بسم اللہ الرحمن الرحیم

(In the name of ALLAH the most beneficent and the most merciful)

Based on National Curriculum
2022-23

9

A Textbook of

Biology

یہ کتاب محکمہ تعلیم حکومت بلوچستان کی جانب سے تعلیمی سال
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Balochistan Textbook Board, Quetta.

Authors:

Prof. Ehsan Elahi
Associate Professor (Head Department of Biology)
Tameer-i-Nau Public College, Quetta

Prof. Dr. Muhammad Ali
M.Phil, Ph.D (Zoology)

Prof. Abid Hussain Qureshi
M.Phil (Zoology)
Govt. Postgraduate Science College,
Quetta.

Editor:

Prof. Shabana Wali
Ph.D (Scholar)

Internal Review Committee

- Dr. ZaighamHasan
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Layout Designing: Muhammad Amjad Qadri
Prepared by: New College Publications, Quetta.
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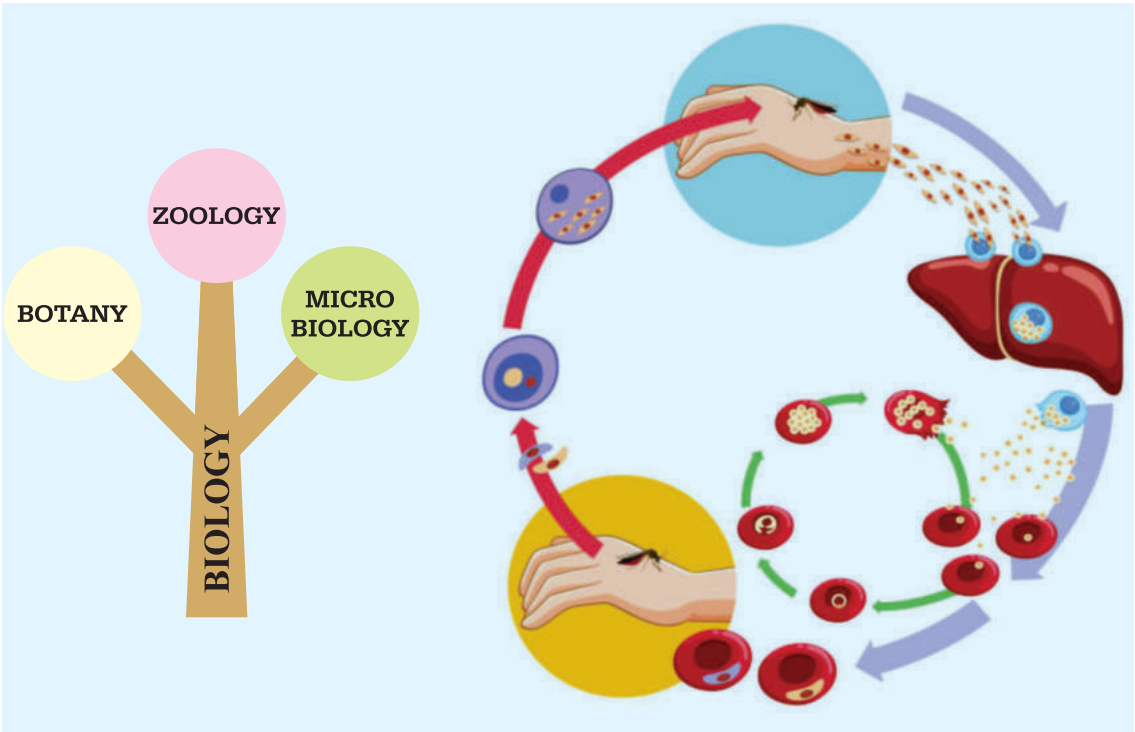
CHAPTER 1

NATURE OF SCIENCE IN BIOLOGY



Learning Outcomes:

Students will be able to:

- Define Biology.
- State Quran instructs to reveal the study of life.
- Define major fields of biology as Botany, Zoology and Microbiology.
- Define with examples that biology has many sub-fields.
  - Cytology
  - Molecular Biology
  - Marine Biology
  - Anatomy
  - Embryology
  - Pathology
  - Immunology
  - Histology
  - Genetics
  - Ecology
  - Morphology
  - Physiology

- ♦ Taxonomy
- ♦ Paleontology
- ♦ Pharmacology
- ♦ Biotechnology

- Relate that biology connects with other natural sciences.
- Distinguish in terms of the broad subject matter in the below fields.
  - ♦ Biophysics
  - ♦ Biochemistry
  - ♦ Computational Biology
  - ♦ Biogeography
  - ♦ Bioeconomics
  - ♦ Biostatistics
- Identify the careers in Biology.
- Explain with examples that Biology is a part of the natural sciences and the life sciences.
- Justify with examples that science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas.
- Describe the steps of the scientific method that is:
  - ♦ Recognition
  - ♦ Observation
  - ♦ Hypothesis
  - ♦ Deduction
  - ♦ Experiments
  - ♦ Results
- Evaluate the terms 'hypothesis', 'theory' and law in the context of research in the natural sciences.

Introduction

The word "science" has been derived from a Latin word "Scientia" which means knowledge or learning. Science is a knowledge in which we study the things around us or principles of nature and try to prove these observations by experiments to get logical results. Biology is the study of living organisms e.g., animals, plants etc. Biology is a significant part of everyday life e.g. progress in biology is providing us with better quality of food, improved health facilities and a hygienic environment etc. In this chapter, we will study about different branches of biology, relation of biology with other branches of science and careers in biology. In this chapter, we will also study about the details of biological method.

1.1 Definition of Biology

The word "Biology" has been derived from two Greek words; "bios" means life and "logos" means study, so the scientific study of life or living organisms is called biology or biological science or life science.

1.2 Quran Instructs to Reveal Study of Life

There are many Quranic injunctions that stress the study of biology. These verses describe the study of organisms and their different aspects of life. Some examples are given below.

A. Origin of Life

Modern biologists believe that life has originated first in oceans and then migrated to land. They also believe that life must have begun with simple cell and with the passage of time it evolved into the plants and animals. In this regard, Allah says in the Holy Quran that:

اَوَ لَمۡ یَرَ الَّذِیۡنَ کَفَرُوۡۤا اَنَّ السَّمٰوٰتِ وَ الۡاَرۡضَ کَانَتَا رَتۡقًا فَفَتَقۡنٰہُمَا ؕ وَ جَعَلۡنَا مِنَ الۡمَآءِ کُلَّ شَیۡءٍ حَیٍّ ؕ اَفَلَا یُؤۡمِنُوۡنَ ﴿۳۰﴾

"Have not the unbelievers then seen that the heavens and earth were closed up, then we opened them, and we made of water every living thing, then do they not believe" (Sura Al-Ambiya-21: Verse-30)

خَلَقَ الۡاِنۡسَانَ مِنۡ صَلۡصَالٍ کَالۡفَخَّارِ ﴿۱۴﴾

"He made man of a clattering clay like the earth were" (Surah Al-Rehman-55: Verse-14)

B. Pairs of plants and animals

We know that plants and animals have male and female partners. New generation of plants and animals are formed by sexual reproduction. In this respect, the Holy Quran says:

وَ مِنۡ کُلِّ شَیۡءٍ خَلَقۡنَا زَوۡجَیۡنِ لَعَلَّکُمۡ تَذَکَّرُوۡنَ ﴿۴۹﴾

" And of everything created we opposite kinds (pairs) that you may thing." (Surah Al-Zariyat-51: Verse-49)

سُبۡحٰنَ الَّذِیۡ خَلَقَ الۡاَزۡوَاجَ کُلَّہَا مِمَّا تُنۡۢبِتُ الۡاَرۡضُ وَ مِنۡ اَنۡفُسِہِمۡ وَ مِمَّا لَا یَعۡلَمُوۡنَ ﴿۳۶﴾

Glorious is the self, who made the pairs of all things of that kind that grows from the earth, and of themselves and of what they known not." (Surah Yasin-36: Verse-36)

C. Communal Life

We know that animals of same species live together in the form of a population. We also know that different "populations" of animals live in the form of "community". For communal life the Holy Quran says:

وَ مَا مِنۡ دَآبَّۃٍ فِی الۡاَرۡضِ وَ لَا طٰٓئِرٍ یَّطِیۡرُ بِجَنَاحَیۡہِ اِلَّاۤ اُمَمٌ اَمۡثَالُکُمۡ ؕ

"There is not a one walking on earth, and not a bird that flies with its two wings, but are communities like you." (Surah Al-Anaam-6: Verse-38)

D. Human Embryology

There are many verses in Holy Quran which stress upon the study of different branches of biology e.g. To explain the development of embryo. The Holy Quran says:

يَخْلُقُكُمْ فِيْ بُطُوْنِ اُمَّهٰتِكُمْ خَلْقًا مِّنْۢ بَعْدِ خَلْقٍ فِيْ ظُلُمٰتٍ ثَلٰثٍ ؕ

"He creates you in your mother's womb in one manner of creation after the other in three folds shadow." (Surah Al-Zamar-39: Verse-6)

E. Locomotion in Animals

Some verses in the Holy Quran explain the locomotion in animals. The Holy Quran says:

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

"And Allah has created every living creature from water, then there are some that walks upon its bellies, and there are some that walk upon two feet and there are some that walks upon four, Allah creates whatever he will, No doubt Allah is powerful over every thing." (Surah Al-Nur-24: Verse-45)

F. Flight of Birds

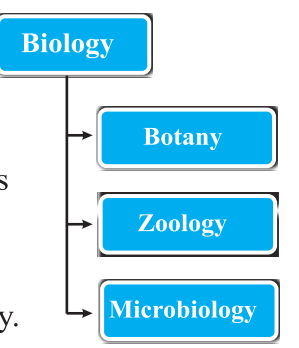
Birds are mentioned in many verses of the Holy Quran. The Holy Quran says:

اَوَلَمْ يَرَوْا اِلَى الطَّيْرِ فَوْقَهُمْ صٰٓفّٰتٍ وَّيَقْبِضْنَ ۛؕ مَا يُمْسِكُهُنَّ اِلَّا الرَّحْمٰنُ ؕ اِنَّهٗ بِكُلِّ شَيْءٍۭ بَصِيْرٌ ۝

"Do they not see the birds above them spreading their wings and closing them? No one holds them but the All-Merciful, truly it is He that watches over all things." (Surah Al-Mulk-67: Verse-19)

1.3 Major fields of Biology

The subject Biology is divided into three major divisions.



a) Microbiology: The scientific study of microorganisms (e.g. Bacteria) is called Microbiology.

b) Botany: The scientific study of plants is called Botany.

c) Zoology: The scientific study of animals is called Zoology.

1.4 Branches of Biology

To study the different aspects of all living organisms, the science of Biology is further divided into many branches. Some examples are as follows:

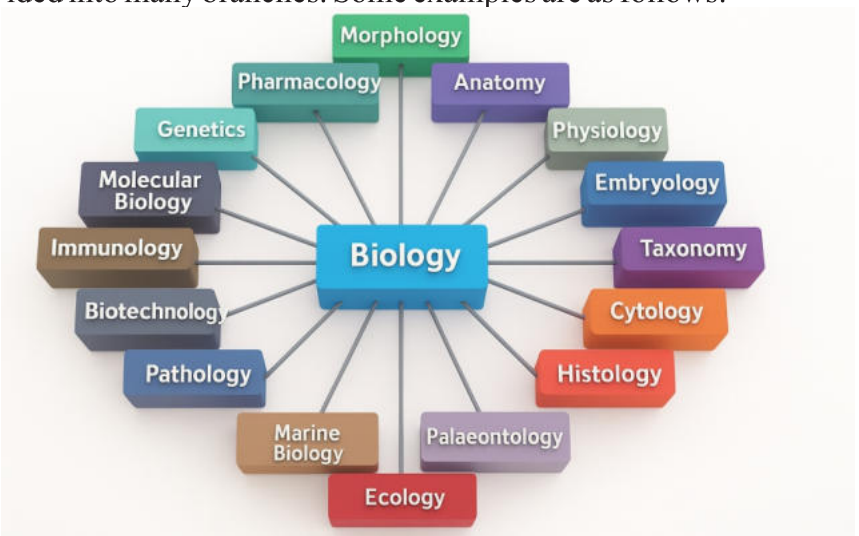


Fig.1.1: Branches of Biology

1. Cytology (Cell Biology)

Cell biology is the study of all the aspects of structure and function of cells. It is also called cytology.

2. Embryology

The study of the development of an embryo to complete individual is called embryology.

3. Genetics

In this branch of biology, we study about genes, genetic variation and heredity in living organisms.

4. Molecular Biology

The branch of biology which deals with the study of structure, composition and interaction of molecules found in the organisms.

5. Pathology

The branch of biology which deals with the causes and treatment of diseases in organisms.

6. Ecology

This branch of biology deals with the relationship between an organism and

environment.

7. Marine Biology

This branch of biology deals with the study of organisms found in oceans.

8. Immunology

This branch of biology deals with the study of immune system or immunity of a body against pathogens.

9. Morphology

It is the scientific study of form and the external structure of living organisms.

10. Anatomy

The study of internal structures of living organisms is called Anatomy.

11. Histology

It is the microscopic study of tissues of animals and plants.

12. Physiology

The study of the functions of different parts of living organisms is called physiology.

13. Taxonomy

It is the study of identification, naming and classification of living organisms into groups and subgroups.

14. Palaeontology

The study of fossils is called palaeontology. It has been further divided in two branches.

(a) Palaeobotany: It is the study of plant fossils.

(b) Palaeozoology: It is the study of animal fossils.

15. Pharmacology

It is the study of drugs and their effects on the cell, tissue, organ or organism.

16. Biotechnology

Biotechnology is the use of living organisms, cells or biological systems, to form useful products to improve human life, agriculture or environment.

1.5 Relationship of Biology with other Sciences

In biology, though we study about living organisms yet it is also related with other branches of science, e.g., biology relies on chemistry to understand photosynthesis in plants, molecular compositions of nucleic acids, proteins, carbohydrates, lipids, etc. statistics is essential in biology for data analysis etc. The

biological functions like movement, blood flow in animals etc., are explained by using laws of physics.

Many new branches of science have been developed by the combination of biology with other sciences. Some examples are as follows:

a) Biophysics: In biophysics, methods and principles from physics are used to study the mechanisms of biological systems, e.g., the principle of lever is used to understand the movement of arms and legs joints in biology.

b) Biochemistry: In biochemistry, we study the chemical processes and substances within living organisms, e.g., compositions and chemical reactions of carbohydrates, proteins and lipids etc.

c) Computational Biology: Computational biology is a science in which computational technique are used to understand and analyze the biological systems.

d) Biogeography: The study of the geographical distribution of living organisms is called biogeography. Each organism lives in a specific geographical region e.g. A camel successfully lives in a warm desert and polar bear lives in cold areas.

e) Biostatistics (Biometry): In biostatistics, statistical methods are used to analyze the different aspects in biology.

f) Bioeconomics: Bioeconomics is the study of the living resources using principles of economics. It helps to estimate about benefits or losses of a business related with living organisms e.g. The cost value and profit value of the poultry business can be calculated.

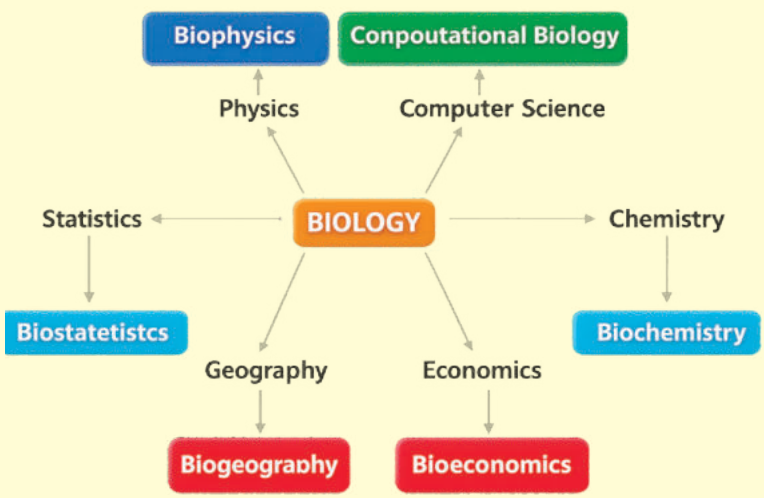


Fig.1.2: Relationship of Biology with other Branches of Science

1.6 Careers in Biology

There are many careers which can be adopted by students of biology. Some careers are as follows:

Class Activity

Teacher should ask about the future planing of their students in their classes and guide them properly.

a) Medicine and Surgery

Medical profession is a noble and one of the most vital profession. There are two main divisions of medical profession i.e. medicine and surgery. Medicine is concerned with the diagnosis and treatment of human diseases e.g., the diagnosis and treatment of malaria of a sick person. Surgery is concerned with the repairing, replacement and removal of different body parts of human beings e.g., repairing of broken bones, kidney transplant or removal of appendix from human body, etc.

After passing MBBS, the doctors may specialize in different fields, e.g., general physician, heart specialist, eye specialist, general surgery, heart surgery etc. BDS and DVM are also medical professions.

b) Agriculture

Agriculture is the cultivation of plants for food, biofuel, fibre and other products used to sustain human life. Agriculturists work for the improvement of crops like wheat, rice, corn, etc. The students can become agriculturist by getting bachelor degree or master degree in agriculture.

c) Horticulture

Horticulture is the branch of agriculture. It is the science of growing gardens, fruits, vegetables, flowers and ornamental plants. This profession can be adopted by getting professional degree in horticulture.

d) Forestry

Forestry is the scientific knowledge in which we study about the production of artificial forest in an area alongwith the protection of natural forest. Forestry is also important for timber, biodiversity management, providing habitat to wildlife etc.

e) Animal Husbandry

It is the professional study of the care, improvement and breeding of livestock (domestic animals) e.g. cow, goat, sheep, etc. Professional courses in animal husbandry can be adopted after F.Sc. The degree holders work in different fields like veterinary, farming, livestock etc.

f) Farming

A person who has got professional degree in fisheries, agriculture, animal husbandry etc. can develop different types of farms e.g., poultry, vegetable, fruit, animal breeding, fish and dairy farms etc.

g) Fisheries

The study of production of all those animals on commercial scale which are obtained from sea or rivers is called fisheries, e.g., fish, prawns, lobsters etc. The experts work to increase the quality and quantity of food obtained from sea and river.

The fisheries profession can be adopted by students after getting BS degree in marine science or zoology and bachelor degree in fisheries.

1.7 Biology as a part of natural and life science

a) Biology as a part of Natural Science

Natural science is a very vast field of science which deals with the study of all aspects of natural world in a scientific way. Its main branches are Physics, Chemistry, Geology, Astronomy and Biology.

Biology is a part of natural science because it helps us to understand living things, e.g., when we study, how plants make their own food by photosynthesis, we are learning biology. Photosynthesis is a topic of natural science because it explains a natural process that occurs in the world around us.

b) Biology as a part of Life Science

Biology deals the study of living organisms but life science is a vast field. In life science we study about the living organisms and the associated knowledge of those factors which influence living organisms.

Suppose a biologist studying the human immune system. This study comes under the heading of biology. For the detailed study he will study cytology for the detection of those white blood cells which are involved in immune system. He will also study microbiology, genetics and physiology.

1.8 Science is a Collaborative Field

Science is a collaborative field that requires interdisciplinary researchers, working together to share knowledge and critique ideas. To complete their work, researchers of different fields have to work together and share their knowledge.

In biotechnology, an organism or the system of an organism is used to produce

useful products for the welfare of humanity on a large scale e.g., insulin is commercially prepared from bacteria by using methods of modern technology. Advancement in the field of health care becomes possible by the collaborative work of experts from different fields e.g., for the research in cancer, a collaboration is required among biologists, chemists, physicists and pharmacists. A combined knowledge of neurologist, physiologist and computer expert is necessary to carry out a research on the human brain. In the same way, collaborative work among agronomists, environmental scientists and meteorologists has helped in the improvement of agriculture.

1.9 Steps of Scientific Method

Scientists work in a systematic way to get the answers of their questions. They want to get a solid answer about a problem without any doubt.

Biological Problem

A problem caused by a living organism or environmental factor that have harmful effects on other living ones is called biological problem. The systematic procedure which is adopted by biologists to get a possible answer of solution of a biological problem is called biological method. This procedure consists of detection of problem, observation, hypothesis, deduction, experiment, theory and finally to develop a scientific law.

1.10 Steps Involved in Biological Method

Following seven steps are involved in biological method

1. Recognition

When biologists come across a biological problem, they detect it carefully. The biologists also use five senses to know the nature of problem.

2. Observations

It is the first phase to solve a biological problem. A biologist uses all the sources to get information about the problem. The observations are of two types i.e. qualitative and quantitative. **Qualitative** observations deal only with qualities or properties. **Quantitative** observation deal with the numerical data. These observations can be understood by a simple example. Suppose a biologist wants to survey about the healthy and diseased plants in an area. His observation is called qualitative when he notes the type of disease. When he records the number of healthy and diseased plants then this

observation is called quantitative.

3. Hypothesis

Hypothesis is a possible answer to a biological problem. It is a simple logical but untested statement which may be the solution of a biological problem. The hypothesis depends upon previous experience and knowledge about a biological problem. A good hypothesis helps a biologist to make a prediction about the solution of a biological problem. A biologist arranges observations in the form of data. After deep thinking, discussions and reasoning a hypothesis is derived from this data.

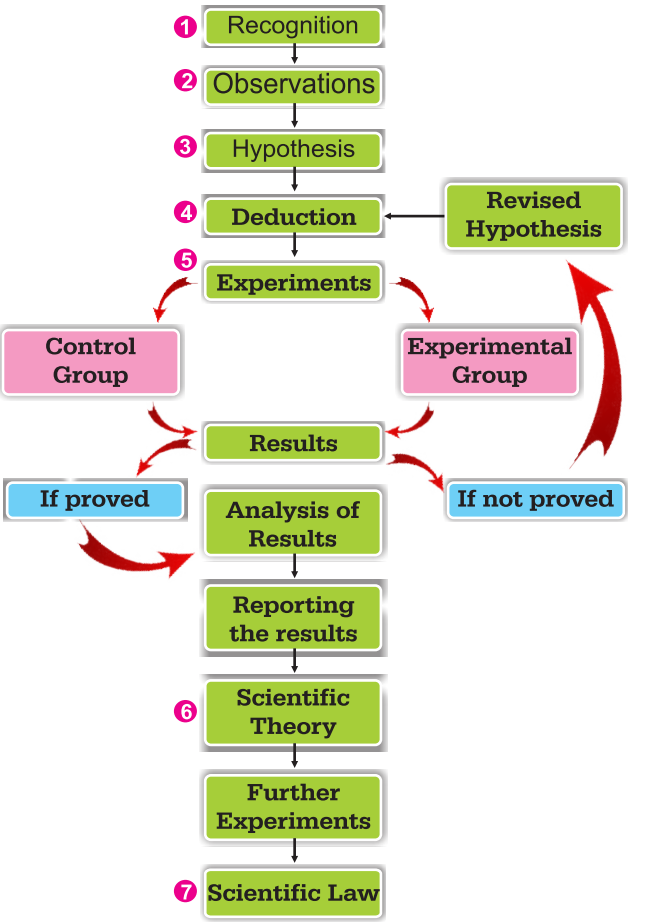


Fig.1.3: Biological Method

4. Prediction / Deduction

There are many hypotheses for a biological problem. After careful and logical thinking, a biologist selects a hypothesis that may be true. This is called deduction or prediction. In other words we can say that a deduction is a possible specific belief about the solution of a biological problem. The deduction is based on "if" and "then" format.

5. Experiment / Testing

The hypothesis may be true or wrong so it should be tested by experiments. Incorrect hypothesis is rejected and a new hypothesis is formulated for experiments. The hypothesis is only accepted when proved by experiments. Experiments are carried out many times on a hypothesis to get a possible conclusion of biological problem.

Analysis

After the completion of experiments, the biologists collect the facts or figures in

the form of data. They analyze the results of the experiments and decide what actions have to be taken next.

The data is compared statistically. Predictions of the hypothesis are compared with those of null hypothesis. If the analysis of data disproves the hypothesis then the biologist selects another hypothesis for testing it with experiments. In this way a final conclusion is drawn on the basis of statistical analysis.

Reporting the Results

After reaching a certain conclusion about a biological problem the biologists share their views with other biologists. It is carried by publishing their work in the form of research papers in scientific journals or in books etc. Publishing the scientific work is an integral part of a biological method.

Do You Know?

Control Group and Experimental Group

The organisms of control group and experimental group are same in the same environment. Experimental group are those organisms who are used in experiments to know the effects of different factors on them. Organisms of control group are not exposed to those factors which are provided to experimental group. The control group is used to compare the results of factor, on experimental group.

e.g. Light is provided to some plants (experimental group) but not provided to other plants (control group). After some days it was found that carbohydrates were formed by experimental group while not formed by control group.

6. Scientific Theory

When a hypothesis is proved by a series of experiments then it is called a scientific theory. A theory remains valid as long as there are no evidences to disprove it. An explanatory theory which gives the final solution of a biological problem and may suggest new and different hypotheses is called productive theory.

7. Scientific Law

When a productive theory is established then other scientists ask questions from different angles to understand this theory. They also formulate other hypotheses to confirm this theory. If the productive theory satisfies the other biologists then it becomes a scientific law. Scientific laws are also called laws of nature because these are permanent rules of nature. Scientific laws are always true. These are in the form of short statements and are universally accepted. For example, Mendel's laws of inheritance are common examples of scientific laws.

Malaria – An Example of Biological Method

Malaria is a common example of biological problem. It is commonly called "chill and fever

Do You Know?

That hypothesis in which no relationship exists between two sets of data being analyzed is called null hypothesis.

disease". According to old belief, the bad air of swampy places was responsible for this disease.

Recognition: Laveran (French Army physician) in 1878, was working on the cause of malaria. He observed some tiny living creatures in the blood of malarial patients. Later on some other physicians also noticed these tiny creatures in the blood of other malarial patients. They called them plasmodium.

Do You Know?

The *Aedes* mosquito transmits dengue virus in human beings.

Observations of different biologists

In the last part of 19th century there were following observations about malaria:

1. People live near marshes mostly effected by malaria.
2. Malaria is not caused by drinking marsh water.
3. Plasmodia are found in the blood of all malarial patients.
4. Malaria is treated only by quinine.

Additional Information

The name malaria is derived from two Italian words i.e. "Mala" means bad and "aria" means air.

Hypothesis

On the basis of these observations, a logical hypothesis was formulated that "malaria is caused by plasmodium".

Do You Know?

According to the report of UNICEF more than I million people died of malaria each year throughout the world.

Deduction

If this hypothesis was true then the deduction would be stated as "**If** malaria is due to plasmodium **then** all the malarial patients should have plasmodium in their blood."

Do You Know?

Incubation Period

The time period between the entry of parasite in host and appearance the symptoms of disease is called incubation period.

Experiments

Biologists then tested this deduction by experiments.

"Blood of hundred malarial patients (experimental group) and hundred healthy persons (control group) was observed under microscope. The blood of all the patients had plasmodia. The plasmodia were not found in the blood of 97

Do You Know?

Why female *anophelese* gets blood and male does not?

Male anophelese does not suck blood. He gets food from the nector of flowers, decomposed bodies etc. The female anophelese sucks human blood to get red blood cells protein which is needed for the maturation of her eggs.

healthy persons but it was quite strange to see that plasmodia were also found in the blood of 3 healthy persons. This showed that these healthy persons will become malarial patients in near future because the plasmodia are in incubation period.

Ronald Ross (British Army physician) proved by experiments that female mosquitoes get plasmodia from malarial patients and transmit them to healthy persons.

Conclusion

The work of different biologists finally proved that plasmodium is the cause of malaria. Female *Anopheles* transmits plasmodium from patient to healthy person.

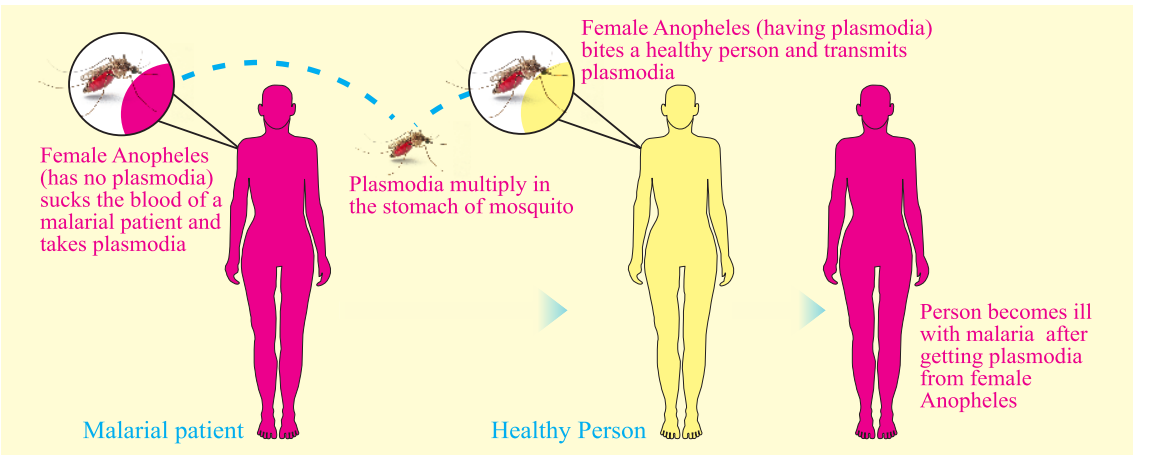


Fig.1.4: Transmission of Malaria

1-11 Role of Hypothesis, Theory and law in the Research Work of Natural Science

Hypothesis, theory and law are very important concepts in the research work to study the natural world in a scientific way. These terms represent different stages and levels of scientific research.

Hypothesis: Hypothesis is a possible answer to a problem. It is the first step of scientific research. It provides a base to a scientist to predict the possible solution of a problem. It guides a scientist to collect the facts to prove his hypothesis.

Theory: Theory is an experimentally proved hypothesis. The process of theory development involves observations, deductions and experiments. It is a well established and logical explanation of a problem. Theory is a generalized principle and the back bone of scientific understanding. For example, cell theory, theory of evolution etc.

Law: An experimentally proved theory that gives the final solution of a problem without any doubt is called scientific law. Laws are solid explanations about a matter. Scientific laws are always true and are often expressed mathematically. These are in the form of short statements. These are universally accepted, for example, Mendel's laws of inheritance

Critical Thinking

Which order of steps is correct to solve a biological problem? Mark ✓ or ✗ in the circles.

a) Recognition → Hypothesis → observations → Deduction → Experiments → Scientific theory → Scientific law

b) Recognition → Observations → Hypothesis → Experiments → Deduction → Scientific law → Scientific theory

c) Recognition → Observations → Hypothesis → Testing → Deduction → Scientific theory → Scientific law

d) Recognition → Observations → Hypothesis → Prediction → Testing → Scientific theory → Scientific law

e) Recognition → Observations → Experiments → Deduction → Hypothesis → Scientific theory → Scientific law

KEY POINTS

- The scientific study of living organisms is called biology or biological science.
- There are three main divisions of biology i.e. Botany, Zoology and Microbiology.
- All aspects of structure and function of cells will be studied in cell biology. It is also called cytology.
- The study of the development of an embryo to a new individual is called embryology.
- In genetics we study about genes, genetic variation and heredity in living organisms.
- In molecular biology we study about the structure, composition and interaction of

molecules found in organisms.

- In pathology we study about the causes and treatment of diseases in organisms.
- Ecology is the branch of biology that deals with the relation between an organism and environment.
- The study of internal structures of living organisms is called anatomy.
- The study of the functions of different parts of living organisms is called physiology.
- The scientific study of fossils is called paleontology.
- Pharmacology is the study of drugs and their effects on the cell, tissue, organ or organism.
- Biophysics is a science that uses methods and principles from physics to study the mechanisms of biological systems
- The study of different compounds and chemical processes in living organisms is called biochemistry
- Computational biology is that branch of biology in which computers are used to understand the biological systems and their relationship with other biological systems.
- The scientific study of the geographical distribution of living organisms is called biogeography.
- Biostatistics is the branch of biology in which statistical methods are used to analyze the different aspects in biology.
- Bioeconomics is the study of the living resources using economic principles.

EXERCISE

A. Multiple choice Questions (MCQs)

1. A biologist is searching new species of plants in an area, the branch of biology relevant to his work is:
   (a) Microbiology (b) Zoology
   (c) Botany (d) Genetics
2. Metabolism, enzyme actions etc., in a living body are studied in:
   (a) Morphology (b) Chemistry
   (c) Cytology (d) Biochemistry
3. The study of basic units of a living body is called:
   (a) Morphology (b) Histology

(c) Pathology (d) Cytology

4. When we observe different organs inside a human body, it means we are studying:
   (a) Morphology (b) Anatomy
   (c) Cytology (d) Histology

5. How characters are transferred from parents to their off springs is studied in:
   (a) Histology (b) Embryology
   (c) Genetics (d) Morphology

6. The science of growing gardens, fruits and ornamental plants is known as:
   (a) Forestry (b) Farming
   (c) Agriculture (d) Horticulture

7. The statement that describes the primary focus of ecology is:
   (a) The study of individuals, organisms and their characteristics
   (b) The study of interactions between organisms and their environment
   (c) The study of evolution of species over time
   (d) The study of structure and functions of ecosystems

8. Which of the following statements is accurate about microbiology?
   (a) The study of structure and function of cells
   (b) The study of evolution of species over time
   (c) The study of bacteria, viruses, fungi
   (d) The study of interactions between organisms and their environment.

9. A doctor carried out diagnostic tests of a patient to know the actual cause of disease. The branch of biology concerned with these investigations is:
   (a) Pharmacology (b) Immunology
   (c) Pathology (d) Molecular biology

10. Encircle the wrong statement:
   (a) Theory is formulated after experiments
   (b) Hypothesis is formulated after observations
   (c) Deduction is formulated after experiments
   (d) Deduction is formulated from untested hypothesis

B. Short Response Questions.

1. How the knowledge of statistics and economics helps in biological

studies?

2. How will you differentiate quantitative and qualitative observations?
3. Briefly describe horticulture, animal husbandry and fisheries.
4. Write a brief note on the relation of biology with geography, technology and physics.
5. You know that plasmodia are the cause of malaria but a healthy person having plasmodia in the blood does not show symptoms of malaria why?
6. Define the following terms:

(i) Microbiology (ii) Physiology (iii) Embryology
(iv) Histology (v) Paelentology (vi) Pharmacology
(vii) Horticulture (viii) Immunology (ix) Biological method
(x) Qualitative observations (xi) Deduction (xii) Scientific theory

C. Extended Response Questions.

1. Relate the verses of Holy Quran which stress upon the study of biology.
2. Explain four steps (observations, hypothesis formulation, deduction and experimentation) of a biological method to solve a biological problem.
3. Justify that biology is a part of Natural science.
4. Do you think that science is a collaborative field? Justify.
5. Malaria in human beings is spread by female anophlese mosquito. Explain it using biological method.

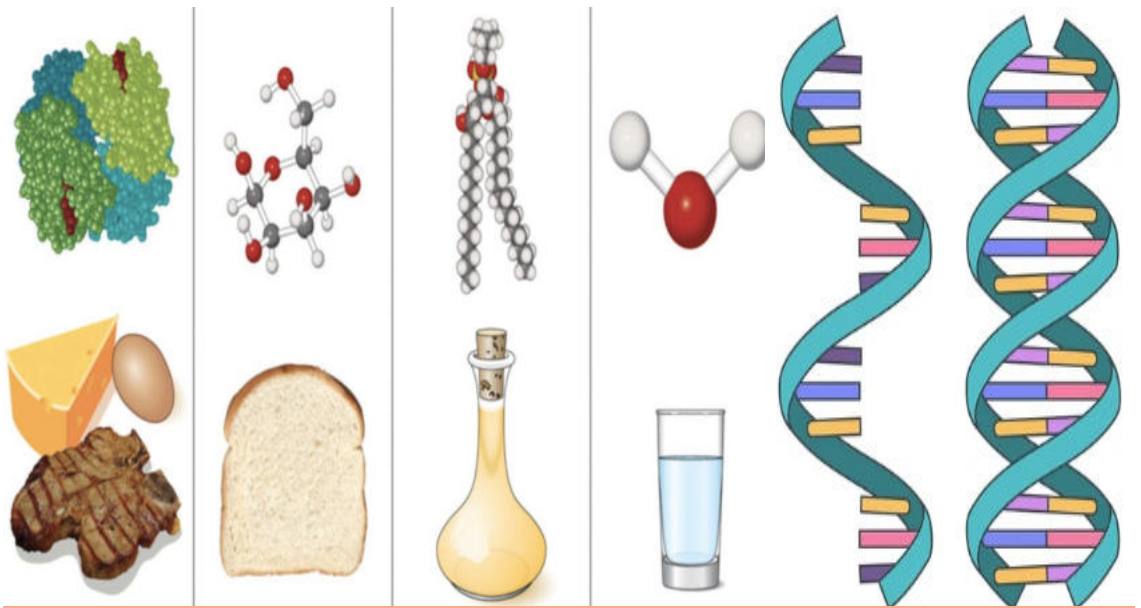
References of Ayat-e-Quran

- **Tafseer-e-Usmani:**
  i) Ayat: Page 1458, Volume-I
  ii) Ayat: Page 2294, Volume-III
  iii) Ayat: Page 2252, Volume-III
  iv) Ayat: Page 1926, Volume-III
  v) Ayat: Page 571, Volume-I
  vi) Ayat: Page 2002, Volume-III
  vii) Ayat: Page 1583, Volume-II
  viii) Ayat: Page 1240, Volume-II
  ix) Ayat: Page 2421, Volume-III

CHAPTER

2

MOLECULAR BIOLOGY



Learning Outcomes:

Students will be able to:

- Define Biochemistry / molecular biology.
- Outline the various types of common biomolecules nucleic acids (DNA, RNA, Proteins, Lipids, Carbohydrates) including their locations inside the cell and main roles.
- Define protein.
- Outline the structure and function and sources of proteins.
- Outline the structure, function and sources of lipids.
- Define Carbohydrates.

- Outline the structure, function and sources of Carbohydrates.
- Identify carbohydrates as monosaccharides, disaccharides and polysaccharides.
- 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.
- Outline function of DNA as carrier of hereditary information.
- Describe briefly the structure of RNA as single stranded macromolecule made of nucleotides with nitrogenous base overhangs.
- Describe briefly types of RNA.
- Outline the function of RNA as aid in converting hereditary information into useful proteins.
- Outline how information in the DNA is converted to information on RNA and then into proteins.

Introduction

All organisms are chemically made up of biological molecules or biomolecules, which include proteins, carbohydrates, lipids and nucleic acids. The study of biomolecules, their processing and significance for living organisms is called biochemistry. In this chapter, we will study about the sources, structures, chemical compositions, types and functions of biomolecules.

2.1 Biochemistry and Molecular Biology

Biochemistry

Biochemistry deals with the study of chemical compounds and the chemical reactions occur in living organisms.

It is a combination of biology and chemistry. Due to this reason it is called biological chemistry or biochemistry. Biochemistry explains the chemical composition of living organisms and the vital processes occurring in them, e.g. respiration, photosynthesis

Molecular Biology

Molecular biology explains the structure, composition and interactions of macromolecules (protein, lipid, nucleic acids etc.) present in living organisms.

2.2 Common Biomolecules

Living organisms contain four types of biological molecules.

1. Proteins
2. Carbohydrates
3. Lipids
4. Nucleic Acids

Do You Know?

Protoplasm is the living content of the cell that is surrounded by a plasma membrane. It is a general term for cytoplasm and nucleoplasm.

Biomolecules	Introduction	Cellular Composition	Main Roles
Proteins	Proteins the most abundant biomolecules in living bodies. They are made up of smaller units called amino acids. *Sources:* Fish, egg, Beef	They are the important constituents of cell membrane, Ribosomes, Mitochondria, Chromosomes etc.	They help in the building and repairing of tissues. Enzymes are proteins which regulate chemical reactions in organisms.
Carbohydrates	Carbohydrates are nature's most abundant bio-molecuels. They are composed off C, H and O in the ratio of 1 : 2 : 1. Their general formula is CH_2O. *Sources:* Sugar, Potato, Rice, Cotton etc.	They are present in the membranous organelles i.e. Mitochondria, Lysosome etc. They are also found in RNA and DNA.	The main role of carbohydrates is to provide energy (ATP) by the break down of glucose. They are the principal source of energy.
Lipids	Lipids are heterogeneous bio-molecules in nature. *Source:* Fats, Oils, Butter etc.	They are the constituents of membranous organelles e.g., Mitochondria, Golgi bodies, lysosome etc.	They help the movement of materials in and out of the cells. They are the reserve energy source in the body.
Nucleic Acids	Nucleic acids are very important biomolecules and are made up of smaller units called nucleotides. They are present in all living organisms as well as viruses.		

Biomolecules	Introduction	Cellular Composition	Main Roles
	Types The nucleic acids are of two types i.e. DNA and RNA.		
	(A) DNA (Deoxyribo Nucleic Acid)	DNA is present in the nucleus of cell coiled over the protein to form chromosomes. DNA is also found in mitochondria and chloroplast.	Genes, the unit of heridity, are composed of DNA. Genes control the production of specific proteins.
	(B) RNA (Ribo Nucleic Acid)	RNA is mainly found in cytoplasm of cell. It is also found in nucleolus, ribosomes, mitochondria and chloroplast.	RNA plays a very important role in the protein synthesis.

2.3 Proteins

Berzelius in 1838 suggested the name protein derived from Greek word "Proteios" which means first or prime. Proteins are very important organic compounds of the cell. Proteins comprise over 50% of the total dry weight of the cell.

Sources

There are two main sources of proteins i.e., animals and plants. Animal sources of proteins includes mutton, beef, chicken, fish, egg, milk, daily products (yogurt, cheese) etc. Plant sources of proteins include: beans, peas, spinach, pumpkins, pumpkin seeds, dry fruits (almond, peanuts), etc.

What are Vitamins?

Vitamins are organic substances that are essential for normal growth and nutrition. They are needed in minute quantities in the diet, act especially as coenzymes in the metabolic process but do not provide energy or serve as building unit. These are present in natural food stuffs or sometimes produced within body.

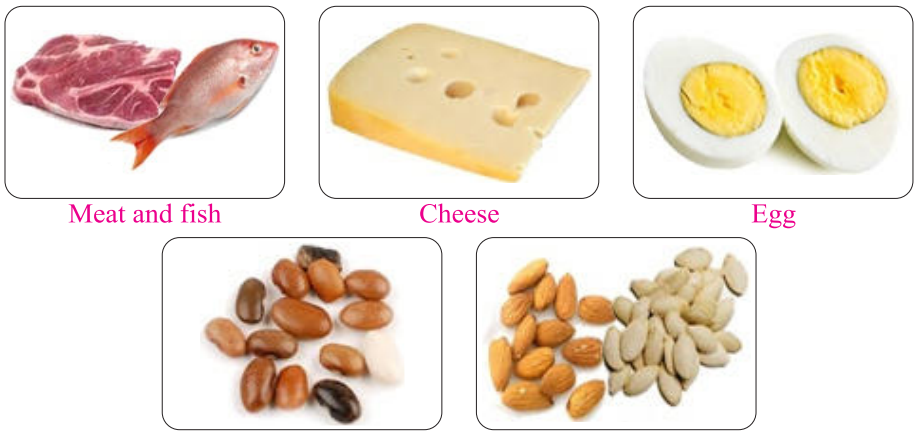
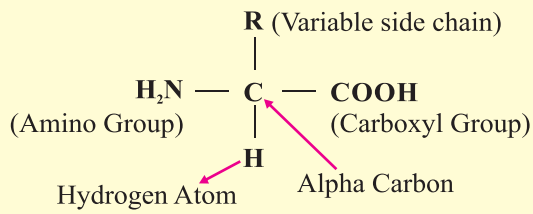


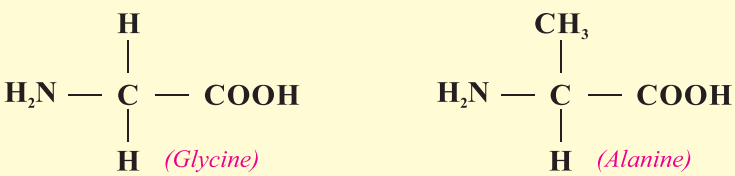
Fig. 2.1: Sources of Proteins

Proteins are made up of amino acids. Amino acids are the structural units or building blocks of proteins. Majority of protein molecules have 300 to 3000 amino-acids. Most of the proteins are made up of 20 common types of amino acids. e.g. Alanine, Glycine, Valine etc. All amino acids are built on a common plan. Each contains a central carbon atom called **"Alpha Carbon"** bonded with hydrogen atom (H), amino group ($-NH_2$), carboxyl group ($-COOH$) and a variable group (R).



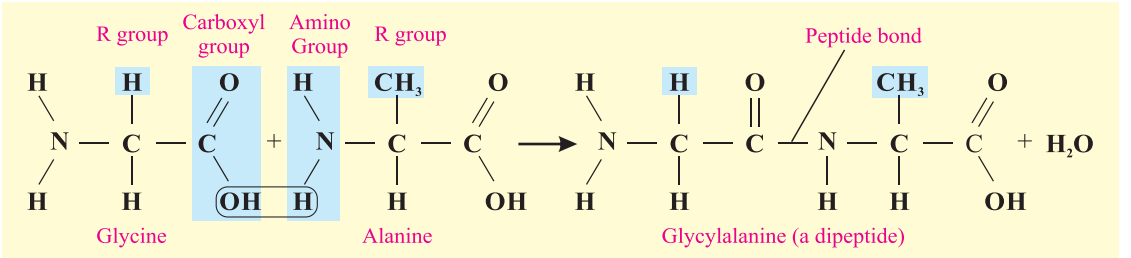
Amino acids mainly differ due to the nature of R-group which determines the individual chemical properties of amino acids.

Example:-



In a protein molecule, the amino acids are arranged like beads on a string linked

by **peptide bonds**. A peptide bond forms when the **carboxyl group** of one amino acid reacts with the **amino group** of next amino acids. An OH^- is released from COOH group of one amino acid while an H^+ is released from NH_2 group of adjacent amino acid. As a result, a water molecule is released forming a bond between N and C called the peptide bond, for example, glycine and alanine combine to form glycylalanine.



Functions of Proteins

Do You Know?

A heterogeneous compound is made up dissimilar constituents.

Proteins are involved in the synthesis of every part of the cell, for example, nuclear membrane, ribosome, mitochondria, chromosomes, lysosomes etc. Enzymes are also proteins and are very important for the chemical reactions in cell. Our muscles, nails, skins etc. are all made of protein. Haemoglobin, a protein found in blood, carries oxygen to all parts of the body. It also transports a part of CO_2. Proteins are the important source of human food, for example, meat, beef, fish. proteins help in the repairing and building of body tissues.

2.4 Lipids

Lipids are heterogeneous oily bio-molecules. The main sources of lipids are animals and plants. The important animal sources of lipids are fatty meat, fatty fish (e.g. salmon), milk, egg and dairy products (yogurt, butter, ghee, cheese) etc.

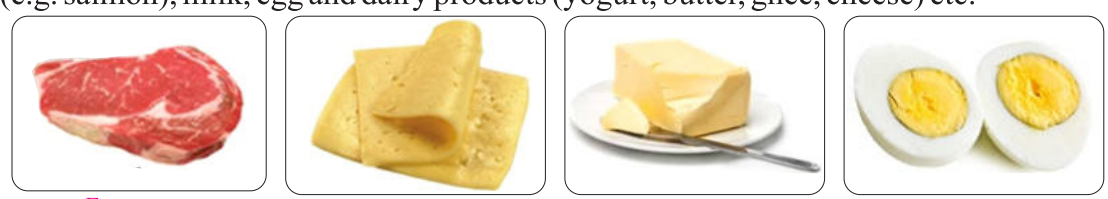


Fig.2.2: Animal Sources of Fats

The plant sources are corn, peanuts, dry fruits (walnut, pistachio, almond),

coconut etc. Oil is obtained from the seeds of many plants, for example, soyabean, sunflower, coconut, corn, cotton etc.


Sunflower


Olive


Nuts and seeds


Soyabean

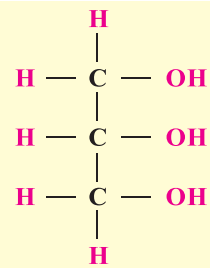
Fig.2.3: Plant Sources of Fats

Lipids are composed of C, H and O but the proportion of oxygen is less. They as compared to carbohydrates. There are many types of lipids but the most abundant lipids in living organisms are fats and oil. A neutral fat is formed by the combination of two compounds, i.e., glycerol and fatty acid.

Additional Information

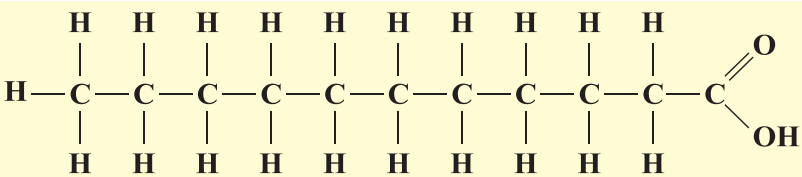
From the liver of cod fish, an oil is lipids obtained called cod liver oil, which contains vitamin A and D that keep our immune system strong. It also lowers the inflammation in the body.

1. Glycerol: It consists of a chain of three carbon atoms. Each carbon has one Hydroxyl group (OH).

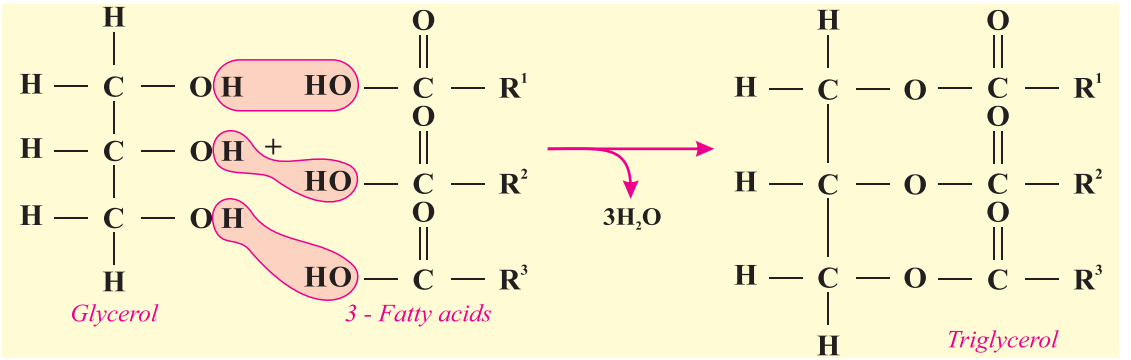


2. Fatty Acid

It is a long straight chain of carbon atoms with a carboxylic group (COOH) at one end. There are single covalent bonds between carbon and hydrogen atoms. At the end there is double covalent bond between carbon and oxygen atom while single covalent bond between carbon atom and hydroxyl group (OH).



Triglycerol is a common lipid. It is formed by the combination of one glycerol and three fatty acids with the release of three H_2O molcules.



Functions of Lipids

Lipids are reserve energy source in the body. Butter and ghee are important in human diet. Lipids help in the transportation of materials in and out of the cells. Prostaglandins, hormone like compounds that control blood pressure, regulate the contraction and relaxation of smooth muscles are lipid in nature. Lipids combine with other molecules to form conjugated molecules, for example, phospholipids are important constituents of cell membrane. Vitamin A and D are also lipid in nature. The deficiency of vitamin A causes night blindness. Vitamin "D" is necessary for bone growth.

Critical Thinking

Name that attractive force which holds two amino acids together.

2.5 Carbohydrates

Carbohydrates are complex biomolecules made of C, H and O in the ratio of 1 : 2 : 1. Their general formula is CH_2O. For example, glucose ($C_6H_{12}O_6$). These are commonly called sugars. The carbohydrates are mostly obtained from plants, for example, sugarcane, potato, carrot, cereals (wheat, rice, beans, barley, corn, grams etc.), fruits (grapes, mango, pineapple etc.). Milk is the only considerable example of animal source of carbohydrates.

Do You Know?

Too much fats in diet makes a person obese and also causes cardio vascular disorder like high B.P, heart attack etc.

Do You Know?

Carbohydrates are 50-80% of the plant's dry weight. There is less than 1% CH_2O in the bodies of animals.

Fig.2.4: Sources of carbohydrates

Functions of Carbohydrates

Carbohydrates are the main source of energy in living organisms. This energy (ATP) is generated during respiration by the break down of glucose with oxygen. Carbohydrates are stored in plants in the form of starch and are the important source of human diet, for example, potato, rice, corn, sugarcane etc. Carbohydrates are the constituents of nucleic acids, for example, ribose sugar in RNA and deoxyribose in DNA. Glucose is the major product of photosynthesis. We know that the life of other organisms directly or indirectly depends upon autotrophic plants. Carbohydrates combine with other compounds to form new compounds, e.g. Glycoproteins, Glycolipids etc. These compounds are the constitutents of plasma membrane. Carbohydrates provide energy for cell division.

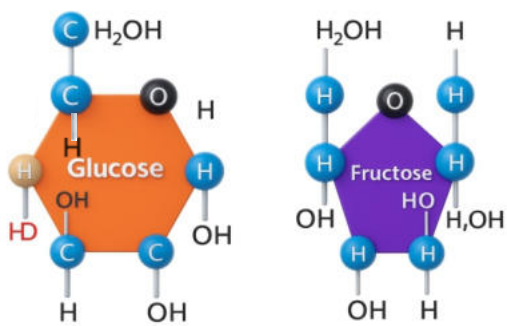
2.6 Types of Carbohydrates

Carbohydrates are divided into three classes i.e., Monosaccharides, Disaccharides and Polysaccharides.

A) Monosaccharides

(Simplest Sugar)

Monosaccharides are true carbohydrates. These are simple sugars with only one saccharide



Monosaccharides

molecule (3-7 carbon). These are colourless, crystalline solids. These are sweet in taste and are easily soluble in water. Their general formula is $C_nH_{2n}O_n$, for example, glucose, fructose etc.

Activity

Write down the general formula of mono, Di and polysaccharides:
i) Monosaccharide =
ii) Disaccharide =
iii) Polysaccharide =

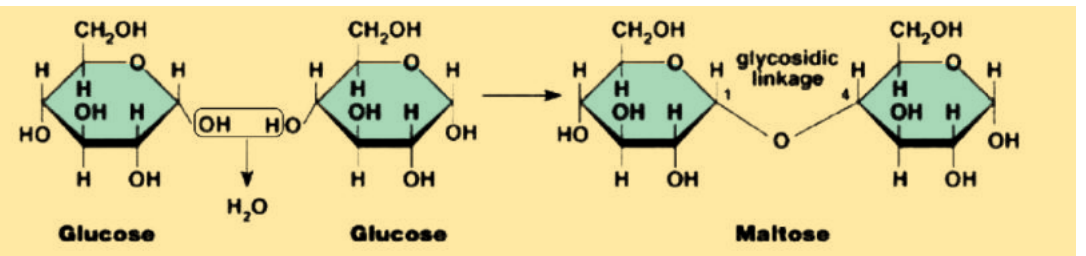
B) Disaccharides

Disaccharides are made up of two monosaccharide units. The most common disaccharides found in nature are maltose, lactose, sucrose, etc. These are less sweet in taste than monosaccharides. These are less soluble in water as compared to monosaccharides. Their general formula is $C_{12}H_{22}O_{11}$. Disaccharides give two monosaccharide units on hydrolysis.

Example

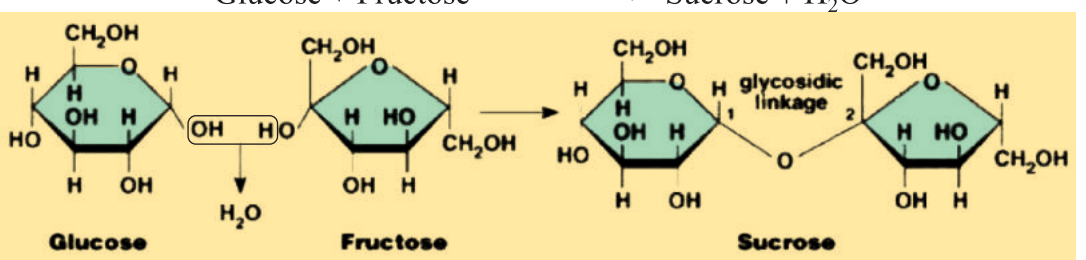
Maltose: It is formed by the union of two glucose molecules forming a glycosidic linkage.

Glucose + Glucose ⟶ Maltose + H_2O



Sucrose (Table Sugar): It is formed by the union of glucose and fructose forming a glucosidic linkage.

Glucose + Fructose ⟶ Sucrose + H_2O



C) Polysaccharides

Polysaccharides contain a large number of monosaccharide units (more than 10). These are the most common and complex carbohydrates in nature. Their general formula is

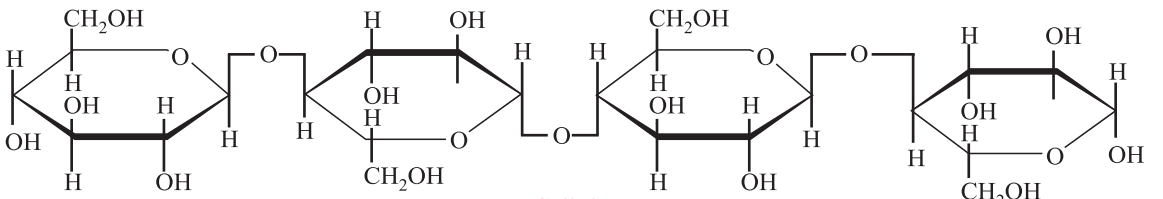
Additional Information

Lipids provide 9Kcal/gm energy while proteins and carbohydrates provide 4Kcal/gm energy.

$(C_6H_{10}O_5)_n$. These are not very reactive chemically. Polysaccharides usually have branched structure. These are non-crystalline, tasteless and insoluble in water but sparingly soluble in hot water.

Critical Thinking

What is difference between ribose and deoxy ribose sugars?



Cellulose

2.7 Structure of DNA

DNA (Deoxyribonucleic Acid) is a polynucleotide chain made up of many nucleotides. Each nucleotide is itself a complex compound composed of three components.

Activity

Write down the structural formula of alanine, glycerine, glycerol, triglycarole, glucose and fructose.

1. Nitrogenous bases: These are two types:
   a) Purine (Adenine, Guanine)
   b) Pyrimidine (Cytosine, Thymine)
2. Pentose (5-carbon) Sugar (Deoxyribose sugar)
3. Phosphate group (—PO_4)

Critical Thinking

How will you identify the three types of carbohydrates on the basis of taste and solubility in water.

In DNA molecule, there are four types of nucleotides. The nucleotides are named due to the nitrogenous base they contain i.e., Adenine nucleotide, Guanine nucleotide, Cytosine nucleotide and Thymine nucleotide.

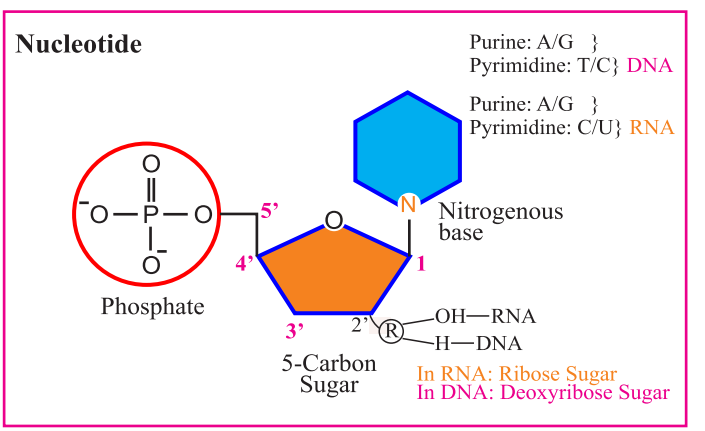


Fig.2.5: Nucleotide

Watson and Crick Model of DNA

James Watson (an American biologist) and Francis Crick (an English chemist) designed a model of DNA in 1953. Due to their unique work, they were awarded Nobel prize in 1962.

Each DNA molecule is made up of two polynucleotides chains / strands which run in opposite direction to each other, twisted into a double helix. The backbone of the ladder (chains) are made of alternately arranged units of phosphate group and pentose sugar. One complete turn of the helix has ten base pairs and 3.4 nm in length. The diameter of DNA molecule is about 2nm (20A°). The two chains are linked just like rungs (steps) in a ladder by the pairs of bases (Purines and Pyrimidines). Each rung consist of a purine matched with pyrimidine. The matching of the bases in highly specific, i.e. A = T, C ≡ G. In a DNA molecule, the amount of adenine is equal to that of thymine and the amount of guanine is equal to that of cytosine.

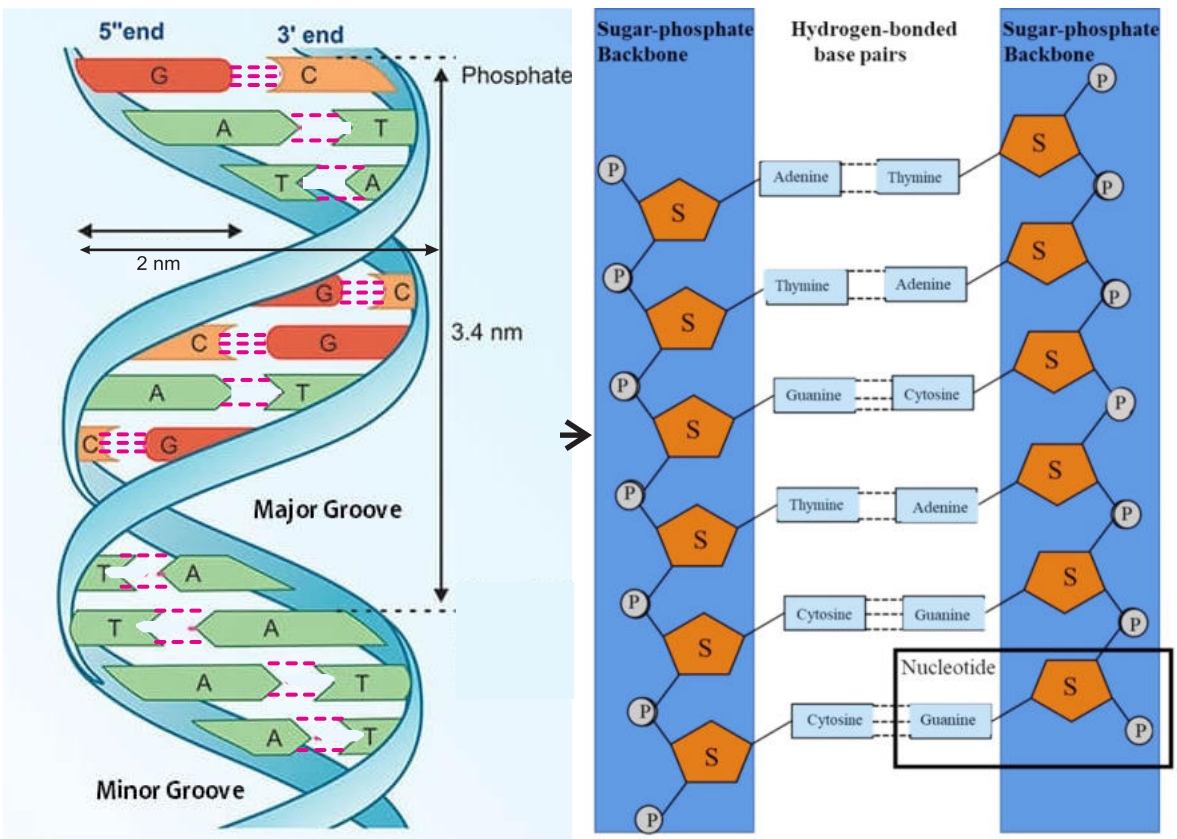


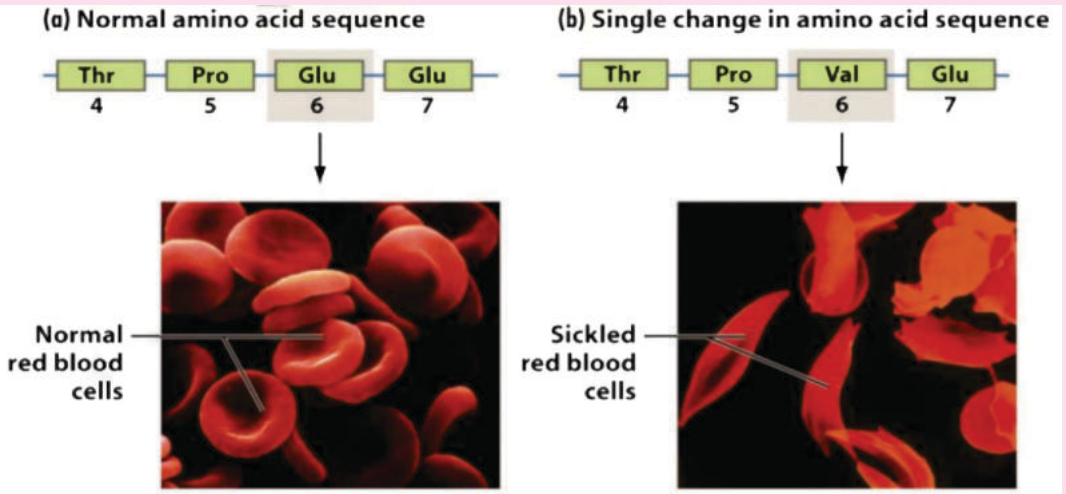
Fig.2.6: DNA

2.8 Function of DNA

DNA is the hereditary material. It transfers characters from parents to offsprings for example, skin colour, blood groups, etc. DNA controls the development and functioning and all living organisms. The transfer of hereditary informations is carried out by genes. It is the short specific portion of DNA. It is the unit of heredity. Each gene contains instructions to build specific proteins. The proteins are responsible for traits and functions in the body.

Additional Information

Arrangement of bases (A.G.C.T) in a gene is highly specific. Any change in the base arrangement will change the gene. This change is called mutation. Due to mutation, faulty informations are transferred to next generation. As a result, the structure of protein will be changed. This faulty protein may become fatal for an organism. (e.g.) in sickle cell anemia, the shape and function of RBCs are changed due to the replacement of only one amino acid out of 574 i.e., glutamic acid (in normal RBC's) by valine (Sickle RBC's).



Sickle Cell

2.9 Structure of RNA

RNA is a single polynucleotide chain. In this chain, many nucleotides are arranged in a linear sequence. Each nucleotide is made up of three different components.

1. **Nitrogenous Bases:** These are of two types:
   (a) Purine (Adenine, Guanine)

(b) Pyrimidine (Cytosine, Uarcil)

2. Pentose Sugar (5-Carbon) (Ribose Sugar)

3. Phosphate Group (—PO_4)

There are four types of nucleotide i.e., Adenine nucleotide, Guanine nucleotide, Cytosine nucleotide and Uracil nucleotide.

These nucleotides link together to form a polynucleotide chain of RNA.

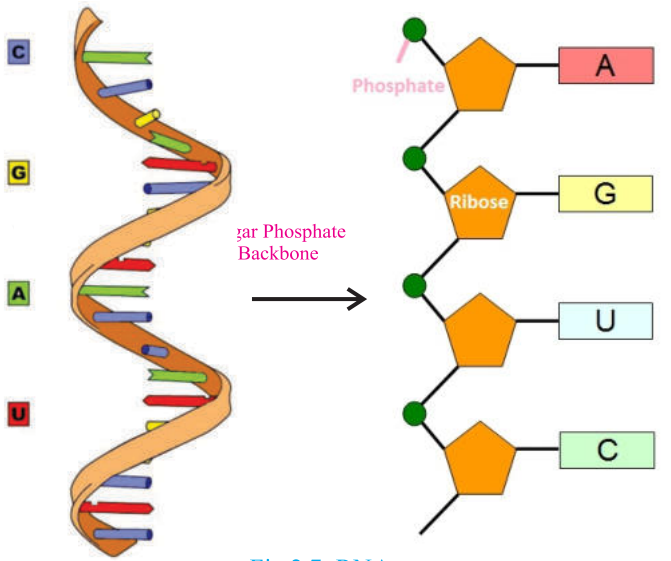


Fig.2.7: RNA

RNA Model

The RNA is a single stranded structure. It is an un-branched poly nucleotide chain. The single strand is made up of sugar and phosphate i.e. in the S – P – S manner. Nitrogenous bases are attached with the sugar.

Types of RNA

There are three types of RNA i.e., messenger RNA (mRNA), transfer RNA (tRNA) and ribosomal RNA (rRNA).

Do You Know?

mRNA is 3-5%, tRNA is 15% and rRNA is 80% of total RNA in a cell.

1. Messenger RNA (mRNA)

It is formed by DNA inside the nucleus. It is the direct complimentary copy of DNA. It consists of single strands of variable lengths. Its length depends upon the size of gene. For example, for a molecule of protein consisting of 10 amino acids, the mRNA will have the length of 30 nucleotides.

2. Transfer RNA (tRNA)

It is formed by DNA inside the nucleus. It is the smallest RNA. It is clover shaped and made up of 73-94 nucleotides.

3. Ribosomal RNA (rRNA)

It is also formed by DNA inside the nucleus. It consists of a single strand which coils at many places. In human beings one rRNA consists of about 1800 nucleotides.

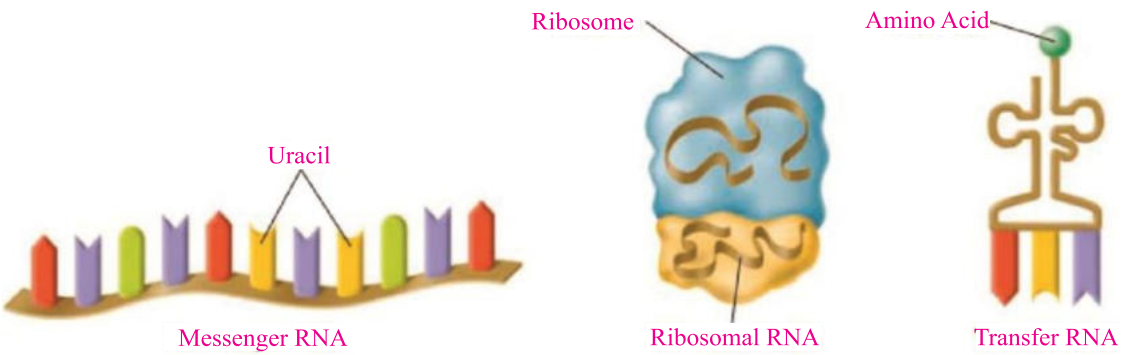


Fig.2.8: Types of RNA

2.10 Function of RNA

RNA is a carrier of information from DNA. Most plant viruses and some animal viruses have RNA as their genetic material instead of DNA. All the three types of RNAs are used in the process of protein synthesis.

Messenger RNA carries the genetic information in the form of codons from DNA to ribosomes. The tRNA brings the amino acids according to the information in the mRNA to form specific protein molecule. Each tRNA picks a specific amino from cytoplasm and takes it to a specific codon on mRNA for protein synthesis. The rRNA is associated with ribosome. It helps in the assembly of amino acids in protein molecules.

2.11 Protein Synthesis

The process of protein synthesis is same in all organisms. In this process the information in DNA is converted to information on mRNA and this information is used to form protein. This whole process is called **gene expression** or **central dogma**.

The process of protein synthesis is completed in two main phases i.e. transcription and translation.

Critical Thinking

Why are DNA and RNA called nucleic acids?

A. Transcription

It is a process by which information in a strand of DNA is directly copied in mRNA strand. This process occurs inside the nucleus. In this process, a specific portion of DNA (gene) that codes for a specific protein, opens by the breaking of hydrogen bonds between nitrogenous bases. A single strand of mRNA (messenger RNA) is formed by pairing the exposed bases on one strand of DNA. The bases on mRNA are complimentary to the bases on DNA.

After the formation of mRNA, the two strands of DNA recoil to resume their double helical structure. The newly formed mRNA now comes out into the cytoplasm through the nuclear pores.

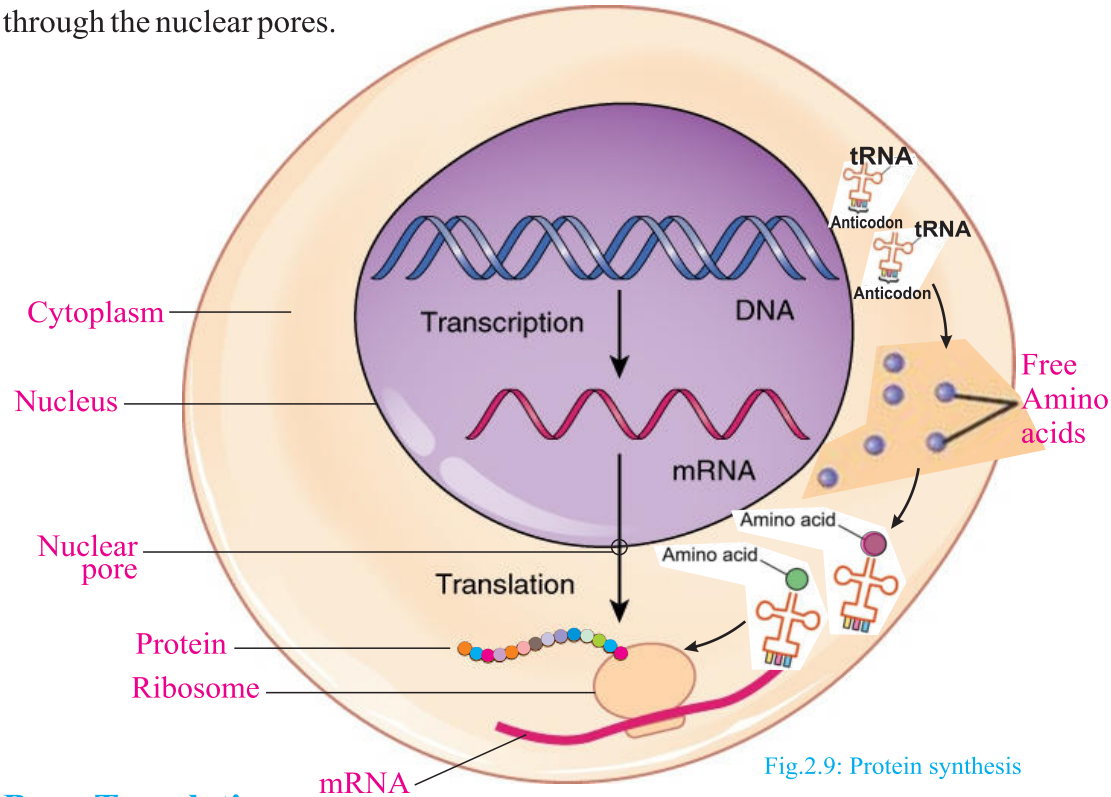


Fig.2.9: Protein synthesis

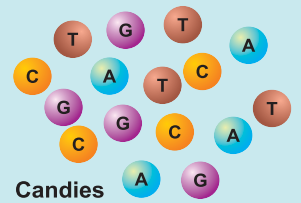
B. Translation

It is a process in which proteins are formed by using RNA molecules. This process occurs in the cytoplasm. The mRNA binds to a ribosome. The information for protein synthesis are present on mRNA in the form of codons (a set of three adjacent bases on mRNA). Each codon codes for a specific amino acid. These codons are translated by tRNA. There are about 40-60 different types of tRNA in cytoplasm. Each transfer tRNA has a set of three bases called anticodon. This anticodon is

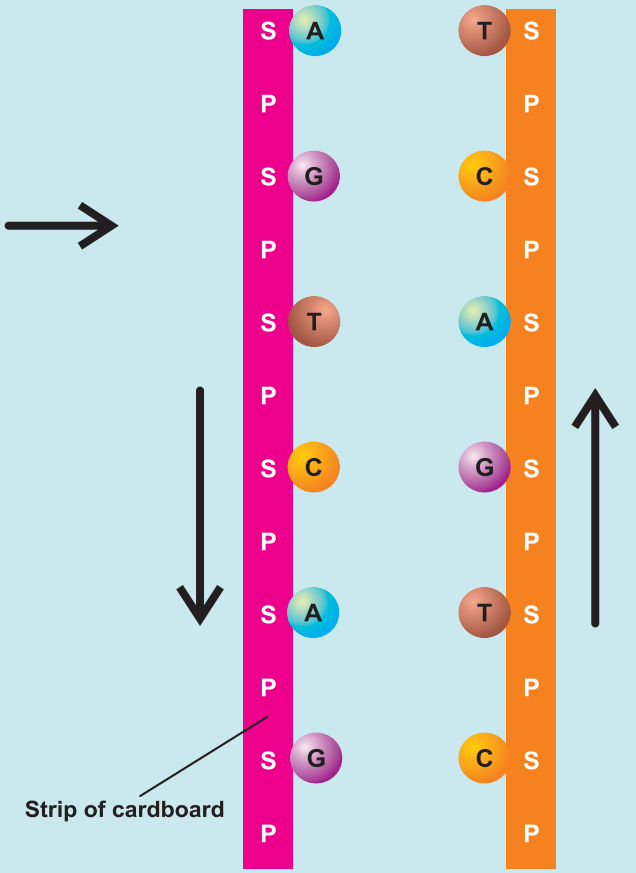
complimentary to codon on mRNA. After matching its anticodon with codon on mRNA, it transfers its amino acid to mRNA. In this way, all amino acids are transferred by tRNA to all the codons on mRNA after matching their anticodons. The amino acids are linked by peptide bonds. In this way, a specific protein is formed by the information provided by DNA.

STEAM ACTIVITY

Construct the models of DNA and RNA by using different materials like strips of cardboard, wooden sticks (used in barbecue), beads, metal wires, soft candies, small plastic balls, wooden toothpick



A = Adenine
T = Thymine
G = Guanine
C = Cytosine



KEY POINTS

- Biochemistry is the branch of science in which we study about chemical compounds and the chemical reactions that occur in living organisms.
- Molecular biology is the branch of biology in which we study about the living organisms at their molecular level.
- There are four types of organic compounds in living bodies i.e. proteins, carbohydrates, lipids and nucleic acids.
- Two amino acids join with each other by a special bond called peptide bond or peptide linkage.
- Lipids are oily heterogeneous biomolecules related to fatty acids.
- The carbohydrates are of three types i.e. monosaccharides, disaccharides and polysaccharides.
- DNA is a polynucleotide. It is a polymer of many nucleotides.
- The model of DNA was proposed by James Watson and Francis Crick in 1953.
- Each DNA molecule is made up of two polynucleotide chains which are twisted around each other. It looks like a twisted ladder.
- Gene is a unit of heredity. It is a specific portion of DNA with specific sequence of nucleotides.
- The change in the DNA or gene is called mutation.
- RNA is a single stranded polynucleotide chain.
- RNA is a carrier of genetic information from DNA.
- RNA helps the DNA in protein synthesis.
- There are three types of RNA i.e. mRNA, tRNA and rRNA.
- The process of protein synthesis is same in all organisms. In this process information in DNA is converted to information on mRNA and this information is used to form protein. This whole process is called gene expression or central dogma.
- The process of protein synthesis is completed in two main steps. i.e. transcription and translation.
- A set of three adjacent bases or nucleotides on mRNA is called codon.
- A set of three bases or nucleotides on tRNA are called anticodon.

EXERCISE

A. Multiple choice Questions (MCQs)

1. One of the following groups contains all polysaccharides:
   (a) Sucrose, glucose and fructose (b) Maltose, lactose and fructose
   (c) Glycogen, sucrose and maltose d) Glycogen, cellulose and starch
2. The most abundant biomolecules in living bodies are:
   (a) Lipids (b) Proteins
   (c) Carbohydrates (d) Nucleic acids
3. Sucrose is found by the combination of:
   (a) Two glucose (b) Glucose and Fructose
   (c) Two fructose (d) Maltose and Manose
4. The carbohdyrate abundant in plants is:
   (a) Glucose (b) Cellulose
   (c) Maltose (d) Sucrose
5. The diametr of DNA molecule is about;
   (a) $2A^{\circ}$ (b) $4A^{\circ}$
   (c) $20A^{\circ}$ (d) $40A^{\circ}$
6. Proteins are synthesized from;
   (a) Glucose (b) Fatty acids
   (c) Amino acids (d) Nucleotide
7. Which one is not true about lipids?
   (a) Vitamin A and D are lipids in nature
   (b) Lipids are reserve energy in the body
   (c) There are the main source of energy in living organisms
   (d) Prostaglandins are lipids in nature
8. The pyrimidine nitrogeous bases in RNA are:
   (a) Cytocine and uracil (b) Adanine and Guanine
   (c) Thiamine and cytocine (d) Thiamine and Uracil
9. The primary function of carbohydrates in living organisms is to:
   (a) Provide structural support
   (b) Serve as primary source of energy
   (c) Store genetic information
   (d) Catalyze biochemical reactions
10. The primary difference between DNA and RNA in terms of structure is:
    (a) DNA is single stranded and RNA is double stranded

(b) DNA contains the base uracil while RNA contains thymine
(c) DNA has 2-OH groups while RNA does not
(d) DNA is double stranded while RNA is typically single stranded

11. The term for the process by which genetic information is passed from DNA to RNA is:
(a) Translation (b) Transcription
(c) Replication (d) Mutation

12. Which of the following is responsible for converting information in DNA to form protein?
(a) Messenger RNA (mRNA) (b) Transfer RNA (tRNA)
(c) Ribosomal RNA (rRNA) (d) Small nuclear RNA (SnRNA)

B. Short Response Questions.

1. Name the four common biomolecules alongwith their main roles.
2. Write a note on the general structure of amino acids.
3. What are monosaccharides?
4. Write functions of lipids.
5. What do you understand by term glycosidic linkage?
6. What are the hydrolysis product of sucrose and Maltose?
7. Give a comparison of DNA and RNA.
8. Write down the names of nucleotides found in RNA and DNA.
9. Write down the functions of DNA.
10. The two strands in DNA are not identical but are complementary. Give reason.
11. Write the important structural and functional differences between DNA and RNA.
12. Name the different types of RNA found in the cell?
13. Define the following terms.
(i) Biochemistry (ii) Molecular biology
(iii) Carbohydrates (iv) Proteins
(v) Glycerol (vi) Protoplasm
(vii) Polysaccharides (viii) Peptide bond
(ix) Transcription (x) Translation

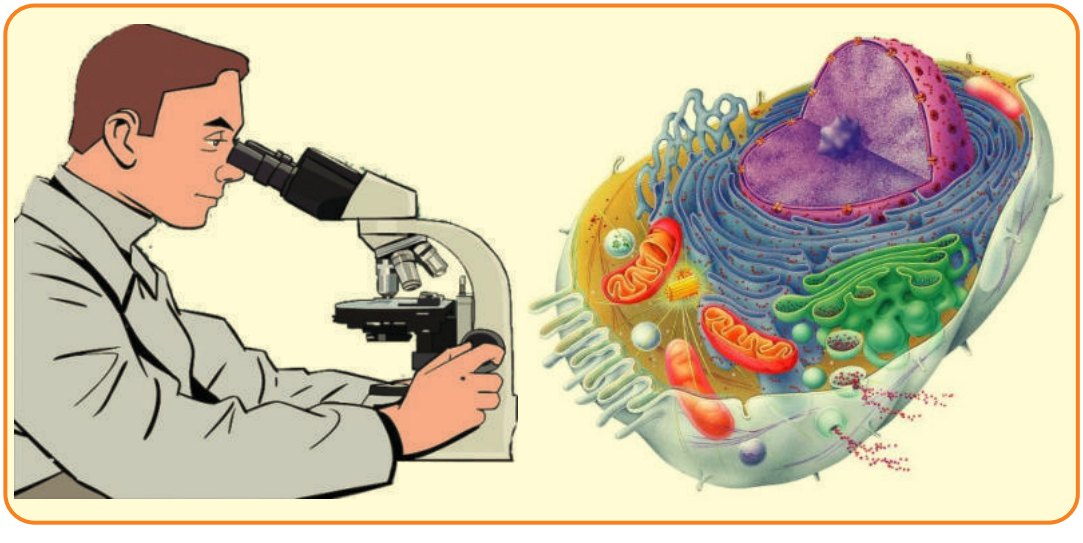
C. Extended Response Questions.

1. How are amino acids linked to form proteins?

2. What are the two kinds of subunits that make up a fat molecule, and how are they arranged in the molecule?
3. Write down the functions of proteins.
4. What are carbohydrates? Write down the properties of disaccharides and polysaccharides.
5. Explain the Watson and Crick model of DNA.
6. What are the three components of a nucleotide? How are nucleotides linked to form nucleic acids?
7. What is central dogma or gene expression? Explain.

CHAPTER
3

CELL AND SUBCELLULAR ORGANELLES



Learning Outcomes:

Students will be able to:

- Describe cell as the basic unit of life.
- Compare with diagrams the structure of animal and plant cells.
- Sketch different sub-cellular organelles (nucleus, mitochondria, cell membranes, etc) and outline their roles.
- Outline structural advantages of plant and animal cells.
- Identify different types of cells (mesophyll cell, epidermal cell, neurons, muscle, red blood cell, liver cell) and sketch their structures.
- Describe the concept of division of labor and how it applies to:
  - ♦ within cells (across sub-cellular organelles)

- ♦ multicellular organisms (across cells)
- Describe Cell Specialization.
- Describe Cell cycle.
- Explain mitosis, meiosis and stages of mitosis, meiosis (by use of sketch and diagrams)
- Explain meiosis and stages of meiosis (by use of sketch and diagram).
- Compare the processes of mitosis and meiosis.
- Outline the signification of mitosis and meiosis.
- Define Stem cells as unspecialized cell.

Introduction

All organisms are made up of cells. We know that new cells arise from the division of pre-existing cells. The division of cells is completed after passing through many phases. The specific process of cell division is called cell cycle. There are two types of cell divisions in living organisms i.e mitosis and meiosis. The division of body cells is called mitosis. In this process one diploid cell (2n) divides to form two new diploid daughter cells. The growth of organisms depend upon mitosis. The division of sex cells is called meiosis. In this process one diploid cell (2n) divides to form four haploid (n) cells called gametes. The sexual reproduction in organisms depends upon meiosis.

In this chapter we will study the structure of plant and animal cells, different types of cells, division of labour within a cell and labour across the cells. Futher, we will also study about the mitosis and meiosis in detail.

3.1 Cell is the basic unit of Life

The organisms may be **unicellular or multicellular.** Cell is the smallest structural and functional unit of life. The cells of different organisms may be different in shapes and sizes but structurally all of them are nearly similar. The activities of an organism is the sum of all the activities of the cells present in that organism. Cells having similar functions group together to form tissues. The animal and plant tissues are different in shapes and functions.

On the basis of structure the cells are of two types i.e **prokaryotic cell** and **eukaryotic cell.** The prokaryotic cell lack nuclear membrane around nucleus while eukaryotic cell contains well developed nuclear membrane.

3.2 Animal and Plant Cell

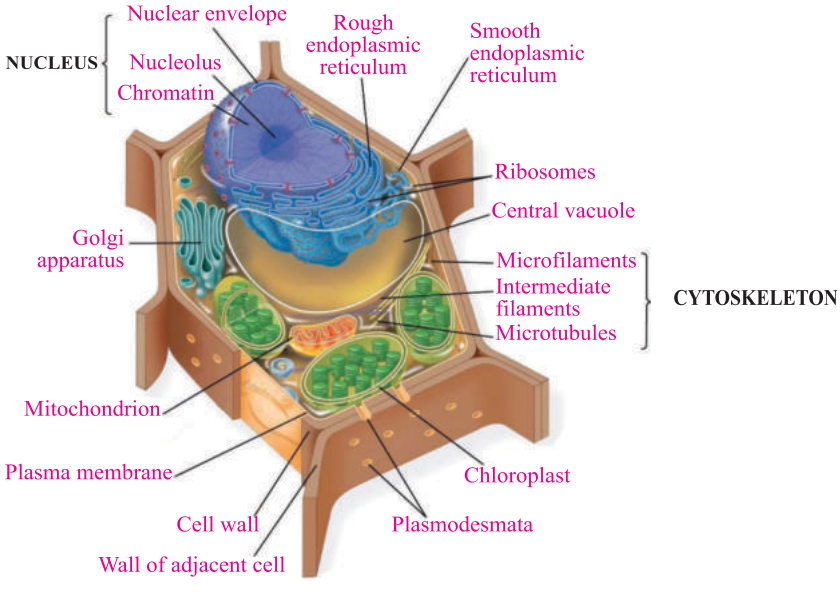


Fig.3.1: The Ultra Structure of a Plant Cell

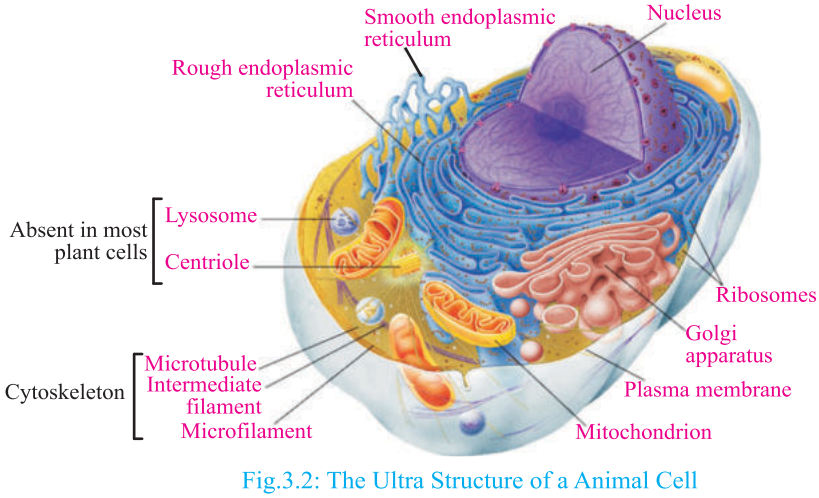


Fig.3.2: The Ultra Structure of a Animal Cell

3.3 Subcellular Organelles

An organelle is sub-cellular structure which has specific function. It performs one or more functions within the cell. There are many types of organelles within a cell. Each organelle has different shape, size and function. Some organelles of plant cells are different from that of animal cells. The organelles of two types i.e., membranous and

non-membranous. Membranous organelles are bounded by plasma membrane while non-membranous organelles have no outer membrane.

Membranous Organelles	Non-membranous Organelles
i) Nucleus ii) Endoplasmic Reticulum iii) Golgi bodies iv) Mitochondria v) Lysosomes vi) Plastids vii) Vacuoles	i) Ribosome ii) Centrioles iii) Cytoskeleton

Table 3.1: Membranous and Non-membranous Organelles

All the organelles are present in cytoplasm. The cytoplasm provides the medium for the organelles to carry out their functions.The detail of subcellular organelles is discussed below:

1. Cell Wall

It is outermost, hard and non-living covering around the cells of prokaryotes, fungi and plants.

In prokaryotes the cell wall is composed of special compound called **peptidoglycan.** It is a complex compound which is made up of sugars and amino acids. The cell wall of fungi contains a special compound called **chitin.**

The cell wall of plants usually have two layers i.e. outer primary and inner secondary wall. Secondary wall is thicker than primary wall. Primary wall is mostly composed of cellulose. The secondary wall is composed of lignin and some other compounds. There are small pores between the cell walls of two adjacent cells called plasmodesmata.

Cell wall gives shape to the cell. It protects the cell from mechanical damage and infection. Cell wall also helps in cell-to-cell interaction. The cytoplasmic connection between two adjacent cells is due to plasmodesmata, which helps in the transportation of materials among cells.

2. Cell Membrane

Cell membrane or plasma membrane is a thin and elastic membrane. It is present around the cytoplasm of all prokaryotic and eukaryotic cells. In animal cells it is the

outer most boundary. In prokaryotes, fungi and plants it is present under the cell wall.

Cell membrane consists of lipid bilayer with embeded proteins. Some of these proteins have attached chains of carbohydrates. The cell membrane is mainly composed of about 60-80% proteins and 20-40% lipids with small quantities of carbohydrates. However, this percentage varies from cell to cell.

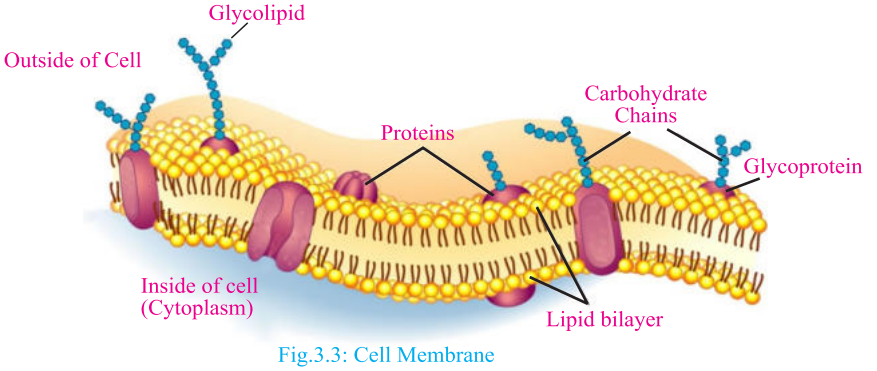


Fig.3.3: Cell Membrane

The cell membrane separates the intracellular components of cell from extracellular environment. It acts as a semi permeable barrier i.e it allows some molecules to pass while prevents the movement of others through it. It controls the transport of materials in (endocytosis) and out (exocytosis) of cell. The chemical messages from one cell to another cell are transmitted through the cell membranes.

Do You Know?

Glycoproteins are special compounds which are composed of carbohydrates and proteins while glycolipids are made up of proteins and lipids.

3. Cytoplasm

It is a gelatinous and semi transparent fluid which contains variety of cell organelles. It contains about 90% water, many organic molecules (proteins, carbohydrates, lipids) and inorganic salts are also present in cytoplasm. It is present between nucleus and cell membrane.

It acts as a site for various metabolic reactions e.g. Glycolysis. It provides suitable conditions for metabolic reactions. Cytoplasm contains various organelles e.g ribosomes, golgi bodies, mitochondria etc.

4. Cytoskeleton

The cytoskeleton is a network of interconnected filaments and tubules that extend from the nucleus to the plasma membrane in eukaryotic cells. The cytoskeleton

consists of microtubules, micro filaments and intermediate filaments.

Microtubules are involved in cell division and are major components of cilia and flagella. Microfilaments or actin filaments are associated with the shape and structure of cell. Intermediate filaments help in giving the shape and strength to the cell.

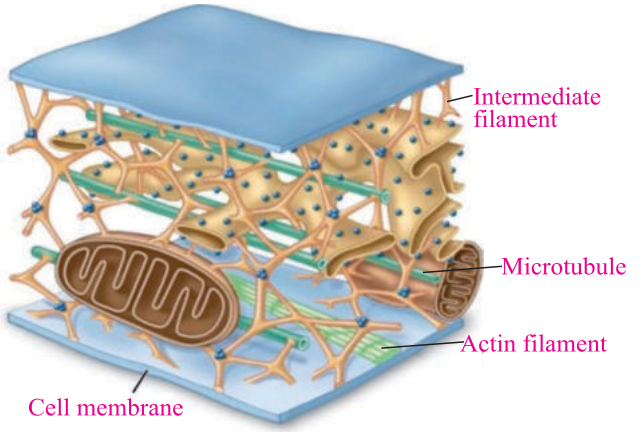


Fig 3.4: Cytoskeleton

5. Nucleus

In 1831, Robert Brown discovered the nucleus in the plant cell. Nucleus is the most prominent organelle within the eukaryotic cell. In animal cell it lies in the centre but in plant cell it lies on one side due to the presence of a large central vacuole.

The nucleus is bounded by a double perforated semi permeable membrane known as the nuclear envelope or nuclear membrane. This membrane separates the nucleus from cytoplasm. The semifluid content of the nucleus is called nucleoplasm which contains nucleolus and chromosomes. The nucleolus is a dark rounded body made up of RNA and protein. It produces ribosomes and ribosomal RNA. The chromosomes are thread like structures. In a non dividing cell, they are in the form of a network of fine threads and are called chromatin.

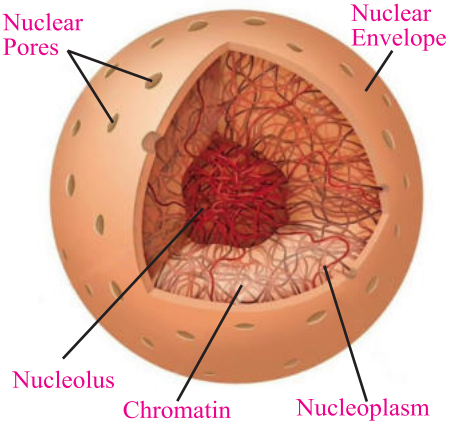


Fig 3.5: Structure of Nucleus

Critical Thinking

Which human cells do not possess nucleus and which cells are multinucleated?

Nucleus is called the brain of cell because it controls the activities of cell like protein synthesis, metabolism, cell division, growth etc. It stores hereditary material in the form of DNA.

6. Endoplasmic Retriculum (ER)

It is a network of interconnected tiny tube like structures called **cisternae**. There are cisternal spaces among cisternae. The network of ER is scattered in the cytoplasm from nuclear envelope to the plasma membrane. The ER are of two types.

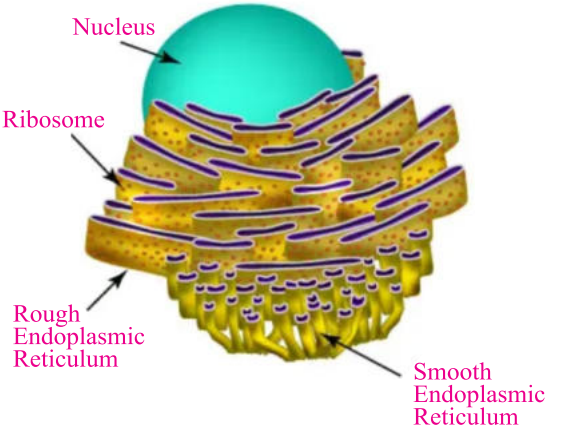


Fig.3.6: Smooth and Rough Endoplasmic Reticulum (ER)

i) Rough Endoplasmic Reticulum (RER)

The endoplasmic reticulum having many attached ribosomes on its surface are called rough endoplasmic reticulum (RER).

ii) Smooth Endoplasmic Reticulum (SER)

The endoplasmic reticulum without attached ribosomes are called smooth endoplasmic reticulum (SER).

"RER" are frequently observed in those cells which are actively involved in protein synthesis and secretion. "SER" synthesize the phospholipids present in membranes. In the liver, they help to detoxify drugs. They are also involved in the transport of large molecules to other parts of

7. Golgi Apparatus

The Golgi apparatus is named after Camillo Golgi, who discovered them in 1898. They consists of a set of flat and disc shaped sacs called **cisternae.** The cisternae are present one above the other in a specific manner. The complete set of cisternae is called Golgi apparatus. They are present both in plants and animals. They are arranged near the nucleus.

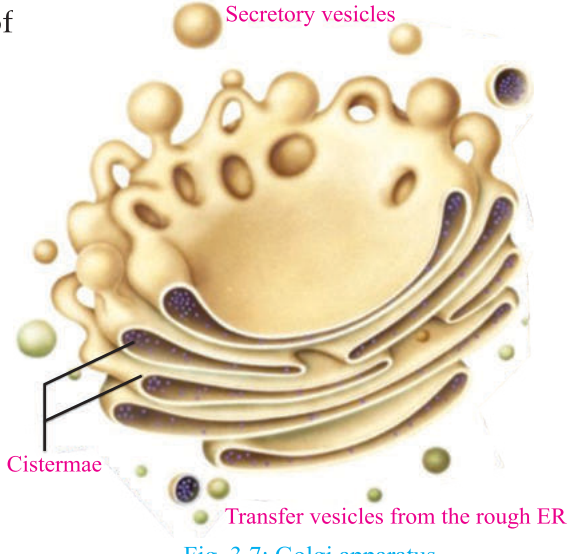


Fig. 3.7: Golgi apparatus

In Golgi complex the proteins and lipids received from the ER are modified and packed into small membrane bounded sacs called Golgi vesicles.

The vesicles which leave the Golgi apparatus move to other parts of the cell. Some vesicles proceed to the plasma membrane, where they discharge their contents outside the cell.

Tid Bit

Mitochondria are also called:

- Power house of the cell or ATP mill in cell.
- Cell furnace or storage batteries.
- Most busy and active organelle in cell.
- Semi autonomous cell organelle.

8. Mitochondria

(Singular Mitochondrion)

Mitochondria were first discovered by Altmann in 1894.

Mitochondria are filamentous structures surrounded by a double-layered membrane. There is a gap between the two membranes. The outer membrane of mitochondrion has smooth surface while the inner membrane forms a number of in foldings called **cristae**. The cristae increase the surface area of inner membrane. Inside the cristae there is a space which is filled by a fluid like material called **matrix**. Matrix contains many types of chemical compounds. Matrix also contains ring like DNA molecules, RNA molecules and ribosomes.

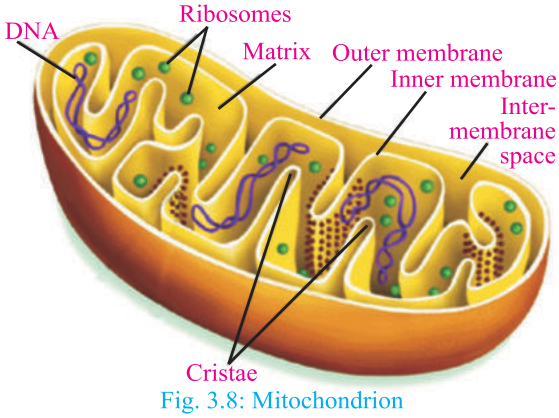


Fig. 3.8: Mitochondrion

Mitochondria produce cellular energy in the form of ATP, hence they are called 'power houses' of the cell.

9. Ribosomes

Ribosomes are granular structures. They were first observed under the electron microscope by George Palade in 1953. They are formed in nucleus. Ribosomes are found both in prokaryotic and eukaryotic cells. They are found free in the cytoplasm or attached with the surface of rough endoplasmic

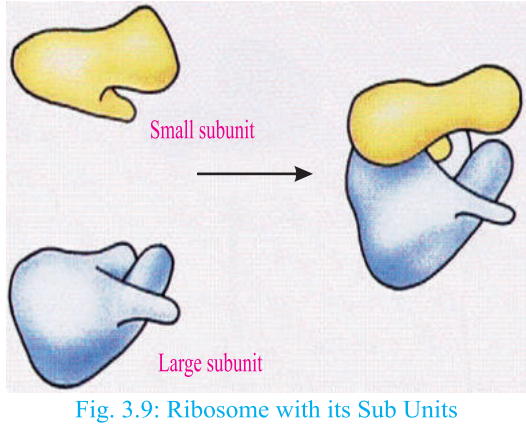


Fig. 3.9: Ribosome with its Sub Units

reticulum. Cells of eukaryotes have larger ribosomes than prokaryotes.

The ribosomes are composed of equal amount of RNA and protein. Each ribosome has two sub units i.e. smaller unit and a larger unit. They are not bounded by membrane.

Ribsomoes are called the protein factories of cell because they play key role in protein synthesis.

10. Centrioles

These are two hollow cylindrical bodies which are formed by the division of centrosome. Each centriole is made up of '27' microtubules. There are **'9' triplet** sets of microtubules. The microtubules are made up of special protein called tubulin. These organelles are not found in plants. They are clearly visible during the division of animal cells.

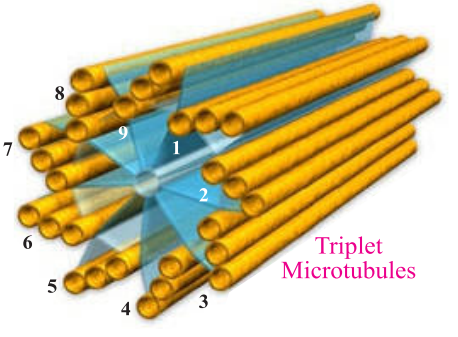


Fig. 3.10: Centriole showing triplet Microtubules

The centrioles form spindle fibers during cell division. The centrioles are also involved in the formation of cilia and flagella in some cells.

11. Lysosomes

Lysosomes are those organelles which are formed by Golgi apparatus. They were discovered by Christian de Duve in 1949.

They are bounded by single membrane which encloses effective digestive enzymes.

The digestive enzymes of lysosomes are capable of digesting various compounds like carbohydrates, proteins, lipids and nucleic acids etc. The lysosomes not only help in intracellular and extracellular digestion but also break down the waste products. They also play a very important role in the

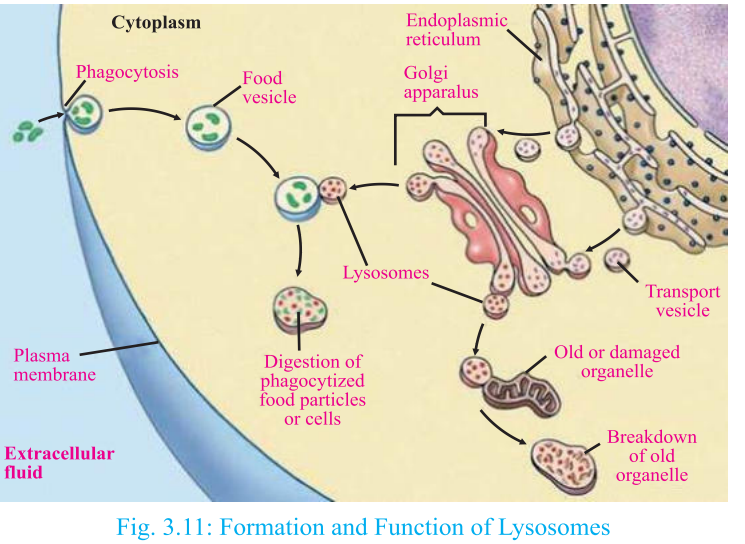


Fig. 3.11: Formation and Function of Lysosomes

breakdown of inactive organelles.

12. Plastids

These are membrane bounded structures which are found only in plant cells. They usually contain pigments and give plant cells their colours. Based on the type of pigments plastids can be classified into chloroplasts, chromoplasts and leucoplasts.

i) Chloroplast

These are oval shaped double membrane structures. There is a space between two membranes. The cavity of the chloroplast is filled with a liquid material called **stroma**. The outer membrane is smooth while the inner membrane forms sac like structures called **thylakoids**. Thylakoids are arranged in stacks like the piles of coins, called **grana** (singular: granum). They contain green pigment chlorophyll, which capture sunlight for photosynthesis. Thylakoids also have small circular DNA and ribosmes.

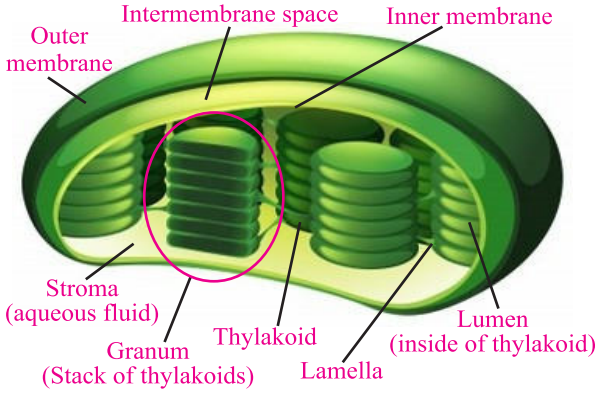


Fig. 3.12: Structure of Chloroplast

ii) Chromoplasts

These organelles contain **coloured pigments** other than chlorophyll. The yellow, red or orange colours in plants are due to chromoplast. They are present in the petals of flowers. Due to the bright colours of chromoplast in petals, the insects attract towards flowers for pollination. The chromoplasts are also found in ripened fruits and vegetables e.g., the red colour of an apple and tomato is due to chromoplast.

Do You Know?

Pollination is a process in which pollen grains from the male part of flower reaches to the female part of flower.

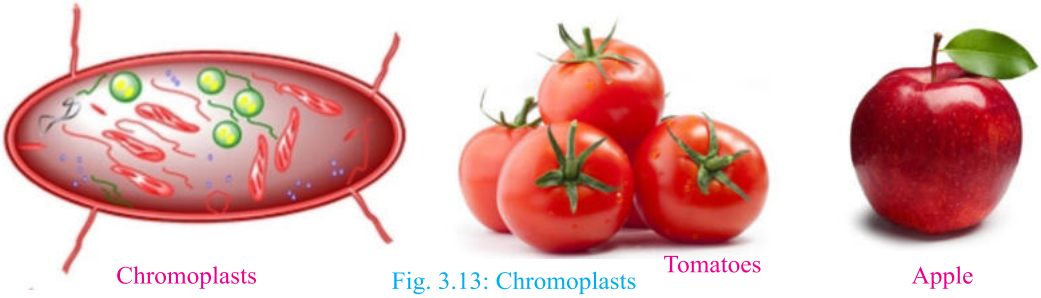


Fig. 3.13: Chromoplasts

iii) Leucoplasts

These are the **colourless plastids** of varied shapes and sizes with stored nutrients. They are usually found in underground parts of the plant and store food e.g. Potato store starch.

Fig. 3.14: Leucoplasts

13. Vacuoles

These are **sac like organelles** in the cytoplasm of both plant and animal cells. They are small in size but large in number in animals cells. In the plant cells there is a central large vacuole which pushes the nucleus at a side. Each vacuole is bounded by a single membrane called **tonoplast**. In plant cells, the tonoplast of central large vacuole encloses a solution of different salts, sugar and amino acids etc. In animal cells there are usually two types of vacuoles i.e food vacuole and contractile vacuole. The food is brought inside the cell by food vacuole while the contractile vacuole is for osmoregulation i.e. regulation of water, like amoeba has both these types of vacuoles.

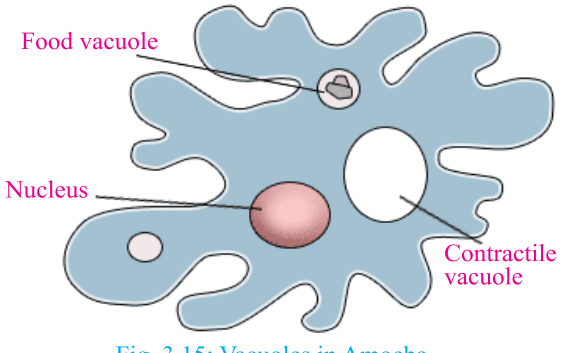


Fig. 3.15: Vacuoles in Amoeba

3.4 Structural Advantages of Plant and Animal Cell

The differences in the structure of plant and animal cells are actually their adaptations. These differences are necessary for their mode of lives.

Plants are autotrophic and sessile. They face a particular environment. On the other hand the animals are heterotrophic and mobile. They face different environments like forest, desert, etc.

Structural Advantages in Plants

(a) Cell Wall

The cell wall gives shape to plant cell. The cytoplasmic connection between two adjacent cells is maintained by **plasmodesmata,** which are present in cell walls. The cell walls give plant stems and wood their stiffness. The cell walls limit the entry of large molecules into the cell that may be toxic to the cell. When water enters into the xylem vessels then the cell walls act as pressure vessels and prevent the over expansion of the cell. The cell walls also protect the plant cells from mechanical injury and infections.

(b) Chloroplast

The chloroplasts absorb sunlight and use it to form food (glucose) with the help of water and carbon dioxide (CO_2) by the process of **photosynthesis.** The life on earth directly or indirectly depends upon plants due to their ability of forming food. Chloroplasts are also essential for human life because they absorb CO_2 from air and release O_2 into the atmosphere. In this way, atmosphere becomes healthy for respiration. If there is no chloroplast in the plant cell then there will be no photosynthesis, so food and O_2 will not be available for organisms. In this condition life on earth will not be possible.

(c) Vacuole

In plant cells there is central large vacuole which is filled with cell sap. The cell sap carry out many functions like stores nutrient, maintains turgor pressure, gives support to cell etc.

Structural Advantages of Animal Cells

a) Cell Membrane

Animal cells have no cell walls. Their outermost covering is cell membrane. This membrane is thin, flexible and porous. The cell membrane performs many functions like provides more flexibility in shape, helps in locomotion, transportatrion of materials in and out of the cell.

b) Lysosomes

The lysosomes are present in all the animal cells. These are absent in the plant cells. Lysosomes contain many digestive enzymes which play many functions like help in intracellular digestion, help to remove the waste materials from the cell.

c) Vacuole

There are many small vacuoles in animal cell. They perform many functions like storage and transport of different substances etc.

3.5 Different Types of Cells

All the cells of organisms have nearly same structure. The cells of different organisms or the cells of organs within the same body have different shapes, sizes and functions. Some examples are as follows:

A) Epidermal Cells and Mesophyll Cells

Leaves are the photosynthetic organs of plants. They are made up of various specialized tissues. Epidermis is the outermost layer of single cells on both upper and lower leaf surfaces. There are many tiny pores in the epidermis called stomata. Each stoma is surrounded by two bean shaped cells called guard cells that contain chlorophyll. The guard cells regulate the opening and closing of stomata to control transpiration. The epidermis is covered by a waxy cuticle. The cuticle prevents water loss and stop the entry of pathogens and unwanted substances into the leaf.

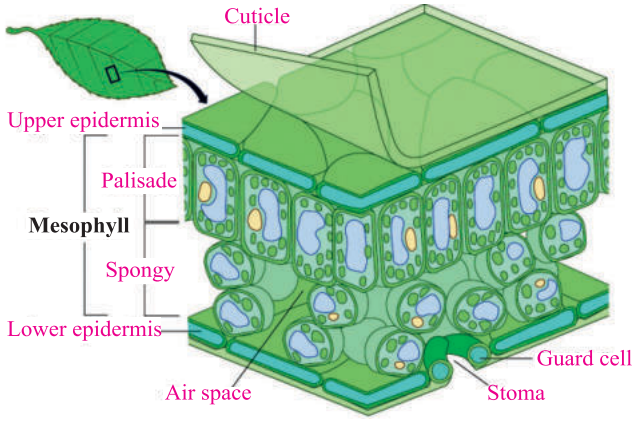


Fig. 3.16: Epidermal cells and mesophyll cells in leaf

The tissues between upper and lower epidermis are called mesophyll tissues. These are of two types i.e., palisade mesophyll and spongy mesophyll. The palisade mesophyll cells are column shaped, tightly packed and are located just below the upper epidermis. These cells contain a lot of chloroplast so are mainly responsible for most of the photosynthesis in the leaf. The spongy mesophyll cells are round, loosely packed and are located below the palisade layer. They have less chloroplast, so carry out less photosynthesis in the leaf.

B) Neurons

The neurons or nerve cells are the structural and functional units of animal's nervous system. These are the longest cells in the animal's body. A typical neuron consists of three main parts.

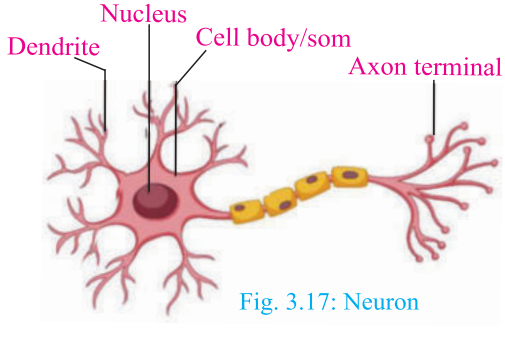


Fig. 3.17: Neuron

Cell body is the main part of the

neuron. Dendrites are the branches arise from cell body. The dendrites carry impulses towards the cell body. Axon is a single and long branch arising from the cell body. It carries impulses away from the cell body.

C) Muscle Cell

A muscle is a bundle of thousands of long cylindrical muscle fibers enclosed in a sheath of connective tissue. The muscles are mainly composed of two types of proteins. i.e. Actin and myosin. There are three types of muscles which are shown below.

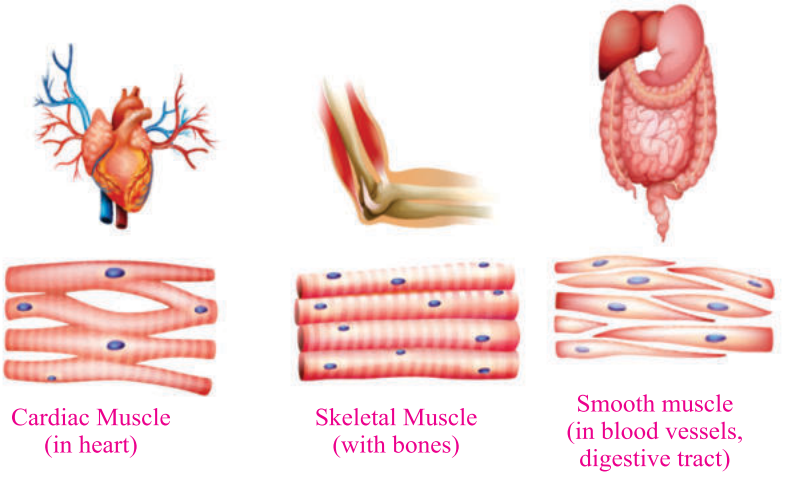


Fig. 3.18: Types of Muscles

D) Red Blood Cells (RBC)

RBCs (Erythrocytes) are component of blood. They are made in bone marrow. Each RBC is small, round and biconcave body surrounded by a membrane. Its red colour is due to a red protein called haemoglobin. The life of an RBC is about 120 days. Its main function is to carry oxygen from the lungs to every cell of the body.

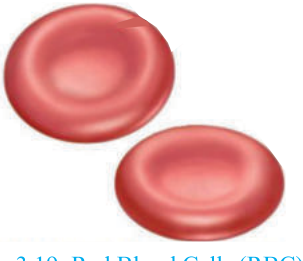


Fig. 3.19: Red Blood Cells (RBC)

Tid Bit

Liver is called the chemical factory of the body. The liver cell is also called hepatocyte.

E) Liver Cell

Each liver cell is round shaped cell. It is enclosed by a membrane. It has a central nucleus around which cytoplasm is present. The cytoplasm has large number of organelles having metabolic and secretory functions

like Golgi bodies, Endoplasmic reticulum etc.

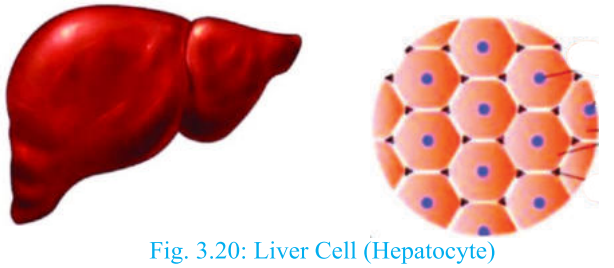


Fig. 3.20: Liver Cell (Hepatocyte)

3.6 Concept of Division of Labour

According to the cell theory, we know that the activities of an organism is the sum total of all the activities of cells present in that organism. There is a division of labour within the cell and across the cells.

A) Division of Labour within a Cell

There is a specific division of labour among the cellular organelles within a cell. Ribosomes play a key role in protein synthesis, so they are called the protein factories of cells. The Golgi complex modifies and packages proteins and lipids into vesicles for transport. Mitochondria produce cellular energy in the form of ATP and are called power houses of the cells. SER synthesizes phospholipids and detoxifies drugs, espacially in the liver. RER are involved in protein synthesis and secretion. Lysosomes contain enzymes that digest macromolecules and wastes. They also break down the old organelles.

Vacuoles store many substances and remove wastes. The centrioles help in the cell division and formation of cilia/flagella. Nucleus controls cell activities like protein synthesis, metabolism, growth etc. The chromosomes and genes are found in nucleus. Nucleus is called the brain of cell. Plastids are found only in plant cells and are site of photosynthesis.

B) Division of Labour Across Cells

Division of labour also occurs across cells in multicellular organisms. Tissues are groups of similar cells that perform a specific function, for example, the contraction of muscle tissue occurs due to the combined action of muscle fibers. Organs are made up different tissues working together, for example, stomach is made up of smooth muscles, glandular muscles, connective tissues etc. Organ systems are formed by organs having related functions, for example, the digestive system consists of mouth,

esophagus, small intestine and large intestine. All organ systems in a body work interdependently and in coordination to maintain the functions of body.

3.7 Cell Specialization

It is a process in which cells with specific structures and functions are formed by unspecialized cells called stem cells. Cell specialization is vital for the survival and functions of multicellular organisms.

Do You Know?

Male gamete and a female gamete unite to form zygote. The zygote divides many times to form embryo.

Cell specialization starts during embryonic development. In the embryo, there are stem cells. These cells are not specialized and can become any type of cell. These cells form different organs of body. Each organ performs a specific function.

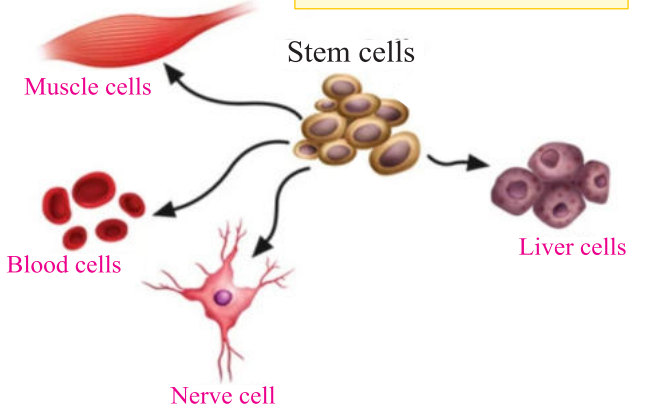


Fig. 3.21: Cell Specialization

3.8 Cell Cycle

Cell division cycle or cell cycle is a process by which a parent cell divides into daughter cells. Cell cycle is a series of events. These events are divided into two main phases i.e., interphase and division /mitotic phase. An interphase is a preparatory phase of cell cycle. In this phase, the matabolic activities of parent cells are at their peak. In division phase, the parent cells divide into daughter cells. There are two types of cell division, i.e., mitosis and meiosis. In mitosis a parent cell divides into two daughter cells. In meiosis, a parent cell first divides into two daughter cells. Each daughter cell further divides into two cells.

Do You Know?

In case of mitosis the time taken by a cell cycle is variable, for example, in yeast (fungus) it is completed in about 90 minutes while takes about 24 hours in human beings.

Phase of Cell Cycle

The cell cycle is divided into two basic phases i.e. Interphase and mitotic / divisions phase.

Critical Thinking

The newly formed cells from a parent cell are called daughter cells, why are not called son cells?

A. Interphase

The interphase is commonly considered as a

resting phase between two successive mitotic phases. In actual practice it is the time during which the cell is preparing for division by undergoing both cell growth and DNA replication. The interphase takes about 90% time of total duration of cell cycle.

The interphase is further divided into three phases.

i) G_1 phase (Gap 1)
ii) S phase (Synthesis)
iii) G_2 phase (Gap 2)

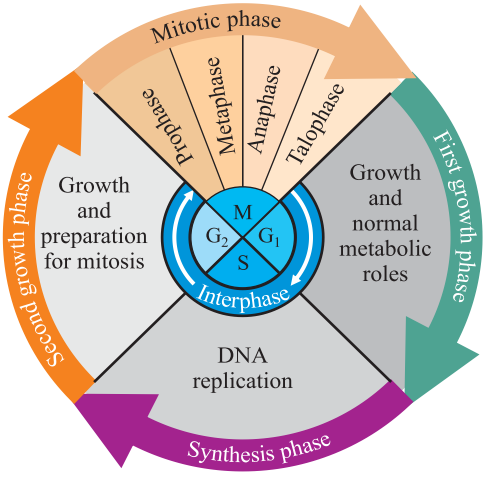


Fig. 3.22: Cell Cycle

I) G_1 Phase

This corresponds to the interval between mitosis and initiation of DNA replication. During G1 phase, the cell is metabolically active and continuously grows in size and increases the number of its organelles.

ii) S or Synthesis

S or synthesis phase marks the period during which DNA synthesis or replication takes place in the nucleus i.e. each chromosome duplicates into two sister chromatids.

iii) G_2 phase

During the "G2" phase, proteins are synthesised for the production of spindle fibres. The centriole duplicates in the cytoplasm.

B. Division Phase (M Phase)

The "M Phase" starts with the nuclear division, corresponding to the separation of daughter chromosomes (karyokinesis) and usually ends with division of cytoplasm (cytokinesis).

Some cells in the adult animals do not undergo cell division (e.g. heart cells) and many other cells divide only occasionally, as needed to replace cells that have been lost because of injury or cell death. Cells that do not divide further, they exit **"G_1" phase** to enter an inactive stage called **quiescent stage (G_0)** of the cell cycle. Cells in this stage remain metabolically active but no longer multiply.

3.9 Mitosis

It was first observed by a German biologist Walther Flemming in 1882. In this division, the parent somatic cell (body cell) divides into two daughter cells in which the

number of chromosomes remain, the same as in the parent cell.

The process of mitosis is divided into two main phases i.e karyokinesis (nuclear division) and cytokinesis (cytoplasmic division).

A. Karyokinesis

It involves the nuclear division. The karyokinesis phase is further divided into four stages:

i) Prophase ii) Metaphase iii) Anaphase iv) Telophase

i) Prophase

It is the first stage of mitosis after interphase. Following events occur in prophase.

- Chromatin network condenses to form chromosomes. Chromosomes are seen to be composed of two sister chromatids attached together at the centromere. The centromere has a protein structure called **kinetochore** where the spindle fibres get attached.
- The centrioles move towards opposite poles of the cell and start to form spindle fibres.
- Nucleolus and nuclear membrane degrade and disappear.

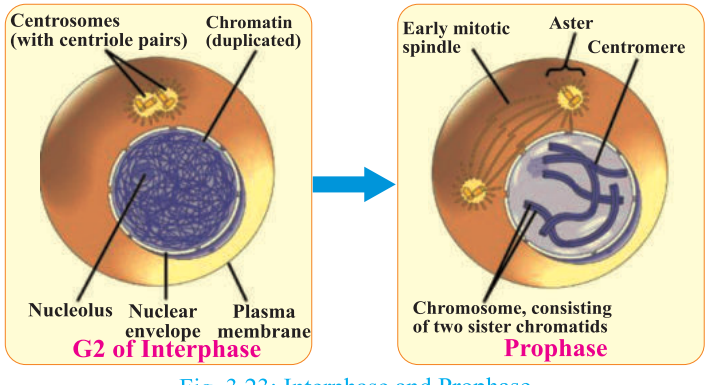


Fig. 3.23: Interphase and Prophase

ii) Metaphase

Following events occur in metaphase.

- The spindle fibres attach to kinetochores of chromosomes called **kinetochore fibres.** A number of non-kinetochore fibres from opposite centrioles attach with each other.
- Two kinetochore fibers from opposite poles attach with each chromosome.
- Chromosomes are moved to spindle equator and get arranged along

metaphase plate. The plane of alignment or arrangement of the chromosomes on the equator is referred as the **metaphase plate**.

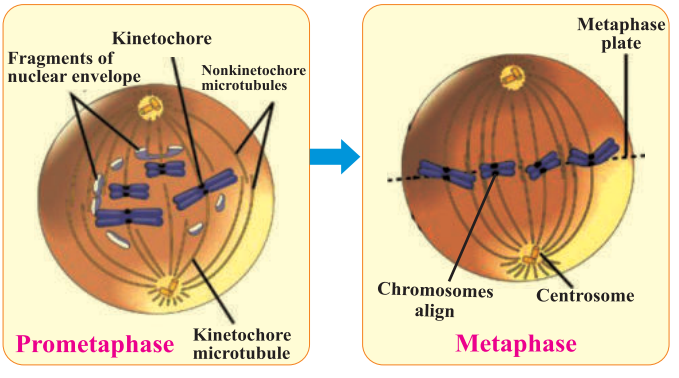


Fig. 3.24: Metaphase

Tid Bit

Those fibers which attach with kinetochores are called **kinetochore spindle fibers** while others are called **non-kinetochore spindle fibers**.

iii) Anaphase

The anaphase stage is characterised by the following events:

- The kinetochore spindle fibres contract and are pulled towards the centrioles.
- Due to pulling force, centromeres split and sister chromatids separate. These sister chromatids are now called **sister chromosomes**.
- The chromosomes are pulled towards the opposite poles.

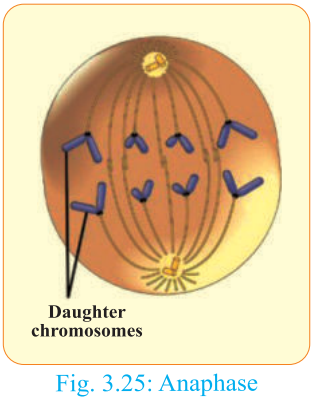


Fig. 3.25: Anaphase

iv) Telophase

This stage shows following events:

- Chromosomes reach at opposite poles and again unfold as chromatin.
- Nuclear envelopes reappear around the two chromosome clusters.
- Nucleolus, Golgi complex and endoplasmic reticulum are reformed.

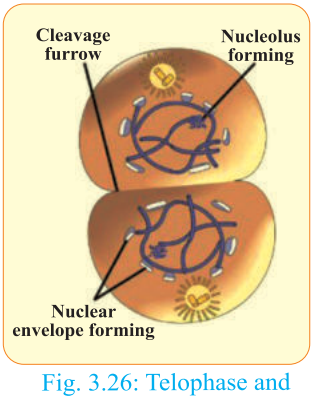


Fig. 3.26: Telophase and Cytokinesis

B. Cytokinesis

It is the physical process of cell division which divides the cytoplasm of parent cell into two daughter cells. In an animal cell, this is achieved by the appearance of a

cleavage furrow in the plasma membrane. The furrow gradually deepens and ultimately joins in the centre dividing the cell into two cells. Plant cells are enclosed by cell walls so the cytokinesis occurs by a different mechanism.

Vesicles of Golgi bodies are collected in the middle of plant cell. They now fuse to form a membranous structure called **cell plate** or **phragmoplast**. The cell plate grows outwards and finally fuses with the plasma membrane and parent cell wall. In this way two daughter plant cells are formed. At the time of cytokinesis the cell organelles like mitochondria, plastids etc get distributed between the two daughter cells.

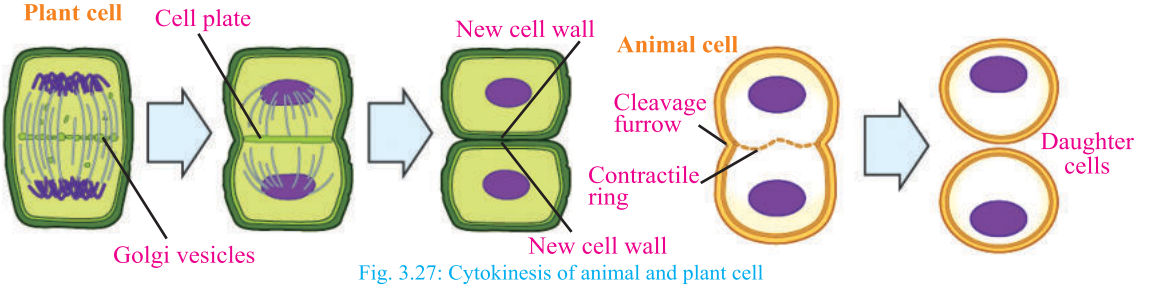


Fig. 3.27: Cytokinesis of animal and plant cell

Significance of Mitosis

1. Mitosis results in the production of diploid daughter cells with identical number of chromosomes.
2. The growth of multicellular organisms is due to mitosis of a single cell (zygote).
3. A very significant contribution of mitosis is cell repair and replacement of old cell by the new one.
4. The cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are being constantly replaced by mitosis.
5. Mitotic divisions in the meristem tissues, the apical and the lateral meristem, result in a continuous growth of plants throughout their life.
6. Regeneration of the lost parts of the body in many organisms takes place by mitosis, e.g. arms of star fish.

Do You Know?

Diploid cells are those cells in which the specific number of chromsomes are found in pairs. They are represented by "2n". Haploid cells are those cells in which the number of chromosomes are half than diploid. In these cells the chromosomes are not found in pairs. They are represented by "n".

Tid Bit

Those cells which form gametes are called germ line cells. Gametes are formed by meiosis.

3.10 Meiosis

The process by which one diploid (2n) cell divides to form four haploid (n) daughter cells is called meiosis. It was discovered in 1876 by a German biologist Oscar Hertwig. Meiosis takes place in plants and animals which ultimately leads to the formation of haploid gametes.

Phases of Meiosis

The process of meiosis starts like mitosis i.e it starts from interphase which include G_1, S and G_2 phases. After interphase, starts two successive phases i.e meiosis - I and meiosis - II.

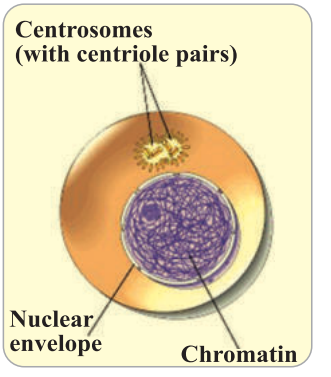


Fig. 3.28: Interphase

MEIOSIS - I

The meiosis – I is completed in two phases i.e. karyokinesis and cytokinesis.

A. Karyokinesis (Nuclear division)

The karyokinesis is completed in four steps i.e prophase-I, metaphase-I, anaphase -I and telophase-I.

a) Prophase - I

It is a complex and longest phase of meiosis. Following events occur in this phase.

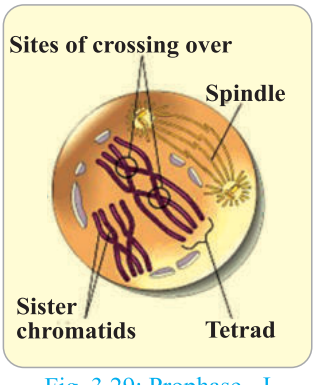


Fig. 3.29: Prophase - I

i) The chromatin material is condensed and appear in the form of chromosomes.

ii) The homologous chromosomes come close to each other and form pairs. This process is called **synapsis.** Each pair of synapsed homologus chromosomes is called bivalent. Each bivalent has four chromatids, so it is called tetrad.

iii) In homologous chromosome pair, the non-sister chromatids attach lengthwise with each other at some places. These places of attachment are called **chiasmata**.

iv) The non-sister chromatids exchange their segments at chiasmata. This process is called crossing over. Due to the **crossing over**, there is an exchange of genetic informations between the homologous chromosomes.

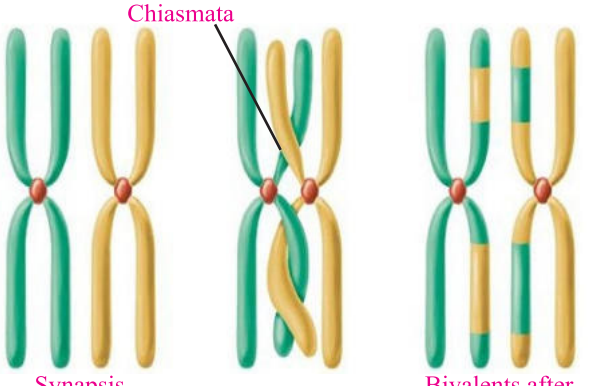


Fig. 3.30: Crossing over

Do You Know?

The homologous chromosomes are chromosome pair in a diploid cell. They have similar shape and size. They have same genes at the same locations (loci).

v) After crossing over the chromosomes become more thick due to further condensation.

vi) The nuclear membrane breaks and nucleoli are disappeared.

vii) Two centrioles migrate to the opposite poles of cell and form spindle fibers.

b) Metaphase - I

The dispersed bivalents in cytoplasm now arrange themselves in the center of cell called equator. In this way, a metaphase plate is formed in the middle of cells. The kinetochore spindle fibers of each side attaches with bivalent of its own side.

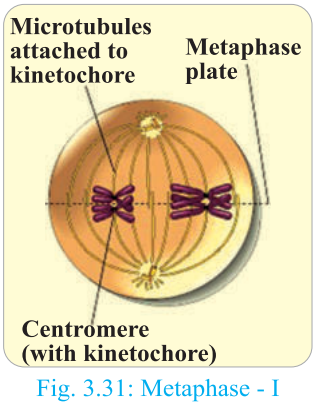


Fig. 3.31: Metaphase - I

c) Anaphase- I

Due to the contraction of kinetochore spindle fibers, the two homologous chromosomes of a bivalent separate from each other and move towards the respective poles. In this phase the centromere does not break.

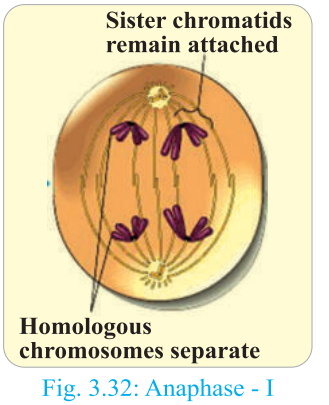


Fig. 3.32: Anaphase - I

d) Telophase - I

Following events occur in this phase.

- Half the number of chromosomes have reached at one pole and half the number of chromosomes have reached at the opposite pole. In this way, two haploid set of chromosomes are formed in the cell.

- The spindle fibers disappear.
- Nucleoli reappear.
- Nuclear membrane reappears around each haploid set of chromosomes.
- The chromosomes uncoil into chromatin material again.

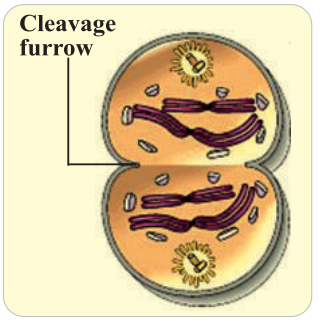


Fig. 3.33: Telophase - I and Cytokinesis

B. Cytokinesis (Cytoplasmic division)

A cleavage furrow is formed in the middle of cell membrane by the division of cytoplasm and divides the cell into two daughter cells. In plant cells, the cytokinesis occurs due to the formation of cell plate.

Interphase - II

There is a brief period of time between two meiotic divisions (Meiosis- I and Meiosis-II) called interphase-II or interkinesis. The interphease-II is different from the interphase-I of meiosis because it has no s-phase. Due to this reason no duplication of chromosomes occurs in meiosis-II.

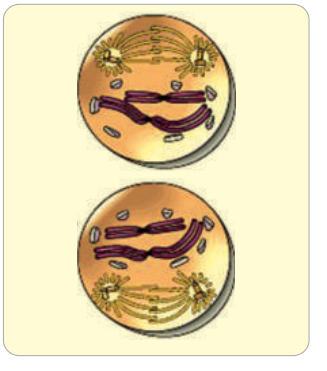


Fig. 3.34: Prophase - II

Meiosis - II

After cytokinesis, the process of meiosis-II starts. The meiosis-II is like normal mitosis. Meiosis-II also has four phases i.e., prophase-II, metaphase-II, anaphase-II and telophase-II.

a) Prophase - II: The chromatin material is condensed to form chromosome. Nuclear membrane and nucleoli disappear. The centrioles on opposite poles of cell form spindle fibers.

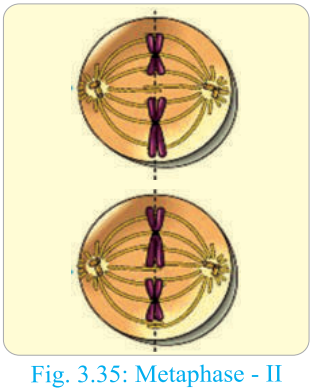


Fig. 3.35: Metaphase - II

b) Metaphase - II: At this stage, the chromosomes align at the equator and the spindle fibres from opposite poles of the spindle get attached to the kinetochores of sister chromatids.

c) Anaphase - II: Due to the contraction of kinetochore spindle fibers, a pulling force is applied on centromere. The centromere breaks due to this force and sister chromatids are separated from each other and move towards opposite poles of cell.

d) Telophase - II

Telophase II: Meiosis ends with telophase II, in which the two sets of chromosomes once again get enclosed by a nuclear envelope.

Fig. 3.36: Anaphase - II

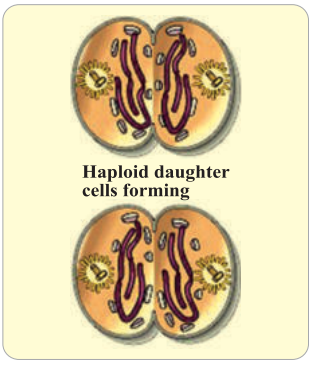


Fig. 3.37: Telophase - II and Cytokinesis

After telophase-II, the process of cytokinesis starts due to which four daughter haploid gametes are formed.

3.11 Comparison of mitosis and meiosis

	MITOSIS	MEIOSIS
1.	It occurs in all somatic cells for growth.	It occurs only in gonads or germline cells for the formation of gametes.
2.	Whole process completes in one division.	The process completes in two divisions.
3.	Prophase is of short duration.	Prophase is of longer duration.
4.	Crossing over does not occur. Chiasmata is not formed.	Crossing over takes place with the formation of chiasmata
5.	Centromeres divide in metaphase.	Centromere do not divide.
6.	All chromosomes behave independently and no pairing of chromosomes occurs.	Homologous chromosomes pair and form Bivalents by synapsis.
7.	2 – Daughter cells are formed.	4 – Daughter cells are formed.

3.12 Significance of Meiosis

I) Due to meiosis, haploid gametes (n) are formed which are the main units for sexual reproduction. By the union of male and female haploid gametes, the

diploid number (2n) is restored in the next generation. In this way, the number of chromosomes of a particular species remains constant generation after generation.

ii) Due to crossing over, new combinations of genes are formed on chromosomes due to which variations occur in new generation. Variations are very important for the process of evolution.

3.13 Stem cells as unspecialized cells

Stem cells are master cells in the body having unique ability to renew themselves and to differentiate into many different types of specialized cells in the body. The stem cells are found in the embryo of organisms. They have no specific functions like other specialized cells in the body. They are immature and unspecialized cells but have ability to grow into any type of specialized cells. Through a process called differentiation.

Stem cells are different from other specialized cells in many ways.

i) They can divide and renew themselves over a long time.

ii) They are unspecialized cell because they do not have tissue specific structures.

iii) They have potential to become specialized cells.

iv) They do not have special morphology.

Examples

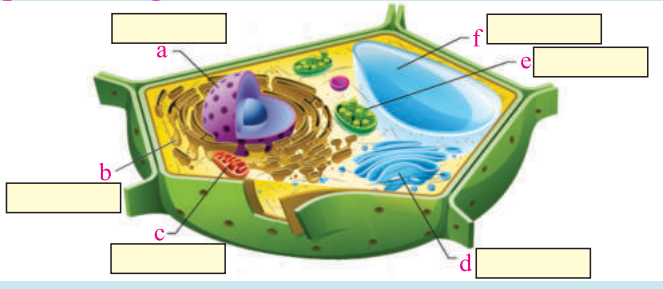
Stem cells are found in both plants and animals. In plants, the stem cells are found close to the tips of shoot and roots and are called meristems. Branches, leaves, flowers, roots, etc., are formed from these meristems.

The embryonic stem cells in human body are the most potent because every types of cells in he body is derived from them. For example, blood cells, brain cells, muscle cells, bone cells etc.

Video Links: Keenly watch some animated videos of mitoses and meiosis on internet. This activity will more clear your concepts about mitosis and meiosis.
https://www.youtube.com/watch?v=_jdSzXvvpH4&t=968s
https://www.youtube.com/watch?v=boX31ln-Ez0
https://www.youtube.com/watch?v=NwwcWqL5hhI&t=17s
https://www.youtube.com/watch?v=GHIlA76-h3c&t=11s
https://www.youtube.com/watch?v=yRLQKZzFb68
https://www.youtube.com/watch?v=Htpn94ToPEg

STEAM ACTIVITY

A. Identify the pointed organelles.



B. Answer the questions.

i) Which one is involved in the breakdown of inactive organelles?

ii) Which organelle receives proteins and lipids from "ER" and packed them into small membranous sacs?

iii) Which one is the energy supplier of cell?

iv) Which letter shows the brain of cell?

v) It is found only in plant cells.

vi) The membrane of which part is called tonoplast.

vii) With which organelle the protein factories are attached.

STEAM ACTIVITY

Find the stages in the given figures of mitosis. Write down the reason of identification in each case.

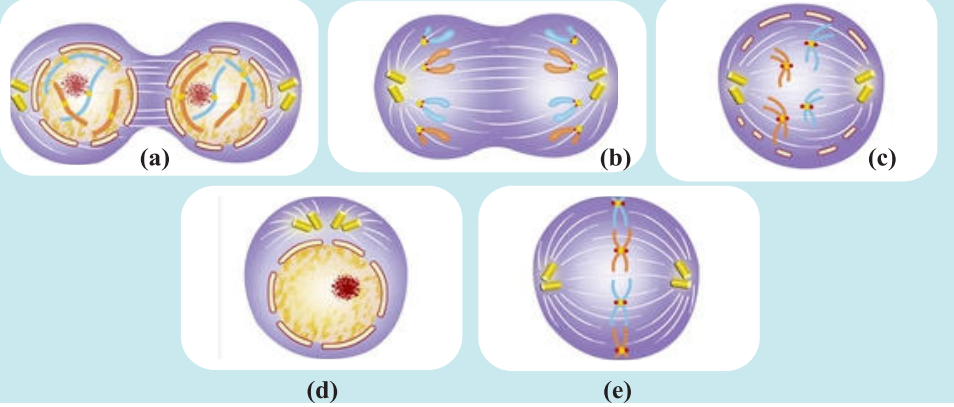


Fig.No.	Name of Stage	Reasons of identification
a		
b		
c		
d		
e		

Critical Thinking

Identify the cell organelles on the basis of their special features.

I) Consists of microtubules, actin filaments and intermediate filaments. ____

ii) The inner membrane of this organelle forms a number of foldings called cristae. ____

iii) The inner membrane of this organalle forms sac like structures called thylakoid. ____

iv) Provide plasmnodesmatal connection between two neighbouring cells. ____

v) This organelle is made up of two sub units (smaller and larger). ____

vi) Responsible for endocytosis and exocytosis. ____

Key Points

- Cell is the smallest structural and functional unit of all organisms.
- Cell membrane or plasma membrane is a thin and elastic membrane. It is present around the cytoplasm of all prokaryotic and eukaryotic cells. In animal cells it is the outer most boundary. In prokaryotes, fungi and plants it is present under the cell wall.
- Cell wall is the outermost covering of the cells of prokaryotes, fungi and plants. It is hard and non-living structure below which cell membrane is present.
- The microscopic pores in the cell walls are called plasmodesmta.
- Cytoplasm is a gelatinous and semi transparent fluid between nucleus and cell membrane.
- The cytoskeleton is a network of interconnected filaments and tubules that extend from the nucleus to the plasma membrane in eukaryotic cells. The cytoskeleton

consists of microtubules, actin filaments, and intermediate filaments.

- Nucleus is called the brain of cell.
- Endoplasmic reticulum is a network of interconnected tiny tube like structures called cisternae.
- Golgi bodies consist of a set of flat and disc shaped sacs called cisternae.
- Ribosomes are called protein factories of cell.
- Centrioles are two hollow cylindrical bodies. Each centriole is made up of "27" microtubules.
- Lysosomes are formed by Golgi bodies. Each lysosome contains digestive enzyme.
- Plastids are membrane bounded structures which are found only in plant cells. They usually contain pigments and give plant cells their colours. Based on the type of pigments plastids can be classified into chloroplasts, chromoplasts and leucoplasts.
- Vacuoles are sac like organelles in the cytoplasm of both plant and animal cells.
- Tissue is a group of cells which are similar in structure and work together to peform a particular function in body. The function of a tissue is the combined actions of all the cells present in that tissue.
- The cell cycle is divided into two basic phases i.e. Interphase and mitotic phase.
- Mitosis is the division of somatic cells. In this case one parent cell divides into two daughter cells. The number of chromosomes remain the same as in the parent cell.
- The process or division by which one diploid (2n) cell divides to form four haploid (n) daughter cells is called meiosis.
- The exchange of segments between non-sister chromatids is called crossing over.

EXERCISE

A. Multiple choice Questions (MCQs)

1. Protein factories of cells are:
   (a) Ribosomes (b) Lysosomes
   (c) Golgi bodies (d) Mitochondrion
2. The organelle discovered by Robert Brown:
   (a) Ribosome (b) Mitochondria
   (c) Lysosome (d) Nucleus
3. Mitochondria are sausage-shaped filamentous structures surrounded by:
   (a) Single layered membrane (b) Double layered membrane
   (c) Triple layered membrane (d) Cellulose

4. The percentage of lipid in cell membrane is:
   (a) 10 - 15% (b) 45 - 50%
   (c) 20 - 40% (d) 60 - 80%
5. The percentage of water in cytoplasm is:
   (a) 60% (b) 70%
   (c) 80% (d) 90%
6. Each centriole is made up of;
   (a) 7 microtubules (b) 27 microtubules
   (c) 17 microtubules (d) 37 microtubules
7. The cell membrane of vacuole is called;
   (a) Protoplast (b) Symplast
   (c) Apoplast (d) Tonoplast
8. Which one is involved in cell division and is major component of cilia and flagella.
   (a) Centrioles (b) Golgi bodies
   (c) Microtubules (d) Ribosomes
9. The cell wall of prokaryotes contains:
   (a) Lignin (b) Peptidoglycan
   (c) Chitin (d) Cellulose
10. Nucleolus is made up of:
   (a) Protein and DNA (b) DNA and Ribosome
   (c) Ribosome and protein (d) Protein and RNA
11. Smooth muscles are found in:
   (a) Heart (b) Blood vessels
   (c) Liver (d) Brain
12. Phragmoplast is formed from:
   (a) Ribosome (b) Vesicle of ER
   (c) Golgi bodies (d) Mitochondrion
13. In which phase of meiosis, the crossing over occurs?
   (a) Telophase - I (b) Metaphase-I
   (c) Anaphase - I (d) Prophase – I
14. In human beings there are 46 chromosomes (2n), what will be the number of chromosomes in their gametes?
   (a) 22 (b) 23

(c) 24 (d) 25

15. DNA replication takes place in:
(a) G_1 phase (b) S phase
(c) M phase (d) G_2 phase

16. Microtubules are formed in:
(a) G_1 phase (b) S phase
(c) M phase (d) G_1 phase

17. Partitioning of daughter chromosomes takes place in:
(a) G_1 phase (b) S phase
(c) M phase (d) G_2 phase

18. The most lengthy phase of meiosis is:
(a) Anaphase - I (b) Metaphase - II
(c) Prophase - I (d) Prophase - II

19. Separation of homologous chromosomes occur during
(a) Prophase - I (b) Metaphase - I
(c) Telophase - I (d) Anaphase - I

B. Short Response Questions.

1. Why is cell called the basic unit of life?
2. How will you briefly describe the cytoskeleton?
3. What do you know about the Golgi bodies?
4. What are neurons? What do you know about the structure of a typical neuron?
5. What are muscle cells? Write down the types of muscles.
6. Briefly describe the cell specialization.
7. Write down the functions of lysosomes.
8. What are the differences between animal and plant cells?
9. Differentiate between smooth and rough endoplasmic reticulum?
10. Distinguish cytokinesis from karyokinesis.
11. Describe the events taking place during G_1 phase of interphase.
12. How does cytokinesis in plant cells differ from that in animal cells?
13. What is quiescent stage (G_0)?
14. What is the significance of meiosis?
15. Distinguish between metaphase of mitosis and metaphase-I of meiosis.
16. Define the following terms

(i) Cell cycle (ii) Granum

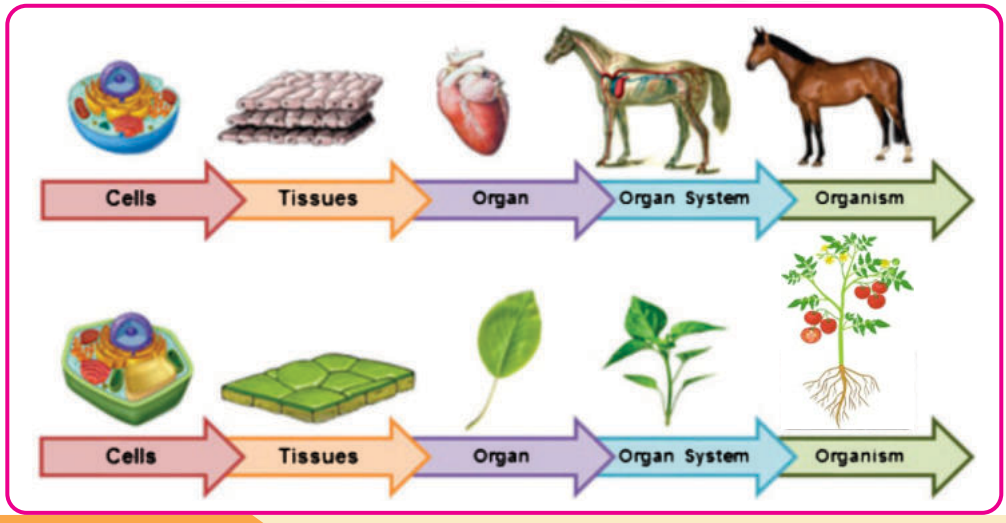
(iii) Plasmodesmata
(iv) Synapsis
(v) G_1 phase (Gap1)
(vi) Chiasmata
(vii) Centromere
(viii) G_2 phase (Gap 2)
(ix) Meiosis
(x) Mitosis
(xi) Crossing over
(xii) S-phase
(xiii) Kinetochore
(xiv) Spindle fibers
(xv) Pharagmoplast

C. Extended Response Questions.

1. Write a detailed note on plastids.
2. Who discovered mitochondria? Explain its structure. Why they are called power house of cell.
3. Write a comprehensive note on nucleus.
4. Explain epidermal and mesophyll cells.
5. Write a detailed note on the division of labour within a cell and across cells.
6. Write a note on the structural advantages of plants and animal cells.
7. Give a comparison between mitosis and meiosis.
8. Describe the stages of meiosis-I with labelled diagram.
9. Explain the stages of mitosis with labelled diagram.

CHAPTER
4

TISSUES, ORGANS AND SYSTEMS



Learning Outcomes:

Students will be able to:

- Distinguish between tissues, organs and systems with examples from animals and plants.
- Describe the concept of emergent properties as gain in functionalities and how it applies to the following:
  - Sub-cellular organelles to cells
  - Cells to tissues
  - Tissues to organs
  - Organs to systems
  - Systems to living organisms.
- Enlist the different types of tissue come together to from the stomach organ in the human body.
- Discuss the different types of tissue come together to form the leaf.
- Discuss the organ systems (digestive, respiratory, cardiovascular, nervous, endocrine and reproductive system) come together to form the human body.
- Describe the disorders of different organ systems.
- Discuss the advantages of homeostasis.
- Discuss the various organs and systems of the human body work to maintain homeostasis.
- Explain plant physiology in terms of structures and roles of various plant organs.

Introduction

We know that cell is the basic structural and functional unit of the body of all organisms. A group of similar cells having similar functions is called tissue. A group of two or more types of tissue that work together to complete a specific function is called an organ. A group of organs having related functions that work together to perform a specific function is called an organ system. An individual or organism is formed by the organization of different organ systems.

In this chapter, we will study about the levels of organization in organisms i.e., from cellular level to organism level. We will also study about the organs or organ system involved in homeostasis, disorders of organs or organ system in animals, structure and roles of various plant organs in plant physiology.

4.1 Tissues, Organs and Systems:

We know that a group of similar cells that work together to perform a specific function is called tissue for example, muscle is a tissue made up of muscle fibers. All muscle fibers work together due to which movement occurs.

There are many types of cells in the epidermis of a leaf. All these cells work together as a tissue. An organ is self contained part of body that performs a specific function or many functions. In the body organs are made up of tissues that work together for a common purpose, for example, stomach is an organ which is made up of different tissues like smooth muscles, glandular tissues etc.

Additional Information

Pineal gland is the smallest while skin is the largest organ of the human body.

Leaf is an organ because it is made up of different types of tissues i.e. epidermal, spongy mesophyll, palisade mesophyll etc. Organ system is a group of different organs having related functions that work together to perform a complex function in the body, for example, the digestion process is completed by digestive system which is made up different organs like esophagus, stomach, small intestine and large intestine.

4.2 Levels of Organization

Levels of organization are also called hierarchy of life. Each upper level of organization will be more complex as compare to lower one, for example, atoms combine to form molecules; Molecules combine to form organelles. Different organelles combine to form cell. Cells combine to forms tissues. Different tissues combine to form organ. Different organs combine to form organ system and different organ systems combine to form the body of an individual.

A. Cell Organelles and Cell

The living subcellular structures in a cell are called cell organelles. These organelles are formed by the specific combination of biomolecule. The division of work inside a cell is carried by these organelles. Each organelle performs a specific function in a cell, for example, ribosomes are specialized for protein synthesis.

Different cell organelles collectively form the cell. All organisms are made up of cells. Different cells have different shapes, sizes and functions. On the basis of number of cells, the organisms are of two types:

i) **Unicellular** (made up of single cell), for example, amoeba, chlamydomonas, paramecium.

ii) **Multi-cellular** (made up of many cells). for example, human body consists of more than 37.2 trillion cells.

B. Tissue

Tissue can be defined as a group of cells having similar structure and function. The multicellular organisms have different types of tissues. Each cell in a tissue carries on its own life processes e.g. protein synthesis and ATP production etc. A cell also carries on some special processes related to the function of the tissue. Muscular and nervous tissues are animal tissues while xylem and epidermal tissues are plant tissues.

C. Organ

An organ is a group of different tissues having related functions. Each organ performs a specific function. Different tissues of an organ perform their specific functions and these functions collectively become the function of that organ. for example, human stomach is an organ. Its function is to digest the food. Two types of tissues are involved in the digestion of food in stomach. The secretary tissues secrete gastric juice for the digestion of food. The muscular tissues contract the wall of stomach for crushing and mixing of the food with gastric juice.

Additional Information

Heart is the first organ that forms during development of the body.

D. Organ System

An organ system is formed by the group of organs having related functions. Each organ carries out its specific function and all the functions of these organs become the function of that system, for example, digestive system consists of mouth, stomach, small intestine and large intestine etc.

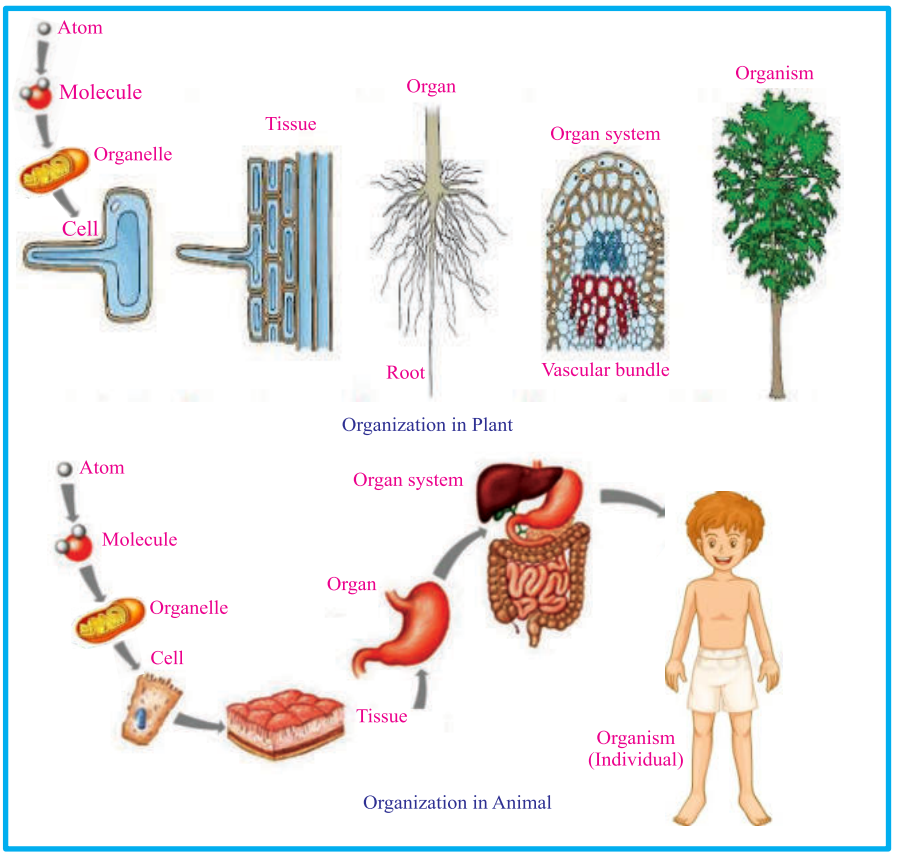


Fig. 4.1: Level of Organization in organisms from atomic to organism level

Organism Level

An individual or organism is formed by the organization of different organ system, for example, the human being. An individual is made up of different systems such as circulatory system, respiratory system, digestive system etc.

There is a coordination between different organs and organ systems of an individual, for example, during playing, our muscles work. For the extra working of muscles there is a need of more food and oxygen to the muscles. This supply is brought about by the increased flow of blood to muscles. The increase in blood flow is controlled by increased heart beat. More oxygen is supplied by lungs to blood. More CO_2 is produced during playing so there is an increase in the rate of respiration to get more oxygen and to remove more CO_2. More heat is produced in our body during playing due to which body temperature increases. To maintain the body temperature, our sweat glands produce sweat from our skin.

4.3 Composition of Stomach on Tissue Level

Stomach is J-shaped muscular sac. It is present beneath the diaphragm. In an adult person, the stomach is nearly 12 inches long and 6 inches wide.

Following tissues combine to form stomach.

A. Smooth Muscles

These muscles in the wall of stomach are present in the form of layers. The inner most layer is called mucosa. Second layer is called sub-mucosa, third layer is called muscularis and the outermost layer of muscles is called serosa.

B. Glandular Tissues

The mucosa has gastric glands composed of three kinds of cells:

1. Chief cells secrete an inactive enzyme called pepsinogen which is converted into an active enzyme pepsin by HCl. Pepsin acts on protein and converts it into partially digested poly-peptides and amino acids.

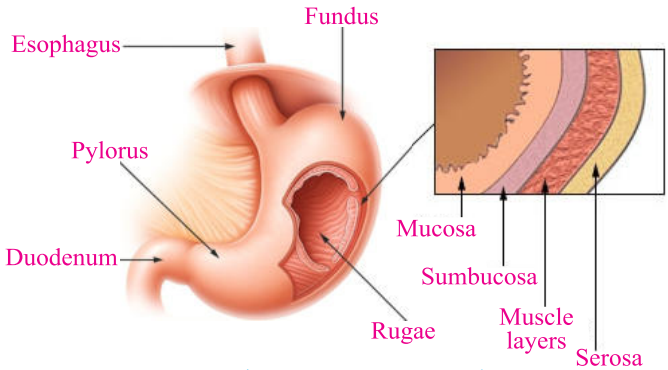


Fig. 4.2: Human Stomach

2. Parietal cells secrete HCl. It softens the food and kills pathogens in food.
3. Mucous cells secrete mucous. The mucous forms a coating on the inner walls of stomach. In this way, walls of stomach become safe from the action of HCl and pepsin.

C. Blood Capillaries

Blood capillaries are also the part of stomach. The walls of blood capillaries are also made of tissues.

4.4 Composition of a Leaf on Tissue Level

Leaves are called the photosynthetic organs of plants. Each leaf is made up of different types of tissues. The cells of leaf system have a variety of specialized structures and functions. The outermost covering of a leaf is called **epidermis**. It is composed of a single layer of cells. This layer of cells forms upper and lower surfaces of a leaf called upper and lower epidermis respectively. There are many tiny pores in the

epidermis called **stomata**. Around each stomata there are two bean shaped cells called guard cells. The guard cells are responsible for the opening and closing of stomata to control transpiration. The epidermis is covered by a waxy layer of cuticle to prevent the loss of water from the leaf and to stop the entry of pathogens and unwanted substances into the leaf.

Do You Know?

Why leaves look green?
When sunlight falls on plants, the green portion of light is reflected by the chlorophyll. Due to this reason the leaves look green.

The tissues between upper and lower epidermis are called **mesophyll tissues**. The mesophyll tissues are of two types i.e palisade mesophyll and spongy mesophyll. The **palisade mesophyll** cells are column shaped. These cells are closely packed and are present just below the upper epidermis. These cells contain a lot of chloroplast so are responsible for most of the photosynthesis in the leaf. The **spongy mesophyll** cells are rounded in shape. These cells are loosely packed and are present beneath the palisade tissues. There are air spaces among spongy mesophyll cells which allow the removal of oxygen and entry of CO_2 into the leaf. There is less chloroplast in spongy mesophyll than palisade mesophyll cells so there is less photosynthesis in spongy mesophyll layer.

In the leaves, there is a central vessel called **midrib**. Many branches arise from midrib called leaf **veins**. The midrib and veins contain xylem for the transportation of water and phloem for the transportation of food.

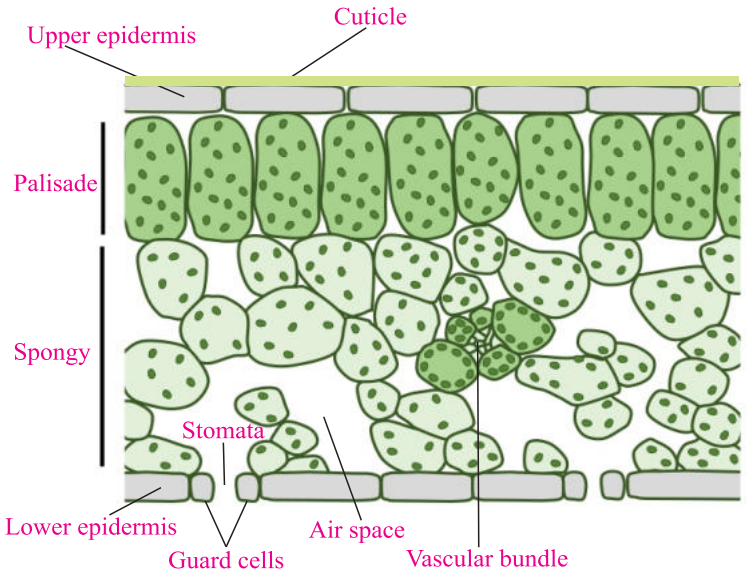


Fig. 4.3: Composition of leaf on tissue level

Activity

Write down the levels of organization from atomic to individual level.

4.5 Human Body

Human body is made up of different organ systems.

1. Digestive System

Food is digested by digestive system and the undigested material is removed from the body. The human digestive system is in the form of tract which starts from mouth, and ends at anus. This system consists of mouth, oesophages, stomach, small intestine and large intestine.

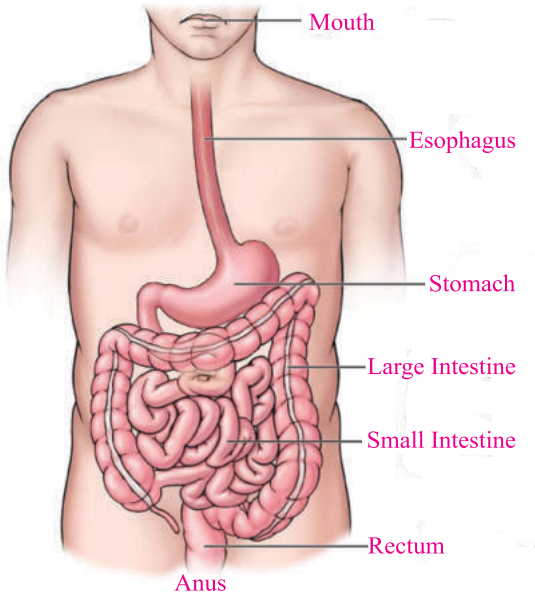


Fig. 4.4: Digestive System

Do You Know?

What is the normal rate of breathing per minute in rest condition?

Additional Information

The length of small intestine in an adult human is about 6-7m while the length of large intestine is about 1.5m.

2. Respiratory System

It is the system of gaseous exchange. Oxygen is taken inside the body where break down of glucose is carried out. By this breakdown, CO_2 and energy (ATP) are produced. ATP is used inside the body while CO_2 is removed from the body.

The respiratory system consists of nose, pharynx, larynx trachea, bronchi, bronchioles, alveoli and lungs.

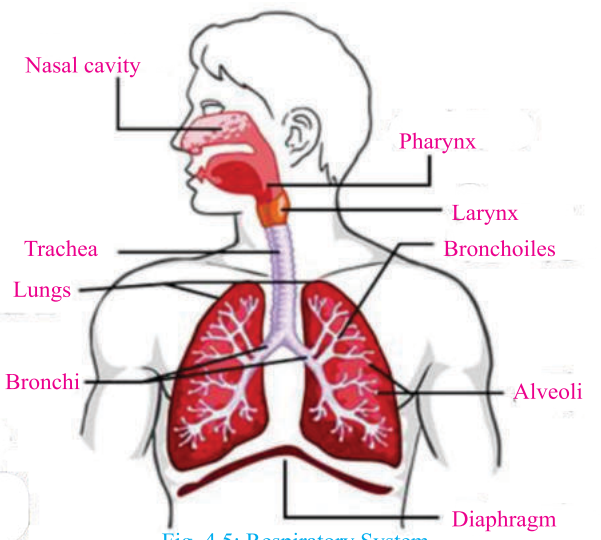


Fig. 4.5: Respiratory System

3. Cardiovascular System

It is the system of blood circulation in the body. Blood supplies O_2 and food to all parts of body. In the same way blood carries CO_2 and waste materials from different organs and carries these materials to excretory organs to remove from the body.

The circulatory system consists of heart, blood vessels (arteries, veins, capillaries) and blood.

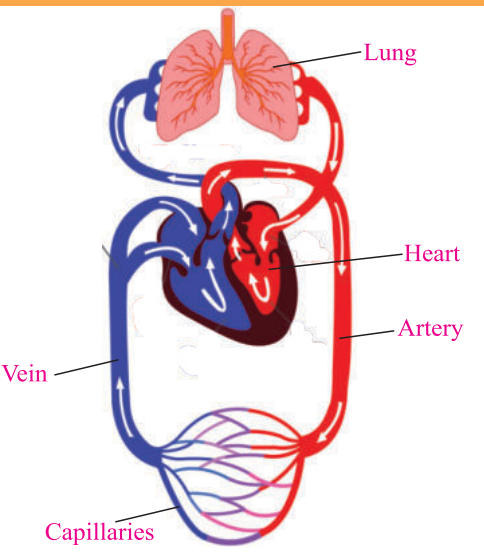


Fig. 4.6: Cardiovascular System

4. Reproductive System

The reproductive system of male and female is different. Both the systems produce gametes, male gametes (sperms) and female gametes (eggs). The sperm and egg unite to form zygote. Zygote divides many times to form embryo. From the embryo new baby is formed inside the body of mother.

Do You Know?

It is generally estimated that the size of human heart is equal to the closed fist of person.

5. Nervous System

The nervous system is the complex network of cells and fibers in the body. It is divided into two parts i.e., central nervous system (CNS) and peripheral nervous system (PNS). The CNS includes brain and spinal cord. The PNS consists of those nerves which arise from brain and spinal cord. It connects the CNS to rest of the body nerves.

The nervous system is the control center of body. It controls and coordinates all body activities, for example heart beat, respiration, movement etc.

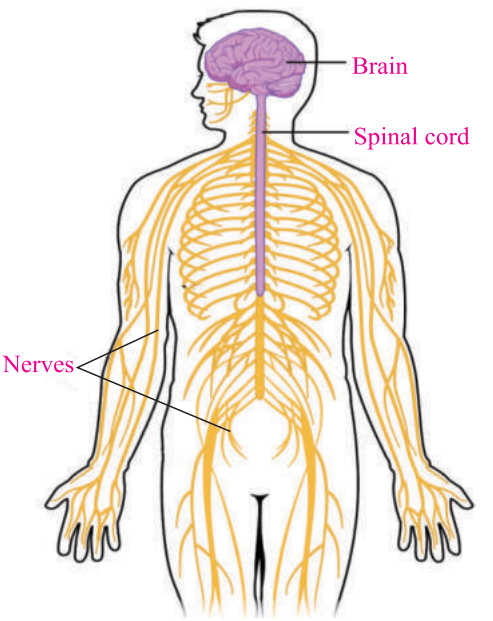


Fig. 4.7: Nervous System

6. Endocrine System

It is a system of some special glands called ductless glands or endocrine glands,

for example, pituitary glands, thyroid gland, etc. These glands produce special compounds called hormones. These hormones are directly added in the blood. The hormones play very important roles for the proper functioning of the human body. The deficiency or over production of hormones cause serious problems and even death.

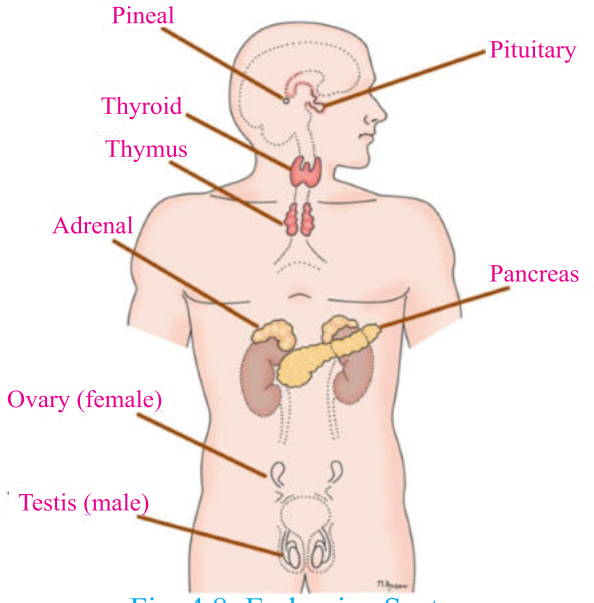


Fig. 4.8: Endocrine System

Do You Know?

The glands which pour their secretion by ducts into other parts of body are called exocrine or ductus glands.

4.6 Disorders of Different Organ Systems

When an organ does not function properly it is called organ disorder. Some examples of organ disorders are as follows:

A. Ulcer

It is a disorder of inner wall of stomach and first part of small intestine (duodenum). When there is improper coating of mucous on the inner wall of stomach or gut then the HCl and pepsin in the gastric juice destroy the tissue of inner walls causing wound. This wound is called **peptic ulcer** or **ulcer**. The ulcer of

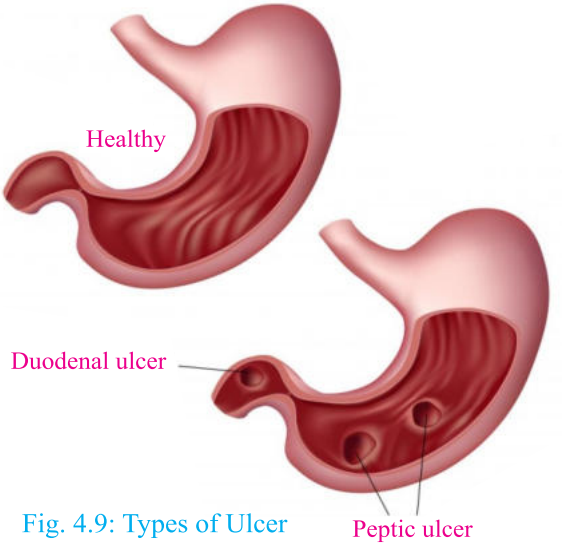


Fig. 4.9: Types of Ulcer

stomach is called **gastric ulcer** while the ulcer of duodenum is called **duodenal ulcer**. Pain in the stomach after meal is the common symptom of ulcer. Severe pain, loss of appetite and nausea are the signs of chronic ulcer.

There could be many reasons of ulcer such as Helicobacter pylori infection excess of HCl or pepsin in stomach, excessive intake of spicy food, coffee, carbonated drinks, excessive smoking, prolong use of pain killer medicines etc. Ulcer can be prevented by avoiding smoking, excessive intake of spicy food, carbonated drinks and over use of medicines. Antacid medicines neutralize the acidic effects of gastric juice. Ulcer caused by bacteria is treated with antibiotics.

B. Heart Attack (Myocardial Infarction)

The term "myocardial Infarction" is composed of two Greek words i.e 'Myocardial' means heart muscles and 'Infarction' means tissue death.

Myocardial infarction is the general term used for damage or death of heart muscles. It is commonly known as heart attack. The causing factors are plaque and thrombus formation in coronary arteries. The factors leading to myocardial infarction are obesity, metabolic syndrome and chronic kidney disease. The potential triggering factors are excessive physical activity, excessive alcohol intake and drug addiction. Most common symptom is severe chest pain or discomfort. The pain travels most often to the left arm. The pain may also travel to the neck lower jaw and back, difficulty in breathing, unconsciousness, anxiety and nausea etc.

The treatment involves the angioplasty and heart bypass surgery. The preventive measures include change in life style, exercise, patient and family

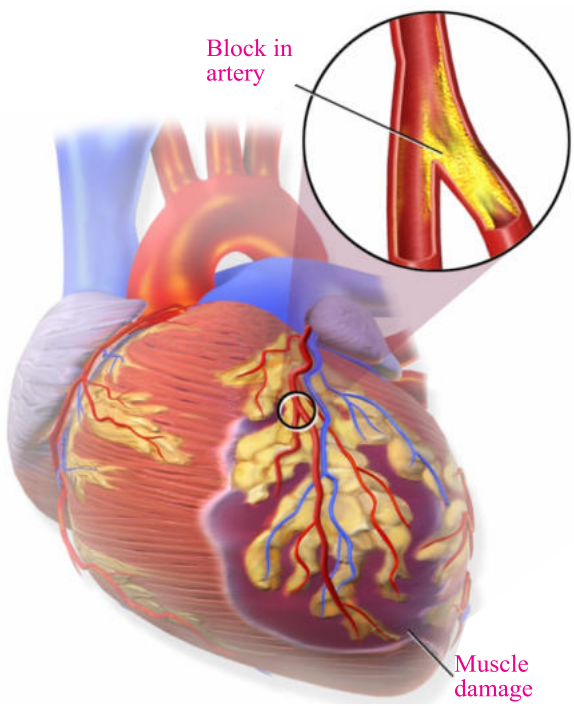


Fig. 4.10: Muscle damage causes blockage of arteries resulting in heart attack

education, control hypertension, no smoking, weight management and medication prescribed according to the need of patient.

C. Pneumonia

It is a respiratory tract disorder. It is a serious disorder of lungs. In this case inflammation occurs in the walls of air sacs (alveoli) and accumulation of fluid and pus in the air sacs of lungs.

Pneumonia is caused by bacteria, virus or fungi. The common symptoms of pneumonia are chest pain, cough, chills, fever, muscle pain, red brown sputum etc. Pneumonia can be treated by antibiotics.

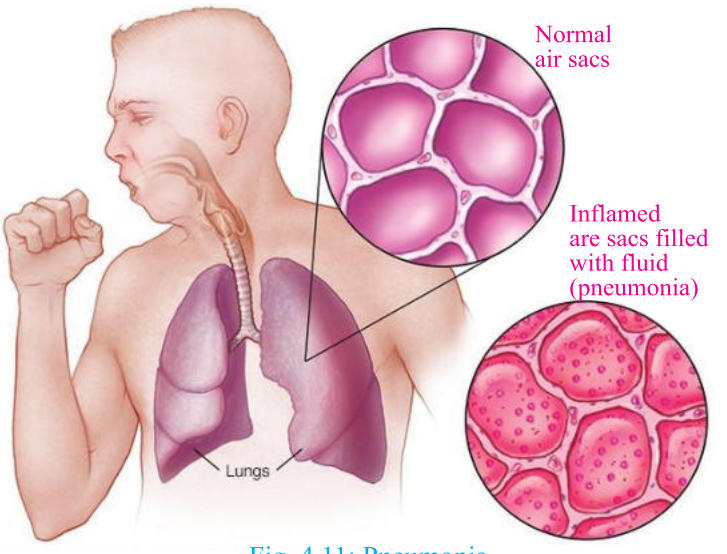


Fig. 4.11: Pneumonia

D. Brain Tumor

It is a disorder of nervous system. In this case an abnormal mass of brain cell is produced as a result of uncontrolled cell division. The tumor may be benign or malignant. The tumor is caused by mutation. It may occur in any age in brain and spinal cord. The common symptoms of tumor are headache, vision problem, hearing problems, seizures, coma etc. Tumor is removed surgically.

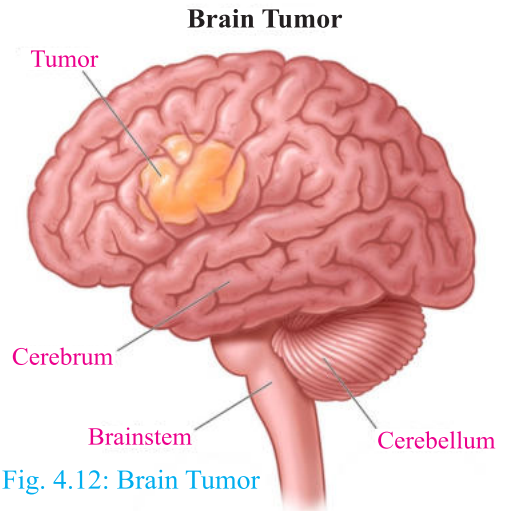


Fig. 4.12: Brain Tumor

E. Goiter

It is a disorder of endocrine glands. In this case the thyroid gland become enlarged due to deficiency of iodine. The primary symptom of goiter is a visible swelling in the front neck. Other symptoms are increased heart rate, increase sweating, increase in body weight, weak nails etc. Thyroid can be treated by proper medicines or may be removed surgically.

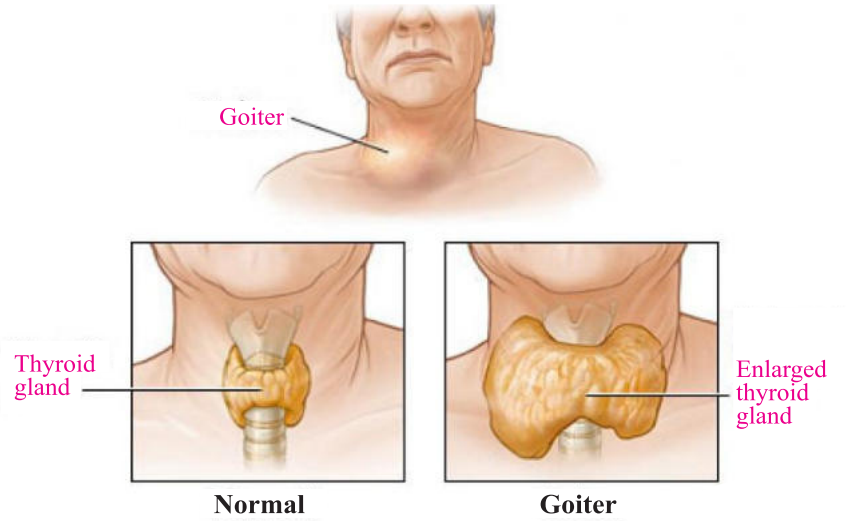


Fig.4.13: Goiter

4.7 Homeostasis

Homeostasis is a process by which living organisms keep their internal environment stable and balanced. The main aspects of homeostasis are osmorgulation (balance of water and salts in the body), excretion (removal of wastes) and thermoregulation (maintenance of constant body temperature).

4.8 Organ and Organ System Involved in Homeostasis

You have already studied that an organ is a group of different tissues having related functions and an organ sytem is formed by the group of organs having related functions. Humans possess highly developed system for homeostasis, the main homeostatic organs are lungs, skin and kidneys.

A. Lungs as Homeostatic Organ

During cellular respiration, CO_2 is produced due to breakdown of organic substances from cells which diffuses in the blood via tissue fluid. CO_2 is an acidic gas which decreases the pH of blood and makes it acidic (normal pH of blood is 7.3 to 7.4). This results in the disturbance of many chemical reactions in our body. Therefore it should be removed immediately. Blood transports CO_2 from tissue fluid to lungs for its removal through respiratory passage.

B. Skin as Homeostatic Organ

Our skin produces sweat through sweat glands, which contains water, salts and small quantity of urea. Skin also performs important role in thermoregulation. The skin

consists of epidermis (outer layer of skin) and dermis. There is a thin layer of fat cells (adipose tissue) around and beneath dermis which acts as an insulator.

The sensory nerve endings in skin are stimulated by cold and warm temperature. The contraction of small erectile muscles, which are attached to hair, forms **"goose bumps"** (i.e. hair erected). It creates an insulating blanket and prevents heat loss from the body. Similarly when body becomes overheated, the hair erectile muscles relax to remove extra heat. Excess heat is also removed through evaporation of sweat.

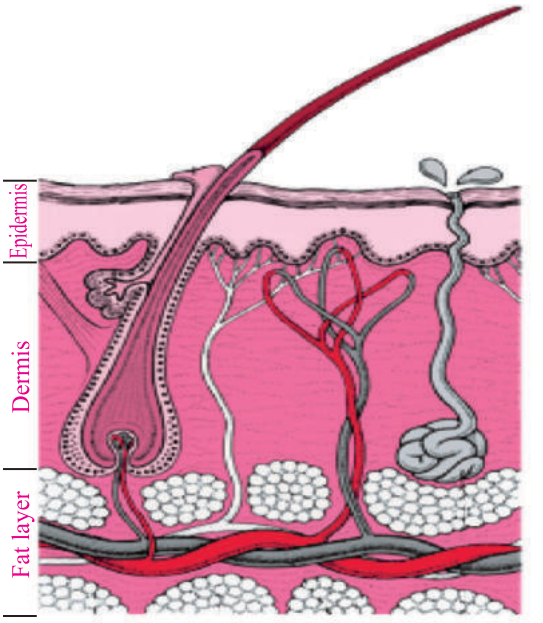


Fig. 4.14: Transverse Section of Human Skin

C. Kidneys as Homeostatic Organs

Kidneys are major excretory and osmoregulatory organs in human. They remove nitrogen containing wastes (like urea, uric acid, ammonia, creatinine etc.), drugs, used hormones, excess salts and toxic substances. Kidneys maintain water balance in the body either absorbing or removing water. They also help in maintenance of blood and lymph composition and volume.

Liver

Liver also helps in homeostasis, for example, It regulates the levels of hepatic glucose. It breaks down the dead RBCs and removes bilirubin (waste of broken RBCs).

Critical Thinking

Can a person donate one kidney to other person and live normally?

Advantages of Homeostasis

The homeostasis is a very important phenomenon in living organisms. Life of an organism is not possible without homeostasis. It keeps the balance of water and salts in the body. It helps to maintain the body temperature. Due to homeostasis the waste products are removed from the body. Homeostasis keep the body environment under control. It keeps the conditions favourable for cell to function. If homeostasis does not maintain properly then processes inside the body will not function properly.

4.9 Structure and Roles of Various Plant Organs in Plant Physiology

Plant physiology is concerned with all those processes which occur within the plant body. In a simple way, we can say that plant physiology is a combined action of root, stem, leaves, flowers, fruits and seeds.

1. Root: It is the underground part of the plant. Roots perform many functions like anchor the plant firmly in the soil, absorb water and minerals by root hairs.

2. Stem: Stem or shoot is the above ground part of plant. Inside stem, there are xylem and phloem tissues. Water and minerals are transported to all parts of plant body by xylem. The phloem transports food from the leaves to all parts of plant.

3. Leaves: A green leaf is called the kitchen of the plant because photosynthesis occurs here and as a result glucose is formed. The extra water is removed from the leaves in the form of vapours. This process is called transpiration. The exchange of gases (CO_2, O_2) also occurs through stomata of leaves.

4. Flower: It is the reproductive part of plant. The bright colours of flowers attract insects for pollination. Male gamets (sperms) are formed in anther of stamen and female gametes (eggs) are formed in the ovaries of carpel. Sperm and egg unite to form zygote by the process of fertilization. Zygote divides repeatedly to form embryo. From the embryo new plant is formed.

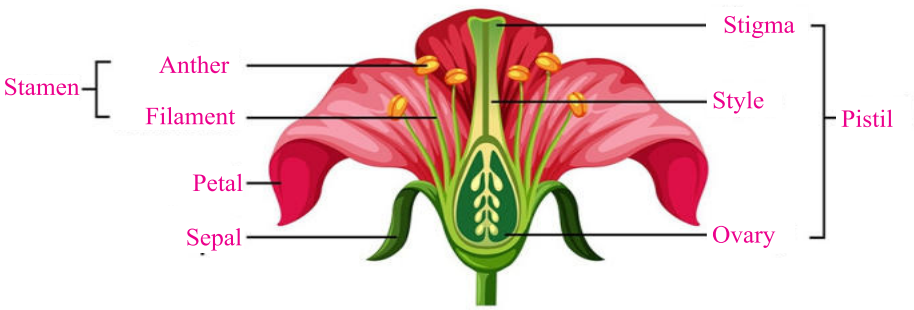


Fig. 4.15: Flower

5. Fruit: The ripened ovary with seeds is called fruit. Seeds are enclosed in fruits. Fruit is a store house of nutrients.

6. Seeds: New plants are formed by the development of embryo present inside the seed by the process called seed germination.

STEAM ACTIVITY

Identify the following on the basis of level of biological organization.

1. Bone
2. Rose plant
3. Cat
4. Nucleus
5. Mesophyll
6. Ribosome
7. Human skeleton
8. Liver
9. Glucose
10. Stomach

S.No.	Level of organization
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Key Points

- The group of cells having similar structure and function together as a unit is called tissue.
- When different tissues having similar functions work together then such a group of tissues is called an organ.
- Different organs who have similar functions that work together to perform a specific function is called an organ system.
- Levels of organization are also called hierarchy of life.
- Unicellular (made up of single cell), for example, amoeba, chlamydomonas, paramecium.
- Multi-cellular (made up of many cells), for example, human body consists of more than 37.2 trillion cells.

- Different tissues of an organ perform their specific functions and these functions collectively become the function of that organ.
- An individual or organism is formed by the organization of different organs and organ systems.
- The outermost covering of a leaf is called epidermis.
- There are many tiny pores in the epidermis called stomata. Around each stomata there are two bean shaped cells called guard cells.
- There is no chlorophyll in the cells of epidermis but guard cells contain chlorophyll.
- The tissues between upper and lower epidermis are called mesophyll tissues. The mesophyll tissues are of two types i.e palisade mesophyll and spongy mesophyll.
- Our skin removes sweat through sweat glands, which contains water, salts and small quantity of urea. Skin also performs important role in thermoregulation. The skin consists of epidermis (outer layer of skin) and dermis.
- The outer covering of root is called epidermis.
- Flower is the coloured and attractive part of plant. It is the reproductive part of plant.
- The male reproductive part is called stamen while female reproductive part is called carpel.
- The bright colours of flowers attract insects for pollination.
- The ripe ovary with seeds is called fruit.

EXERCISE

A. Multiple choice Questions (MCQs)

1. A group of cells having similar structure and function is called:
   (a) Organ (b) Tissue
   (c) Organ system (d) Organism
2. The living sub-cellular bodies in a cell are called;
   (a) Inclusions (b) Tissue
   (c) Organelles (d) Organ
3. Which statement is not correct during playing?
   (a) More heat is produced (b) Increase in blood flow
   (c) More O_2 is released (d) More CO_2 is released

4. The spongy mesophyll cells are:
   (a) Round in shape (b) Triangular in shape
   (c) Column shaped (d) Irregular in shape
5. Liver breaks down the:
   (a) Dead WBCs (b) Dead RBCs
   (c) Platelets (d) Plasma
6. Zygote after repeated divisions form:
   (a) Seed (b) Embryo
   (c) Root (d) Leaf
7. Which one of the following contains chlorophyll?
   (a) Epidermal cells (b) Flower
   (c) Guard cells (d) Xylem tissues
8. The disorder of nervous system is:
   (a) Ulcer (b) pneumonia
   (c) Tumor (d) goiter
9. One of the following is not nitrogeneous waste?
   (a) Ammonia (b) Uric acid
   (c) Bilirubin (d) Urea
10. In the skin, the thin layer of fat cells is called:
   (a) Cutin (b) Dermis
   (c) Adipose tissue (d) Epidermis

B. Short Response Questions.

1. What are the advantages of homeostasis?
2. Justify that lungs are homeostatic organs?
3. What is the role of skin in osmoregulation and thermoregulation?
4. Define the endocrine glands and write their role in human body.
5. Define the following terms
   (i) Organ (ii) Epidermis (iii) Midrib
   (iv) Respiratory System (v) Excretory system (vi)Homeotasis
   (vii) Goose bumps (viii) Thermoregulation (ix) Embryo
   (x) Fruit

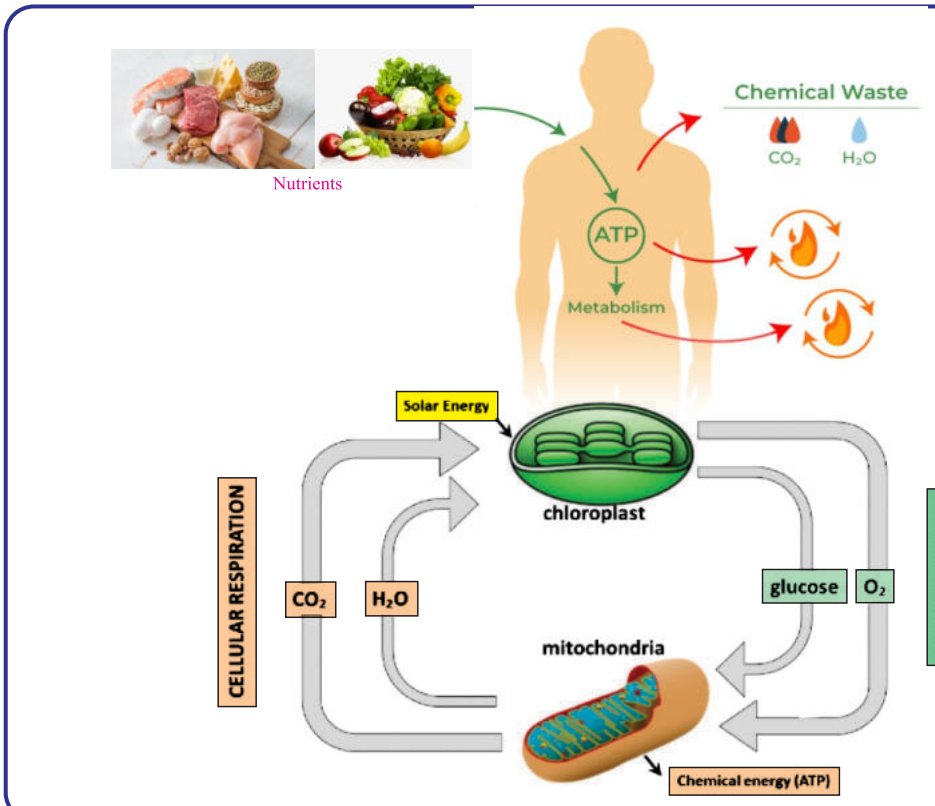
D. Extended Response Questions.

1. Explain the levels of organization in living organisms.
2. Write a detailed note on composition of stomach.
3. Explain the composition of a leaf on tissue level.
4. Discuss the roles of various plants organs in plant physiology.
5. Write a note on human nervous system.

CHAPTER

5

METABOLISM



Students Learning Outcomes:

Students will be able to:

- Define metabolism, catabolism and anabolism with examples.
- Define Enzymes and describe their characteristics.
- Show the mechanism of enzyme action.
- Assess the factors which could influence enzyme activity.
- Describe competitive, and non-competitive inhibition.
- Discus the role of ATP as energy currency.
- Describe photosynthesis in plants.
- Explain aerobic respiration and anaerobic respiration.

Introduction

Metabolism is a set of chemical reactions in the body to keep us alive. These biochemical reactions are accelerate of by naturally produced protein compounds in the living bodies called enzymes. In this chapter we will study about the nature of enzyme, their characteristics, mechanism of enzyme action, factors affecting the rate of enzyme action and models for the explanation of enzyme action.

All living organisms require energy to sustain life and to carry out their different functions. This energy is related to the food of organisms. Bioenergetic describes how living organisms obtain and transform energy. Life of an organism is dependent on energy transformation. Photosynthesis and respiration are the two main processes for energy transformation. In this chapter we will study about the processes of photosynthesis and respiration in detail.

5.1 Metabolism

The sum of biochemical reactions within a cell in order to maintain life is called metabolism. The word metabolism is derived from a Greek word "metabole" which means "to change". The chemical reactions taking place in living organisms are called biochemical reactions. The life of an organism is sustained due to these biochemical reactions. These reactions occur step by step in a specific manner. If these reactions occur slowly in a body then all the activities of body will become disturbed. In order to speed up these reactions enzymes are required.

Due to metabolism energy, is formed which is used in vital processes like movements, growth etc. This energy is also used for the synthesis of new organic materials.

Categories of Metabolism

Metabolism can be divided into two categories i.e., anabolism and catabolism.

(A) Anabolism

In these biochemical reactions larger molecules are formed by smaller molecules, for example, synthesis of protein molecules from amino acids.

(B) Catabolism

In these biochemical reactions, larger molecules are broken down into smaller molecules for example, breakdown of protein molecules into amino acids.

All the biochemical reactions are actually energy transfer reaction. Energy is released in catabolism and is utilized in anabolism.

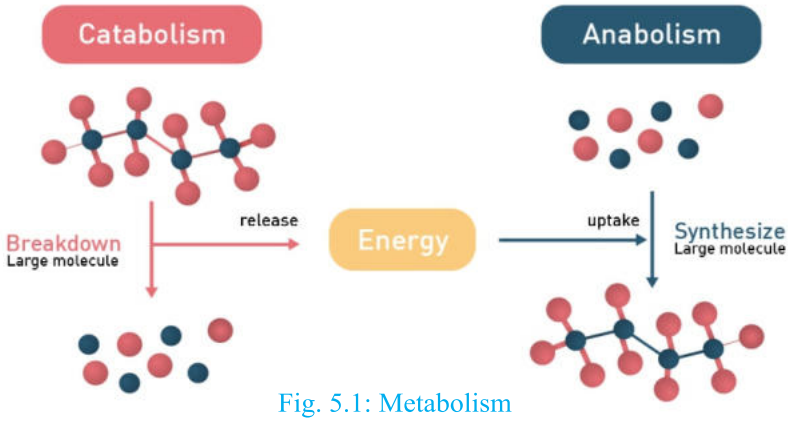


Fig. 5.1: Metabolism

5.2 Enzyme And Their Characteristics

Enzymes are **biocatalysts.** They speed up the chemical reaction in living bodies. The enzymes speed up the metabolic reaction by lowering the activation energy. Without enzymes, the metabolic reactions would proceed at low speed so making life impossible. For example, the digestion of food is carried out in a short period of 3 to 4 hours help of many enzymes like pepsin, maltase, lipase etc. Without the participation of these enzymes, the process of digestion would take a long time for completion.

The characteristics of enzymes are as follows.

1. Enzymes are protein in nature.
2. Enzymes are globuluar in shape.
3. The structure of enzymes change during reactions but they regain their actual shapes after the completion of biochemical reactions.
4. Enzymes are not consumed during the biochemical reactions.
5. They increase the rate of reaction many folds.
6. Enzyme only accelerates the rate of chemical reaction but does not initiate it.
7. Enzymes are usually very specific in their function i.e. they catalyse only one type of reaction. For example, lipase acts only on lipids.
8. Enzymes work in a limited range of pH, temperature and substrate concentration.
9. Only a small amount of an enzyme can catalyse the reaction.
10. The amount of enzyme varies in cell according to its requirement.
11. The activities of enzymes are increased by activators while inhibitors stop their activities.

Do You Know?

Each chemical reaction needs a minimum amount of energy to start called activation energy.

12. Some enzymes require some additional compounds for their proper functioning called co-factors.

5.3 Mechanism of Enzyme Action

When an enzyme attaches with a specific substrate then a temporary bond is formed between the two called enzyme-substrate complex. In this complex, enzyme catalyzes the reaction and substrate is transformed into product. After this, the ES complex breaks and products are released from the enzyme. The enzyme is now ready to join with another substrate.

The mechanism of an enzyme action can be summarized as follows:

$$E + S \longrightarrow ES\ Complex \longrightarrow EP\ Complex \longrightarrow E + P$$

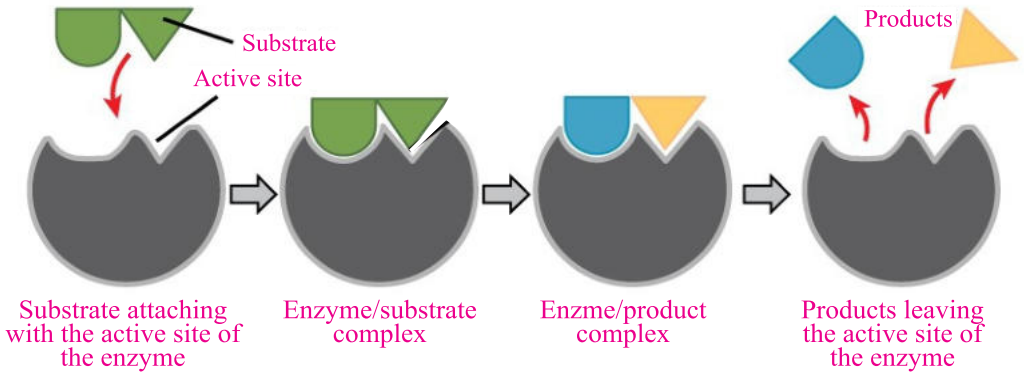


Fig. 5.2: Mechanism of enzyme action

Models for the explanation of Enzyme Action

Two models were presented by biologists to explain the mechanism of enzyme action.

A. Lock and Key Model

This model was proposal by a German chemist Emil Fischer in 1894. According to this model, the enzyme acts as a lock while substrate acts as a key. The enzyme (lock) possess a rigid cavity or active site in which only one substrate with specific shape (key) can fit.

This model explains enzyme specificity but does not explain all the enzymatic reactions.

Activity

Study the lock and key enzyme action and induced fit model of enzyme action by animated videos through internet.
(Video links are given at the end of chapter).

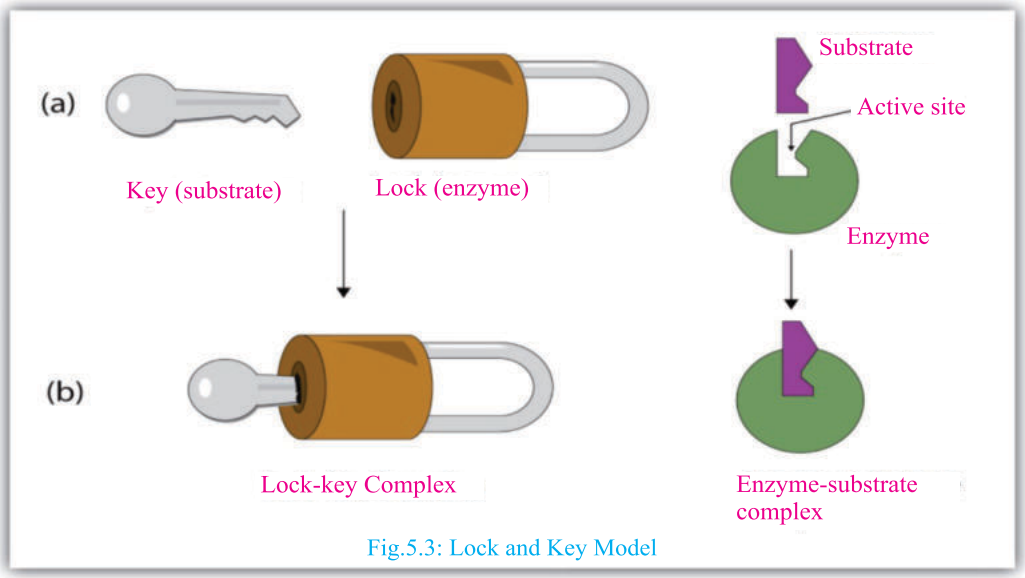


Fig.5.3: Lock and Key Model

B. Induced Fit Model

This model was proposed by an American biologist Daniel Koshland in 1958. This model is also called "hand and glove" model. According to this model, enzymes are not rigid but are flexible structures. The active site of an enzyme slightly changes its shape as the substrate interacts with the enzymes. As a result ES-Complex forms. As products are released from the enzyme, the active site regains its previous shape.

Induced fit model is more acceptable than "lock and key" model of enzyme action because it explains all the enzymatic reactions.

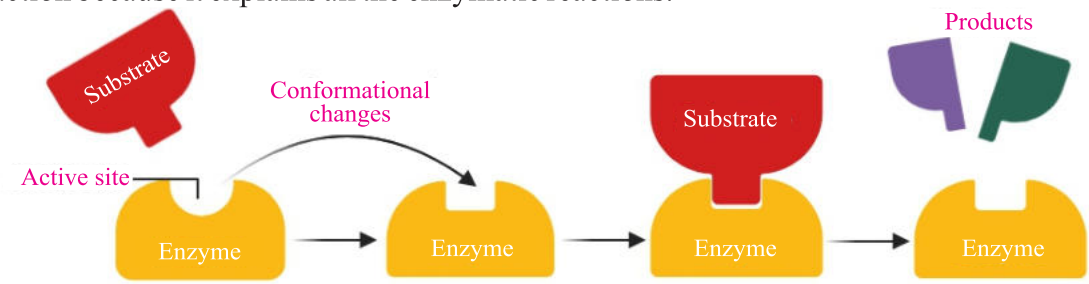


Fig.5.4: Induced-fit Model -
The enzyme active site form a complementary shape to the substrate after binding

5.4 Factors Affecting the Rate of Enzyme

Enzymes work in specific environment. The activities of enzymes are affected by any change in conditions which alter their chemistry and shape. The rate of enzyme action is affected by many factors. Some important factors are as follows.

1. Enzyme Concentration

The rate of a biochemical reaction increases by increasing the enzyme concentration but upto a certain limit.

Reason: Increasing enzyme concentration speeds up the biochemical reaction as long as there is enough substrate. After a time limit, all substrate molecules bind to enzyme. This is called saturation point. After this point, more enzyme would not increase the reaction rate further due to unavailability of substrates.

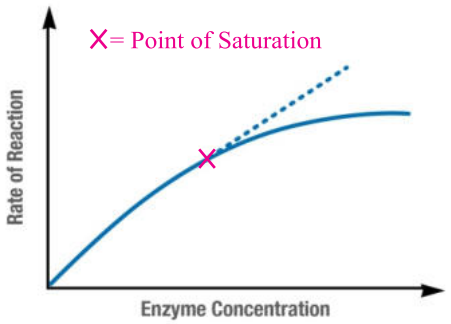


Fig.5.5: Effect of Enzyme concentration

2. Substrate Concentration

In the presence of enzymes, an increase in substrate concentration increases the rate of enzyme action but upto a certain limit.

Reason: When enzymes are present at reaction site and substrate concentration is increased, rate of reaction increases. After some time, a limit is reached where any further increase in the substrate does not increase the rate of reaction any more. It is due to the occupation of all active sites of enzymes by substrate molecules. This point is called saturation of active sites. In this condition, free active sites are not available for more substrate molecules. So, rate of reaction does not increase.

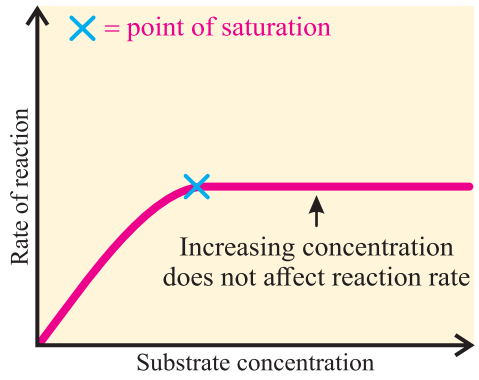


Fig.5.6: Effects of substrate concentration

Do You Know?

The food like meat, fruits may spoil bad because of the enzyme activity. Therefore, it is advised to keep such foods in refrigerator because the enzyme activity becomes slow at lower temperature.

3. Effect of Temperature

The rate of enzyme action increases with the increase in temperature but only to a certain point. When temperature is raised above this point, then heat energy increases the vibration of atoms of enzyme molecules. As a result, the globular structure of enzyme destroys. This is called denaturation of enzymes. At this point the rate of enzyme action decreases rapidly or blocks completely.

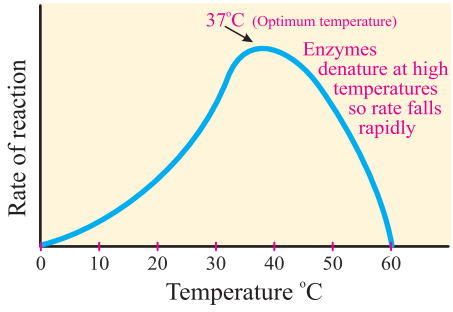


Fig.5.7: Effect of temperature

Every enzyme works at its maximum rate at a specific temperature called optimum temperature, e.g. 37°C is the optimum temperature for the enzymes action in human body.

Activity

Find the pH of different food substances by searching internet.

4. Effect of pH

Each enzyme works at its maximum rate at a narrow range of pH called optimum pH. A specific pH of a medium is necessary for the proper functioning of an enzyme. The enzyme activity is decreased by slight changes in pH while the extreme changes in pH cause denaturing of enzyme.

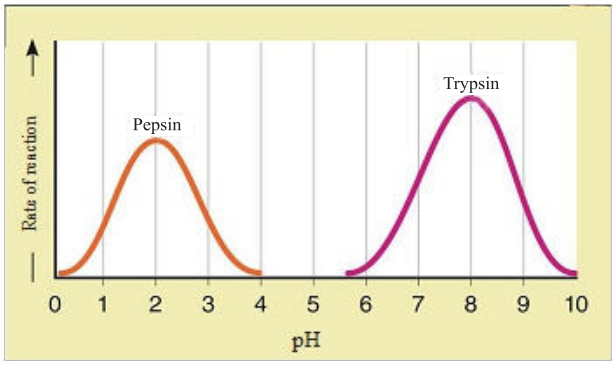


Fig.5.8: pH range

Every enzyme has its own specific optimum pH value. For example, pepsin and trypsin are protein digesting enzymes. Pepsin works in stomach and its optimum pH is 2.00 (acidic) while trypsin work in intestine and its pH is 8.0 (alkaline).

5.5 Competitive and Non Competitive Inhibitors

The substance which binds to an enzyme and stops its activity is called enzyme inhibitor. For example, poison, drugs like pencillin, antibodies etc.

Inhibitor reacts with an enzyme in place of substrate. As a result, an enzyme inhibitor complex is formed instead of ES-complex. Due to this reason, the substrate is not changed into product. The enzyme inhibitor complex blocks the active site of enzymes temporarily or permanently.

Do You Know?

Germinating seeds have enzymes which convert insoluble stored food into simpler soluble substances for example the enzyme amylase digest starch and converts it into maltose.

There are two types of inhibitors i.e., irreversible inhibitors and reversible inhibitors. The irreversible inhibitors permanently stop the activity of an enzyme. While the reversible inhibitors temporarily stop the activity of an enzyme. There are two types of reversible inhibitors.

a) Competitive Inhibitors

The morphology or structure of these inhibitors is similar with actual substrate.

They compete with the substrate to occupy the active site. They occupy the active sites instead of substrate. As a result no chemical reaction occurs.

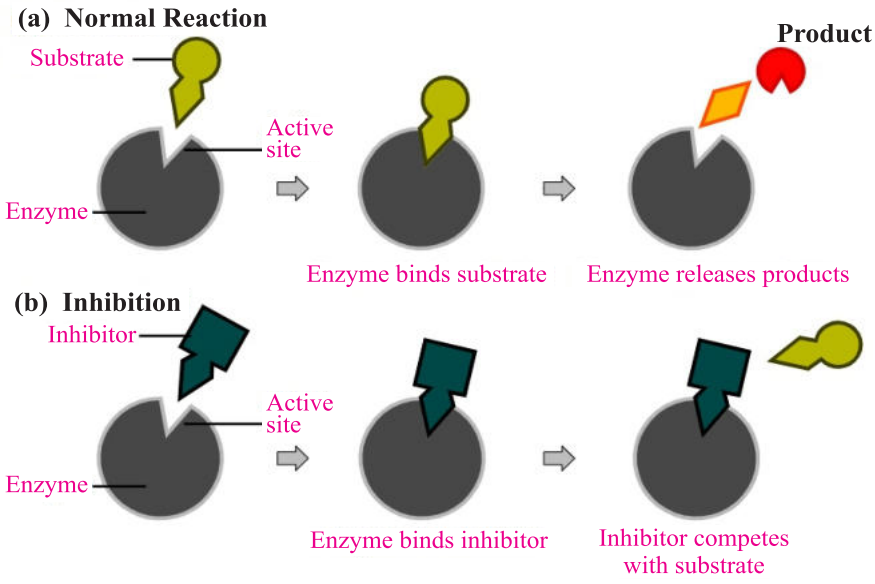


Fig.5.9: Competitive Inhibition

A competitive inhibitors occupies the active site temporarily. It does not damage enzymes permanently. The process of competitive inhibition depends upon the relative concentration of substrate and inhibitors.

(i) If the concentration of competitive inhibitors is high than the chances of inhibition are high.

(ii) If the concentration of substrate is increased then the active sites will usually be occupied by the substrate. As a result product will be formed.

b) Non-Competitive Inhibitors

These inhibitors have different morphology or structure from substrates. They do not compete with substrate for binding in the active sites of enzyme. They form enzyme inhibitor complex at a place other than active site called allosteric site. As a result, the enzyme structure is changed. Now the substrate cannot fit into the active site so catalysis fails to take place.

Skill: Analyzing

Relate enzyme activity with antibiotics by searching internet and try to find out the reason why antibiotics are not effective against viruses.

The non-competitive inhibition is not affected by increasing the concentration of substrate because active sites are not available in their proper shapes.

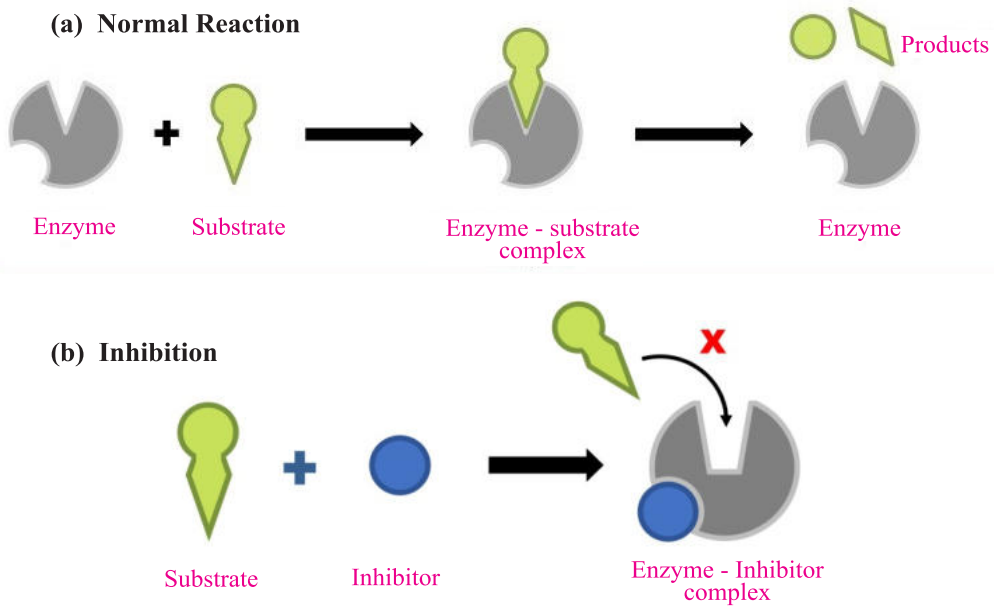


Fig.5.10: Noncompetitive Inhibition

5.6 Role of ATP as Energy Currency

Life of an organism is impossible without the constant supply of energy. All the life processes like movement, development, reproduction etc. depend on the availability of energy. The living organisms use energy in the form of ATP (Adenosine tri phosphate). It is called the energy currency of cell because it is an energy rich compound. It temporarily stores energy and quickly supply energy when energy is needed by various cellular processes, for example, muscle contraction, synthesis of molecules, transportation of molecules across cell membrane etc. The ability of ATP to store and release energy is because of its unique structure.

Do You Know?

One molecule of glucose after complete oxidation releases 36 ATP molcules.

ATP molecule consists of three components:

1. Adenine (Nitrogen base)

2. Ribose (Five carbon sugar)
3. Three Phosphate Groups.

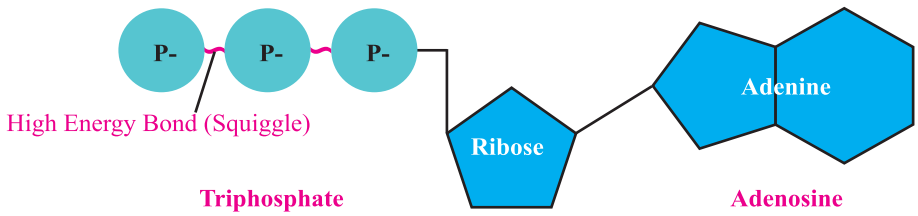


Fig.5.11: Chemical Structure of Adenosine Triphosphate (ATP)

Adenine is covalently bonded with ribose sugar to form a compound called adenosine.

$$\text{Adenine} + \text{Ribose Sugar} \longrightarrow \text{Adenosine}$$

Three phosphate groups are linked in a linear chain with adenosine to form ATP. The bonds between phosphate groups are high energy bonds. These are represented by a specific curved sign (~) called squiggle. The breakdown of this high energy bond releases 7.3 K cal/mol energy. This energy is used by the cells to carry out their functions.

ATP-ADP Cycle

There is a constant formation and breakdown of ATP in the cells. ATP molecules are constantly broken down to form Adenosine diphosphate (ADP) and inorganic phosphate (P*i*) with the release of energy (7.3Kcal/mol).

$$ATP + H_2O \longrightarrow ADP + Pi + 7.3\text{Kcal/mol}$$

This energy is used by the cells to carry out their functions.

The ATP molecules are also constantly formed by the union of ADP and P*i* by using 7.3Kcal/mol energy

$$ADP + Pi + \text{energy} \longrightarrow ATP$$

This energy is obtained from the breakdown of glucose molecule during respiration.

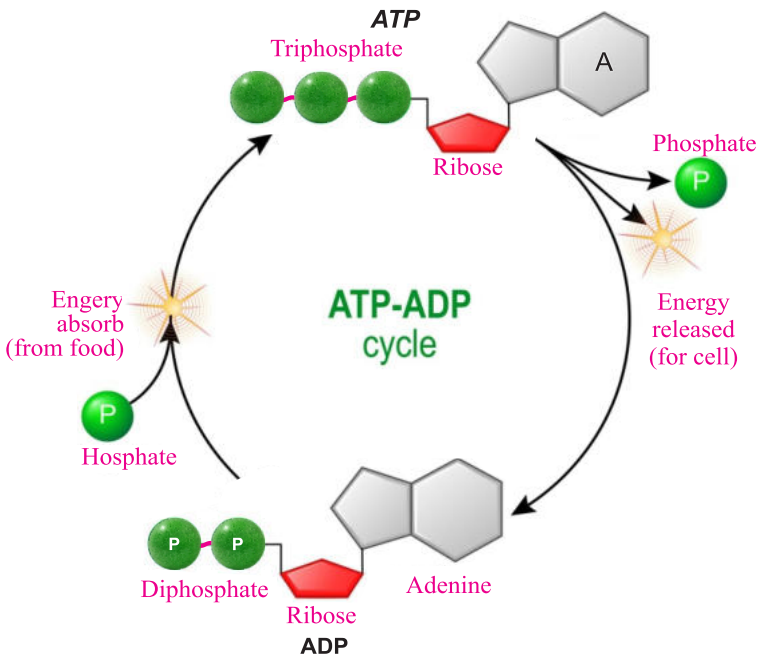


Fig.5.12: ATP – ADP Cycle

5.7 Photosynthesis

Photosynthesis is a biochemical process in green plants to form glucose from water and CO_2 in the presence of sunlight and chlorophyll by releasing oxygen. The word photosynthesis has been derived from two Greek words 'photo = light' and 'synthesis = to make'.

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

Photosynthesis is a fundamental process for the manufacturing of food in plants.It is an anabolic process. Autotrophic organisms use water and CO_2 to form their food (glucose). This process occurs in the presence of sunlight and chlorophyll. During this process oxygen is released as a by-product.

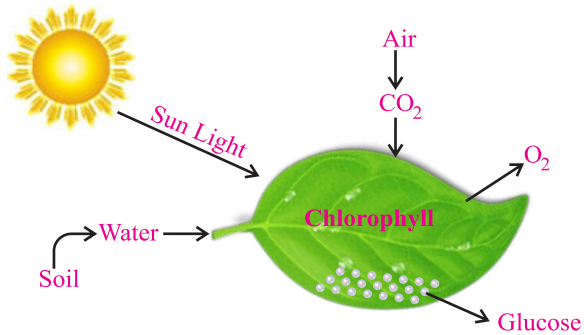


Fig.5.13: Photosynthesis

Importance

We know that life of an organism is not possible without the constant supply of energy. Food is the main source of energy. Animals and many other forms of life are heterotrophs so they cannot prepare their food. They directly or indirectly depend on green plants for their food.Plants are autotrophs. They can prepare their food by photosynthesis. In a simple way, we can say that all the organisms depend upon photosynthesis.

Mechanism of Photosynthesis

The process of photosynthesis occurs in two main phases.

A. Light Reactions

B. Dark Reactions

A. Light Reactions (Hill Reactions)

These reactions were discovered in the granum of chloroplast by Robert Hill in 1937. These reactions are also called "Hill reactions" due to the name of discoverer.

It is the first phase of photosynthesis. It is completed after passing through a series of chemical reactions. These reaction occur in the granum of chloroplast. In these reactions light energy is captured and is used to make high energy molecule i.e. ATP (Adenosine triphosphate) and NADPH (Nicotinamide adenine dinucleotide phosphate).

Events of Light Reactions

Following events occur during light reactions.

a) Removal of Electrons

Light strikes the chlorophyll molecules to remove electrons from it. In this way the chlorophyll becomes electron deficient.

b) Photolysis of Water

Water molecule is broken down by light. As a result, hydrogen ions (H^+), electrons and oxygen are released.

The oxygen is released in air while electrons enter into chlorophyll to compensate the electron deficiency.

$$H_2O \longrightarrow 2H^+ + 2e^- + \frac{1}{2} O_2$$

c) Formation of ATP

The electrons which were emitted from chlorophyll, pass through an electron transport chain. The electron transport chain involves a series of compounds in which

each compound first receives electrons (reduction) and then releases electrons (oxidation). In this way each compound first reduces and then oxidizes. During this process, energy is released. This energy is used by ADP and Pi to form ATP.

$$ADP + Pi + Energy \longrightarrow ATP$$

d) Formation of $NADPH_2$

The electrons of chlorophyll and H^+ of water now react with NADP (already present in granum) to form $NADPH_2$.

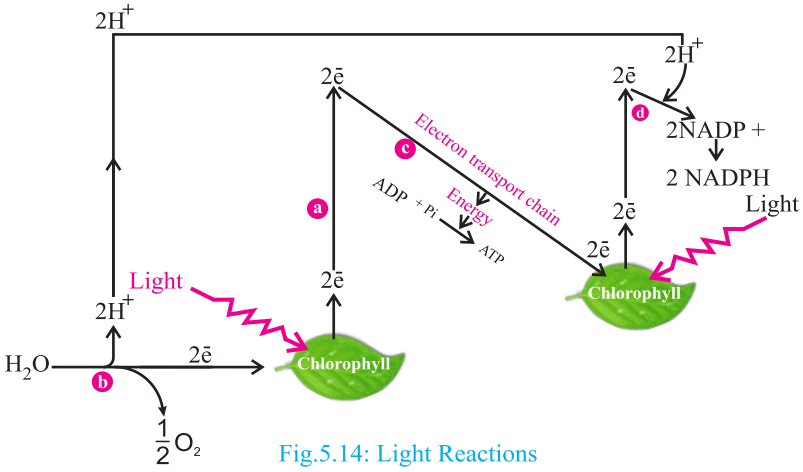


Fig.5.14: Light Reactions

B. Dark Reactions (Calvin Cycle)

These reactions were discovered by Melvin Calvin and his colleagues in the stroma of chloroplast. These are also called "Calvin reactions" after the name of discoverer. Calvin got Nobel prize in 1961.

It is the second phase of photosynthesis. It is completed after passing through cyclic reactions. These reactions do not need light energy and use energy from ATP and NADPH molecules synthesized during light reactions. In these reactions CO_2 is reduced to form glucose.

Events of Dark Reactions

The dark reactions are completed in following three main phases.

Critical Thinking

How does the life of all organisms on earth depend upon photosynthesis?

a) Carbon Fixation

In this phase, three molecules of CO_2 react with a preexisting 5-carbon compound called ribulose biphosphate (RuBP). As a result an unstable 6-carbon

compound is formed called 3-keto-2-carboxyarabinitol 1, 5-biphosphate. It quickly breaks down into six 3-carbon compounds called phosphoglyceric acid (PGA).

b) Reduction

The six PGA molecules are then reduce to 3-carbon compound called phosphoglyceraldehyde (PGAL). This reduction occurs by using those ATP and NADPH which were formed during light reactions. The PGAL molecules are then used to form glucose.

c) Regeneration

The PGAL molecules are also used to form original 5-carbon RuBP by using the ATP.

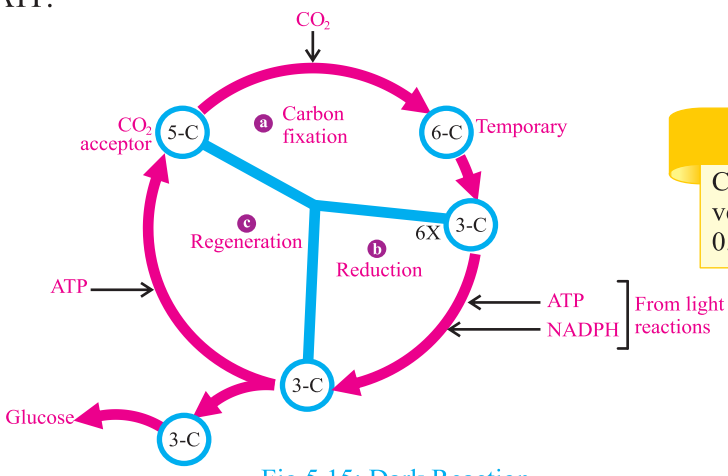


Fig.5.15: Dark Reaction

Do You Know?

CO_2 is present in atmosphere in very low amount i.e. only 0.03% - 0.04%.

5.8 Respiration

The series of chemical reactions in which food molecules are broken down and energy is released in the form of ATP is called respiration.

All organisms need a constant supply of energy for their survival. Food is the source of energy. This energy is obtained by the breakdown of food molecules, especially glucose molecules. Respiration is a series of complex oxidation reduction (redox) reactions. In these reactions the glucose molecules are broken down and energy is released. This energy is transformed into ATP. This ATP is used by the cells to perform their activities.

Types of Respiration

There are two types of respiration. These types depend on the availability of

oxygen for the breakdown of glucose molecules.

A. Anaerobic Respiration

It is also called fermentation. It takes place in the absence of oxygen. In this case incomplete oxidation of glucose occurs with the release of less amount of energy. Anaerobic respiration occurs in two phases. In the first phase glucose molecule is broken down into two molecules of pyruvic acid as formed in aerobic respiration. In the second phase pyruvic acid is not completely oxidized due to the absence of oxygen. As a result of anaerobic respiration 2ATP molecules are formed by the breakdown of one molecule of glucose. The breakdown of pyruvic acid occurs differently in different organisms. In yeast the pyruvic acid is broken down into ethyl alcohol and CO_2.

$$\text{Glucose} \longrightarrow 2\ \text{Ethanol} + 2CO_2 + 2ATP$$

In some bacteria and mammal muscles the pyruvic acid is broken down into lactic acid.

Additional Information

Yogurt is formed by the process of fermentation.

$$\text{Glucose} \longrightarrow 2\ \text{Lactic acid} + 2ATP$$

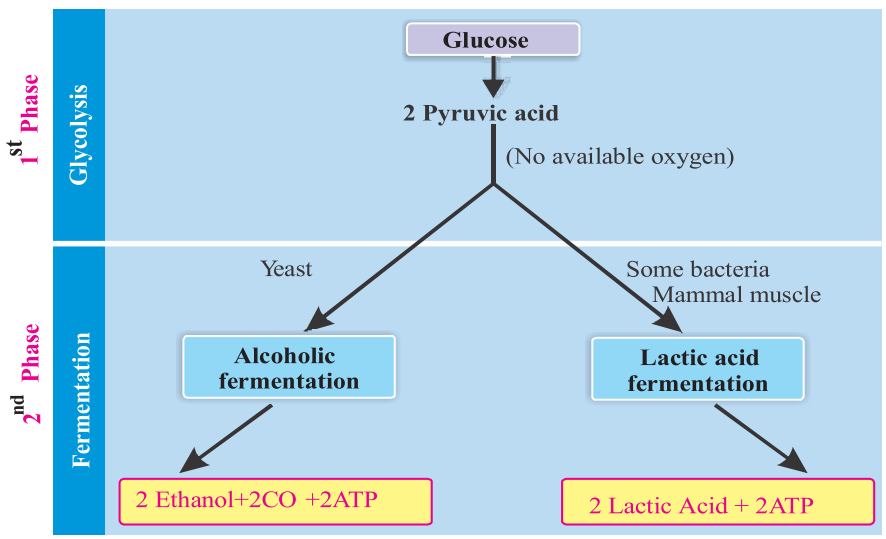


Fig.5.16: Anaerobic Respiration

B. Aerobic Respiration

It is also called cellular respiration. It takes place in the presence of oxygen. In this case complete oxidation of glucose occurs with maximum release of energy. Aerobic respiration is completed in two phases. In the first phase glucose molecule is broken down into two molecules of pyruvic acid. In the second phase, the two molecule of pyruvic acid are oxidized. As a result, water and CO_2 are formed with the release of

energy in the form of ATP.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{Enzymes}} 6CO_2 + 6H_2O + \text{Energy (36 ATP)}$$

By the complete breakdown of one molecule of glucose, 36 ATP molecules are formed.

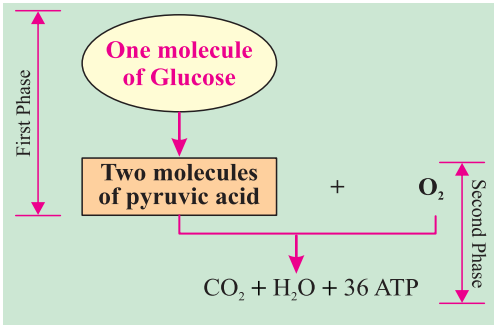


Fig.5.17: Aerobic Respiration

Mechanism of Aerobic Respiration

Aerobic respiration is a complex series of chemical reactions. These reactions occur in the cytoplasm and mitochondria. In these reactions the organic food (glucose) is completely broken down into CO_2 and H_2O with the release of energy in the form of ATP.

Aerobic respiration is a continuous process, but for the convience it is divided into three main phase.

A. Glycolysis
B. Kreb's cycle
C. Electron transport chain

A. Glycolysis

It is the first stage of respiration. It occurs in cytoplasm and does not require oxygen. Due to this reason, this stage occurs in both types of respiration i.e. anaerobic and aerobic. In this stage one 6-C compound (Glucose) is broken down into two 3-C (Pyruvic acid) molecules.

$$\text{Glucose} + \text{ADP} + \text{NAD}^+ \longrightarrow 2\text{Pyruvic acid} + \text{ATP} + \text{NADH}$$

B. Kreb's Cycle (Citric Acid Cycle)

This stage occurs in mitochondria. Before entering into the Kreb's cycle, the pyruvic acid reacts with coenzyme A and is converted into a 2-C compound called

Acetyle-Co A. In Kreb's cycle, complete oxidation of pyruvic acid takes place. As a result ATP, NADH and $FADH_2$ are formed.

$$\text{Pyruvic acid} + \text{coenzyme A} \xrightarrow[\text{NAD}\ \ \text{NADH}]{\text{CO}_2} \text{Acetyle CoA}$$

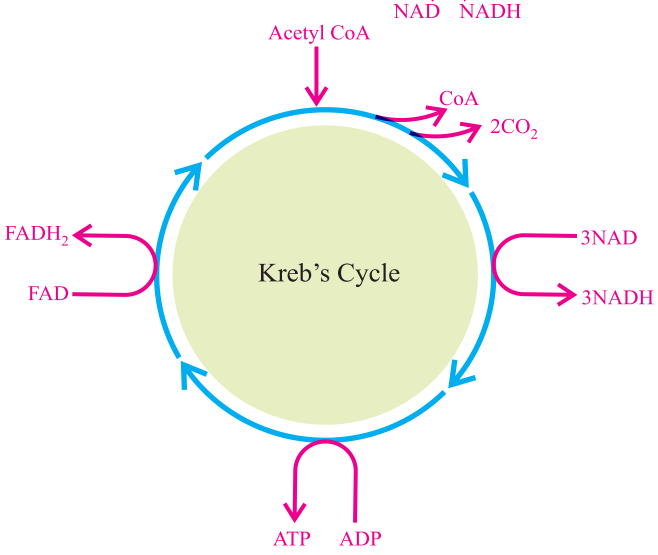


Fig.5.18: Kreb's Cycle

C. Electron Transport Chain (ETC)

This stage occurs in mitochondria following reactions occur at this stage.

i) NADH and $FADH_2$ which were produced during Kreb's cycle release electrons and hydrogen ions.

ii) The electrons pass through a series of electron carriers. During their movement, electrons lose energy and this energy is used in the formation of ATP from ADP.

iii) At the end of the stage or chain the electrons and hydrogen ions combine with molecular oxygen to form water.

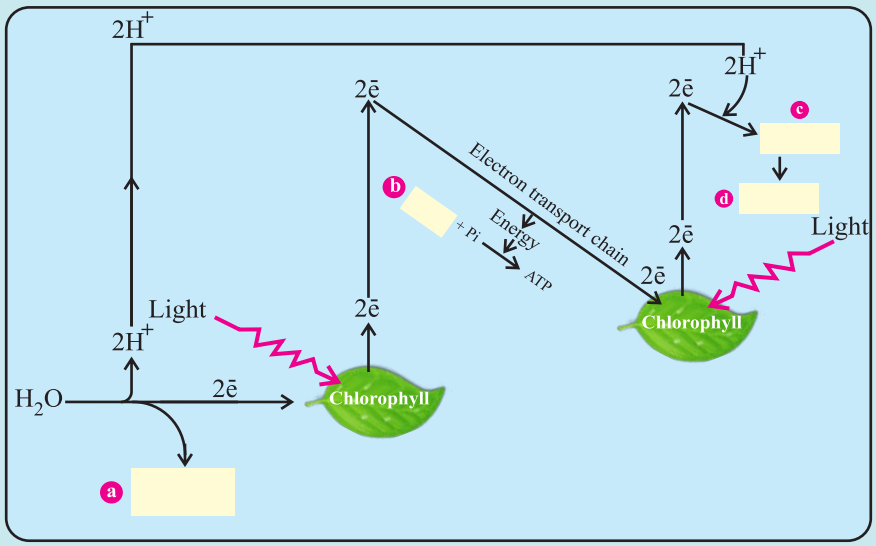
$$ADP + FADH_2 + NADH \xrightarrow{O_2} ATP + NAD^+ + FAD^+ + H_2O$$

Activity

By using internet, watch some animated videos about photosynthesis and respiration. Note the points that what have you learned from those videos.
(Video links are given at the end of chapter).

STEAM ACTIVITIES

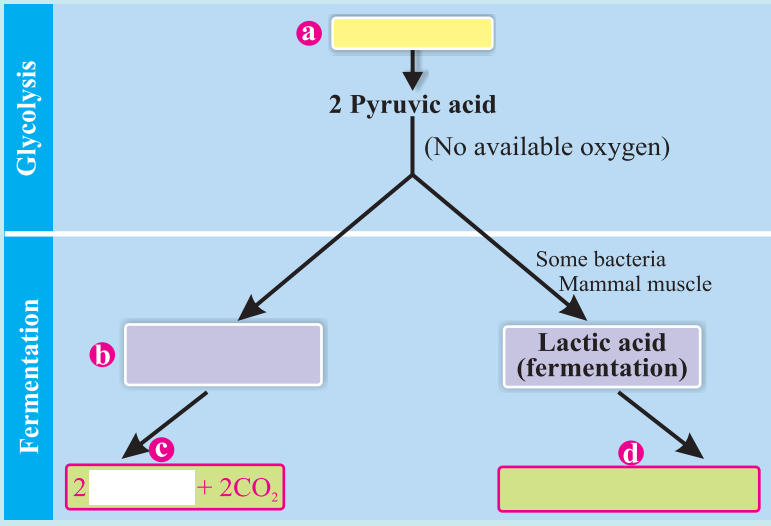
a. Identify and write the names of the missing compounds a, b, c and d.



b. Make the model of enzyme action by using coloured cardboard.

STEAM ACTIVITIES

c. Identify and write the missing compound's names at a, b, c and d.



d. Build the model of a "ATP" by using low cost materials like cardboard, wires, plastic balls etc.

Key Points

- The sum of biochemical reactions within a cell or living organism in order to maintain life is called metabolism.
- Enzymes are biocatalysts. They speed up the chemical reaction in living bodies. The enzymes speed up the metabolic reaction by lowering the activation energy.
- Lock and Key Model: The enzyme (Lock) possess a rigid cavity or active site in which only one substrate with specific shape (Key) can fit (Lock and Key model).
- Induced fit model is also called hand and glove model. According to this model enzymes are not rigid bodies but are flexible structures. The active site of an enzyme slightly changes its shape as the substrate interacts with the enzymes.
- The substance which binds to an enzyme and stops its activity is called enzyme inhibitor.
- The living organisms use energy in the form of ATP (Adenosine tri phosphate). It is called the energy currency of cell because it is an energy rich compound.
- Photosynthesis is a biochemical process of green plants to form glucose from water and CO_2 in the presence of sunlight and chlorophyll by releasing oxygen.
- Light reactions occur in the granum of chloroplast. In these reactions light energy is captured and used to make high energy molecule i.e., ATP (Adenosine Triphosphate) and NADPH (Nicotinamide Adenine dinucleotide Phosphate).
- Dark reactions occur in the stroma of chloroplast. In these reactions CO_2 is reduced to glucose.
- The series of chemical reactions in which glucose molecules are broken down and energy is released in the form of ATP is called respiration.
- Aerobic respiration is also called cellular respiration. It takes place in the presence of oxygen. In this case complete oxidation of glucose occurs with maximum release of energy.
- Anaerobic respiration is also called fermentation. It takes place in the absence of oxygen. In this case incomplete oxidation of glucose occurs with the release of less amount of energy.
- Glycolysis occurs in cytoplasm and does not require oxygen. Due to this reason, this stage occurs in both types of respiration i.e. anaerobic and aerobic. In this stage one 6-C compound (Glucose) is broken down into two 3-C (Pyruvic acid)
- Krebs cycle (Citric Acid Cycle) occurs in mitochondria.
- In Krebs cycle complete oxidation of pyruvic acid takes place. As a result ATP, NADH and $FADH_2$ are formed.

EXERCISE

A. Multiple choice Questions (MCQs)

1. The induced fit model for the mechanism of enzyme action was proposed by:
   (a) Emil Fischer (b) Singer and Nicolson
   (c) Daniel Koshland (d) Schleiden and Schwann
2. The function of ATP is:
   (a) Storage of Energy (b) Generation of Energy
   (c) Consumption of Energy (d) Transformation of Energy
3. Anaerobic respiration takes place in:
   (a) Cytoplasm (b) Endoplasmic Reticulum
   (c) Nucleus (d) Mitochondria
4. The products of alcoholic fermentation are:
   (a) Lactic acid and ethanol (b) Lactic acid and Co_2
   (c) Ethanol and CO_2 (d) Ethanol and CO_2
5. Raw material for photosynthesis are:
   (a) Water and glucose (b) CO_2 and glucose
   (c) Glucose and chlorophyll (d) Water and CO_2
6. During aerobic respiration the net gain of ATP is:
   (a) 34 (b) 36
   (c) 38 (d) 40
7. The number of ATP molecules obtained from one molecule of glucose in anaerobic respiration are:
   (a) 5 (b) 4
   (c) 3 (d) 2
8. The primary purpose of catabolism in cellular metabolism is to:
   (a) Synthesize new biomolecules
   (b) Generate energy for cellular process
   (c) Store energy for future use
   (d) Repair damaged tissues
9. The lock and key model of enzyme action states that:
   (a) Enzymes change their shape to fit substrates
   (b) Enzymes and substrates have specific shapes

(c) Enzyme are non-specific and bind to any substrate
(d) Enzyme are denatured by substrate

10. The induced fit model of enzyme action states that:
(a) Enzymes remain rigid and unchanged
(b) Enzymes changes shape to fit substrate
(c) Substrate changes shape to fit enzyme
(d) Enzymes are non-specific and bind to any substrate

11. When an inhibitor binds to the active site of an enzyme this inhibition is called:
(a) Non-competitive inhibition (b) Competitive inhibition
(c) Allosteric inhibition (d) Irreversible inhibition

12. The products of light reactions of photosynthesis are:
(a) Glucose and oxygen (b) ATP and NADPH
(c) Water and Carbon dioxide (d) Chlorophyll and light

13. The difference between light reactions and dark reactions in terms of location is:
(a) Light reactions occur in stroma, dark reactions occur in thylakoid membrane
(b) Light reactions occur in thylakoid membrane, dark reactions occur in stroma
(c) Both reaction occur in stroma
(d) Both reaction occur in thylakoid membrane

14. The three stages of aerobic respiration are:
(a) Glycolysis, fermentation and electron transport chain
(b) Glycolysis, pyruvate oxidation and Kerb's cycle
(c) Glycolysis, Kerb's cycle and electron transport chain
(d) Glycolysis, photosynthesis and Kerb's cycle

B. Short Response Questions.

1. What is the difference between catabolism and anabolism?
2. What is an active site and how is it important?
3. What is the importance of photosynthesis?
4. Write the mechanism of enzyme action.
5. Write a brief note on fermentation.

6. Differentiate between aerobic and anaerobic respiration.
7. Why is ATP the major energy currency of all living cells.
8. Interpret the role of chlorophyll in relation with light in photosynthesis.
9. How do plants get water and carbon dioxide for photosynthesis?
10. Write down the process of photosynthesis and respiration in the form of equations.
11. Define the following terms

(i) Metabolism	(ii) Substrate
(iii) Enzyme	(iv) E-S complex
(v) Active site	(vi) Optimum pH of enzyme
(vii) Inhibitors	(viii) ATP
(ix) Photosynthesis	(x) Fermentation
(xi) Aerobic respiration	(xii) Glycolysis
(xiii) Denaturation of enzyme	(xiv) Photolysis of water
(xv) Electron transport chain	

C. Extended Response Questions.

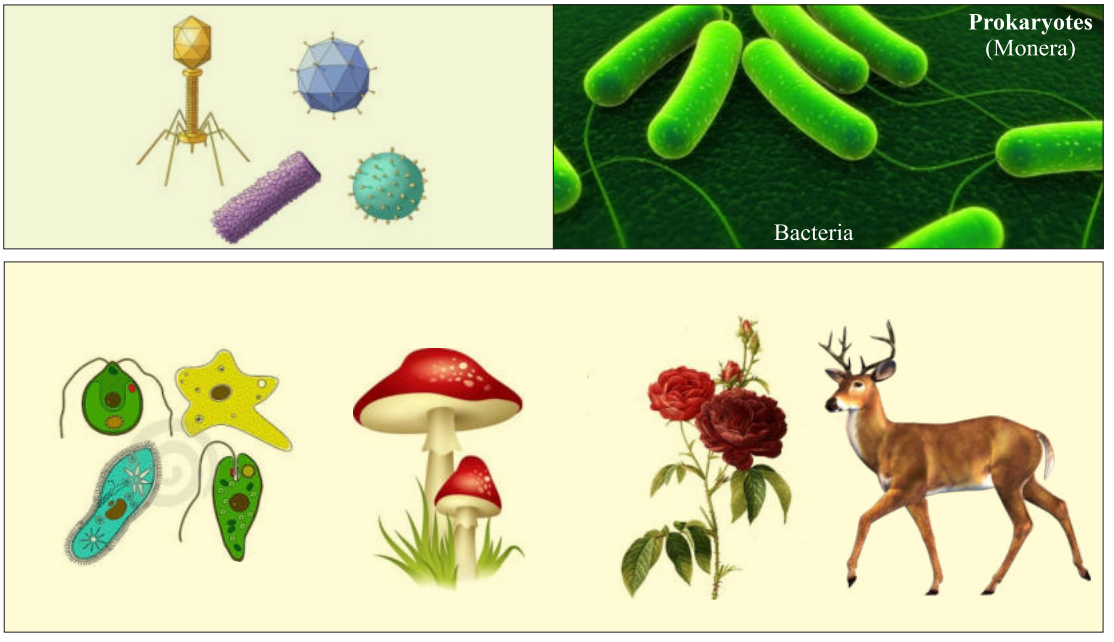
1. Describe lock and key model and induced fit model for mechanism of enzyme action.
2. List down the characteristics of enzymes.
3. Explain the factors which affect the enzymetic action.
4. Write down the events of light and dark reactions.
5. Explain the mechanism of aerobic respiration.
6. Compare photosynthesis and respiration.

Videos links:

https://www.youtube.com/watch?v=scusxqaJIpc
https://www.youtube.com/watch?v=A4drW8yJDGY
https://www.youtube.com/watch?v=wNG2uPao8BI
https://www.youtube.com/watch?v=AZBKQ3LwkfQ
https://www.youtube.com/watch?v=rlH1ym916Fo

CHAPTER 6

BIODIVERSITY AND CLASSIFICATION



Students Learning Outcomes:

After studying this chapter, students will be able to:

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

Introduction

Earth is the only planet of the solar system upon which life exists. According to biologists there are about 8.7 million species of living organisms on earth which are quite different from each other. The variety of life present on Earth is called biodiversity. In this chapter, we will study about the variety of organisms found on Earth. We will also study how the living things are classified and how scientific names are given to them. In this regard, we will study five kingdom classification system, three distinct domains of organisms, taxonomic ranks of classification and binomial nomenclature.

6.1 Biodiversity and Classification

The term biodiversity has been derived from two words i.e.,"Bios" means life and "Diversity" means variety. The variety of life present on earth is called Biological Diversity or biodiversity.

Biodiversity is a measure of different forms of life present on the earth i.e. microorganisms, fungi, plants and animals. It depends upon many factors such as availability of food, water, temperature, soil, altitude, climate etc.

The arrangement of organisms into groups and sub groups on the basis of similarities and differences is called classification. The branch of biology which deals with classification is called taxonomy and the expert in taxonomy is called taxonomist.

6.2 Advantages of Classification

There are thousands of different animals and plants living on earth having similarities and differences among them. Biologists can not deal with them unless they are properly classified. Classification is based on similarities which show their common ancestory. It helps to know the relationship between organisms and their evolution.

6.3 History of Classification Scheme

The history of classification system of living organisms is as old as man started to know them. The work of different biologists for the classification of organisms is discussed below.

Aristotle (384 - 322 BC) was a Greek philosopher. He is called the father of science. He is also considered as the founder of biological classification. He classified the organisms in to two groups i.e. plantae (plants) and animalia (animals). He classified the animals on the basis of habitat. Theophrastus (371 - 287 BC) was student of Aristotle and called father of botany. He classified plants on the basis of marphology.

Abu - Usman Aljahiz (776 - 868 AD) was an Arab thinker. He wrote a famous book "Kitab Al-Hayawan". Carolus Linnaeus (1707 - 1778) was a Swedish biologist. He organized plants and animals from level of kingdom down to species. Linnaeus is called the father of modern taxonomy. He proposed different levels or ranks for classification. He also introduced two kingdom system of classification.

From Aristotle to late 1800,s the living things were divided into two kingdoms i.e. plantae and animalia. The two kingdom system is based on the mode of nutrition. The autotrophs were included in plantae while heterotrophs in animalia. This system has many short comings for example, euglena is a unicellular organism which shows characters of both plants and animals, therefore it can not be placed clearly in either of the two kingdoms. This system was also unable to explain prokaryotes and eukoryotes.

Five kingdom system was introduced by Robert Whittaker (1969). It is based on cellular organization and mode of nutrition. These five kingdoms are:

1. Monera
2. Protista
3. Fungi
4. Plantae
5. Animalia

Robert Whittaker

In 1982, Margulis and Schwartz modified the five kingdoms system of Robert Whittaker by naming kingdom Monera as Prokaryotae.

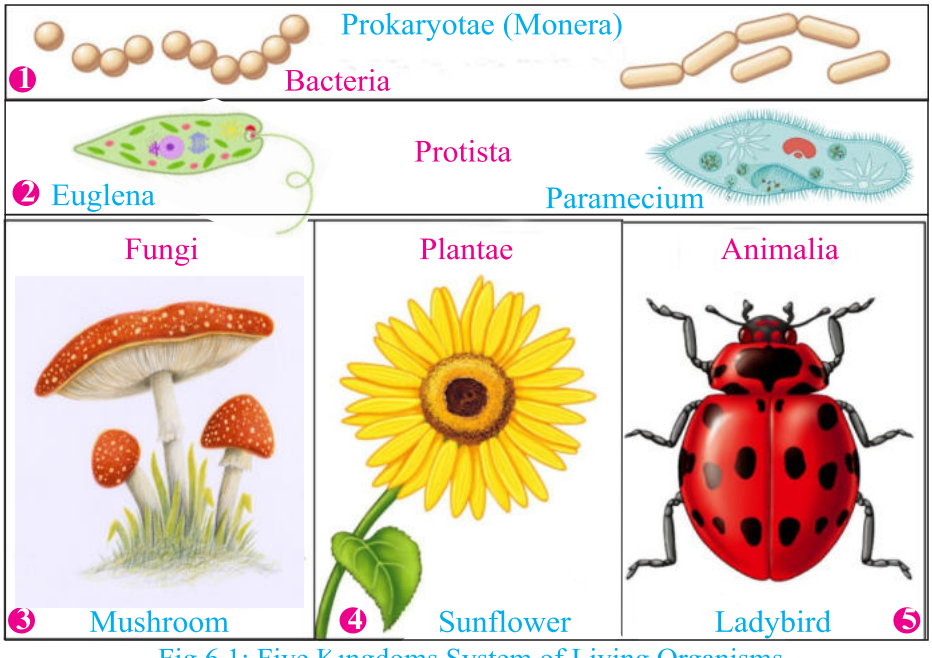


Fig.6.1: Five Kingdoms System of Living Organisms

6.4 Three Distinct Domains of Organisms

On the basis of nucleus, the organisms are of two types i.e., prokaryotes and eukaryotes.

A. Prokaryotes

The single celled microscopic organisms without proper nuclei are called prokaryotes. These are of two types i.e., archeobacteria and eubacteria. Archeo is a Greek word which means "ancient". It is a small group of primitive form of bacteria. They look like bacteria but are genetically different from bacteria. They often live in extreme environments like hot springs, salt lakes etc. "Eu" is a Greek word which means "True". It is a large group which includes true bacteria. They are commonly found in air, water, soil etc. For example, nitrogen fixing bacteria.

B. Eukaryotes

Critical Thinking

Are bacteria found in some types of our food?

Eukaryotes are those organisms who have well organized nuclei in their cells. For example, protists, fungi, plants, animals, Carl Woese in 1977 classified all the organisms into three domains on the basis of disorganized and organized nucleus.

1. Archea] Prokaryotes
2. Eubacteria]
3. Eukarya] Eukaryotes

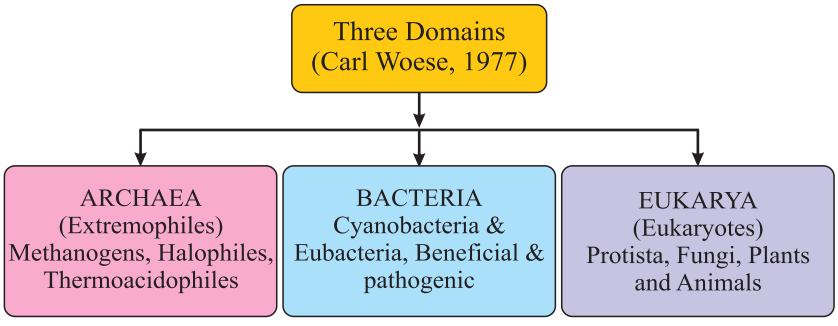


Fig.6.2: Three Domains

6.5 Taxonomic Ranks of Classification

In taxonomy, the groups of organisms are arranged in the form of a ladder, in which each step is at a higher level than the lower one. This is called hierarchy. In hierarchical arrangement each level is called a "rank". There are seven major ranks in the taxonomic classification, i.e., kingdom, phylum, class, order,

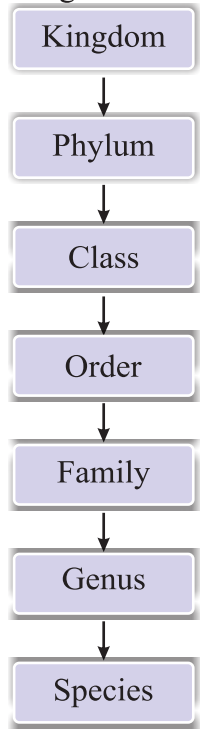


Fig.6.3: Linnaeus System of classification

family, genus and species. Each rank represents a taxon. In this arrangement kingdom is the largest and species is the lowest taxon.

1. **Species:** It is a group of individuals that can interbreed with one other in nature and produce fertile offsprings.
2. **Genus:** Closely related species are placed in a group called genus.
3. **Family:** It is a group of closely related genera.
4. **Order:** It is a group of closely related families.
5. **Class:** It is a group of closely related orders.
6. **Phylum:** It is a group of closely related classes.
7. **Kingdom:** All the closely related phyla are placed in the largest group called kingdom.

The taxonomic classification of some organisms is given in the following table:

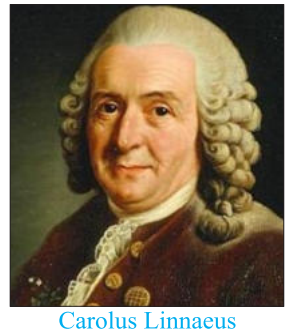
Table 6.1

Taxonomic Ranks	Rice	Potato	Cat	Human
Kingdom	Plantae	Plantae	Animalia	Animalia
Phylum	Tracheophyta	Tracheophyta	Chordata	Chordata
Class	Liliopsida	Magnoliopsida	Mammalia	Mammalia
Order	Poales	Solanales	Carnivora	Primates
Family	Poaceae	Solanaceae	Felidae	Hominidae
Genus	*Oryza*	*Solanum*	*Felis*	*Homo*
Species	*sativa*	*tuberosum*	*catus*	*sapiens*

6.6 Binomial Nomenclature

The method of giving two word names to the plants and animals is called "Binomial Nomenclature".

Carolus Linnaeus in 1753 suggested the rules for giving biological names to organisms. He gave a name of two-words to species he knew.



Carolus Linnaeus

Rules for "Binomial Nomenclature"

The words used for naming of an organism are of Latin or Greek Origin.

1. The first part of the name is generic name i.e. it is the name of genus to which species belong.
2. The second part of the name is specific name i.e. it is the name of particular species.
3. First letter of generic name is always written capital while the specific name is in small letter.
4. Both the names of an organism are underlined, if hand written and italicized, if typed, for example, *Brassica campestris or* Brassica campestris

Brassica campestris is the name of mustard (sarson). Brassica is the name of genus while campestris is the name of species.

Table 6.2: Examples of Binomial Nomenclature

Organisms	Scientific Names	
	Typed	Hand Written
Pea	*Pisum sativum*	Pisum sativum
Corn	*Zea mays*	Zea mays
Frog	*Rana tigrina*	Rana tigrina
Cat	*Felis catus*	Felis catus
Human	*Homo sapiens*	Homo sapiens

Importance of Binomial Nomenclature

a) Common names vary from country to country and also vary from region to region within a country, for example, the Urdu name of "garlic" is "lehson." It is also called "thoom" in hindko, "ugga" in Pashto.
These common names cause many problems specially in biological research. It means the name of a specie should be the same throughout the world.

b) In some cases same name is used for different organisms which also causes confusions, for example, roses are flowering plants but the same name is used for certain rose lichens.

c) The binomial nomenclature indicates the generic relationship of a particular species, for example, the common cat *(Felis catus)* and lion *(Felis leo)* have same genus i.e Felis.

Do You Know?

Lichens are combination of two organisms i.e., a fungus and an alga living together for mutual benefits.

6.7 Complications of Classifying Viruses

Viruses are an important group of microbes. They can only be seen with electron microscope. They spread diseases in living things. The viruses are inactive outside the living host. They show their life functions only inside the host cells. They do not fit in the five kingdoms system due to many reasons.

a) They are neither prokaryotes (bacteria) nor eukaryotes (fungi, plants, animals).

b) They have both properties like living and non-living things. Their non-living properties are; they have no protoplasm, they can be crystalized, they do not respire, etc. Their living properties are; they have nucleic acids (DNA or RNA), they show reproduction. Due to these reasons the viruses are considered on the borderline of living and non-living things.

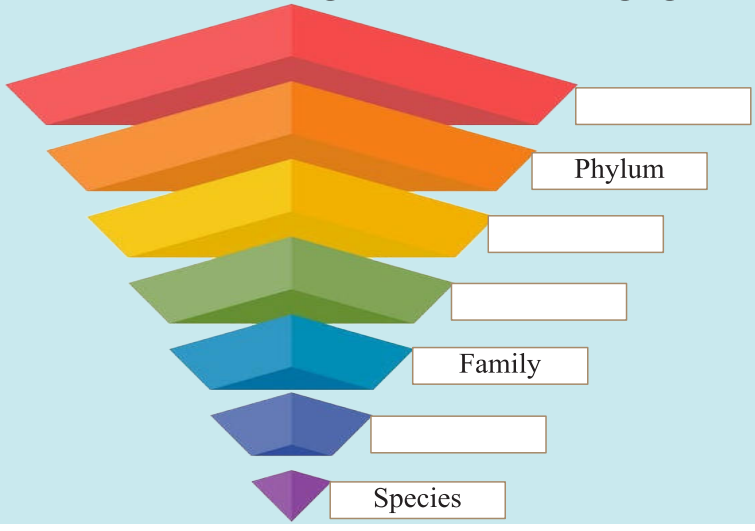
c) They do not have any cellular organization while five kingdoms system classifies the organisms on basis of their cellular organization and mode of nutrition. So they do not fit in five kingdom classification system.

d) The mode of nutrition is unclear in viruses while it is a fundamental characteristics of five kingdom system.

ACTIVITIES

a. Compile a complete list of biologists discussed in this chapter along with their works.

b. Write down the names of missing taxa in the following figure.



c. Write down the classification of human being.

Key Points

- The variety of living things on earth is called biodiversity.
- The method of giving two word names to the organisms is called binomial nomenclature.
- Carolus Linnaeus in 1753 introduced the rules for giving biological names to organisms.
- Five kingdom system for the classification of organisms was introduced by Robert Whittaker in 1969.
- In 1982, Mergulis and Schwartz modified the five kingdoms system of Robert Whittaker. They placed unicellular algae in protista while multicellular algae were placed in kingdom plantae.
- Carl Woese in 1977 classified all the organisms into three domains on the basis of disorganized and organized nucleus.
- According to the taxonomic ranks of classification, species is the smallest while kingdom is the largest group of organisms.
- Viruses are not clearly fit in the five kingdoms system because they show the non-living and living characters.
- The arrangement of organisms into groups and sub groups on the basis of

similarities or differences is called classification.

- The branch of biology which deals with classification is called taxonomy and the expert in this field is called taxonomist.
- Aristotle (384-322 BC) is called father of science.
- Theophrastus (371-287 BC) is called father of botany.
- Abu Usman Aljahiz (776-868 AD) wrote a famous book Kitab Al Hayawan on animals.
- Carolus Linnaeus (1707 - 1778) is called the father of modern taxonomy.
- Three distinct domains of organisms are archea, eubacteria and eukarya.
- The method of giving two word scientific name to an organism is called binomial nomenclature.

EXERCISE

A. Multiple choice Questions (MCQs)

1. Who is called the father of science?
   (a) Theophrastus (b) Carolus Linnaeus
   (c) Robert Whittaker (d) Aristotle
2. The classification of living organisms by Aristotle based on:
   (a) Respiration (b) Excretion
   (c) Habitat (d) Mode of nutrition
3. Meaning of biodiversity is:
   (a) Diversity of plants (b) Diversity of animals
   (c) Diversity of viruses (d) Diversity of life
4. Five kingdoms system was introduced by:
   (a) Robert Brown (b) Robert Whittaker
   (c) Aristotle (d) Carolus Linnaeus
5. *Rana tigrina* is the scientific name of:
   (a) Cat (b) Frog
   (c) Pea (d) Human beings
6. *Zea mays* is the scientific name of:
   (a) Rice (b) Wheat
   (c) Frog (d) Corn

7. The branch of biology that deals with the classification and naming of organisms is:
   (a) Morphology (b) Anatomy
   (c) Physiology (d) Taxonomy
8. Three domain system of organisms is introduced by:
   (a) Aristotle (b) Robert Whittaker
   (c) Carolus Linnaeous (d) Carl Woese
9. The term Tracheophytes is used for:
   (a) Non-vascular plants
   (b) Vascular plants
   (c) Organisms without proper nucleus
   (d) Those organisms who are not clearly fit into plants and animals

B. Short Response Questions.

1. Do you think that classification is necessary for the proper study of organisms? Briefly describe your answer with some facts.
2. Write down the biological names of pea, potato and corn.
3. Why is it difficult to classify the viruses with other organisms?
4. Define the following terms
   (i) Prokaryotes (ii) Hierarchy
   (iii) Species (iv) Taxonomy
   (v) Binomial nomenclature (vi) Biodiversity

C. Extended Response Questions.

1. What is five kingdom classification system for living organisms? Who introduced this system? Who modified the five kingdom system?
2. Write a comprehensive note on three distinct domains of organisms.
3. Explain in detail the taxonomic ranks of classification.
4. Who introduced binomial nomenclature? What are the rules for binomial nomenclature? What is the importance of binomial nomenclature?

CHAPTER
7

FORM AND FUNCTION IN PLANTS

Students Learning Outcomes:

Students will be able to:

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

- Explain the mechanism of food translocation by the theory of Pressure Flow Mechanism.
- Describe the process of gaseous exchange in plants.
- Define homeostasis and describe its importance.
- Describe the mechanisms of adaptations in plants for the excretion.
- Explain osmotic adjustments in plants.
- Describe different types of asexual reproduction i.e. binary fission, budding, spore formation and vegetative propagation.
- Distinguish between vegetative propagation and artificial propagation.
- Explain vegetative propagation in plants (through stem, suckers and leaves).
- Describe the two methods of artificial vegetative propagation (stem cuttings and grafting)
- Rationalize how parthenogenesis is a type of asexual reproduction.
- Define cloning.
- Explain sexual reproduction in Plants.
- Describe seed germination and its significance.
- Explain different methods of seed dispersal.

Introduction

Substances required by plants for survial and growth are called nutrients. There are two types of nutrients, i.e., macronutrients and micronutrients. Plants absorb dissolved minerals from soil by root hairs. Some water and all minerals are utilized by the plants while surplus water is removed from the plant by transpiration through stomata.

The upward movement of water alongwith dissolved minerals (sap) is called ascent of sap. The process of ascent of sap is best explained by "TACT" theory. Food is prepared in the leaves and then transported to all cells of the plant body. This process is called translocation. The process of translocation is well explained by pressure flow mechanism. In this chapter, we will study about the nutrition in plants, types of nutrients, internal structure of root and root hairs, absorption of water and minerals through root, transpiration, upward movement of water alongwith dissolved nutrients from roots to leaves, transportation of food from leaves to other parts of body. We will also study about gaseous exchange, homeostasis, asexual and sexual reproduction, artificial vegetative, propagation, parthenogenesis and cloning in plants.

7.1 Mineral Nutrition in Plants

The mineral nutrients are present in the soil and are absorbed by the plants in the form of ions. Among these, 16 elements have been found vital for plant growth and development.

7.2 Macronutrients and Micronutrients

Due to their need by plants, the inorganic nutrients are of two types, for example, macronutrients and micronutrients.

A. Macronutrients

The nutrients which are required in large amounts are called macronutrients. These are nine in numbers.

B. Micronutrients

The nutrients which are required in trace amounts are called micronutrients. These are 14 in numbers but 7 are mostly required by plants i.e. B, Cl, Cu, Fe, Mn, Mo and Zn. The other 7 are Al, Co, Na, Ni, Se, Si and V, required in trace amounts.

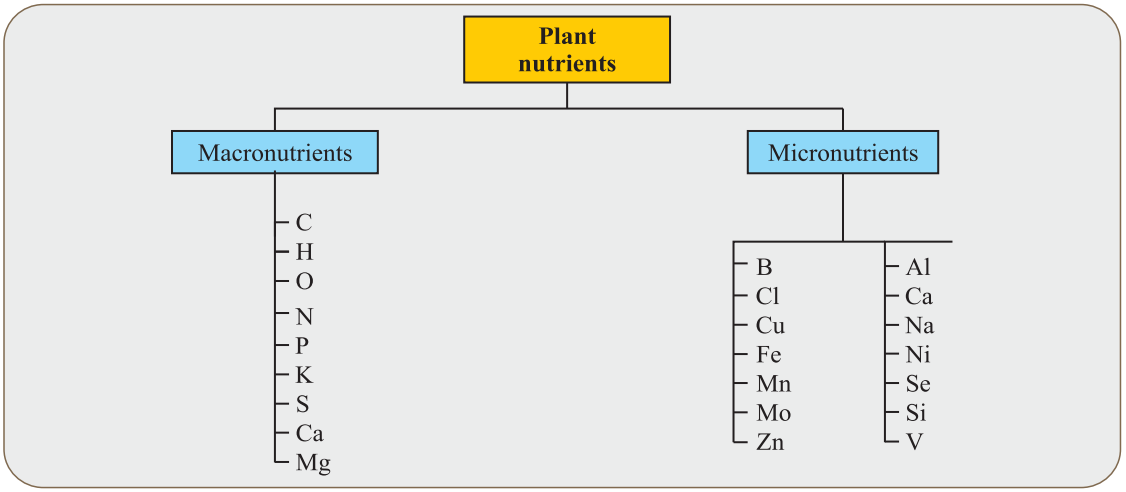


Fig.7.1: Plant Nutrients

Additional Information

In human body the %age of C, H and O is C = 18.5%, H = 9.5% and O = 65%.

Carbon, hydrogen, and oxygen are the basic elements of life. These are essential macronutrients for all living organisms. Carbon (C)is the basic element of all biomolecules like carbohydrates, proteins, lipids and nucleic acids. Hydrogen (H) is present in all biomolecules alongwith carbon. It is also the component of water without which life is not possible. It is involved in ATP formation. Oxygen (O) is the component of water and biomolecules. It is essential for aerobic respiration.

7.3 Role of Nitrogen and Magnesium

Role of Nitrogen in Protein Synthesis

Nitrogen is a macronutrient which is absorbed from soil by the plant in the form

of nitrates (NO_3). Nitrogen is fundamental component of amino acids. These amino acids combined to form proteins. These proteins are necessary for the growth of plants. In case of deficiency of nitrogen in plants the growth of a plant is badly effected.

Role of Magnesium in Chlorophyll Formation

Magnesium is a macronutrient which is absorbed from the soil through roots of plants. Magnesium is an important component of chlorophyll. It plays an important role in chlorophyll formation. It is the central atom in the chlorophyll molecule. Plants can not form chlorophyll efficiently without magnesium. Magnesium also activates those enzymes which are needed for the synthesis of chlorophyll. A deficiency of magnesium can cause chlorosis (yellowing of leaves). The chlorosis occurs due to deficiency of chlorophyll. This condition is responsible for poor photosynthesis and weak plant growth.

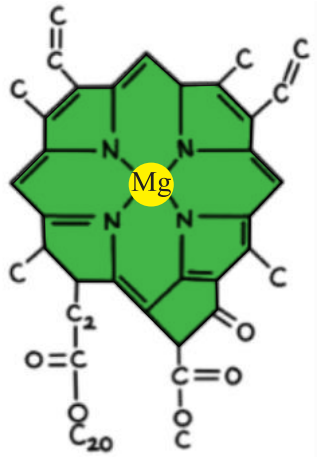


Fig.7.2: Central Mg atom in chlorophyll molecule

7.4 Transport in Plants

Like all other organisms, the cells of plant body also require food and oxygen. In the same way it is necessary to remove the waste products from the plant body. In order to supply materials to different parts of the plant body and to remove the waste materials from the body there is a need of transport system. In plants, water and minerals are transported to all cells of the body by xylem tissues. Food is transported from leaves to different parts of the body by phloem tissues. The extra water is removed from the plant body through the stomata in leaves.

7.5 Internal Structure of Root and Root Hair

Root

Root is the underground part of the plant. It absorbs water and nutrients from the soil. It also anchor plants firmly into the ground.

Internal Structure of Root

The central portion of the root is composed of conducting tissues i.e. xylem and phloem. Outside the conducting tissues there is a narrow layer of thin walled cells called pericycle. Pericyle is surrounded by single layer of cells called endodermis. Outside endodermis there is a wide zone of thin walled large cells called cortex. The cortex is surrounded by a single layer of cells called epidermis. Root hairs arise from epidermis.

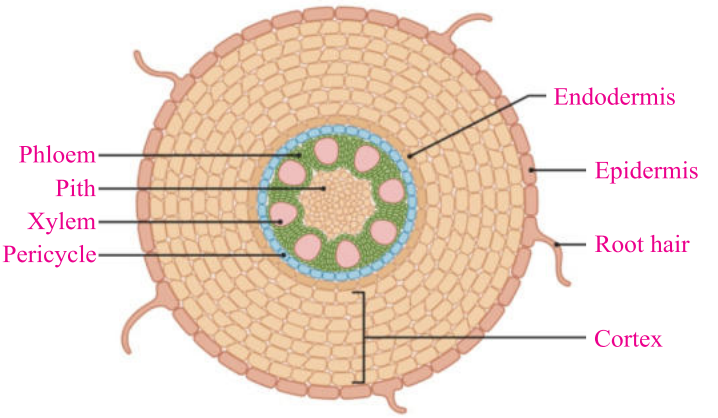


Fig.7.3: Internal structure of a root

Root Hair

Root hairs are the extensions of root epidermal cells. These are hair like thin walled fine tubular structures.

These are only found in the fully developed roots. Due to root hairs, the surface area of absorption of root increases. They absorb water and minerals from soil. They have thin walls. There is more salt concentration in their cytoplasm as compared to the soil water. Due to these reasons, the water enters into root hairs by osmosis.

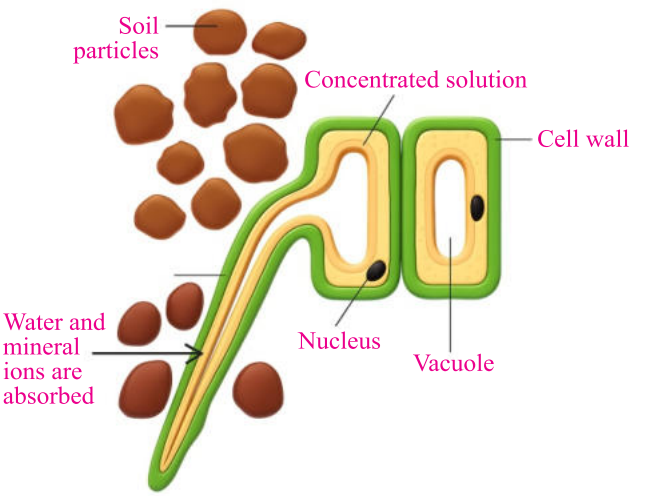


Fig.7.4: Root hairs

7.6 Uptake of Water and Minerals through Roots

Minerals are dissolved in water and form solution. This solution is absorbed by the root hairs and is carried out by passive and active uptake.

A) Passive Uptake

The passive uptake involves **diffusion** and **osmosis**. The uptake through cell

walls and intercellular spaces is called **apoplast pathway** while through the plasmodesmata (channels in cell membranes of adjacent cells) is called **symplast pathway**. Apoplast pathway is faster than symplast pathway.

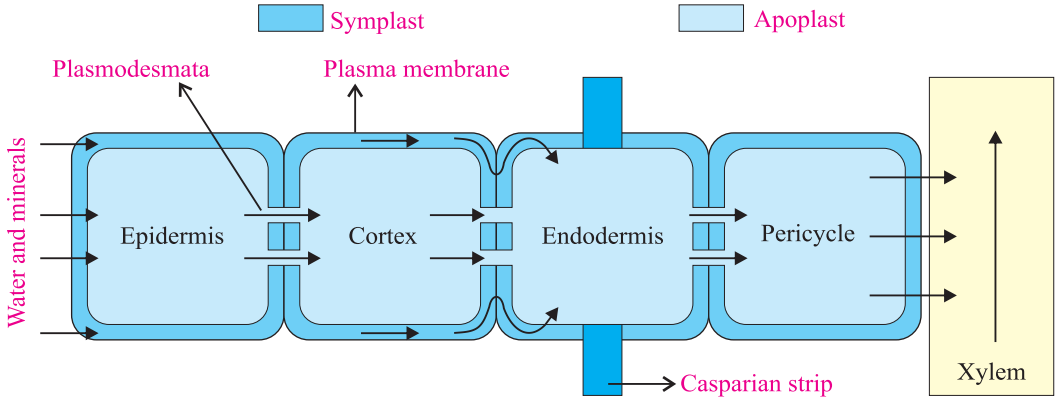


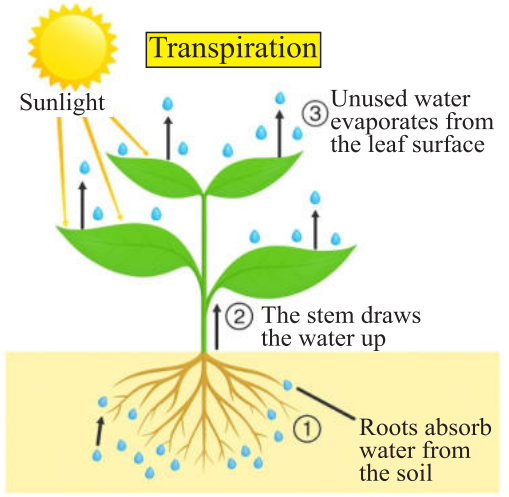
Fig.7.5: Pathway of water and minerals from soil to xylem

B) Active Uptake

Most of the ions are taken up by the roots through the process of active transport. In this case the ions move from their low concentration area to high concentration area. It occurs through cell membrane by using energy in the form of ATP.

7.7 Transpiration

The loss of water vapours from the aerial parts of the plant mainly through stomata into the atmosphere is called transpiration. Plant uses only a small fraction of water absorbed. The remaining water is lost in the atmosphere by transpiration. Less



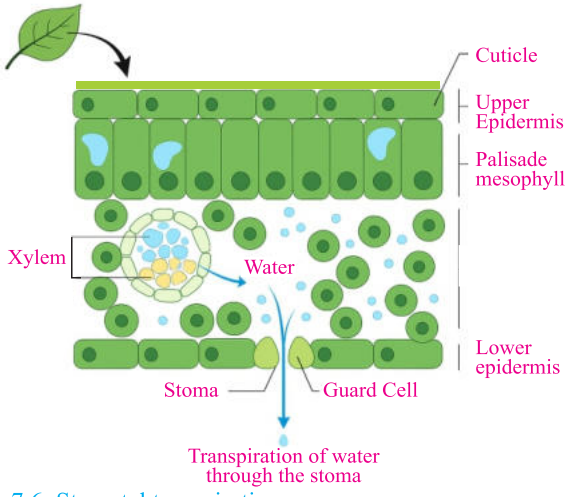


Fig.7.6: Stomatal transpiration

than 3% of the transpiration is carried out through lenticels. Lenticles are special pores in the stem of plants. About 5% of the total transpiration takes place through cuticle. It is estimated that about 90% of the total transpiration is carried out through stomata. The stomatal transpiration occurs in two steps.

i) Evaporation of water from the cell walls of mesophyll cells into the inter cellular spaces.

ii) Diffusion of water from intercellular spaces into the atmosphere through stomata.

Transpiration is linked with surface area of leaves and the stomatal opening and closing. stomata are small pores on the surface of leaves. Each stoma is surrounded by two bean shaped guard cells. The surface area of the leaf is directly linked to how much transpiration can occur. The reason is that a large surface area provides more stomata through which water vapours can esscape. The size and number of stomata on the leaf surface affect how much water vapours are lost. During the day time the stomata are opened so rate of trasnpiration is high. At night the stomata are closed so transpiration does not occurs.

7.8 Factors Affecting the Rate of Transpiration

There are many factors which affect the rate of transpiration, i.e., humidity, temperature and wind.

1. External Humidity

Humidity directly effects the rate of transpiration. When water vapours are high in atmosphere then transpiration becomes low and if the humidity is low then the rate of transpiration will be high.

2. Temperature

Rate of transpiration is greatly affected by temperature. It increases with rise in temperature to a certain limit. Rise in temperature increase the rate of transpiration

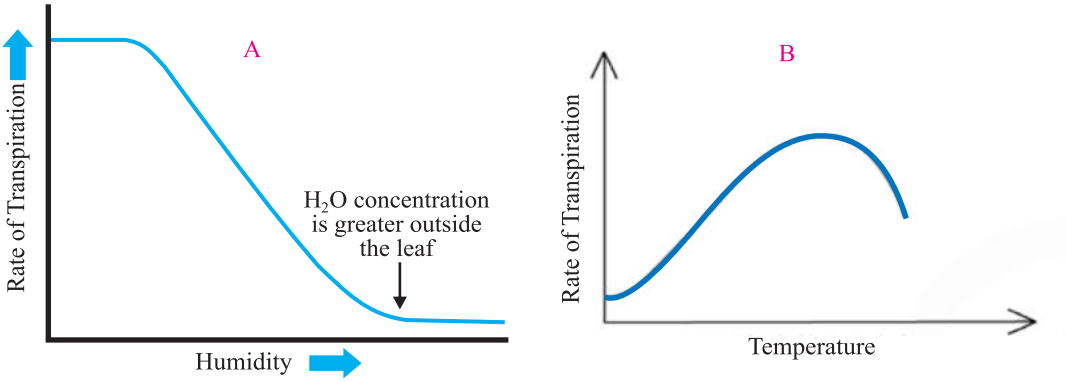


Fig.7.7: Effects of Humidity (A) and Temperature (B) on Rate of Transpiration of Plant

because rate of evaporation increases with rise in temperature. It is estimated that within a certain limit, a rise of temperature by 10°C doubles the rate of transpiration. If the temperature exceeds 40 - 45°C then stomata get closed and transpiration ceases.

3. Wind

The rate of transpiration increases with velocity of wind speed, because the wind removes the water vapours around the leaves and brings dry air near the leaves. As a result humidity around the leaves decreases due to which rate of transpiration increases.

Do You Know?

TACT theory was presented by two Irish biologists Dixon and jolly in 1894.

7.9 Mechanism of Transport of Water and Salts in Plants

The water alongwith dissolved minerals in the xylem is called sap and its upward movement is called ascent of sap. The mechanism of ascent of sap is well explained by "TACT" theory. The "TACT" stands for Transpirational pull, Adhesion, Cohesion and Tension. According to this theory the water is not pushed from the bottom by the roots but pulled up by a tension. This tension is created by transpiration called transpirational pull.

a) Transpirational pull: Loss of water vapours from the aerial parts of plants (especially through leaves) is called transpiration. Transpiration provides a pulling force which help in the ascent of sap.

b) Adhesion: The column of water in xylem vessels does not break due to adhesion. Adhesion is the property of water molecules to adhere with the walls of xylem tubes.

c) Colesion: The water molecules stick to each other due to hydrogen bonding, forming an unbroken column in the xylem.

d) Tension: Transpiration pull creates a negative pressure that pulls water upward through the xylem.

e) Mechanism: Due to strong walls, the xylem vessels do not collaps by that tension which is created by transpirational pull.

During transpiration, water evaporates from mesophyll tissues of leaves into the inter-cellular spaces. From here, water evaporates outside the leaves through stomata. When more water is lost from mesophyll tissues then these tissues draw water from the

xylem of leaf due to cohesion. In this way a tension is created among the cells. This tension is called transpirational pull. This pull is transmitted downwards. As a result leaf xylem draws water from the xylem of stem which draws water from the xylem of roots. The xylem of roots draws water from the root hairs which finallydraws water from the soil. In this way a continuous column of water is formed from the roots to the leaves.

Tid bit

The upward movement of a liquid in a narrow bore tube due to cohesion and adhesion is called capillary action.

The route of water and minerals from soil to leaves is summarized in figure.

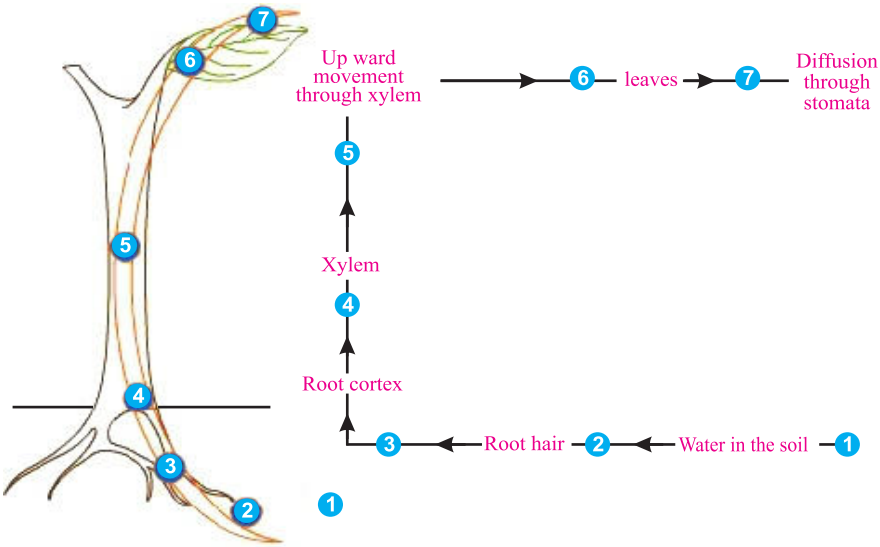


Fig.7.8: Steps involved in Transport of Water from Roots to Leaves

7.10 Translocation of Food in Plants

Food is prepared in the leaves and is then transported to other parts of plant body through phloem tissues. This transportation process is called translocation. Phloem is formed by sieve tube elements and companion cells.

The translocation of food in phloem is in the form of sucrose (sugar). This transportation of sucrose is explained by "pressure flow mechanism". According to this theory "the movement of water containing sucrose through sieve tube is from source to sink. **Source** is an area where sugar is prepared (e.g. green leaves) or an area where the sugar concentration is high. On the other hand **sink** is an area where the sugar is used, (e.g., root) or where the concentration of sugar is low. A storage organ is the first sink

because it receives sugar from a source but it becomes source when it supplies sugar to other organs. e.g. roots of sugar beet.

The transportation of sugar through phloem involves the following steps.

- Glucose is formed in leaves (source) during photosynthesis. Most of this glucose is converted into sucrose.
- This sucrose is then pumped from leaves to sieve tubes by using ATP.
- The concentration of sucrose now increases in the sieve tubes. There is more water in xylem tissues then sieve tubes so water enters into sieve tubes from nearby xylem by osmosis. As a result hydrostatic pressure increases in sieve tubes.
- Hydrostatic pressure moves the sucrose in sieve tubes towards sink (e.g. root, fruit)
- The sucrose is unloaded in sink. Water moves out of the sieve tubes by osmosis and enters into nearby xylem vessels.
- Due to the removal of water the hydrostatic pressure decreases in sieve tubes.

Do You Know?

The pressure flow mechanism was presented by E. Munch in 1930.

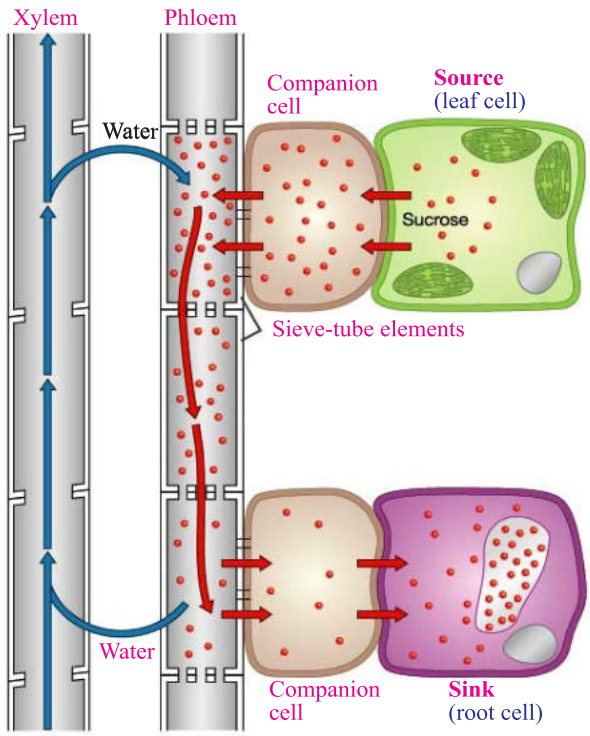


Fig.7.9: Transportation of Food through Sieve Tubes Present in Phloem

7.11 Gaseous Exchange in Plants

All plants need exchange of gases for both respiration and photosynthesis. In contrast to animals, they have no organ system for gaseous exchange. Thus each cell of plants carries out exchange of gases according to its need which occurs only by diffusion.

Interesting Information

Lenticels appear as small dots to the naked eye, but through microscopic examination they can be seen as cluster of loose cells in the cork (layer of bark).

The process of respiration occurs constantly day and night while photosynthesis takes place mostly during day time in the presence of light in chlorophyll containing cells.

Tid Bit

All respiratory surfaces need to be thin, have a large surface area, be kept moist and have a good supply of oxygen.

Gaseous exchange in aquatic plants takes place by diffusion across wet surfaces while in land plants through stomata and lenticels. Spongy mesophyll cells have large air spaces from where gaseous exchange takes place.

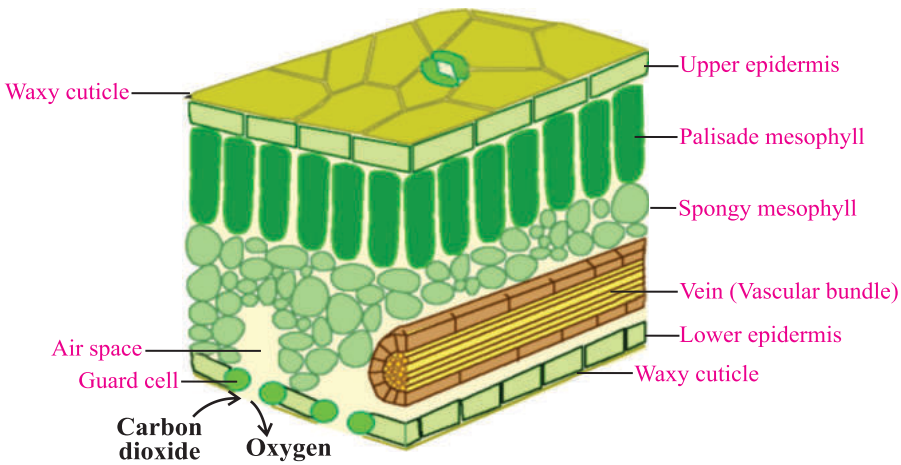


Fig.7.10: Internal structure of leaf showing gaseous exchange

During the day time, mesophyll cells are involved in both photosynthesis and respiration. During photosynthesis plants get CO_2 from air through stomata. The oxygen is generated in photosynthesis

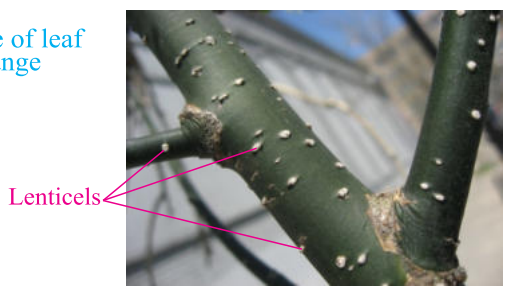


Fig.7.11: Lenticel

which is either used in cellular respiration or removed through stomata, while Co_2 produced during respiration is utilized for photosynthesis. However, at night when photosynthesis is not taking place, the stomata of leaf and lenticels of stem get oxygen from the environment and remove CO_2 through same openings.

7.12 Homeostasis and its Importance

The ability of an organism to maintain its internal conditions constant or nearly constant level is called homeostasis.

The homeostasis is maintained by three processes.

1. Osmoregulation

It is the maintenance of water and salts in the body fluid.

2. Thermoregulation

It is the maintenance of optimum body temperature.

3. Excretion

It is the removal of waste products from the body.

Importance of Homeostasis in Plants

Homeostasis keeps the body environment under control and keeps the condutions favourable for cells to functions.

It helps the plants to survive in changing environment. It helps to remove waste products from plant body. Without homeostasis, plants could wilt or even die. It keeps the water, minerals and nutrient levels in plant cell. It controls the opening and closing of stomata. Homeostasis helps the plants to take in CO_2 from air for photosynthesis. It also helps to release the oxygen into the air formed during photosynthesis.

In a simple way we can say that without homeostasis, the plant body can not carry out normal functions. It is the key process for the survival of plants.

7.13 Adaptations in plants for Excretion

The plants exhibit many adaptations to adjust themselves in changing environment. Thus plants have ability to respond the external environmental changes and keep their internal environment constant.

A) Excretion of Gases and Water

All plants, during the day time exhibit both photosynthesis and respiration side by side. Thus some oxygen produced in photosynthesis is utilized in cellular respiration while rest of oxygen is removed in air. Similarly, CO_2 produced during cellular

respiration is utilized in photosynthesis. However, during dark when photosynthesis stops, the leaf and stem cells get oxygen from the environment and release CO_2 through lenticels. Water molecules are removed through stomata. At night, sometime extra water is removed through special cells found on the margins of leaves known as hydathodes and this phenomenon is called guttation. In young roots, diffusion helps in gaseous exchange through general root surface.

Fig.7.12: Removal of water through hydathodes (guttation)

B) Excretion of other Metabolic Wastes from Plants

In plants, there are some other metabolic wastes such as calcium oxalate (deposited in crystal form within leaves and stems e.g. tomato), resin (pines), latex (rubber plants), gums (keeker). The falling of leaves and stalk of some plants in autumn for the removal of wastes. In some other plants it is stored in their trunk and remain as harmless crystals. Metabolic wastes of plants are also excreted through sepals of flowers, fruit and seed coats. Aquatic plants remove their metabolic wastes by diffusion.

Critical Thinking

What is the importance of waxy material around the plant body especially fruits?

Fig.7.13: Removal of other Metabolic Wastes from Plants

7.14 Osmotic Adjustments in Plants

On the basis of osmoregulation plants are classified into four main groups, hydrophytes, mesophytes, xerophytes and halophytes.

Hydrophytes

These are aquatic plants, grow either submerged or partially submerged in water, for example, water lily, hydrilla and lotus. These plants normally do not face the shortage of water. Many adaptations are made by hydrophytes for osmotic adjustment, for example, xylem is poorly developed, leaves have large surface area containing numerous stomata and root hairs are absent.

Water Lily

Hydrilla

Lotus

Fig.7.14: Some examples of Hydrophytes

Mesophytes

These plants grow in soil with moderate water supply, for example, angiosperms like rose, sheesham, mango, wheat etc. Many adaptation are made by mesophytes for osmotic adjustment, for example, stomata are protected by guard cells and a layer of cuticle outside the leaf which reduces water loss.

Fig.7.15: Mesophytes (Rose and Wheat Plants)

Xerophytes

These plants grow in dry and hot regions where rainfall is scanty and thus possess ability to survive long dry period e.g. cactus, euphorbia etc. They show the following adaptations for osmotic adjustment.

- Thick cuticle layers.
- Reduced number of stomata.

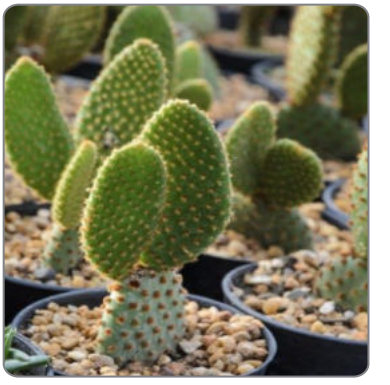


Fig.7.16: Cactus

- Possess water storage tissues (thus also called succulent plants).
- Reduction of surface area of leaves, many leaves transform into thorns.
- Deep extensive root systems help in absorption of water and salts.

Halophytes

These plants grow in areas of high salinity such as sea shores, for example, Rhizophora (Mangrove Tree). In Pakistan, mangrove trees are mainly found in Indus delta. Following adaptations are made in these plants for the osmotic adjustment.

Fig.7.17: Mangrove

- Salts concentration in their cell sap (fluid in vacuole of cell) is higher than their surrounding water.
- Some possess salt glands at the margin of leaves to remove surplus salt, for example, sea milkwort.
- Thick cell wall that is covered with mucilaginous sheath to conserve water.

7.15 Asexual Reproduction

Asexual reproduction is the process by which a single organism produces genetically identical offspring. This type of reproduction is most common in unicellular organisms but can also be found in multi-cellular organisms as well. It is rapid and simple way of reproduction. There are different ways of asexual reproduction in various organisms.

i) Binary Fission

It is common method of asexual reproduction in prokaryotes, protozoans, algae and some invertebrates.

In this method a cell simply copies its DNA and then splits into two daughter cells, giving a copy of its DNA to each daughter cell. In protozoans binary fission is just like mitotic cell division where the division of nuclus is followed by cytoplasm.

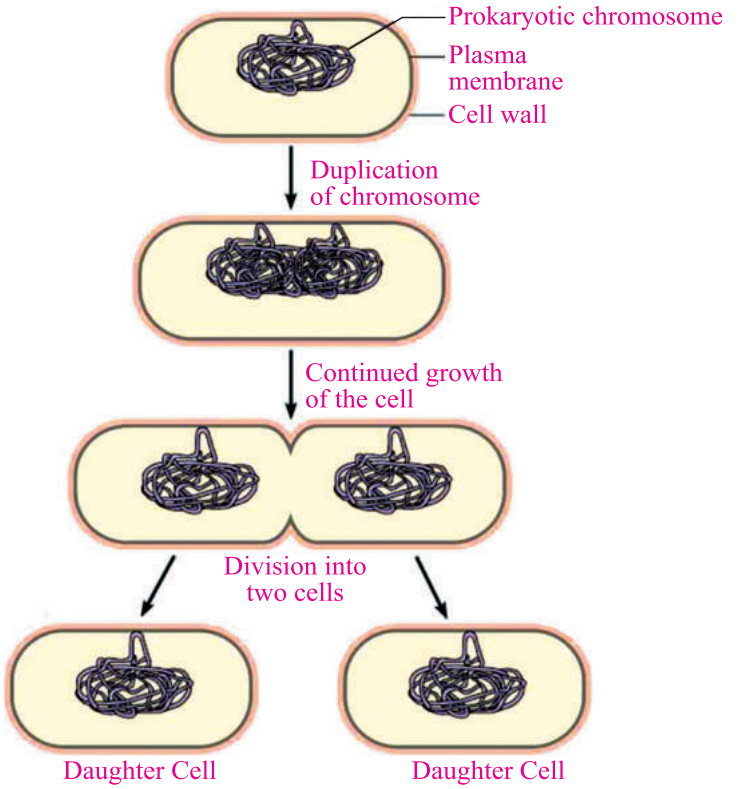


Fig.7.18: Binary Fission in Bacteria

ii) Budding

In this kind of asexual reproduction a new organism is developed from an outgrowth called bud. This bud is formed as a result of cell division in particular site on parent body. The new organism continues to be attached to its parent as it slowly grows and only detaches or separates from the parent when it becomes mature. In some cases bud separate from parent body and as a result colonies of individuals are formed. Budding occurs in fungi e.g., yeast etc.

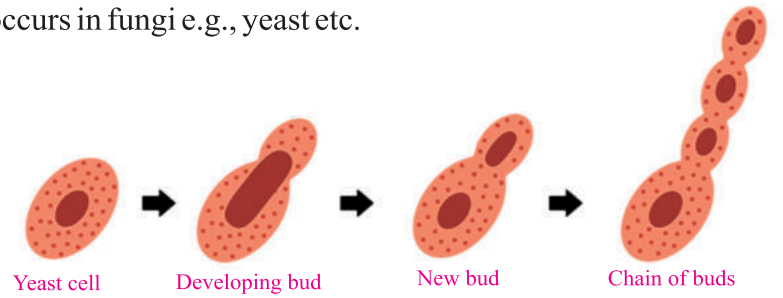


Fig.7.19: Budding in Yeast

iii) Spore Formation

This process of asexual reproduction is usually found in bacteria, fungi and non-flowering plants. In this method of reproduction, the parent body produces hundreds of tiny spores which can grow into new organism. The spores are similar microscopic, tough, resistant and round shaped bodies. On favorable condition each spore grows into a complete organism. Spores behave like seeds.

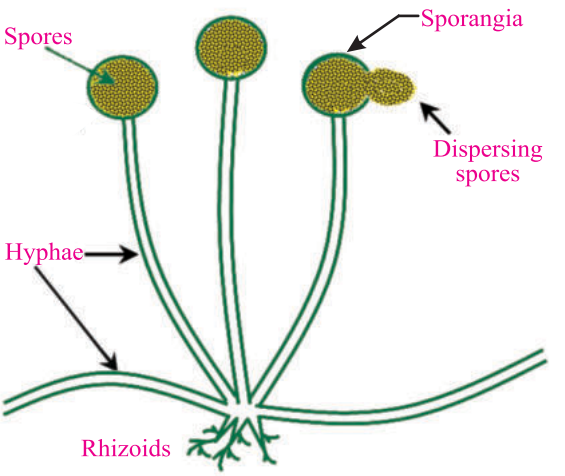


Fig.7.20: Spore Formation in Rhizopus

iv) Vegetative Propagation

It is a type of asexual reproduction occurring in plants. The new plant grows from a fragment of parent plant. Many plants naturally reproduce this way but it can also be induced artificially. The vegetative reproductive structures include root, stem and leaves. The vegetative propagation is genetic clones of parent plant. Desired characteristics can be retained by this process.

7.16 Differences between Natural and Artificial Propagation

	Natural Vegetative Propagation	*Artificial Vegetative Propagation*
i)	It refers to natural development of new plant without human intervention.	It refers to artificial development of new plant by means of human intervention.
ii)	Occurs through roots bulb, corms, tuber, rhizome etc.	Occurs through cutting, layering and grafting.
iii)	Helps to avoid physical barriers in sexual reproduction.	Desirable characters are acquired over generations.

7.17 Types of Vegetative Propagation

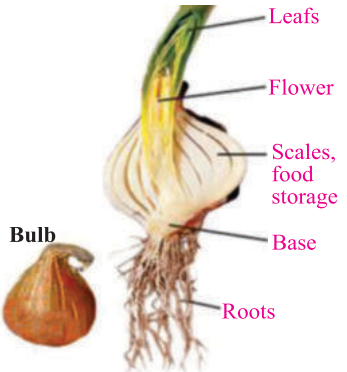
It involves the development of new plant from a part of single mature plant. The new plant grows and develops naturally without human intervention. Vegetative propagation may takes place in many ways.

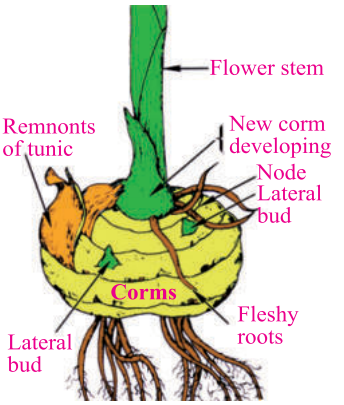
i) Bulb

These are swollen parts of the underground stem called the bulb that is surrounded by layers of fleshy scale-like leaves. These leaves are a source of food storage and provide nourishment for the new plant. Plant, that develop from bulbs are onions, daffodils, lilies and tulips.

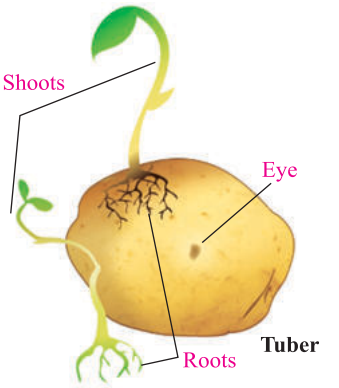
ii) Corms

These are enlarged bulb like underground stems. These vegetative structures store nutrients in fleshy solid stems which are surrounded by scale-like leaves. Plants that develop from corms include crocus, gladiolus and garlic.





Corm



Potato Tubers

Fig.7.21

iii) Tubers

These are vegetative organs that may develop from stem or root. Stem tuber arises from rhizomes or runners that become swollen from storing nutrients. Potatoes are the example of stem tuber.

Root tubers originate from roots that have been modified to store nutrients. These roots become enlarged and may give rise to new plant. Sweet potato is the example of root tuber.

iv) Suckers

These are plant shoots that arise from buds on underground roots and stems. A number of shrubs and trees propagate through sucker, for example, apple, cherry, banana, rose etc.

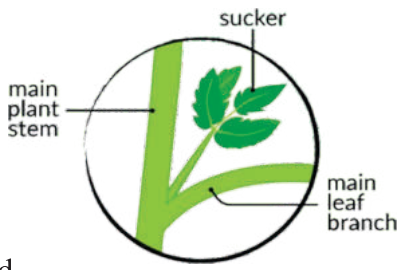


Fig.7.22: Sucker

v) Rhizome

Rhizome or root stalk is a type of stem situated

either at the soil surface (above ground rhizome) or inside soil (underground rhizome). The rhizome contains nodes from which roots and shoots originate. The primary function of rhizome is the storage of nutrients and provides support to plant. However, rhizomes are also source of vegetative propagation. The examples of underground rhizomes include ginger, oak, grass species and bamboo while above ground rhizome include ferns and irises

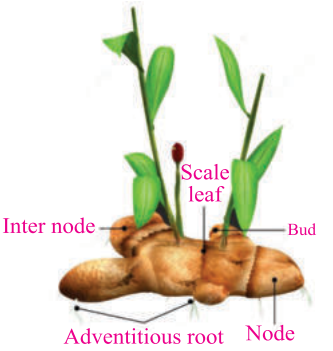


Fig.7.23: Rhizome in Ginger

vi) Layering

It is a type of plant propagation where roots found on a stem are still attached to parent plant. Examples of plants propagated by layering include climbing roses, raspberries, black berries and grapes.

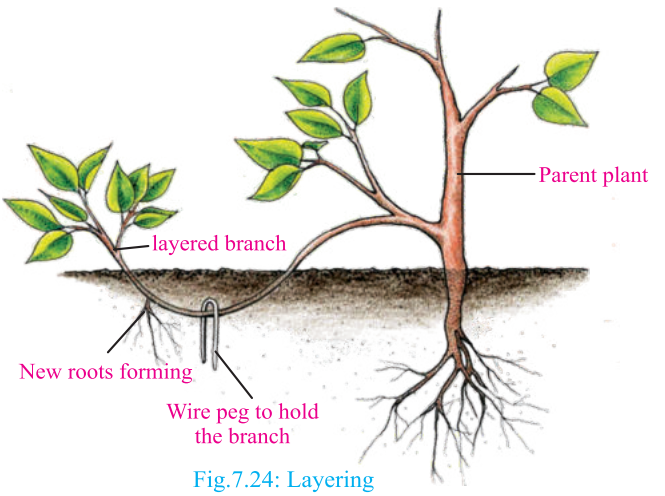


Fig.7.24: Layering

vii) Runners

It is a natural process of vegetative propagation. The runner or stolons originate from the base of parent plant and grow horizontally along or just above the soil surface. Nodes are the points from where roots, stems and leaves arise. When a node comes in contact with the soil then it develops roots. From the upper nodes shoots and leaves are formed. In this way identical plants are formed from a parent plant, for example, grasses, strawberries etc.

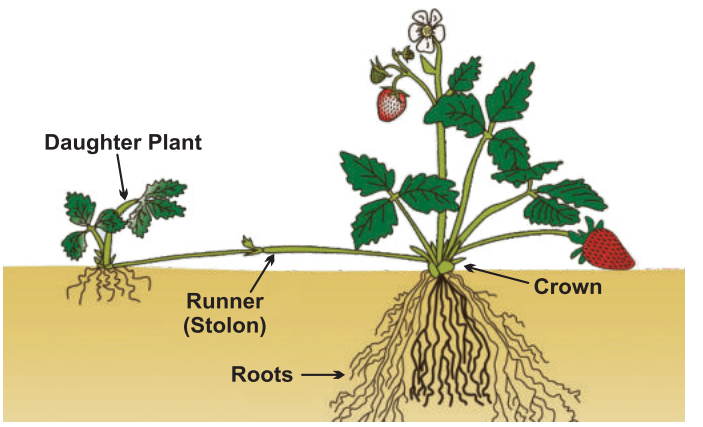


Fig.7.25: Runner

viii) Leaves

Begonia and Bryophyllum are the examples of vegetative propagation by leaves. In this case buds arise from the margins of leaves. These buds are reproductive in nature. When these buds become mature then they separate from the leaves. Under favourable conditions each bud gives rise to a new plant.

Fig.7.26: Vegetative propagation by leaf

7.18 Artificial Vegetative Propagation

Farmers frequently use artificial vegetative propagation which are described as follows:

i) Grafting

In this process, part of stem of desirable plant is grafted into a rooted plant called stock. The part that is grafted is called scion. Both are cut out at an oblique angle, placed in close contact with each other, and are then held together. The vascular systems of both the plants grow and fuse, forming a graft. After a period of time, scion starts bearing flowers and fruits. Grafting is widely used in roses, grapes, citrus, almond plants etc.

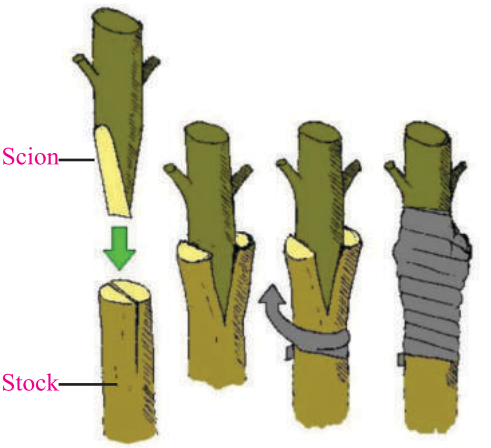


Fig.7.27: Grafting

ii) Stem Cutting

In this process, a portion of stem containing nodes and inter nodes is placed in moist soil and allowed to grow roots. This method is used for sugarcane, roses and money plants.

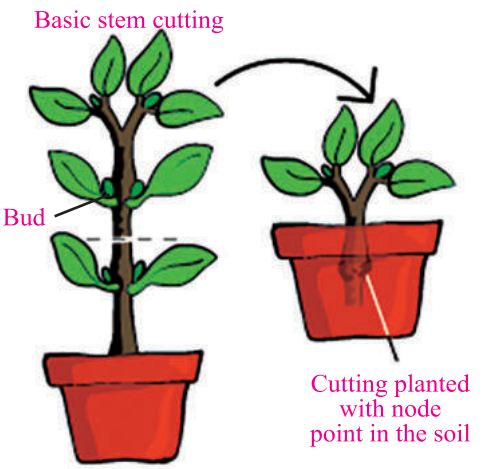


Fig.7.28: Cutting Steps

7.19 Parthenogenesis

It is a type of asexual reproduction in which growth and development of embryo occurs without fertilization. Parthenogenesis naturally occurs in some fishes, amphibians and insects like honey bees, aphids etc. Parthenogenesis is also called incomplete sexual reproduction because only one gamete (egg) is used in the process.

In plants the development of ovary into fruit without fertilization is called parthenocarpy and such fruits are called parthenocarpic fruits, which are seedless i.e. banana and some grape species.

Critical Thinking

A plant has 20 chromosomes in its leaf cells. The plant shows alternation of generation. What is the correct number of chromosome in the gametes and in the cells used for asexual reproduction.

7.20 Cloning

Cloning is a process of producing a genetically identical copy of a cell, organ or an organism from a single parental cell. The plants can be propagated by a special technique of cloning called tissue culture. In this method genetically identical plant is developed from a single plant cell. The tissue culture is carried out in a germ free medium which contains proper nutrients.

7.21 Sexual Reproduction in Plants

Sexual reproduction is a type of reprorduction in which a haploid female and a male gamete fuse to form a diploid zygote which develops into a new diploid organism.

Alternation of Generation

One complete life cycle of a plant consists of two generations that alternate with each other. Therefore, the whole mechanism is called alternation of generations.

Life Cycle of Angiosperm (Flowering Plant)

Angiosperm plants show heteromorphic alternation of generation in which dominant sporophyte (2n) alternates with reduced gametophyte (n).

A. Sporophyte Generation

The main plant body of a flowering plant is sporophyte. It contains roots, stem, leaves and flowers.

Flowers are the reproductive organs of angiosperms and contain male and female structures. Each flower consists of pedicel, thalamus, sepals, petals, stamens and carpel. The **thalamus** is a modified stem. The **sepals** and **petals** are not essential for reproduction. Sepals are protective parts of flower and petals attract insects for

pollination. **Stamen** is the male reproductive part of flower and consisting of long filament having bilobed anther at its tip. In anther haploid microspores are produced by meiosis inside the pollen sacs. **Carpel** is the female reproductive part of flower. The basal broader part of the carpel is ovary, elongated part is style and terminal broad part of carpel is stigma. Ovary contains ovules. Inside each ovule four haploid megaspores are formed by meiosis. Three of them degenerate while one megaspore remains alive.

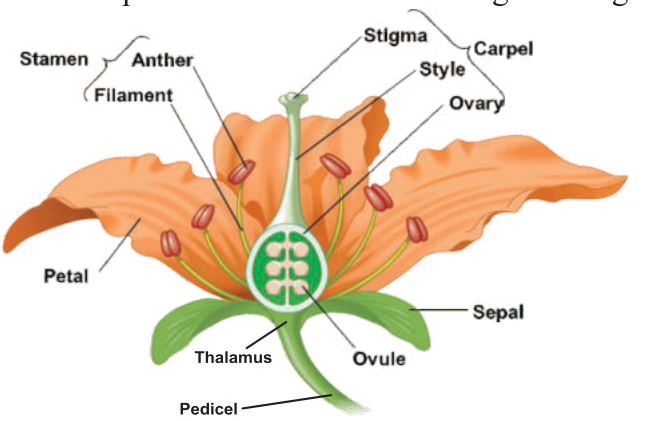


Fig.7.29: Structure of Flower

Pollination

The transfer of pollen grains from anther of stamen to the stigma of carpel is called pollination. The pollination may takes place either by insects, wind or by water.

B. Gametophyte Generation

Two types of gametophytes are formed by two types of spores. i.e. microspore froms male gametophyte while megaspore forms female gametophyte. Both the gametophytes are reduced and haploid (n).

Male gametophyte

When a pollen grain falls on the stigma of carpel then it germinates to form pollen tube. The nucleus of the pollen grain divides by mitosis into two nuclei.

i) Generative nucleus.

(ii) Tube nucleus.

The generative nucleus again divides into two sperm nuclei. The pollen

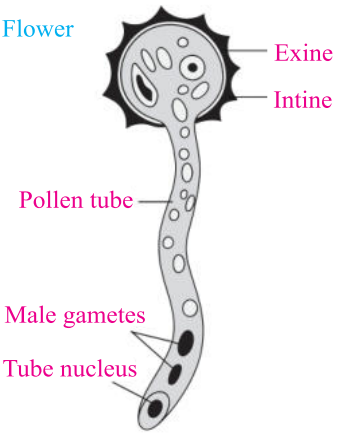


Fig.7.30: Male gametophyte

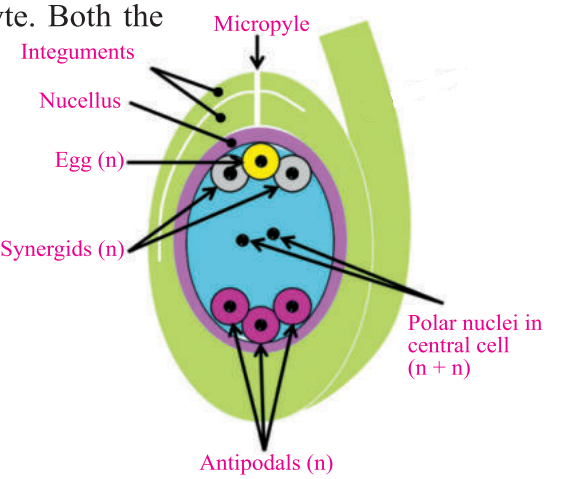


Fig.7.31: Female gametophyte

tube with one tube nucleus and two sperms
is called **male gametophyte**.

Female Gametophyte

Inside the ovule the remaining single functional megaspore divides by mitosis to form female gametophyte or embryo sac. The walls of ovule are called integuments. There is a hole in the integuments called micropyle. The embryo sac is surrounded by a tissue called nucellus. Embryo sac initially contains eight cells but later on becomes seven celled.

i) Three antipodal cells.

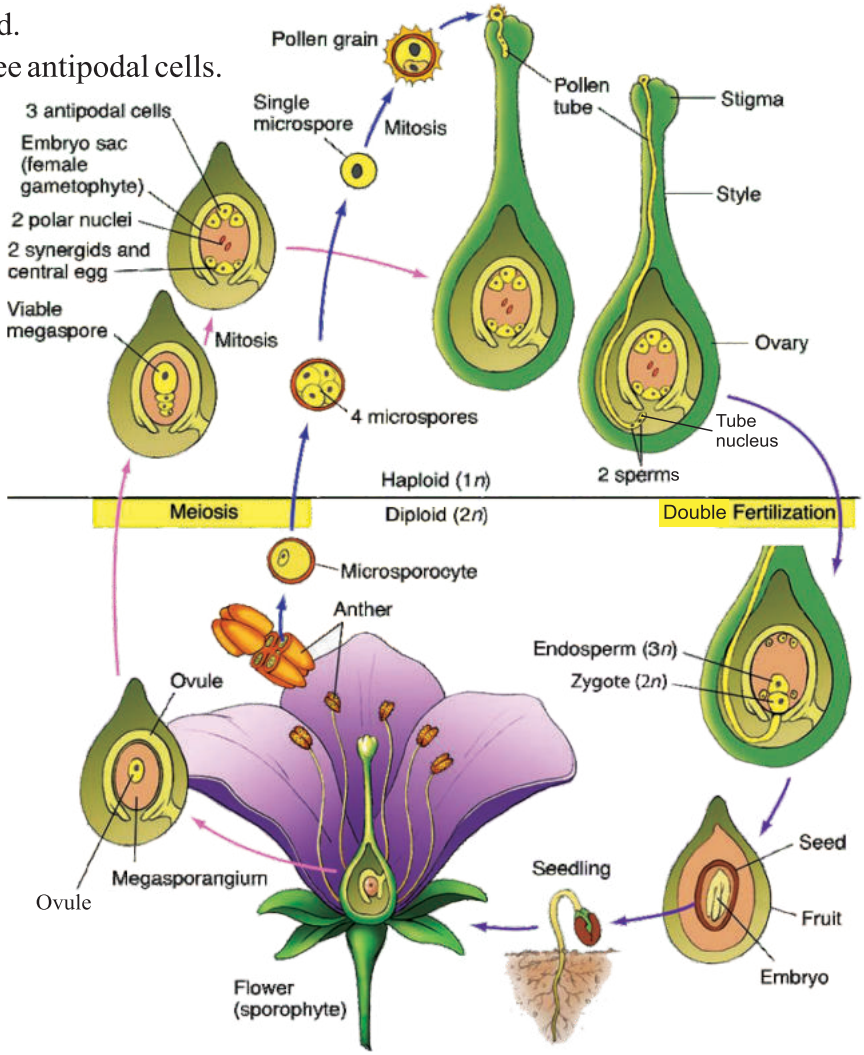


Fig.7.32: Life cycle of angiosperms

ii) One fusion nucleus (formed by the union of two nuclei).
iii) Two synergids.
iv) One egg or oospore.

Double Fertilization

The pollen tube (male gametophyte) grows downward and after passing through style it enters into the ovule through micropyle. The two sperms are released into ovule while tube nucleus degenerates.

i) One sperm fuses with egg to form zygote (2n).
ii) Second sperm fuses with diploid nucleus to form endosperm (3n).

Double fertilization is found only in angiosperms.

Seed and Fruit Formation

The zygote after repeated division by mitosis forms an embryo. The endosperm is used as a stored food at the time of germination. After formation of endosperm and embryo, the ovule increases in size to form seed. Its integument becomes hard and dry to form seed coat or testa and micropyle closes. After these changes the size of ovary enlarges. This ripened ovary is now called fruit.

Seed Germination

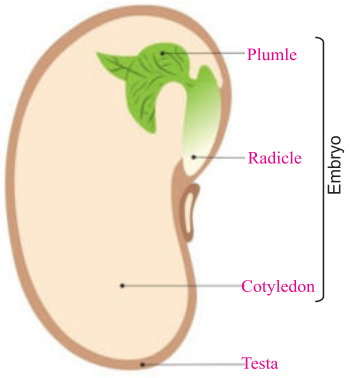
When a seed is grown in the soil then germination starts. Germination is the process during which the reserve food present in the seed is broken down and the embryo starts to grow. It begins when a seed starts to absorb water. As a result a flowering plant (sporophyte) is formed.

7.22 Seed Germination

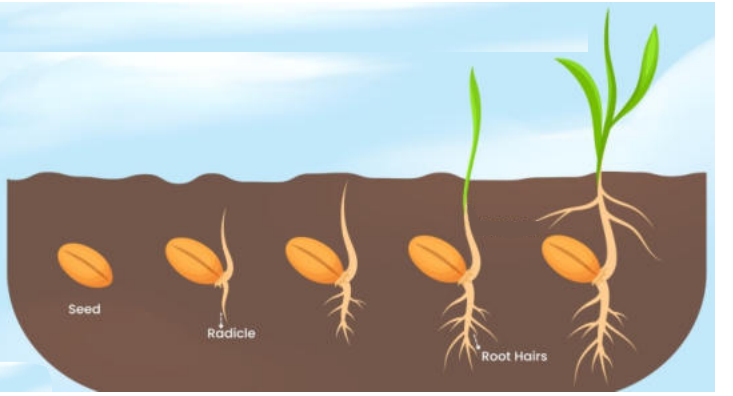
Seed germination is a process by which a seed develops into a new plant. This process needs proper conditions like water, air and suitable temperature. In this process, a seed absorbs water and swells up. The seed coat (testa) bursts and the embryo inside the seeds begins to grow. From the embryo two fine structures arise. One is called radicle which grows downward and later on forms roots to anchor the plant in soil and absorbs minerals and water from soil. The other structure is called plumule. It grows upward and later on forms the shoot on which leaves and flowers are formed.

Germination is the first step in the life cycle of plants. It is the primary method through which plants reproduce. The food of animals and human beings depends upon

the seed germination.



Internal Structure of Seed



Germination Process

Fig.7.33: Seed Germination

7.23 Methods of Seed Dispersal

The scattering of seeds away from parent plant to other locations is called dispersal of seeds. There are many ways by which seeds are dispersed to suitable places for germination.

i) By Wind

The seeds of many plants are dispersed by wind. These seeds are light in weight and have special structures like hairs or wings, for example, milkweed, maple, dandelion etc.

ii) By Water

These seeds have the ability to float on water. Water carries them away from parent plant, for example, lotus, water lily, etc.

iii) By Animals

The dispersal of seeds by animals is carried out by many ways.

a) Some seeds have hooks, awns or sticky surfaces. These seeds attach to bird feathers or animal fur and are carried to new locations, for example, medicago, grasses etc.

b) Animals eat fruit but can not digest their seeds. These seeds pass out undigested from their bodies. In this way they are carried to new location, for example, cherry, black berry, tomato etc.

iv) By Explosion

The fruits of some plants eject seeds forcefully on ripening. In this way seeds are scattered around the plants, for example, broom, jewelweed, okra etc.

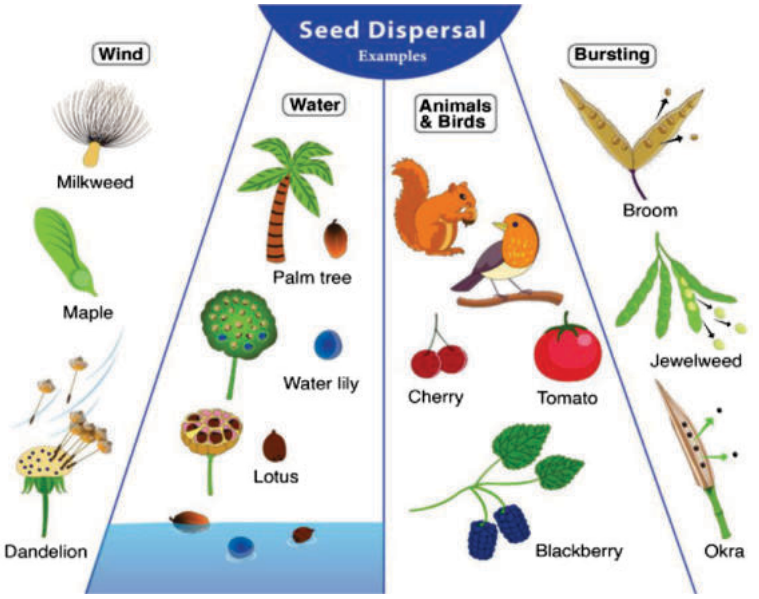
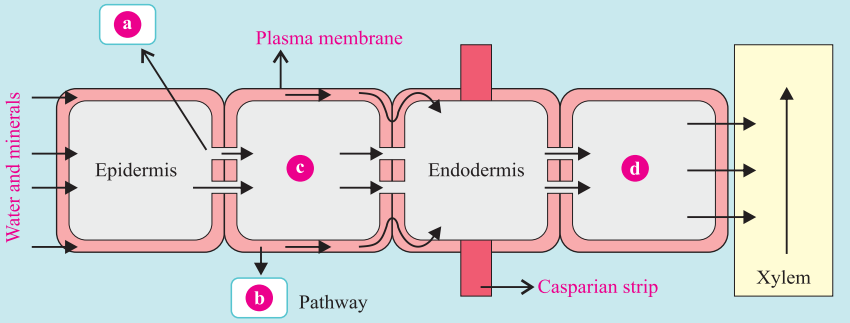


Fig.7.34: Methods of Dispersal of Seeds

STEAM ACTIVITY

a. Write down the names of components mention in the following figure.

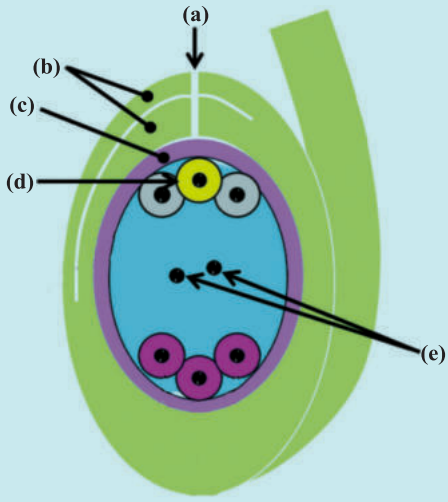


S.No.	Designated Point	Name of Component
1	a	
2	b	
3	c	
4	d	

STEAM ACTIVITY

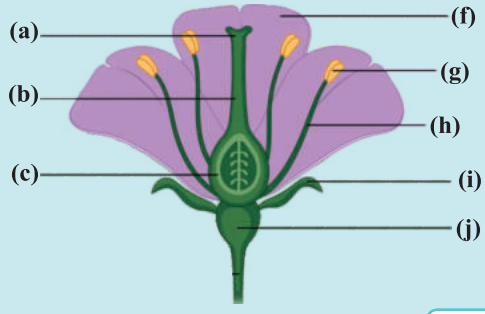
b. Identify the components of embryo sac and answers the questions.

1. Which part will form the testa of seed.
2. Which part is involved in the formation of zygote.
3. It is the gateway of male gametophyte.
4. The food for germinating seed is prepared by this part.
5. Embryo sac is surrounded by this tissue.



STEAM ACTIVITY

Answers the questions about the labeled parts in the following figure.



i) Which part attracts the insects for pollination.
ii) Which part is microsporangium.
iii) Its plural form is called calyx.
iv) Embryo is formed in it.
v) Which part is called thalamus.
vi) Which part receives pollen grain.
vii) Which letter shows the style of pistil?
viii) It is thin stalk of male part of flower.

KEY POINTS

- The nutrients which are required in large amounts are called macronutrients.
- The nutrients which are required in trace amounts are called micronutrients.
- The movement of substances between the different parts of the body and out of the organism is called transportation.
- The passive uptake involves diffusion and osmosis. The passive uptake through cell walls and intercellular spaces is called apoplast pathway while through the plasmodesmata (channels in cell membranes of adjacent cells) is called symplast pathway.
- The loss of water vapours from the aerial parts of the plants into the atmosphere is called transpiration.
- The water alongwith dissolved minerals in the xylem is called sap and its upward movement is called ascent of sap.
- According to cohesion – tension theory the water is not pushed from the bottom by the roots but pulled up by a tension. This tension is created by transpiration called transpirational pull.
- Food is prepared in the leaves and is transported to other parts of plant body through phloem tissues. This process is called translocation.
- According to pressure flow mechanism "the movement of water containing sucrose through sieve tube is from source to sink due to the difference of sucrose between these two sites.
- Osmoregulation is the maintenance of water and salts in the body fluid.
- Asexual reproduction is the process by which a single organism produces genetically identical offspring.
- In vegetative propagation the new plant grows from a fragment of parent plant or a specialized reproductive structure.
- Parthenogenesis is a type of asexual reproduction in which growth and development of embryo occurs without fertilization.
- Cloning is the process of producing genetically identical individuals of an organism either or artificially.
- Sexual reproduction produces off-springs by the fusion of gametes resulting in offspring genetically different from their parents.
- Alternation of generation is a process in the life cycle of plants. In this case sporophyte and gametophyte generations alternate with each other.
- Double fertilization is found only in angiosperms.
- The ripe overy with seeds is called fruit.

EXERCISE

A. Multiple choice Questions (MCQs)

1. The essential components of an amino acid is:
   (a) Magnesium (b) Sulphur
   (c) Nitrogen (d) Sodium
2. In plants, food is stored in the form of:
   (a) Glucose (b) Starch
   (c) Sucrose (d) Proteins
3. The estimated percentage of transpiration through stomata is:
   (a) 1-2% (b) 5%
   (c) 50-60% (d) 90%
4. The translocation of food in phloem is in the form of:
   (a) Maltose (b) Glucose
   (c) Sucrose (d) Fructose
5. The transpiration is not effected by:
   (a) Wind (b) Temperature
   (c) Humidity (d) Gravity
6. The direction of food transport in plants is:
   (a) Upward (b) Downward
   (c) Horizontal (d) From source towards sink
7. One of the following is not a type of asexual reproduction.
   (a) Binary fission (b) Budding
   (c) Gametogenesis (d) Grafting
8. The plants which store water in their bodies are called.
   (a) Succulents (b) Mesophytes
   (c) Aquatic (d) Halophytes
9. The vegetative structures of plants which store nutrients in fleshy stems surrounded by scale like leaves are called;
   (a) Bulbs (b) Suckers
   (c) Corms (d) Rhizomes
10. The role of "Mg" in plant growth is:
   (a) It is necessary for seed and flower development
   (b) It is important component of chlorophyll
   (c) It required for cell division and growth
   (d) It improves root growth and seed production

11. The primary function of root hairs is:
    (a) To anchor the plant (b) To absorb water and minerals
    (c) To transport food (d) To produce food for plant
12. The mechanism of translocation in phloem tissue is called:
    (a) Active transport (b) Passive transport
    (c) Pressure flow hypothesis (d) Diffusion
13. The adaptation made by plants for osmoregulation is:
    (a) Closing of stomata during drought
    (b) Increase transpiration rate
    (c) Reduce root growth
    (d) Increase photosynthesis rate
14. The common example of artificial vegetative propagation?
    (a) Bulb (b) Grafting
    (c) Rhizome (d) Tuber
15. One of the following plants is commonly propagated by stem cutting.
    (a) Rose (b) Sugar cane
    (c) Money plant (d) All of the above
16. Cloning is a process of:
    (a) Creating new species
    (b) Creating an exact copy of the organism
    (c) Mixing genes from different organisms
    (d) Evolving an organism over time

B. Short Response Questions.

1. Briefly explain macronutrients.
2. What are the functions of phosphorus and potassium in plants?
3. Write down the two functions each of boron and iron in plants.
4. What is the role of "Mg" in chlorophyll formation?
5. How metabolic wastes (except water and gases) are removed from plants?
6. Briefly describe the internal structure of root.
7. Write a short note on transpiration.
8. What are the directions of food transport in plants?
9. What is the significance of transpiration?
10. Differentiate natural and artificial propagation.
11. Write a short note on cloning.
12. Write a note on root hairs.
13. What are the effects of opening and closing of stomata on transpiration?

14. What is homeostasis? Write down its importance.
15. What are halophytes? Write down their adaptations.
16. Define the following terms

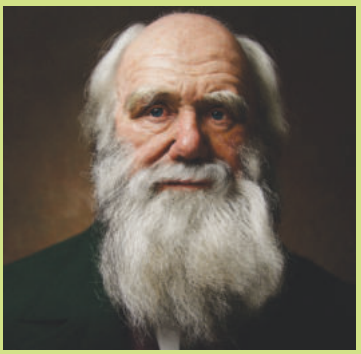
(i) Herbivores	(ii) Macronutrients	(iii) Micronutrients
(iv) Nutrition	(v) Cuticle	(vi) Transpirational pull
(vii) Osmotic pressure	(viii) Transpiration	(ix) Cortex
(x) Guard cells	(xi) Sink	(xii) Pericycle
(xiii) Source	(xiv) Cohesion	(xv) Reproduction
(xvi) Pollination	(xvii) Embryo	(xviii) Budding
(xix) Fertilization	(xx) Artificial propagation	

C. Extended Response Questions.

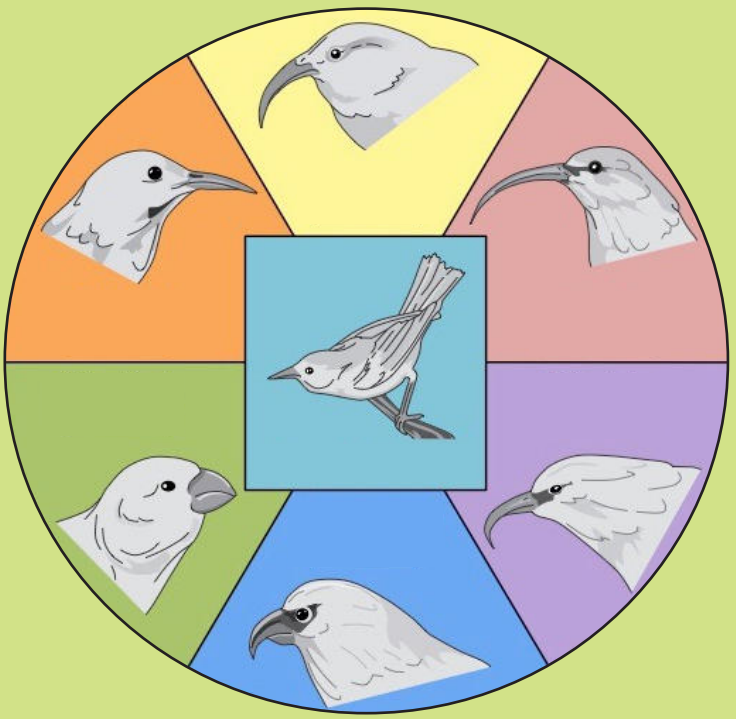
1. Explain the cohesion-tension theory for ascent of sap.
2. How food is translocated in plants? Explain with the help of pressure flow mechanism.
3. Illustrate the mechanism of opening and closing of stomata.
4. How uptake of water and minerals occur through roots?
5. What are factors affecting the rate of transpiration?
6. What are different methods of asexual reproduction in plants? Explain briefly.
7. Explain different types of artificial vegetative propagation in plants.
8. Define flower and explain its different parts.
9. What is vegetative propagation? Describe its types.

CHAPTER 8

EVOLUTION



Charles Darwin



Students Learning Outcomes:

Students will be able to:

- Explain the theory of evolution by natural selection with examples.
- Define Species.
- Describe speciation.
- Discuss briefly the observations Darwin made during his voyage on HMS Beagle.
- Describe sources of variation which can lead to speciation and evolution.
- Describe evidence of evolution with regards to the following:
  - Paleontology (fossil record)
  - Comparative anatomy (homologous structures, vestigial structures)
  - Selective breeding.

Introduction

The central idea of biological evolution is that all life on earth share a common ancestor. Evolution is the "descent with modification". In this chapter, we will study about evolution and natural selection. Some evidences in support of evolution have also been provided. Evolution depends upon natural selection. Natural selection is a mechanisms in evolution by which organisms best adapted to their environment tend to survive and reproduce. These organisms pass their adapted characters to their offsprings through genes. Due to this process, changes occur in offsprings. A brief description of main theories concerning the origin of life are also presented in this chapter.

8.1 Concept of Evolutionary Theories

A brief overview of the main theories of evolution is given below:

A. Lamarck Theory

This theory was presented by Jean Baptiste Lamarck. According to this theory the organisms have evolved by the use and disuse of body parts and through the inheritance of acquired characteristics, for example, giraffes stretched their necks to reach higher leaves on trees. This trait was passed on to their offspring.

B. Darwin Theory

This theory was proposed by Charles Darwin. This theory was based on natural selection. According to this theory, those organisms are more likely survive and reproduce that adjust themselves with environment. Their adapted characters are then passed into their offsprings. As a result, changes occur in offsprings.

C. Mutation Theory

This theory was proposed by Hugo de Vries. According to this theory, evolution occurs due to sudden mutation in genes rather than gradual changes. Due to mutation, new characters are developed in coming generations.

8.2 Observations of Darwin during his Voyage

Darwin went on a voyage around South American coast and the islands of Pacific Ocean. This program was arranged by American Navy to get scientific informations. At that time, the age of Darwin was just 22 years. He sailed as a biologist in a ship named "H.M.S. Beagle". He completed his voyage in six years i.e. from 1831-1837. During his voyage he studied plants, animals and geological formation of that area. When he visited Galapagos islands in the pacific, he observed huge tortoises

present on different islands which showed much differences. Similarly, the closely related species of finches on these islands had beaks of different shapes and sizes. Darwin thought that these different beaks could be due to different kinds of food found on these islands.

Fig.8.1: H. M. S. Beagle

After his return to England, he spent another 12 years in collecting more facts to support his ideas which led to write his famous book "The Origin of Species".

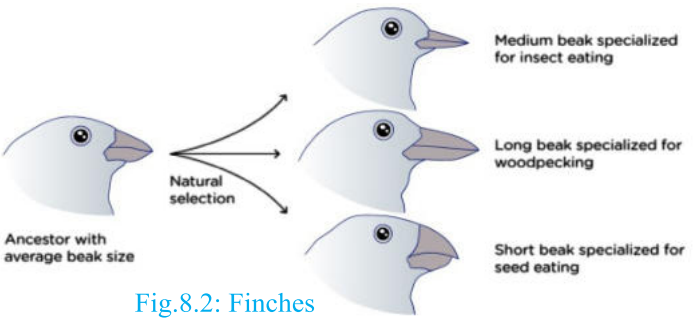


Fig.8.2: Finches

Fig.8.3: Giant Tortoise

8.3 Evolution and Natural Selection

Biological Evolution or Evolution may be defined as a process of slow and gradual development or change in the living beings over a long span of time.

Additional Information

The size of Galapagos tortoise is about 4 feet, weight 475pounds, average life span is 100 years and it feeds on plants.

Biological evolution is a genetic change in a population of organisms over time. It is not a change which can occur in the life time of an individual but that takes place in the characteristics of a population over many generations. The genetic change is the basis of evolution through which new species arise.

8.4 Theory of Evolution by Natural Selection

This theory is a fundamental concept in evolution. This theory explains how species change over time and adopt to their environments. This theory was presented by Charles Darwin and Alferd Russel Wallace in mid 19th century. Charles Darwin and A.R Wallace published a joint paper in 1858-59 which was later included in the famous book of Darwin "The Origin of species by Natural Selection".

This theory is based on following observations.

i) Over production

All plants and animals have a tendency of over production. If overproduction is not checked, it will lead to overpopulation on earth, for example, an oyster lays about 60 million eggs. If the entire offsprings survive and multiply, it will be 8 times the size of earth in a year.

ii) Struggle for Existence

Fig.8.4: Struggle for Existence

Natural resources are limited in the environment for organisms like food and space. As a result, competition occurs among organisms for survival and reproduction. This competition may occur within the members of same population or between the members of different populations, for example, suppose the population of wolves in an area, where food resources are limited, each wolf tries to get food but faster and stronger wolves get more food than others.

iii) Variations

The differences between individuals of the same species is called variation. The variations are caused by genetic and environmental factors, for example, no two individuals are alike. Even real brothers and sisters are not the same. Darwin considered it genetic variation.

Some of the variations can be passed from parents to offsprings through genes. Darwin observed that useful variations are inherited from the parents to their offsprings.

iv) Natural Selection

Darwin regarded that in the struggle for existence only those individuals survive who are best fitted to the new conditions. Such individuals possess advantageous variations. Those which are unfit perish. In this way the fittest are automatically selected and the unfits are eliminated by nature.

v) Origin of New Species

Darwin considered that variations were useful and favourable variations were transmitted to other generations and formed new species. As natural selection continues for a long period, the descendants may be quite different from ancestors due to their adaptations under various environmental conditions, for example, Darwin observed "13 finches" on Galapagos Islands. They had different beak shapes and sizes. These variations in their beaks were due to the adaptations for different food sources available on the islands.

8.5 Evidences of Evolution

According to theory of evolution, all the existing organisms have evolved by the modification in their ancestors. Biologists have put forwarded many evidences in the support of evolution. Some evidences are as follows:

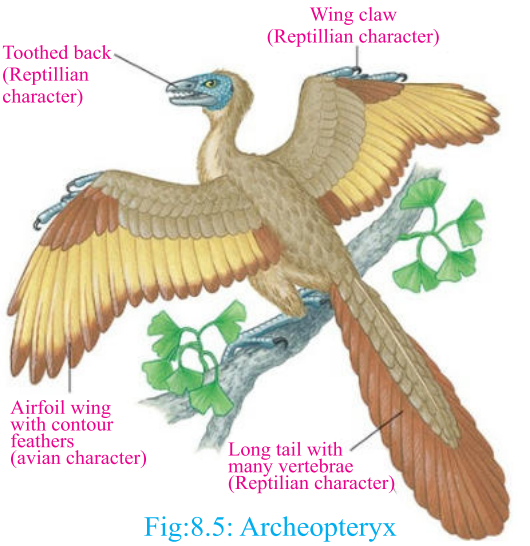


Fig:8.5: Archeopteryx

i) Evidence from Palaeontology

Palaeontology is the study of fossils (the dead remains of organisms of past burried in soil or rocks).

Palaeontology provides a direct evidence of evolution. The study of fossils shows that the modern organisms have evolved from the organisms of past, for example, archeopteryx (a fossil bird) shows both the characters of reptiles and birds. The detailed study of this bird shows that birds have evolved from reptiles.

ii) Evidence from Comparative Anatomy

The study of internal body structures of living organisms is called anatomy. The study of comparative anatomy supports the theory of evolution. There are differences in the organisms of past and present time but they have similar type of organs.

a) Homology and Analogy

Those organs which have same fundamental structures but they are modified for different functions are called homologous organs, for example, the forelimbs of human

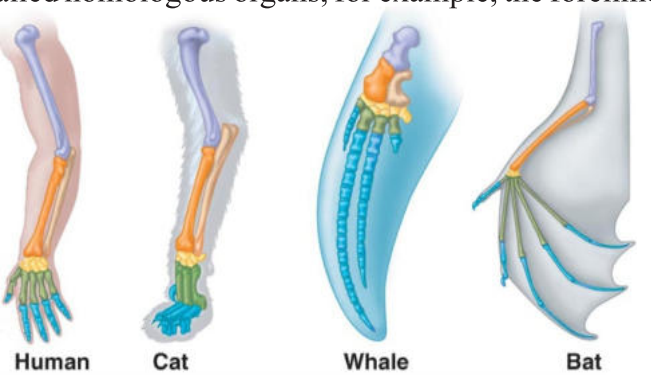


Fig.8.6: Homologous organs

cat, whale and bat are homologous. All these have same skeleton but with different functions. Analogous organs are those which have same function but different structures, for example, wings of insect, birds and bat are meant for flying but they have different structures.

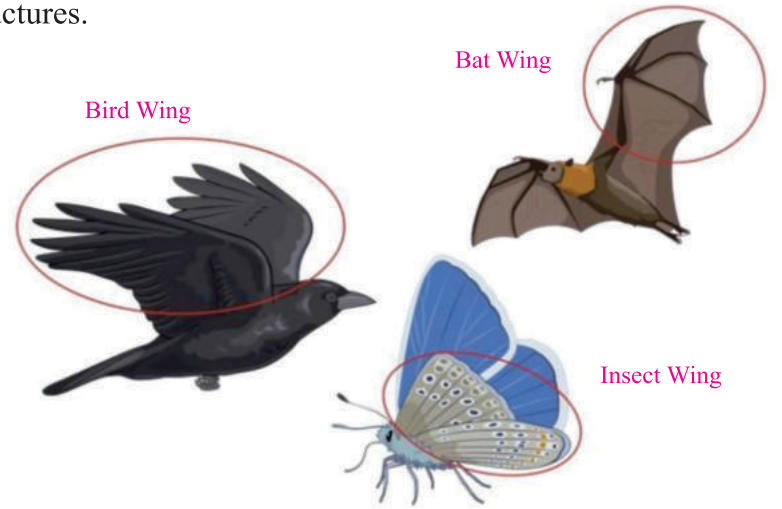


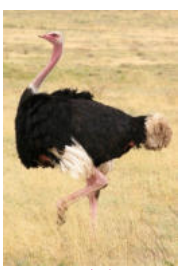
Fig.8.7: Analogous organs

b) Vestigial Organs

In some animals, various non functional organs are present known as vestigial organs. It is supposed that once such organs were functional but

Interesting Information

Monkey is different from apes. Monkeys have tails and narrow chest. Apes are tailless and have broad chests.



Ostrich

Kiwi

Fig.8.8: Flightless bird

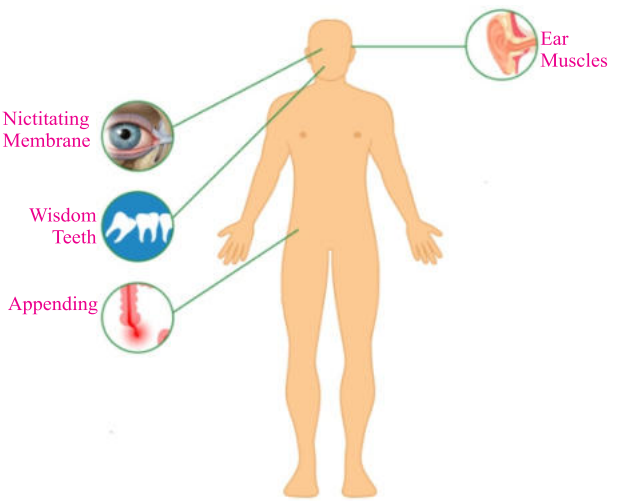


Fig.8.9: Human Vestigial Organs

in the course of evolution, they became reduced and functionless, for example, in flightless birds like kiwi and ostrich, the wings have lost their functions. Humans also have some vestigial organs like appendix, wisdom teeth, tail bone, ear muscle, nictitating membrane, etc.

b) Selective Breeding

Selective breeding is a process in which the selective plants and animals are crossed to get desired results. Darwin was also impressed by evidence provided by selective breeding in the favour of evolution, for example, more diversity is seen in domestic dogs and pigeons by selective breeding. It provides simple evidence of human ability to alter species by selective breeding procedure over a short period of time. A lot of changes have been found in the crops of maize, wheat, tomato and many fruits.

8.6 Sources of variation that can lead to speciation

Differences in the same basic character among the members of same species is called variation, for example, different skin, eye and hair colours in human beings.

Variation is the beauty of nature. There are many sources of variations that can lead to speciation and evolution . Some of these sources are as under:

i) Mutation: The sudden change in the nucleotide sequence of DNA or gene is called mutation. Due to mutation, new characters are developed in offsprings. These changes cause speciation and evolution.

ii) Geographic Isolation: Some times the separation of species occus due to land barriers and geographic changes. When organisms of a population are splitted by physical barriers like mountains, rivers or oceans then they form different groups. Each group lives in a different environment and adapts their new environment. After many generations, each group develops new traits. This separation lead to evolutions and speciation.

iii) Hybridization: When interbreeding occurs between the members of different species, then new species are formed. These new species show a unique combination of characters, for example, zebroid is formed by the cross between horse and zebra.

iv) Selective breeding by Human: The new species are also formed by the human activities i.e. selective breeding, for example, formation of new varieties of wheat by crossing different types of wheat plants.

Horse Zebra Zebroid

Fig. 8.10: Hybridization

8.7 Species

Species is a group of same organisms having common characters and can interbreed to produce fertile offsprings. Species is the main concept to understand the concept of biodiversity and the organization of life on Earth.

8.8 Speciation

Speciation is the evolutionary process by which new species are formed from a common ancestor. Speciation occurs when a group within a species separates from the other members of its species. This separation may be due to shortage of food, reproduction or geographical distribution. After isolation, the species adapt new characters according to the demand of new environment. As time and generations continue, these adapations are passed in generation after generation. After many generations through continuous selection, new species may evolve from a common ancestor. Small difference between parents and offspring can accumulate in successive generation so that descendants become very different from their ancestors. This process is called speciation.

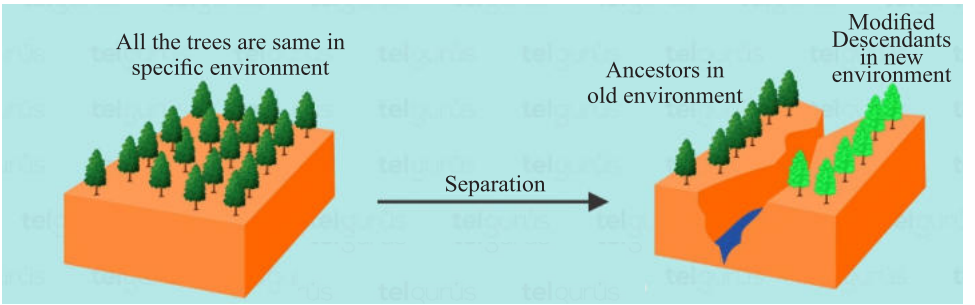


Fig. 8.11: Speciation

Example: The ancestors of finches had average beak size. With the passage of time variations have occurred in the beaks of descendants due to the availability of different types of foods in new environments. As a result the beaks of descendants became different from their ancestors.

KEY POINTS

- Biological Evolution or Evolution may be defined as a process of slow and gradual development or change in the living beings over a long span of time.
- According to theory of evolution the species change over time and adapt to their environment.
- Species is a group of same organisms having common characters and can interbreed to produce fertile offsprings.
- Speciation is the evolutionary process by which new species are formed from a common ancestor.
- The sudden change in the nucleotide sequence of DNA or gene is called mutation.
- Palaeontology is the study of fossils (the dead remains of organisms of past burried in soil or rocks).
- Those organs which have same fundamental structures but they are modified for different functions are called homologous organs.
- Analogous organs are those which have same function but have different structures.
- The Origin of Species by Natural Selection' is the famous book of Charles Darwin.
- The theory of natural selection was presented by Charles Darwin and Alferd Russel Wallace in mid 19th century.
- Darwin observed 13 finches on Galapagos island.
- *Archeopteryx* (a fossil bird) shows both the characters of reptiles and birds.
- Wisdom teeth, ear muscles, tail bone, nictitating etc., are the examples of vestigial organs in human beings.

EXERCISE

A. Multiple choice Questions (MCQs)

1. Aristotle classified the organisms on the basis of:
   (a) Respiration (b) Excretion
   (c) Reproduction (d) Mode of nutrition
2. The change in the sequance of nucleotides of DNA or gene is called:
   (a) Variation (b) Speciation
   (c) Mutation (d) Hybridization
3. Differences in the same basic characters is called:
   (a) Morphology (b) Homology
   (c) Analogy (d) Variations

4. The change in an organisms after many generations is due to:
   (a) Diseases (b) Evolution
   (c) Over production (d) Deficiency of food
5. When different species of dogs interbreed new species of dogs are formed. This process is called:
   (a) Immunization (b) Vaccination
   (c) Hybridization (d) Evalution
6. Different eye colours in human beings is an example of:
   (a) Evolution (b) Variation
   (c) Speciation (d) Hybridization
7. The direct evidence of evolution is:
   (a) Embryology (b) Paeleontology
   (c) Physiology (d) Homology
8. Analogous organs have:
   (a) Same function and same structure
   (b) Different function and same structure
   (c) Same function and different structure
   (d) Different function and different structure
9. The process through which new species are formed from a common ancestor is called:
   (a) Hybridization (b) Variation
   (c) Interbreeding (d) Speciation

B. Short Response Questions.

1. List down the observations of Darwin which he noted at Galapagos islands.
2. How was Darwin impressed by the evidence obtained from selective breeding?
3. What are vestigial organs? Give some examples of vestigial organs found in human beings.
4. Define the following terms
   (i) Mutation (ii) Evolution
   (iii) Natural selection (iv) Species

(v) Anatomy (vi) Palaeontology

C. Extended Response Questions.

1. Explain the theory of evolution by natural selection in detail.
2. Write a comprehensive note on those sources of variation that can lead to speciation.
3. Describe the differences between homology and analogy with examples.

Glossary

Active transport	It is the movement of molecules across a cell membrane from the area lower of concentration to higher concentration by using energy in the form of ATP.
ADP	A nucleotide made up of adenine, ribose sugar and two phosphate groups. When ATP releases one phosphate then it is converted into ADP.
Aerobic Respiration	It is a type of cellular respiration which occurs in the presence of abundant gaseous oxygen and in which complete oxidation of glucose takes place.
Anaerobic respiration (Fermentation)	It is a cellular respiration in which incomplete oxidation of glucose takes place without the utilization of gaseous oxygen.
ATP (Adenosine Tri Phosphate)	It is high energy organic compound which is used by the cells to perform their activities. ATP is called the energy currency of cell.
Biological evolution	Biological Evolution or Evolution may be defined as a process of slow and gradual development or change in the living beings over a long span of time.
Budding	In budding a new organism is developed from an outgrowth called bud. This bud is formed as a result of cell division in particular site on parent body.
Calvin cycle (Dark reactions)	These reactions occur in the stroma of chloroplast where reduction of CO_2 takes to form glucose.
Cell cycle	The sequence of events of cell division.
Cohesion tension theory	According to this theory the upward movement of water from roots to leaves is due to tension (created by transpirational pull) and cohesion among water molecules.
Cytokinesis	The division of one cell into two daughter cells after the telophase.
Competitive inhibitors	A competitive inhibitors occupies the active site temporarily.
Dark reactions (Calving cycle)	These reactions occur in the stroma of chloroplast in the absence of light. In these reactions the reduction of CO_2 takes place to form glucose.
Enzyme	These are biocatalysts. These are globular proteins which speed up the biochemical reactions by lowering the activation energy and remain unchanged after the reaction.
Fermentation	It is a cellular respiration in which incomplete oxidation of glucose takes place without the utilization of gaseous oxygen.
Fossil	The dead remains of the organisms who were existed in the past.
Genetics	Branch of biology which deals with the heredity and variations.
Gene	Gene is a unit of heredity. It is a specific portion of DNA in which

	there is a specific sequence of nucleotide.
Hill Reactions (Light reactions)	The reactions of photosynthesis in granum of chloroplast in the presence of light due to which light energy is converted into chemical energy (ATP, $NADPH_2$)
Homologous organs	The organs of different organisms who have similar structures but different functions.
Induced fit model	Induced fit model is also called hand and glove model. According to this model enzymes are not rigid bodies but are flexible structures. The active site of an enzyme slightly changes its shape as the substrate interacts with the enzymes
Krebs Cycle	These are cyclic reactions of respiration which occur in mitochondrion; due to the complete oxidation of pyruvic acid ATP, $NADH_2$ and $FADH_2$ are formed.
Light reactions	The reactions of photosynthesis in granum of chloroplast in the presence of light due to which light energy is converted into chemical energy (ATP, $NADPH_2$)
Lock and key model	Lock and Key Model: The enzyme (Lock) possess a rigid cavity or active site in which only one substrate with specific shape (Key) can fit (Lock and Key model).
Mesophyll	These are green cells of leaves which are involved in the process of photosynthesis due to the presence of chloroplasts in them.
Mutation	It is the change in the DNA due to which changes occur in an organism.
Nucleic acids	These are nitrogen containing organic compounds which are formed in nucleus and are acidic in nature (e.g) RNA, DNA.
Nutrition	The process involve in taking and utilization of nutrients for maintaining life.
Neurons	The neurons or nerve cells are the structural and functional units of animal's nervous system. These are the longest cells in the animal, body. A typical neurons consists of three main parts.
Non-competitive inhibitors	Non-Competitive inhibitors form enzyme inhibitor complex at a place other than active site called Allosteric Site.
Organelle	The living sub-cellular structures in a cell (e.g) Ribosome ER etc.
Osmosis	It is the movement of water molecules from the area of low solute concentration to higher solute concentration through a semi permeable membrane.
Osmoregulation	Osmoregulation is the maintenance of water and salts in the body fluid.
Palisade mesophyll	The upper layer of cells of green leaves on which light strikes.
Passive transport	The movement of molecules from higher conc. To lower conc. thout using chemical energy (e.g) diffusion, osmosis etc.
Prokaryotes	The organisms which can prepare their own food i.e autotrophic organism (e.g) plants.

Pressure flow mechanism	According to pressure flow mechanism "the movement of water containing sucrose through sieve tube is from source to sink due to the difference of sucrose between these two sites. Source is an area where sugar is prepared (e.g. green leaves) or an area where the sugar concentration is high. On the other hand sink is an area where the sugar is used (e.g. Root) or where the concentration of sugar is low.
Quiescent stage (G0)S	It is an inactive stage of the cell cycle.
RNA (Ribonucleic Acid)	It is a single strand of nucleotides. It helps in protein synthesis according to the genetic informations provided by DNA.
Scientific method	The systematic procedure adopted by a scientist to get a final answer of a problem.
Spongy mesophyll	It is the lower layer of mesophyll tissue of leaf which contain air spaces for the exchange of gases.
Substrate	The substance on which enzyme act in biochemical reactions.
Speciation	Speciation is the evolutionary process by which new species are formed from a common ancestor
Taxon	Each group of organisms in taxonomy is commonly called taxon.
Transpiration	The loss of water vapours from the aerial parts of the plants especially through stomata.
Transcription	In transcription, the mRNA is formed by DNA in nucleus.
Tubers	Tubers are vegetative organs that may develop from stem or root.
Ulcer	The effected area of stomach or duodenum due to the action of HCl or pepsin.
Vitamins	These are special organic compounds which are essential in small amounts for the proper functioning of a body.
Vestigial organs.	The non-functional organs of organisms are called vestigial organs.
White Blood Cells	These are one of the formed elements of blood. They are colourless and have nucleus. They form defence system in body.
Wilting	The loose condition of plants due to removal or shortage of water in green parts.
Xylem	These tissues are tube like structures for the conduction of water and minerals from the roots to the leaves.
Xerophytes	Xerophytes plants grow in dry and hot regions where rainfall is scanty and thus possess ability to survive long dry period.
Zygote	In sexual reproduction the male and female gametes unite to form a diploid (2n) body called zygote.

INDEX

About the Authors

Professor Ehsan Elahi is currently working as an Associate Professor at Tameer-e-Nau Post Graduate College, Quetta Cantt. He has served as a teacher for nearly 45 years in the field of Biology.

He achieved 5th position in matriculation across Balochistan in 1975. He got first position in B.Sc from the University of Balochistan in 1985 and received a Gold Medal from the Honourable Minister of Education. Later, he again secured first position in M.Sc (Botany) from the University of Balochistan in 1988.

Professor Ehsan Elahi taught Biology and Chemistry for 7 years at Tameer-i-Nau School. He then served as a Botany professor in college for 37 years. He has written 22 guidebooks for First and Second Year students. He is also the author of the current Textbook and Practical Manual for Biology 9th Class, based on the National Curriculum 2006, which is being taught in Balochistan Board. In addition, he wrote the Model Textbook of Biology for 9th Class and co-wrote the First Year Biology Book Based on the National Curriculum 2022-23. His research paper on juniper forestation was published in a national journal in 1989. In 2021, he received the Best Teacher Award in Biology from the All Pakistan Teachers' Association. He also served as a co-supervisor in the Botany Department at the University of Balochistan in 1989.

Since 2010, he has been a result-oriented teacher at the BASE Group of Colleges in Wah Cantt.

Besides his academic work, Professor Ehsan Elahi also played an active role during National Emergencies. He was among the first responders during the 2005 earthquake in Kashmir and the 2008 earthquake in Ziarat. He served as the Programme Director in the Natural Disasters Management Cell, working for relief efforts and the resettlement of displaced people (IDPs) in KPK.

Dr. Muhammad Ali retired Professor College.

He did his post graduation in Zoology with specialization in Entomology from University of Balochistan, Quetta. He has completed his M.Phil in Parasitology and Ph-D in Herpetology from the University of Balochistan, Quetta. He has also got diploma in Biological Sciences and Science Education from University of Hiroshima, Japan.

He has been teaching Biology for the last 40 years in various colleges of Balochistan and remained resource person for college teachers training. He was rewarded best teacher award from the Chief Minister of Balochistan in 2014. He has published many research

papers in national and international science journals. He has served head examiner and paper setter for Zoology theory and practical examination of Intermediate, Graduate and Postgraduate classes.

Abid Hussain Qureshi is serving as an Associate Professor of Zoology at Government postgraduate Science College, Quetta.
He did his Postgraduation in Zoology with specialization in Parasitology from University of Balochistan, Quetta. He has completed his M.Phil in Biotechnology from Balochistan University of Information Technology and Management Sciences, Quetta. At present he is doing his PhD from University of Balochistan. He has also done advance level English language course from Pakistan English Coaching Center, Quetta. He has been awarded best college teacher award in college teacher training program in 2002. He has published research papers in international journals. He is also co-author of Biology practical journals of intermediate classes, he remained head examiner and paper setter of first year Zoology theory and practical in Balochistan Board of Intermediate and Secondary Education, Quetta. He has been teaching to Intermediate, Graduate and Postgraduate classes for last 25 years in various colleges of Balochistan.