they attract birds and other animals which help in seed dispersal.

Leucoplasts

Leucoplasts are non-pigmented plastids. They are food storing organelles usually found in roots, bulbs and stem tubers. They store carbohydrates, proteins or lipids.

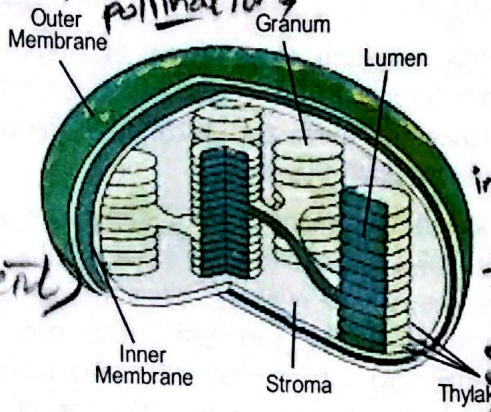


Fig 3.11: Structure of chloroplast

Vacuole

A vacuole is a membrane bound fluid filled sac. Animal cell may have many small vacuoles which exist temporarily. 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** which is then digested into simple molecules. Food vacuoles also store food.

Plants cells have a large central vacuole as shown in figure 3.12. It is formed by joining small vacuoles. The membrane of plant vacuole is called **tonoplast**. It contains liquid called **cell sap**. Cell sap has dissolved materials like mineral salts, sugars, and amino acids. It also provides support and helps in growth. The primary role of the central vacuole in a plant cell is to maintain turgor pressure within the plant cell. **Turgor pressure** occurs when the fluid content of a cell pushes the cell membrane against the cell wall in order to provide shape to the plant cell.

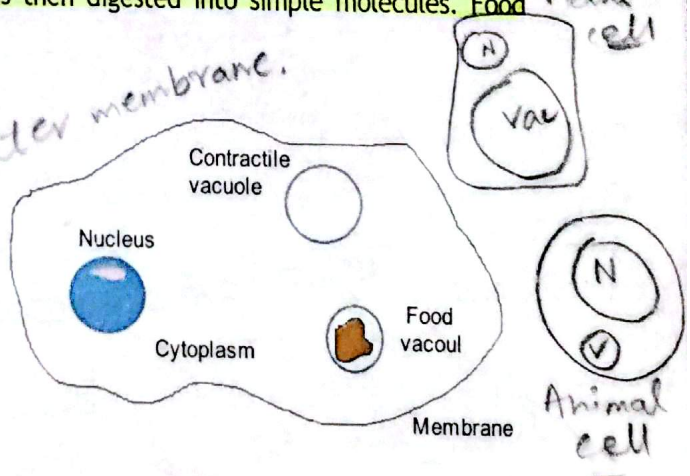


Fig 3.12: Structure and types of vacuole in animal cell

Centrioles

Centrioles are hollow open ended cylinder like structures. They are found in animal cell. They exist in pairs near the nuclear envelope. Each centriole consists of nine triplets of microtubules. At the start of cell division centrioles duplicate and two pairs move to the opposite poles, thus help in the formation of spindle apparatus. They are also involved in the formation of cilia and flagella.

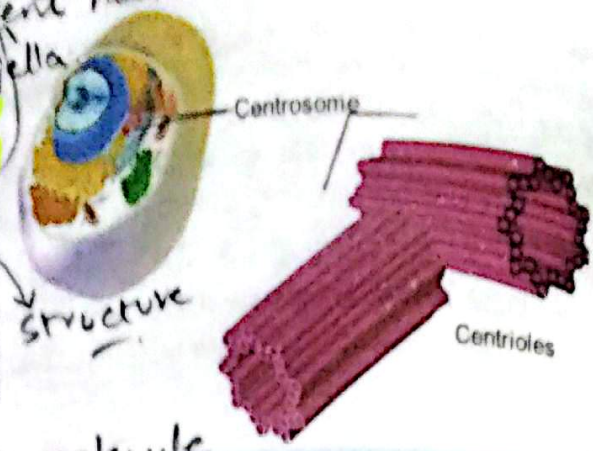


Fig 3.13: Pair of centrioles

Cytoskeleton

Cell has a system of a variety of fibrous proteins throughout the cytoplasm. These proteins collectively form cytoskeleton. Three types of cytoskeletal fibres are identified in the cell. These include; microtubules, microfilaments and intermediate filaments.

Microtubules are made up of **tubulin** protein. They are unbranched hollow tube like structures. Microtubules give rise to spindle fibres, cilia and flagella. **Microfilaments** are very thin protein fibres. They consist of contractile proteins mainly **actin.** They are responsible for the streaming movements of the cytoplasm. The overall cell movement is also regulated by the microfilaments. **Intermediate filaments** are composed of a variety of proteins including **keratin** and **vimentin.** They form a branching network in the cell. They maintain the cell structure, and also fix cells with each other to form tissues.

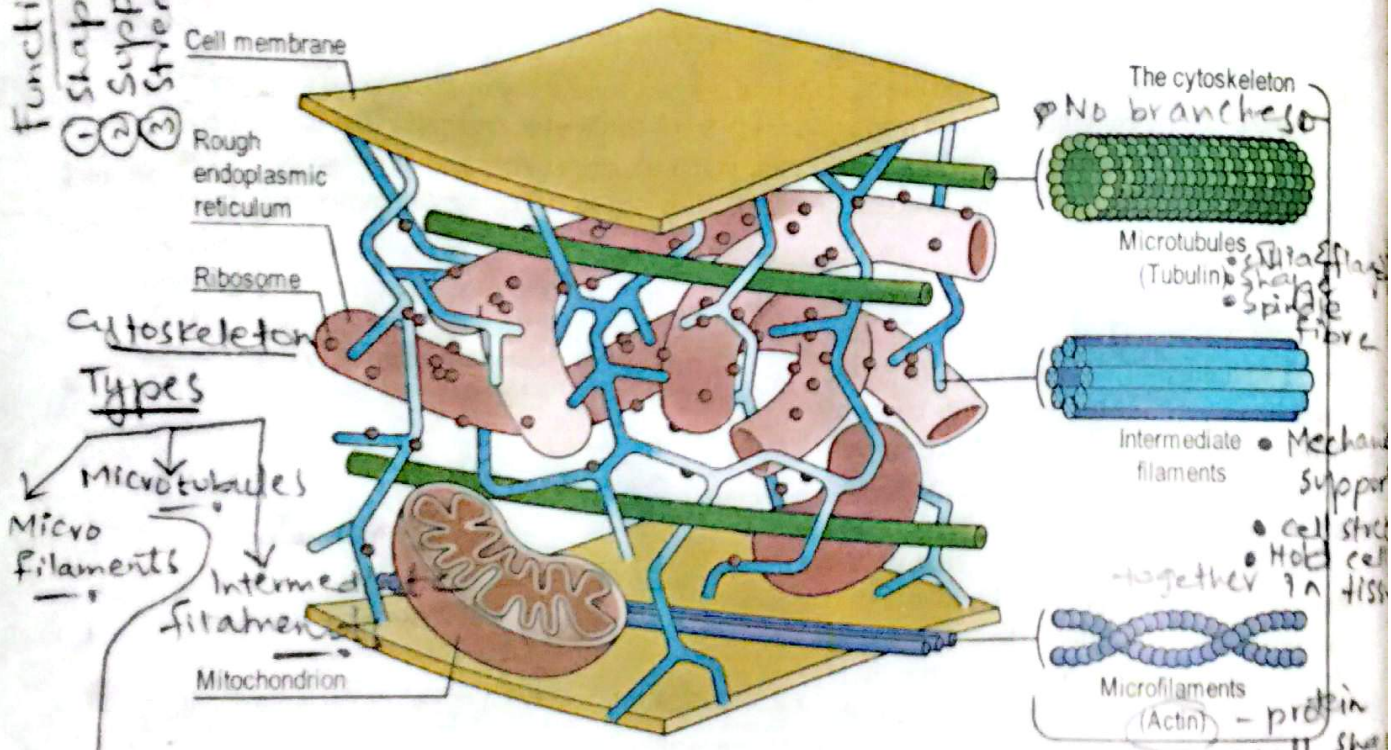


Fig 3.14: Structure and types of cytoskeleton

Cilia and Flagella

Some eukaryotic cells have extensions that look somewhat like hair. These structures are called **cilia**. Some cells have whip like extensions called **flagella**. 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**. The basal body serves to anchor a cilium or flagellum to the cell. The function of cilia and flagella is movement.

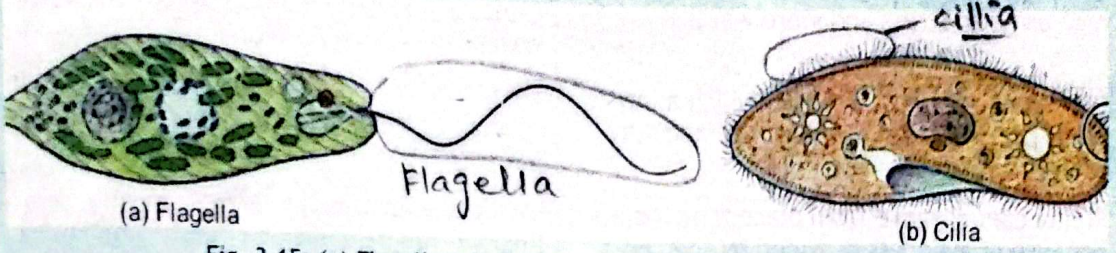


Fig. 3.15: (a) Flagellum in *Euglena* (b) Cilia in *Paramecium*

Nucleus

Cell activities like **metabolism**, **growth** and **reproduction** need to be well regulated. In eukaryotic cell this role is served by the nucleus. Nucleus acts as control centre of the cell because it contains hereditary material DNA.

Nucleus is surrounded by two membranes which collectively form the **nuclear envelope.** Nuclear envelope bears **nuclear pores** at points where both membranes fuse with each other. Through nuclear pore nucleus communicates with the cytoplasm. Some nutrients and proteins enter the nucleus through these pores and ribosomes and mRNA leave the nucleus. Nucleus contains a fluid called **nucleoplasm**.

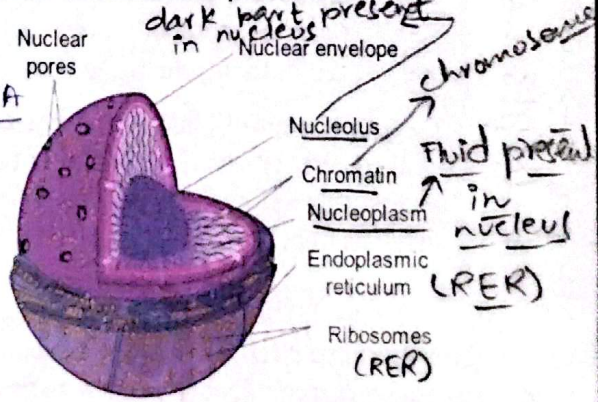


Fig 3.16: Structure of nucleus

Nucleolus is a round darkly stained area in the nucleus. Ribosomes are assembled at this point. Here ribosomal RNA (rRNA) is formed which combines with proteins to form ribosomes. It disappears for some time during cell division.

Hereditary material in the nucleus is actually in the form of chromatin. Chromatin consists of **DNA** fibres coiled on **histone** proteins. During cell division chromatin fibres condense into more tightly coiled threads known as **chromosomes.** Each species has its own unique chromosomal set different from other species.

3.1.2 Structural advantages of animal and plant cell

The cells of living organisms have basic similarities in structure due to common origin, however, they differ in many respects. Cell wall makes a major difference in plant and animal cell. The presence of cell wall in plant cell and absence in animal cell is reflected in their life styles.

Advantages of having cell wall in plant cell	Advantages of not having cell wall in animal cell
Due to cell wall adjoining plant cells are cemented with each other. Supportive	The supportive structure of an animal as a whole is not dependent on a cell wall but rather on the collective arrangement and

structure of plant as a whole is thus formed by cell wall.	organization of tissues, organs, and skeletal systems present in the animal's body.
Transport channels in plants, xylem and phloem, are also formed because of presence of cell walls.	In animal cells, since they lack a cell wall, the transport of fluids, nutrients, and gases occurs through different structures and mechanisms.
The rigid wall helps plant cell to withstand high osmotic stress and store water.	Animal cells cannot withstand high osmotic pressure and cannot store larger volumes of water.
Plant cell can become turgid which allows plant parts to maintain structure and stay upright.	Animal cell cannot become turgid to provide support to the body
Plants cannot move from place to place because of rigidness provided by the cell wall.	Lack cell walls which makes then very flexible. Animal cells can move. Animal cells/ animals can move to suitable environmental conditions, find shelter and better feeding fields and opportunities for reproduction.
Due to rigid structure plant cell cannot reproduce at a faster rate.	It also helps animal cell to divide and reproduce at faster rate.

3.2 CELL SPECIALIZATION

In multicellular organisms, cells are specialized to perform their specific roles. Daughter cells formed by mitosis process undergo changes in a process called **differentiation**. They alter in size, structure, metabolic activities and physiological responses. As a result, they become specialized in their role in the body. Some examples of the specialized cells are given below.

Epidermal cells of plants form protective covering of root, stem and leaves. They are flattened cells which pack tightly to form a continuous outer layer of plant body. Epidermal cells having some additional roles are modified accordingly. For example, **root hair cells** which absorb water and minerals from the soil and **guard cells** of leaves which regulate the opening and closing of stomata.

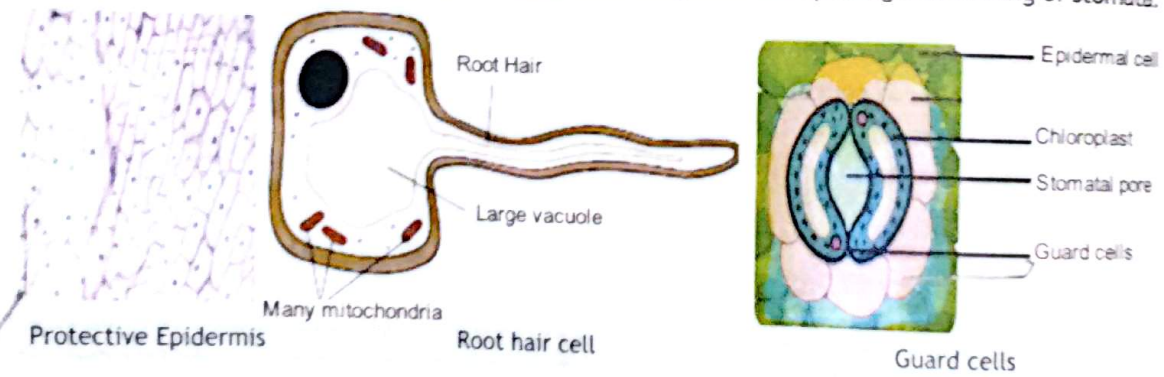


Fig 3.17: Epidermal cells

Mesophyll cells are photosynthetic cells of plants. They are present in plant leaves. They contain a large number of chloroplasts. Chlorophyll and other photosynthetic pigments are anchored in the thylakoid membranes of chloroplasts. These pigments absorb light energy and use it to produce food in photosynthesis process.

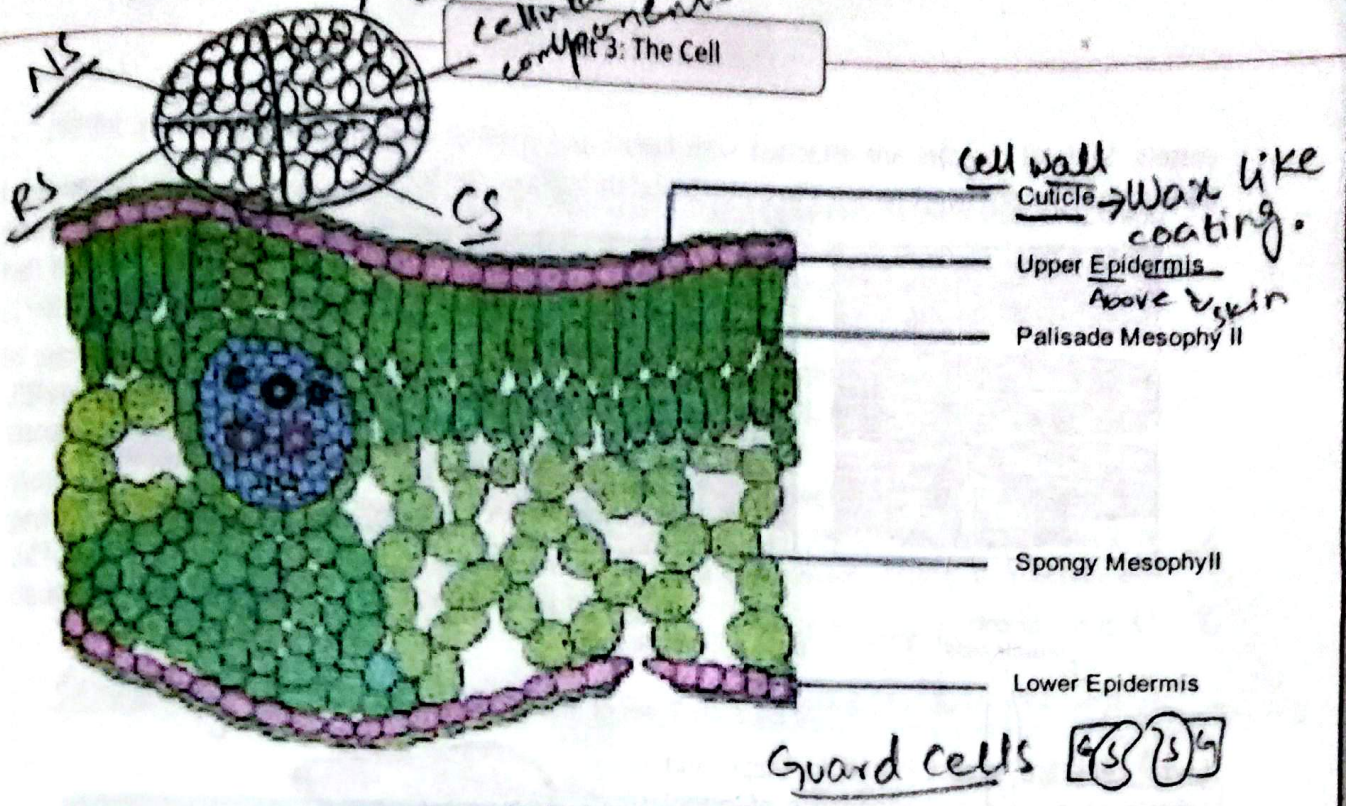


Fig 3.18: Mesophyll cells

Red blood cells (RBCs) are haemoglobin filled cells to transport oxygen in the body. They are biconcave disk-shaped cells. This shape provides more surface area to absorb and release oxygen. Nucleus, mitochondria, endoplasmic reticulum etc, are absent in RBCs. It enables RBCs to accommodate more haemoglobin. These cells are very flexible so they can easily pass through blood capillaries. The average age of RBCs is 120 days.



Fig 3.19: Red Blood cells

Neurons are the cells of nervous system. They are responsible for coordination in the animal bodies. To accomplish this job their structure is very unique. A neuron cell has a **cell body** and two types of cytoplasmic fibres. One of them are **dendrites** which conduct nerve impulses to the cell body. Others are **axons** which conduct messages away from the cell body. The dendrites and axons make it possible for neurons to communicate with far away cells of the body.

Muscles cells have ability to contract and relax. Locomotion, breathing movements, blood pumping by the heart, change in size of eye pupil, peristaltic contraction of the gut, speech movements of tongue, lips etc. are result of the muscle contraction. To produce contractions muscle cells, have elongated shape and are filled with **actin** and its associated contractile proteins. Smooth muscles are present in the walls of internal hollow organs like stomach, intestine and blood

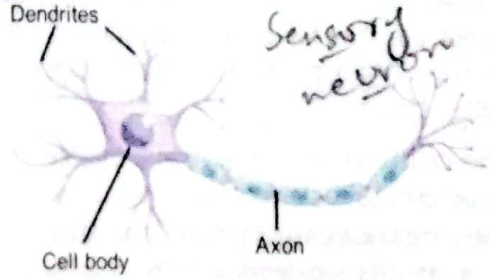


Fig 3.20: Neuron

vessels. Skeletal muscles are attached with bones and produce movements of bones at joints. Cardiac muscles are heart muscles to pump blood throughout the body.

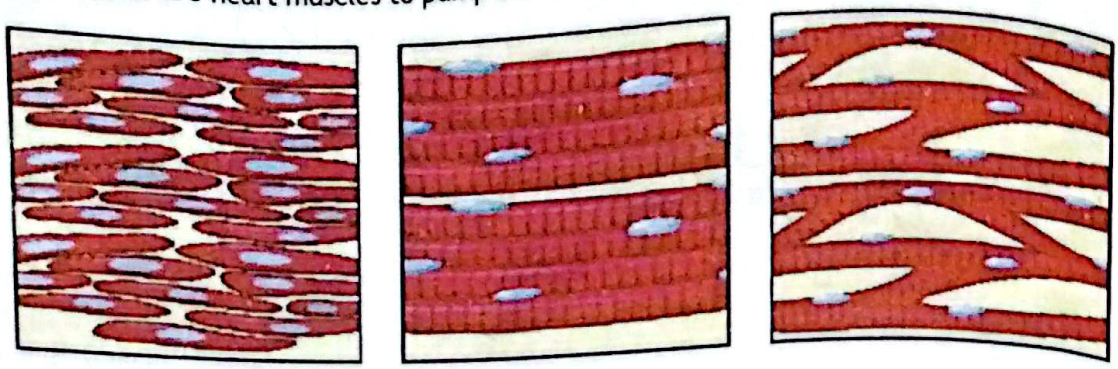


Fig 3.21: Types of muscles

Liver cells are almost round in shape and have prominent nucleus and abundance of cytoplasmic organelles. They are metabolically most active cells of the body. Their few important roles are;

a. Storage of glycogen, iron and some vitamins.
b. Detoxification of toxic substances.
c. Production of clotting proteins of blood.
d. Recycling of old red blood cells.

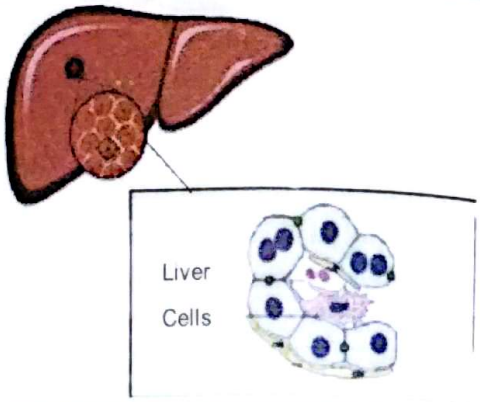


Fig 3.22: Liver and liver cells

3.3 DIVISION OF LABOUR

Within a cell different organelles perform their assigned roles. **Mitochondria** act as powerhouse of the cell as they produce energy for the cell. **Ribosomes** remain engaged in protein synthesis. **Chloroplasts** harvest light energy to manufacture organic food. For the normal survival and functioning of a cell its organelles must do their specified jobs. The performance of given function by different organelles is the division of labour.

Cell is the unit of life, so a cell can perform all basic function of life. A cell can respire, take and utilize nutrients, grow in size, reproduce, show movements etc. In unicellular organisms, a single cell lives as an organism and performs all these life processes independently.

A huge number of cells assemble a body of multicellular organism. In multicellular organism it is not possible for billions or trillions cells to perform all life tasks independently. So cells arrange in groups to perform some given role. A group of cells performing same function is called **tissue**.

The cell originating from same zygote change their cell lines and differentiate into unique structures suitable for their roles. Muscles cells are elongated to make the body parts move by their contractions. Neurons form thin cytoplasmic fibres to conduct messages in the body. Muscles cells and neurons cannot exchange their function. Similarly, RBCs transport oxygen and bone tissue provides mechanical support. In plants mesophyll cells prepare food by photosynthesis process and phloem cells transport this food to all parts of the plant body.

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3.4 Stem cells

Around 220 types of cells are identified in human body. These cells vary in their size, shape and role. However, all these types of cells have a common origin. They all develop from a single cell the zygote. A cell which gives rise to cells of other types is called the stem cell. The zygote is very basic stem cell which has ability to produce all kinds of cell an organism.

In sexually reproducing organisms, life starts from zygote. As the development progresses, different cell lines are formed. Each cell line has its own stem cell. Brain, liver, and other body tissues are products of stem cells.

Stem cells by themselves are not differentiated and are un-specialized. Each daughter cell produced by division of a stem cell has capacity to remain un-specialized stem cell or differentiate into mature cell of some tissue. So stem cells divide, renew themselves and daughter cells differentiate into distinct cell type.

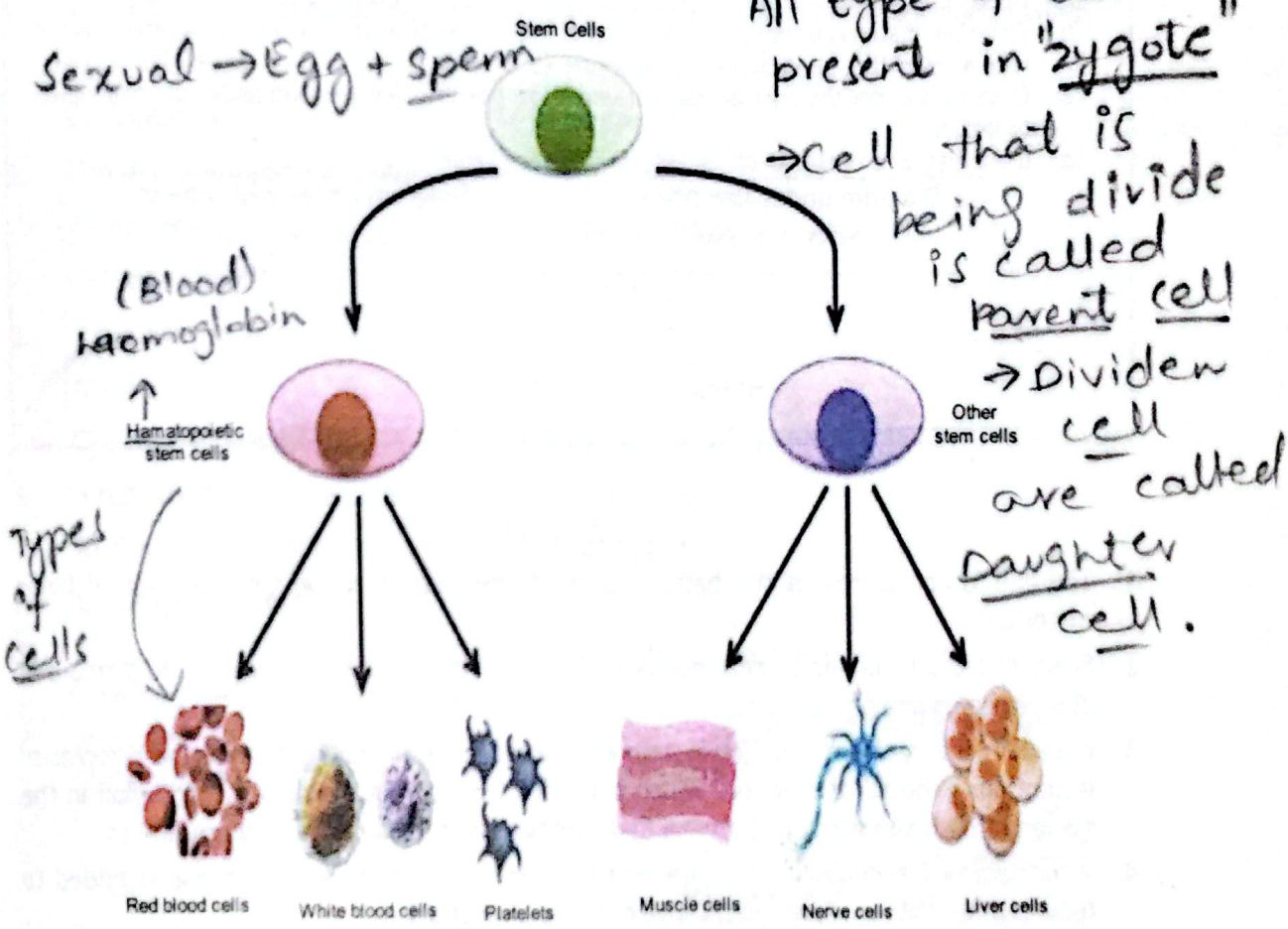


Fig 3.23: Stem cells and formation of specialized cells

STEAM ACTIVITY 3.1

Study of a plant cell

a. Place a small piece of onion skin in a drop of water on a slide and cover it with a cover slip.
b. Observe it under the microscope first under low power objective then under the high power objective.

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c. Draw diagrams of onion skin cells in following table.

Diagram under low power objective lens	Diagram under high power objective lens

Steam Activity 3.2

Study of an animal cell

a. Gently pass the broad end of tooth pick on the inner side of your cheek.
b. Place the material o tooth pick in a drop of methylene blue solution on a slide and cover it with a cover slip.
c. Observe it under the microscope first under low power objective then under the high power objective.
d. Draw diagrams of human cheek cells in following table.

Diagram under low power objective lens	Diagram under high power objective lens

SUMMARY

1. The cell is considered as the basic unit of life because it is the smallest unit of living material.
2. Every cell is surrounded by cell membrane. The cell membrane is a highly fluid mixture of phospholipids and proteins.
3. A nucleus is a double membrane system with pores that communicates with the cytoplasm. It contains genetic information, which is carried by the DNA. Nucleolus is a region in the nucleus that is the site for ribosomal RNA synthesis and ribosome assembly.
4. Mitochondria are double membrane organelles in which the inner membrane is folded to form cristae. Mitochondrion is the site of aerobic respiration.
5. Golgi bodies are a series of flattened membrane sacs that process, sort, and modify proteins synthesized on the ER, and transport proteins to the plasma membrane, to the outside the cell and the lysosomes.
6. The endoplasmic reticulum is a series of internal membranes with many functions, i.e., protein synthesis lipid synthesis and transport.
7. Ribosomes are the site of protein synthesis.
8. Lysosomes breakdown organic molecules like proteins into simpler compounds that can be used by the cells.

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9. Plant cell has cell wall, plastids and large vacuole.
10. Mesophyll cells, epidermal cells, neurons, muscles, red blood cells and liver cells are adapted to their particular functions.
11. Within a cell different organelles perform their assigned roles as there is division of labour.
12. A cell which gives rise to cells of other types is called the stem cell.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. A network of channels extending from cell membrane to nuclear membrane is called:

   A) centriole B) endoplasmic reticulum

   C) ribosomes D) centrosome

2. The site of enzyme synthesis in cells is:

   A) lysosome B) smooth endoplasmic reticulum

   C) Golgi bodies D) ribosome

3. What are the functions of mitochondria?

   A) lipid synthesis B) protein synthesis

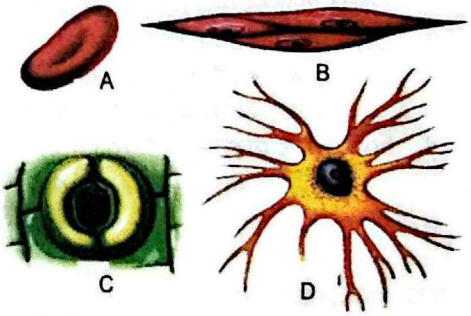
   C) photosynthesis D) cellular respiration

4. A red blood cell and a plant root hair cell both have:

   A) Cellulose cell wall B) haemoglobin

   C) Large surface area D) nucleus

5. The diagrams show cells from different types of tissues (not drawn on scale). Which type of cell contracts when it is stimulated?



6. Which of the following cell organelles does not contain DNA?

   A) Nucleus

   B) Lysosomes

   C) Chloroplast

   D) Mitochondria

7. Phospholipids are required for cell membrane formation are synthesized in:

   A) Mitochondria D) Cytoplasm

   C) Endoplasmic Reticulum D) Smooth Endoplasmic Reticulum

8. Cytoskeleton is an important component of eukaryotic cells. Which of the following statement correctly describes cytoskeleton?

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A) All the cytoskeletal structures are made up of same protein
B) There is no contractile protein in any cytoskeletal component.
C) Cytoskeleton provides mechanical support and has role in cell division.
D) The entire cytoskeleton is present around the cell membrane.

9. The shape of normal red blood cells is:
   A) Oval
   B) Crescent
   C) Biconvex
   D) Biconcave

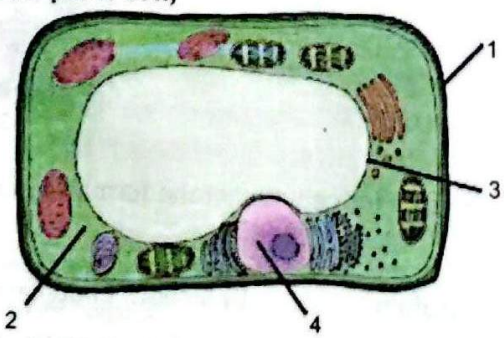
10. Plastids of different types are correctly represented by:

	Photosynthetic	Pigmented	Food storage	Colour variety
A)	Chloroplasts	Leucoplasts	Chromoplasts	Chloroplasts
B)	Chromoplasts	Chloroplasts and chromoplasts	Chromoplasts and leucoplasts	Chromoplasts
C)	Leucoplasts and chloroplasts	Chromoplasts and leucoplasts	Leucoplasts	Chloroplasts
D)	Chloroplasts	Chloroplasts and chromoplasts	Leucoplasts	Chromoplasts

11. Which of the following statement correctly represents ribosomes?
   A) They are present only in eukaryotic cell.
   B) They are produced in the nucleus then migrate to the cytoplasm where they synthesize proteins.
   C) They are covered by single membrane.
   D) All ribosomes are attached to the inner surface of RER.

Section II: Short Answer Questions

1. Why mitochondria are known as powerhouse of the cell?
2. What makes red blood cells more suitable for the transport of oxygen?
3. Give the modifications of epidermal cells for;
   a. Exchange of gases
   b. Absorption of water and minerals.
4. Following diagram shows a plant cell;

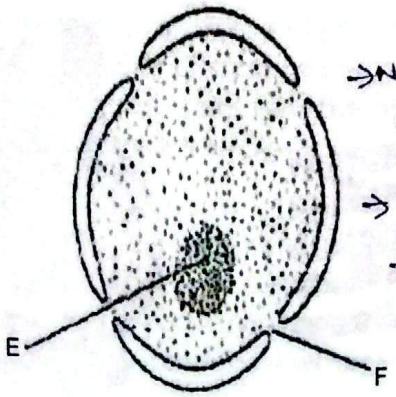


Keeping in view the parts labeled 1 to 4, answer the following questions:
   a. Give the number indicating the structure which controls the cell activities?

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b. Name a biochemical process taking place in part 2.
c. What will happen to cell if part 1 is removed and part 3 is overfilled with water?

5. The diagram below represents a nucleus.



SER
→ No attached ribosomes
→ Detoxify the toxic substance

RER
→ Attached ribosomes
→ Protein synthesis

a. Name the structure labeled E and F.
b. Give the function of F.
c. Which cytoplasmic organelles are formed by E?
d. What happens to E during cell division?

6. Cell shape is related to cell function. Give three examples to support your answer.
7. Plasma membrane has two main components according to fluid mosaic model. Which component represents fluid and which component represents mosaic?
8. Select the structures which are present in all cells of all kingdoms. Write one function of each selected structure.

   Cell membrane; Nucleus; Chromosomes; Cytoplasm; Ribosome; RER; SER; Golgi apparatus; Lysosome; Mitochondria; Centriole; Cilia; Flagella; Cell wall; Cytoskeleton; Vacuole; Plastids

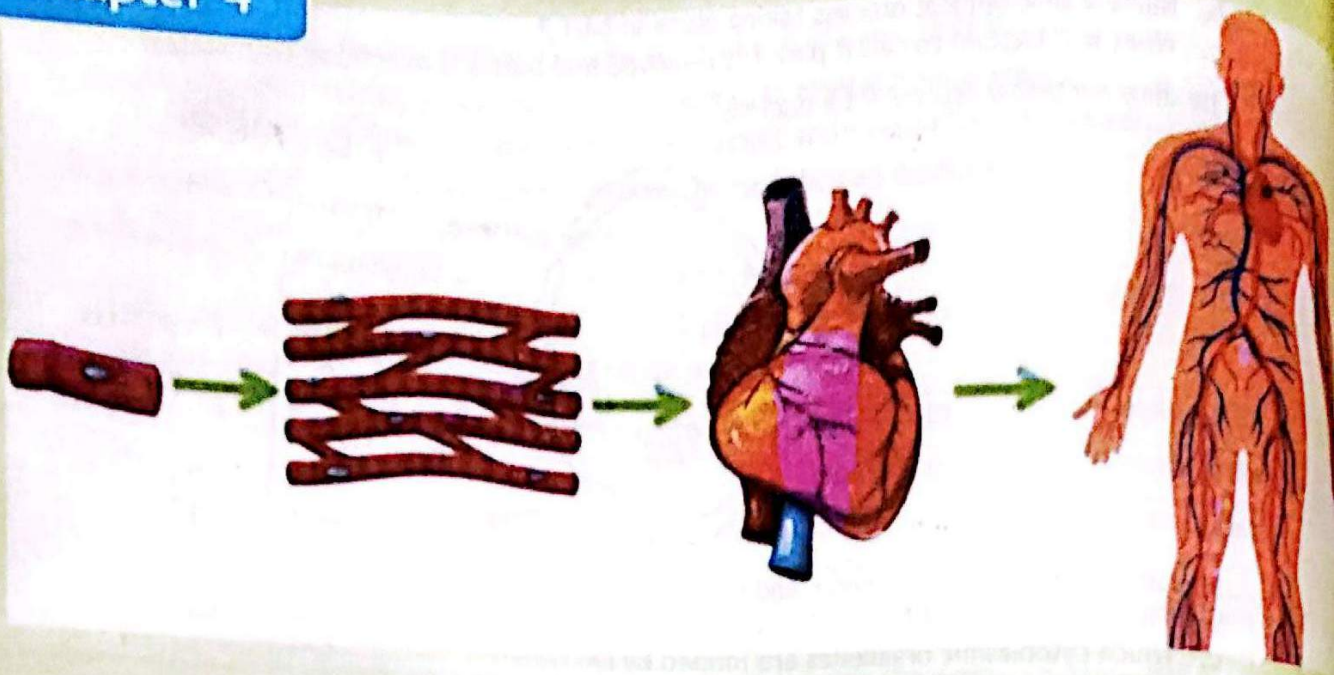
9. Which cells in animals and plants do not have a nucleus? How do these cells perform their functions without nucleus?
10. Unripe oranges are green in colour. After ripening their colour changes. Suggest which organelles' number changed in them during ripening?
11. Which organelles are abundant in the salivary gland cell? Explain.

Section III: Extensive Answer Questions

1. Explain the structural model of cell membrane and give the roles of cell membrane.
2. How cell wall is important in the lifestyle of plants?
3. If a cell is rich in SER, list the roles in which this cell will be more efficient.
4. Give the significance of muscles in the life of animals.
5. Give the types of plastids and enlist the roles of each type.
6. Describe the structure and functions of animal cell. How it is different from plant cell?
7. Justify how the cells of leaf have a variety of specialized structure and function.
8. State the relationship between structure and function of mesophyll cells, epidermal cells, neurons, muscles, red blood cells and liver cells
9. Describe the role of the cell membrane in maintaining equilibrium while exchanging matter?

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Chapter 4



TISSUES, ORGANS AND ORGAN SYSTEMS

SLOs: After completing this lesson, the student will be able to:

1. Describe the concept of emergent properties as gain in functionalities and how it applies to the following:
   a. going from sub cellular organelles to cells
   b. going from cells to tissues
   c. going from tissues to organs
   d. going from organ to systems
   e. going from organ systems to living organisms
2. Distinguish between tissues, organs and systems, with examples from animals and plants.
3. Enlist the different types of tissues come together to form the stomach organ in the human body.
4. Discuss the organ systems come together to form the human body.
5. Describe the advantages of homeostasis.
6. Discuss the various organs and systems of the human body work to maintain homeostasis.
7. Discuss the different types of tissues come together to form the leaf.
8. Explain plant physiology in terms of structure and roles of various plant organs.

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4.1 THE LEVELS OF ORGANIZATION

Whether we study an individual organism or the world as whole, we can identify a pattern of increasing complexity. **Atoms** react with each other to form molecules. Small **biomolecules** join together to form large **macromolecules** like proteins, lipids, nucleic acids and carbohydrates. These macromolecules assemble to form cell organelles. **Cell organelles** are the parts that make up a cell, like the nucleus, ribosomes and the mitochondria. Each individual organelle has a specific role to play. When multiple organelles are combined, they make a single **cell**.

The cells in complex multicellular organisms like human beings are organized into **tissues** i.e., groups of similar cells that work together on a specific task. **Organs** are structures made up of two or more tissues organized to carry out a particular function, and groups of organs with related functions make up different **organ systems**. Several organ systems work together in harmony to make an **organism**.

At each level of organization—cells, tissues, organs, and organ systems—structure is closely related to function. For instance, the cells in the small intestine that absorb nutrients look very different from the muscle cells needed for body movement. The structure of the heart reflects its job of pumping blood throughout the body, while the structure of the lungs maximizes the efficiency with which they can exchange gases.

Table 4.1: The Levels of Organization and their explanation

Level of Organization	Explanation	Example
 Atomic Level	Atoms are defined as the smallest unit of an element that still maintains the property of that element.	Carbon, Hydrogen, Oxygen
 Molecular Level	Atoms combine to form molecules which can have entirely different properties than the atoms they contain.	Water, DNA, Carbohydrates
 Organelle Level	Biomolecules assemble in a specific way to form organelle. Organelles are sub-cellular structure.	Nucleus, ribosomes
 Cellular Level	Cells are the smallest unit of life. Cells are enclosed by a membrane or cell wall and in multicellular organisms often perform specific functions	Muscle cell, Skin cell, Neuron
 Tissue Level	Tissues are groups of cells with similar functions	Muscle, Epithelial, Connective

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 Organ Level	Organs are two or more types of tissues that work together to complete a specific task.	Heart, Liver, Stomach,
 Organ System Level	An organ system is group of organs that perform related functions.	Digestive System, Circulatory System
 Organism Level	An organism has several organ systems that function together.	Human

4.1.1 Types of animal tissues

Humans—and other large multicellular animals—are made up of four basic tissue types: epithelial tissue, connective tissue, muscle tissue, and nervous tissue. **Epithelial tissue** covers, protects and secretes glandular secretions. It forms skin and lining of tubes and organs. **Connective tissue** connects, transports, supports and stores. It is found in blood, bone, cartilage, fat, loose and dense connective tissues. **Muscular tissue** moves body parts or substances. It is found in heart, tubes and muscles. **Nervous tissue** carries messages around the body. It forms brain, spinal cord and nerves.

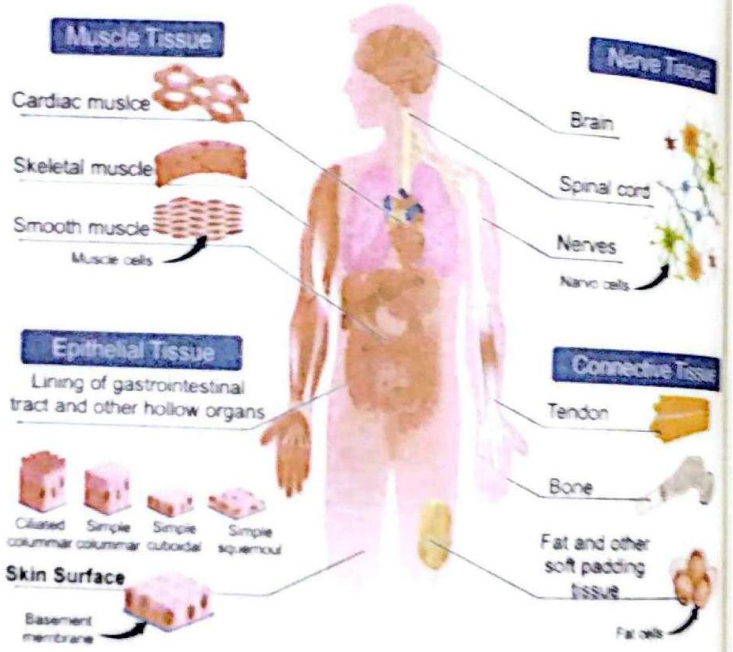


Figure 4.1: Types of tissues in humans

4.1.2. Organs

Organs, such as the heart, the lungs, the stomach, the kidneys, the skin, and the liver, are made up of two or more types of tissues organized to serve a particular function. For example, the heart pumps blood, the lungs bring in oxygen and eliminate carbon dioxide, and the skin provides a barrier to protect internal structures from the external environment.

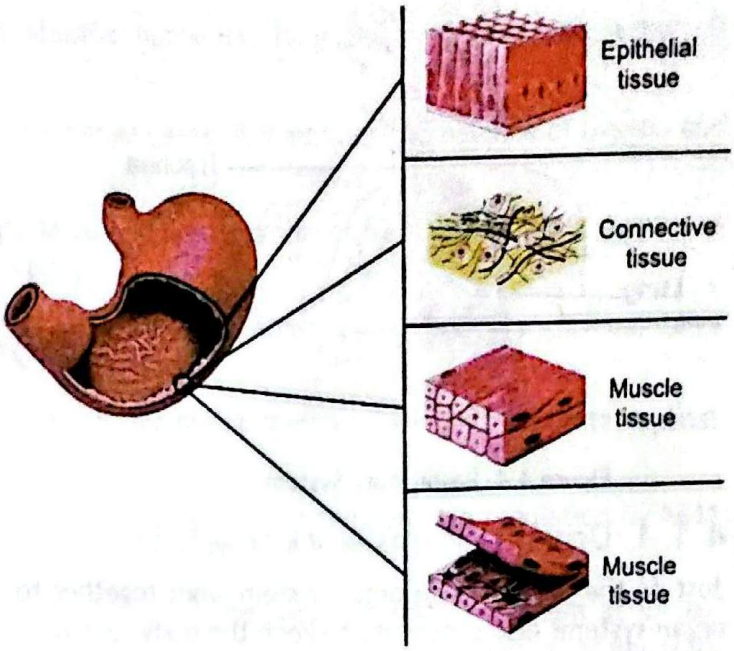


Figure 4.2 Stomach as an organ

Most organs contain all four tissue types. The layered walls of the stomach provide a good example of how tissues form an organ. The stomach wall has four layers that work together to digest food and protect the body.

1. **Mucosa:** Innermost layer, producing mucus to shield the stomach from acid and enzymes.
2. **Submucosa:** Layer containing blood vessels, nerves, and glands that support digestion.
3. **Muscularis:** Layer of smooth muscle that contracts and relaxes to mix food.
4. **Serosa:** Outermost layer, a thin membrane protecting the stomach from surrounding organs.

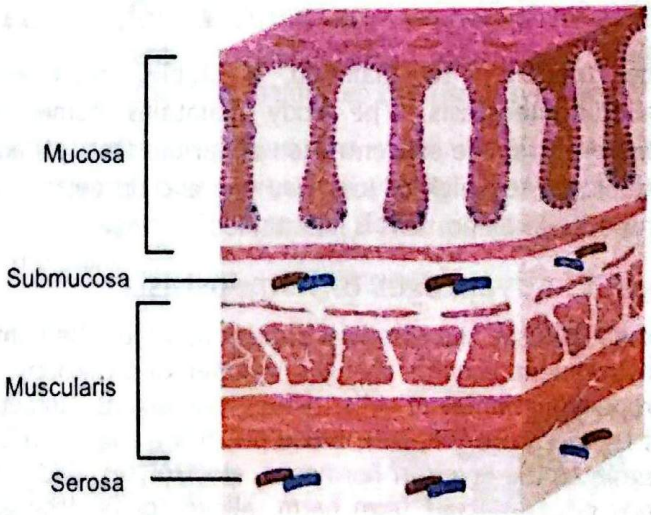


Figure 4.3: Stomach wall and its layers

4.1.3. Organ systems

Organs are grouped into **organ systems**; in which they work together to carry out a particular function for the organism.

For example, the heart and the blood vessels make up the cardiovascular system. They work together to circulate the blood, bringing oxygen and nutrients to cells throughout the body and carrying away carbon dioxide and metabolic wastes. Another example is the respiratory system, which brings oxygen into the body and gets rid of carbon dioxide. It includes the nose, mouth, pharynx, larynx, trachea, and lungs.

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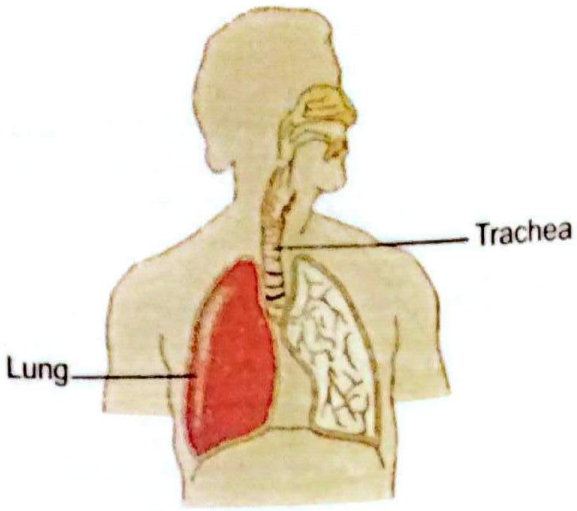


Figure 4.4: Respiratory System

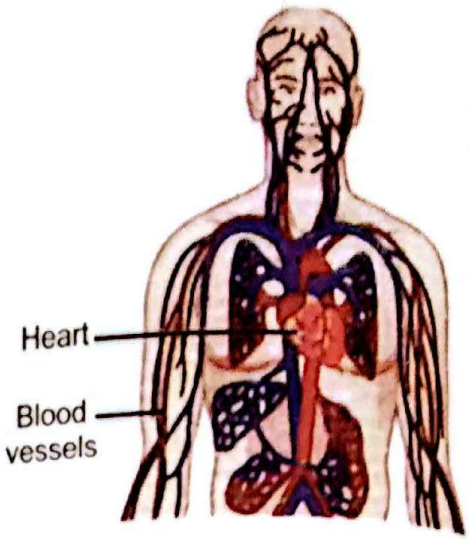


Figure 4.5: Circularity System

4.1.4. Organ systems work together

Just as the organs in an organ system work together to accomplish their task, the different organ systems also cooperate to keep the body running.

For example, the respiratory system and the circulatory system work closely together to deliver oxygen to cells and get rid of the carbon dioxide that these cells produce. The circulatory system picks up oxygen in the lungs and drops it off in the tissues, then performs the reverse function for carbon dioxide. The lungs expel the carbon dioxide and bring in new oxygen-containing air. Only when both systems are working together can oxygen and carbon dioxide be successfully exchanged between cells and environment.

4.2 HOMEOSTASIS

The tendency to maintain a stable, relatively constant internal environment is called **homeostasis**. The body maintains homeostasis for many factors for example, temperature, the concentration of various ions, pH and the concentration of glucose. If these values get too high or low, you can end up getting sick. All enzymes of the body can work properly if homeostasis is maintained.

4.2.1. Advantages of homeostasis

Homeostasis is the essential process by which the human body maintains a consistent internal environment despite changes in external situations. This precise equilibrium promotes the proper functioning of cells, tissues, and organs. Homeostasis controls vital body functions such as temperature (98.6°F), blood pH, blood sugar levels, blood pressure, and hydration. It also regulates the levels of hormones, electrolytes, and minerals. By maintaining homeostasis, the body defends itself from harm, allows for healthy growth and development, and promotes overall health. For example, when blood sugar levels rise after a meal, homeostasis causes insulin release to lower them; when temperature lowers, homeostasis causes shivering to produce heat. This self-regulation enables humans to adapt, deal with stress, and stay healthy.

4.2.2 Maintaining homeostasis

All the organ systems of body work together in the body to achieve homeostasis.

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Cardiovascular system transports substances towards and away from the cells. It maintains levels of gases and wastes, body temperature and pH.

Digestive system digests foods and absorbs nutrients, minerals, vitamins, and water. It maintains levels of nutrients in blood.

Respiratory system transports air and exchange gases. It maintains the balance of oxygen and carbon dioxide in the body.

Urinary system removes excess water, salts, and waste products from the blood. It maintains levels of water, salts, H^+ and wastes in body.

Nervous system receives information and controls other organ systems. It maintains homeostasis by rapidly controlling body functions.

Integumentary system makes a barrier. It maintains temperature and protects against infection by microorganisms.

Muscular system provides movement and support. It helps in temperature regulation by heat production.

Skeletal system supports and protects soft tissues of the body; provides movement at joints; produces blood cells; and stores minerals. It maintains the level of calcium and other minerals in the blood.

Endocrine system provides communication within the body and directs long-term change in other organ systems. It maintains balance of many blood components like glucose, water, calcium etc.

4.3 PLANT TISSUES

Plants are multicellular eukaryotes with tissue systems. Plant tissues are composed of cells that are similar and perform a specific function. Different tissues combine to form organs. Each organ itself is also specific for a particular function together making up the tissue systems.

Plant tissues differentiate into three main types: dermal, ground, and vascular tissue. **Dermal tissue** covers and protects the plant. The **ground tissue** serves as a site for photosynthesis, provide support, and helps to store water and sugars. The **vascular tissue** transports water, minerals, and sugars to different parts of the plant.

4.3.1. Plant organs and organ systems relation with plant physiology

Plant tissues form **organs** (such as leaves, stems, or roots), each of which perform a specific set of functions. Leaves perform photosynthesis. Stems support the plant and transport substances.

Together, organs often work to form **organ systems.** Vascular plants have two distinct organ systems: a shoot system, and a root system. The **shoot system** consists of two portions: the vegetative (non-reproductive) parts of the plant, such as the leaves and the stems, and the

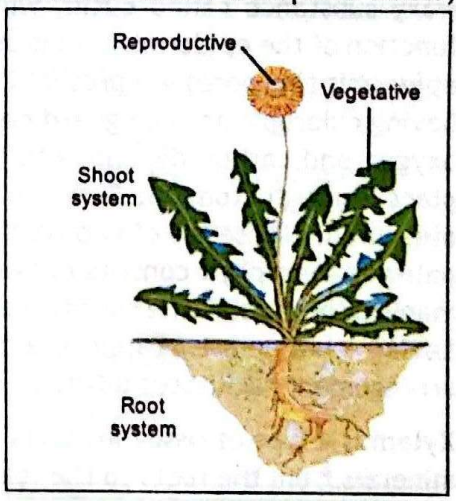


Fig 4.6: Plant organ systems

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reproductive parts of the plant, which include flowers and fruits. The shoot system generally grows above ground, where it absorbs the light needed for photosynthesis. The **root system**, which is usually underground anchors the plant into the ground, absorbs water and minerals, and serves as a storage site for food.

4.3.2. Structure and Functions of Cells of a Leaf

Leaves are thin, flat organs responsible for photosynthesis in the plants. It develops laterally at the node. It is an important part of the shoot system as it performs photosynthesis and transpiration. Leaf cells need water, carbon dioxide and light for photosynthesis and oxygen for respiration. Leaves transfer the synthesized food to other parts of the plant. So, there are varieties of functions and accordingly there are varieties of cells, in the leaf. Each type of cell performs a special function.

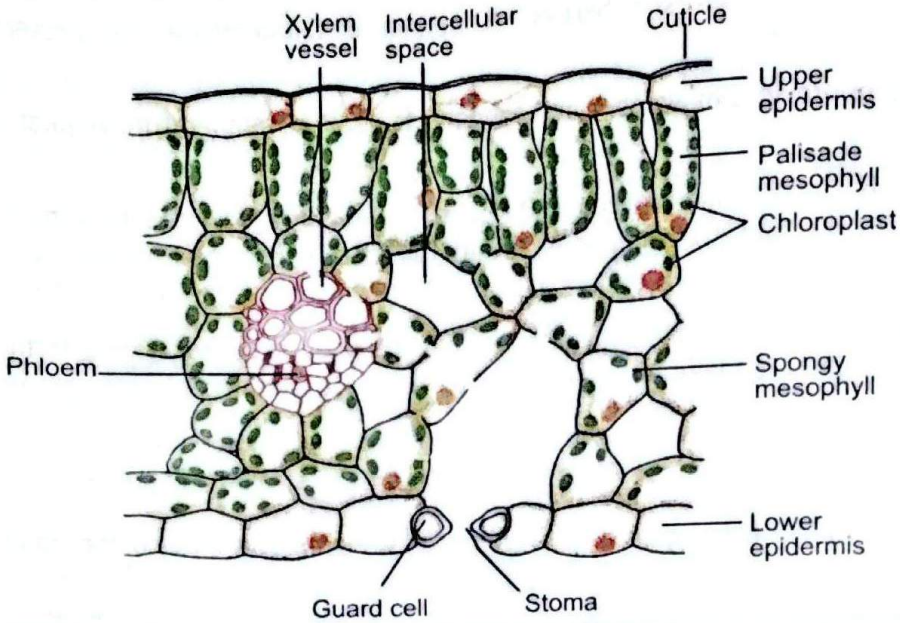


Fig 4.7: Transverse section of a leaf

Epidermis is the outermost layer. It is a single layer of cells, covering the leaf surface. A waxy substance called **cutin**, which forms the cuticle, covers the upper epidermis. The function of the epidermis is to protect the tissues and to prevent loss of water. On the lower epidermis tiny pores are present called **stomata**. Each stoma is enclosed by two guard cells, having chloroplasts. The **guard cells** control the opening and closing of stoma. Exchange of oxygen and carbon dioxide with the environment and evaporation of water vapour takes place through stomata. Between the two-epidermal layers lies the group of cells called **mesophyll**. These are of two types i.e., **palisade mesophyll** and the **spongy mesophyll**. The palisade mesophyll consists of two or three layers of cylindrical cells. These cells contain many chloroplasts. The spongy mesophyll consists of loosely arranged irregular shaped cells having chloroplast. Large intercellular spaces are present among these cells. This arrangement facilitates diffusion of gases. **Vascular bundle** consists of xylem and phloem.

Xylem is a type of tissue in plants that acts like a transportation system, carrying water and minerals from the roots to the leaves. It's made up of four main components:

1. Tracheids: Long, hollow tubes that carry water.
2. Vessels: Wider tubes that help water flow faster.
3. Xylem parenchyma: Cells that store food and water.
4. Xylem fibres: Strong fibres that support the plant.

Phloem transports food, sugars, and other essential nutrients produced by photosynthesis. It carries the prepared food from the leaf to other parts of the plant. Phloem consists of:

1. Sieve tube cells: Special cells that help move nutrients.
2. Companion cells: Cells that assist sieve cells.
3. Phloem fibres: Strong fibres providing support.
4. Phloem parenchyma: Cells storing and processing nutrients.

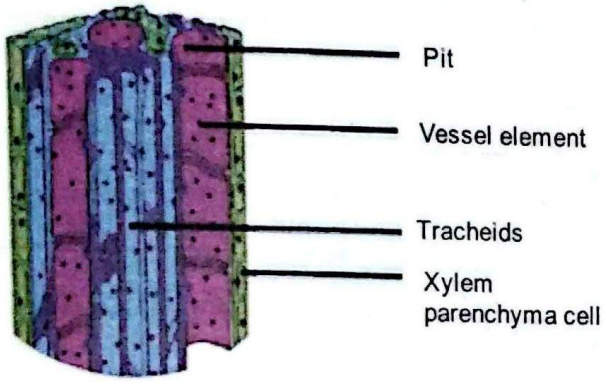


Figure4.8: Xylem structure

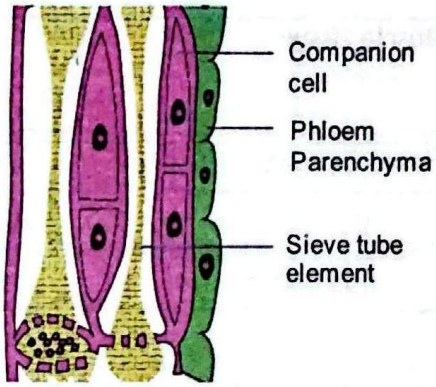


Figure 4.9: Phloem structure

STEAM ACTIVITY: Study of animal tissues	
Materials required	**Main skills practised**
Compound microscope Prepared slides of sections of animal's epithelial, connective, muscle and nervous tissue Charts of animal's epithelial, connective, muscle and nervous tissue	Following instructions Using microscope Observing slides Making drawings Interpreting results Making conclusions

Introduction

In this activity you will have an opportunity to observe animal tissues. You will identify shape of cells and relate it with function of tissue.

Points for pre-lab discussion

Q.1. What is a tissue?

Q.2. How do animals support their body parts, absorb materials or move?

Q.3. Do you expect any "photosynthetic tissue" in animals?

Q.4. What is the location of different tissues in animals?

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Procedure

a. You are provided with charts and slides of four types of tissues.
b. Study the features of these tissues from charts.
c. Examine each tissue type one by one under the microscope using the low power lens first and then the high power lens to see greater details.
d. Fill in the following table using the results of your observations.

TISSUE	DIAGRAM: LABEL MAJOR PARTS
Epithelial tissue	
Connective tissue	
Muscle tissue	
Nervous tissue	

SUMMARY

1. Cell organelles are sub cellular structures which work together to form cells.
2. Group of cells with similar functions make tissues.
3. Organs are structures made up of two or more tissues organized to carry out a particular function.
4. Groups of organs with related functions make up different organ systems.
5. All organ system work in a coordinated way to keep the organism living and working.
6. The tendency to maintain a stable, relatively constant internal environment is called homeostasis.
7. Different organ systems of an organism work together to maintain homeostasis.
8. Plant tissues differentiate into three main types: dermal, ground, and vascular tissue.
9. Animal tissues differentiate into four main types: epithelial, connective, muscular and nervous tissue.

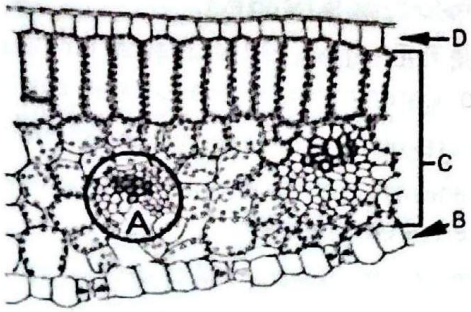
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EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. The diagram shows cells in part of the leaf of a green plant. Which region contains cells which are responsible for the process of transport?



2. The table shows three functions of cells which row is correct?

	absorption	support	transport
A	red blood cell	muscle cells	root hair cell
B	root hair cell	xylem vessel	red blood cell
C	muscle cell	red blood cell	xylem vessel
D	xylem vessel	root hair cell	muscle cell

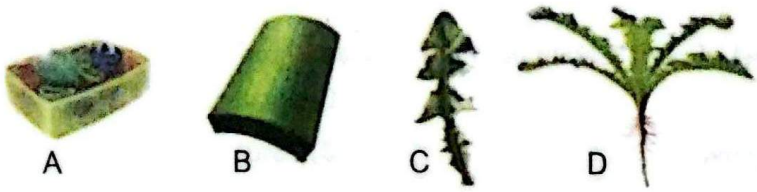
3. What are the functions of xylem and phloem in green plants?

	xylem	phloem
A	support and transport of sugars	transport of water
B	transport of sugars	support and transport of water
C	support and transport of water	transport of sugar
D	transport of water	support and transport of sugars

4. If tissue level is not developed in the level of organization, which next level will not form?

A) Molecular level B) atomic level C) organ level D) organelle level

5. Following diagram shows level of organization in a plant. Which one is the organ level?



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6. Which of the following lists the levels of body organization from smallest to largest?
   A) organism, organ system, organ, tissue, cell
   B) tissue, cell, organ, organ system, organism
   C) organ, organ system, organism, tissue, cell
   D) cell, tissue, organ, organ system, organism

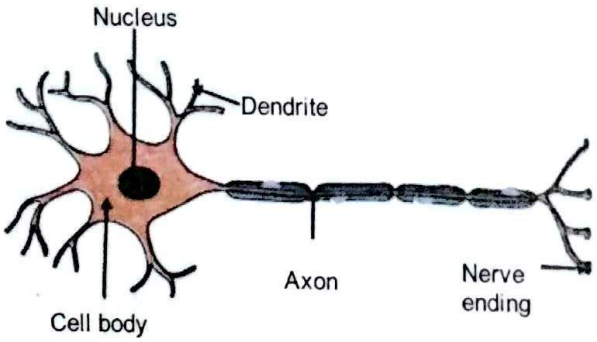
7. This statement about Homeostasis is incorrect:
   A) because of this, the fluctuations of the internal environment are of extremely narrow range as compared to that of the external environment
   B) there is one system regulating the homeostatic activities
   C) homeostatic mechanisms keep the internal environment constant despite wide changes in the external environment
   D) homeostasis is necessary for the survival of cells

8. Which of the following statements best describes homeostasis?
   A) keeping the body in a fixed and unaltered state
   B) dynamic equilibrium
   C) maintaining a near-constant internal environment
   D) altering the external environment to accommodate the body's needs

9. Organisms have the ability to change and modify their internal conditions according to the environment through:
   A) osmoregulation
   B) excretion
   C) thermoregulation
   D) all of the above

10. You can observe spongy mesophyll and xylem in the section of leaf. These are part of the same:
   A) cell and organism
   B) organ and organism
   C) cell and tissue
   D) tissue and organ

11. The diagram shows a sample of material taken from an organism.



Which level of organization does this diagram show?
A) cell
B) organ
C) organ system
D) tissue

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12. Which structure is not an organ?

A) artery
B) flower
C) spinal cord
D) xylem

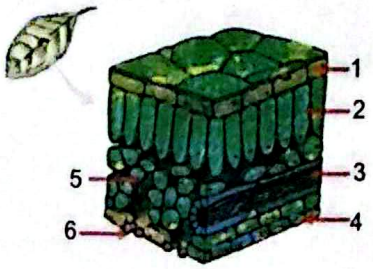
13. Which description of xylem is correct?

A) a cell used for absorption
B) an organ system used for conduction
C) a tissue used for transport
D) an organ used for transport

14. Which structure is at a different level of organization from the other three?

A) kidney
B) liver
C) neuron
D) lung

15. The diagram shows tissues from section of leaf. Which type of cells will perform photosynthesis?



A) 1 and 4
B) 2 and 5
C) 2 and 3
D) 3 and 6

Section II: Short Answer Questions

1. Can you differentiate between:

(a) Organ and organelle
(b) Animal and plant tissues
(c) Xylem and phloem
(d) Epithelial and muscular tissue
(e) Nervous and connective tissue
(f) Epidermal and ground tissue
(g) Root and shoot system
(h) Vegetative and reproductive part of plants

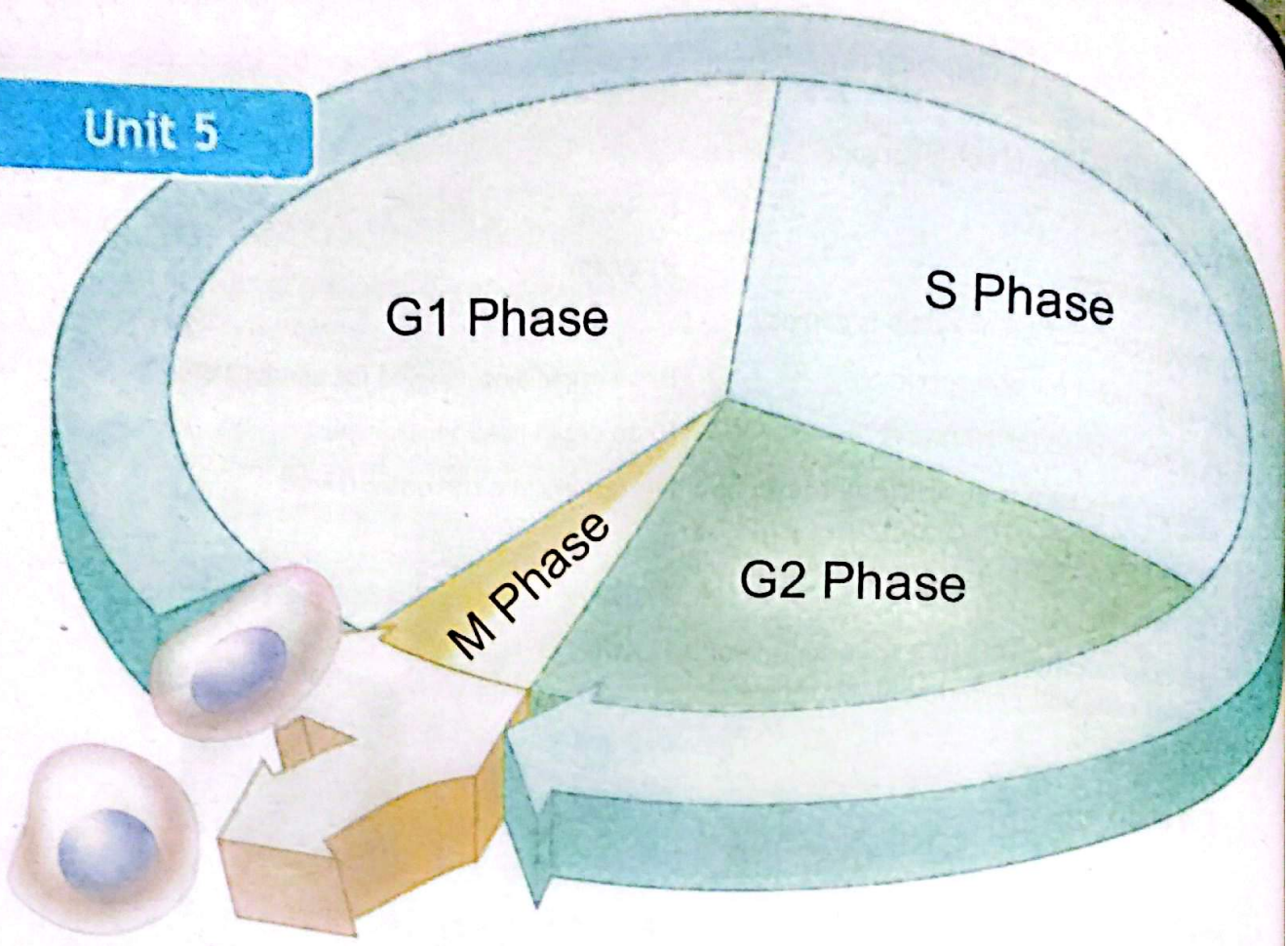
2. How different tissues form stomach?
3. Why respiratory and cardiovascular systems work together?
4. How temperature is regulated in our body?

Section III: Extensive Answer Questions

1. Justify how the cells of leaf have a variety of specialized structure and function.
2. Give an account of levels of biological organization.
3. Explain the functions of different organ system of humans.
4. How different organ systems of human's work together to maintain homeostasis?
5. Cells and tissues are adapted to perform their function in the best way. Explain this statement by using example of leaf.

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Unit 5



Cell Cycle

SLOs: After completing this lesson, the student will be able to:

1. Describe cell cycle
2. Explain mitosis meiosis and stages of mitosis and meiosis, by use of sketch and diagrams
3. Compare the process of mitosis and meiosis.
4. Outline the significance of mitosis and meiosis.

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The new cells originate by division in the pre-existing cell. The cell which divides is called parent cell and the new cell formed as a result of division are called daughter cell. The process of cell division is needed for development, growth, healing and for sexual and asexual reproduction. Cell not only increase in number but also manage to transfer genetic characteristics to the next generations. During cell cycle, cells grow in size, form new molecules and organelles, replicate their chromosomes and divide by equally distributing genetic material in the daughter cell.

5.1 CELL CYCLE

The cell cycle is the sequence of events which involves growth of newly formed cell, replicates its genome and divides into two daughter cell ultimately. It consists of two main phases; interphase and mitotic phase.

Interphase: Interphase is the period in cell cycle between two consecutive divisions. It is divided into G_1 (Gap 1), S (Synthesis), and G_2 (Gap 2).

G_1 phase: It starts with the production of new cell. Cell grows in size, increases the number of its organelles, forms needed proteins and other substances. During this phase cell prepares itself for the next phase of cell cycle (S phase). It forms enzymes and nucleotides of DNA required for replication process.

S phase: It is the synthesis phase of DNA. The cell replicates its entire genetic material to form its two copies. That is why each chromosome has two chromatids during cell division, one for each of the daughter cell. These chromatids are attached with one centromere and are called sister chromatids.

G_2 phase: During this phase cell prepares for mitotic phase. Cell forms proteins especially those required for the formation of spindle fibres. Also cell accumulates energy to complete the division process. More mitochondria are formed.

G_0 phase: During G_1, cell may exit the cell cycle and enter in G_0 phase. In G_0 cell stops to divide. Some cells e.g., neurons, once mature never divide again. They remain in G_0 forever. Cell of liver, kidneys etc. enter G_0 temporarily. When needed they re-enter the cell cycle and start to divide again. Many epithelial cells divide continuously. They never enter in G_0 phase.

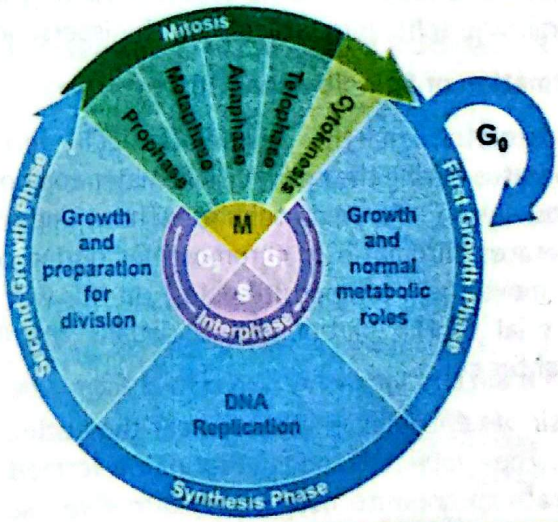


Fig 5.1: Cell cycle

Mitotic phase (M phase): During this phase cell divides into daughter cell.

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Cancer is a disease of cell cycle. Unlike normal cells of the body, cancer cells do not have a proper functioning cell cycle control system and therefore divide excessively. This excessive growth can result in an abnormal mass of cells called tumour. Not all tumours are cancerous however, a benign tumour is an abnormal mass of essential normal cells. They always remain at their original site in the body. A malignant tumour is cancerous. It is capable of spreading into neighbouring tissues and often to other distant parts of the body. The spread of cancer cells beyond their original site is called metastasis.

5.2 MITOSIS

The cell division in which parent cell produces two daughter cells with the same number of chromosomes as in the parent cell. Mitosis is a continuous and very fast process which takes less than an hour, but to study easily it is divided into **karyokinesis** and **cytokinesis.**

Karyokinesis

It is division of the nucleus, which form two nuclei in a dividing cell. It is further divided into; **prophase, metaphase, anaphase** and **telophase.**

Prophase

During interphase hereditary material is found in the form of very thin threads called chromatin. If a cell is going to divide, all of its chromatin fibres duplicate during S phase of interphase.

Prophase is the longest phase of cell division. At the start of prophase chromatin fibres coil up and condense into chromosomes. Due to duplication all chromosome consists of two chromatids. The chromatids of each chromosome are attached to each other at centromere.

Nucleolus disappears as its DNA is packed into chromosomes. At the end of prophase nuclear membrane splits into vesicles which disperse in the cytoplasm.

Formation of Spindle apparatus.

Cytoskeleton of the eukaryotic cell forms spindle apparatus during the cell division. Major component of the cytoskeleton are microtubules. The spindle apparatus separates chromatid or chromosomes during cell division and move them to opposite poles. In this way hereditary material of the parent cell is equally distributed into daughter cell.

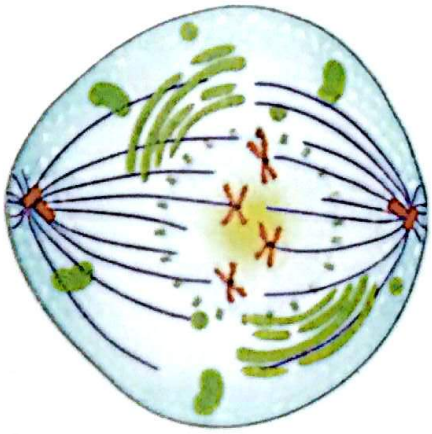


Fig 5.2: Spindle apparatus

A pair of centrioles is situated near the nucleus of animal cell. They duplicate and another pair is formed. Both pairs migrate to opposite poles. They also give rise to spindle fibres. Spindle apparatus is formed around the nucleus, but as soon as nuclear envelop disintegrates, spindle fibres penetrate in to the region of nucleus. They later on attach to the centromere of chromosome and pull them to their poles.

There are no centrioles in plant cell, the spindle apparatus of plant cell is formed without centrioles.

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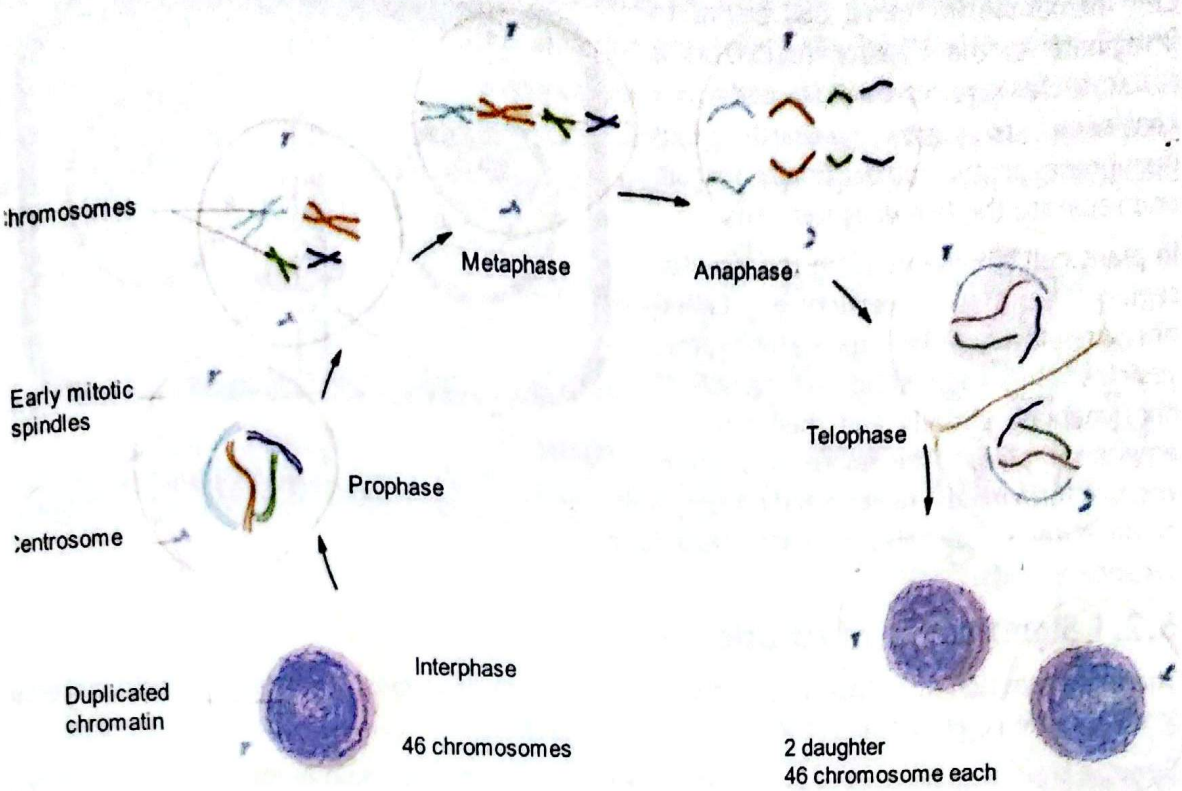


Fig 5.3: Mitosis

Metaphase

Chromosomes are aligned at the equator of spindles. Two spindle fibres, one from each pole, are attached at the centromere of chromosomes.

Anaphase

Spindle fibres pull the centromeres which split and chromatids are separated from each other. Individual chromatids are pulled until they reach their respective poles.

Telophase

Chromatids reach at their poles. They uncoil and lengthen to form chromatin fibres again. The spindle apparatus disintegrates. Nuclear membrane is formed around chromatin at each pole. Nucleoli reappear in both nuclei.

Cytokinesis

It is division of the cytoplasm which results in the formation of two daughter cells. It starts while telophase is in progress. The pattern of cytokinesis is different in animal and plant cell.

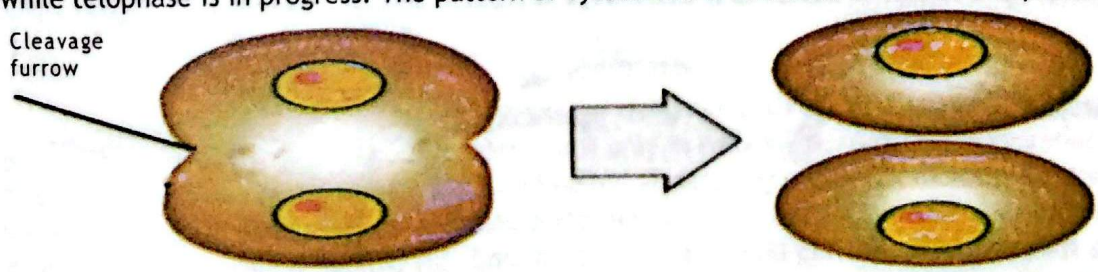


Fig 5.4: Cytokinesis in animal cell

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Cell membrane in animal cell begins to invaginate in the equator region. As a result, a **cleavage furrow** is formed which continues to grow inward. Cell membranes in the furrow finally join up and separate the two daughter cells.

In plant cell spindle fibres in the equator region form a structure called **phragmoplast**. Golgi apparatus forms vesicles which appear in the centre of phragmoplast initially and then grow at equatorial plane. The content in these vesicles form middle lamella and primary walls of daughter cells. Later on some cells form secondary walls.

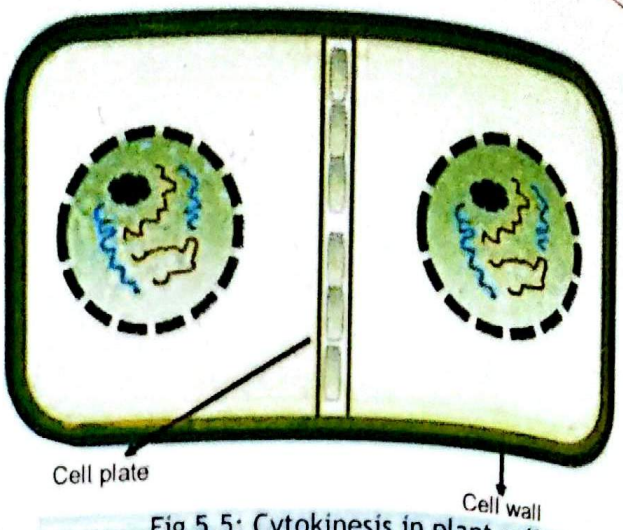


Fig 5.5: Cytokinesis in plant cell

5.2.1 Significance of Mitosis

The main function of mitosis is to maintain the number of chromosomes and genetic material in dividing cells. Following is the significance of the mitosis.

Genetic stability: Mitosis produces two daughter cells with the same number of chromosomes as in parent cell. Before the start of cell division, DNA of the parental chromosomes replicates to form two exact copies. Daughter cells thus will have same genetic information.

Development and growth: Life of multicellular organisms start from a single cell, the zygote. The continuous cell division process leads to the development of an adult. The organisms also grow in size by increasing cell number. Thus the development and growth of multicellular organisms depends on mitosis.

Cell replacement and wound healing: The replacement of worn out cells involves mitosis. The epithelial cells of skin, digestive tract and respiratory tract die off regularly. They are replaced by identical cells produced by mitosis. Damage, repair and wound healing depends on the process of mitosis.

Regeneration: Some animals have ability to form whole part of the body if it is removed accidentally. This is called regeneration. For example; sea star can regenerate arm, earthworms can regenerate head, and salamander can regenerate its limb. The production of new cells to form missing parts involves mitosis.

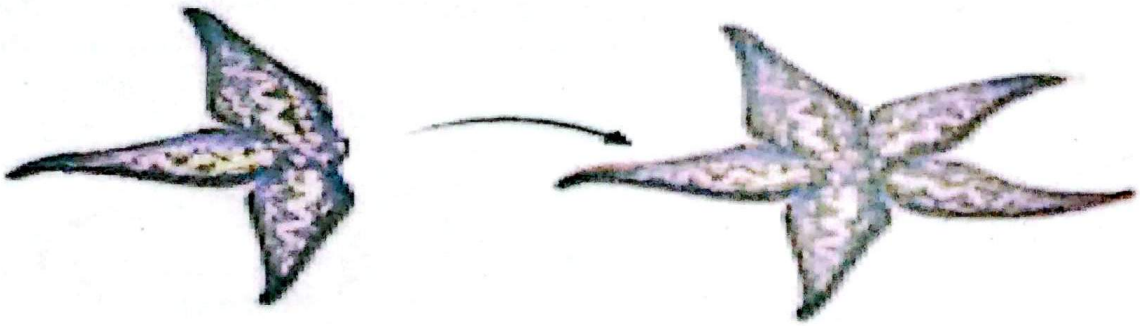


Fig 5.6: Regeneration of arm in Sea star

Asexual reproduction: Mitosis is the basis of asexual reproduction. This reproduction involves only one parent. All asexually produced offspring are genetically identical to their parent organism. The vegetative propagation is very common in plants. It involves new plant formation from root, stem or leaf of parent plant. Potato, onion, garlic, ginger, grasses etc. reproduce asexually. Many animal species like sponges, planaria and hydra undergo asexual reproduction.

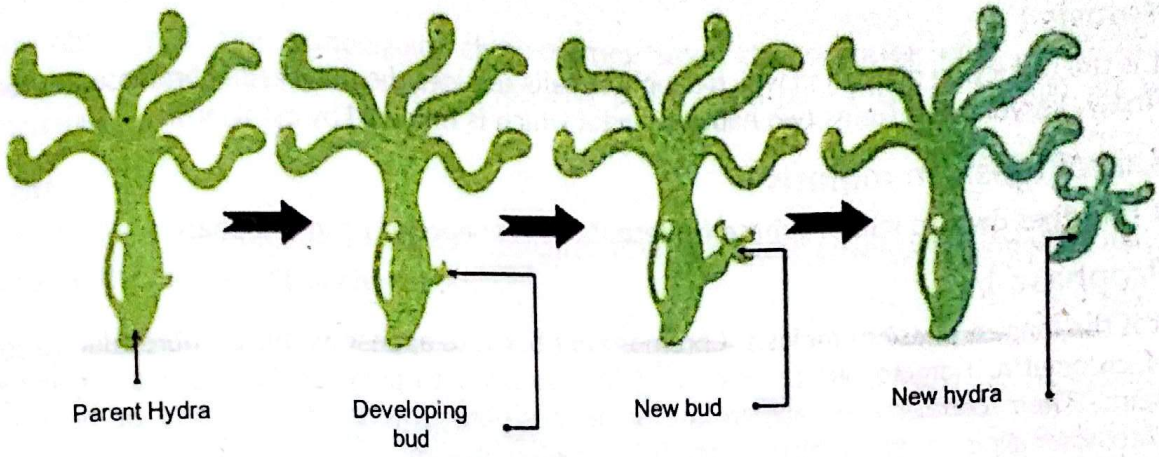


Fig 5.7: Budding in Hydra

Cloning and tissue culture: Mitosis has made it possible for scientists to produce a very large number of identical copies of the living organisms in artificial environment. This process is called cloning or tissue culture if small mass of tissue cells is used.

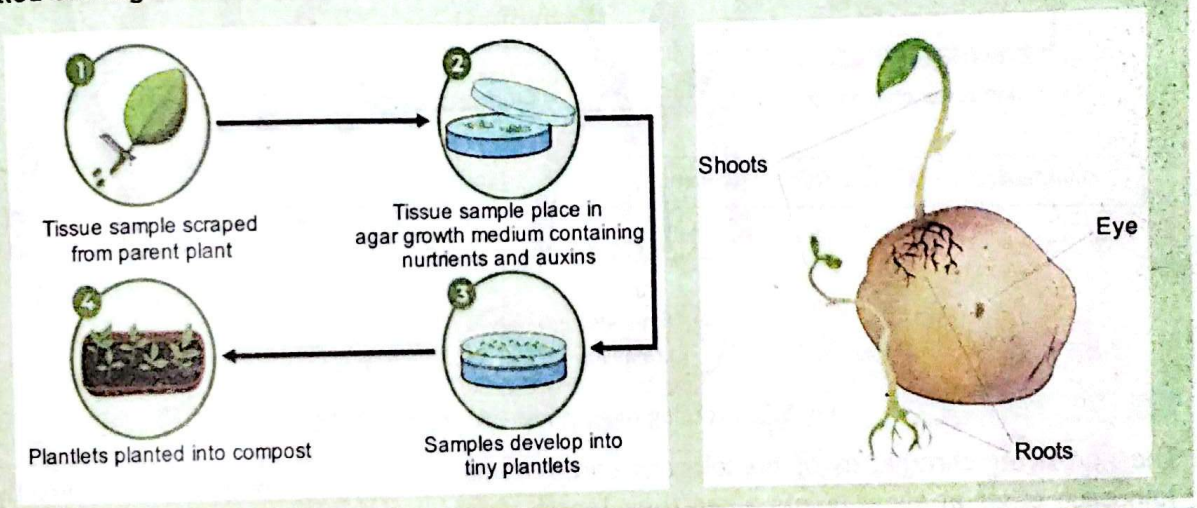


Fig 5.8: Cloning by (a) Tissue culture (b) Vegetative propagation in potato

5.3 MEIOSIS

It is a type of cell division which give rise to four daughter cells each having half the number of chromosome of the parent cell. It takes place only in cells involved in sexual reproduction. The parent cells are **diploid** which produce **haploid** gametes by process of meiosis. Cells which have two sets of chromosomes are called diploid (2n) and cells with half the number of chromosomes are called haploid (n). Chromosomes in a diploid cell are in homologous pairs. Haploid cells carry one member of each homologous pair.

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Meiosis is a continuous process but for convenience is divided into **interphase I, meiosis I, interphase II** and **meiosis II.**

Interphase I

Before the onset of division process, cell forms a copy of its genome by replication process. That is why chromosomes appear with two chromatids during division process.

Meiosis I

It is the reduction division in which daughter cells reduces the number of chromosomes to half. Firstly, karyokinesis forms two haploid nuclei which is followed by cytokinesis.

Karyokinesis in meiosis I

It is further divided into **prophase I, metaphase I, anaphase I** and **telophase I.**

Prophase I

It is the longest phase of meiosis. Chromosomes begin to appear as thicker fibres due to coiling of chromatin. Homologous chromosomes line up point to point against each other and form pairs. Their centromeres are in the same position. This pairing process of homologous chromosomes is called **synapsis**. Each pair is called bivalent.

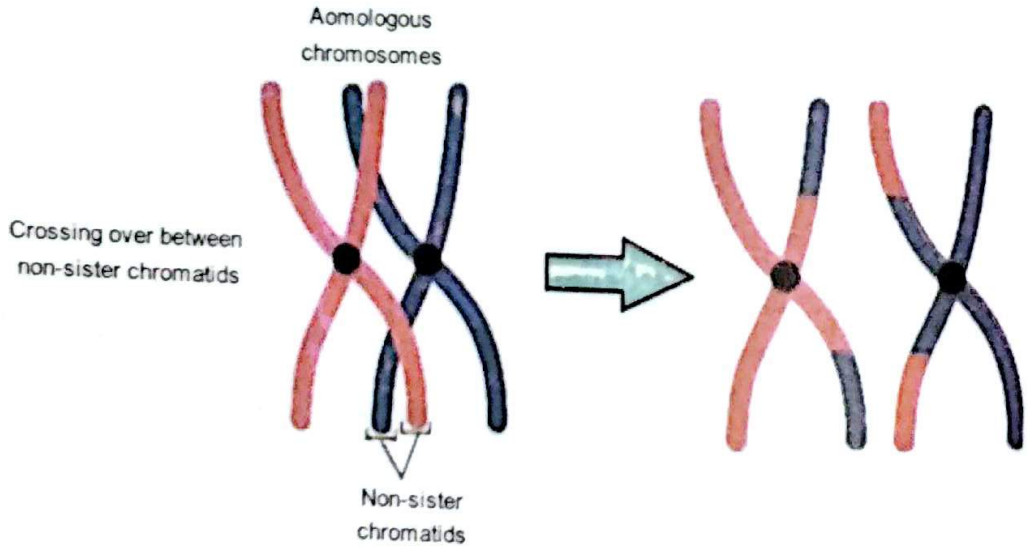


Fig 5.9: Crossing over in non-sister chromatids

The non-sister chromatids of homologous chromosomes join each other at some points along their length. Such points are called **chiasmata**. Each chiasma is a site for the exchange of some genetic material between chromatids. The exchange of segments of non-sister chromatids during prophase I is called **crossing over**.

Sister chromatids are two exactly similar copies attached by a centromere while the chromatids of two homologous chromosomes are non-sister chromatids.

At the end of prophase I, chromosomes are fully condensed and paired chromosomes repel each other. However, they are still attached at chiasmata.

Nucleoli and nuclear envelop disappear. Spindle apparatus is formed.

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Metaphase I

Bivalents are arranged at the equatorial plate. Spindle fibres are attached to the centromere of chromosome. One member of a homologous pair receives a spindle fibre from one pole and other member from the opposite pole.

Anaphase I

Spindle fibres pull the homologous chromosomes from the opposite ends. Separated chromosomes of each pair move to the opposite poles. Each pole receives haploid set of chromosomes.

Telophase I

Once at their pole, chromosomes uncoil into chromatin. A nuclear envelop is formed at each pole around the haploid set of chromatin.

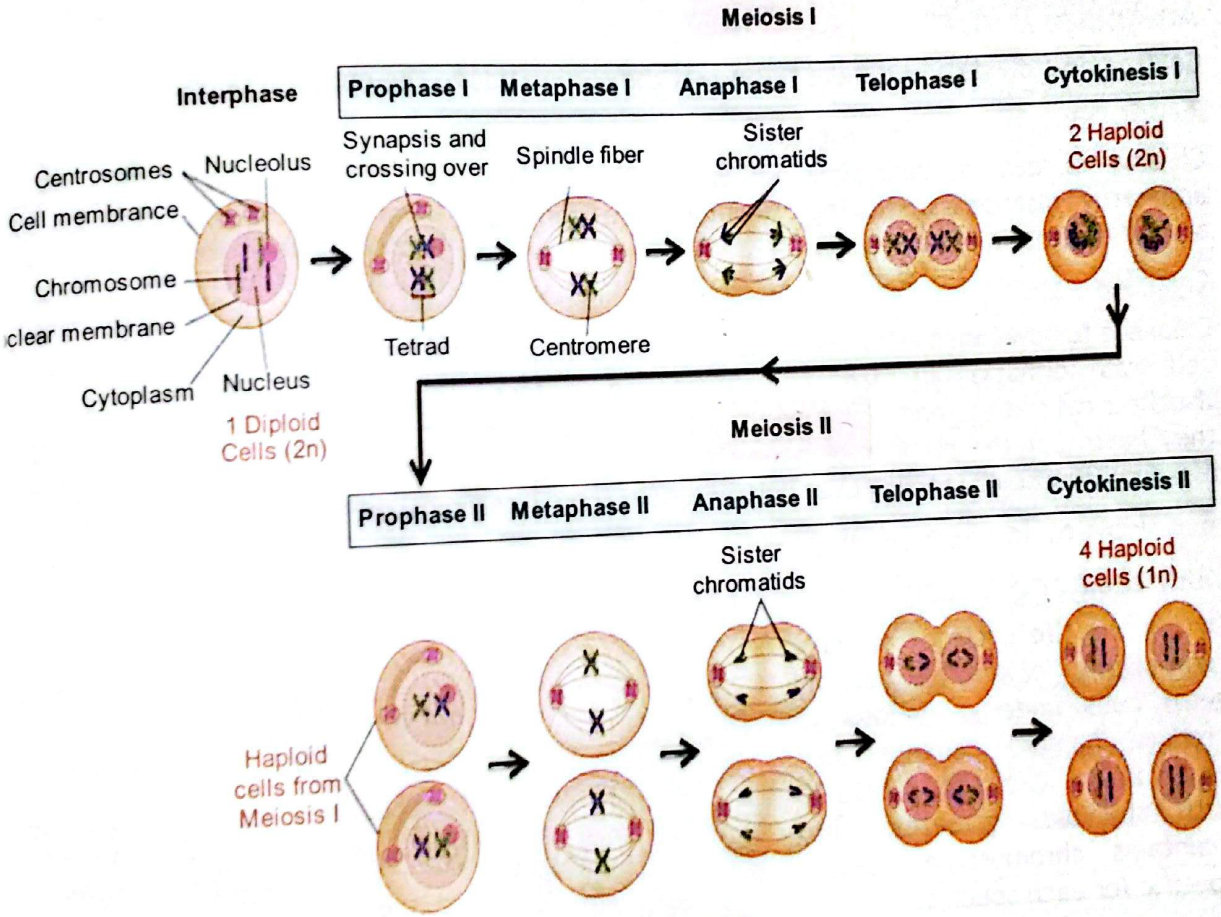


Fig 5.10: Meiosis

Cytokinesis

Cytokinesis occurs by cleavage in animal cell and by forming cell wall in plant cell. Although each daughter cell is haploid with half the number of chromosomes, their chromosomes are composed of two chromatids. Due to crossing over, these chromatids are not genetically identical. They must be separated in meiosis II.

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Two haploid daughter cells thus formed enter in interphase II.

Interphase II

This phase varies in length but there is no further DNA replication during this phase.

Meiosis II

It is similar to mitosis and is divided into **prophase II, metaphase II, anaphase II** and **telophase II.**

Prophase II

Chromatin coils again so chromosomes appear as thick fibres. Spindle apparatus is organized. Nucleoli disappear and nuclear envelop disintegrates.

Metaphase II

Chromosomes line up separately around the equator of the spindles. Spindle fibres are attached to the centromere of chromosome. Like mitosis here each chromosome is attached by a fibre from both poles.

Anaphase II

Centromeres divide and spindle fibres pull the chromatids to the opposite poles.

Telophase II

Chromatids reach at their poles and uncoil. The spindle apparatus disappears. Nuclear envelops are formed around chromatin at each pole.

Germ cell are diploid which undergo meiosis to from haploid gametes. All other diploid cells of body undergo mitosis and are called somatic cells.

Cytokinesis

Cleavage furrow forms cell membrane in animal cells and cell wall formation in plant cells gives rise to four daughter cells at the end of meiosis process. All cells formed by meiosis process are haploid as they have half the number of parental chromosomes. Also they have variations in genetic makeup because of crossing over between homologous chromosomes during meiosis I.

4.4.1 Significance of meiosis

Maintenance of chromosomes in sexual reproduction

During the life cycle of sexually reproducing organisms, diploid germ cells undergo meiosis to produce haploid daughter cell which act as gametes. Fusion of such haploid gametes thus maintains chromosome number specific for each species.

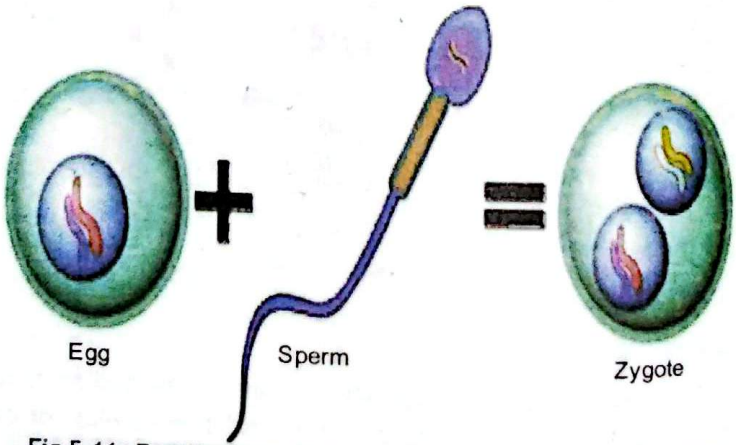


Fig 5.11: Fertilization: fusion of sperm and egg cell to form zygote

Human have 46 chromosomes in their somatic cells. The haploid gametes (eggs and sperms) formed by meiosis have 23 chromosomes. In fertilization process a 23 chromosome sperm fuses with an egg also having 23 chromosomes. The original chromosome number of 46 is restored in the zygote.

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Plants have two alternating generations, diploid sporophyte and haploid gametophyte. The sporophyte produces haploid spores by meiosis.

Genetic variations

Variations are the differences among the members of same species. They are necessary for the survival of species in changing environment. It is because of meiosis that new combinations of genes appear in gametes and then in zygote. Crossing over and chromosomal combination provide basis of variations.

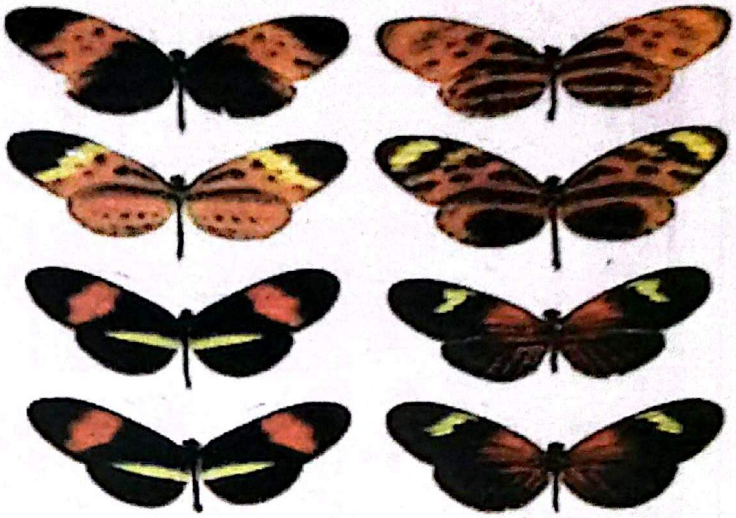


Fig 5.12: Variation in Butterfly patterns

Table 5.7 Comparison of mitosis and meiosis

Mitosis	Meiosis
It occurs in somatic cells	It occurs in germ line cells
Cell divides only once	Cell divides twice
It produces two daughter cells	Four daughter cells are produced
Daughter cells produced are diploid	All daughter cells are haploid
Daughter cells become part of somatic body	Daughter cells form gametes
All chromosomes remain independent of each other	Homologous chromosomes pair with each other
No chiasmata formation	Chiasmata are formed
There is no crossing over during mitosis process	Crossing over takes place during meiosis I
Daughter cells are genetically alike.	Daughter cells are genetically different from each other and parent cell
In most cases daughter cells can divide again.	Gametes produced by meiosis cannot divide any more.

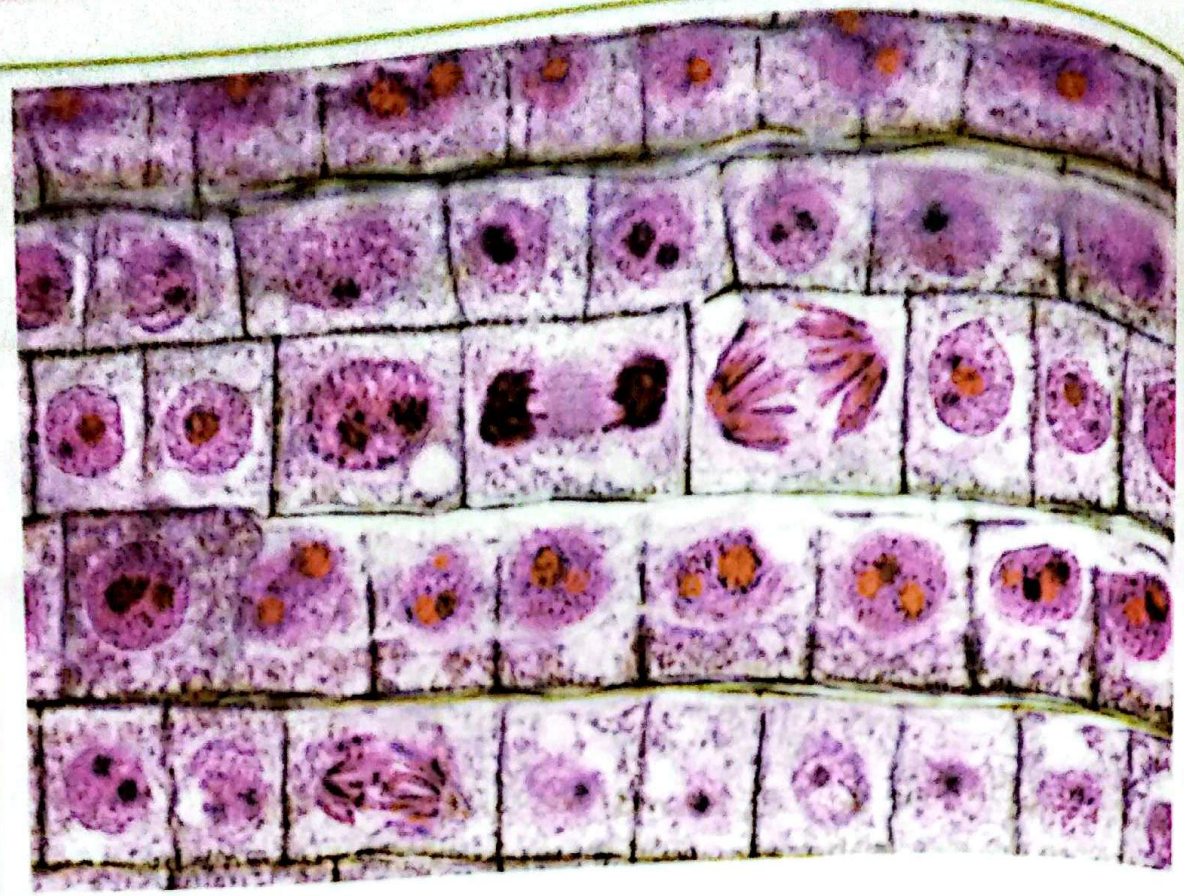
STEAM ACTIVITY 5.1

Study of Mitosis in onion root tip

Materials Required

Compound microscope, Acetocarmine stain, Water, Burner, N/10 Hydrochloric acid, Filter paper, Coverslip, Aceto alcohol (Glacial acetic acid and Ethanol in the ratio 1:3), Glass Slide, Onion root peel, Forceps, Blade, Watch glass, Dropper, Needle, Vial.

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Procedure

1. Place an onion on a tile
2. With the help of a sharp blade, carefully snip the dry roots of the onion
3. Place the bulbs in a beaker containing water to grow the root tips
4. It may take around 4 to 6 days for the new roots to grow and appear
5. Trim around 3 cm of the newly grown roots and place them in a watch glass
6. With the help of forceps, shift it to a vial holding freshly prepared aceto-alcohol i.e., a mixture of glacial acetic acid and ethanol in the ratio 1:3
7. Allow the root tips to remain in the vial for one complete day
8. With the help of forceps, pick one root and set in on a new glass slide
9. With the help of a dropper, allow one drop of N/10 HCl to come in contact with the tip of the root. Additionally, add around 2 to 3 drops of the acetocarmine stain
10. Heat it lightly on the burner in such a way that the stain does not dry up
11. Excessive stain can be carefully treated using filter paper
12. The more stained part of the root tip can be trimmed with the help of a blade.
13. Discard the lesser stained part while retaining the more stained section
14. Add a droplet of water to it
15. With the help of a needle, a coverslip can be mounted on it
16. Gently tap the coverslip with an unsharpened end of a needle in order for the meristematic tissue of the root tip present under the coverslip to be squashed properly and to be straightened out as a fine cell layer

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17. The onion root tip cells' slide is now prepared and ready to be examined for different stages of mitosis
18. Observe and study mitosis by placing the slide under the compound microscope. Focus as desired to obtain a distinct and clear image

Observations and Conclusion

1. The slide containing the stained root tip cells is placed on the stage of the compound microscope, changes taking place are noted and sketched.
2. The different phases of mitosis, such as prophase, metaphase, anaphase and telophase can be observed.

SUMMARY

1. The cell cycle is the period from beginning of one division to the beginning of the next division.
2. Interphase can be divided into the first gap phase (G_1), the chromosomal synthesis (S), and the second gap phase (G_2).
3. During G_1 phase the cell grows and prepares itself for the S phase. DNA and the chromosomes are replicated during the S phase. During G2 phase, protein synthesis increases for cell division.
4. Spindle apparatus separates chromatid or chromosomes during cell division.
5. During mitosis, identical chromosomes are distributed to each daughter cell. Chormosomal number remains after mitosis.
6. Mitosis is divided into two phases.
7. Karyokinesis divides nucleus in four phases i.e., Prophase, Metaphase, Anaphase and Telophase.
8. Cytokinesis divides cytoplasm to form two individual cells.
9. Mitosis is important for genetic stability, development, growth, cell replacement, wound healing, regenration, asexual reproduction, tissue culture and cloning.
10. A diploid cell undergoing meiosis completes two successive cell divisions (Meiosis I and Meiosis II) to give rise to four haploid cells which later form gametes.
11. During meiotic prophase I, the members of a homologous pair of chromosomes undergo synapses and crossing over, during which segments of DNA strands are exchanged between homologous (non-sister) chromatids.
12. During meiosis II the two chromatids of each chromosome separate and one is distributed to each daughter cell. Each former chromatid is now referred to as chromosomes.
13. In sexual reproduction, two haploid gametes fuse to form a single diploid zygote.
14. Meiosis is important for mainrenance of chromosomal number in sexual reproduction and genetic variations.

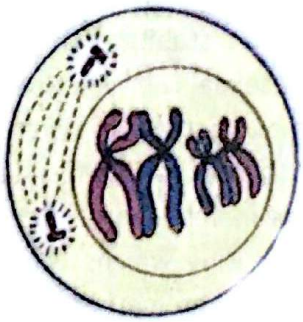
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EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. A bivalent consists of:
   A) Two chromatids and one centromere
   B) Four chromatids and two centromeres
   C) Four chromatids and four centromeres
   D) Two chromatids and two centromeres
2. During cell division spindle fibres attach a chromosome at:
   A) Centromere
   B) Telomere
   C) upper arm of chromosome
   D) lower arm of chromosome
3. Crossing over results in genetic recombination. It occurs between:
   A) Two chromatids of the same chromosome.
   B) Two chromatids of any two non-homologous chromosomes
   C) Two chromatids of opposite gametes
   D) Two chromatids of homologous chromosomes
4. The spindle apparatus of plants differs from that of animals in not having:
   A) microtubules
   B) equator of spindle
   C) centrioles
   D) centromere
5. Substance and energy required for the replication of DNA is accumulated in the cell during:
   A) G_1
   B) G_2
   C) S phase
   D) M phase
6. All of the following events takes place both in mitosis and meiosis except:
   A) Condensation of chromatin to form chromosomes
   B) Formation of spindle apparatus
   C) Nuclear envelop and nucleolus disappear
   D) Chromosomes pair for crossing over
7. The cell shown in this diagram is passing through:

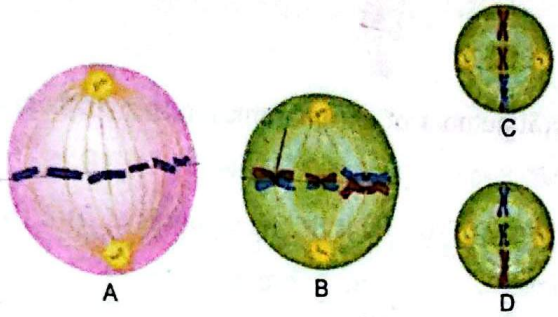


   A) Prophase I of meiosis
   B) prophase of mitosis
   C) telophase of meiosis I
   D) anaphase of meiosis II
8. The longest phase of meiosis is:
   A) Interphase I
   B) Prophase I
   C) interphase II
   D) prophase II

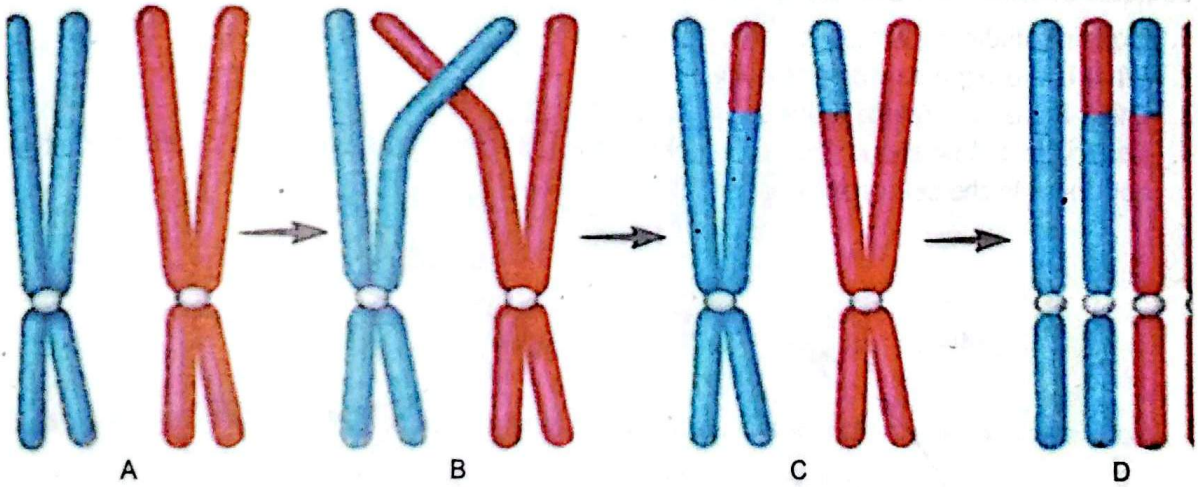
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9. What causes the number of chromosomes to reduce to half when a cell divides by meiosis?
   A) replication of DNA during interphase I
   B) separation of homologous chromosomes during meiosis I
   C) separation of sister chromatids of all the chromosomes during meiosis I.
   D) crossing over during meiosis I

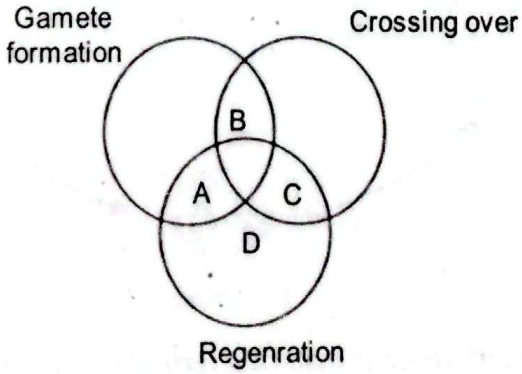
10. Which of the following cell is at Metaphase I stage?



11. This diagram is showing different stages of crossing over. Which stage contains chiasma?

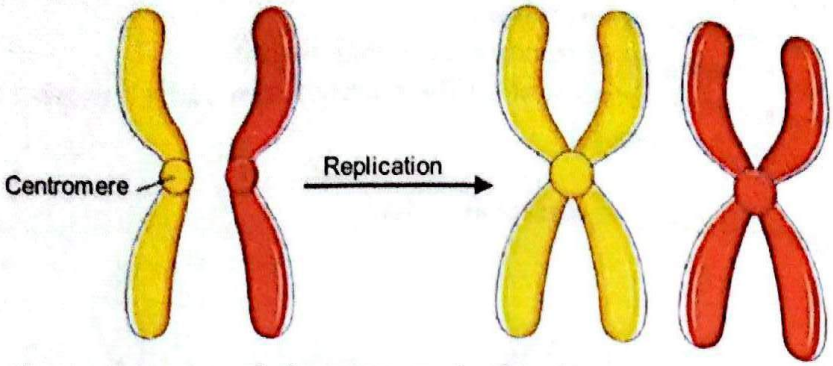


12. Which processes involve meiosis?



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13. diagram shows replication of chromosomes.



What is the total number of chromosomes in this diagram?

A. 2 B. 3 C. 4 D. 6

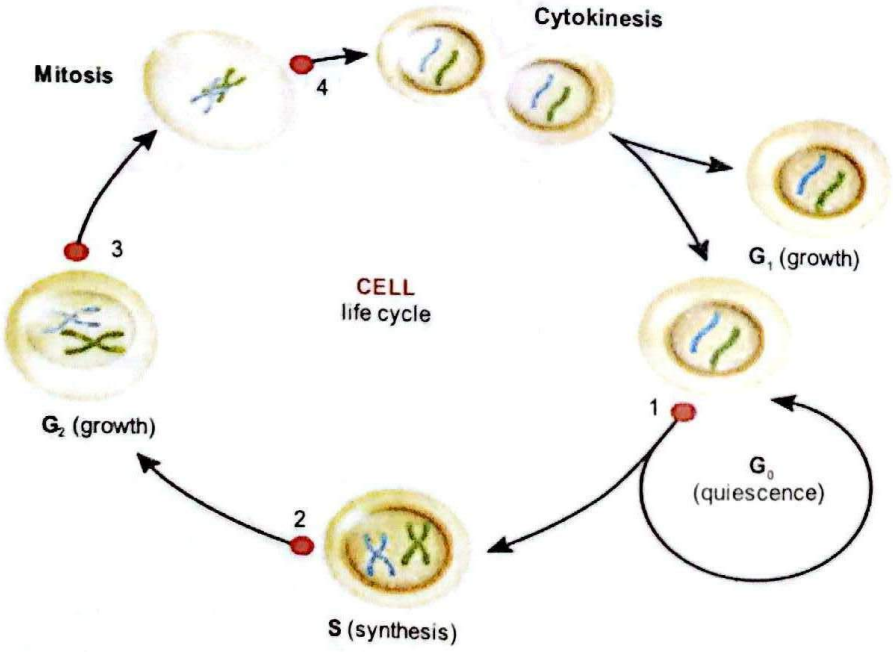
14. Chromosomal number of Fruit fly is 8. The gametes of fruit fly contain:

A. 2 chromosomes B. 4 chromosomes

C. 8 chromosomes D. 16 chromosomes

Section II: Short Answer Questions

1. Explain spindle apparatus in detail
2. What is the significance of crossing over?
3. Enlist the events taking place during G_1 phase.
4. Cell cycle below shows the formation of two daughter cells, cell A and cell B. Cell A continues in the cell cycle while cell B exits in G_0.



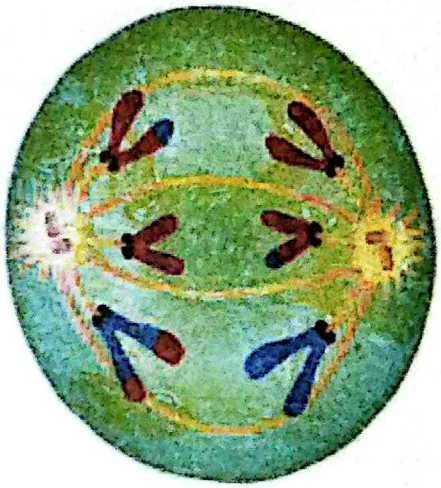
What will be the difference in materials they synthesize after the production of cell A and cell B?

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5. Why do epithelial cells of skin divide continuously?
6. Give differences between meiosis I and meiosis II.
7. In rapidly dividing cells which phase of cell cycle is reduced? Explain.
8. What is the difference between cytokinesis of a plant cell and an animal cell?
9. Both skin cells and cancerous cells divide rapidly. Why cancerous cells are harmful but skin cells are not?
10. How haploid organisms produce gametes?
11. Downs syndrome is due to extra copy of chromosome number 21. That is why Down syndrome people have 47 chromosomes. Why their chromosome number is high?

Section III: Extensive Answer Questions

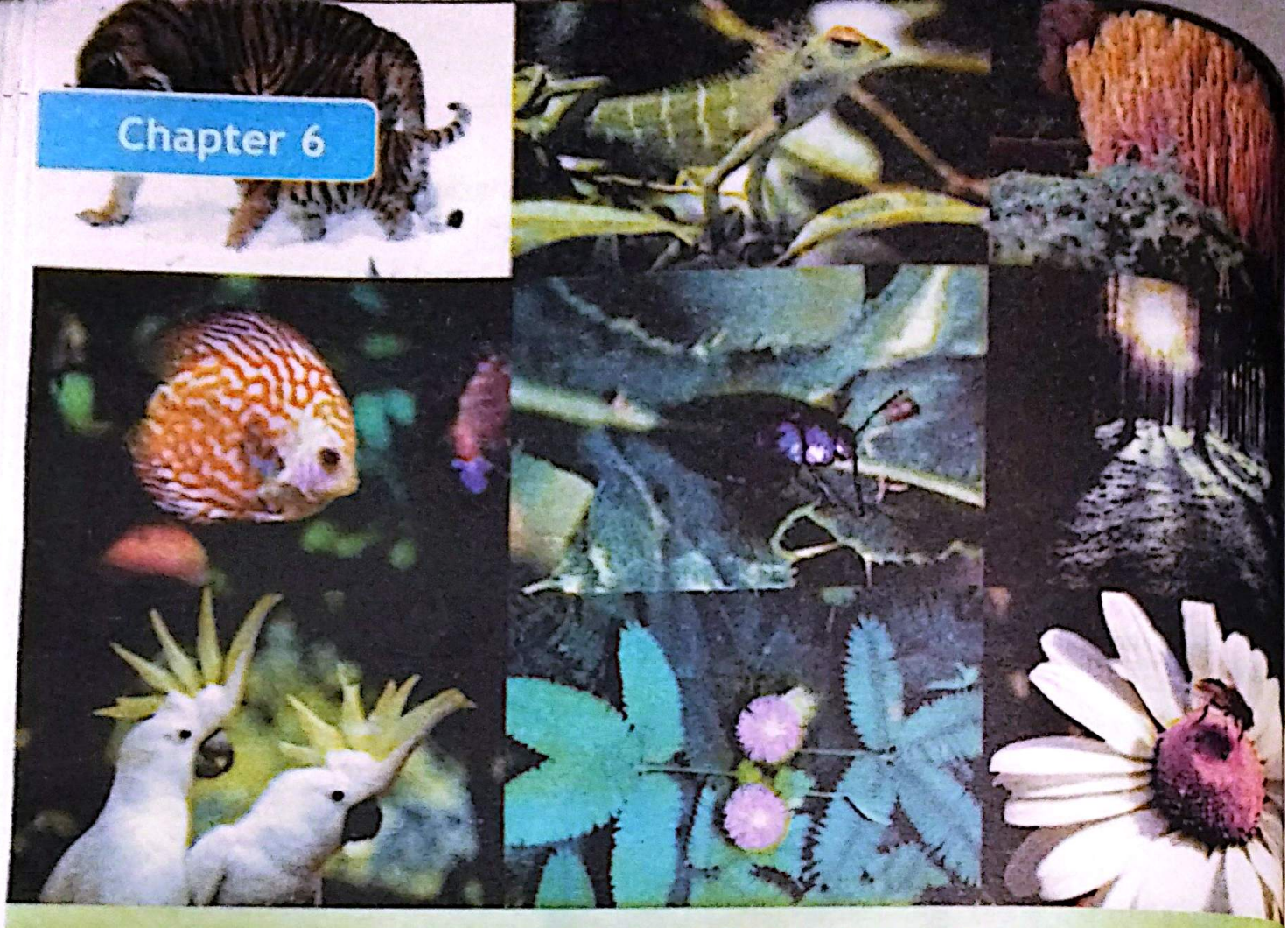
1. If a cell completes meiosis I but meiosis II fails to occur, what type of anomalies will appear in the two daughter cell thus formed?
2. A cell is shown in this diagram. Answer following questions after observing it.



   a. Give at least one finding on the basis of which you can identify it animal or plant cell.
   b. Identify the stage of cell division the given cell is passing through?
   c. Enlist the reasons of your identification.
3. Meiosis II is identical to mitosis, justify the statement.

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Chapter 6



BIODIVERSITY

SLOs: After completing this lesson, the student will be able to:

1. Define biodiversity and classification.
2. Describe advantages of classification.
3. Discuss the history of classification schemes.
4. List the three distinct domains into which living organisms are broadly classified into.
5. List the taxonomic ranks of classification.
6. Define species
7. Outline the binomial nomenclature system.
8. Describe the complications of classifying viruses.

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We have already learned that biology is the study of living organisms. The living organisms have been divided into major groups so that they can be studied easily.

6.1 DEFINITION AND INTRODUCTION TO BIODIVERSITY

The similarity among living organisms is that they share all the characteristics of life, i.e., movement, respiration, sensitivity, nutrition, excretion, reproduction and growth. At the same time these living things differ from one another and their variety is enormous.

6.1.1 Biodiversity

If you look around you will find variety of various kinds of organisms. The term biodiversity comes from two words bio and diversity mean variety within species and among species. Biodiversity has ecological and economic importance. It provides us with food, fuel, clothing, shelter etc. Biodiversity is defined as "the variety of living organisms on earth".

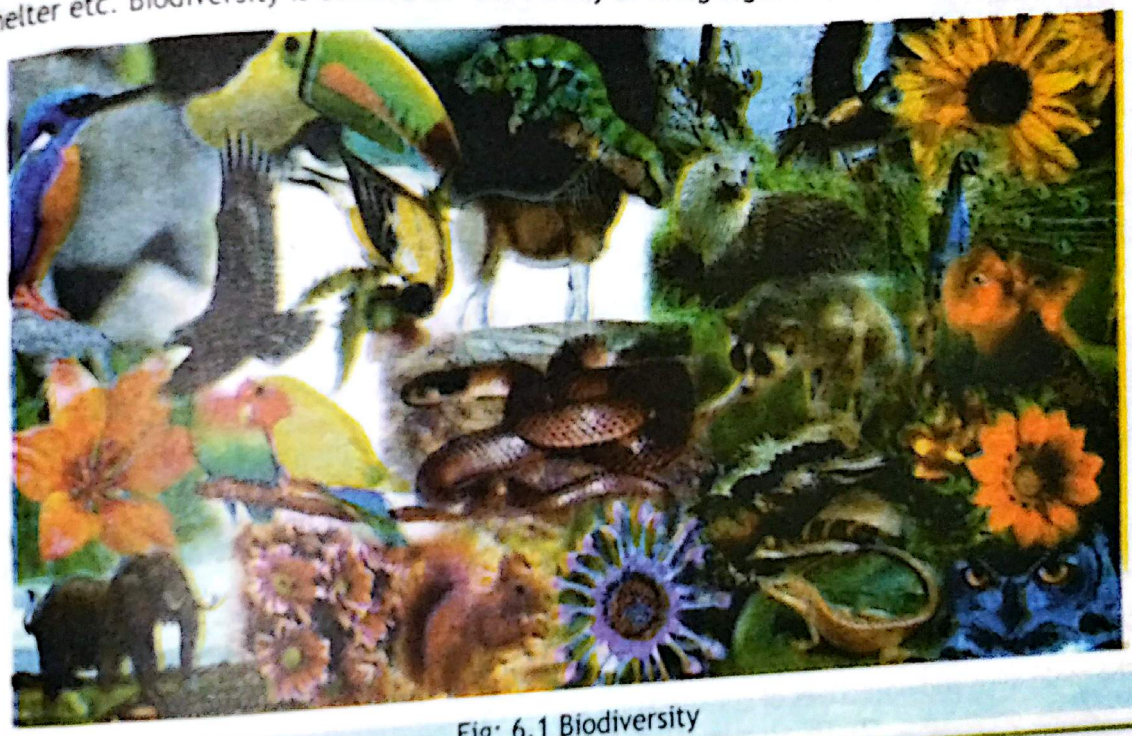


Fig: 6.1 Biodiversity

STEAM ACTIVITY 2.1

Take a chart paper. Cut pictures of various plants and animals from old newspapers or magazines and paste on the chart paper. You have placed all the organisms together at one place. What is it? This is biodiversity.

The natural biodiversity provides us oxygen, clean water and air. They help in recycling of nutrients. They enable the plants to grow. Pests are controlled by organisms such as by insects, birds and fungi. They protect us from flooding and regulate climate. They help in pollination and crop production. Biodiversity provides food and medicines derived mainly from plants. The industrial materials such as building materials, fibres, dyes, resins, gums, adhesives, rubber and oil etc., are derived directly from plants.

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6.2 CLASSIFICATION

Biologists have devised ways of grouping organisms. The grouping of organisms is called **classification. Taxonomy** is the branch of biology concerned with identification, naming and classification of organisms. Suppose you were asked to classify the living organisms of your surroundings. What criteria would you use to classify the organisms? The scientific study of diversity of organisms and their evolutionary relationship is called **systematics.**

STEAM ACTIVITY 6.2

Write the names of the organisms in their respective groups on the basis of having similar characteristics.

Rose, guava, fowl, pigeon, mango, sparrow, snake, crocodile, sunflower, lizard, cat, tiger, cow, tortoise, goat, dove. For example, rose, fowl, snake and goat have been placed in separate groups.

Group 1	Groups 2	Group 3	Group 4
Rose, ...	Fowl, ...	Snake, ...	Goat, ...

Why did you put rose and mango in one group whereas, fowl and pigeon in another group?

You placed the organisms of similar characteristics in groups. For example, you made a group of flowering plants with Rose, mango, guava and sunflower. You made another group of fowl, pigeon, dove, and sparrow. All of them have the similar characteristics in each group.

You have separated the organisms into groups on the basis of similarities and differences. Thus, you have classified the organisms.

To put organisms into separate groups on the basis of similarities and differences is called classification.

6.2.1 Advantages of Classification

The main aims and objectives of classification are: (1) To determine similarities and differences between organisms. (2) To arrange organisms on the basis of similarities and differences. (3) Identification of the organisms to study them systematically. (4) To find out evolutionary relationships among organisms.

6.3 HISTORY OF CLASSIFICATION

The Greek philosopher Aristotle was the first person who classified the living organisms. In 700s, Abu Usama Aljahiz described 350 species of animals. In the end of 15th century many biologists have worked on criteria classification.

Andrea Caesalpino (1519-1603): He divided plants into fifteen groups and called them genera.

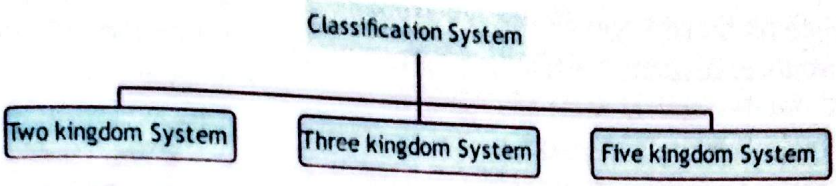
John Ray (1627-1705): He published important works on the classification of plants.

Tournefort (1656-1708): He introduced the taxa of class and species

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Carolus Linnaeus (1707-1778): He grouped species according to similar physical characteristics.

According to earlier classification system, organisms were classified into two kingdoms, then three-kingdom and then five-kingdom system.



1. **Two-kingdom classification system:** It is the oldest system and classifies organisms into two kingdoms. The two-kingdom classification was proposed by Carolus Linnaeus. The living organisms were classified into Kingdom Plantae and Kingdom Animalia. This classification was based on nutrition and locomotion. Those organisms which could move and had a defined shape and structure and were able to ingest food in either liquid or solid-state were classified under kingdom Animalia while others under kingdom Plantae.

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 separate kingdom was introduced for such organisms.

2. **Three-kingdom classification system:** The German Scientist Ernst Haeckel proposed a third kingdom, **Protista** to accommodate *Euglena* like organisms and to separate unicellular microscopic organisms from multicellular ones.

3. **Five-kingdom classification system:** In 1937 E-Chatton suggested the terms 'Procariotique' to describe bacteria 'Eucariotique' to describe plant and animal cells. In 1967 Robert Whittekar introduced five-kingdom classification system. The five kingdoms are: Monera, Protista, Fungi, Plantae and Animalia. In the five kingdom system bacteria and archaea were combined in a single kingdom Monera, because they shared the prokaryotic form of cell structure.

> The organisms which lack nucleus in their cells are called **prokaryotes** while the organisms which have nucleus in their cells are called **eukaryotes.**

6.4 CLASSIFICATION- THE THREE DOMAINS SYSTEM

In biology, a domain is the highest in taxonomic rank of classification for all living organisms. **Domain** is group of kingdoms or taxonomic category above the kingdom.in 1990 Carl Woese introduced a three domains system of classification. The three domains of life are Archaea, Bacteria and Eukarya.

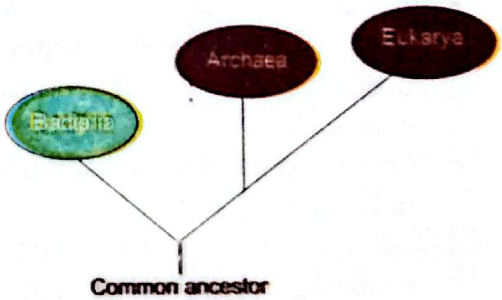


Fig. 6.2: The three domains of life

Classification into three domains is based on:

1. Difference in the sequence of nucleotides in the rRNA (ribosomal Ribonucleic acid) of the cell.
2. The cell's membrane lipid structure.
3. Its sensitivity to antibiotics.

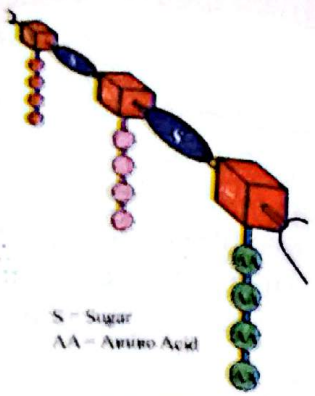
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1. The Domain Archaea

The domain Archaea have the following characteristics:

a. Archaea are prokaryotic cells.
b. The cell walls of Archaea contain no peptidoglycan.
c. Different rRNA(ribosomal RNA) are found in Archaea than Bacteria and Eukarya.
d. Archaea are not sensitive to some antibiotics that affect bacteria. They are sensitive to some antibiotics that affect the Eukarya.
e. Archaea often live in extreme environmnet.
f. Archae membrane can withstand higher temperature and stronger acid concentration.
g. Archaeal creatures include : Methanogens, Halophiles, Thermoacidophiles.

Peptidoglycan or murein is a polysaccharide, consisting of sugar and amino acids that form a layer surrounding the cytoplasmic membrane of most bacterial species.



2. The Domain Bacteria

The domain bacteria have the following characteristics:

a. Bacteria are prokaryotic cells.
b. The cell walls of bacteria contain peptidoglycan.
c. They contain rRNA that is unique to bacteria.
d. Bacteria are sensitive to traditional antibacterial antibiotics but are resistant to most antibiotics that affect eukarya.

1. Microorganisms that produce methane as a metabolic byproduct is called methanogens.
2. Microorganisms that live in high salt concentration are called halophiles.
3. The microorganisms that can live in high temperature and high acidity are called thermoacidophiles.

3. The Domain Eukarya

The domain Eukarya (also spelled Eucarya) have the following characteristics:

a. Eukarya have eukaryotic cells.
b. Not all Eukarya have cells with a cell wall. Their cell wall contains no peptidoglycan, but possess polysaccharides.
c. Eukarya contains rRNA that is unique to Eukarya.
d. Eukarya are resistant to traditional antibacterial antibiotics but are sensitive to most antibiotics that affect eukaryotic cells.

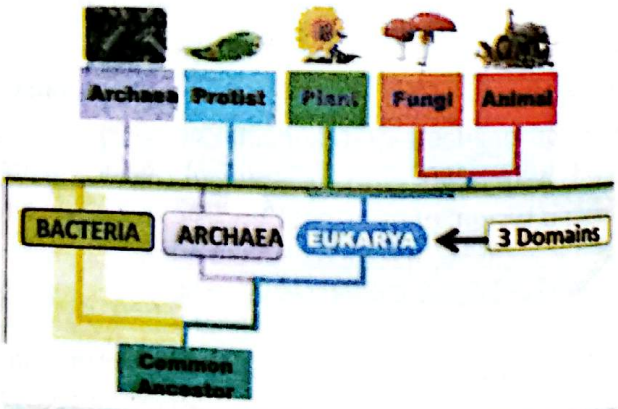


Figure 6.3: Domain Eukarya

The domain Eukarya are divided into four kingdoms: Protista, Fungi, Plantae and Animalia.

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1. **Protista:** Protists include eukaryotic organisms with unicellular or colonial organization. These are mostly aquatic. It is a diverse group of organisms. It includes: Animal like protists called protozoa e.g., *Amoeba*. Plant like protists called algae e.g., *Euglena*. Fungi like protists e.g., slime molds. Protists can obtain nutrients in a variety of ways, including: Autotrophy, heterotrophy, mixotrophy, saprobic or saprotrophic, parasitic.
2. **Fungi:** Fungi are eukaryotic organisms which have chitin in their cell wall. Fungi are saprotrophic decomposers. Mostly fungi are multicellular. Some fungi are unicellular. The examples of fungi are black bread mold, yeast, mushroom, etc.
3. **Plantae:** The members of kingdom plantae are eukaryotic multicellular and autotrophic with chloroplasts containing chlorophyll. Their cell wall is made up of cellulose e.g., moss, mustard.
4. **Animalia:** Animals are multicellular heterotrophic eukaryotes. Animals lack cell wall and chlorophyll. They can generally move from place to place. This kingdom includes invertebrates e.g., insects, starfish and vertebrates e.g., fish, frogs and man.

The organisms that are capable of producing their own food are called **autotrophs** (photosynthetic mode of nutrition) e.g., green plants, autotrophic bacteria, and algae. These are producers.

Organisms which eat other plants or animals as food are called **heterotrophs** (ingestive mode of nutrition) e.g., animals, animal like protists, etc. These are consumers

The organisms that depend on dead, decaying matter are called **saprotrophs** (absorptive mode of nutrition) e.g., fungi, bacteria. These are decomposers.

6.5 TAXONOMIC RANKS OF CLASSIFICATION

The group into which organisms are classified are known as taxonomic categories or **taxa** (singular 'taxon'). The taxa form a ladder, called **taxonomic hierarchy**. There are eight main taxonomic ranks: domain, kingdom, phylum or division, class, order, family, genus and species.

The **domain** is the highest taxonomic rank above the kingdoms. Domain is divided into kingdoms.

Kingdoms: The kingdom is the largest taxon or rank. Each kingdom is further divided into smaller taxa in the following way:

Phylum (Division: for plants and fungi): A phylum is a group of related classes.

Class: A class is a group of related orders.

Order: An order is group of related families.

Family: A family is a group of related genera.

Genus: A genus is a group of related species.

Species: A species is a group of similar organisms.

Plural: Phylum = Phyla, Class = Classes, Order = Orders, Family = Families, Genus = Genera, Species = Species

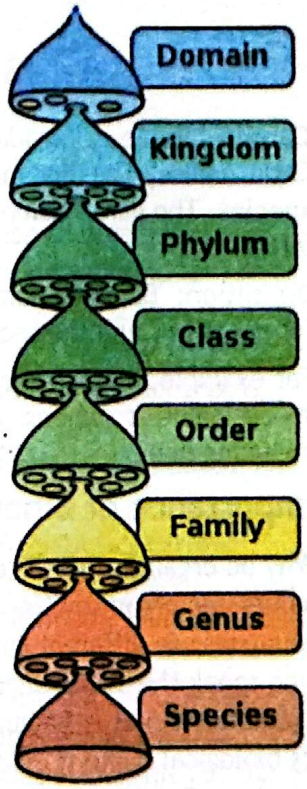


Figure 6.4: Taxonomic ranks of classification

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Table 2.1: Simple classification of human and pea

Taxa	Human	Taxa	Pea
Kingdom	Animalia	Kingdom	Plantae
Phylum	Chordata	Division	Magnoliophyta
Class	Mammalia	Class	Magniopsida
Order	Primate	Order	Fabales
Family	Homonidae	Family	Fabaceae
Genus	*Homo*	Genus	*Pisum*
Species	*Homo sapiens*	Species	*Pisum sativum*

6.6 SPECIES

Species is a group of similar organisms capable of interbreeding or exchanging genes among themselves and producing fertile offspring e.g., *Homo sapiens* (human), *Rosa indica* (rose).

Cross between a male donkey and a female horse produces mule. It is infertile, because of the odd number of chromosomes, they can't reproduce. So, it is not a species. Species is the most basic unit of classification, as well as a taxonomic rank.

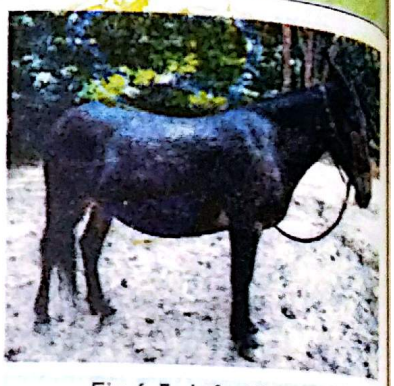


Fig 6.5: Infertile mule

6.7 BINOMIAL NOMENCLATURE

Carolus Linnaeus introduced a naming system to give each organism a name consisting of two Latin names. The first name is **genus** name and the second name represents the particular **species**. The genus name begins with a capital letter but the species name begins with a small letter.

Definition: Binomial nomenclature is a system for naming organisms using two terms, the first for the genus and the second for the species.

For example, biological name of human beings is *Homo sapiens*. Our genus name is *Homo* and specie name is *sapiens*. A genus may have many species e.g., all cats belong to genus *Felis* including lion.

Importance of Binomial Nomenclature

Why do organisms need to be given a scientific name in Latin? Why can't we just use common names for organisms? A common name will vary from country to country because different countries use different languages. Hence there was a need for a universal language. Even those who speak the same language sometime use different common name for the same organisms. Example: Brinjal is **Baigun** in Urdu, **Bataoon** in Punjabi, **Vagton** in Sindhi. Is it not confusing? Its biological name is *Solanum melangena*. Find out the Punjabi, Sindhi, Pushto or other local names or German, French, Spanish, Arabic, Russian, Chinese names of the following organisms which will show the importance of biological name.

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1. Potato - *Solanum tuberosum*
2. Rice - *Oryza sativa*

A scientific name has the advantage of using for a single kind of animal, plant or microorganism all over the world.

6.8 COMPLICATIONS OF CLASSIFYING VIRUSES

Viruses show characteristics of both living and nonliving things. The living characteristics of viruses are:

1. They occur in different varieties.
2. They have their own genetic material in the form of either RNA or DNA.
3. They reproduce using the material of the host cell they infect.
4. They enter the cells of living organisms and cause diseases.

Prions are composed of proteins only. Viroids are composed of circular RNA only. Both causes infectious diseases in certain plants. Both are acellular particles. They are not included in any kingdom of classification system.

The non-living characteristics of viruses are:

1. They lack cellular structure and enzyme system.
2. They can be crystallized and store in bottle.
3. They do not respire.
4. Viruses behave as non-living, inert infectious particles outside the host.

Viruses are at the borderline of living and non-living. So, they are not included in any domain and kingdom under modern classification.

SUMMARY

1. Biodiversity is the variety of organisms on Earth.
2. The grouping of organisms is called classification.
3. Taxonomy is concerned with identification, naming and classification of organisms.
4. The scientific study of diversity of organisms and their evolutionary relationship is called systematics.
5. Aristotle was the first person who classified the living organisms.
6. According to earlier classification systems organisms were classified into two kingdoms, three kingdoms and then five kingdom system.
7. Two-kingdom classification system classifies organisms into two kingdoms the Plantae and Animalia.
8. Three system classification system introduced the third kingdom Protista to separate unicellular microorganisms from multicellular ones.
9. Five-kingdom classification system includes the kingdoms Monera, Protista, Fungi, Plantae and Animalia.
10. Domain is a group of kingdoms or taxonomic category above the kingdom.
11. The three domains of life are domain Archaea, domain Bacteria and domain Eukarya.
12. Classification into three domains is based on sequence of nucleotides in the rRNA of the cell.
13. The four kingdoms of domain Eukarya are Protista, Fungi, Plantae and Animalia.

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14. The group into which organisms are classified are known as taxonomic categories or taxa.
15. The kingdom is largest taxon or rank. Each kingdom is further divided into smaller taxa which are: Phylum, Class, Order, Family, Genus and Species.
16. Species is a group of organisms that consist of similar individuals capable of interbreeding.
17. Binomial nomenclature is the biological system of naming the organisms. In it the name is composed of two terms. The first term indicates the genus and the second term indicates the species of the organism.
18. Viruses are at the borderline of living and nonliving. There are not included in any domain or kingdom under modern classification

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Into which kingdom you place a multicellular land organism that performs photosynthesis:

   A) monera B) protista C) plantae D) animalia

2. Which kingdom is mismatched with the characteristics?

   A) fungi - usually saprotrophic
   B) animalia - rarely ingestive
   C) protista - various modes of nutrition
   D) plantae - photosynthetic

3. The kingdom to which the algae belongs is:

   A) animalia B) protista C) plantae D) fungi

4. Scientific name has advantages of:

   A) same name applied to different organisms.
   B) same organisms have different name in different areas
   C) has no scientific basis.
   D) has scientific basis and is universally accepted.

5. Binomial nomenclature was introduced by:

   A) Aristotle
   B) Carolus Linnaeus
   C) Ernest Haeckel
   D) R.H Whittaker

6. The organisms that feed on dead, decaying matter are called:

   A) saprotrophs B) autotrophs C) heterotrophs D) parasites

7. Viruses are assigned to the kingdom:

   A) Plantae
   B) Protista
   C) Fungi
   D) Not included in any kingdom

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8. The common characteristic of viruses, prions and viroids is:

A) Respiration B) Movement C) Infectious nature D) Excretion

9. Colonial organization is the unique feature of kingdom:

A) Animalia B) Protista C) Fungi D) Plantae

10. Which option is correct regarding the mode of nutrition of following organism?

	Animal	Prokaryote	Fungi	Plant
A)	heterotrophic	heterotrophic	ingestive	autotrophic
B)	ingestive	absorptive	autotrophic	heterotrophic
C)	ingestive	heterotrophic	absorptive	photosynthetic
D)	absorptive	autotrophic	ingestive	autotrophic

11. Viruses are not included in any domain or classification as:

A) they are poorly understood.

B) they are too large.

C) they are of various colours.

D) they are not considered as organism.

12. A related groups of genera consists of:

A) a phylum B) a class C) an order D) a family

13. In which of the following the first letter is capitalized in binomial nomenclature?

A) genus B) class C) species D) family

14. If humans and cats belong to the same class, they must belong to the same:

A) phylum B) order C) family D) genus

Section II: Short Answer Questions

1. Why are the following scientists famous for?

(a) Aristotle (b) Carolus Linnaeus (c) Carl Woese

2. Define:

(a) Biodiversity (b) Classification (c) Taxonomy (d) Systematics

(e) Domain (f) Taxa (g) Species.

3. What is domain? Name the three domains of life.

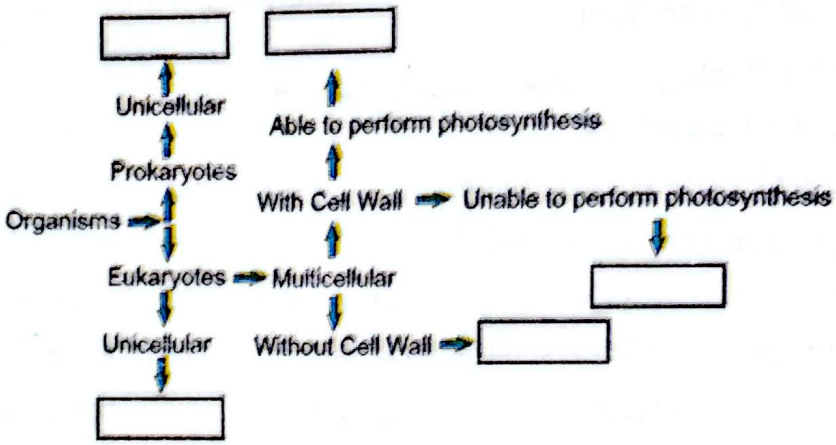
4. What are basis of classification of life into domains?

5. Can you differentiate between? :

(a) Bacteria and Protists (b) Fungi and Plants (c) Plants and Animals.

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6. Answer the following with supportive reasons.
   (a) Which the simplest domain?
   (b) Which is the complex domain?
   (c) Are most bacteria harmful?
   (d) Which domain/s can flourish or survive in most adverse conditions?
7. Compare the two-kingdom, three kingdom and five-kingdom system of classification.
8. Compare the three-domain system of classification.
9. Why mule is not regarded as a species.
10. Complete the following chart:

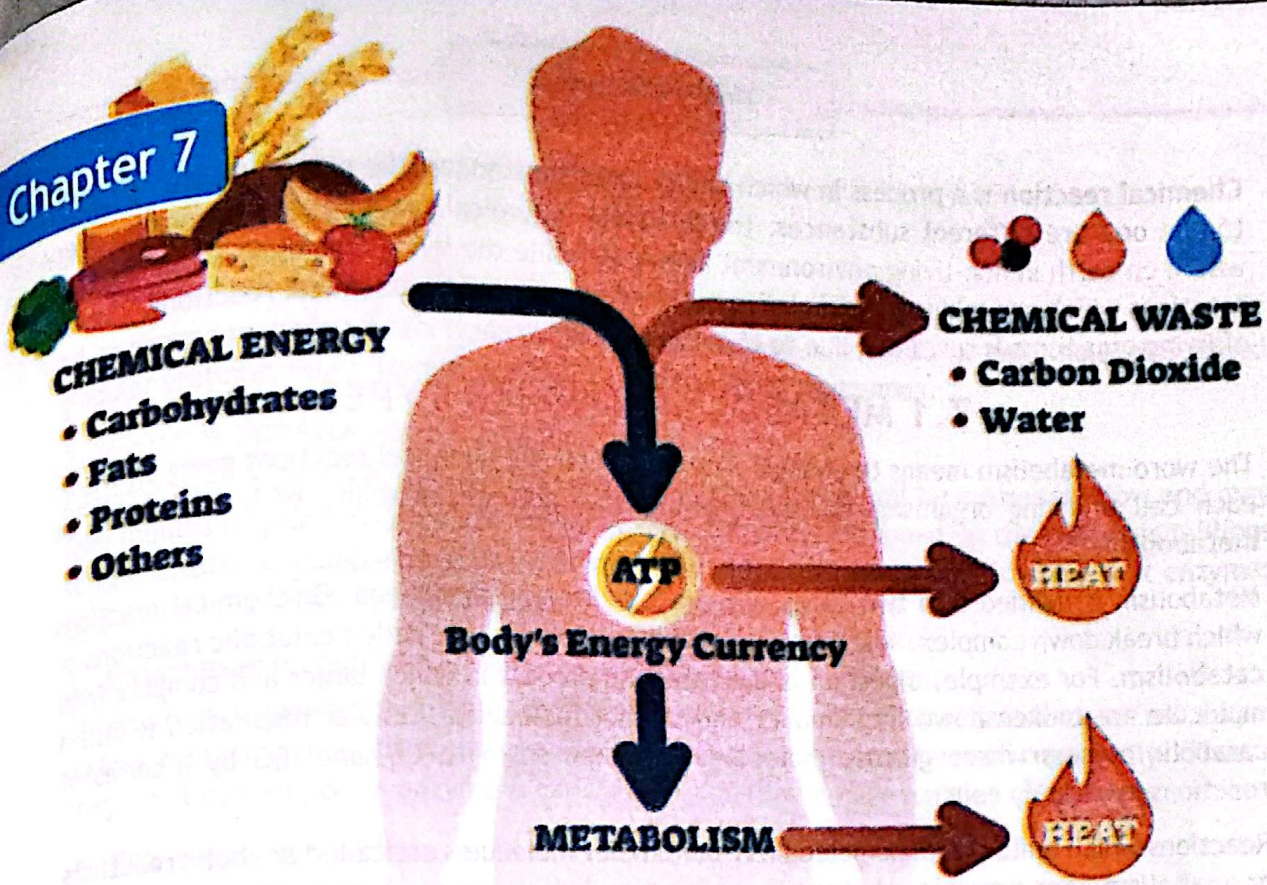


Section III: Extensive Answer Questions

1. What is biodiversity? Write the importance of biodiversity in the natural ecosystem.
2. Describe classification. How are the organisms classified?
3. What are the main aims and objectives of classification?
4. Give an account of history of classification.
5. What are the characteristics of the domain Archaea?
6. What are the characteristics of the domain (a) Bacteria (b) Eukarya?
7. What are the diagnostic characteristics of the four kingdoms of domain Eukarya?
8. Describe the taxonomic ranks of classification.
9. Write a brief note on species.
10. What is Binomial nomenclature? Describe aims, principles and importance of Binomial nomenclature using local examples.
11. State the complications of classifying viruses.

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Chapter 7



METABOLISM

SLOs: After completing this lesson, the student will be able to:

1. Define metabolism, catabolism and anabolism with examples.
2. Define enzymes and describe their characteristics.
3. Show the mechanism of enzyme action.
4. Assess the factors which could influence enzyme activity.
5. Describe competetitive and non competetive inhibition.
6. Discuss the role of ATP as energy currency.
7. Describe photosynthesis in Plants.
8. Explain aerobic respiration and anaerobic respiration.

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Chemical reaction is a process in which one or more substances, the **reactants**, are converted to one or more different substances, the **products**. Chemical reactions are happening every where on earth in non-living environment as wel as inside the living organisms. Those chemical reactions which are taking place in living organisms are called **biochemical reactions**. The life of living organisms is sustained due to these biochemical reactions.

7.1 METABOLISM AND ITS TYPES

The word metabolism means to change. The sum of all the chemical reactions going on within each cell of living organisms for the maintainance and sustainability of life is known as **metabolism**.

Metabolism is divided into two types, i.e. catabolism and anabolism. Biochemical reactions which break down complex molecules into simpler molecules, are called **catabolic reactions** or **catabolism**. For example, digestion is the catabolic process in which larger and complex food molecule are broken down into smaller and simpler molecules. Cellular respiration is also a catabolic process where glucose molecules is broken down to CO_2 and H_2O by a series of reactions in all body cells.

Reactions which build complex molecules from simpler molecules are called **anabolic reactions** or **anabolism**. For example, photosynthesis is an anabolic process where simple molecule like CO_2 and H_2O are converted to lager molecule glucose. Condensation of glucose molecules to form glycogen in muscle and liver cells is also anabolic reaction. Usually, energy is released in catabolism and it is utilized in anabolism.

7.2 ENZYMES AND THEIR CHARACTERISTICS

Vital biochemical reactions taking place in the body must occur quickly and precisely for a cell to perform and survive. These metabolic reactions in living organisms are sped up by specific proteins in the body called biological catalysts or enzymes. **"Enzymes are biologically active globular proteins made by living cells, which tremendously speed up the biochemical reactions"**. Each cell synthesizes its own enzymes and the type of enzymes produced in each cell are specific which is determined by the genes active in that cell.

Enzymes act on specific molecules in the cell called **substrates**. The **substrates** are the molecules entering into chemical reactions. After binding to their specific enzyme, substrates undergo chemical changes resulting in a new bonding arrangement between the molecules. The substrates modified by enzymes are called **products**.

The enzymes, which stay inside the cells to speed up the reactions, are called **intracellular enzymes** (e.g., enzymes of glycolysis working in the cytoplasm). Often the enzymes made inside the cells are allowed to go out of the cell to do their work outside. These enzymes are called **extracellular enzymes** (e.g., pepsin enzyme working in the stomach cavity). Fungi and bacteria release extracellular enzymes to digest their food. Study of structure, type and role of enzymes is called enzymology.

Science Titbits: If you chew your food longer, more starch digesting enzymes amylase is produced and mixed to food that helps in breakdown of food especially starch. Moreover, the process of chewing also triggers the production of HCl in the stomach that regulate the lower pH in stomach to activate the enzyme pepsin, which breakdown the protein.

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7.2.1 Characteristics of enzymes

Enzymes have following characteristics.

1. Enzymes are Globular Proteins

All enzymes are made up of chains of amino acids folded to form 3D protein molecules called globular proteins. Few enzymes are RNA in nature called **ribozymes.**

2. Enzymes increase rate of reaction

Reaction may initiate without involvement of enzymes, but it will be extremely slow and may take months or years to complete the reactions. The enzymes speed up the reactions millions of times faster as compared to non-enzymatic reaction. It is important to know that enzymes only speed up a reaction and do not start a chemical reaction.

3. Enzymes are required in small quantity

Structure of enzymes may slightly change during reaction but they regain their actual shape, so they remain unchanged at the end of the reaction. So they can be used repeatedly. Thus, a very small quantity of an enzyme is capable of catalysing a huge amount of substrate.

4. Enzymes are specific

Enzymes are usually very specific so catalyse only one type of reaction and it will not act on a different substrate. For example, amylase will only act on starch and not on proteins or fats.

5. Enzymes require co-factor

Many enzymes require an additional non-protein component for their proper functioning called **cofactor.** Cofactor usually act as bridge between protein part of enzyme and its substrate or may provide energy to enzyme. There are three types of cofactors:

a. Activator: Some enzymes require detachable inorganic ions as cofactor called activator such as Zn^{++}, Fe^{++}, Cu^{++} and chlorides etc. For example, activity of salivary amylase is increased in the presence of chloride ions.

b. Prosthetic group: If the cofactor is an organic molecule tightly and permanently attached to the enzyme it is known as prosthetic group. For example, Flavin Adenine Dinucleotide (FAD), Haem group etc.

c. Coenzyme: if the cofactor is detachable organic molecule it is called **coenzyme.** Examples of co-enzymes are NAD (nicotinamide adenine dinucleotide), coenzyme A and vitamin A and C.

6. Regulation of enzyme production and activity

Synthesis of enzymes within the cells and can be increased or decreased by a cell according to requirements. Enzyme activity can be regulated by inhibitors or activators within or from out of cell.

7. Enzymes make metabolic pathway

Many enzymes work together in a specific sequence to make metabolic pathways. Metabolic pathway is a series of connected chemical reactions where multiple intermediate molecules are produced before conversion of an initial substrate into final product.

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8. Energy of activation

Minimum amount of extra energy required to activate the molecule to react or start the reaction is called **energy of activation.** Enzymes lower the activation energy so that these reactions can take place at body temperature. Enzymes lower the activation energy by changing the shape and charge of the substrate. Enzyme may provide entirely different mechanism of reaction to lower the activation energy.

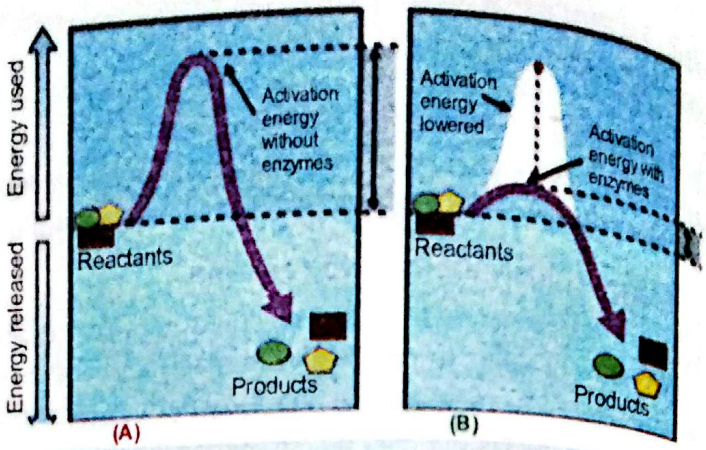


Fig. 7.1: Energy of activation (A) without enzymes (B) with enzymes

7.3 MECHANISM OF ENZYME ACTION

Most enzymes are far larger protein molecules than the substrates they act on. Specific part on the globular surface of enzyme where substrate binds and actually take part in reaction is called the **active site**. The active site is usually a very small portion of the enzyme which is a charge bearing cavity having a specific shape.

Specific substrate molecule temporarily binds to the active site of enzyme to form **Enzyme Substrate (ES) complex**. Once the ES complex has formed, enzyme catalyzes the reaction to convert the substrate in to product, thus converting the ES complex to **Enzyme Product (EP) Complex**. Finally, EP complex breaks up into products and enzyme. The enzyme molecule remains unchanged at the end of the reaction and is available again if needed for same reaction again (fig 7.2).

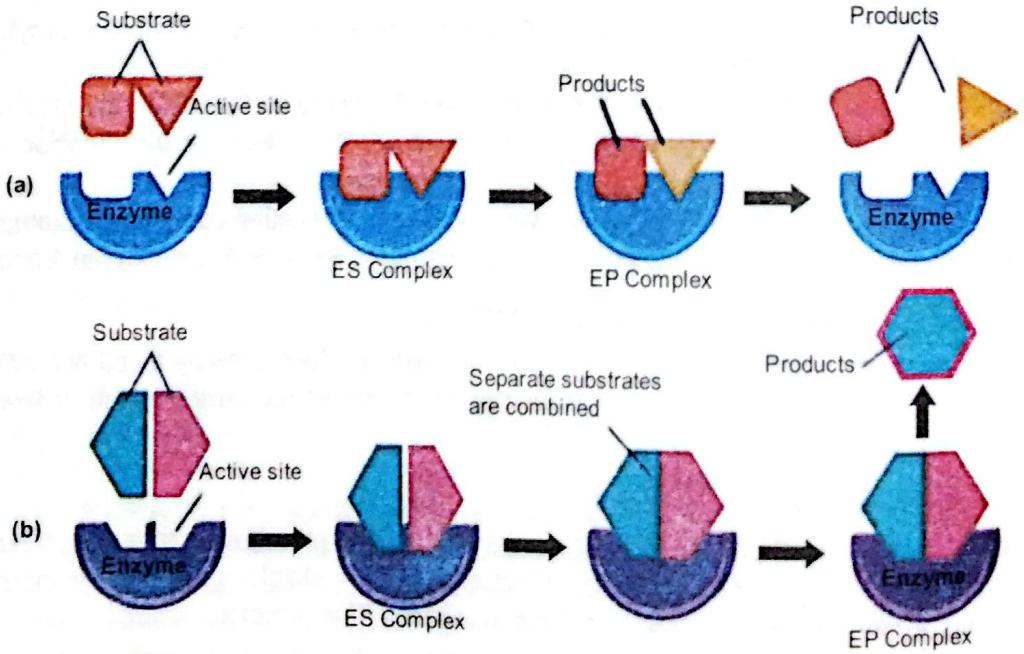


Fig. 7.2: Mechanism of Enzyme actions (a) Breakdown (b) Synthesis

Mechanism of enzyme action can be explained by the help of following models:

7.3.1: Lock and Key Model

In 1894, a Germen chemist **Emil Fischer** proposed the **lock and key model** to explain the mechanism of enzyme action. According to this model, the active site of enzyme is rigid structure and it does not modify during or after the reaction. The substrate is imagined being like a key and enzyme is imagined like a lock with a highly specific keyhole as its active site. As lock is opened by only a specific key, similarly only a specific substrate can bind to a specific enzyme having complementary active and then converted to product.

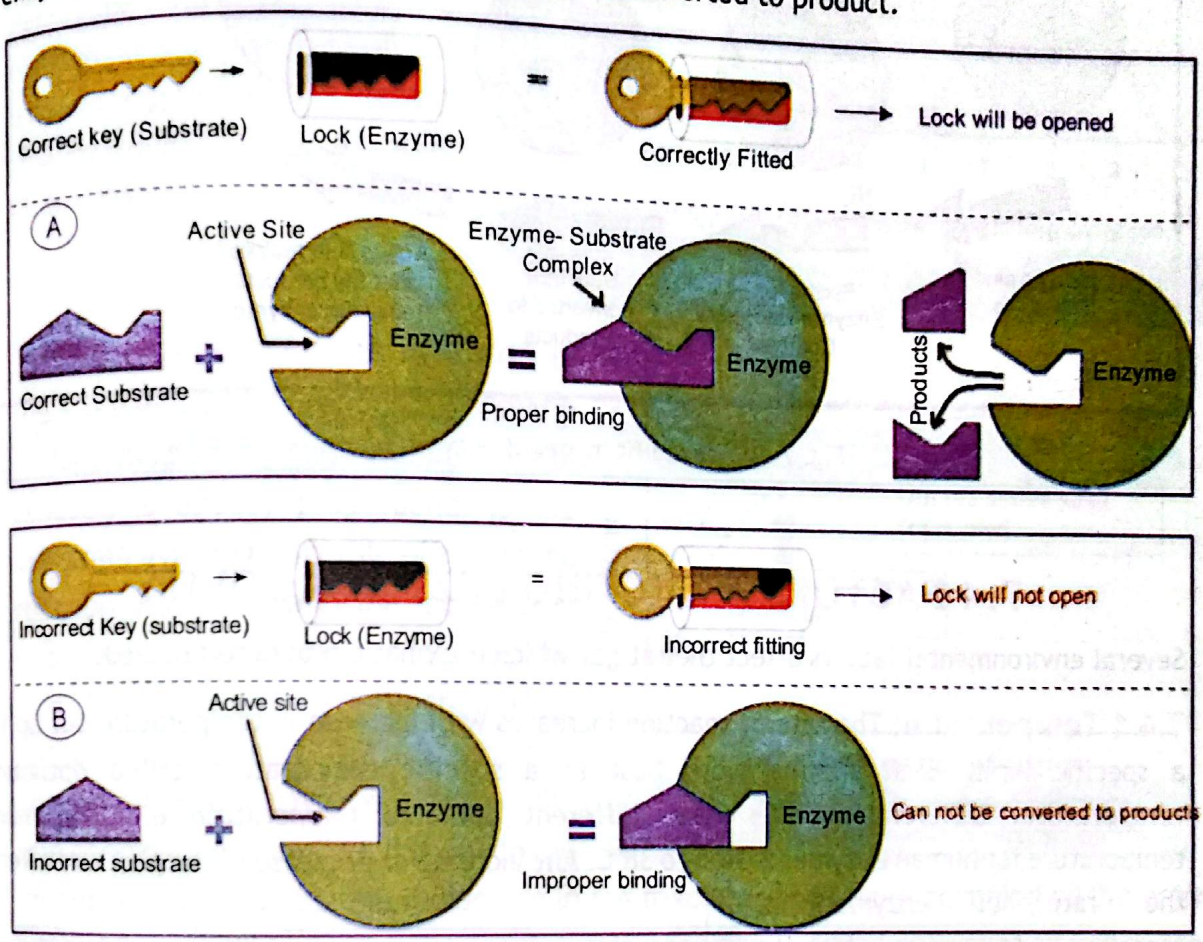


Fig. 7.3 Lock and Key Model of enzyme action. A. binding of proper substrate B. Binding of incorrect substrate

7.3.2: Induced fit model

In 1958, an American biologist **Daniel Koshland** proposed another model named induced fit to model to explain the mechanism of enzyme action. It describes that when a correct substrate binds to enzyme, it induces a slight and temporary change in the shape of its active site so that substrate properly fits and converted to products. This model is more acceptable and widely applicable than the lock and key model. According to this model, active site is not a rigid structure rather it is flexible just like a rubber glove, which is elastic and slightly stretches so that it fits on the hands for better functioning.

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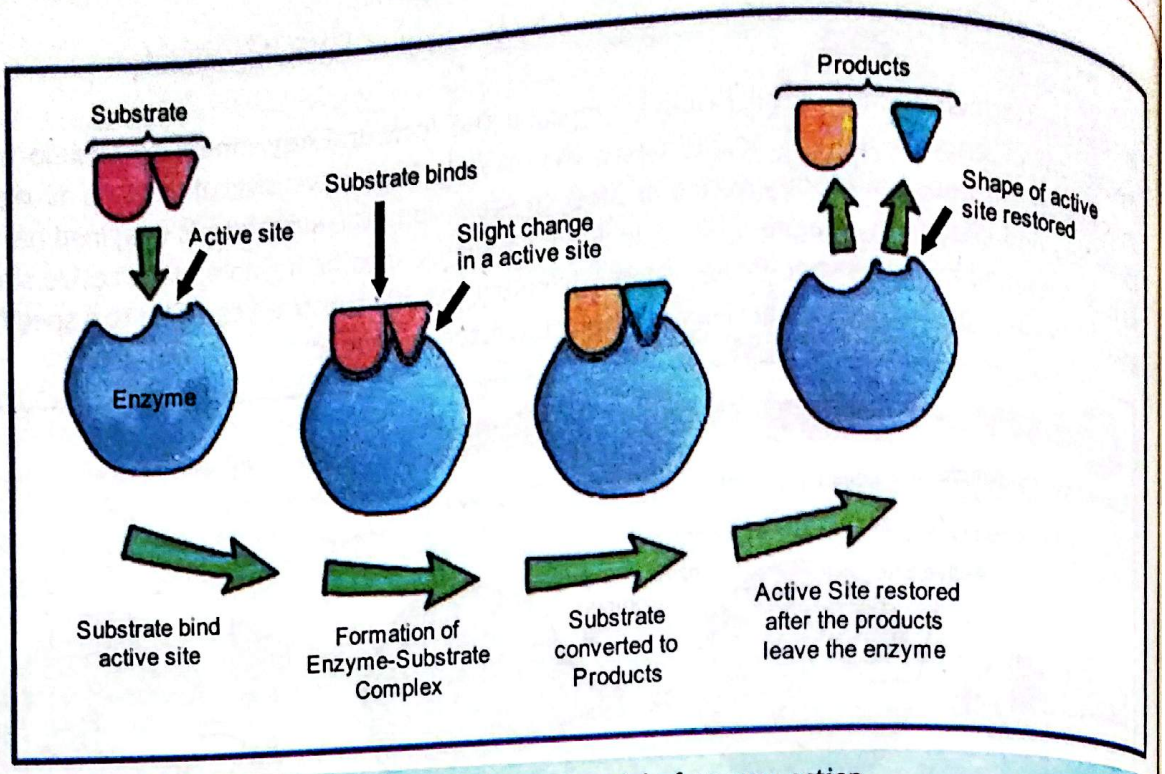


Fig. 7.4: Induced fit model of enzyme action

7.4 FACTORS AFFECTING ENZYME ACTIVITY

Several environmental factors affect the rate at which enzymatic reactions proceed.

7.4.1 Temperature: The rate of reaction increases with increase in temperature but up to a specific limit. Each enzyme work best at a specific temperature called **optimum temperature.** Different enzymes have different optimum temperature e.g., optimum temperature for human enzymes is 36°C to 38°C. Any increase or decrease in temperature affect the rate of enzymatic reaction. At very high temperature atoms of the enzyme molecule start vibrating vigorously so, globular structure and active site of enzyme is damaged and it is called denatured. At very low temperature enzyme remain inactive due to fall in available activation energy. They will regain their catalytic activity when normal temperatures are restored.

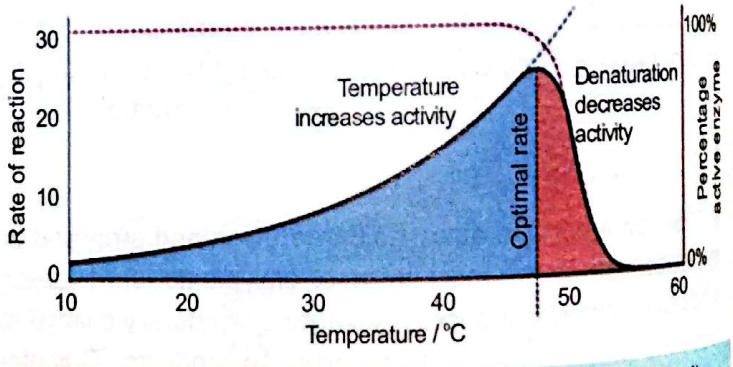


Fig. 7.5: Effect of temperature on the rate of enzyme activity

7.4.2 pH: pH of medium affect the enzyme functioning. Each enzyme perform best at a specific pH, which is called optimum pH. Slight change in pH of the reacting medium below or above the optimum pH reduce the rate of reaction. Extreme changes in pH denature the enzyme. For example, pepsin and trypsin are both protein digesting enzymes. Pepsin perform best in acidic medium in stomach at 2.00 pH whereas Trypsin perform best in alkaline medium in small intestine at 8.00 pH.

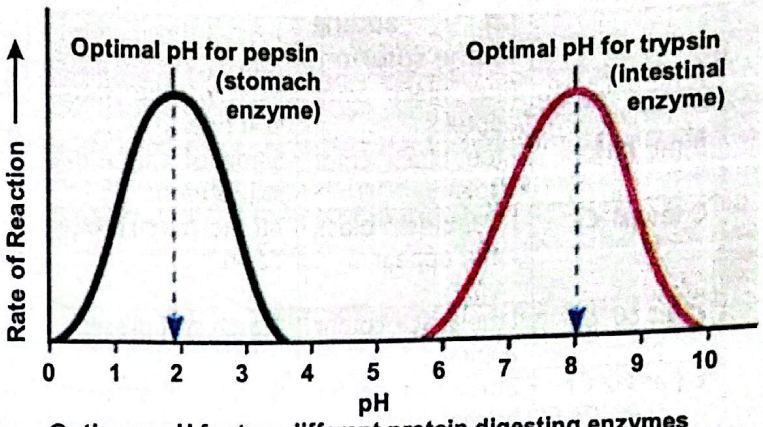


Fig. 7.6: Effect of pH on the rate of enzyme controlled reaction

7.4.3 Substrate concentration: In the presence of enough enzyme molecules at the reaction site, the rate of reaction is directly proportional to the substrate available. So, rate of enzymatic reaction increases with the increase in substrate concentration up to a certain limit. After that, a point is reached when further increase in substrate concentration will have no effect on the rate of enzymatic reaction. It is due to the presence of extra substrate molecules in the medium which have occupied all the active sites of the available enzyme molecules, this condition is called saturation of active site.

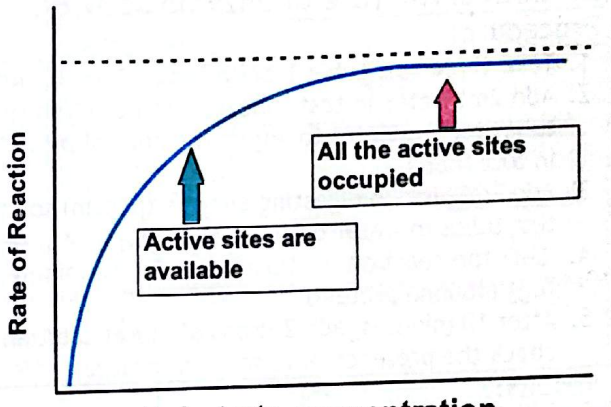


Fig. 7.7: Effect of Enzyme and substrate concentration on the rate of enzyme action

Inhibitors are molecules produced in the cell or enter into the cell from outside and stop the enzymatic reactions while **activators** are molecules that increase the rate of enzymatic reaction.

STEAM ACTIVITY 7.1

Temperature affects the rate of enzyme activity.

Procedure:

1. Take five test tubes labelled as A, B, C, D and E. Add 5ml starch solution with pH about 7.0 to all the test tubes.
2. Place test tube A in water bath set at 0°C, test tube B at 20°C, test tube C at 40°C, test tube D at 60°C, test tube E at 80°C for 5 minutes to adjust the temperature of the solutions.
3. Add 1ml starch digesting enzyme (amylase) solution to each test tube A to E, containing the starch solution.
4. After adding enzyme solution into the test tubes, keep the test tubes in specific water baths for 10 minutes to allow the enzyme (amylase) to act on substrate (starch).

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5. After 10 minutes, add 1 drop of iodine solution to each test tube to check the presence of starch.

Results:

Test tubes	Observations on adding iodine solution	Results	Logical conclusion of enzyme activity
A (at 0°C)	Blue black color appears	Most of the starch still present	At low temperatures the enzyme (amylase) broke down the starch slowly due to no or lower activation energy available.
B (at 20°C)	Blue black color appears	Some of the starch still present	
C (at 40°C)	No blue black color appear	All the starch broken down	At the optimum temperature the enzyme (amylase) broke down the starch quickly and completely.
D (at 60°C)	Blue black colour appear	Starch still present	At high temperatures the enzyme (amylase) broke down the starch slowly or not at all due to denaturation of the enzyme's active site.
E (at 80°C)	Blue black colour appear	Starch still present	

STEAM ACTIVITY 7.2

pH affects the rate of enzyme activity.

Procedure:

1. Take three test tubes labelled as A, B and C. Add 5ml protein (egg albumin) solution in each tube.
2. Add 2ml water in test tube A, 2ml HCl (*) in test tube B and 2ml NaOH in test tube C and left the tubes for 5 minutes to adjust the neutral pH in test tube A, acidic pH in test tube B and alkaline pH in test tube C.
3. Add 2ml protein digesting enzyme (pepsin) solution to each test tube A, B and C and place all three test tubes in water bath set at 37°C.
4. Left the reaction mixture tubes for 10 minutes to allow the enzyme (pepsin) to act on substrate (egg albumin protein).
5. After 10 minutes, add 2 drops of Biuret solution to each test tube and note any change in colour to check the presence or absence of protein.

Results:

Test tubes	Observations on adding Biuret solution	Results	Logical conclusion of enzyme activity
A (neutral pH)	Pink or purple colour may appear	Most of the protein still present	At neutral pH, the pepsin enzyme could not break down the protein due to inactivation or denaturation.
B (acidic pH)	No pink or purple colour appear	Protein absent, as it is broken down	At acidic pH the pepsin enzyme broke down the protein quickly and completely.
C (alkaline pH)	Pink or purple colour appear	protein still present	At alkaline pH, the pepsin enzyme could not break down the protein due to denaturation.

*optimum pH for pepsin activity is 2-3 pH which is maintained due to presence of an acid like HCl

7.5 ENZYME INHIBITION

Sometimes enzymes are not able to perform their role due to the presence and interference of some chemicals at the reaction site, this phenomenon is called **enzyme inhibition.** The chemical substance which react with enzyme in place of substrate but does not convert to products thus inhibiting the enzyme action is called **inhibitor.** Inhibitors may block or damage active site temporarily or permanently. Generally, enzyme activity may be temporarily inhibited by accumulated products within the cell to regulate the rate of

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reaction. External factors responsible for enzyme inhibition are poisons, cyanide, antibiotics, some drugs or accumulated products. Enzyme inhibition may be of two major types:

7.5.1 Competitive inhibition

If enzymes are inhibited due to presence of molecules which occupy the active site due to their similarity in structure and shape to substrate is called competitive inhibition. Such inhibitors are neither converted to products nor they allow the actual substrate to bind hence reaction does not proceed. Competitive inhibition is temporary and can be reversed if the concentration of actual substrate is increased than the concentration of inhibitor molecules.

7.5.2 Non-competitive inhibition

The structure and shape of these inhibitors do not resemble the substrate molecules so they do not occupy the active site. They may attach to enzyme surface at a point other than active site called **allosteric site**. They alter the globular shape of enzyme and damage the active site of enzyme, Thus, actual substrate will not be able to bind to active site and reaction stops.

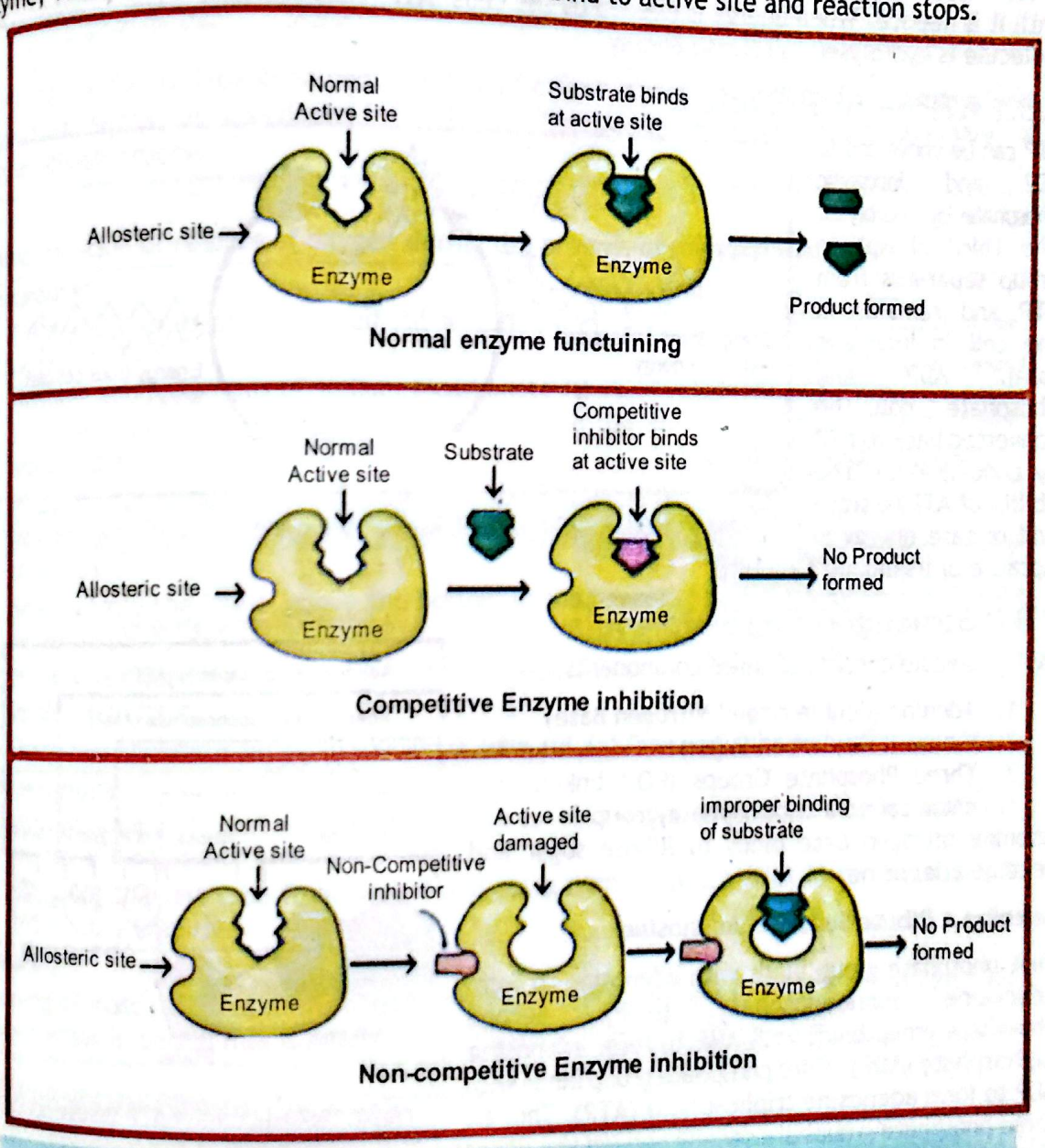


Fig.7.8: Competitive and non-competitive inhibition of enzyme

7.6 ROLE OF ATP-THE ENERGY CURRENCY OF CELL

Life of the living organisms is possible only if constant supply of energy is available in its cells. All the life processes like movement, development, reproduction, thermoregulation, active transport, etc. depend on the availability of energy. The living organisms, use and store energy at the cellular level in the form of Adenosine tri phosphate (ATP). ATP is commonly called the **"energy currency"** of cell because it is an energy rich compound that can store and release energy and can be used much like money. When organic molecules (glucose, amino acids etc.) are broken down in the cells, energy is released that can be captured and stored in ATP molecules. The energy remains stored in the ATP until it is needed. When energy is needed by the cells, ATP molecule is hydrolysed to release energy.

Science Titbits

Normally, human cells depend upon the hydrolysis of 100 to 150 moles of ATP per day to ensure proper functioning. ATP is synthesized by catabolic reactions e.g. complete oxidation of one glucose molecule during cellular respiration generate net 36 ATP molecules. Plants can also use light energy to produce chemical energy as ATP.

7.6.1 ATP — ADP Cycle

ATP can be converted to ADP and inorganic phosphate by hydrolysis. The third phosphate group separates from ATP and remains in the cell in inorganic form. ADP and phosphate can be converted back to ATP by condensation. The ability of ATP to store and release energy is because of its unique structure.

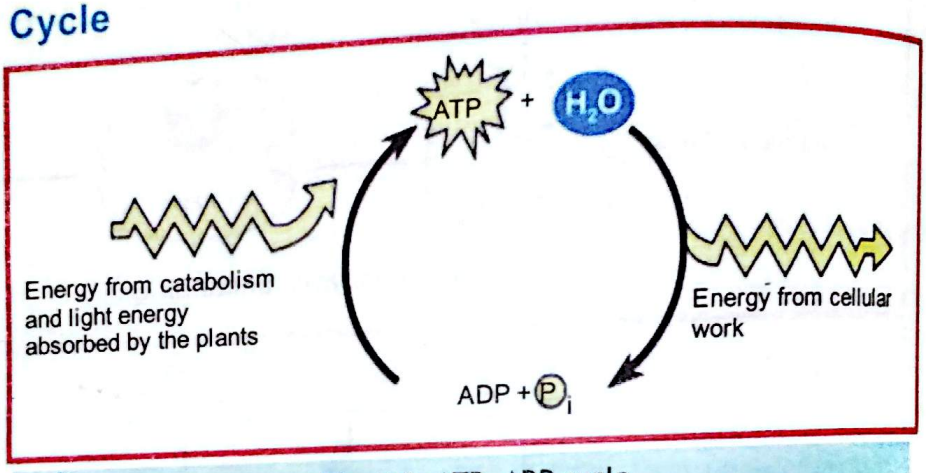


Fig. 7.9: ATP- ADP cycle

7.6.2 Structure of ATP Molecule

ATP molecule consists of three components:

1. Adenine (double ringed Nitrogen Base)
2. Ribose (Five Carbon Sugar)
3. Three Phosphate Groups (PO_4) linked in a chain called a **triphosphate group**

Adenine nitrogen base binds to Ribose sugar and become **adenosine.**

Adenine + Ribose Sugar → Adenosine

First phosphate group binds with adenosine to form **adenosine monophosphate (AMP).** Second phosphate group binds with AMP to form **adenosine diphosphate (ADP).** Third phosphate group binds with ADP to form **adenosine triphosphate (ATP).** Thus all three phosphate groups are serially bonded in a linear chain with adenosine to form ATP.

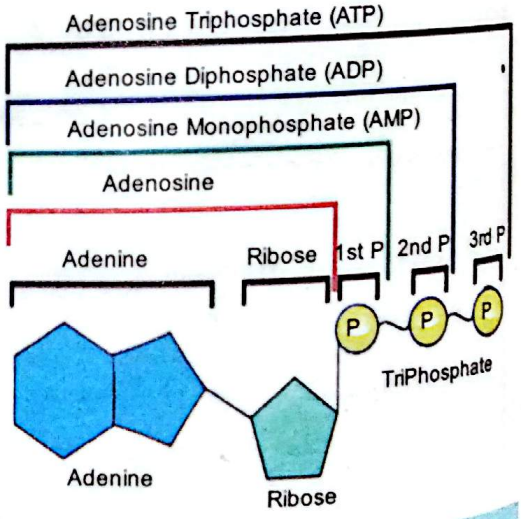


Fig. 7.10: Structure of ATP (high energy bonds indicated by wavy lines)

High Energy Bonds

The covalent bonds between phosphate groups are called "high energy" or "energy-rich" bonds. The two bonds linking the phosphate group together are represented by a specific sign of wavy lines. The energy stored in these bonds may be used by the cells to carry out their functions. Generally, one molecule of adenosine triphosphate (ATP) on hydrolysis to ADP provides 7.3 kcal of energy per mole. This reaction releases energy so it is exothermic in nature.

7.7 PHOTOSYNTHESIS

Photosynthesis is an important biochemical process taking place in plants, algae and cyanobacteria. During this process plants absorb light energy in the presence of chlorophyll and use carbon dioxide and water to make glucose. Oxygen is produced as a by-product during photosynthesis.

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{12H_2O} \xrightarrow[\text{ChlorophyII}]{\text{Light}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Water}}{6H_2O} + \underset{\text{Oxygen}}{6O_2}$$

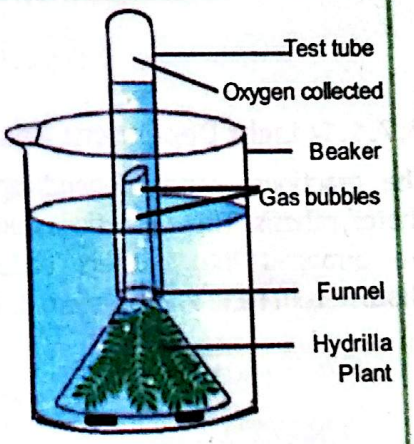
Nearly all life forms depend on photosynthesis for food directly or indirectly. Photosynthesis involves a series of coordinated reactions. The above equation shows summary of photosynthesis process.

STEAM ACTIVITY 7.3

Demonstration of release of oxygen during the process of photosynthesis:

Procedure:

1. Take a 500 ml beaker and half fill it with transparent water.
2. Dissolve about 5 grams of sodium bicarbonate ($NaHCO_3$) in water that will produce CO_2 in water for the use of aquatic plant.
3. Place few branches of Hydrilla plant in the beaker and cover it with an inverted glass funnel that is fully dipped in water.
4. Slightly raise the funnel above the bottom of the beaker for mixing and free water circulation.
5. Put a water filled inverted test tube on the neck of funnel as shown in figure.
6. Place this apparatus set up in the sun or light for 2-3 hours for photosynthesis to occur.



Observations

1. Bubbles of a gas will start coming out and move upward through water in test tube and collect at the top of the test tube above water level.
2. Bring out the test tube from beaker and put a burning match stick in the test tube, it burns more brightly.

Results:

Burning of match stick confirms that during experiment, the gas collected in the test tube above water is oxygen that is produced during the process of photosynthesis.

7.7.1 Mechanism of Photosynthesis

Photosynthesis occurs in two phases called as light dependent and light independent reactions. In the first phase, light energy is absorbed and then used to produce energy rich molecules ATP

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and NADPH. These reactions take place in chloroplasts. These reactions occur only in the presence of light so are called **light dependent reactions.** During the second phase carbon dioxide is reduced by NADPH to form glucose molecule. This reduction requires energy which is provided by ATP. These reactions do not use light directly; hence they are known as light **independent reactions.**

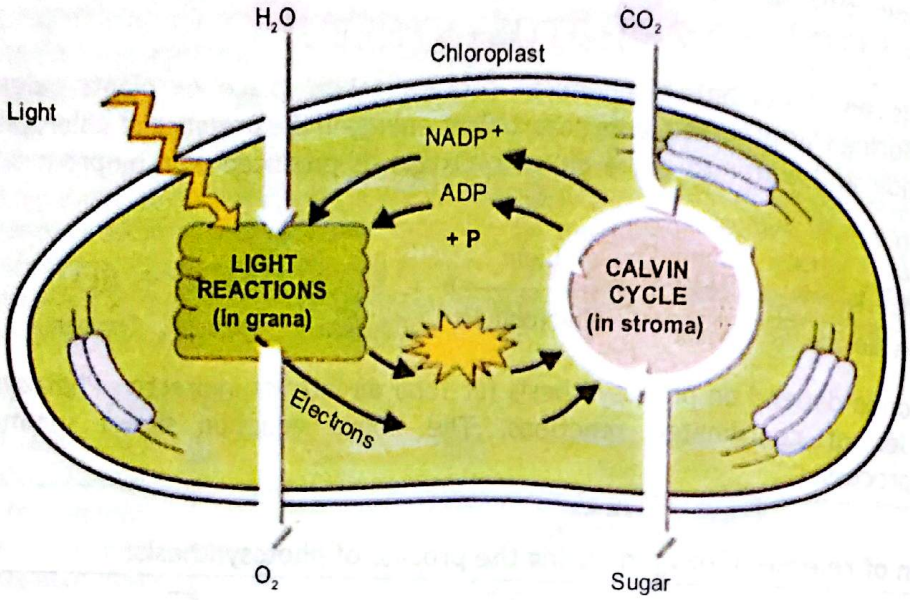


Fig. 7.11: An overview of photosynthesis

7.7.1.1: Light Dependent Reactions of Photosynthesis

The reactions, which depend upon light energy, are called light dependent reactions of photosynthesis. These reactions take place in thylakoid membranes where photosynthetic pigments are arranged into clusters called photosystems. There are two types of photosystems: **Photosystem I** and **Photosystem II.** Process of light dependent reactions starts from photosystem II.

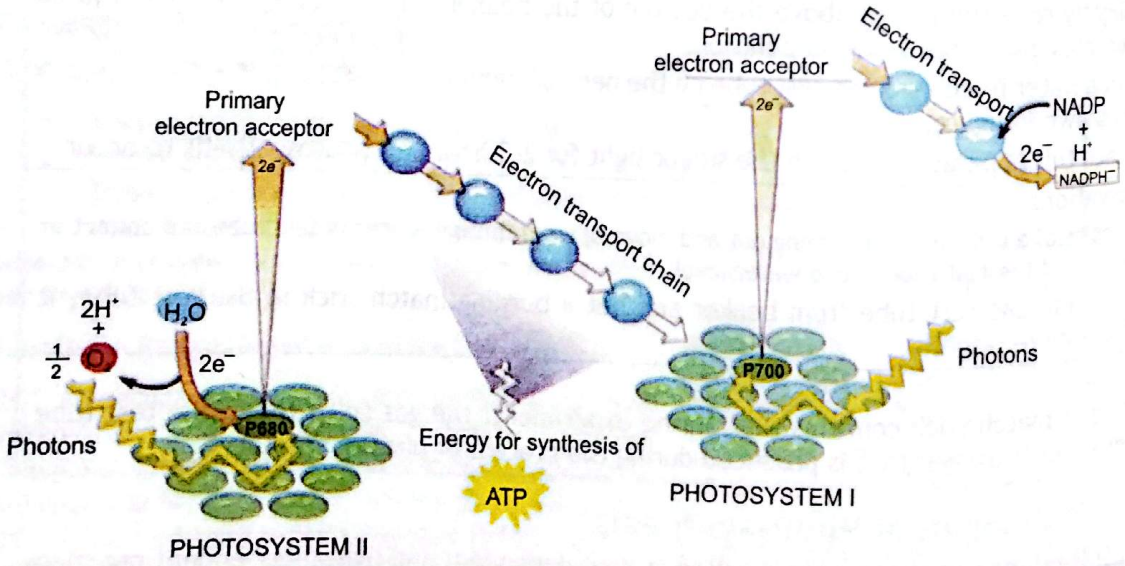


Fig. 7.12: Light dependent reactions of photosynthesis

1. Chlorophyll a of photosystem II absorbs light and a pair of electrons is emitted from it which are accepted by a molecule called primary electron acceptor.
2. At the same time, water molecule also splits into oxygen atom, two hydrogen ions (H^+) and two electrons. Splitting of water takes place to compensate the electron loss of light affected chlorophyll of photosystem II and is called **photolysis of water.**
3. Oxygen is released out of leaf through stomata.
4. Electron pair from primary electron acceptor passes through a chain of molecules called electron transport chain (ETC). Electrons passing through ETC, gradually release energy which is used for ATP synthesis.
5. Light also acts on photosystem I which also gives out an electron pair. These electrons and two H^+ of water reduce $NADP^+$ to NADPH.

7.7.1.2: Light Independent Reactions of Photosynthesis

Once the light reactions produce ATP and NADPH, a photosynthetic cell can fix carbon dioxide to synthesize sugar molecules. These reactions does not depend directly on light that is why it is called **dark reactions** or **light independent reactions.** It takes place in stroma of chloroplast.

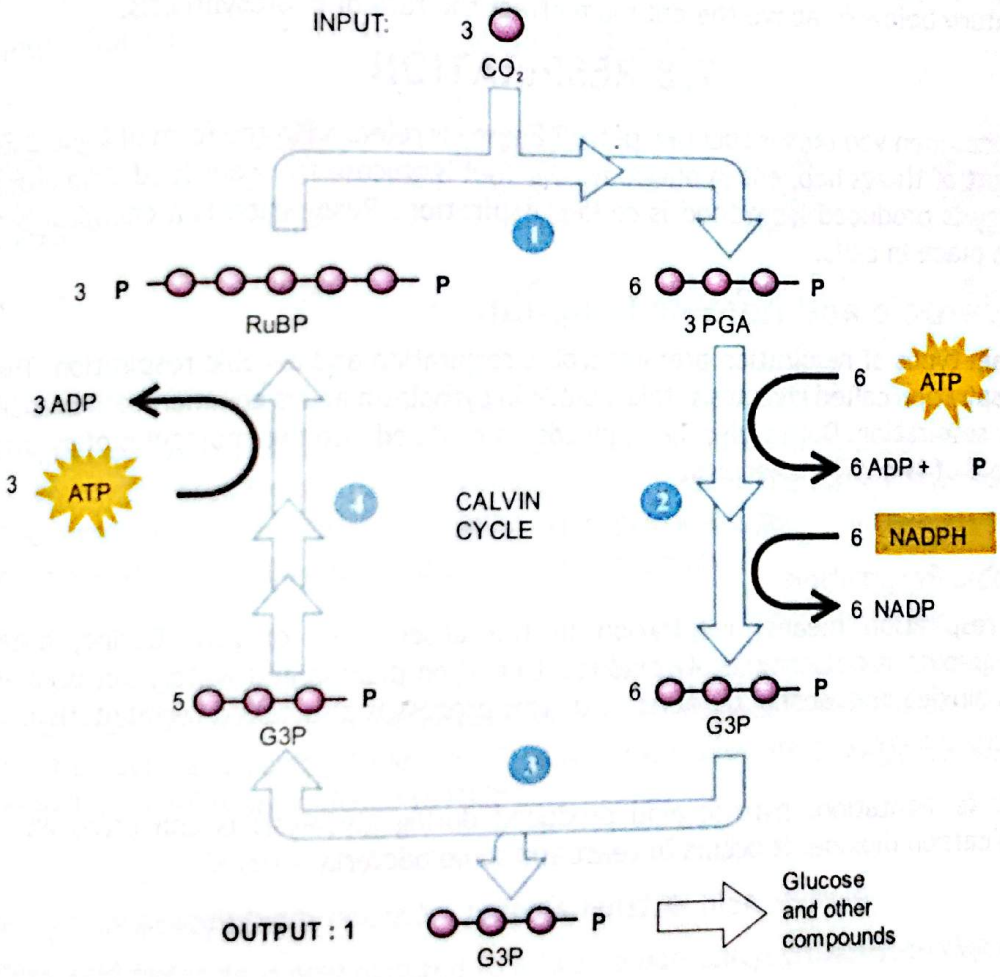


Fig. 7.13: Calvin cycle

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The sequence of reactions in this phase was first described by Melvin Calvin and his colleagues so is known as **Calvin cycle** as well.

1. Carbon dioxide combines with an already existing 5-carbon molecule (RuBP) to form a 6-carbon intermediate molecule.
2. This 6-carbon molecule is unstable and splits into two 3-carbon molecules (3PGA).
3. Now these 3-carbon molecules are reduced to 3-carbon sugar molecule (G3P) by NADPH using energy of ATP.
4. These 3-carbon sugar molecules are used to synthesize glucose and also to regenerate original 5-carbon molecule for next Calvin cycle.

7.7.2 Limiting Factors of Photosynthesis

Rate of photosynthesis can be affected by following environmental factors called a **limiting factor** of photosynthesis.

1. More light intensity and duration of light increase the process of photosynthesis.
2. Carbon dioxide is one of the raw material (substrate) for photosynthetic reaction. More CO_2 concentration increase the rate of photosynthesis but only up to a specific point.
3. Rate of photosynthesis is highest at 25°C called optimum temperature for photosynthesis. Temperature below or above the optimum affect the rate of photosynthesis.

7.8 RESPIRATION

What happens when you burn a fuel like petrol? Energy is released in the form of light and heat. The same sort of things happens in our body. Our fuel is glucose from our food. The process by which energy is produced from food is called **respiration**. Respiration is a chemical process, which takes place in cells.

7.8.1 Anaerobic and Aerobic Respiration

The two main types of respiration are: anaerobic respiration and aerobic respiration. The first phase of respiration called glycolysis, takes place in cytoplasm and is common both in anaerobic and aerobic respiration. During glycolysis, glucose is oxidized into two molecules of pyruvic acid with the yield of two ATP molecules.

Glucose → 2 Pyruvic Acid + 2 ATP

a. Anaerobic Respiration

Anaerobic respiration means, respiration in the absence of oxygen. During, anaerobic respiration glucose is not completely oxidized to carbon dioxide and water, but is converted into carbon dioxide and alcohol or lactic acid. This process is also called **fermentation**.

Alcoholic fermentation

In alcoholic fermentation, pyruvic acid produced during glycolysis is converted into ethyl alcohol and carbon dioxide. It occurs in yeast and some bacteria.

Pyruvic Acid → Ethyl Alcohol + Carbon dioxide

Lactic acid fermentation

During tough and continuous exercise our heart and lungs cannot provide enough oxygen to skeletal muscles as per increased requirement. During such vigorous exercise or labour, muscle

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cells start to carry out anaerobic respiration and each pyruvic acid molecule is converted into lactic acid. Bacteria which convert milk to yogurt also produce lactic acid.

Pyruvic Acid → Lactic Acid

7.8.1.1 Importance of Anaerobic Respiration

Anaerobic respiration is important for living organisms in following ways:

(1) The earliest living organisms would have to produce energy by anaerobic respiration because the early earth had no free oxygen in its atmosphere.

(2) Anaerobic respiration by bacteria is used in cheese and yogurt making.

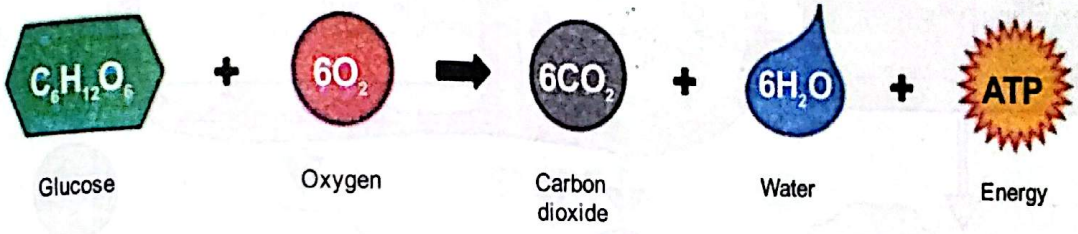
(3) Fermentation by yeast is used in wine making and baking industry.

(4) Anaerobic respiration, in the form of lactic acid fermentation provides some energy to muscle cells during running, labour or strenuous exercise.

7.8.2 Aerobic Respiration

Aerobic respiration means respiration in the presence and use of oxygen. During aerobic respiration, glucose molecule is completely broken-down in the presence of oxygen, to produce comparatively large amount of energy along with production of carbon dioxide and water.

Aerobic respiration can be summed up by the following equation.



7.8.3 Mechanism of Aerobic Respiration

The breakdown of glucsose does not take place in a single step but in a series of chemical reactions. Energy released from breakdown of glucose is stored in the form of chemical energy in ATP. The complete process of aerobic respiration is divided into four main phases; glycolysis, formation of acetyl CoA, Krebs cycle and electron transport chain.

1. Glycolysis

Glycolysis takes place in cytoplasm of the cell, outside the mitochondria. It occurs both in anaerobic and aerobic respiration. A single molecule of glucose is broken down into two molecules of pyruvic acid having 3 carbons. Two ATP molecules are produced as net energy gain. Two NAD^+ molecules are reduced to NADH.

Glucose → 2 Pyruvic Acid + 2 ATP + 2 NADH

2. Formation of Acetyl CoA

Each pyruvic acid molecule is now oxidized to a two-carbon acetyl group which also combines with coenzyme A to form acetyl Co A. Carbon dioxide is removed and NADH is produced. The acetyl Co A enters mitochondrion where it will take part in Krebs cycle.

2 Pyruvic Acid + 2 CoA → 2 Acetyl CoA + 2 CO_2 + 2 NADH

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3. Krebs Cycle

Krebs cycle is a cyclic process which takes place in mitochondrial matrix. Coenzyme A is released and acetyl group is passed through a series of reactions. The products of this process are CO_2, NADH and $FADH_2$. Some energy is released to produce ATP directly, while more energy is produced by oxidation of NADH and $FADH_2$ in ETC.

$$2 \text{ Acetyl CoA} \rightarrow 4CO_2 + 2 \text{ ATP} + 6 \text{ NADH} + 2 FADH_2$$

4. Electron Transport Chain (ETC)

Electron transport chain is a series of electron carrier molecules located in the inner membrane of mitochondria. The electrons that are removed by oxidation of glucose molecules during glycolysis and Krebs cycle are carried to ETC by NADH and $FADH_2$. When electrons coming through NADH pass through ETC, they provide enough energy to synthesize three ATP molecules. However, each $FADH_2$ produces only two ATP molecules. The final electron acceptor is oxygen atom which ultimately combines with hydrogen ions to produce water.

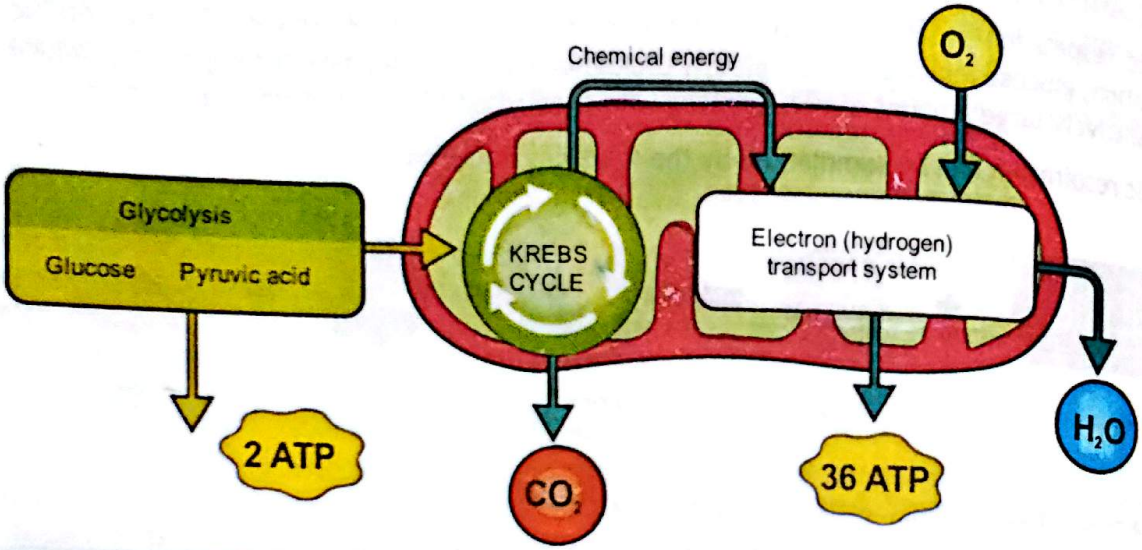


Fig. 7.14: An overview of aerobic respiration

ATP usage in body:

The energy produced as ATP by cellular respiration is used in many ways e.g., working of muscles, nerve impulse transmission, growth and repair of cells, active transport, gland etc. In human body brain uses maximum energy in the form of ATP i.e., 25% of ATP.

SUMMARY

1. The sum of all the chemical reactions that occur within a cell or organisms is called metabolism.
2. An enzyme is a biological catalyst which greatly increases the speed of a chemical reaction without being consumed.
3. An enzyme lowers the activation energy necessary to get a reaction going.
4. An active site of enzyme is a three dimensional region where substrate come into close contact and there by react more rapidly.

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5. Most enzymes need a co-factor. Most inorganic co-factors are metal ions. A co-enzyme is an organic co-factor such as NAD, and co-enzyme A. FAD is the prosthetic group for enzymes.
6. Enzymes work best at specific temperature and optimum pH.
7. In plants photosynthesis occurs in chloroplasts.
8. During photosynthesis, light energy is captured by chlorophyll and converted to chemical energy in a way that ultimately results in carbohydrate synthesis.
9. During the light dependent reactions of photosynthesis, chlorophyll electrons become excited. These electrons reduce NADP, forming NADPH and some of their energy is used to phosphorylate ADP, forming ATP.
10. During dark reactions, energy of ATP and NADPH is used to chemically combine carbon dioxide with hydrogen.
11. Cell uses two different types of catabolic pathways to extract free energy from glucose i.e., aerobic respiration and anaerobic respiration.
12. Aerobic respiration is a redox process in which electrons are transferred from glucose (which becomes oxidized) to oxygen (which becomes reduced).
13. The chemical reactions of aerobic respiration occur in four stages: glycolysis, formation of acetyl CoA, the Krebs cycle and the electron transport chain.
14. During glycolysis, which occurs in cytoplasm, a molecule of glucose is degraded to form two molecules of pyruvic acid.
15. Pyruvic acid is converted into acetyl CoA, which enters the Krebs cycle.
16. Water is formed when oxygen combines with Hydrogen and with electrons from the electron transport chain.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

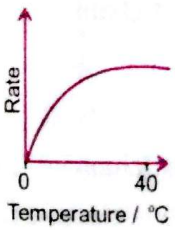
1. Which is true about enzyme?

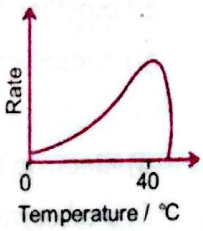
A) all enzymes are not protein
B) all enzymes are vitamins
C) all enzymes are proteins
D) all proteins are enzyme

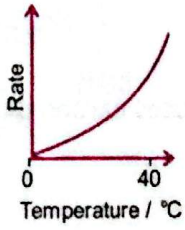
2. Lock and key hypothesis of enzyme action supports that:

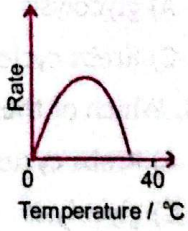
A) active sites are flexible
B) active sites are rigid
C) active site efficiency increases
D) active site can change its shape

3. Which graph shows how temperature affects the rate of an enzyme-controlled reaction?

A) 

B) 

C) 

D) 

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4. What is true about cofactors?

A) break hydrogen bond in proteins
B) help facilitate enzyme activity
C) increase activation energy
D) are composed of proteins

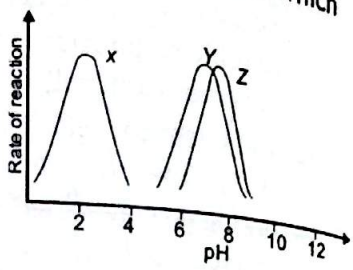
5. Change in pH can alter the active site by affecting the:

A) ionization of amino acids
B) Shape of substrate
C) ionization of cofactor
D) Ionization of coenzyme

6. The catalytic region on enzyme recognizes and binds the substrate and carries the reaction. This region is called as:

A) cofactor
B) activator
C) inhibitor
D) active site

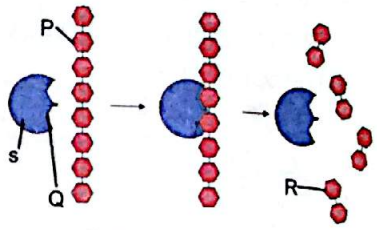
7. The graph shows the activity of three digestive enzymes at different pH levels. Which statement is correct?



A) Enzyme X and Y are both active at pH 7
B) Enzyme X and Z are both active at pH 4
C) Enzyme Y and Z are both active at pH 4
D) Enzyme Y and Z are both active at pH 7

8. The diagram shows an amylase molecule catalysing the breakdown of a starch molecule. Which are the labelled parts P, Q, R and S?

	Enzyme	Product	Substrate	Active site
A	P	Q	R	S
B	R	S	P	Q
C	S	P	Q	R
D	S	R	P	Q



9. Glycolysis is the breakdown of

A) fructose
B) glucose
C) lactose
D) maltose

10. The mechanism of ATP synthesis is

A) phosphorylation
B) photosynthesis
C) respiration
D) glucose

11. In aerobic respiration pyruvic acid changes to

A) glucose
B) fructose
C) Acetyl CoA
D) citric acid

12. Which of these uses oxygen as the final acceptor?

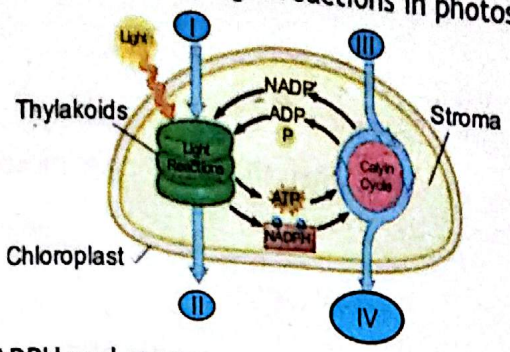
A) glycolysis
B) electron transport chain
C) Krebs cycle
D) photosynthesis

13. Which of these produces carbon dioxide?

A) Krebs cycle
B) electron transport chain
C) glycolysis
D) photosynthesis

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14. What are the products of light reactions in photosynthesis?



A) ATP, NADPH and oxygen
B) ATP and NADP
C) ATP,PGA and oxygen
D) PGA and oxygen

15. The diagram shows an overview of photosynthesis.
Which numbered molecules is organic biomolecule?

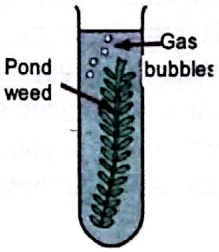
A. I
B. II
C. III
D. IV

16. Which feature helps plants to make most food by the process of photosynthesis?

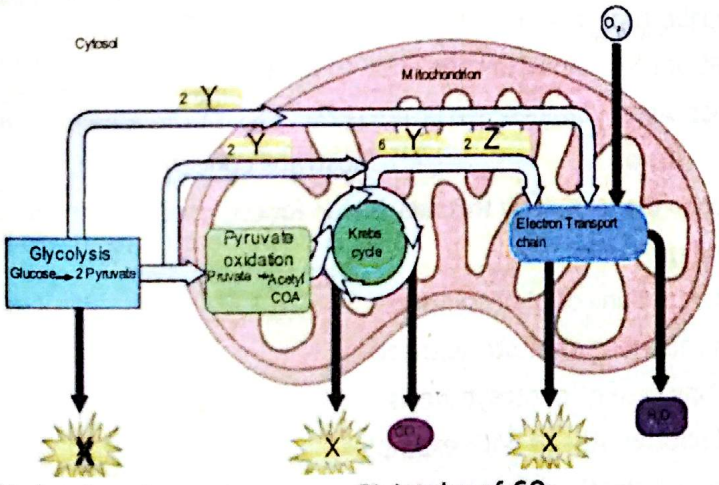
A) broad and flat leaves
B) spiny leaves
C) yellow leaves
D) curled leaves

17. The diagram shows a pond weed in a test tube filled with water. Which conditions would cause the plant to produce more bubbles?

	Dissolved CO_2	Light	Temperature
A	Present	Bright	Cool
B	Present	Bright	Warm
C	Present	Dim	Cool
D	Absent	Dim	Warm



18. Which of the following processes is used by plants to make oxygen during the process of photosynthesis?



A) intake of water
B) intake of CO_2
C) photolysis of water
D) Calvin cycle

19. The diagram shows overview of cellular respiration.

Which labelled part represents NADH?

A) X only B) Y only

C) Z only D) both Y and Z

20. A child left a carton on the lawn for two days. When the carton was picked up, the grass under it had turned yellow. What caused the grass to change colour?

A) lack of oxygen
B) lack of carbon dioxide
C) lack of light
D) lack of water

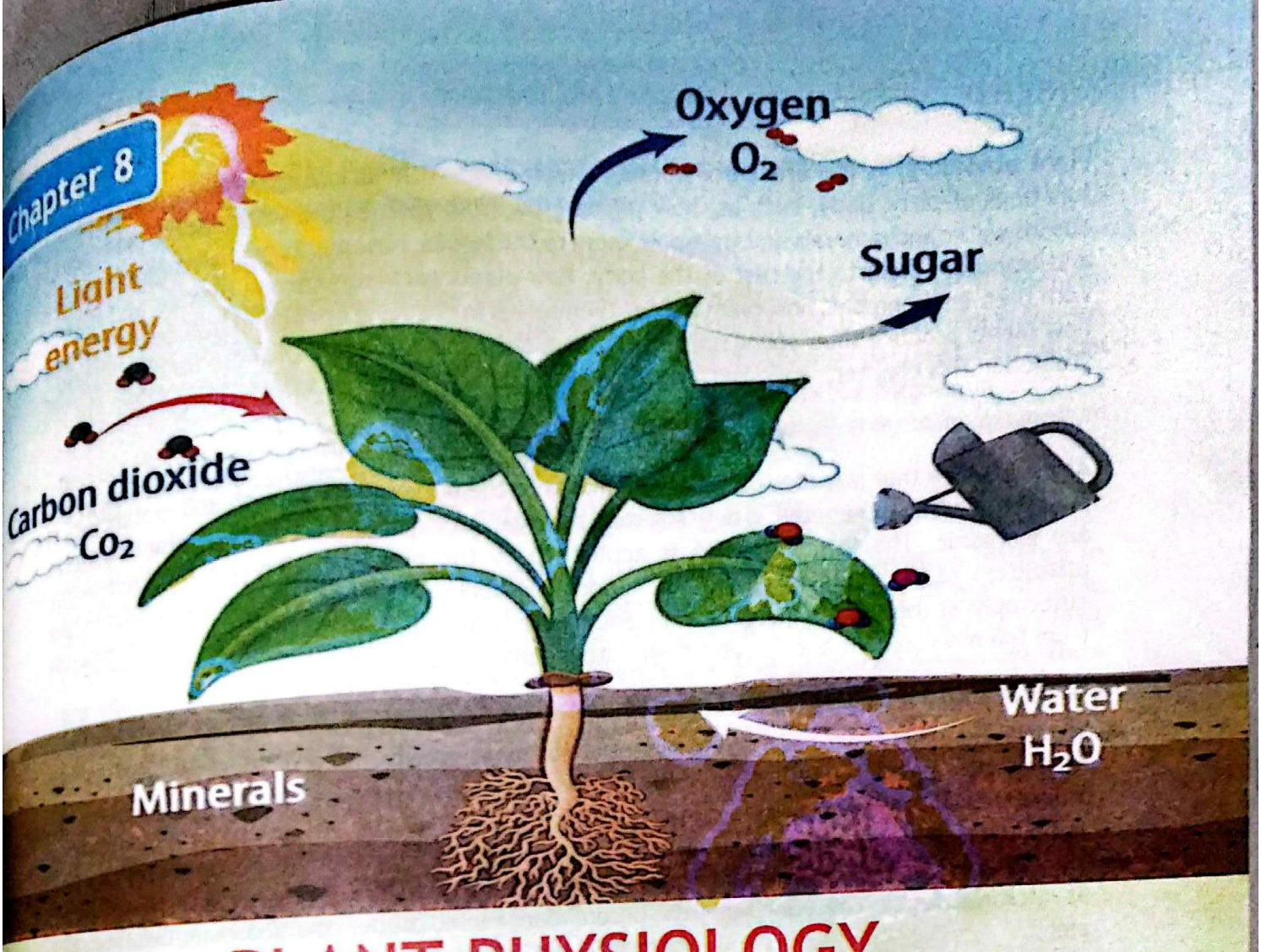
Section II: Short Answer Questions

1. Why enzymes are called biological catalyst?
2. Name the factors affecting enzyme activity.
3. At what pH pepsin and trypsin enzymes act the best?
4. What happens to an enzyme when it is frozen below 0°C?
5. Which protein digesting enzyme functions in acidic medium?
6. How enzyme lowers the activation energy?
7. Why are enzyme specific and why can't each one speed up many different reactions?
8. Why small quantity of enzyme is enough for catalysing large number of substrate molecules into products?
9. According to induced fit model, the active site is flexible. Does it mean that any substrate can attach with this flexible active site? If not, then explain.
10. Sketch the structure of ATP.
11. Write the equation of: a) photosynthesis b) fermentation c) aerobic respiration.
12. Name the products of anaerobic respiration in muscle cells.
13. Why a part of photosynthesis is called dark reactions.
14. How photosynthesis and aerobic respiration are interlinked with each other

Section III: Extensive Answer Questions

1. Define enzyme and describe their characteristics and specifications.
2. What is energy of activation? Explain with reference to enzyme.
3. What happens to enzymes when you increase or decrease?
   (a) Temperature (b) pH (c) Substrate concentration.
4. Only the related key can open the lock. How this fact is true for enzyme? Explain with examples.
5. Describe the structure and uses of ATP.
6. Describe and sketch light reactions of photosynthesis.
7. Describe and sketch dark reactions of photosynthesis.
8. Explain the factors affecting rate of photosynthesis.
9. Compare respiration and photosynthesis with examples.
10. What are the advantages and significance of anaerobic respiration and fermentation in your daily life?

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PLANT PHYSIOLOGY

SLOs: After completing this lesson, the student will be able to:

1. Define mineral nutrition in plants.
2. Categorize minerals nutrients of plants into micronutrient and micronutrients.
3. State that nitrogen is important in protein synthesis and magnesium for chlorophyll formation.
4. Conceptualize the transport and its need.
5. Explain the internal structure of root and root hair.
6. Describe how roots take up water and minerals.
7. Describe how roots take up water and mineral salts by active and passive absorption.
8. Describe transpiration and relate this process with the cell surface and stomatal opening and closing.
9. Describe temperature, wind and humidity as factors affecting the rate of transpiration.
10. Explain the mechanism of food translocation by the theory of pressure flow mechanism.
11. Describe the process of gaseous exchange in plants.
12. Define homeostasis and describe its importance.
13. Describe the mechanism of adaptations of plants for the excretion.
14. Explain osmotic adjustment in plants

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Plant physiology is the branch of botany, which deals with various questions related to the functions of plant body, such as, how plants grow from seed to the whole body, how plants absorb water and minerals and transport them to the leaves, how plants prepare organic solutes and transport them to the rest of the body, how plants exchange carbon dioxide and oxygen with their environment, how plants adapt themselves in changing environmental conditions and how plants produce their young ones to continue their species. Some of these functions will be studied in this chapter, while some have been discussed in other chapters.

8.1 NUTRITION IN PLANTS

Any substance that provides necessary elements to the organism for growth and metabolism is called **nutrient.** In general, a nutrient may be organic or inorganic, however, plant nutrients are inorganic. The term **nutrition** is applied to all the processes that are involved in the utilization of nutrients in growth or various metabolic activities of the body. Plants are autotrophs as they obtain inorganic nutrients such as water, carbon dioxide and certain minerals from the environment and convert them into organic compounds.

8.1.1 Types of plant nutrients

Sixteen elements have been found essential for plant growth. Nine of these are required in fairly large quantities (greater than 0.05% dry weights) and are therefore known as **macronutrients.** These include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, calcium, and magnesium. The remaining seven elements are needed in traces or small amounts (less than 0.05% dry weight) for normal plant growth and development that are known as **micronutrients.** These include iron, boron, manganese, copper, molybdenum, chlorine, and zinc.

Although, each mineral nutrient is very important for normal plant growth, here you will learn about the importance of only nitrogen and magnesium. The role of rest of the plant nutrients will be discussed in biology grade 11.

Importance of nitrogen in protein synthesis

Nitrogen is a macronutrient in the plant which is mainly absorbed by the plant from soil through their roots in the form of inorganic nitrogenous compounds like nitrates (NO_3). The major source of nitrates in the soil is the decomposition of **dead organic matter.** However, in the **nitrogen depleted soils,** it can be added in the form of nitrogen fertilizers. In plant body these **nitrogenous compounds** are used to make amino acids, nucleotides, and chlorophyll. The amino acids are then utilised in protein synthesis. As the protein is the most abundant organic constituent of the plant body therefore, nitrogen deficiency in plant can lead to severe growth retardation. The most obvious symptom of nitrogen deficiency in

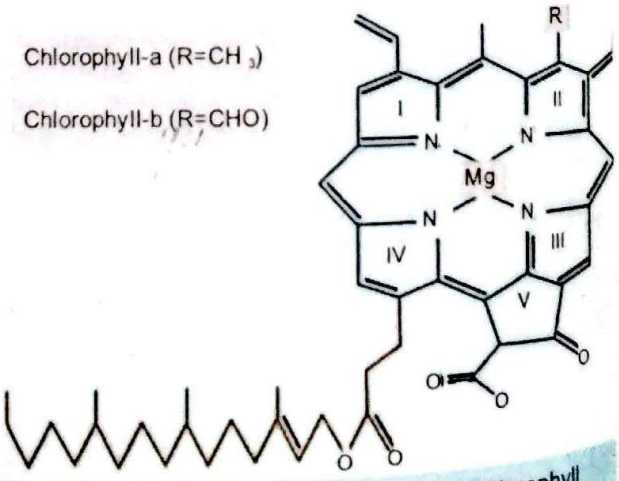


Figure: 8.1: Molecular Structure of Chlorophyll

plant is the **chlorosis** i.e., yellowing of plant leaves due to deficiency of minerals, as the deficiency of nitrogen inhibits chlorophyll formation.

Importance of magnesium in chlorophyll formation

Magnesium is a macronutrient in the plant which is mainly absorbed by the plant from soil through their roots in the form of inorganic Mg^+ ions. The major source of magnesium in the soil is the decomposition of **dead plant debris**. However, in the magnesium depleted soils, it can be added in the form of dolomitic limestone or magnesium fertilizers like Magnesium sulphate ($MgSO_4$). In plant body, the magnesium is used to make chlorophyll therefore, magnesium deficiency in plant can also lead to chlorosis.

8.2 TRANSPORT IN PLANTS

You have learnt that plants absorb nutrients from the soil which are then utilized in the leaves to prepare organic nutrients by photosynthetic activity. These **organic solutes** are also to be moved to different parts of the plant body. When organic solutes are utilized in plant body, some waste compounds are also produced which are then removed out of the plant body. All these movements of materials are generally referred to as transport in plants.

8.2.1 Need of Transport

In a plant body, transport occurs at three different levels:

At 1st level, the materials are moved from outside to inside the plant body because plant needs mineral nutrients and water to maintain its life activities which are to be absorbed from the soil, however, gases like CO_2 and O_2 are obtained from air.

At 2nd level, the materials are transported with in the plant body from one place to another because the inorganic nutrients must be transported to the leaves so that they can be used to prepare organic solutes by photosynthetic activity. These organic solutes are also to be moved to different parts of the plant body so that they can be used in plant growth and metabolism.

At 3rd level, the materials are moved from inside to outside the plant body because when organic solutes are utilized in plant body, some waste compounds are also produced which are then removed out of the plant body. These are the reasons why transport in plants occurs at three different levels.

8.2.2 Structure of root and root hairs

Root is an underground part of the plant, which serve as the **organ of uptake** of mineral nutrients and water. It possesses large surface area due to extensive branching system and root hairs which make them favourable for organ of uptake.

Dicot plants have **tap root** which consists of a thick **primary root** that bears several

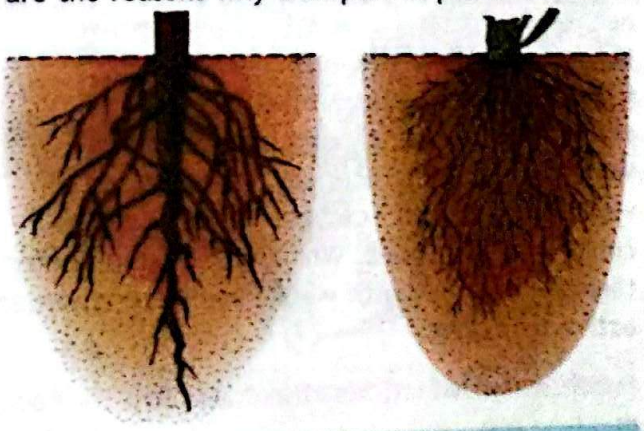


Figure: 8.2: Tap root in Dicot plants (Left), Fibrous Adventitious root in Monocot plants (Right)

secondary roots. Each secondary root further consists of large number of tertiary roots. On the other hand, monocot plants have **fibrous adventitious roots** that show no differentiation of primary, secondary, and tertiary roots.

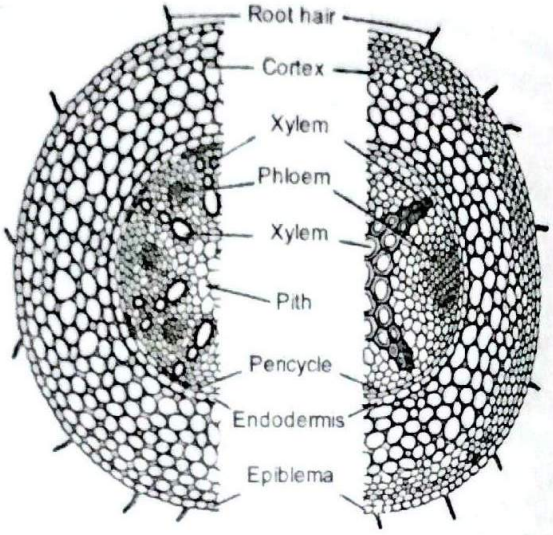


Figure: 8.3: T.S. of monocot root (Left), T.S. of dicot root (Right)

Internal structure of root and root hairs

In both monocot and dicot roots, the outermost layer is called **epidermis**. Many cells of the epidermis have extensions that are penetrated in the spaces among soil particles. These extensions of the root epidermal cells are called **root hairs**, which increase approximately 67% surface area of the root. Inner to the epidermis is a ground tissue, the **cortex**. The inner lining of the cortex is called the **endodermis**. The endodermal cells have deposition of a wax, the **suberin** in their radial walls. These depositions are in the form of strips called the **Casparian strips**. Inner to the endodermis is the **pericycle** which surrounds the innermost **vascular bundles**. The vascular bundle consists of xylem and phloem which are arranged in the form of ring in monocot root with central ground tissue called as **pith**. Whereas, in the dicot roots, the vascular bundles are present in the form of star shape in the centre of the root without the presence of pith.

8.2.2 Uptake of mineral salts and water by active and passive transport

Plant roots serve two vital functions: anchoring the plant in soil and absorbing essential minerals and water. For the process of **photosynthesis**, plants require three key nutrients: carbon dioxide, water, minerals. It also needs light. To obtain these nutrients, roots develop an extensive branching system and are covered by root hairs. These root hairs are the primary sites for the absorption of water and minerals. With these raw materials (minerals and water from the soil, carbon dioxide from the air, and light energy), plants synthesize all the compounds they need. While most minerals enter the root hairs or epidermal cells of the roots through bulk flow with water, some are absorbed through **diffusion, facilitated diffusion, or active transport**.

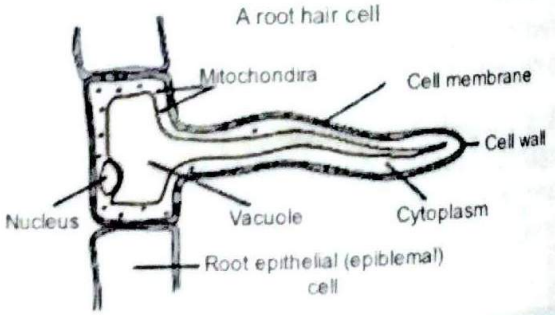


Figure: 8.4: Structure of root hair

Mechanism of mineral absorption by root

Plants absorb minerals from water in the soil. When minerals are stuck to soil particles and not dissolved in water, plants can't use them. Only those minerals can be absorbed that are

dissolved in soil water. Plants take in minerals through root cells by passive transport and also by active transport that require energy, specifically ATP.

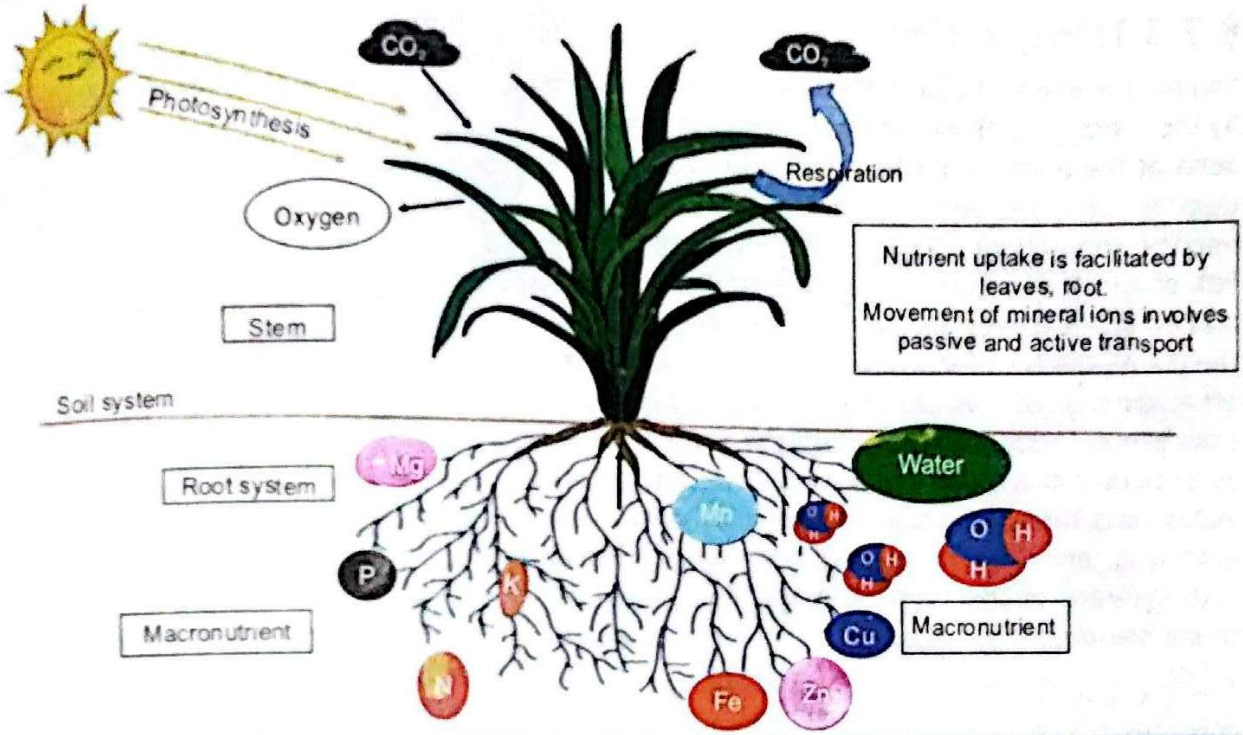


Figure: 8.5: Uptake of mineral nutrients by the plant

Passive uptake happens through **diffusion**, as minerals move along their **concentration gradient** through plasmodesmata to cells in the root's cortex, endodermis, and pericycle before reaching the xylem cells. They are then pulled up by transpiration.

Certain nutrients are transported from the soil into the epidermal cells of roots through their cell membranes by a process called **facilitated diffusion**. In facilitated diffusion, proteins within the cell membrane act as carrier molecules to help move nutrients across the membrane. These carrier proteins are found in the cell membranes of epidermal and other root cells.

Active transport, on the other hand, requires energy and allows plants to take in minerals even when their concentration inside the root cells is higher than in the soil. This is against the natural concentration gradient, and it involves the use of ATP. Active transport is selective and relies on respiration.

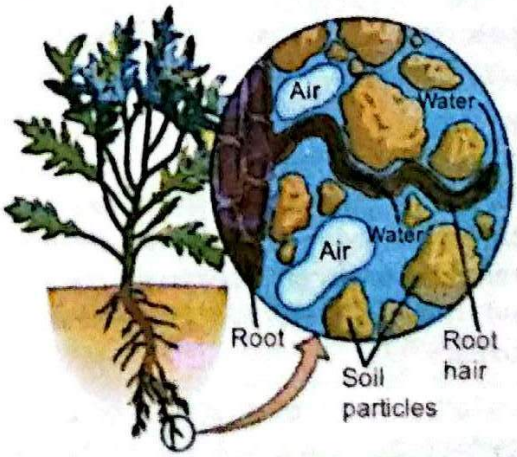


Figure: 8.6: Uptake of water by the plant

Mechanism of water absorption by root

Absorption of water by roots occur by means of a passive transport mechanism called osmosis. This is the movement of water molecules through a partially permeable membrane from an area where they are more concentrated to an area

where they are less concentrated. If water moves into a cell through osmosis, it's called **endosmosis**, and if it moves out of the cell, it's called **exosmosis**.

8.2.3 Transpiration

You have learnt that plants absorb water from the soil by the roots. This absorbed water moves in the aerial parts of the plant from where the most of this water (approx. 99%) has been lost in the form of vapours into the atmosphere. This loss is called **transpiration**. 90% of this loss occurs through the stomata present mainly in the leaves and some other aerial parts of the plant. This is called **stomatal transpiration**. Some other amount of this absorbed water (7-9%) is lost from general body surface through the **cuticle**, called as **cuticular transpiration**. A very little amount of water (less than 3%) is also lost through **lenticels** which are scar like regions (with ruptured epidermis and loosely packed underlying cortical cells) present in the stem. This is called **lenticular transpiration**.

Critical Thinking

Does a submerged aquatic plant perform transpiration.

Why transpiration is sometimes called necessary evil.

Can you think that the shape and the size of the leaves would be an adaptation of the plants in different habitats such as aquatic and terrestrial.

Transpiration is a vital process for the plant as it not only provides cooling effect to the plant but also help to absorb the water and dissolved minerals and to move them in upward direction to the leaves. Therefore, without transpiration plants are unable to survive. On the other hand, transpiration is disadvantageous as it shows great loss of absorbed water so, an unchecked excessive transpiration can lead to the wilting (loss of **turgor**) and ultimately death of the plant.

Relation of transpiration with leaf surface area and Stomatal opening and closing

As you have learnt that transpiration mainly occurs through the **stomata**, which are present on the leaf surface. So, the plants having large surface area of the leaves having more stomata show greater rate of transpiration as compared to the plants having narrow and reduced surfaces of the leaves having less stomata.

Similarly, more transpiration is generally observed in day time than night as the stomata are widely open during day and nearly close at night.

Science Titbits

One crucial nutrient, nitrogen (N), is often scarce in both rock particles and soil water. Many plants have developed beneficial partnerships with other organisms to obtain these limited nutrients. For example, mycorrhizal fungi and nitrogen-fixing bacteria in the root nodules of legumes are examples of such partnerships. Fungal associations with the roots of higher plants enhance the plant's ability to absorb minerals like phosphorus and trace metals such as zinc and copper. A root infected with mycorrhizal fungi can absorb phosphate at a faster rate than an uninfected root. In exchange for their services, mycorrhizal fungi receive sugars and protection from the plant, ultimately increasing the plant's efficiency in acquiring mineral nutrients. Mycorrhizae form associations with plants from a wide range of plant families, covering approximately 90% of flowering plants.

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8.2.4 Factors affecting the rate of transpiration.

The rate of transpiration is influenced by several environmental factors like temperature, wind, and humility etc. The rate of transpiration can be measured by using a simple apparatus called the potometer which is shown in the diagram. Students under the guidance of their teachers should plan simple experimental activities to investigate the effect of these factors on the rate of transpiration using the potometer.

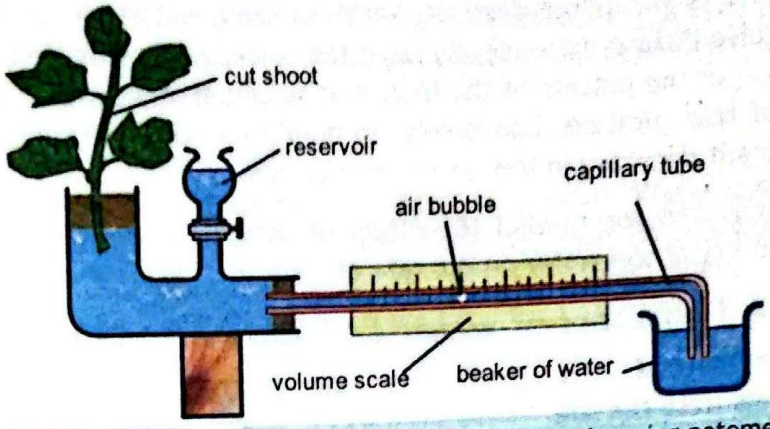


Figure: 8.7: Investigation of rate of transpiration by using potometer

Effect of temperature

On a sunny day with strong sunlight, the air temperature rises, and this increase in temperature lowers the humidity in the air. As a result, more water evaporates from the surfaces of plant mesophyll cells, which leads to a higher rate of transpiration. For every 10°C increase in temperature, the rate of transpiration roughly doubles. However, when the environmental temperature becomes very high, around 40-45°C, it causes the stomata on plant leaves to close. This closure helps the plant conserve its much-needed water because excessive loss can be harmful.

If these higher temperatures persist for an extended period and the soil doesn't have enough water, the plants may start to wilt and could eventually die.

Effect of Wind

Wind is moving air, and it speeds up the diffusion of water molecules. This leads to a higher rate of transpiration from the surfaces of mesophyll cells. In contrast, when the air is calm and still, the movement of water molecules (diffusion) slows down, resulting in a decreased rate of transpiration.

Scientific Enquiry

To instigate the effect of temperature on rate of transpiration, set the apparatus as shown in the figure 8.7, observe the movement of bubble in potometer and record the readings with appropriate intervals. Perform the experiment in different temperatures in a growth room. Remember that other conditions like sun light, wind and humidity should be constant. Take the mean reading of every experiment and plot a graph to show the relationship of rate of transpiration against temperature. Interpret your results and make conclusion.

To instigate the effect of wind on the rate of transpiration, set the apparatus as shown in the figure 8.7, observe the movement of bubble in potometer and record the readings with appropriate intervals. Perform the several experiments by putting the potometer at different distances in front of pedestal fan so that different velocities of wind can be investigated. Remember that other conditions like sun light, temperature and humidity should be constant. Take the mean reading of every experiment and plot a graph to show the relationship of rate of transpiration against different velocities of wind. Interpret your results and make conclusion.

Similarly, plan an activity to instigate the effect of humidity on the rate of transpiration.

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Effect of Humidity

Humidity is the percentage of water vapours in the air. In dry air (low humidity), water molecules diffuse more rapidly from the surfaces of **mesophyll cells**, air spaces, and through stomata to the outside of the leaf. This results in more water being lost, which increases the rate of transpiration. Conversely, in humid air, the diffusion rate slows down, leading to a significant decrease in the rate of transpiration.

Similarly, can you predict the effect of other factors like sun light, CO_2 concentration and availability of soil water on the rate of transpiration.

8.2.4 Transport of water and salts within plant body (Ascent of Sap)

Root epidermal cells absorb water and minerals from the soil. These substances are then transported from roots to the leaves. This upward movement of water and dissolved minerals through the xylem tissue is known as the "**ascent of sap.**" This process requires a passage and a significant amount of force because it occurs against the force of gravity, especially in tall plants. It is now quite evident that passage of ascent of sap is the xylem tissue and the most widely accepted theory that explains the force responsible for ascent of sap is called the "**TACT theory.**"

Passage of Ascent of Sap

Xylem is a complex and permanent tissue which act as passage for ascent of sap. Two type of xylem cells: **Tracheids** and **Vessel** are very important. Tracheids are long, dead cells with pointed ends and Xylem vessels are long, dead, and thick-walled tube-like structures formed by the fusion of vessel cells (vessel elements) placed end to end. Both are essential for water and mineral transport as well as structural support.

TACT Theory

According to the TACT theory, four factors work together to create a force that move water and minerals up a plant. These factors are **Transpiration pull**, **Adhesion**, **Cohesion**, and **Tension**, forming the acronym TACT.

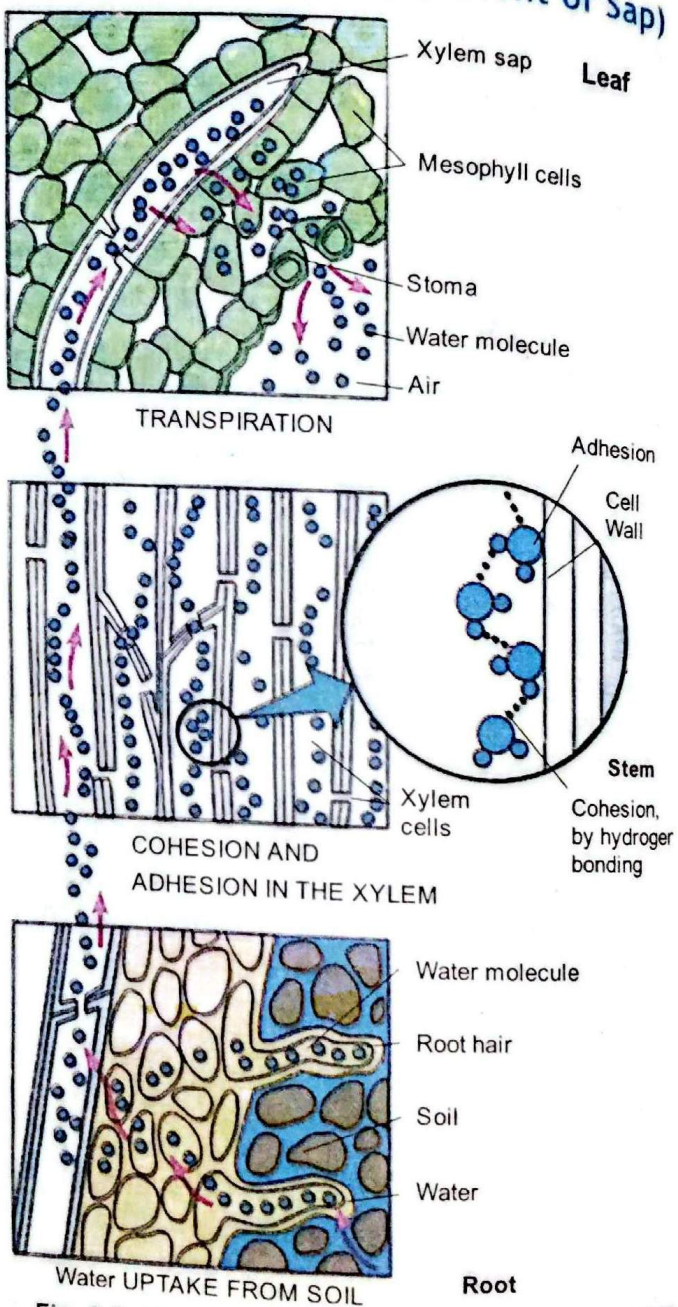


Fig. 8.8: Movement of water in xylem through TACT Mechanism

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i) Transpiration Pull

When stomata (tiny openings) on leaves are open, water evaporates from the leaves into the air, creating a pulling force known as **transpiration**. This pull makes water move from the roots to the stem and then to the leaves through the xylem tissue.

ii) Adhesion

Adhesion is the attraction between water molecules and other substances. Water is strongly attracted to the walls of the xylem cells because both water and cellulose (in cell walls) are polar molecules. This adhesion helps water move upward in the plant against gravity. It also keeps water in the xylem when transpiration is not happening.

iii) Cohesion and Tension

Cohesion is the attraction between nearby water molecules, which is possible because water is a polar molecule. Tension refers to the tension created in the water column. These forces help hold the water molecules together in a continuous column within the xylem.

How TACT Force Works

Imagine the column of water in the xylem as strong as a steel wire. Hydrogen bonds among water molecules create cohesion, holding the water molecules together like a string. As long as transpiration continues (water evaporating from leaves), the string of water remains tense and is pulled upward as a single unit. This bulk flow of water to the top of the plant is driven by solar energy, as it's the evaporation from leaves that causes the transpiration pull.

8.2.5 Transport of organic solute within plant body

The transport of prepared food (organic solutes) to different parts of the plant through the phloem tissue is **translocation.**

Passage of Translocation

It is evident that translocation occurs through phloem tissue which are complex and permanent plant tissue. Sieve tube elements and companion cells are important components of phloem.

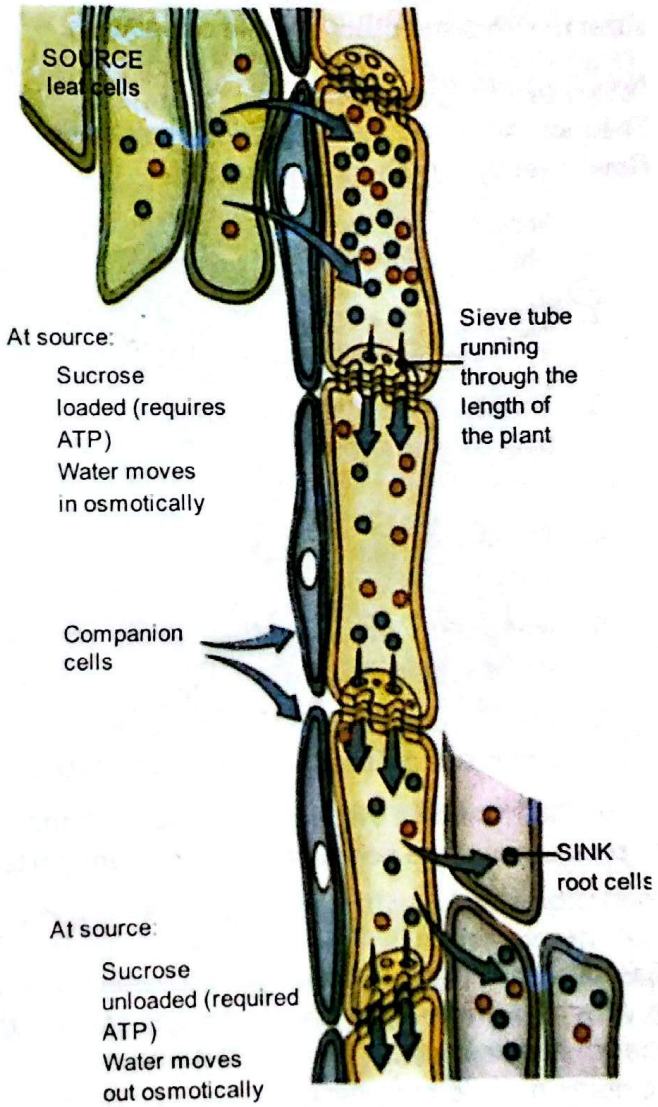


Figure: 8.9: Pressure flow Mechanism for Phloem Transport: Sugar is actively loaded into the sieve tube at the source. As a result, water moves into the sieve tubes by osmosis. At the sink, the sugar is actively unloaded, and water leaves the sieve tube by osmosis.

Sieve Tubes are long tube-like structures that transport organic solutes (like sucrose) throughout the plant. Since sieve tube elements lack nuclei, companion cells next to them control their functions. Together, sieve elements and companion cells act as conducting channels for moving organic solutes.

Direction of Translocation

This movement is not just up or down; it goes in various directions. We usually say that translocation goes from a "**source**" to a "**sink.**" A "source" supplies food (like leaves making food), and a "sink" uses food (like roots or storage organs). Leaves are sources, fruits are sinks, and stems and roots can act as both.

Composition of Translocating Fluid (Phloem Sap)

Phloem sap contains about 10-25% dry matter. Most of this dry matter is sucrose (a kind of sugar), with some other organic compounds.

Mechanism of Translocation (Pressure Flow or Mass Flow Theory)

The most accepted idea for how organic solutes moves in plants is the "**pressure flow" or "mass flow" theory**. Here's how it works:

1. Sugars produced in source regions, like leaves or storage areas, are loaded into the phloem's sieve tube elements by **companion cells**.
2. This active transport raises the sugar concentration and reduces the water concentration in the phloem. This makes the phloem cells more concentrated.
3. Water moves into the phloem through osmosis from nearby xylem cells, increasing **hydrostatic pressure** (pressure from water) in the phloem cells. This pressure pushes the sucrose solution away from the source (usually a leaf).
4. The pressure difference, from the high-pressure source to the lower-pressure sink, causes translocation. It's like water being pushed through a hose.
5. When the solution reaches a sink, like the roots, root cells actively absorb the organic solutes. This makes the phloem sap diluted
6. The loss of solutes in phloem sap increases solute potential and water potential, causing water to flow back into the xylem tubes.

So, it's like a system of moving food and water around the plant, driven by differences in pressure and the needs of different plant parts.

8.3 GASEOUS EXCHANGE IN PLANTS

Gaseous exchange is the type of respiration that occurs at organismic level. Gaseous exchange is when the entire organism exchanges gases with the environment. The goal is to make sure that the organism must be provided with oxygen which is needed for cellular respiration, where complex organic compounds are broken down, and carbon dioxide is produced which is to be removed in outer environment. Every cell in a plant does its own gas exchange, depending on what it needs. This exchange mainly happens through two openings: stomata (tiny openings in leaves) and lenticels (small openings in stems). This exchange of gases happens through a process called diffusion.

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8.3.1 Pattern of gaseous exchange in leaves (Photosynthetic parts)

The plants being photosynthetic autotrophs show different pattern of gaseous exchange in day and night through the leaves.

Table: 8.1 Pattern of gaseous exchange between plant and environment

	In daytime	In nighttime
Inhale	Carbon dioxide (CO_2)	Oxygen (O_2)
Exhale	Oxygen (O_2)	Carbon dioxide (CO_2)

During the day, plants are busy with both photosynthesis (making food) and respiration. The rate of photosynthesis varies throughout the day as it mainly depends upon light intensity. Generally, the rate of photosynthesis is greater than rate of respiration, therefore, the photosynthesis needs more carbon dioxide than what respiration produces, so plants bring in extra carbon dioxide from the environment. On the other hand, photosynthesis produces more oxygen than respiration needs, so plants release excess oxygen.

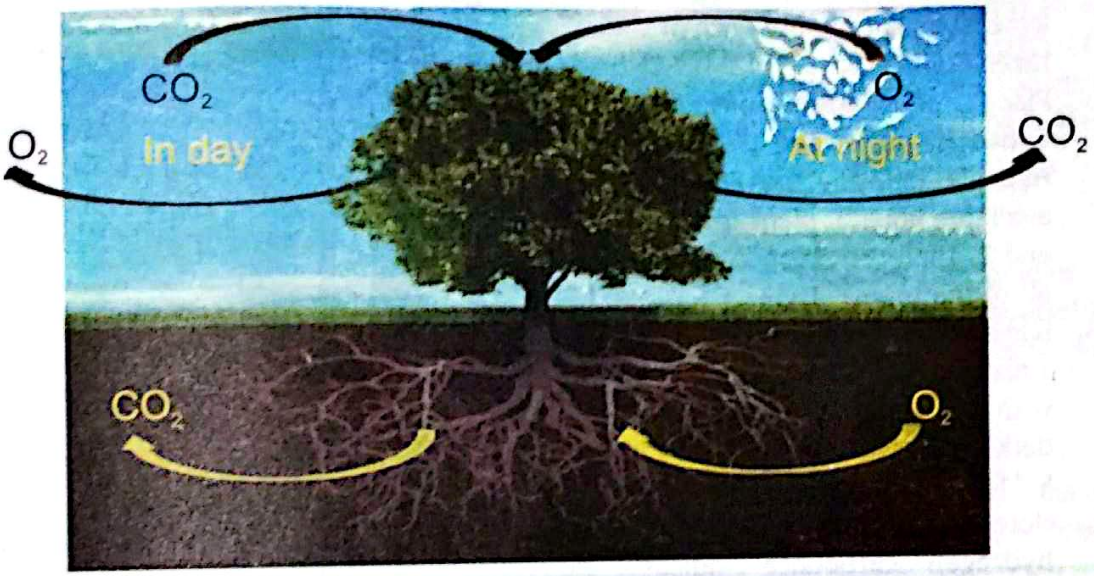


Figure: 8.10: Pattern of gas exchange in leaves and roots in day and night

At night, plants act more like animals. They absorb oxygen and release carbon dioxide because there's no photosynthesis happening in the dark.

During dawn and dusk, when light intensity is low, the rates of photosynthesis and respiration become equal. This means the carbon dioxide produced by respiration is enough for photosynthesis, and the oxygen released by photosynthesis is used in respiration. At this point, there's no net exchange of gases with the environment, and we call it the "**compensation point of photosynthesis.**"

8.3.2 Pattern of gas exchange in roots (non-photosynthetic parts)

Roots also exchange gases with air in soil through root epidermal cells which involves absorption of oxygen and release carbon dioxide because there's no photosynthesis happening in the roots and it remains same day and night.

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STEAM ACTIVITY

Unveiling Plant Respiratory Patterns in Day and Night

Objective:

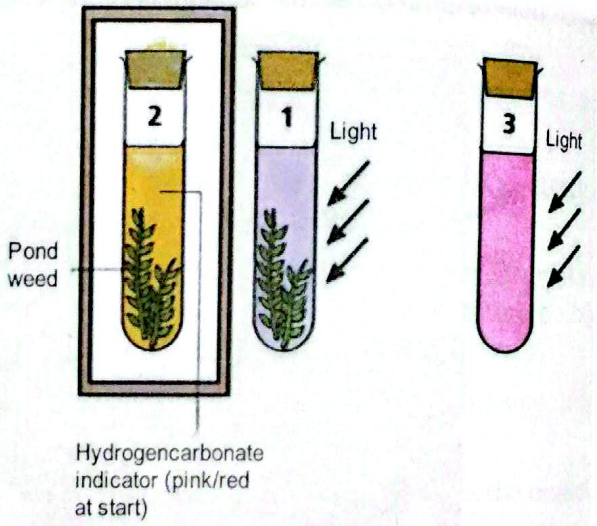
To recognize how does a plant's exposure to light and darkness impact its gas exchange?

Principle:

The increase or decrease in carbon dioxide concentration will be tested in this inquiry by using hydrogen carbonate indicator. It goes from pink or red to yellow when carbon dioxide builds up. The indicator becomes purple when carbon dioxide concentrations fall.

Procedure

1. Take three test tubes of 50ml volume and wash them properly with tap water then rinse them with distilled water and finally with hydrogen carbonate indicator (the indicator will change colour if the boiling tube is not clean).
2. Add 30ml hydrogen carbonate indicator solution into each of the three boiling tubes.
3. Place equal-sized pieces of **Canadian pondweed (Elodea)** or **Hydrilla** or any other locally available aquatic plant in tubes 1 and 2, then use stoppers to close all of the tubes.
4. Use a bench lamp to expose tubes 1 and 3 to light, then cover tube 2 with aluminum foil or put it in a dark cabinet or black box (Figure 8.11).
5. Note the colour of each tube's **hydrogen carbonate indicator** after a period of 24 hours.



Experiment to compare gas exchange in plants kept in the dark and in the light

Result

The indicator in tube 2 (plant in the dark) should turn yellow, the indicator in tube 1 (plant in the light) should turn purple, and the indicator in tube 3 (the control), which was initially pink/red, should not change colour.

Interpretation

In simple terms, hydrogen carbonate indicator helps us see changes in acidity caused by carbon dioxide. When there's more carbon dioxide, it turns orange/red, and when there's less, it becomes purple. An experiment with this indicator and plants showed that in light, plants use more carbon dioxide in photosynthesis than they produce in respiration. In the dark, plants produce carbon dioxide through respiration. A control tube without a plant showed that the plant caused the color change. However, it's noted that the indicator can

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react to changes in acidity or alkalinity, not just carbon dioxide. Despite this, understanding how leaves work suggests changes in carbon dioxide are more likely.

Reflection

Suggest students to emphasize the significance of gas exchange in plants for animal life on Earth. Encourage them to complete the potential consequences if plants were to become extinct.

8.4 HOMEOSTASIS IN PLANTS

Homeostasis in plants refers to the adjustment or adaptation of plants to varying degrees of environmental temperatures and availability of water and salts in the soil.

8.4.1 Importance of Homeostasis

Homeostasis in plants is essential for their survival, growth, and reproduction. Homeostatic mechanisms help plants respond to temperature changes, allowing them to survive in various climate. Homeostasis ensures that plants maintain adequate hydration levels. Homeostasis allows plants to respond to various stress conditions, such as drought, salinity, pathogens, and herbivores. Plants can activate specific defense mechanisms to mitigate damage. It enables them to adapt to changing environmental conditions and maintain internal stability, ultimately contributing to their ecological success.

8.4.2 Excretion in plants

Unlike animals, excretion in plants is a very broad term, which encompasses the removal of anything from plant body. Plants have a different way of getting rid of waste compared to animals. Plants make various organic and inorganic compounds that they store for different reasons and remove when needed. Following are different ways of excretion in plants.

Excretion of carbon dioxide and oxygen

Carbon dioxide is the waste of respiration which is excreted from plant body at night during gaseous exchange process. Similarly, oxygen is the waste product of photosynthesis which is excreted in daytime.

Excretion of water

Water is produced as waste product of both photosynthesis and respiration, and it is also absorbed from soil. The excretion of water occurs through the plant body through the process of transpiration.

Excretion through leaves

Plant cells have large vacuoles that can store useful and unwanted substances. Sometimes, these stored substances can build up and form crystals in the vacuoles. Leaves are key players in this process. When the leaves are loaded with large number of pigmented compounds, they turn yellow. Remember, this yellowing is not due to lack of chlorophyll as happens in chlorosis. Such leaves are generally fallen from plants in autumn season. In this way leaves

Critical Thinking

Can you differentiate between chlorotic leaves and excretophores?

act as organ of excretion, therefore, such leaves are also called **excretophores**. This is why gardeners use decomposed autumn leaves as a mineral-rich source for plants.

Excretion through stem and branches

Some trees deposit unusual chemicals in their branches and trunks, especially in old xylem that's no longer used for water transport. **Ebony trees**, for instance, produce very dark wood in their centres. Scientists consider these deposits as waste materials. Although, these wastes are not removed but are dumped in one part of the body as we put the trash in dust bin however, it is still present in the home.

Excretion through roots

Some plants actively release waste compounds into the soil, almost like using them as chemical weapons against other plants competing for resources. Conifer trees are known for this phenomenon.

8.4.3 Osmotic adjustment (Osmoregulation) in plants

Osmotic adjustment, also known as osmoregulation, is like a plant's way of maintaining the right balance of water and solutes in its body. This balance creates three different situations: hypotonic, hypertonic, and isotonic.

Hypotonic Situation

When a cell is in a dilute condition with more water and less solute, water moves into the cell, making it swell up and turgid.

Hypertonic Situation

If a cell is in an environment with less water and more dissolved solute has inside (cell sap), water moves out of the cell, causing it to shrink and become flaccid.

Both of these situations, hypotonic and hypertonic, require the plant to make adjustments to keep solute and water concentration in balance.

Isotonic Situation

The best scenario for a cell is when the water and solute balance inside and outside the cell is just right. In this "isotonic" situation, there's no net movement of water in or out of the cell. However, this balance is rarely found in a plant's natural environment.

Osmotic adjustment in different plants groups

Plants are categorized into three groups based on their water availability: **hydrophytes** (live in water-rich environments), **mesophytes** (thrive where water is moderately available), and **xerophytes** (adapted to extreme dry conditions). These groups have distinct adaptations:

Table: 8.3 Comparison of osmotic adjustment in different groups of plant

Features	Hydrophytes	Mesophytes	Xerophytes
Habitat	Aquatic	Terrestrial (moderate)	Terrestrial (severely dry)
Osmotic conditions of medium	Hypotonic	Nearly isotonic	Strong hypertonic
Problems faced by plant	Flooding	No drastic problem	Severe dehydration
Rate of transpiration	Very high rate	Medium rate	Very low rate

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SUMMARY

1. The chapter on plant physiology explores various aspects of plant functions, including nutrition, transport, gas exchange, and homeostasis.
2. Plants, as autotrophs, derive nutrients from the environment to synthesize organic compounds essential for growth and metabolism. Sixteen elements, including macronutrients and micronutrients, are crucial for plant health. Nitrogen and magnesium play pivotal roles in protein synthesis and chlorophyll formation, respectively.
3. Transport mechanisms facilitate the movement of water, minerals, and organic solutes within plant tissues. The roots absorb water and minerals from the soil, while translocation through the xylem and phloem ensures distribution to various plant parts. Transpiration, driven by factors like temperature and humidity, aids in water uptake and nutrient transport.
4. Plants engage in gas exchange through stomata and lenticels, regulating oxygen and carbon dioxide levels essential for photosynthesis and respiration. Diurnal variations in gas exchange patterns reflect the dynamic interplay between photosynthetic activity and environmental conditions.
5. Homeostatic mechanisms enable plants to maintain internal equilibrium amidst fluctuating environmental factors like temperature and water availability. Excretion processes, including gas release and waste deposition, contribute to plant health and ecological balance.
6. Plants regulate water and solute balance through osmotic adjustment, adapting to hypotonic, hypertonic, and isotonic conditions. Different plant groups exhibit distinct adaptations based on their water availability, showcasing the remarkable diversity of plant responses.
7. In essence, plant physiology elucidates the remarkable strategies plants employ to thrive in diverse habitats, highlighting their critical role in ecosystem dynamics and human well-being.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Chlorosis occurs due to the deficiency of

   (A) sulphur (B) magnesium

   (C) phosphorus (D) calcium

2. Most of the uptake of water and minerals from soil takes place through

   (A) epidermal cells (B) root cap

   (C) root (D) root hair

3. The sugar moves through phloem mostly in the form of

   (A) glucose (B) sucrose

   (C) maltose (D) lactose

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4. Which category of plants stores a small amount of water and has a thin cuticle?

(A) Hydrophytes (B) Xerophytes

(C) Mesophytes (D) Succulents

5. What is a key role of leaves in managing waste in plants?

(A) Storing waste materials (B) Producing chlorophyll

(C) Absorbing water from the soil (D) Converting waste into energy

6. When the rate of photosynthesis become equal to that rate of respiration in the plant body, which of the following pattern of gaseous exchange occurs between plant and its environment:

A) Carbon dioxide is absorbed, and oxygen is released

B) Oxygen is absorbed, and carbon dioxide is released

C) Both carbon dioxide and oxygen are absorbed

D) Neither carbon dioxide nor oxygen are absorbed

7. What is the role of companion cells in the translocation process?

A) They store excess solutes in the phloem

B) They help regulate water potential in the xylem

C) They actively transport sugars into the phloem's sieve tube elements

D) They assist in the absorption of water by roots

8. What drives the translocation of organic solutes in plants?

A) Differences in sugar concentration (B) Differences in leaf size

B) Differences in root structure (D) Differences in stem length

9. According to the TACT theory, what are the four factors that work together to move water and minerals up a plant?

A) Temperature, humidity, sunlight, and soil type

B) Transpiration pull, Adhesion, Cohesion, and Tension

C) Stomata, xylem, phloem, and roots

D) Leaves, stems, roots, and flowers

10. What drives the bulk flow of water to the top of the plant according to the TACT theory?

A) Root pressure B) Soil moisture

C) Solar energy from photosynthesis D) Transpiration from the leaves

Section II: Short Answer Questions

1. Why is transpiration called necessary evil?
2. What is the composition of translocating food?

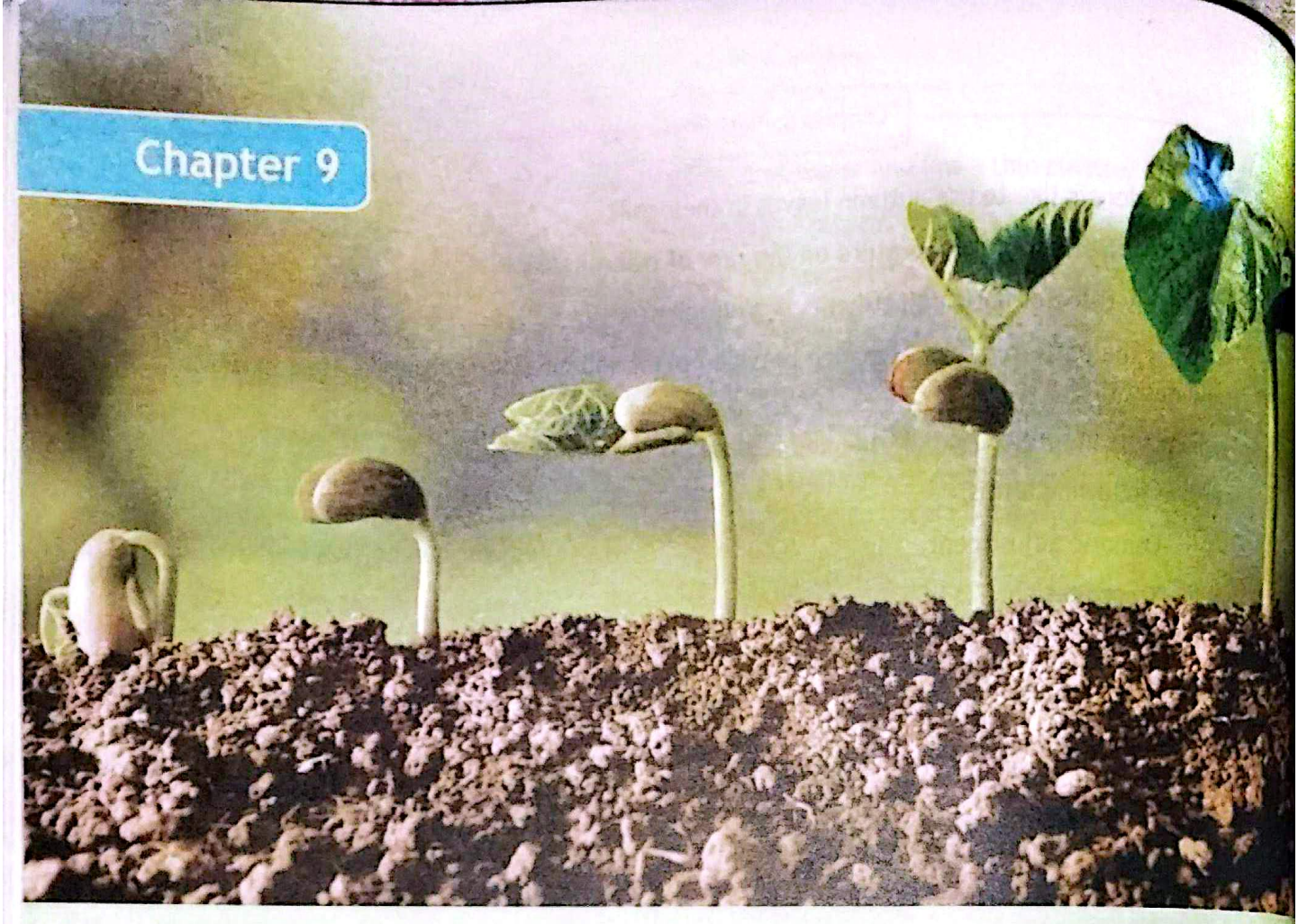
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3. Why gardeners like to use autumn leaves in their soil?
4. What is the effect of temperature on the rate of transpiration?
5. Write any three osmotic adjustments in hydrophytes.
6. What is the pattern of gas exchange between plant and environment at the time of dawn and dusk?
7. Why plants absorb carbon dioxide and release oxygen during daytime.
8. Define following terms:
   i. Osmotic adjustment,
   ii. Transpiration,
   iii. Translocation,
   iv. Micronutrients,
   v. Excretophores,
   vi. Vascular bundle,
   vii. Xylem
   viii. Adhesion,
   ix. Cohesion,
9. Write the difference between:
   (a) Micronutrients and macronutrients
   (b) Hydrophytes and xerophytes
   (c) Monocot root and dicot root
   (d) Transpiration and translocation
   (e) Translocation and ascent of sap
   (f) Xylem and phloem
   (g) Pattern of gaseous exchange in leaves and roots

Section III: Extensive Answer Questions

1. State that nitrogen is important in protein synthesis and magnesium for chlorophyll formation.
2. Explain the internal structure of root and root hair.
3. Describe how roots take up water and mineral salts by active and passive transport.
4. Describe transpiration and relate this process with the cell surface and stomatal opening and closing.
5. Describe temperature, wind and humidity as factors affecting the rate of transpiration.
6. Explain the mechanism of food translocation by the theory of pressure flow mechanism.
7. Describe the process of gaseous exchange in plants.
8. Describe the mechanism of adaptations of plants for the excretion.
9. Explain osmotic adjustment in plants.

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Chapter 9

PLANT REPRODUCTION

SLOs: After completing this lesson, the student will be able to:

1. Describe different types of asexual production i.e., Binary fission, Budding, spore formation and vegetative propagation.
2. Explain vegetative propagation in plants through stem suckers in Leaves.
3. Describe the two methods of artificial vegetative propagation (stem cuttings and grafting).
4. Distinguish between vegetative propagation and artificial propagation.
5. Rationalize how parthenogenesis is a type of asexual reproduction.
6. Define cloning.
7. Explain sexual reproduction in plants.

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Plants, like all living organisms, have a remarkable ability to produce and create new young ones. This is called **reproduction**. In biology, understanding how plants reproduce is like discovering the secret to their life story. Just like animals, plants have their own unique ways of creating new generations. In this chapter, we will explore the diversity in plant reproduction, ranging from simple **asexual reproduction**, where a single parent generates genetically identical offspring through methods excluding gamete formation or **meiosis**, to the complex sexual reproduction, which is accomplished by involvement of two parents, gamete formation, and the production of genetically diverse **offspring**.

9.1 ASEXUAL REPRODUCTION

Asexual reproduction is a straightforward method of creating new plant life. In this process, only one parent plant is involved, and it gives rise to offspring that are essentially **clones**, sharing the exact genetic makeup of the parent. What makes asexual reproduction distinct is that it doesn't rely on the formation of specialized reproductive cells called **gametes** or the complex process of meiosis, which shuffles genetic material to produce **variation**. Instead, asexual reproduction relies on simpler methods, such as cell division or the growth of specialized structures. This simplicity and **genetic uniformity** make asexual reproduction a reliable and efficient way for some plants to propagate and expand their population. Asexual reproduction includes binary fission, budding, spore formation and vegetative propagation

9.1.1 Binary Fission

Binary fission is a simple way of making more of something. It's like splitting something into two equal parts. This method is commonly used for making more of certain tiny living things, like **bacteria**, some one-celled creatures called **protozoa**, and some small animals without backbones but no true plant is known to use this process.

In bacteria, First, the copy of their DNA is formed so that there are two identical sets. Then, these sets move to opposite ends of the bacteria. Next, the middle part of the bacteria starts to fold in, dividing the stuff inside into two parts. A new wall forms between these two parts. This whole process ends with two new bacteria, which will keep growing and eventually split into more.

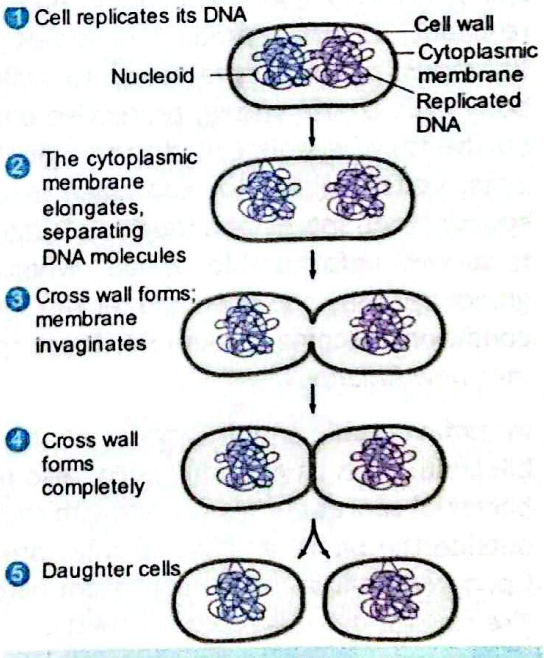


Figure: 9.1: Steps of Binary fission in Bacteria

9.1.2 Budding

In this kind of asexual reproduction, a tiny outgrowth called **bud** emerges on the parent's body. Imagine it like a small bulge. In yeast, which is a single-celled fungus, this outgrowth forms on one side of the cell. Inside the cell, the nucleus splits into two by mitosis, and one of these new nuclei goes into the outgrowth.

Sometimes, the parent cell can have more than one of these outgrowths growing at the same time. Each outgrowth gets bigger and becomes more like the parent. Eventually, the outgrowth

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can break away from the parent. In other cases, the outgrowths stay attached, and this leads to groups of individuals living close together, almost like a little community.

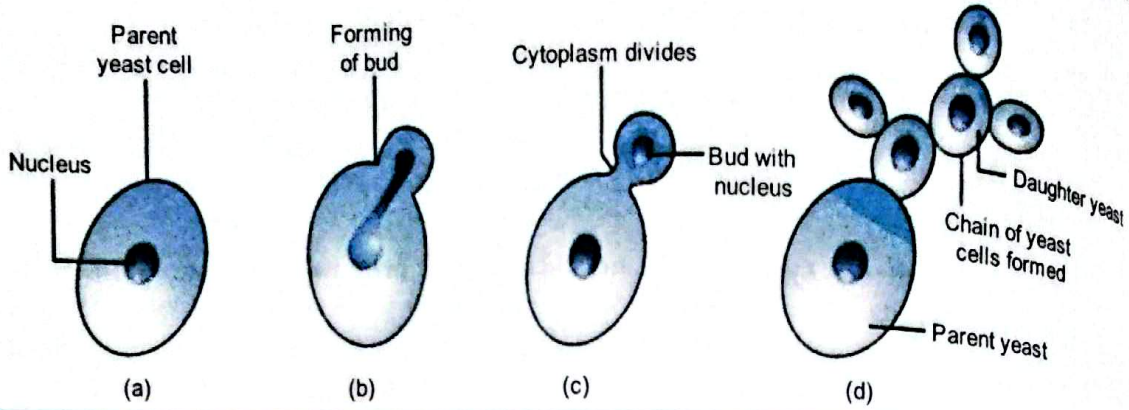


Figure: 9.2: Process of budding in yeast

In higher plants, the outgrowths are often developed which are of two types i.e., **vegetative buds** and **floral buds**. The vegetative buds give rise to new branches and leaves, and floral buds give rise to new flowers.

9.1.2 Spore Formation

Spores are very small, unicellular, non-motile, thick walled resistant, asexual reproductive bodies. In many fungi, like **Rhizopus**, when they're ready to make new ones, their body cells create strong, protective bags called **sporangia** on the tip of a stalk called **sporangiophores**. Inside these bags, cells divide a lot and make many tiny cells called **spores**. Each spore has a tough shell called a cyst that helps it survive unfavourable period. When the sporangia are grown up, they pop open and let the spores out. When the conditions become favourable, these spores start growing into new *Rhizopus*.

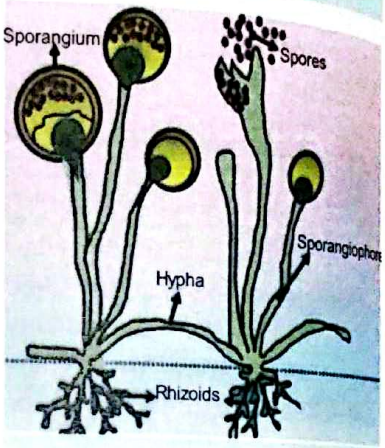


Figure: 9.3: Spore formation in *Rhizopus*

In unfavourable conditions, some types of filamentous bacteria, such as **actinomycete**, also make spores. These bacterial spores are also tough with thick walls. They form outside the bacterial cells, so they are called **exospores**. Upon germination each spore from parental filament give rise several new bacterial filaments.

This is important to note that the microspore and megaspore in seed producing plants are not the part of asexual reproduction. Similarly, the spores of **bryophytes** and **pteridophytes** that give rise **gametophyte** body are also not supposed to be the part of asexual reproduction because during such spore formation meiosis generally involves.

Critical Thinking

Under unfavourable conditions, some species of bacteria reproduce by forming spores, e.g., *Clostridium* and *Bacillus* species. These bacterial spores are also thick-walled. They are formed inside bacterial cells, so are called endospores. In this way these bacteria are capable to pass unfavourable period. When conditions are good, each endospore germinates and resumes normal life again. What do you think that endospore formation is a reproductive process?

9.1.3 Parthenogenesis

Parthenogenesis is the development of an offspring directly from unfertilized eggs. In flowering plants is defined as the asexual formation of a seed from the maternal tissues of the **ovule**, avoiding the processes of meiosis and **fertilization**, leading to embryo development. This can happen due to various triggers, such as changes in environmental conditions or hormonal signals. Parthenogenesis in plants is also known as **apomixis** (a process by which plants develop seeds or embryos without sexual fertilization).

Since parthenogenesis involves the creation of offspring without the fusion of genetic material from two parents, it is considered a form of asexual reproduction.

9.1.4 Vegetative Propagation

Flowering plants generally reproduce sexually by means of their flowers, but some also make babies without flowers, which we call **"vegetative propagation."** There are two kinds: one that plants do on their own, which we call **"natural vegetative propagation,"** and another that people help with when needed, called **"artificial vegetative propagation."**

Methods of Natural Vegetative Propagation

Natural vegetative propagation in plants refers to the process by which plants reproduce asexually using their own natural mechanisms, without any human intervention. In this method, new plants are generated from various **vegetative structures** of the parent plant, such as roots, stems, leaves, or specialized structures like runners or bulbs. These structures develop into independent plants, and since they originate from the same parent, they often have identical genetic characteristics. Following are the types of natural vegetative propagation.

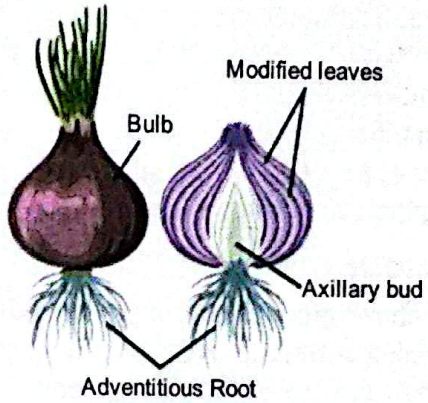


Figure: 9.4: Bulb (Onion)

i) Bulbs

Bulbs are compact, thickened, vertically growing, underground stems enveloped by thick, succulent (fleshy) leaves, serving as reservoirs of stored nutrients. Beneath the bulb's base, adventitious roots sprout, while shoots emerge from its upper region. Each shoot is capable to be developed into a new plant. Species like tulips, onions, and lilies utilize bulb to produce their young ones.

ii) Corm

Corms are compact, thickened, vertically growing, underground stems that store food but not enveloped by fleshy leaves. At the top of a corm, you will find buds. These buds give rise to shoots, which then develop into

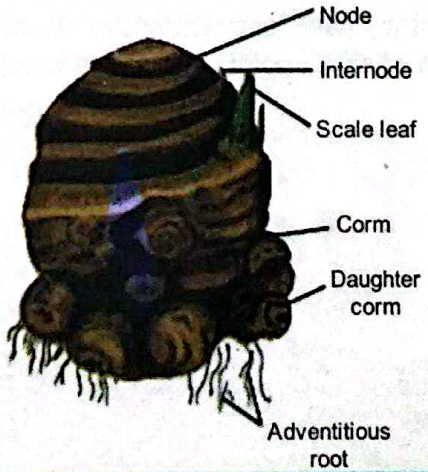


Figure: 9.5: Corm (Colocasia)

new plants. Examples of plants that reproduce using corms include dasheen (*Colocasia esculenta*) and garlic (*Allium sativum*).

iii) Rhizome

Rhizomes are flat, horizontal underground stems that have small scale-like leaves. Along the rhizome, there are distinct **nodes** and **internodes**. At these nodes, buds are formed. The buds on the upper side of the rhizome grow into shoots, while the lower side produces adventitious roots. These shoots are capable to develop into new plants. Plants like ginger, ferns, and water lilies use rhizomes for reproduction.

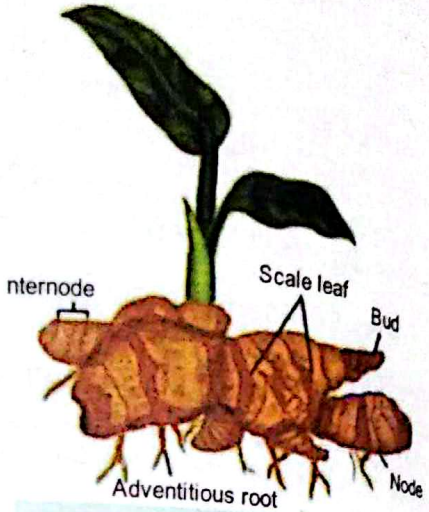


Figure: 9.6: Rhizome (Ginger)

iv) Stem tubers

Stem tubers are swollen tips of underground stem that primarily serve as storage structures found in certain plants. Stem tubers often have "eyes" or bud clusters on their surface, from which new shoots can grow when conditions are suitable. Examples of plants that produce stem tubers include potatoes and yams. These structures serve as a source of food and a means of propagation for the plants that produce them.

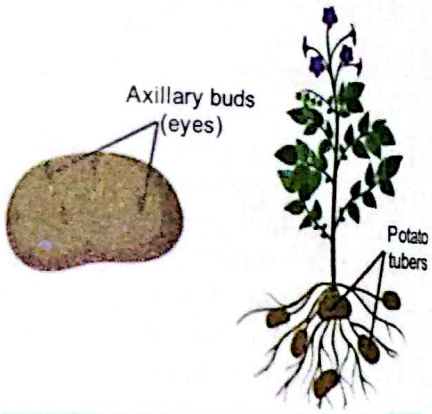


Figure: 9.7: Stem tuber (Potato)

v) Stolon or Runners

The above-ground parts of plants like strawberries and creeping buttercups are typically very short, with most of their structure below the ground. These short stems are known as **rootstocks**, and they carry leaves and flowers. After the main shoot has bloomed, side buds create long shoots that grow horizontally along the ground, often called **stolons or runners**. These runners have small scale-like leaves at specific points, and they have long sections between these points. At each of these points where the leaves are, there is a

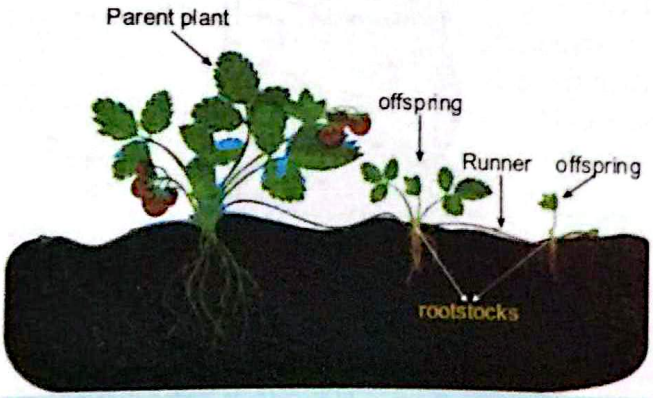


Figure: 9.8: Stolon or Runner

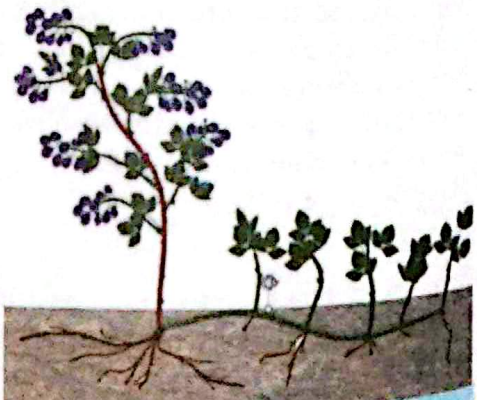


Figure: 9.9: Suckers

bud that has the potential to grow into both a shoot and roots. So, a whole new plant can develop at these points, getting nourishment from the parent plant through the runner for a while. Eventually, the runner dries up and withers away, leaving a new independent plant growing a short distance from the parent. This is how a strawberry plant, for example, can make many new plants without using seeds.

vi) Suckers

Suckers typically emerge as small shoots from the underground parts of a plant, such as the root system or near the base of the main stem. These shoots can develop into new plants. As the suckers grow, they form their own stems, leaves, and roots. They essentially become self-sustaining plants but remain connected to the parent plant for a period. Suckers may receive nutrients and water from the parent plant, helping them establish themselves. This is especially beneficial in adverse conditions where it might be challenging for new plants to survive on their own. Over time, the suckers develop their own root system and become less dependent on the parent plant for sustenance. Eventually, they can thrive independently. Suckers are a common method of natural vegetative propagation in various ground cover plants such as lawn grass.



Figure: 9.10: Vegetative propagation by leaves in Bryophyllum

vii)Vegetative propagation by leaves

In **Bryophyllum**, a type of plant, new plantlets are created along the edges of its leaves. These plantlets are like tiny versions of the parent plant. When they detach from the parent plant and fall onto the soil below, they have the ability to grow and develop into separate, self-sustaining plants.

Methods of Artificial Vegetative Propagation

Artificial vegetative propagation is adapted when people purposely grow plants to meet specific needs. The part of the plant used for this is called a "**vegetative propagule.**" These methods help keep the good qualities of plants, like taste, color, and resistance to diseases. Two common methods of artificial vegetative propagation are stem cuttings and graftings.

(i) Stem Cuttings

Stem cuttings are small segments or cut pieces of stem having at least one node. You can make new plants from some plants by placing a cut piece of a stem in water or damp soil. Roots start growing from the bottom of the stem into the soil, while the top part keeps growing and making leaves. If sometimes, the cutting does not start growth, then the cut ends must be treated with a special plant

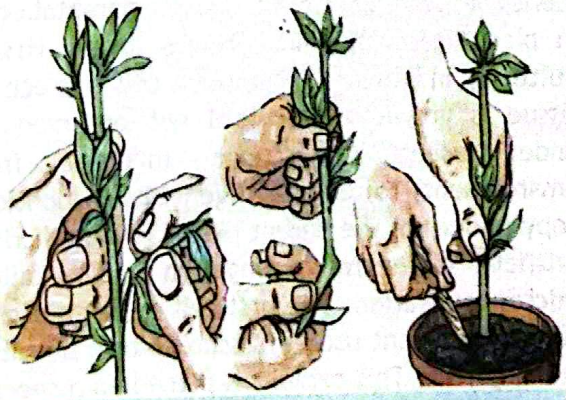


Figure: 9.11: Propagation by Stem cuttings

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hormone called auxin to stimulate the growth. Sometimes, it is required to cover the top part of the cutting with plastic or a glass jar to reduce water loss. This method is often used to propagate roses, ivy, grapevines, and chrysanthemums.

Critical Thinking

Sweet potato is an enlarged root. Farmers place it in moist sand or soil until it produces several plantlets. Then the plantlets are removed and planted. This process is used to produce many plants from a single plant. Is it artificial or natural vegetative propagation and it belongs to which type?

(ii) Grafting

This method involves joining two plant parts together to create a single, new plant. This method is commonly used to reproduce desirable plant varieties, like fruit trees or ornamental plants, and it's a skilled practice often performed by gardeners and farmers.

Two plant parts are involved in grafting: the **scion** and the **rootstock**. The scion is the upper part of the plant, which includes the desired characteristics such as specific fruit or flower traits. The rootstock is the lower part, which provides the root system and stem support. A skilled gardener makes precise cuts on both the scion and rootstock. The cuts are usually made at specific angles to maximize contact between the two parts. The scion is carefully attached or inserted into the rootstock. This connection is crucial for the transport of water, nutrients, and other substances between the two parts. To ensure a secure connection, the graft is typically bound with grafting tape, rubber bands, or other materials. This helps hold the scion in place until the graft heals. Once the graft has healed, the plant begins to grow, producing leaves, flowers, and fruit based on the characteristics of the scion.

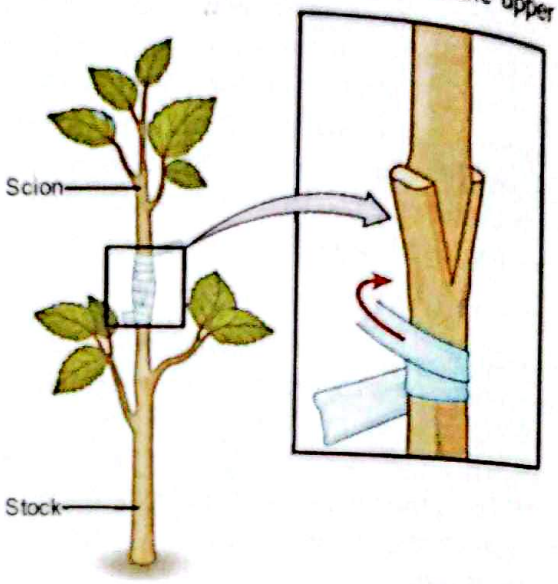


Figure: 9.12: Propagation by grafting

(iii) Cloning (Tissue culturing)

Cloning is a method of producing genetically identical individual from the single parental cell. In plants term "cloning" refers to the tissue **culturing** in which a single plant cell or piece of tissue is grown on artificial nutrient medium under aseptic conditions (microbe free environment) to develop a genetically identical copy (**clone**) of the parent plant. This method of artificial vegetative propagation is also called **micropropagation**. The first cell or tiny piece of the parent plant used in tissue culture is called an "**explant.**" This explant is placed on a special nutrient medium to grow and become an

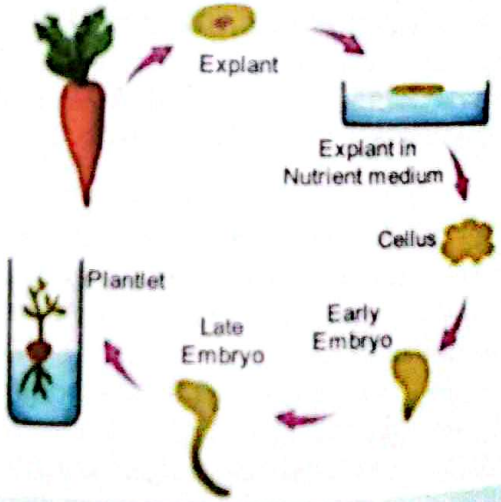


Figure: 9.13: Steps in plants tissue culturing

undifferentiated mass of cells known as "**callus.**" The callus is then treated with different substances to make it produce shoots and lateral roots. This whole process results in the creation of a young plant called a "**plantlet.**" These plantlets are carefully moved into the soil in their natural surroundings to continue growing.

9.2 SEXUAL REPRODUCTION

Sexual reproduction in plants like animal also involves the fertilization of **gametes** (egg and sperm) and formation of **zygote** and **embryo.** Different groups of plants, like bryophytes, pteridophytes, and seed plants (spermatophytes) have different mechanisms of gamete formation and fertilization. In bryophytes and pteridophytes, the sperms are like little swimmers; they can move around and find the egg cells. So, they need water to do this. It could be dew or rain, but water is the key to their reproductive success. On the other hand, seed producing plants (**gymnosperms** and **angiosperms**) have their own methods. They don't rely on water to get their sperms to the egg cells. They have special techniques for this what you are going to learn further in this chapter.

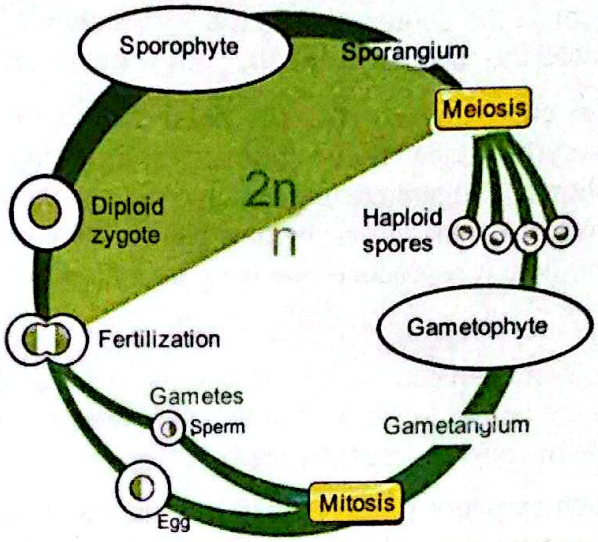


Figure: 9.14: Lifecycle of plants

One of the prominent features of plants is the **diplo-haplontic lifecycle** i.e., haploid **gametophyte** (gamete producing plant body) generation and diploid **sporophyte** (spore producing plant body) generation that regularly alternate with each other during the lifecycle. In some plants like bryophytes, the gametophyte generation is more prominent (dominant) while the sporophyte is very much reduced. In rest of the plant kingdom sporophyte is dominant generation whereas gametophyte is very small creature.

9.2.1 Sexual Reproduction in Flowering plants (Angiosperms)

In flowering plants (angiosperms), the major plant body is the sporophyte, which may be a herb, shrub or a tree. **Flowers** are the reproductive parts of these plants.

Structure of a flower

A flower is like a plant's special tool for making new plants. It's a part of the plant that's been changed and adapted for the job of reproduction. A flower generally consists of a stalk called **pedicel.** This is like the flower's stem, holding it up. At the top of the pedicel,

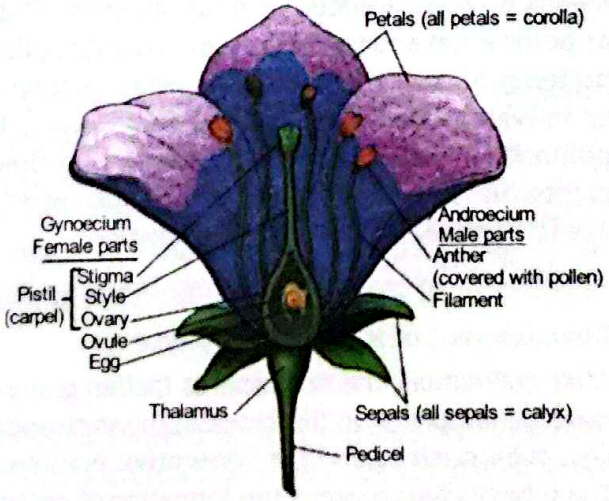


Figure: 9.15: Structure of a typical flower

there's a swollen part called the **thalamus**. It's like the flower's platform. The thalamus generally possesses four kind of parts called **floral leaves** which are arranged in whorls (circles) on the upper surface of **thalamus**. The outermost circle is called the "**calyx.**" It's made up of green leaves called "**sepals,**" and it's like a protective cover for the inside parts of the flower. Just inside the calyx, there's another circle called the "**corolla.**" which consists of variously colored floral leaves called **petals**. Deeper inside, you'll find the "**androecium,**" which is all about the male parts of the flower, called "**stamens.**" These are important for making pollen. Right in the center, there's the "**gynoecium.**" This is where the female parts are, in something called the "**carpel**" or "**pistil.**" This is where the magic happens, where new seeds start to form.

The calyx and corolla, the outer two circles, are like the flower's protectors. They keep everything safe inside but do not take part in reproduction directly therefore, called **accessory whorls**. The androecium and gynoecium, the inner two circles, are the real stars of the show when it comes to making new plants. They are the ones that make the flower's magic happen and help it reproduce why they are called **necessary whorls**.

Formation of microspores and megaspores

Each stamen consists of a long stalk, the **filament** and a bilobed swollen tip called the **anther**. In the anther lobes, four **pollen sacs (microsporangia)** are present that produce haploid **pollen grains (microspores)** by meiosis.

Each carpel or pistil consists of a sac like structure in the bottom called **ovary**, a long tubular structure above the ovary called **style** and a swollen tip present on the style called **stigma**. The ovary contains one to numerous **ovules (megasporangia)**. Each ovule possesses one spore mother cell that undergoes meiosis to produce four **megaspores**. Out of four, only one is capable to survive further and becomes **functional megaspore**.

Pollination

When microspores are formed, the wall of pollen sacs bursts and the microspores are liberated. The microspores are transferred from anther of stamen to the stigma of carpel by means of wind, insects, or other animals. This event is known as **pollination** and the microspores during pollination are called **pollen grains**. If the pollination occurs within the same flower or between two flowers of the same plant, it is called **self-pollination** and if it occurs between two flowers of separate plants, it is called **cross pollination** which ensures more genetic variability in coming generations.

Critical Thinking

Sometimes pesticides are used to control the attack of insect pests on the crops, however, pesticides are quite effective to prevent the loss by insect pests. Even though, the farmers get lower yield than normal. Why it is so?

Formation of male and female gametophytes

Development of Male gametophyte

After pollination, the microspores (pollen grains) germinate on the surface of stigma to produce a male gametophyte. In this process, the microspore nucleus first divide by mitosis to form two nuclei i.e., **tube nucleus** and the **generative nucleus** which divides further to form two **sperm nuclei**. The tube nucleus controls the formation of **pollan tube** which microspore, passes down through the style and ultimately penetrate the ovule. This whole structure that comprises microspore body, pollan tube, tube nucleus and the two sperm nuclei, is referred to as **male gametophyte**.

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Table 9.1: Adaptations in insect-pollinated and wind-pollinated flowers

Feature	Insect Pollinated Flowers	Wind Pollinated Flowers
Size	Generally large	Generally small
Color	Petals brightly colored	Petals green or dull in color
Nectar	Produce nectar	Do not produce nectar
Floral arrangement	Flowers face upwards	Flowers hang down for easy shaking
Stamens and stigmas	Enclosed inside ring of petals	Hang out of ring of petals
Pollen grains	Small number produced/ heavy and sticky	Large number produced/light with smooth surface
Stigma	Pinhead shaped with no branches	Feathery branches for catching pollen

Development of Female gametophyte

Meanwhile, the nucleus of functional megaspore in the center of ovule divides three times by mitosis to make 8 nuclei. At this stage, three nuclei out of eight migrate at one end of the ovule, the central one of them becomes **egg** while two side one are called **synergids**. Three other nuclei migrate at another end of the ovule, and act as **antipodals**. The remaining two daughter nuclei rest in the center of the ovule and are called **polar nuclei** which in some cases fuse together to become diploid **secondary nucleus** before the entry of sperm. This whole structure which comprises body of megaspore, three antipodals, two synergids, two polar nuclei or secondary nucleus and an egg, is referred to as **female gametophyte or embryo sac.**

Fertilization and the formation of zygote and endosperm nucleus

When the pollan tube penetrate the ovule, one sperm nucleus is fused with egg to form diploid **zygote** and other sperm nucleus is fused with polar nuclei or secondary nucleus to make triploid **endosperm nucleus**. Since one male gametophyte contributes two sperm nuclei for fertilization, therefore, this event is called **double fertilization**. It is assumed that the rest of nuclei in embryo sac such as synergids and antipodals control the process of fertilization.

Critical Thinking

Why fertilization in angiosperms is called double fertilization?

9.2.2 Seed and fruit formation

After fertilization, the ovule is transformed into seed therefore, it is defined as **"ripened ovule"** whereas, the surrounding wall of the ovary is transformed into fruit, hence it is defined as **"ripened ovary"**.

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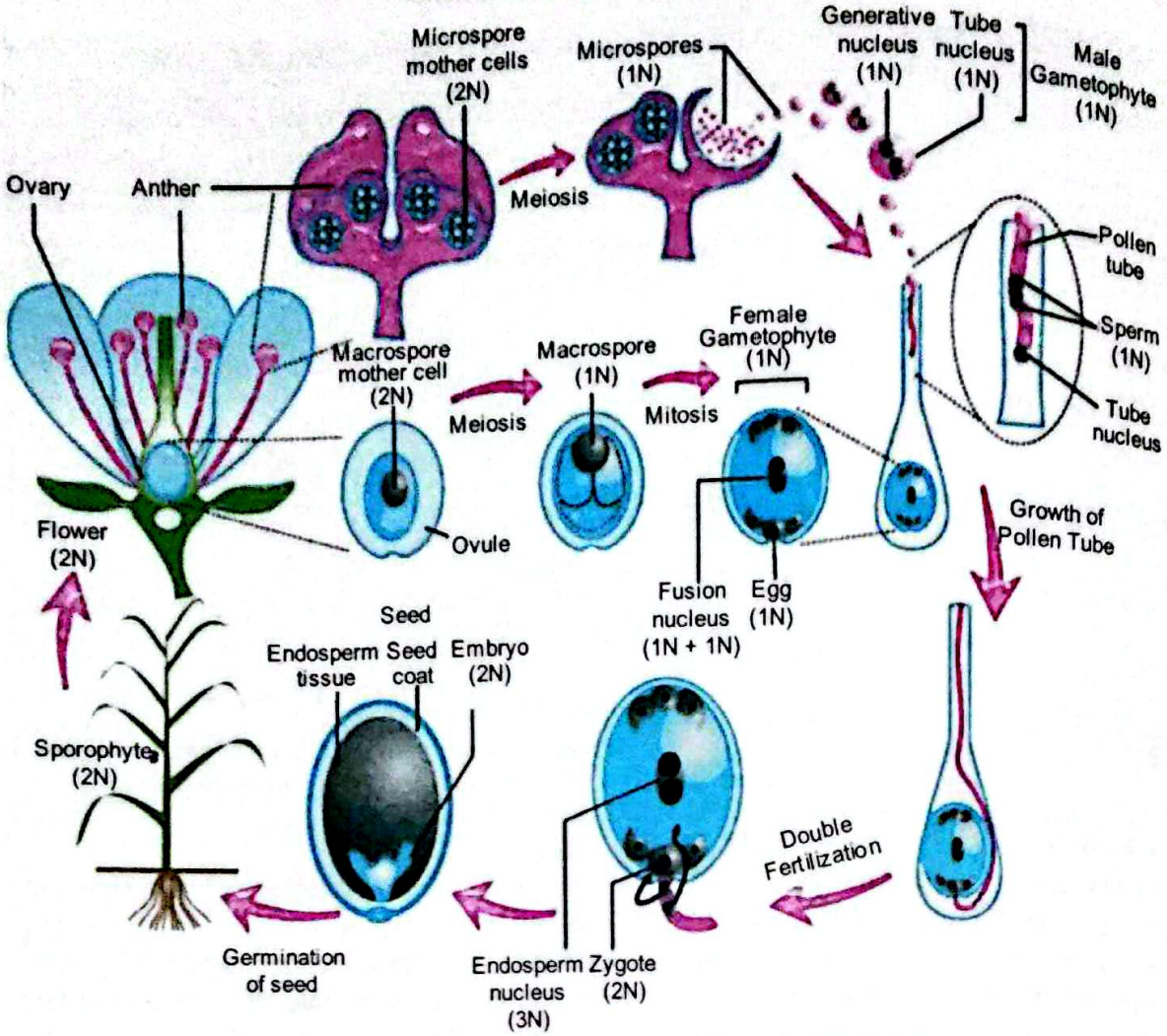


Figure: 9.16: Different steps of sexual reproduction in plants

Structure of seed

Critical Thinking

Why are angiosperms called closed seeded plants?

Angiosperm seeds are made up of three important parts:

1. **Embryo:** This part comes from the union of male and female cells (zygote). It's like a baby plant that's not fully grown yet.
2. **Endosperm:** The second part is called the endosperm. It's like a storage space for food and comes from a special cell inside the seed.
3. **Seed Coat:** The last part is like the seed's protective jacket. It's called the seed coat and it develops from the outer part that used to wrap around the seed when it was part of the plant.

The seed coat can be thin like paper (think of peanuts) or thick and tough (like coconuts). It keeps the baby plant safe from harm and stops it from drying out. There's a little mark on the seed coat called the "**hilum**," which is where the seed used to be connected to the plant. Nearby, there's something called the "**micropyle**," which is like a door that the seed uses to get water.

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Inside the seed, embryo is an immature plant. It consists of a **radicle**, a **plumule** and one or two **cotyledons** (seed leaves). The radicle of embryo grows into new root while the plumule grows into new shoot upon seed germination. Therefore, radicle and plumule are called **embryonic root** and **embryonic stem** respectively. The embryonic stem above the point of attachment of cotyledon(s) is called **epicotyl**. The embryonic stem below the point of attachment is **hypocotyl**. Within seed, there is a store of nutrients for the seedling that will grow from embryo. In angiosperms, the stored food is derived from the endosperm tissue. This tissue is rich in oil or starch and protein. In many seeds, the food of the endosperm is absorbed and stored by cotyledons.

Science Titbits

Based of number of cotyledons and some other features the angiosperms are classified into two classes i.e., monocots and dicots.

So, inside a tiny seed, there's a whole world waiting to grow into a new plant.

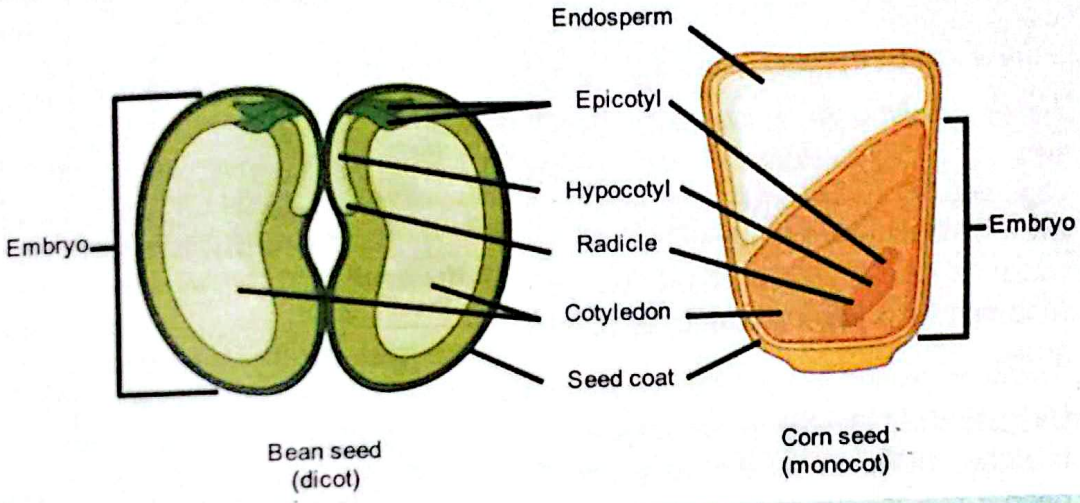


Figure: 9.17: Structure of seed

9.2.3 Seed germination

For seeds to start growing, they need to be in the right place and at the right time. This process is called seed **germination**, and it's like the start of a plant's life. In this process, the seed absorbs water, which makes it swell and breaks open the seed coat. First, a root pops out from a part called the radicle. This root grows quickly and starts taking in water and nutrients from the soil. Then, a tiny shoot called the plumule begins to grow. It stretches up and out of the soil. There are two main ways seeds can start growing:

STEAM ACTIVITY 9.1: GERMINATION OF SEEDS

Take few seeds of commonly growing plants in your vicinity, plant them together in the pot, and observe the germination process day wise by picking one germinating seed every day.

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1- Epigeal Germination

In this type, the part called the **hypocotyl** stretches out and forms a hook, pulling the seed **leaves (cotyledons)** above the ground. Beans, cotton, and papaya are examples of seeds that do this.

2- Hypogeal Germination

Here, it's the **epicotyl** that stretches and forms a hook, but the **seed leaves (cotyledons)** stay underground. Peas, maize, and coconuts are examples of seeds that germinate this way.

So, seeds have their own ways of getting started on their journey to becoming full-grown plants!

Conditions for seed germination

For seeds to start growing, they need the right conditions, both inside and outside. Inside, the seed must have a living baby plant (embryo) and enough stored food.

Outside, there are three key conditions:

1. **Water (Moisture):** Most seeds have very little water inside them. They can't start growing until they soak up water from the environment. This water is used to break down stored food and help parts of the baby plant grow.
2. **Oxygen:** Just like we need oxygen to breathe, the cells in the baby plant need it too. It helps them do their job.
3. **Temperature:** Different seeds like different temperatures to start growing. For most plants, the best temperature is between 25-30°C.

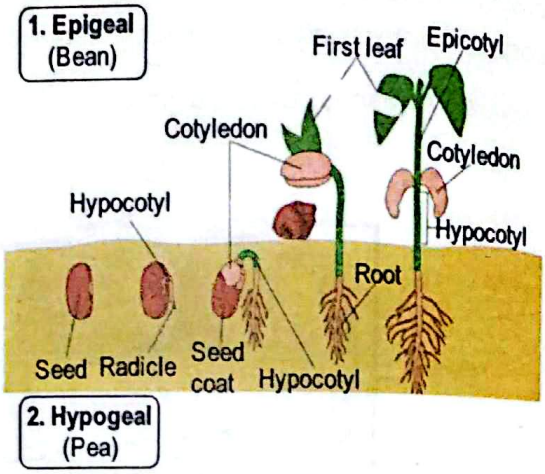


Figure: 9.18: Types of seed germination

So, when the seed gets these conditions right, it's like a green light for the baby plant to begin its journey!

STEAM ACTIVITY 9.2:
Revealing secrets of plant reproduction

Objective:

Investigate the structure of flowers and gain insights into the reproductive mechanisms of plants.

Materials Required:

1) Assorted flowers (various species), 2) Scalpels or small knives, 3) Disposable gloves,

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4) Magnifying glasses, 5) Petri dishes or small trays, 6) Notebooks and pens, 7) Camera or smartphones for documentation.

Procedure:

1. Begin by discussing the significance of flowers in plant reproduction and the different parts of a typical flower (petals, sepals, stamens, pistil).
2. Distribute various types of flowers to students, ensuring a diverse selection.
3. Provide disposable gloves and scalpels or small knives for flower dissection. Emphasize safety precautions during the handling of cutting tools.
4. Instruct students to carefully dissect the flowers, identifying and observing each part. Focus on the arrangement of reproductive structures within the pistil and stamens.
5. Encourage the use of magnifying glasses or capture snapshot with their smart phones for a closer examination and ask students to sketch the dissected flowers in their notebooks and paste the floral parts on a hard chart to make herbarium sheets as shown in figure 9.19.



Figure: 9.19: Presentation of floral parts on herbarium sheets

Results

Ask students to identify specific adaptations related to attracting pollinators and achieving successful fertilization. Ask students to compare their findings and discuss the similarities and differences in flower anatomy.

Interpretation

Discuss the observed variations in flower structure among different plant species and how these variations contribute to successful pollination. Prompt a class discussion on the importance of flowers in plant reproduction, linking the observed structures to the process seed and fruit formation. Discuss the relation between the overuse of insecticide by farmers and insect pollinators in plant reproduction. Conclude the activity by reinforcing the role of flowers as essential components of the plant life cycle.

Reflection

This flower dissection activity provides students with a hands-on exploration of flower anatomy, offering valuable insights into the reproductive strategies employed by different plant species.

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SUMMARY

1. Plants, like all living organisms, have various methods of reproduction, each tailored to their unique biology. This chapter deals into the diversity of plant reproduction, from simple asexual methods to complex sexual processes.
2. Asexual reproduction involves a single parent and results in genetically identical offspring, often called clones. Methods include Binary Fission, Budding, Spore Formation, Parthenogenesis, and Vegetative Propagation
3. Binary Fission is common in bacteria, where the cell divides into two identical parts. Budding is seen in yeast and some plants, where an outgrowth (bud) develops and eventually detaches to form a new individual. Spore Formation is utilized by fungi and certain bacteria, where spores are produced and dispersed to germinate into new organisms. Parthenogenesis involves the development of offspring from unfertilized eggs, occurring in plants like flowering plants through a process called apomixis. Vegetative Propagation in plants produce new individuals from vegetative structures like roots, stems, leaves, or specialized structures without the involvement of seeds.
4. Sexual reproduction involves the fusion of gametes (egg and sperm) from two parents, leading to genetically diverse offspring. This process varies among plant groups:
5. Reproduction involves flowers, with male gametes produced in the pollen and female gametes in the ovule. Pollination leads to fertilization and the formation of seeds and fruits.
6. Seeds consist of an embryo, endosperm for nourishment, and a protective seed coat. Germination occurs when seeds absorb water and sprout into new plants under suitable conditions.
7. Understanding plant reproduction unveils the intricate mechanisms that drive their life cycles. From the simplicity of asexual methods to the complexity of sexual processes, each strategy ensures the continuation of plant life. Through hands-on activities like flower dissection, students gain valuable insights into the reproductive strategies and adaptations of different plant species, enriching their understanding of the natural world.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. **Select the correct answer**

(i) Which of the following is incorrect about asexual reproduction?

A) single parent contributes genetic material

B) no gamete formation is involved

C) offspring are genetically identical

D) contributes in evolution of new species

(ii) Which of the following is the benefit of sexual reproduction?

A) this is rapid way of reproduction

B) this is complex mechanism of reproduction

C) it can occur any time in lifecycle

(D) it contributes genetic variability in successive generations

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(iii) Which of the following modes of asexual reproduction generally occurs during unfavorable conditions?

A) Binary fission
B) Budding
C) Spore formation
D) parthenogenesis

(iv) Which of the following processes is also known as apomixis?

A) Binary fission
B) Budding
C) Spore formation
D) parthenogenesis

(v) Which of the following is compact, thickened, vertically growing, underground stem enveloped by thick, succulent (fleshy) leaves, serving as reservoir of stored nutrients:

A) Bulb
B) Corm
C) Rhizome
D) Stem tuber

(vi) In Bryophyllum, small plantlets that are much like tiny versions of the parent plant, are created along the:

A) root tip
B) edges of its leaves
C) stem surface
D) all of these

(vii) If sometimes, the stem cutting does not start growth, then the cut ends must be treated with which of the following special plant hormone to stimulate the growth?

A) somatotrophin
B) Abscissic acid
C) auxin
D) Ethene

(viii) The first cell or tiny piece of the parent plant used in tissue culture is called:

A) baby plant
B) plantlet
(C) seedling
D) explant.

(ix) Which of the following part of the plant that's been changed and adapted for the job of reproduction:

A) flower
B) Leave
C) root
D) meristematic tissue

(x) Which of the following parts of the flower are called accessary whorls?

A) Androecium and gynoecium
B) calyx and corolla
C) Androecium and corolla
D) calyx and gynoecium

Section II: Short Answer Questions

1. Define cloning. Which process of plant is supposed to be a cloning?
2. Enlist any two suitable conditions for germination of seed,
3. Explain the structure of embryonic stem.

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4. Explain the role of livestock.
5. Explain the event of double fertilization in angiosperms.
6. Explain the structure of embryo sac.
7. Justify that sexual reproduction in plants is more beneficial than asexual reproduction.
8. Define/Describe/Explain briefly:
9. Apomixis, pollination, male gametophyte, epigeal germination, fertilization, binary fission, budding, sporangiophores, rootstock, bulb, rhizome.
10. Write the differences between
    (a) Asexual reproduction and sexual reproduction
    (b) Artificial vegetative propagation and natural vegetative propagation
    (c) Scion and rootstock
    (d) Grafting and stem cutting
    (e) Bulb and rhizome
    (f) Binary fission and budding
    (g) Hypogeal and epigeal germination
    (h) Self and cross pollination

Section III: Extensive Answer Questions

1. Explain the procedure of plant tissue culture and illustrate your answer with suitable diagram.
2. Describe the structure and development of male and female gametophytes.
3. Define seed germination. Explain its two types and write down the conditions for germination.
4. Explain the mechanism of binary fission and budding in bacteria and yeast respectively.
5. Describe any two methods of artificial vegetative propagation in plants.
6. Describe the structure if a typical flower and draw its suitable diagram.
7. Describe the methods of natural vegetative propagation in plants.

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Unit 10

EVOLUTION

SLOs: After completing this lesson, the student will be able to:

1. [SLO: B-09-B-05] Describe sources of variations which can lead to speciation and evolution
2. [SLO: B-09-B-01] Explain the theory of evolution by natural selection with examples
3. [SLO: B-09-B-04] Discuss briefly the observations Darwin made during his voyage on HMS Beagle
4. [SLO: B-09-B-06] Describe the evidence of evolution with regards to the following:
   - Palaeontology (fossil record)
   - Comparative anatomy (homologous structures, vestigial structures)
   - Selective breeding
5. [SLO: B-09-B-03] Describe speciation

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The number of species of living things on earth currently exceeds a million. Each specie has its own manner of living and working. Some species appear to be highly similar to one another, whereas others do not. In many ways, a horse and a zebra are similar. Both of them, however, have some traits not present in the other. Through the process of progressive transformation, all of the species alive today evolved from earlier ones. One definition of evolution is a change that occurs to living things over time.

10.1 VARIATION AND EVOLUTION

10.1.1. VARIATION

The term variation refers to the differences in traits displayed by members of the same species. For instance, although all domestic cats are members of the same species, they differ greatly in terms of size, coat colour, eye colour, hair length, and other characteristics. Variations are beneficial for living organism as it helps in increasing their chances of survival of the particular organisms. These are desirable variations as it helps them be more advanced and immune. Variations can sometime lead to a genetic defect hence becoming a harmful and an undesirable variation.

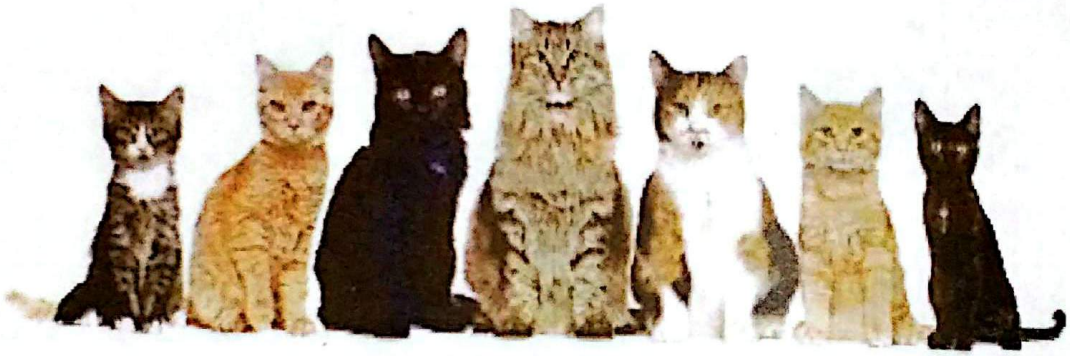


Figure10.1: Variations in domestic cats

You are already aware of the meiotic process. Meiosis along with other factors serve as the main sources of variation. They are as follows:

1. Genetic recombination results from crossing over during gamete development.
2. Different chromosome combinations in gametes are formed by independent collections of chromosomes.
3. The process of fertilization in which one of the countless sperms fuses with an egg.
4. A mutation in the gamete-forming germ cells.
5. Gene flow, or the transfer of genes from one population of a species to another.

10.1.2. EVOLUTION

According to scientists, the Earth is more than four billion years old. New life forms developed from unicellular organisms. All current living things developed gradually from earlier ones. Evolution is the gradual alteration of a population's or species' traits over time in response to the environmental conditions. Evolutionary changes can always be passed on to next generations.

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How variation promote evolution?

Some individuals of a population may have an advantage over other members as a result of population variations. These individuals will be able to have more progeny. Consequently, the population will gradually see more instances of that specific variant. With these variations, they will have a better chance of survival and reproduction. That's evolution.

An inherited trait or group of traits that increases an organism's chances of survival in specific environmental conditions is known as an adaptation. Members of a specie's population will compete with one another for resources. Only the healthiest, fittest, and strongest will survive and reproduce. If food or water is in little supply, there is little room for sharing, and there aren't many available partners.

10.2. Theory of Natural Selection

Natural selection is the process through which organisms who possess traits that are helpful for reproduction in a certain environment produce more children in the following generation. As a result, they gradually expand the population's genetic diversity. Natural selection theory is based on:

1. **Overproduction:** All living creatures are very fertile so that their populations could grow quickly to produce large number of offspring.
2. **Competition:** We can observe that population sizes do not rise to a very high level even after overproduction. The numbers largely stay constant. This is because food supplies and other resources are scarce. As a result, there is competition for resources and food.
3. **Variations:** No two organisms ar the same. They will not have the same opportunities to survive and reproduce as others. A large portion of this diversity is heritable. Such qualities are inherited from parents through the genes of the offspring.
4. **Natural selection:** Only those organisms who live and reproduce can give rise to the next generation. And only those organisms with the desirable variations will live till reproductive age. The population will have more advantageous genetic variations and fewer harmful ones after many generations. Natural selection is essentially an elimination process. Only fittest organisms will survive.

10.2.1. DARWIN'S VOYAGE

After a five-year voyage around the world in the ship HMS Beagle, **Charles Darwin** put forth the Theory of Natural Selection in 1838. In 1859, he released a book titled "**On the Origin of Species by Natural Selection**" recording his observations.

Charles Darwin was able to create his theory of natural selection when he visited the Galapagos Islands. He found a number of finch species that varied from island to island. He noticed that the form of the birds' beaks varied depending on the kind of food they ate. Darwin believed that the processes of speciation and adaptation were linked. The overall accumulation of adaptations in different environments, isolated from the original environment by geographic barriers, would lead to the formation of a new species from an ancestral form. The two groups could differ sufficiently over many generations to be classified as two different species. Darwin identified three basic patterns in biological diversity: (1) global, (2) local, and (3) variation over time in species.

Natural selection causes population-wide changes in gene frequencies over time; as a result, individuals with more advantageous traits will be more prevalent in the population and individuals with less advantageous traits will be less prevalent.

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Analysing a case study of Variation and Selection

The phrase "Changes in the environment can bring about changes in a population by natural Selection" is supported by evidence.

All reported variants of the peppered moth (*Biston betularia*) in the UK up until 1848 had light colours with dark patches. A dark-coloured moth was discovered in 1848, and by 1895, dark-coloured moths made up 95% of the peppered moth population. This variety's dark colour resulted from a mutation.

The moths fly at night and rest on tree trunks throughout the day. The light-coloured lichens growing on the tree trunks blended in with the colour of the light-coloured moth, giving it excellent concealment from predator birds. As the industrial revolution progressed, sulphur dioxide pollution from coal burning drove out lichens that were growing on trees in industrial locations, exposing the darker bark.

The predator birds can now easily locate and consume the light-coloured moths that are resting on dark-coloured trunks. Light-coloured moths are "seen and eaten by the birds" when they settle on dark-coloured trunks. The birds are serving as snoopers. The dark colour was the adaptive variable that resulted in the selection advantage. 90% of the peppered moth population in England during the industrial era of pollution was black. 'Industrial Melanism' is the name given to the specific phenomenon. After the 1950s, England's industrial pollution was reduced, and as a result, the number of light-coloured moths also increased.



(a): Unpolluted environment **(b): Polluted environment**

Fig. 10.2: (a) The light and dark coloured forms of the peppered moth are resting on a lichen-covered tree. (b) The light and dark coloured forms of the peppered moth are resting on a lichen free tree trunk, which was darkened by industrial air pollution.

10.3. EVIDENCES OF EVOLUTION

The evidence for evolution is compelling and extensive. Looking at every level of organization in living systems, biologists see the signature of past and present evolution.

10.3.1. Evidence from Palaeontology

In addition to offering strong evidence that ancient species were distinct from modern ones, fossils also show the evolution of organisms across time. To determine how long ago an organism lived in relation to another, scientists classify and age fossils from all around the world. The resulting fossil record shows the evolution of form over millions of years and tells the tale of the past. For example, researchers have found extremely comprehensive records demonstrating how humans and horses have evolved.

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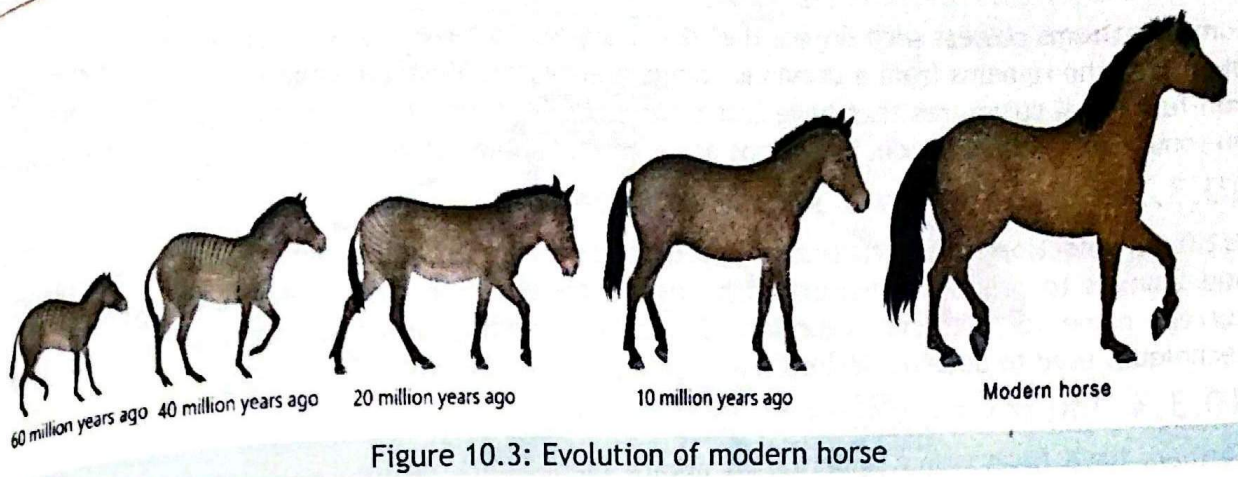


Figure 10.3: Evolution of modern horse

10.3.2. Evidence from Comparative Anatomy

Comparative anatomy is the study of similarities and differences in the body structures of various organisms to understand their evolutionary relationships. By comparing the anatomy of different species, scientists can identify homologous structures and vestigial organs. Comparative anatomy provides strong evidence for evolution, helping us understand how species adapt and change over time. By analysing these structural similarities and differences, scientists can reconstruct evolutionary histories and better comprehend the diversity of life on Earth.

Homologous structures have shared features inherited from a common ancestor. For example, the forelimbs of vertebrates (humans, birds, whales, and cats) have similar bone structures despite being used for different purposes (arm, wing, flipper, and leg). The shapes and sizes of these bones have evolved over time in different animals, but their general structure has remained the same. The existence of structures in creatures with the same fundamental shape is another type of evidence supporting evolution.

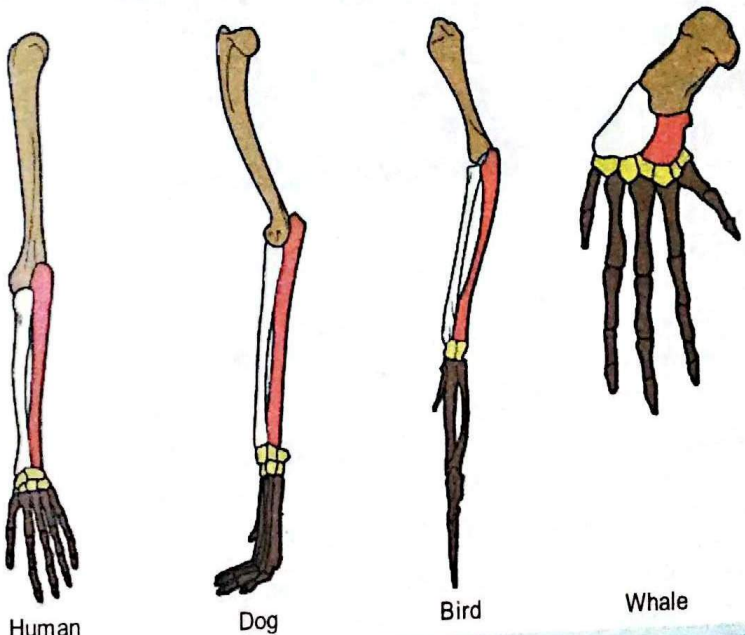


Fig 10.4: Homologous structure of bones of limbs of mammals

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Some organisms possess such organs that don't appear to have any function at all now and are likely just the remains from a previous common ancestor. **Vestigial organs** are these inactive, non-functional structures that have lost their use over time. Wings on flightless birds, leaves on some cacti, and appendix in humans are a few examples of vestigial organs

10.3.3. Evidence from Selective breeding

Artificial selection is the practice of breeding domesticated and genetically enhanced plants and animals to produce offspring with desired genetic features. Selective breeding is the current name for artificial selection. **Selective breeding** and **hybridization** are the two techniques used to develop desired features in plants and animals.

10.3.4. Improving plants by selection

Farmers have been using selection to create plants with desired features for ages. They frequently choose varieties that will cause the plants to grow larger, more quickly, be drought-resistant, etc.

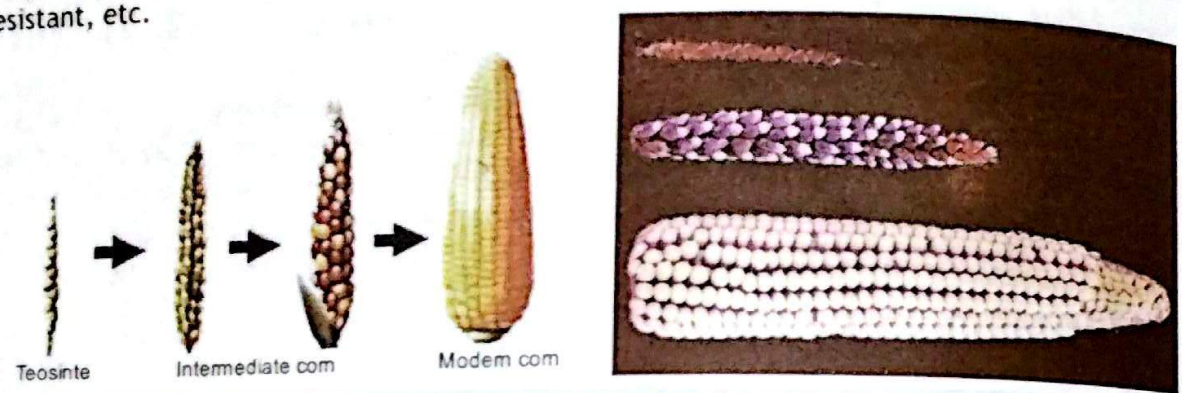
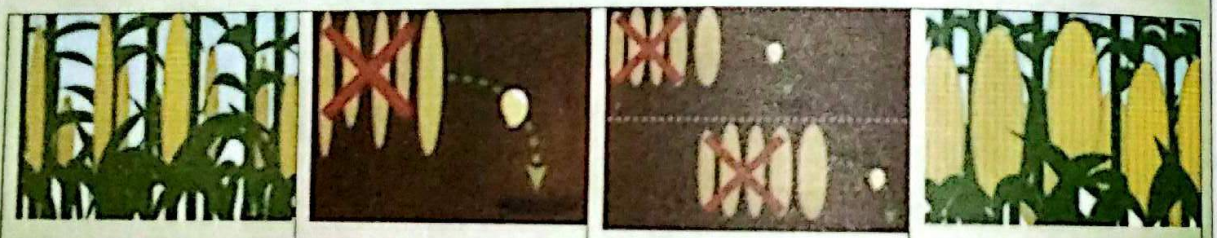


Figure 10.5: Improving Plants by selection

Artificial selection produces crops with higher yields



1. Natural variation occurs in the wild population.	2. Seeds for the next generation are chosen only from individuals with the most desirable traits.	3. Repeat this process for several generations.	4. Over time, the yield of the crop increases.

10.3.5. Improving animals by selection

Animals have also been the subjected to selection. Cows that generate a lot of milk and high-quality meat are chosen for selective breeding. They serve as parents for the following generation. In this manner, a breed of cow that can produce more milk than the original breed is created.

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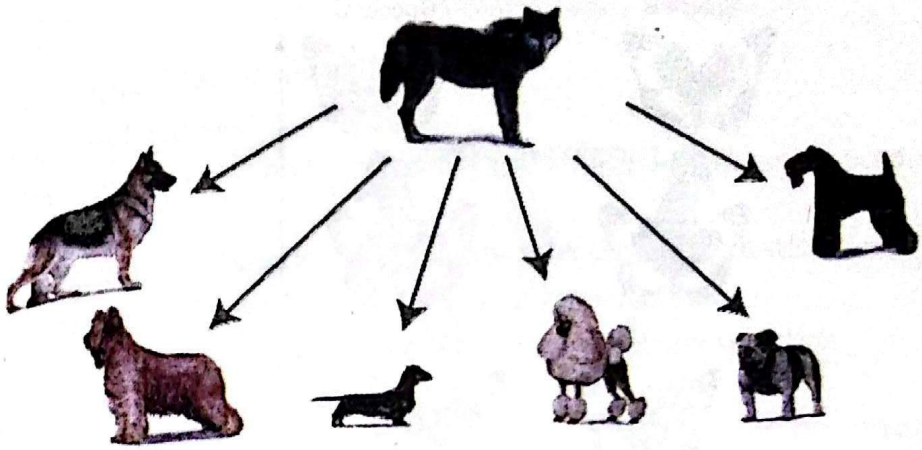


Fig. 10.6: Dog breeds produced from wolf by artificial selection

Table 10.1. Comparing Natural Selection and Artificial Selection

Natural Selection	Artificial selection
Selection occurs when natural environmental condition changes.	It is selected by man.
Varieties are produced by mutations.	Varieties are produced by selective breeding.
It operates in natural population.	It operates in domesticated population.
It is a slow process and takes thousand to millions of years.	It is a fast process and results are immediate (in the next generation).
It is responsible for the great biological diversity.	It is responsible for new varieties different from starting generation.

10.3 SPECIATION

Speciation is the process by which a single species splits into two or more distinct species. This occurs when a group of individuals within a species becomes isolated from the rest, either geographically or through other barriers.

Imagine a population of butterflies living in a forest. Over time, a river forms, dividing the population into two groups. The butterflies on each side of the river can no longer mate with those on the other side. As a result, they begin to adapt to their separate environments, developing distinct characteristics. As the isolated groups evolve independently, genetic differences accumulate. These changes can arise from gene mutations, random events and natural selection. The isolated groups become reproductively isolated, meaning they can no longer interbreed successfully. This can be due to geographic barriers, behavioural and physiological differences. Over thousands of generations, the isolated groups evolve into distinct species. They develop unique characteristics, making them unable to interbreed or produce fertile offspring.

For example, Galapagos finches have different beak shapes adapted to various food sources. Polar bears and brown bears are separate species due to geographic isolation.

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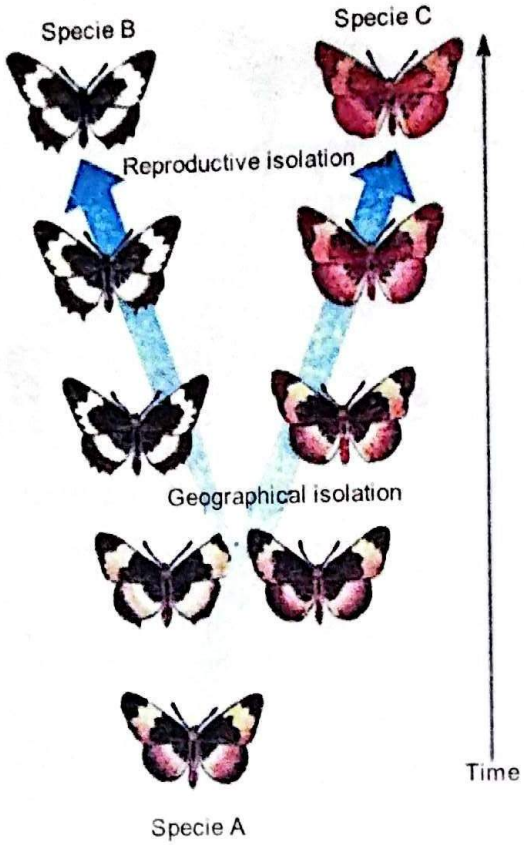


Fig 10.7: Speciation

SUMMARY

1. The differences in traits displayed by members of the same species is called variation.
2. Meiosis along with other factors serve as the main sources of variation.
3. Evolution is the gradual change of a population's or species' traits over time in response to the environmental conditions.
4. An inherited trait or group of traits that increases an organism's chances of survival in specific environmental conditions is known as an adaptation.
5. Natural selection is the process through which organisms who possess traits that are helpful for reproduction in a certain environment produce more children in the following generation.
6. After a five-year voyage around the world in the ship HMS Beagle, Charles Darwin put forth the Theory of Natural Selection.
7. The evidence of evolution is provided by palaeontology (fossil record), comparative anatomy (homologous structures, vestigial structures) and selective breeding.
8. The evolutionary process by which new biological species arise is called speciation.

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EXERCISE

Section i: Multiple Choice Questions

Select the correct answer:

1. The process of ------ and------- generate variation, and -------- produces adaptation to the environment.
   A) sexual recombination ----- natural selection -----mutation
   B) genetic drift----mutation ---- sexual recombination
   C) mutation ------- sexual recombination ----natural selection
   D) mutation------ natural selection-----genetic drift
2. Natural selection is sometimes described as "survival of the fittest." Which of the following most accurately measures an organism's fitness?
   A) its mutation rate
   B) how many fertile offspring it produces
   C) its ability to withstand environmental extremes
   D) how much food it is able to make or obtain.
3. The smallest biological unit that can evolve over time is
   (A) a specie
   (B) an individual organism
   (C) an ecosystem
   (D) a population
4. Which of the following pairs of structures is least likely to represent homology?
   (A) the wings of a bat and the forelimbs of a human
   (B) the haemoglobin of a baboon and that of a gorilla
   (C) the brain of a cat and that of a dog
   (D) the wings of a bird and those of an insect
5. Organisms produce many more offspring that can possibly survive on the limited amount of resources available to them. The offspring that are most likely to survive are those that:
   (A) are born first and grow fastest
   (B) are largest and most aggressive
   (C) have no natural predators
   (D) are best adapted to the environment
6. Natural selection operates to produce changes in:
   (A) individuals
   (B) populations
   (C) races
   (D) genes
7. Speciation is the evolutionary process by which:
   (A) a new population is formed
   (B) a new breed is formed
   (C) a new specie is formed
   (D) a new race is formed
8. A mutation is:
   (A) a change in appearance
   (B) a change in behaviour
   (C) a change in gene
   (D) a change in the environment

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9. farmers have bred Neli- Ravi buffalo to produce more milk than older breeds. Which process was used to produce these cattle?

(A) adaptation (B) natural selection

(C) genetic engineering (D) selective breeding

10. Which results from the process of natural selection and adaptation?

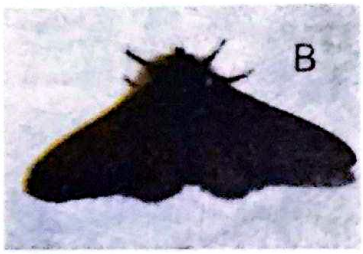
(A) artificial selection (B) evolution

(C) reproduction (D) selective breeding

Section II: Short Answer Questions

1. Explain the homologous structures in plants.
2. Why the theory of evolution was attributed to Darwin?
3. What is meant by descent with modification?
4. The diagram shows two varieties of moths in England.





   a. Which variety was more common when there was more air pollution? Give reason as well.

   b. Which variety is more common in England nowadays? Give reason as well.

5. Define/Describe/Explain briefly:

   evolution, homologous organs, speciation, natural selection, artificial selection, industrial melanism, palaeontology, comparative anatomy, vestigial organs, selective breeding,

6. Differentiate between natural and artificial selection.

Section III: Extensive Answer Questions

1. What is variation? Explain the sources of variation.
2. Assess selection as a possible means of evolution.
3. Explain the theory of evolution by natural selection with examples.

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4. Discuss briefly the observations Darwin made during his voyage on HMS Beagle.
5. Describe speciation.
6. Describe the evidence of evolution according to palaeontology.
7. How comparative anatomy proves evolution?
8. Describe the evidence of evolution according to Selective breeding.
9. A specie o snail may have a yellow, pink or brown shell. Each colour shell may have dark bands, or have no bands. The snails are eaten by birds. Following observations were made:
   i. Most snails living on a plain background have no bands.
   ii. Most snails living on green background are yellow.
   iii. Most snails living on rough background have bands.
   (a) Suggest an explanation of these observations.
   (b) Predict the colour of snails living on dead leaves.
   (c) Suggest which colour snails will be in summer and autumn.
10. Many small volcanic islands are located near South America; these are called Galapagos islands. There is only one species of finches on South America continent but there are 14 species of finches on Galapagos islands. Why there are more species on Galapagos islands as compared to main land?

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Glossary

A.F.A King: An American scientist who listed twenty observations in 1883 about spread of malaria.

Abu Usama Aljahiz: He described 350 species of animals.

Accessory Whorls: Additional floral structures beyond the essential reproductive parts, including sepals and petals, which may serve protective or attractive functions.

Acetyl CoA: Acetyl-CoA is an important biochemical molecule in cellular respiration. It is produced from Pyruvic acid and carries two carbon atoms to Kreb's cycle.

Actinomycete: A group of bacteria characterized by filamentous growth and their ability to produce antibiotics.

Active site: The part of the enzyme where the substrate binds.

Active Transport: Energy-requiring process by which substances are transported across cell membranes against their concentration gradient.

Adenosine Tri Phosphate (ATP): Molecule responsible for storing and transferring energy within cells.

Adhesion: Attraction between different molecules, such as water and the walls of xylem vessels.

Aerobic respiration: Respiration, which occurs in the presence of oxygen.

Agar: is a jelly like substance obtained from cell walls of some species of red algae.

Agriculture: Is the science of improving farming methods.

Amino acid: Compound which are the building blocks of proteins.

Anabolism: The building up complex substances from simpler ones.

Anaerobic : Growing or metabolizing only in the absence of molecular oxygen.

Anatomy: I study of the internal structure of the organisms.

Andrea Caesalpino: He divided plants into fifteen groups and called them genera.

Androecium: The male reproductive organ of a flower, consisting of one or more stamens, each comprising a filament and an anther where pollen is produced.

Angiosperms: A diverse group of flowering plants characterized by enclosed seeds within fruits.

Animalia: Are multicellular heterotrophic eukaryotes.

Anopheles: A mosquito (female) that spread plasmodium the malarial parasite in man.

Anther: The part of the stamen where pollen grains containing male gametes are produced.

Antipodals: Three cells in the embryo sac of flowering plants, located at the opposite end of the micropyle, possibly playing a role in embryo development.

Apoenzyme : Protein portion of an enzyme that requires the presence of a specific co-factor to become a complete functional enzyme.

Apomixis: A form of asexual reproduction in plants where seeds are produced without fertilization.

Archaea: A domain that consists of single cell prokaryotic organisms.

Artificial Vegetative Propagation: A method of plant reproduction that involves human intervention, such as cutting, grafting, or tissue culture, to produce genetically identical clones of a parent plant.

Ascent of Sap: Process by which water and nutrients are transported from roots to leaves in plants.

Asexual Reproduction: Reproduction that does not involve the fusion of gametes, resulting in offspring genetically identical to the parent organism.

Autophagy: A process in which cell eats its own organelles which are damaged or no more needed.

Auxins: Are a type of plant hormones.

Bacteria: *A domain that* are microscopic, single-celled organisms that exist in their millions, in every environment, both inside and outside other organisms.

Binary Fission: A form of asexual reproduction in bacteria and some other single-celled organisms, where a parent cell divides into two identical daughter cells.

Binomial nomenclature: The biological system of naming the organisms. In it the name is composed of two terms. The first term indicates

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the genus and the second term indicates the species of the organism.

Biochemistry: Study of chemical constituents found in an organism and chemical reactions taking place in the living organism.

Biodiversity: The variety of organisms on earth.

Bio-economics: Study of biology from economic point of view.

Bioelements: The elements found in all living organisms.

Biogeography: Study of distribution of plants and animals in different geographical regions of the world.

Biological method: The series of steps that are used to solve a biological problem.

Biology: Study of living organisms.

Biophysics: Applies approaches and methods traditionally used in physics to study biological phenomena.

Biostatistics: The application of statistical techniques to scientific research in the field of biology.

Biotechnology: Is the use of living organisms or their components to make useful products.

Botany: Study of plants.

Bryophyllum: A genus of succulent plants known for their ability to produce plantlets along the margins of their leaves.

Bryophytes: Non-vascular plants including mosses, liverworts, and hornworts, characterized by their lack of specialized vascular tissues.

Bud: A small, undeveloped shoot containing embryonic tissue that can grow into a leaf, flower, or shoot.

Bulbs: Underground storage organs consisting of layers of fleshy leaves surrounding a central bud, capable of producing new shoots.

Callus: Undifferentiated plant tissue formed in response to injury or tissue culture, capable of developing into roots, shoots, or other structures.

Calvin cycle: Cyclic series of reactions in the chloroplast stroma in photosynthesis which fixes carbon dioxide and produces carbohydrates.

Calyx: The outermost whorl of a flower, typically consisting of sepals.

Canadian Pondweed (Elodea): Aquatic plant commonly used in experiments to demonstrate photosynthesis and cellular respiration.

carbon fixation: The initial steps in the C3 cycle in which carbon dioxide reacts with the ribulose bisphosphate to form a stable organic molecule.

Carolus Linnaeus: He grouped species according to similar physical characteristics

Carpel: The female reproductive organ of a flower, comprising the stigma, style, and ovary, where ovules are located.

Casparian Strips: Bands of suberin in the cell walls of the endodermis, preventing water and solute movement between cells.

Catabolism: The breakdown of complex substances to simpler substances in a cell with the release of energy.

Centromere: Constructed region of a chromosome where sister chromatids are attached to one another and where the chromosomes attaches to a spindle fibre.

Chitin: A nitrogen-containing structural polysaccharide that forms the exoskeleton of insects and the cell walls of many fungi.

Chlorosis: A condition in plants characterized by yellowing of leaves due to insufficient chlorophyll production.

Chromatids: One of the two identical parts of chromosomes.

Chromatin: The complex of DNA, protein, and RNA that makes up eukaryotic chromosomes.

Chromosomes condensed thread like structures in the nucleus of cell, composed of chromatin and containing the genes.

Chrysanthemum: A genus of flowering plants in the family Asteraceae, cultivated for their ornamental flowers.

Citrate (citric acid): A 6-carbon organic acid.

Citric acid cycle: Series of chemical reactions in aerobic cellular respiration with the release of metabolic energy which is used to produce ATP; also known as the Krebs cycle and the tricarboxylic acid (TCA) cycle.

Class: A group of related orders.

Classification: Grouping of organisms

Clone: Genetically identical individuals produced through asexual reproduction, such as vegetative propagation.

Coenzyme A (CoA): Organic cofactor responsible for transferring groups derived from organic acids.

Co-enzymes: Non-protein organic molecule that aids the action of the enzyme to which it is loosely bound.

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Cofactor: A non-protein substance needed by an enzyme for normal activity; some cofactors are inorganic (usually metal ions;) others are organic cofactors, known as coenzymes.

Cohesion: Attraction between molecules of the same substance, such as water molecules sticking together.

Companion Cells: Specialized cells associated with sieve tube elements in the phloem, assisting in nutrient transport.

Compensation Point of Photosynthesis: Light intensity at which the rate of photosynthesis equals the rate of respiration in plants.

Computational biology: Applies computational methods to analyze large collections of biological data.

Concentration Gradient: Difference in concentration of a substance between two regions.

Contractile vacuoles: A special kind of vacuole found in small freshwater animals or animal like protests to remove out extra water.

Corms: Underground storage stems similar to bulbs but lacking fleshy leaves, used for storing nutrients and producing new shoots.

Corolla: The whorl of a flower consisting of petals, often serving to attract pollinators.

Cortex: Region of tissue in plant roots and stems between the epidermis and vascular tissue, involved in storage and transport.

Cotyledons: The seed leaves of a plant embryo, which may store nutrients and facilitate early growth.

Cristae: Small finger like projections formed by the inner membrane of mitochondria.

Cross pollination: Pollination involving the transfer of pollen from the stamen of one flower to the stigma of another flower on a different plant.

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

Culex: A mosquito that spreads malarial parasite in birds.

Cuticle: Waxy, waterproof layer covering the outer surface of leaves and stems.

Cuticular Transpiration: Transpiration through the waxy cuticle covering leaf surfaces.

Cytology: Study of the structure and functions of the cell.

Dead Organic Matter: Decomposed organic material, providing nutrients for plant growth.

Dead Plant Debris: Non-living plant material, including leaves, stems, and roots, resulting from natural processes or decay.

Deduction: Are the logical consequences of the hypothesis.

Denaturation: Loss of normal shape by an enzyme so that it no longer functional caused by an abnormal pH and high temperature.

Dengue fever: Caused by dengue virus and spread by *Aedes aegypti*.

deoxyribonucleic acid (DNA): Double stranded nucleic acid; contains genetic information coded in specific sequences of its constituent nucleotides.

Diffusion: Passive movement of molecules from an area of higher concentration to an area of lower concentration.

Dipeptide: A compound consisting of two amino acids linked by a peptide bond.

Disaccharide: Sugar that contains two units of a monosaccharide e.g., maltose.

Domain: Is a group of kingdoms or taxonomic category above the kingdom

Double fertilization: A unique reproductive process in flowering plants where two sperm nuclei fertilize different nuclei within the embryo sac, leading to the formation of both an embryo and endosperm.

Ecology: Interrelationship of organisms and their environment.

Egg: The female gamete produced by the ovary of a flower.

Electron transport chain: Chain of electron carriers in the cristae of mitochondria. The electron release energy as they pass down the chain and this is used to produce ATP

Embryo Sac: The female gametophyte of a flowering plant, containing the egg cell and other supportive cells.

Embryo: The early developmental stage of a multicellular organism, typically contained within a seed.

Embryology: Study of the development of an organism from a fertilized egg.

Embryonic Root: The primary root that emerges from the seed embryo during germination.

Embryonic Stem: Undifferentiated cells within the embryo capable of developing into various specialized cell types.

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Endodermis: Innermost layer of the root cortex, regulating the movement of water and nutrients into the vascular tissue.

Endosmosis: Inward movement of water across a semipermeable membrane.

Endosperm Nucleus: The central cell within the embryo sac that undergoes fertilization to form the endosperm.

Endosperm: Nutrient-rich tissue formed during double fertilization in flowering plants, providing nourishment to the developing embryo.

Enzymes: Organic catalyst usually a protein that speeds up a reaction in cell due to its particular shape.

Epicotyl: The region of the embryonic stem located above the cotyledons, which develops into the shoot system of the plant.

Epidermis: Outermost layer of cells covering plant surfaces, providing protection and regulating water loss.

Eukarya: Is a domain or a large taxonomy group that is made up of organisms that contain a nucleus within their cells.

Evolution: The gradual alteration of a population's or species' traits over time in response to the environmental conditions.

Exosmosis: Outward movement of water across a semipermeable membrane.

Exospores: Spores produced externally by certain fungi, allowing for dispersal and reproduction.

Explant: A tissue sample taken from a plant for use in tissue culture or regeneration experiments.

Facilitated Diffusion: Movement of molecules across a membrane facilitated by transport proteins.

Family: Is a group of related genera.

Farming: Is the growth of crops and animals to provide food, wool and other products.

Female gametophyte: The haploid generation in the life cycle of a plant that produces female gametes, typically found within the ovule of a flower.

Fertilization: The fusion of male and female gametes to form a zygote, initiating the development of a new organism.

Fibrous adventitious roots: Roots originating from plant parts other than the primary root, forming a fibrous root system.

Filament: The slender stalk of a stamen that supports the anther.

Fishery: Raising or harvesting fish and other aquatic life.

Floral Buds: Undeveloped flower structures containing floral meristems.

Floral Leaves: Modified leaves of a flower, including sepals, petals, stamens, and carpels.

Flowers: Reproductive structures of angiosperms, typically consisting of sepals, petals, stamens, and carpels.

Forestry: Is the science of planting, managing and caring for forests.

Functional megaspore: The surviving megaspore within the ovule that undergoes further development into the female gametophyte.

Fungi: Are eukaryotic organisms that are saprotrophic decomposers. Mostly fungi are multicellular. Some fungi are unicellular.

Gametes: Haploid reproductive cells, including sperm and egg cells, capable of fusion during sexual reproduction.

Gametophyte: The haploid generation in the life cycle of a plant, producing gametes through mitosis.

Generative Nucleus: The nucleus within a pollen grain that divides to produce sperm cells.

Genetic uniformity: The condition where offspring are genetically identical to the parent organism, as seen in clones.

Genetics: Study of genes, and heredity in organisms is called genetics.

Genus: A group of related species.

Germination: The process by which a seed embryo begins to grow and develop into a new plant.

Glycerol: A three-carbon alcohol, with a hydroxyl group on each carbon; a component of neutral fats and phospholipids.

Glycolysis: The breakdown of glucose during cellular respiration, which results in the formation of ATP and pyruvate.

Grapevines: Vines of the genus Vitis, cultivated for their fruit, used in winemaking and culinary applications.

Guanine: A nitrogenous purine base that is component of nucleic acids

Gymnosperms: A group of seed-producing plants characterized by naked seeds, typically enclosed within cones.

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Gynoecium: The female reproductive organ of a flower, comprising one or more carpels.

Haemoglobin: Iron contains protein in red blood cells that combines with oxygen and transports oxygen.

Haplo-diplontic lifecycle: A life cycle characteristic of higher plants, alternating between a haploid gametophyte and a diploid sporophyte generation.

Hilum: The scar on a seed marking the point of attachment to the ovary wall.

Histology: Microscopic study of tissues of organisms.

Histones: Proteins on which DNA coils to form chromatin fibers and chromosomes.

Homeostasis The tendency to maintain a stable, relatively constant internal environment.

Homologous chromosomes: Chromosome pair of the same length, centromere position and staining pattern that possess genes for the same traits at corresponding loci. One homologous chromosome is inherited from one parent and second from the other parent.

Horticulture: it means the art of gardening.

Humidity: Amount of water vapor present in the air.

Hydrilla: Submerged aquatic plant often used in studies of

Hydrogen carbonate Indicator: Chemical solution used to detect the presence of carbon dioxide in photosynthesis experiments.

Hydrostatic pressure: Pressure exerted by a fluid due to its weight and gravity.

Hypocotyl: The region of the embryonic stem located below the cotyledons, which develops into the root system of the plant.

Hypothesis: A tentative explanation of the observations that might be true.

Immunology: Ability of the body to protect itself from foreign substances and cells including infectious microbes.

Internodes: The segments of a stem between nodes.

Interphase: Phase of cell cycle from the formation of a cell till the start of next division.

Intracellular digestion: A process in which complex substances are digested within a cell.

intron: In eukaryotes, a non expressed (noncoding) portion of a gene, that is excised from the RNA transcript. The coding portion of a gene is called exon.

Ivy: A genus of climbing or creeping vines in the family Araliaceae, commonly used for ornamental purposes.

John Ray: He published important works on the classification of plants.

Kingdom: the largest taxon or rank.

Krebs cycle: The series of reactions during which pyruvate the end product of glycolysis enters the cycle to form citric acid and is finally oxidized to carbon dioxide also called citric acid cycle. It occurs inside mitochondria.

Law: A theory that has been verified and appears to have wide application

Lenticels: Pores in the bark of woody stems, allowing gas exchange between internal tissues and the atmosphere.

Lenticular transpiration: Transpiration through lenticels, small openings in the bark of woody stems.

Lipase: Fat-digesting: enzyme.

Macromolecules: A large organic molecule having many functional groups.

Macronutrients: Essential nutrients required by plants in relatively large quantities, including nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur.

Male gametophyte: The haploid generation in the life cycle of a plant that produces male gametes, typically found within pollen grains.

Marine biology: study of organisms that live in sea.

Megasporangia: Structures within the ovule that produce megaspores, which develop into female gametophytes.

Megaspores: Haploid spores produced by megasporangia, which give rise to the female gametophyte.

Meiosis: The process of cell division that reduces the chromosome number by half, leading to the formation of gametes.

Mesophyll cells: Cells in the interior of leaves responsible for photosynthesis.

Messenger RNA (mRNA): RNA that specifies the amino acid sequence of a protein; transcribed from DNA.

Metabolism: All the chemical reactions that take place within a living organism.

Microbiology: Study of micro-organisms e.g., viruses, bacteria etc.

Micronutrients: Essential nutrients required by plants in small quantities, including iron,

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manganese, zinc, copper, molybdenum, boron, and chlorine.

Micropropagation: A method of plant propagation involving the growth of plant tissues under sterile conditions to produce clones.

Micropyle: The opening in the integuments of an ovule through which the pollen tube enters during fertilization.

Microsporangia: Structures within the anther that produce microspores, which develop into pollen grains.

Microspores: Haploid spores produced by microsporangia, which develop into pollen grains.

Moisture: Water content in the environment, essential for plant growth and metabolic processes.

Molecular biology: Study of biology at molecular level.

Morphology: Study of the size, shape, and structure of animals, plants, and microorganisms.

Myoglobin: A haemoglobin-like oxygen transferring protein found in muscle.

NAD+/NADH: Oxidized and reduced forms, respectively, of nicotinamide adenine dinucleotide; it is a coenzyme that transfers electrons in catabolic pathways, including cellular respiration.

NADP+/NADPH: Oxidized and reduced forms, respectively, of nicotinamide adenine dinucleotide phosphate; coenzyme that acts as an electron (hydrogen) transfer agent, particularly in anabolic pathways, including photosynthesis.

Natural selection: The process through which organisms who possess traits that are helpful for reproduction in a certain environment produce more children in the following generation.

Natural vegetative propagation: Plant reproduction that occurs without human intervention, such as through the growth of runners or rhizomes.

Necessary whorls: The essential floral structures required for sexual reproduction, including stamens and carpels.

Neutral fat: A lipid used for energy storage, consisting of a glycerol covalently bonded to one, two or three fatty acids.

Nitrogen Depleted Soils: Soil lacking sufficient nitrogen for plant growth.

Nitrogenous Compounds: Chemical compounds containing nitrogen, essential for various biological processes in plants.

Nodes: Points on a stem where leaves, branches, or flowers originate.

Nucleoside: Molecule consisting of a nitrogenous base (purine or pyrimidine) and a pentose sugar.

Nucleosomes: Repeating units of chromatin structure, each consisting of a length of DNA wound around a complex of eight histone molecules (two of four different types) plus a DNA linker region associated with a fifth histone protein.

Nucleotide: A molecule composed of one or more phosphate groups, a 5-carbon sugar (ribose or deoxyribose) and nitrogenous base (purine or pyrimidine).

Nutrient: Substances essential for the growth and maintenance of organisms, including plants, obtained from the environment.

Nutrition: The process by which organisms acquire and utilize nutrients for growth, metabolism, and other biological functions.

Offspring: The new generation of organisms produced through reproduction.

Order: group of related families.

Organ systems Groups of organs with related functions.

Organic solutes: Organic compounds dissolved in plant fluids, contributing to osmotic regulation and nutrient transport.

Organs: Structures made up of two or more tissues organized to carry out a particular function.

Ovary: The swollen basal portion of the carpel containing ovules, which develop into seeds after fertilization.

Ovule: The structure within the ovary of a flower that contains the female gametophyte and develops into a seed after fertilization.

Oxidation: The loss of an electron by an atom or a molecule.

Oxidation-reduction: A chemical reaction in which one atom or molecule gains an electron while the other atom or molecule involved in the reaction losses an electron.

Oxidative phosphorylation: Process by which ATP production is tied to an electron transport system that uses oxygen as the final acceptor, occurs in mitochondrion.

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Oxygen: A gas essential for aerobic respiration and metabolic processes in plants.

P680: Chlorophyll a molecules that serve as the reaction centre of Photosystem II, named by their absorption peak at 680 nm.

P700: Chlorophyll a molecules that serve as the reaction centre of Photosystem I, named by their absorption peak at 700 nm.

Parthenogenesis: A form of asexual reproduction in which an unfertilized egg develops into a new individual.

Passive Transport: Movement of substances across cell membranes without the use of energy.

Pathology: Study and diagnosis of disease.

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Pectin: A structural fiber found in the cell wall of plants.

Pedicel: The stalk that supports a single flower or inflorescence.

Pentose: A sugar molecule containing five carbons.

Pepsin : An enzyme produced in the stomach that initiates digestion of proteion.

Peptide bond: A distinctive covalent carbon-to-nitrogen bond that links amino acids in peptides and proteins.

Peptide: A compound consisting of a chain of amino acid groups. A dipeptide consists of two amino acids, a polypeptide of many amino acids.

Peptidoglycan: A modified protein or peptide possessing an attached carbohydrate; component of the bacterial cell wall.

Pericycle: Tissue layer in plant roots giving rise to lateral roots.

Petals: Modified leaves of a flower, often brightly colored to attract pollinators.

Pharmacology: study of drugs.

Phloem Sap: Sugary fluid transported through the phloem, containing sugars, amino acids, and other organic compounds.

Phosphodiester linkage: Covalent linkage between two nucleotides in a strand of DNA or RNA; includes a phosphate group bonded to the sugars of two adjacent nucleotides.

Phospholipids: Fatlike substances in which there are two fatty acids and a phosphorus-containing group attached to glycerol; major components of cellular membranes.

Photolysis: The photochemical splitting of water in the light-dependent reactions of photosynthesis, catalyzed by a specific enzyme.

Photometer: Instrument used to measure light intensity.

Photon: A particle of electromagnetic radiation; one quantum of radiant energy.

Photophosphorylation: The production of ATP in photosynthesis.

Photosynthesis: Process by which green plants and some other organisms convert light energy into chemical energy, producing oxygen and carbohydrates from carbon dioxide and water.

Photosystem: A group of chlorophyll molecules, accesory pigments, and associated electron acceptors that emits electrons in response to light; located in the thylakoid membrane (in photoautorophic eukaryotes).

Phylum: A group of related classes.

Physiology: Study of the functions of various organs of the organisms.

Pistil: The female reproductive organ of a flower, comprising one or more carpels.

Pith: Central tissue in the stems of certain plants, primarily involved in storage and support.

Plant Physiology: The study of how plants function and the processes that occur within them.

Plantae: Members of kingdom plantae are eukaryotic multicellular and autotrophic with chloroplasts containing chlorophyll.

Plantlet: A small, immature plant produced asexually from a parent plant.

Plasmodium: A microorganism and parasite that causes malaria in man.

Plumule: The embryonic shoot located above the cotyledons in a seed.

Polar Nuclei: Two nuclei in the central cell of the embryo sac that fuse with a sperm nucleus during double fertilization to form the endosperm.

Pollen Grains: Microscopic structures produced by the anthers of flowers, containing male gametes.

Pollen Sacs: Structures within the anthers that contain pollen grains.

Pollen Tube: A tubular structure that grows from a pollen grain into the ovule to deliver sperm cells during fertilization.

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Pollination: The transfer of pollen from the anther to the stigma of a flower, facilitating fertilization.

Polymer: A molecule built up from repeating sub units of the same general type (monomers) such as protein, nucleic acid or polysaccharides.

Polypeptide: A compound consisting of many amino acids linked by peptide bonds.

Polysaccharide: A carbohydrate consisting of many monosaccharide subunits; examples are starch, glycogen, and cellulose.

Primary root: The first root to emerge from a plant embryo, forming the basis of the root system.

Prokaryotes: Organisms whose cells lack a defined nucleus.

Proteins: A large complex organic compound composed of amino acids.

Protista: Include eukaryotic organisms with unicellular or colonial organization.

Protozoa: Single-celled eukaryotic organisms belonging to the kingdom Protista, exhibiting diverse forms and lifestyles.

Pteridophytes: A group of seedless vascular plants, including ferns and horsetails, characterized by the presence of vascular tissues.

Purines (pure'eenz): Nitrogenous bases with carbon and nitrogen atoms in two attached rings; components of nucleic acids, ATP, NAD^+, and certain other biologically active substances. Examples are adenine and guanine.

Radicle: The embryonic root of a plant embryo, which develops into the primary root.

Recombinant DNA: Any DNA molecule made by combining genes from different organisms.

Reproduction: The process by which organisms produce offspring, ensuring the continuation of their species.

Rhizomes: Underground stems that grow horizontally, producing roots and shoots at nodes to propagate plants.

Rhizopus: A genus of filamentous fungi commonly found on decaying organic matter, known for its rapid growth and asexual reproduction.

Ribonucleic acid (RNA): A family of single-stranded nucleic acids that function mainly in protein synthesis.

Ribulose bisphosphate (RuBP): A 5-carbon phosphorylated compund with a high energy potential reacts with carbon dioxide in the initial step of the Calvin cycle.

Ribulose bisphosphate: A five carbon phosphorylated compound with a high energy potential reacts with carbon dioxide in the initial step of Calvin cycle.

Ripened Ovary: The matured and enlarged base of the carpel containing seeds, often forming the fruit.

Ripened Ovule: The matured ovule containing the fertilized embryo, often forming the seed.

Root Hairs: Tiny, hair-like extensions of root epidermal cells, increasing surface area for nutrient absorption.

Rootstock: The underground portion of a grafted plant that provides the root system.

Rubisco: Common name of ribulose bisphosphate carboxylase, the enzymes the reaction of carbon dioxide with ribulose bisphosphate in the Calvin cycle.

Runners: Horizontal stems that grow above ground and produce new plants at nodes along their length.

Science: A system of knowledge about the physical, chemical, and biological universe and the things that occur in it is called science.

Scientific method: An approach for solving scientific problem.

Scion: The aboveground portion of a grafted plant that provides the shoot system.

Secondary Nucleus: The nucleus within the central cell of the embryo sac that fuses with a sperm nucleus during double fertilization to form the endosperm.

Seed Coat: The protective outer covering of a seed, derived from the integuments of the ovule.

Seed Leaves: The cotyledons of a germinating seed, which provide nutrients for early seedling growth.

Selectively Permeable: Property of membranes allowing certain substances to pass while restricting others.

Self-Pollination: Pollination that occurs within the same flower or between flowers of the same plant, leading to fertilization.

Sepals: Leaf-like structures at the base of a flower, collectively known as the calyx, typically serving to protect the flower bud.

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Sieve Tubes: Tubular structures in phloem tissue, responsible for transporting organic nutrients.

Sink: Plant organ or tissue importing sugars for storage or growth.

Source: Plant organ or tissue exporting sugars to other parts of the plant.

Speciation the evolutionary process by which new biological species arise.

Species: A group of similar organisms capable of interbreeding.

Sperm nuclei: Haploid nuclei within pollen grains that fuse with egg nuclei during fertilization.

Sporangia: Structures within plants where spores are produced through meiosis.

Starch: A polysaccharide composed of alpha glucose subunits; made by plants for energy storage.

Stem cells: Mother cells which give rise to cells of other types.

Stomata: Small pores in the epidermis of leaves and stems, regulating gas exchange and water loss.

Stomatal transpiration: Transpiration through openings called stomata on leaf surfaces.

Suberin: Waxy substance found in the cell walls of the endodermis, creating a waterproof barrier.

Substrate: A substance on which an enzyme acts; a reactant in an enzymatically catalyzed reaction.

Systematics: Scientific study of diversity of organisms and their evolutionary relationship. **Aristotle**: the first person who classified the living organisms.

TACT theory: Theory explaining the movement of water through plants, involving transpiration, adhesion, cohesion, and tension.

Tap root: Primary root in certain plants that grows straight down and gives rise to lateral roots.

Taxa: The group into which organisms are classified.

Taxonomy: Is concerned with identification, naming and classification of organisms.

Tension: Pulling force exerted on water molecules in the xylem due to transpiration.

Tissues: Groups of similar cells that work together on a specific task.

Tournefort: He introduced the taxa of class and species

Tracheids: Type of elongated cells in xylem tissue responsible for water transport in gymnosperms and ferns.

Transfer RNA (tRNA): RNA molecules that bind to specific amino acids and serve as adapter molecules in protein synthesis. The tRNA anticodons bind to complementary mRNA codons.

Translocation: Movement of sugars and other organic compounds through a plant, primarily in the phloem.

Transpiration pull: Force created by transpiration, causing water to move upward through the xylem.

Transpiration: Loss of water vapor from plant surfaces, primarily through stomata.

Tricylglycerol: A neutral fat consisting of a glycerol combined chemically with three fatty acids; also called triglyceride.

Triose: A sugar molecule containing three carbons

Turgor: Pressure exerted by the fluid contents of plant cells against the cell wall, providing support and rigidity.

Variation: The differences in traits displayed by members of the same species.

Vascular bundles: Strands of xylem and phloem tissues responsible for transporting water, nutrients, and sugars throughout the plant.

Viruses: Are at the borderline of living and nonliving. There are not included in any domain or kingdom under modern classification.

Woese: Introduced a three domains system of classification.

Xylem Vessel: Tubular structure in xylem tissue, conducting water and minerals upward from roots to shoots in angiosperms.

Zoology: Study of animals.

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ABOUT THE AUTHORS

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Prof. Jawaid Mohsin was born on 12th February in 1945 in the province of Bihar. Malik is the title given to his ancestor Syed Ibrahim by the king Tughlaq. Syed Ibrahim was a saint, the commander in chief of the army and conqueror of Bihar. Syed Ibrahim is the descendent of Hazrat Ghos-e-Azam, Syed Abdul Qadir Jilani (رحمۃ اللہ علیہ) at the seventh generation. The ancestors of Syed Ibrahim migrated from Iraq to Afghanistan and settled in the village "Bunt Nagar" near Ghazni. Prof.Jawaid is a former head for the department of Zoology, Federal Government Postgraduate College, H-8 Islamabad` where he served for more than twenty-five years. He is also a former Principal, Federal Government College, H-9, F-10/4 Islamabad and Director Colleges and Director and Director Administration, Federal Directorate of Education, Islamabad. He has contributed his services to FBISE in various capacities such as paper setter, head examiner etc. He developed the modern question paper of FBISE which consists of three parts i.e., MCQ's, short answer question and extensive answer questions is now used all over Pakistan. In 1968 he did his post-graduation in zoology with specialization in Entomology, from Dhaka University, East Pakistan (former). He taught in Muhammadpur College, Quaid-e-Azam College and the prestigious Notre Dame College of Dhaka. He taught various classes for more than forty-five years in various capacities. He has also worked as Education Officer, in Nigeria for four years. He has successfully completed the 61st advance course in administration and development held in 1996 at National Institute of Public Administration (NIPA), Karachi. In 1995. He was awarded a shield by the honourable Mr. Rafiq Tarar, the then President of Pakistan, for his services to humanity. He has published four research papers in Science Journals of Pakistan on Butterflies of Pakistan. He has contributed articles on science and sports in Urdu and English dailies of Islamabad. He is co-author and managing author of more than fifty textbooks on General Science and Biology as well as Biology Practical Notebooks. He has travelled to Singapore, Thailand, Indonesia, India, Bangladesh, UAE, Saudi Arabia, Egypt, Italy, Holland, UK, Qatar, USA and Nigeria. He has also served as a National Consultant, Science Education, JICA sponsored project for the promotion of Student centered and Inquiry based SCIB) learning, National Institute of Science and Technical Education, Ministry of Education, Islamabad, He retired from survive on 12th November 2005. He has published four literary books in Urdu on which a student has obtained M.Phil., Degree from a university in Islamabad. He has served as book reviewer at National curriculum Council (NCC) and member interview committee of FPSC for selection of faculty for a number of years.

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Ruqayya Shaikh did her M.Sc and M.Phil in Animal Sciences from Quaid-i-Azam University, Islamabad. She started her professional career as a Zoology lecturer at Islamabad College for girls, F-6/2, Islamabad. At present she is working as Associate Professor in the same institute. She has been teaching General Science to secondary school classes, Biology to SSC, HSSC and BS classes, Zoology to B.Sc classes for the last two decades. Recently she certified in instructional leadership, College of Education, University of Massachusetts, USA.

She was the part of the General science Curriculum development team, Grade 4-8, under National Curriculum council. She worked as textbook reviewer for General science Grade 4, General Science Grade 5, Biology HSSC I and Biology HSSC II. She served as FBISE Biology course committee member. The author conducted a number of teacher training programs. She is the co-author of General Science 6, 7 and Biology 9 and 10. Her video lectures of General Science and Biology are available on youtube channel Ruqayya Shaikh ICG.

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Mr. Abid Ali Mughal is currently the Assistant Professor and Head of the Biology Department at Islamabad Model College for Boys H-9 Islamabad. He completed his M.Sc (Hons) in Plant Sciences from the University of Sindh Jamshoro in 2002, where he was awarded the Vice Chancellor's Medal for achieving first position. From 2002 to 2003, he served as a Research Fellow at PAEC's Nuclear Institute of Agriculture Tandojam. In 2003, he began his teaching career as a lecturer in Botany at F.G. Degree College Wah Cantt. His research interests include investigating factors affecting tDNA transfer from Agrobacterium to Soybean for his M.Phil in Biotechnology, and studying the effects of chronic exposure to antibiotics on rural populations for his Ph.D. in Environmental Sciences. Mr. Mughal has presented his research papers at international conferences in Lithuania, the Netherlands, and France. He is the Co-author of NBF Biology for grades 11 & 12 according to the curriculum 2006, and the Principal author of Biology for grade 12 of KPK textbook board based on Curriculum 2006. His interactive video lectures covering all biology topics are available on his website www.BiologyGuardian.com and YouTube channel www.youtube.com/c/BiologyGuardian. Currently, he is a member of the Course Committee of SSC and HSSC Biology in the Federal Board and a Co-opted member of the Board of Studies of Botany at Quaid-i-Azam University Islamabad.

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