

BIOLOGY

Grade 11

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

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Preface

The curriculum is the central guide that decides what is essential for teaching and learning. A textbook is one of the main tools to deliver the intent and the content of the curriculum. Therefore, it should have such an attribute that it presents relevant, practical, and useful knowledge and the process of skills for the overall development of a learner in accordance with the curricular aims and intents. This textbook '**Biology Grade 11**' has been developed to address the main aims of the Secondary Level (Grade 11-12) Physics Curriculum and is aligned with the intent of the National Curriculum Framework for School Education, 2076.

This book was prepared and edited by an academic team that includes Mr. Suraj Babu Ghimire, Mr. Sumant Kumar Ranjit, Mr. Pashupati Shrestha and Mr. Lav Dev Bhatta. Several people notably; the Director Generals Mr. Ima Narayan Shrestha and Mr. Baikuntha Prasad Aryal, Professor Dr. Krishna Bakta Maharjan, Dr. Kamal Prasad Achary, Mr. Umanath Lamsal, Mr. Keshar Bahadur Khulal, Mr. Heramba Raj Kandel, MS. Mina Shrestha, MS. Pramila Bakhathi, Mr. Rup Bahadur Shaha, Mr. Ram Krishna Shrestha, Mr. Santhosh Lamsal, Mr. Sanjib Bhandari, Ms Shrijana Dungal and Mr. Yub Raj Adhikari also contributed significantly on the development of this book. The language of this book was edited by Mr. Basu Dev Osti.

Effort has been made to make the book activity oriented and interesting to the learners. All the contents of each lesson in this textbook are equally important. However, teachers can adapt the contents and tasks to the need of their learners and classroom contexts. This textbook can be used as a major resource for classroom teaching but it is not all in all. The teachers are also encouraged to explore other resources in addition to this book and use them to supplement the curricular contents as provisioned in the curriculum. The Curriculum Development Centre always welcomes constructive feedback for the betterment of its publications.

Curriculum Development Centre
Sanothimi, Bhaktapur

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Unit

1

Biomolecules And Cell Biology



James Watson
&
Francis Crick

In the 1950s, James Watson (1928) and Francis Crick (1916–2004) unveiled the double helix structure of DNA using X-ray diffraction images. This breakthrough earned them the 1962 Nobel Prize in Physiology or Medicine. The DNA model provided insights into replication and the transmission of genetic information in humans.

Chapter 1.1

BIOMOLECULE

Consider the diversity of life around us - from the tiniest microorganisms to complex plants and animals.

- i. What is the common thread that unites all living things at the molecular level?
- ii. How might these molecules serve as the building blocks of life?
- iii. How do biomolecules create unique characteristics in different organisms?
- iv. What biomolecules are there in the last meal you ate, and how do they support your body?

1.1.1 GENERAL INTRODUCTION

Think about the incredible variety of living things, from tiny microorganisms to the complex structures of plants and animals. What ties them all together at the tiniest level? Well, it's all about molecules! Cells and organisms are made of different kinds of molecules called **biomolecules**. These special molecules are like the building blocks of life, coming in different sizes from simple ones like carbon dioxide and water to big ones like proteins. As the smaller molecules are soluble and easily transported, they frequently enter the general chemical activity of cells known as **metabolism**. Larger molecules tend to be used for structural purposes and some can be described as "informational" molecules, concerned with carrying genetic information (DNA and RNA) and the expression of that information (proteins). The collection of the biomolecules in the cell is called **cellular pool**.

Biomolecules of cellular pool can be classified into two types:

1. **Organic Compounds:** These are the compounds, basically, composed of carbon in combination with other elements like H, O, N, S, etc. For example, carbohydrates, proteins, fats, nucleic acids, hormones and vitamins.
2. **Inorganic Compounds:** These are the compounds found in the bulk of physical and non-living universe like elements, non-metals and their compounds. For example, water, minerals, salts, and ions.

Do you know?

Living cells are primarily made up of C, H, N, O, P, and S, which make up about 99% of their mass. The remaining 1% consists of elements like Ca, Fe, Zn, Na, K, Cl with water (H and O) making up around 70% of a cell's mass.

Cellular pool obtains chemicals from external environment through membranous covering of cell organelles and plasma membranes. Based on molecular weight and solubility, the biomolecules are classified into two types:

- a) **Micromolecules:** Biomolecules such as water, gases, minerals, sugars, amino acids, and nucleotides which are of small size and low molecular weight are called micromolecule.
- b) **Macromolecules:** Biomolecules which are structurally complex, larger in size, and of high molecular weight are called macromolecules. They are of four classes: carbohydrates, lipids, proteins, and nucleic acids.

To better understand the composition of macromolecules in our cells, the following table presents the four classes of macromolecules along with their approximate percentage by weight.

Component	Cellular Mass (%)
Water	70 - 90
Proteins	10 - 15
Carbohydrates	3
Lipids	2
Nucleic acids	5 - 7
Ions	1

1.1.2 CARBOHYDRATES

Consider your daily breakfast routine. What is your preferred morning food, and do you recognize the nutritional significance of this choice in providing energy for the day?

Carbohydrates (*L. carbo* = carbon, *G. hydro* = water) are the biomolecules composed of carbon, hydrogen, and oxygen. The ratio of hydrogen to oxygen is typically 2:1, like in water, therefore, it is also known as "hydrates of carbon". The general formula for carbohydrates is $C_x(H_2O)_y$. Chemically, carbohydrates are aldehyde and ketone derivatives of polyhydroxy alcohol. Those with an aldehyde group (-CHO) at the terminal position are called aldoses, while those with a ketone group ($>C=O$) at the subterminal position are termed ketoses. They are the primary source of energy for all living beings and are also referred to as saccharides (*G. saccharin* = sugar) meaning sugar.

CLASSIFICATION OF CARBOHYDRATES

Carbohydrates are categorized into three groups based on their chemical complexity:

- 1) Monosaccharides (Monomers)
- 2) Oligosaccharides (Oligomers)
- 3) Polysaccharides (Polymers)

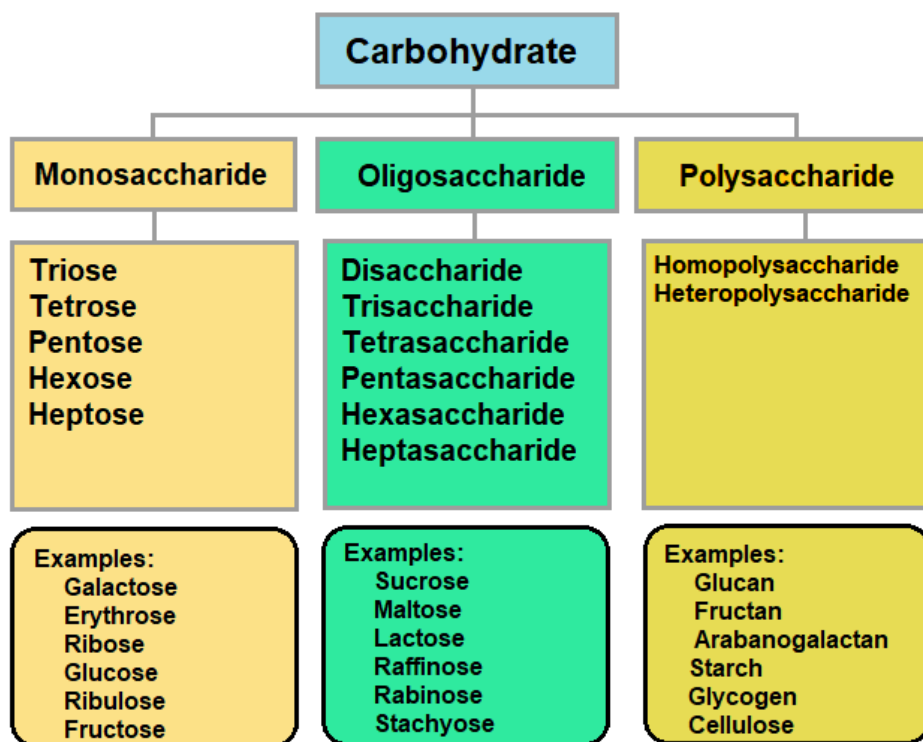


Figure: 1.1.1 Classification of carbohydrate

1. Monosaccharides ($C_nH_{2n}O_n$)

Monosaccharides are the simplest forms of carbohydrates and cannot be broken down into smaller units. Some common examples are glucose, fructose, and galactose. Structurally, monosaccharides are composed of polyhydroxy compounds, with all carbon atoms having a hydroxyl group, except one, which contains either an aldehyde or a ketone group. Monosaccharides with free aldehyde and ketone groups are termed reducing sugars because they can reduce Cu^{2+} to Cu^+ form. They are highly soluble in water and taste sweet.

Do you know?

Derived monosaccharides are the modified monosaccharides obtained by alteration (the addition or removal) of functional groups. Key derivatives include deoxy sugar (e.g., deoxyribose of DNA), amino sugars (e.g., glucosamine), sugar acid (e.g., ascorbic acid), and sugar alcohol (e.g., mannitol).

E.g. Glucose + Acetyl group $\rightarrow$ N-acetylglucosamine

The general formula for monosaccharides is $C_nH_{2n}O_n$, where n is an integer from 3 to 7. Based on the number of carbon atom, they are classified as follows:

Table 1.1.1 Types of monosaccharide based on the number of Carbon and functional groups

Monosaccharides	Aldose	Ketose
Trioses ($C_3H_6O_3$)	Glyceraldehyde	Dihydroxyaxetone
Tetroses ($C_4H_8O_4$)	Erythrose	Erythrulose
Pentoses ($C_5H_{10}O_5$)	Ribose	Ribulose
Hexoses ($C_6H_{12}O_6$)	Glucose	Fructose
Heptoses ($C_7H_{14}O_7$)	Glucoheptose	Sedoheptulose

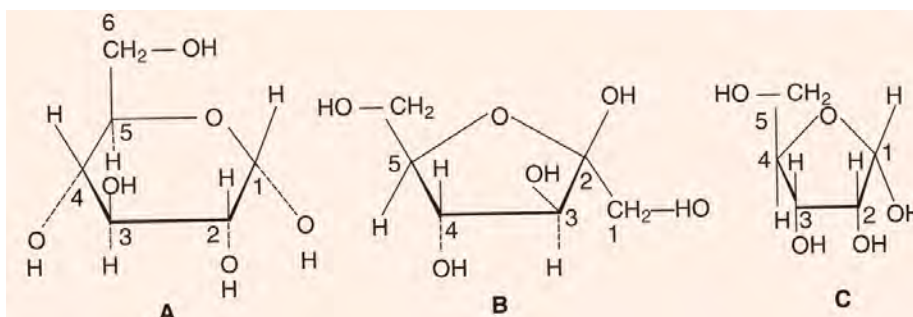


Figure 1.1.2 Ring structures of monosaccharides:

(A) glucose, (B) fructose and (C) ribose

Glucose, an aldohexose with six carbon atoms ($C_6H_{12}O_6$), is the most abundant monosaccharide in nature. They have five hydroxy groups and one aldehyde group with six carbon atoms all together. It is a white, crystalline, sweet-tasting substance that is highly soluble in water.

2. Oligosaccharides

Oligosaccharides (G. *oligo* = a few) are the chains of 2 to 10 monosaccharides linked by glycosidic bonds. They generally taste sweet and are water soluble. Some important oligosaccharides are:

Number of monosaccharide	Oligosaccharide	Example
2	Disaccharide	Sucrose (glucose + fructose) maltose (glucose + glucose) lactose (glucose + galactose)
3	Trisaccharide	raffinose (galactose + glucose + fructose) mannotriose, rabinose
4	Tetrasaccharide	Stachyose (2 galactose + glucose + fructose), scordose
5	Pentasaccharide	verbascose

The most abundant oligosaccharides in the animal and plant cells are the disaccharides such as sucrose, maltose and lactose. Raffinose ($C_{18}H_{32}O_{16}$) is made of three sugar molecules: galactose, glucose, and fructose. Stachyose ($C_{24}H_{42}O_{21}$) is made of four sugar molecules: two molecules of galactose, one molecule of glucose, and one molecule of fructose.

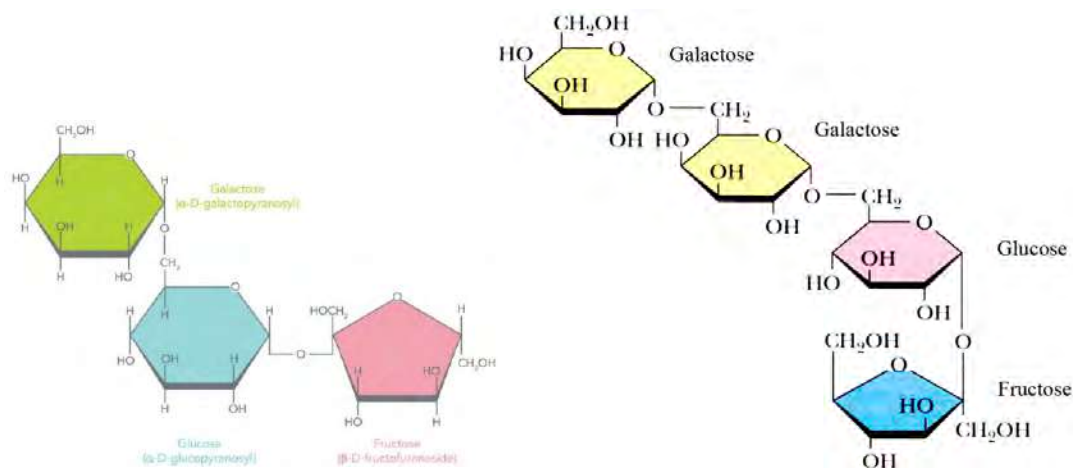


Figure 1.1.3 Schematic molecular structure of (a) Trisaccharide: Raffinose ($C_{18}H_{32}O_{16}$), (b) Tetrasaccharide: Stachyose ($C_{24}H_{42}O_{21}$)

Do You Know?

Raffinose is commonly found in various plants, especially in seeds and legumes. It serves as a reserve carbohydrate, providing a source of energy for the growing plant embryo.

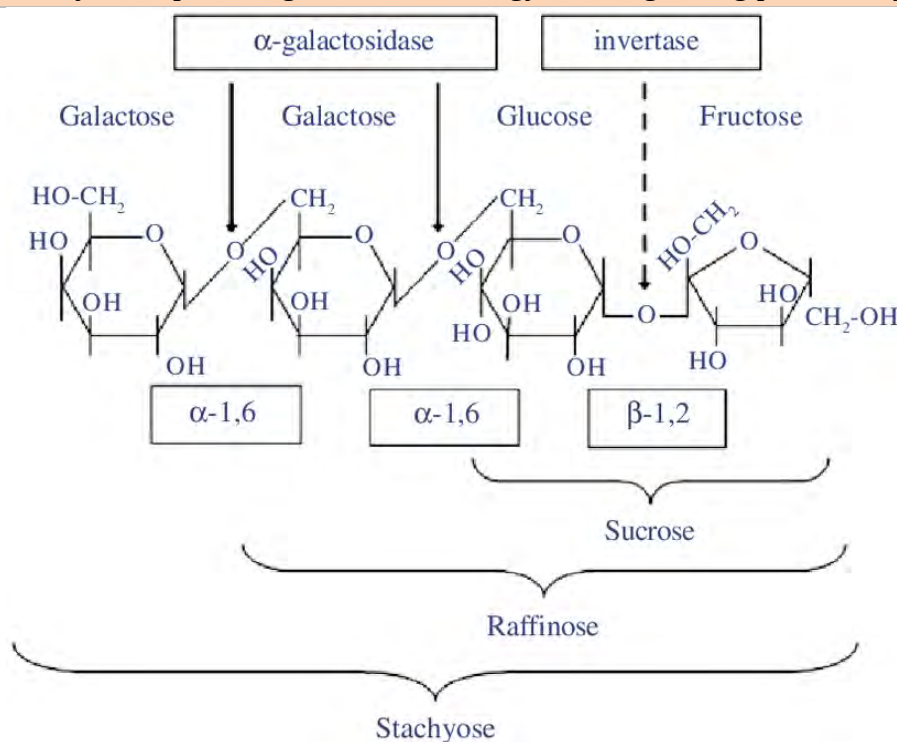
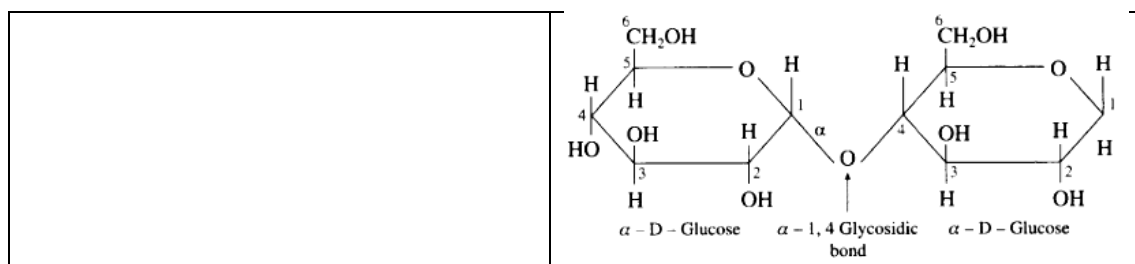


Figure 1.1.7 Molecular structure of Mono-Di-Tri-Poly-saccharide



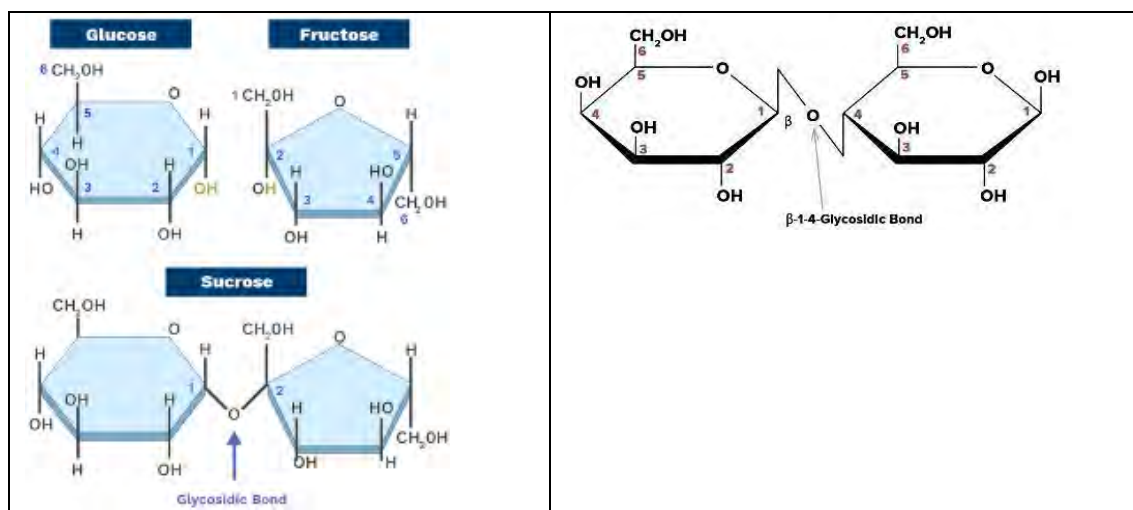


Figure 1.1.4 Molecular Structure: (a) sucrose, (b) maltose and (c) lactose

3. Polysaccharides

Polysaccharides are complex molecules composed of ten to thousands monosaccharides. They are also known as glycan. Despite their long size, polysaccharides do not function as reducing sugars. They are not water soluble and lack a sweet taste. For example, starch, cellulose, glycogen, and dextrin. Starch serves as a food storage in plants, but animals store it in the form of glycogen, and cellulose is a structural component of plant cell wall. Thus, they can be classified into two functional types:

- Structural polysaccharides (cellulose in plant cell wall; chitin in fungal cell wall; mannan in yeast cell wall; peptidoglycan in bacterial cell wall)
- Nutrient polysaccharides (starch in plant and bacterial cell, glycogen in animal cell)

Based on their composition, they can also be classified into:

- Homopolysaccharides/homoglycans:** They are polymers of only one type of monosaccharide. For example, glucan (made of glucose), fructan (made of fructose).
- Heteropolysaccharides/heteroglycans:** They are polymers of many types of monosaccharide. For example, arabanogalactans.

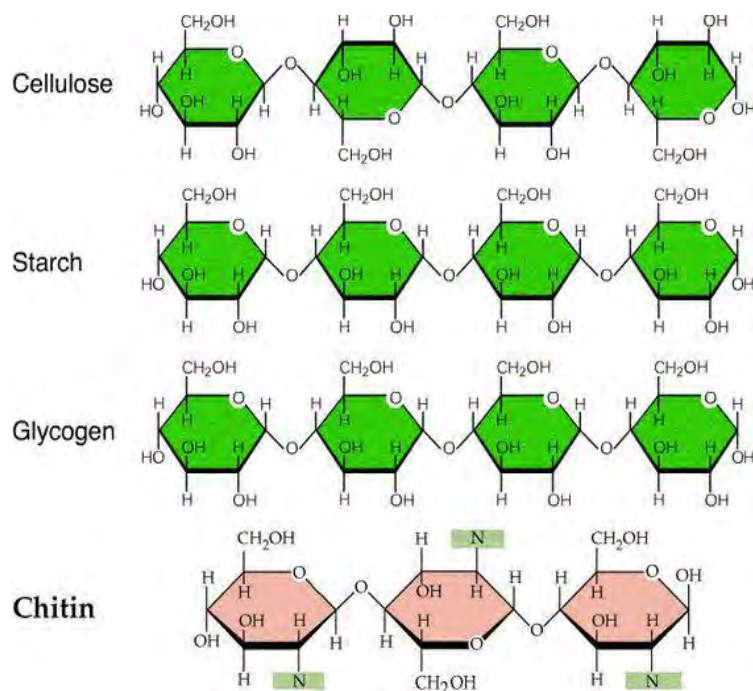


Figure 1.1.8 Molecular structure of some polysaccharides

Activity 1.1

Demonstrate structures of polysaccharide using cotton balls and toothpicks. Differentiate glucose, galactose, and fructose with colored cotton balls. Construct sucrose, maltose, and lactose models, identifying glycosidic bonds.

(Optional: Further explore branching in starch and cellulose for a hands-on understanding of polysaccharides.)



Figure 1.1.9 Water colour, cotton and toothpick

Materials required: Gather small cotton balls (approximately 1 cm in diameter), three different nontoxic watercolors to represent glucose, galactose, and fructose, and toothpicks

Procedure

Steps 1 | Color Coding Monosaccharides:

- Soak one cotton ball in each color to represent the three different monosaccharides (glucose, galactose, and fructose).
- Allow the colored cotton balls to dry.

Step 2 | Building Disaccharides:

- Use toothpicks to represent glycosidic bonds between the colored cotton balls.
- Combine the cotton balls with toothpicks to visually demonstrate the formation of disaccharides.
- For example, use toothpicks to connect glucose and fructose cotton balls to create a model of sucrose.

Functions of Carbohydrates

Carbohydrates are essential for various functions in our body:

1. Approximately 50% of our total energy comes from breaking down carbohydrates.
2. Monosaccharides like ribose and deoxyribose are structural elements in nucleic acids. Polysaccharides like cellulose and hemicellulose form the plant cell wall.
3. Starch serves as a storage polysaccharide in plants, while glycogen (animal starch) is a primary reserve food stored in the liver and muscles.
4. Carbohydrates support the synthesis of fats and amino acids.
5. Glucose plays a crucial role in preventing the incomplete oxidation of fats and the formation of ketone bodies in the blood.

Activity 1.2

Draw structures of monosaccharides (glucose, fructose) and simple polysaccharides (like maltose) in a chart paper using different colors. And label the bonds between monomers. Discuss how these structures contribute to the overall understanding of carbohydrates.

1.1.3 AMINO ACIDS

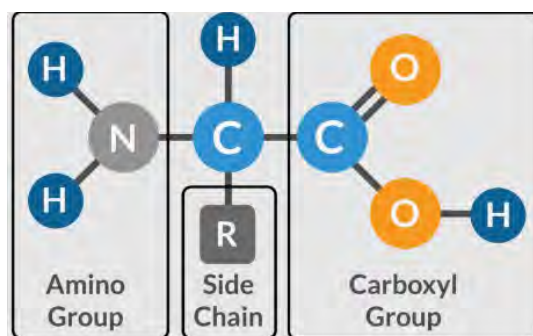


Figure 1.1.10 Amino acid (schematic)

Amino acids are organic acids that comprises amino group (-NH_2) attached to a alpha carbon next to carboxylic group (-COOH). The alpha carbon also possesses alkyl group (R) and a Hydrogen atom. A molecule of amino acid comprises both, basic group (amino: -NH_2) and acidic group (carboxyl: -COOH). Therefore, such organic molecules that show both acidic and basic properties are known as amphoteric molecules. A long chain of amino acids linked by peptide bond forms protein. Thus, amino acids are the building blocks of proteins. Here are some characteristics of amino acids:

1. Amino acids are the fundamental units that form proteins.
2. Every amino acid has at least one acidic carboxylic group (-COOH) and one basic amino group (-NH_2).
3. They are clear, solid crystals.
4. Amino acids are soluble in water but don't mix well with organic solvents.
5. In nature, there are 20 different types of amino acids.
6. For example, alanine, glycine, serine, leucine, isoleucine, and more. The simplest one is called glycine.

Formation of Peptide Bond.

When two amino acids get linked at -COOH group of one amino acid and -NH_2 group of another amino acid, a peptide bond (-CO-NH-) is formed releasing a water molecule. This connection between amino acid molecules is referred to as a peptide linkage. A chain of multiple amino acids joined together in succession forms a polypeptide chain.

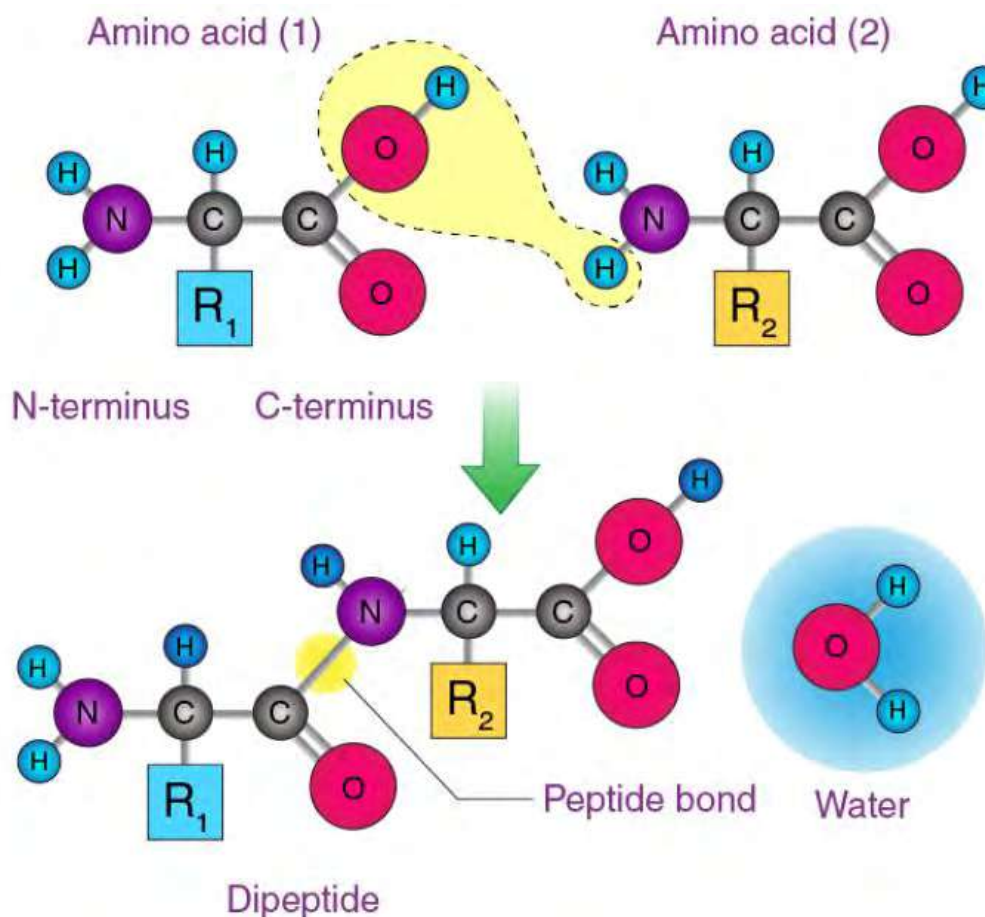


Figure 1.1.11 Peptide bond of protein

CATEGORIES OF AMINO ACIDS

Do you know?

There are some amino acids which are usually not essential, except in times of illness and stress. They are called conditionally essential amino acids. Some of them are arginine, glycine, proline, serine, and tyrosine.

There are 20 different types of amino acids that are commonly found in nature. They can be categorized into two main groups based on their role in the body:

- i. Essential Amino Acids:** These are the amino acids that human body cannot produce on its own, so they must be obtained through diet. There are nine essential amino acids: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Histidine is not synthesized by all human.

ii. Non-Essential Amino Acids: The human body can synthesize these amino acids, so it is not necessary to obtain them from diet. There are 11 non-essential amino acids: alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, and tyrosine.

Activity: Exploring Amino Acids and Proteins

Objective: To understand amino acid classification and protein types through group activities.

Materials Needed:

- Printed handouts of amino acid and protein information
- Paper and pens for each group

Procedure:

- Divide class into small groups composed of 6 - 7 students.
- Briefly discuss importance of amino acids and proteins.
- To identify amino acids, ask each group to make lists of essential and non-essential amino acids after conducting research using handouts, textbook.
- Discuss functions and sources of each.
- Let each group present their findings including their importance.
- Summarize and conclude the session with feedback, assignments words to encourage further exploration.

Amino acid	Function	Source	
Essential AA			
Non-essential AA			
Protein	Function	Source	
			
			

Functions of Amino Acids

Amino acids play crucial roles in our body:

- They serve as the building blocks of proteins and enzymes.
- Amino acid (Tryptophan) synthesizes vitamin (niacin) and plant hormone (Indole Acetic Acid: IAA).
- Tyrosine is essential for the synthesis of animal hormones like thyroxine, epinephrine and melanin pigments.
- Amino acid (glycine) is essential to synthesize heme and protoporphyrin.
- Several non-protein amino acids are required to synthesize antibiotics.
- In prokaryotic cell wall, peptides in association with carbohydrate form peptidoglycans.

1.1.4 PROTEINS

Proteins (*G. proteios* = of the first rank) are long chains of a large number of chemically bonded amino acids. They are the most complex and varied macromolecules that form more than 50% of the cell's dry weight. Enzymes, basically proteins, control all body reactions.

Around 20 different amino acids in a specific sequence form distinct protein whose specific sequence is determined by gene.

CATEGORIES OF PROTEINS

A. Based on chemical nature and solubility, proteins are divided into three categories:

- a) Simple proteins
- b) Conjugated proteins
- c) Derived proteins

a) Simple proteins: They are made up of only amino acids. For example, albumins, globulins, histones, protamines, etc.

b) Conjugated proteins: They contain simple proteins associated with some non-protein components. These additional components are known as prosthetic groups. Some specific types of conjugated proteins are:

1. **Glycoproteins:** These result from the combination of protein and glucose, as seen in substances like mucin of saliva.
2. **Phosphoproteins:** They are formed by the combination of amino acids and phosphate. For example, caesin of milk and ovovitellin of eggs.
3. **Lipoproteins:** These are the combination of amino acids and lipids. They are found in various proteins such as those in the brain, serum, and the chemical composition of biological membranes. For example, High density lipoprotein (HDL).
4. **Nucleoprotein:** They are formed by the combination of amino acids and nucleic acids. They are located in the chromosomes of cells. For example, histone protein.
5. **Chromoprotein:** They are formed by the combination of amino acids and colored pigments containing elements like Fe, Cu, Mg, or Cobalt. For example, hemoglobin and the retina of the eye.

c) Derived proteins: These proteins are formed by the partial hydrolysis of simple and conjugated proteins. For example, peptones and proteoses.

B. Based on the shape, proteins are categorized into two types:

1. **Fibrous proteins** show twisted structure, forming long fiber-like arrangements. They are strong, elastic and insoluble in water, and are exclusively found in animals. For example, keratin, elastin, myosin, collagen, etc.
2. **Globular proteins** are roughly spherical, water-soluble and are predominantly found in plants, such as albumin and globulin. For example, egg albumin, serum, glutelins, etc.

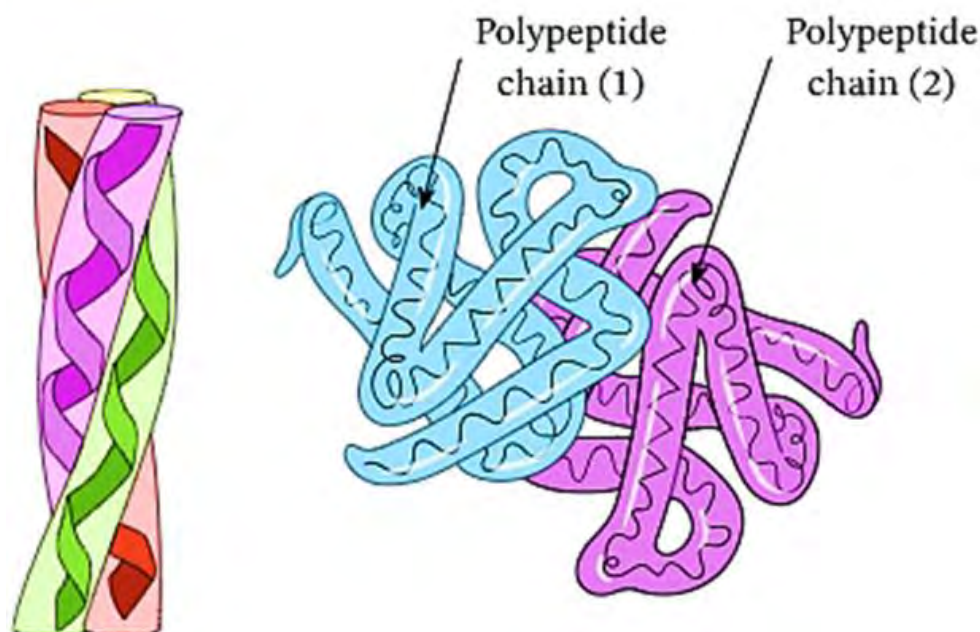


Figure 1.1.12 Types of Protein (a) Fibrous and (b) Globular

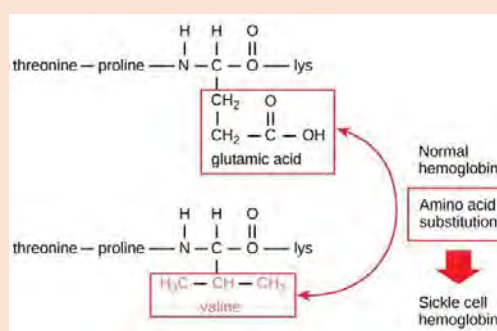
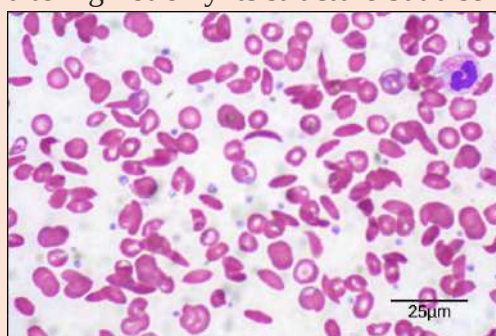
STRUCTURE OF PROTEIN

Proteins are, basically, polymers of numerous amino acid molecules. Proteins exhibit various configurations or structures based on which it can have following four levels:

1. Primary structure
2. Secondary structure
3. Tertiary structure
4. Quaternary structure

Do You Know?

The sequence of a protein is determined by the DNA of the gene responsible for the coding of the protein. A change in DNA sequence brings change in the sequence of amino acids altering not only its structure but also its function.



For example, in sickle cell anemia, one of the polypeptide chains that makes hemoglobin suffers a slight alteration in amino acid sequence. The glutamic acid normally located as the sixth amino acid of the hemoglobin β chain is replaced by valine.

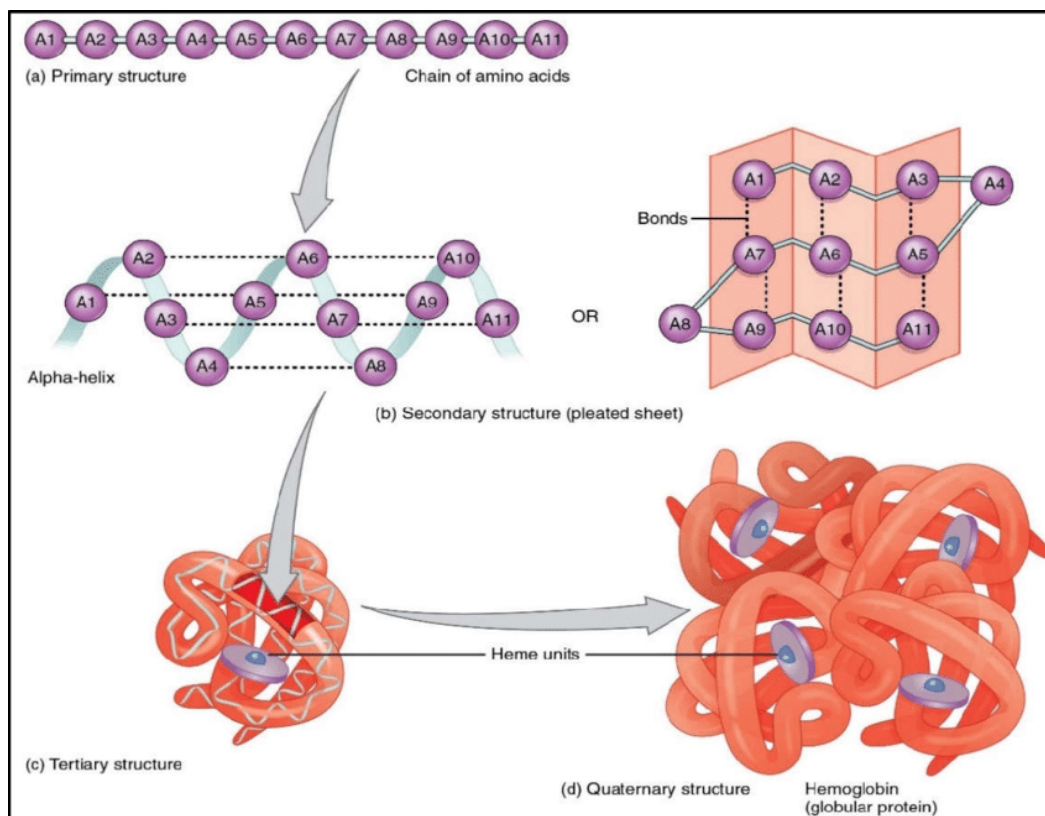


Figure 1.1.13 Primary, Secondary, Tertiary and Quaternary structures of protein

1. Primary structure

Arrangement of amino acids in a polypeptide chain is the primary structure of a protein. It is a linear arrangement of amino acids and has only peptide bonds. Insulin is the smallest protein which shows primary structure.

2. Secondary structure

Secondary structure of protein is a regularly repeated polypeptide chain resulting three dimensional shapes. In this type, the polypeptide chain bends and folds due to molecular force and gives a special shape to the protein. Between carbonyl oxygen, there is a hydrogen atom. The force originated from the hydrogen bond twists the polypeptide chain into its helical structure. This is called alpha - helix. Such proteins are found in hair, wool and in fibrous substances.

3. Tertiary structure

Tertiary protein structure describes more compact arrangement in which helical and non-helical parts of a polypeptide chain fold back on themselves. This type of structure is characteristic of globular proteins, where the folding is facilitated by the non-helical regions.

In a tertiary protein, the polypeptide chain is held together by bonds like ionic bonds, hydrogen bonds, hydrophobic interactions, and disulfide bonds.

4. Quaternary structure

In the proteins which are made of two or more polypeptide chains, the quaternary structure describes how these chains are arranged relative to each other and the interactions that hold this arrangement together. For example, ribonuclease, haemoglobin, and immunoglobulins.

Do You Know?

Why does the transparent fluid in an egg turn white when boiled?

Egg whites have proteins called albumins with a specific 3D shape due to bonds between amino acids. Heating breaks these bonds and reveals hydrophobic amino acids. These amino acids stick together, forming a network that gives the egg white opaque structure. Each protein has a unique shape. If the environment's temperature, pH, or chemicals change, the protein's shape can be affected, causing it to lose its structure and become a jumbled string of amino acids, called denaturation. Denatured proteins often lose their function.

Functions of Proteins

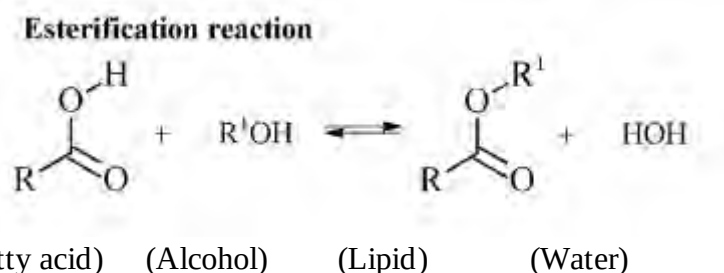
1. Structural proteins are crucial for building and repairing body tissues, supporting growth.
2. Proteins also serve as energy sources. They provide 5.65 kcal of energy per gram, with a physiological fuel value of 4.0 kcal per gram.
3. Nearly 2000 different kinds of enzymes are known to act as enzymes or biocatalysts which regulate life processes
4. Insulin is a hormone (protein) that regulates glucose level in the body.
5. Antibodies or immuno-globins are proteins that develop immunity/protect the body against foreign bodies.
6. Thrombin and fibrinogen are proteins that prevent bleeding by clotting blood.

1.1.5 LIPIDS OR FATS

Why do our bodies need fat?

Can you think of any common foods that are a good source of fats?

Lipids consist of fats and fat-like substances composed of carbon, hydrogen, and oxygen. It has lower oxygen content compared to carbohydrates. They are insoluble in water but soluble in organic solvents like acetone, ether, and alcohol. A significant amount of oxygen is required for their oxidation to generate energy. True lipids are essentially esters derived from the combination of fatty acids and alcohol. An ester is an organic compound formed by the union of a fatty acid with alcohol.



where,

R = CH₃, CH₅, etc.

Figure 1.1.15 Structures of ester formation

FATTY ACIDS

Fatty acids are large molecules containing acidic groups. The general formula is $R - \text{COOH}$, where, $R = \text{CH}_3, \text{CH}_5$, etc. There are two types of fatty acids.

1. Unsaturated fatty acids
 - a) **Unsaturated Fatty acids:** These fatty acids have one or more double bonds between their carbon atoms, which results in lower melting points. They are typically in a liquid state at room temperature and are commonly found in plant-based oils such as sunflower oil, mustard oil, soybean oil, olive oil, as well as in nuts, seeds, avocados, and some fatty fish like salmon and sardines. These oils are usually clear or semi-transparent.

For examples, Oleic acid (one double bond), Linoleic acid (two double bonds), Linolenic acid (three double bond).

- b) **Saturated Fatty acids:** These fatty acids have single bonds between their carbon atoms, resulting in higher melting points. They are generally in a solid state at room temperature and are commonly found in animal products like meat and dairy, as well as in some plant-based oils such as coconut oil and palm oil. These fats are often opaque or cloudy.

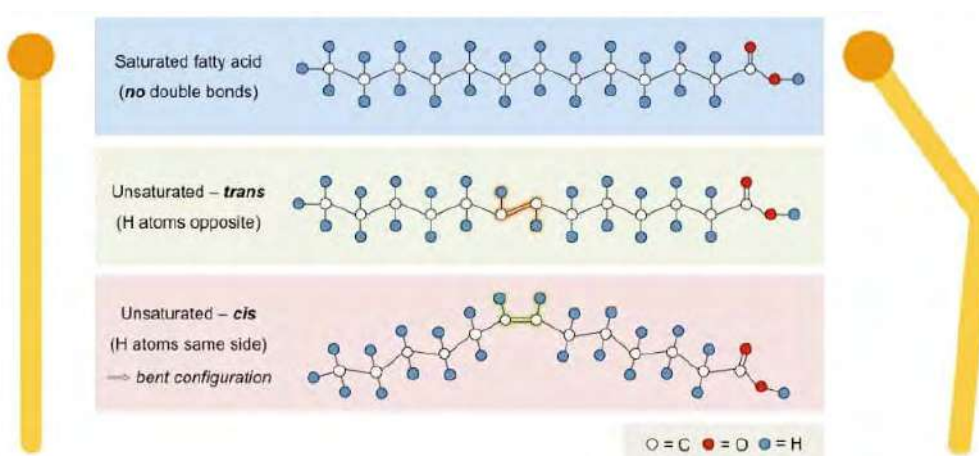


Figure 1.1.16 Saturated and unsaturated fatty acid

Project work

Design posters using chart paper and colour pens in groups to compare how unsaturated fatty acids are different from saturated fatty acids including examples and sources.

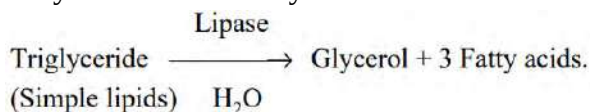
CLASSIFICATION OF LIPIDS

Lipids are grouped into three categories:

1. Simple lipids
2. Complex or conjugated lipids
3. Derived lipids

1. Simple Lipids

They are esters of fatty acids and alcohol.



They are broadly categorized into the following types:

- i. Neutral fats
- ii. Oils
- iii. Waxes

i. Neutral fats: They are triesters of fatty acids and glycerol. Hence, it is also known as glycerides or triglycerides. Each molecule of glycerol can react with three molecules of fatty acids. Depending upon the number of fatty acids attached, they are called monoglyceride, diglyceride or tri-glyceride. It can be found in solid state in room temperature.

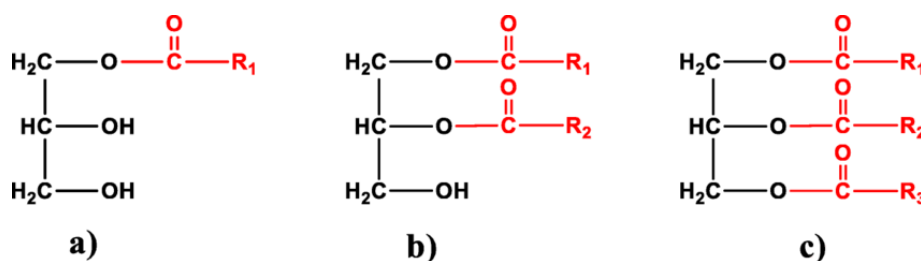


Figure 1.1.17 Types of Glycerides

- a. **Monoglyceride:** One molecule of glycerol + one molecule of fatty acid.
- b. **Diglyceride:** One molecule of glycerol + two molecules of fatty acids.
- c. **Triglyceride:** One molecule of glycerol + three molecules of fatty acids.

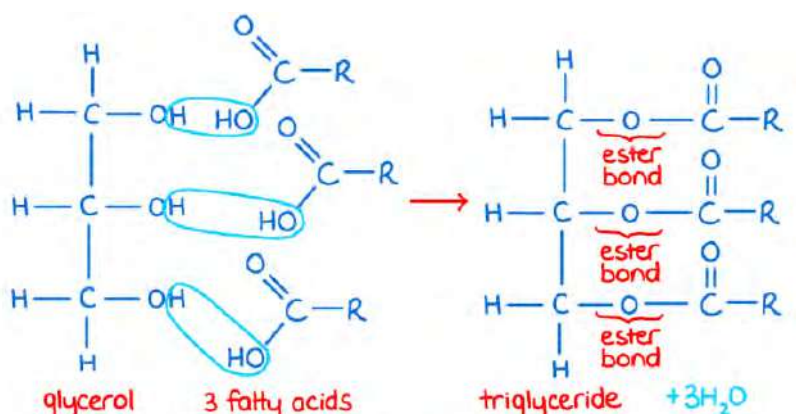


Figure 1.1.18 Triglyceride or Triester

- ii. **Oils:** Oils are fats rich in unsaturated fatty acids (with more than one double bond). Plant-based oils, such as olive oil and sunflower oil, are liquid at room temperature, usually clear or semi-transparent. Unsaturated fatty acids can combine with oxygen and other chemicals and turn into solid saturated state called Vanaspati ghee and margarine. This process is called hydrogenation.

- iii. **Waxes:** Waxes are esters of long chain saturated fatty acids (with single bond) and long chain alcohol except glycerol. Waxes are chemically inert. They are protective in functions and form water insoluble coating on hair and skin in animals and on stems, leaves, and fruits of plants. The important types of waxes are as follows:
1. **Plant wax:** This type of lipid forms a coating on plant parts to reduce the rate of transpiration and prevent.
 2. **Bee's wax:** It is secreted by abdominal glands of worker honeybees.
 3. **Paraffin Wax:** Paraffin wax is a petroleum-derived wax composed of long-chain saturated hydrocarbons (alkanes). It is widely used in candles, cosmetics, and food coatings.
 4. **Lanolin (wool fat):** It is obtained from sheep's wool. It is secreted by sebaceous gland and get deposited onto the wool fibers.



Figure 1.1.19 Waxes

2. Complex lipids

These lipids are complex as they form by the combination of lipids with either carbohydrates, phosphates, or proteins.

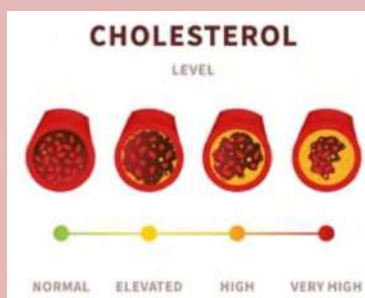
- a. **Glycolipids** (Glycolipids = lipids + carbohydrate): They are formed by the combination of lipids with carbohydrate molecules. They are key components of cell membrane and white matter in nerve tissue. For example, cerebrosides and ganglioside.
- b. **Phospholipids** (Phospholipids = lipids + phosphate): These lipids include a phosphate group, resulting in polar molecules that bear hydrophilic and hydrophobic ends. They are essential for the formation of plasma membrane and other endomembranes in cells. For example, Lecithin, Cephalins, Plasmalogens, etc.
- c. **Lipoprotein** (Lipoprotein = lipids + protein molecules): Lipoproteins are lipids associated with protein molecules. They transport cholesterol in blood. Its types include High density lipoprotein (HDL), Low density lipoprotein (LDL), Very low density lipoprotein (HDL) and Chylomicron.

3. Derived Lipids

Derived lipids are obtained from the modification (hydrolysis or oxidation) or breakdown of other lipids. They include compounds such as fatty acids, sterols, and glycerides. These molecules are essential to store energy, send signals in body and form cellular structures.

Importance of Steroids:

Do you know?



Cholesterol is a steroid lipid associated with abnormal thickening of artery walls, potentially raising blood pressure and causing circulatory issues.

1. Cholesterol is a precursor for sex hormones like progesterone, testosterone, and adrenocortico-tropic hormones like cortisol.
2. When cholesterol is exposed to ultraviolet rays, it produces vitamin D, essential for the growth of bone.
3. It helps in the formation of hormones like estrogen, testosterone and cortisol, and fat-dissolving bile acids.

Functions of Lipid:

1. Lipids serve as food reserve in plants and animals.
2. Lipids provide over twice the energy of an equal amount of carbohydrates.
3. Lipid deposited in subcutaneous tissues insulates heat.
4. Triglycerides stored in adipose tissue serve as a food reserve.
5. It acts as a solvent for fat-soluble vitamins (A, D, E, K).
6. It protects organs like eyeballs from mechanical injury by absorbing impact.
7. Phospholipid forms membranes in various organs.
8. Glycolipids form components of cell membranes and myelin in nerve cells.
9. Bile salts is derived from modified cholesterol and is essential in fat metabolism.
10. Lipoprotein helps to prevent bacterial infection.
11. Cholesterol is a precursor of vitamin D which is essential for the development of bone.

1.1.6 NUCLEIC ACIDS

- Have you ever wondered how our body stores and transmits genetic information?
- What role do you think nucleic acids play in this process?

Nucleic acids are the most essential molecules of life primarily composed of C, O, H, N, and P. They are complex, long-chained and larger than most proteins. These nucleic acids are made up of a few nucleotides. In other words, nucleic acids are the polymers of nucleotides.

Structure of Nucleotide

A nucleotide is composed of three components:

- i. Pentose sugar
- ii. Nitrogenous bases
- iii. Phosphoric acid

Do you know?

Friedrich Meischer (1868) isolated nucleic acids from nuclei of pus cells, establishing them as genetic material for all organisms, including viruses. Oswald Avery's (1944) work further supported nucleic acids as carriers of genetic information.

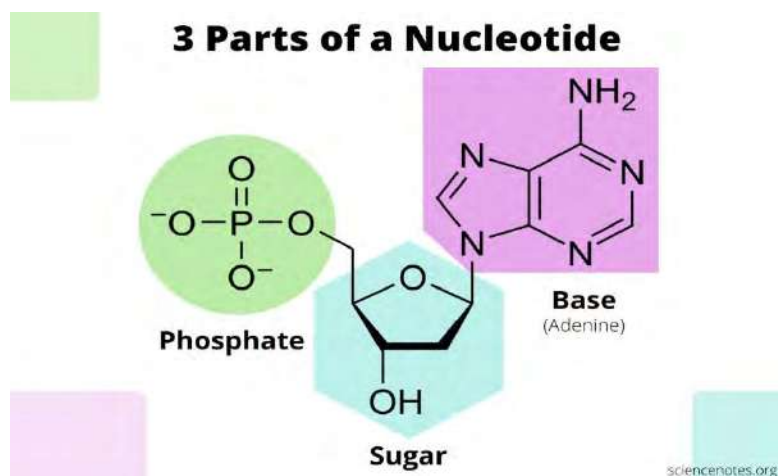


Figure 1.1.20 Three components of nucleotide

Do You Know?

Nucleosides are the building blocks of nucleotides. For convenience,

Nucleoside = Nitrogenous base + Pentose sugar

Nucleotide = Nucleoside + Phosphate group

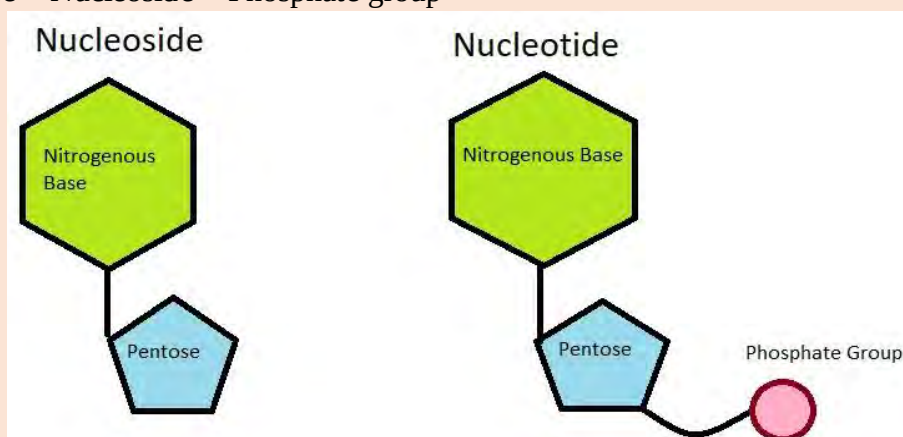


Figure 1.1.20 Structural differences between Nucleoside and nucleotide

- i. **Pentose sugar:** There are two types of pentose sugars present in two types of nucleic acids - Ribonucleic acid (RNA) contains ribose sugar and deoxyribonucleic acid (DNA) contains deoxyribose sugar.

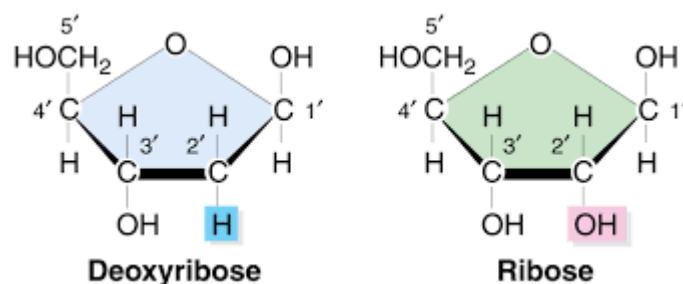


Figure 1.1.21 Structures of deoxyribose and ribose sugars

ii. Nitrogen base: They can be categorized into two classes:

1. **Purines:** There are two rings in their structure (6 + 5 membered). Purines are **Adenine** (A) and **Guanine** (G).
2. **Pyrimidines:** There is one ring in their structure (6 membered). Pyrimidines are **Cytosine** (C), **Thymine** (T) and **Uracil** (U). (**Uracil** is present only in RNA while **Thymine** is present only in DNA).

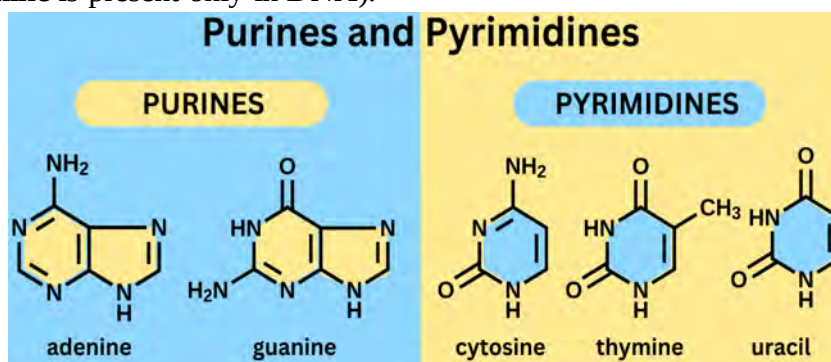


Figure 1.1.22 Structures of purine bases (Adenine and guanine) pyrimidine base (Cytosine, thymine and uracil)

In fact, there exists complementary bases - purine base attaches to specific pyrimidine base, i.e.

- Adenine pairs with Thymine (A = T) by two hydrogen bonds.
- Cytosine pairs with Guanine (C≡G) by three hydrogen bonds.

iii. Phosphoric acid:

It has a phosphate group that connects two nucleotides by a phosphodiester bond.

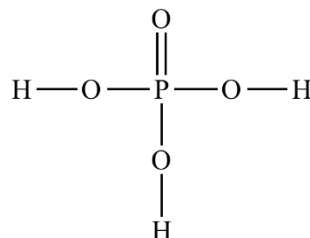


Figure 1.2.23 Phosphoric acid

TYPES OF NUCLEIC ACIDS

Two types of nucleic acids are:

1. Deoxyribonucleic acid (DNA)
2. Ribonucleic acid (RNA)

A. Deoxy-Ribonucleic Acid (DNA)

DNA is a molecule made of two nucleotide-chains which coil around each other forming a double helix. It is present in almost all cells (at nucleus, mitochondria, and plastids) except some viruses. It carries genetic instructions essential for growth, development, functioning and reproduction. A nucleotide has deoxyribose sugar, phosphoric acid, and one of four nitrogenous bases: A, T, G or C.

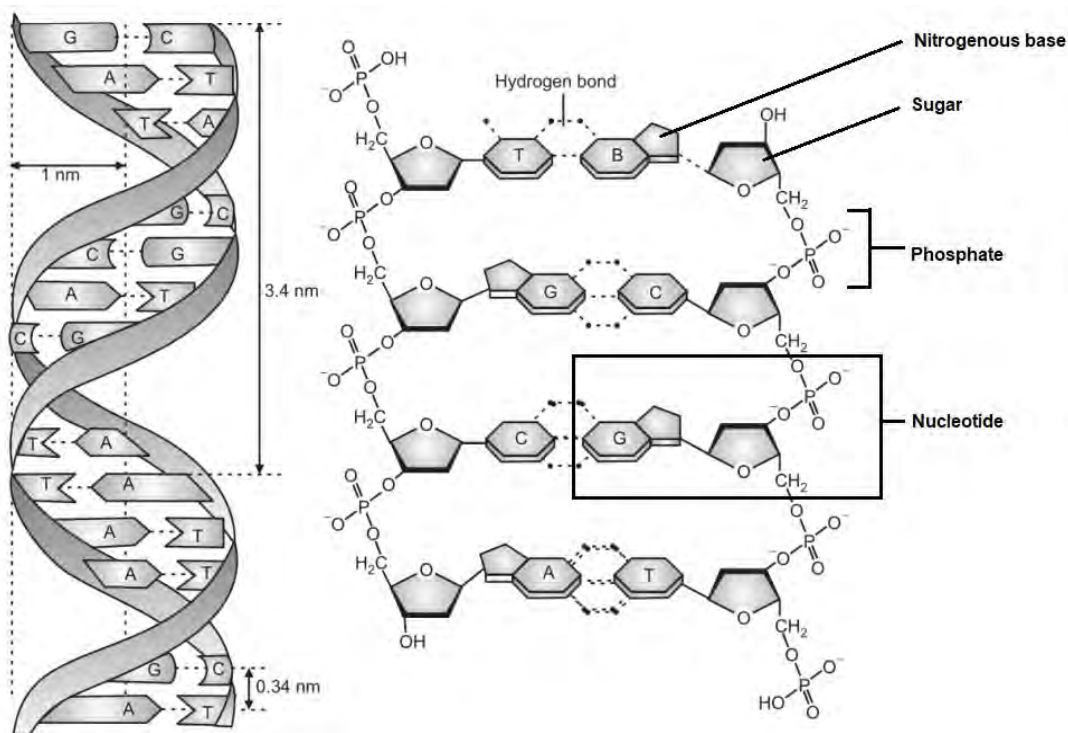


Figure 1.1.23 DNA Structure (Watson and Crick Model)

Characteristics of DNA:

- DNA has two parallel chains of polynucleotides running as a right-handed double helix.
- The strands are spirally coiled that run in opposite directions (one in 3' - 5' direction and another in 5' - 3').
- They have sugar-phosphate chains outside and purines and pyrimidine bases inside.
- These two strands are held together by weak hydrogen bonds between purine (A and G) and pyrimidine bases (T and C).
- The distance between strands is 2 nanometer (nm). There are 10 base pairs in a turn (3.4 nm), with a gap of 0.34 nm between pairs.
- DNA has 28% adenine, 24% guanine, 20% cytosine, and 28% thymine.
- Nucleotides in a helix connect with phospho-diester bonds.

Functions of DNA

- Being a genetic material, it carries genetic information in the form of a sequence of nitrogenous bases.
- DNA copies genetic information to pass it to cells of the next generation.

- Crossing over in DNA causes variation in off springs.
- Alteration in components of DNA causes mutation, an inheritable genetic change.
- Transcription of DNA synthesizes RNAs for different cell functions.
- It regulates cellular metabolism through RNA and protein synthesis (Central Dogma).

B. Ribonucleic Acid (RNA)

RNA is a single stranded chain of ribonucleotides synthesized in the nucleus but found in the nucleolus, cytoplasm, and on ribosome membranes. Generally, it is single stranded and functions as a hereditary material in some viruses and helps in protein synthesis.

Structural Details:

1. RNA is a macromolecule smaller than DNA.
2. It is a single-stranded polynucleotide chain.
3. It is composed of nucleotides linked together by 3'-5' phosphodiester bonds.
4. Each ribonucleotide consists of a ribose sugar, a nitrogen base (Adenine, Guanine, Cytosine, or Uracil) and a phosphate.

Types of RNA:

1. **Messenger RNA (mRNA):** It is the most abundant type of RNA. It translates genetic information from DNA to ribosomes for protein synthesis.
2. **Ribosomal RNA (rRNA):** It is a stable RNA linked with ribosomes.
3. **Transfer RNA (tRNA):** It acts as an adapter, carrying amino acids to the protein synthesis site.

Functions of RNA:

1. Messenger RNA (mRNA) carries coded information to synthesize polypeptide chains/proteins and enzymes.
2. RNA forms compact genes for genetic engineering via reverse transcription.
3. Transfer RNA (tRNA) transfers specific amino acids to the ribosome for protein synthesis.
4. RNA possesses a cap region for the attachment of ribosome.
5. RNA acts as a genetic material in some viruses.

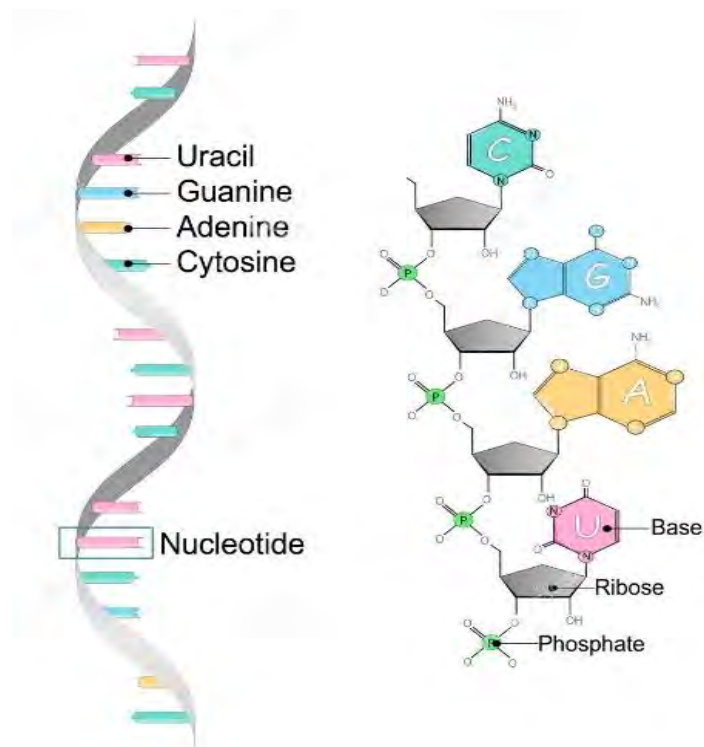


Figure 1.1.24 Structure of RNA

Activity: 1.3

Designing a Watson and Crick DNA Model with Clay.

Objective: The objective of this project is to understand the structure of DNA (Watson and Crick) by creating a tangible model of the DNA molecule using locally available materials such as colorful clay, color and toothpick.

Materials Required:

- Clay (different colors)
- Toothpicks or wooden sticks
- Marker/Paper-flag for labeling

[Note: Use of locally available materials is encouraged]

Steps:

- Decide colors for different DNA components: Pentose sugar be blue, phosphate be red and nitrogenous bases of four other different colors.
- Roll ten 2-centimeter-wide spheres of a particular color (to represent Pentose sugar), equal number of 0.5 centimeter wide spheres of another color (to represent pentose sugar) and differently coloured smaller spheres in half their number (to represent four nucleotide bases: adenine (A), thymine (T), cytosine (C), and guanine (G)).
- Place a strong and long stick to be in the middle as an axis.
- Over a base of hard plywood, place out two long strands of spheres (alternately big and small) of different colors on floral wire to represent the DNA strands around the central axis.
- Attach adenine-thymine and cytosine-guanine pairs to toothpicks.
- Insert toothpicks into the biggest spheres in floral wire.
- Twist floral wires slightly between each toothpick, counter-clockwise at the top.

- h. Carefully twist the two strands around each other to form the double helix structure.
- i. Add additional details to the model, such as labeling the nucleotide bases or highlighting the sugar-phosphate backbone.
- j. Showcase your model to the class and explain its different components and its importance.



1.1.7 MINERALS

Minerals are inorganic substances crucial for the effective operation of the human body. Minerals, found in small quantities, are vital cell components, constituting approximately 2-3% of the body. Due to their crucial role in metabolism, they are essential for overall body growth and development. Since the body continually loses minerals, a regular intake from food is necessary.

The human body predominantly relies on five major minerals: calcium, phosphorus, potassium, sodium, and magnesium. Additionally, trace elements like iron, zinc, copper, and iodine are vital but needed in smaller quantities.

CATEGORIES OF MINERALS

There are about 25 types of minerals. Based on their amounts required by the organisms. They have been categorized into two groups:

- a. **Macro-elements:** These elements are required in large amount. They include calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), Chlorine (Cl), Nitrogen (N) and phosphorus (P).
- b. **Micro-elements:** These elements are required in small amounts (> 1 gram). They include copper (Cu), cobalt (Co), chromium (Cr), zinc (Zn), selenium (Se), iron (Fe), manganese (Mn), iodine (I), fluorine (F), molybdenum (Mo), etc.

Table 1.1.8 Macro Elements

Macro Elements	Symbol	Functions
Calcium	Ca	It provides strength and rigidity to bones and teeth. It forms the exoskeleton of invertebrates (CaCO_3). It forms the shells of molluscs (CaO). It helps to form the middle lamella in plant cell walls. It is used as fertilizer in bone dust.
Magnesium	Mg	It imparts rigidity to bones and teeth. It contributes to the structure of chlorophyll pigment. It acts as a co-factor for enzymes such as ATP-ase.
Potassium	K	It aids in maintaining the electrical potential across membranes. It facilitates the conduction of nerve impulses.

Sulphur	S	It plays a role in protein synthesis, such as keratin. It synthesizes organic compounds like Co-enzyme A.
Sodium	Na	It shares similar functions with potassium. It maintains the balance of anions/cations and osmotic balance in cellular fluids. It acts as a co-factor in photosynthesis and respiration.
Nitrogen	N	It helps to synthesize proteins, nucleic acids, and organic compounds. It also synthesizes chlorophyll.
Phosphorus		It helps to synthesize nucleic acids, ATP, and proteins. It helps to synthesize phospholipids for membranes. It forms bone and tooth enamel.
Chlorine	Cl	It forms a significant component of blood plasma. It facilitates the exchange of gases in tissues during respiration (chloride shift).

Table 1.1.9 Trace Elements

Trace Elements	Symbol	Functions
Copper	Cu	It acts as an electron carrier in cytochrome oxidase respiratory system and photosynthesis. It contributes to melanin production.
Iron	Fe	It serves as an oxygen carrier in hemoglobin and myoglobin (respiratory pigments). It transports electrons to carriers in cytochromes during respiration and photosynthesis. It helps in synthesizing chlorophyll. Its deficiency leads to anemia.
Iodine	I	It is an essential component of hormone thyroxine; its deficiency causes goiter and cretinism in children.
Manganese	Mn	It is necessary for the oxidation of fatty acids. It is essential for enzymes in respiration and photosynthesis, with mitochondria rich in manganese. It together with phosphatases helps in developing bone.
Molybdenum	Mo	It supports nitrogen fixation catalyzed by the enzyme nitrogenase. It helps to form proteins.

Activity 1.4

Analyze and categorize mineral-rich foods consumed by your family and explain their health benefits.

Objective: Identify and list the mineral-rich foods regularly consumed in your family's diet.

Steps:

- a. Collect and list the food items consumed by your family.
- b. Conduct research using reliable sources such as textbooks, reference books, and the internet to identify the mineral content of these foods.
- c. Categorize the foods by their mineral content.
- d. Provide a brief explanation of the health benefits associated with each mineral-rich food.

1.1.8 ENZYMES

**Have you ever thought about how your body breaks down the food you eat?
What role do you think enzymes play in this process?**

Enzymes are special proteins that speeds up chemical reactions in living things without itself undergoing any change. Thus, they are also known as biocatalysts. Based on the site of action, enzymes can be of two types:

- a) **Exoenzymes:** The enzyme like enzymes of digestive juices that function outside living cell are called exoenzymes.
- b) **Endoenzymes:** These are the enzymes that function inside living cells. For example enzymes found inside mitochondria (in Kreb's cycle).

Substrate is the biochemical over which enzymes act. However, if there are more than one biochemical participating in the reaction, then they are called reactants.

Do You Know?

The term 'enzyme' (G. *enzymos* = leavened) was coined by German physiologist Wilhelm Kuhne (1878). Buchner (1903) isolated the first enzyme. Sumner (1926) first discovered the protein nature of enzymes; he purified and crystalized Urease enzyme for which he was honored with the Nobel prize (1946).

CHARACTERISTICS OF ENZYMES

1. Enzymes are usually globular proteins, and they can include inorganic or organic substances for their activity.
2. They are hydrophilic and form hydrosol in free-state.
3. They are highly specific in their action, catalyzing only a single reaction, but different enzymes can act on the same substrate to produce different products.
4. All enzyme-catalyzed reactions are theoretically reversible, depending on energy requirements, reaction availability, end product concentration, and pH.
5. They are highly efficient, so a small amount can catalyze a large amount of substrate.
6. Enzymes don't start chemical reactions but speed them up, not altering the equilibrium but by lowering the activation energy.
7. They are separately coded by genes as they are proteins.
8. Heavy metals and high-energy radiation can inactivate or denature protein structure.

Biological Importance of Enzymes:

1. Enzymes mediate almost all chemical reactions in living organisms.
2. They can function as a biocatalyst at biological temperatures.

3. They are pH-specific so it functions at required pH at different parts of body.
4. Reactions which are mediated by enzymes do not require harsh treatment.
5. Enzymes force living organisms to live in optimum environment as enzymes are functional only at specific conditions.
6. Enzyme formation is controlled by separate regulatory genes, allowing precise regulation of enzyme activity.

1.1.9 WATER

Water is the most common inorganic substance in cells, forming a significant part of all living organisms, whether on land or in water. It constitutes 60%-70% of body weight and occupies 75%-90% of the protoplasm. While it doesn't provide energy, water is crucial for sustaining life.

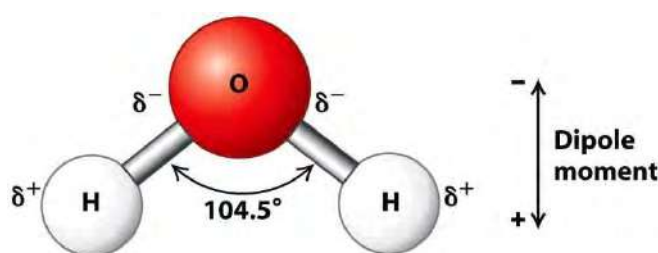


Figure 1.1.25 Water Molecules

Structurally, the water molecule, H_2O , is composed of two hydrogen atoms and one oxygen. It behaves as a dipole, with the oxygen atom sharing electrons with two hydrogen atoms. This creates a slightly positive end and a slightly negative end, leading to weak hydrogen bonding and the formation of a lattice structure.

Biological Functions of Water

1. Water acts as an effective solvent, dissolving soluble materials.
2. It participates in ionic reactions, aiding ionization in water.
3. It facilitates heat loss with minimal water loss, contributing to cooling through evaporation of sweat.
4. High surface tension and cohesion enable water conduction through plant xylem vessels.
5. It serves as a medium for transporting substances like nutrients in the body.
6. It provides an environment for organisms living in water.
7. It eliminates waste products in solution form, primarily as urine and to a lesser extent as sweat, maintaining homeostasis.

EXERCISE

A. Choose the best alternative.

Which of the following is not correctly classified as a type of biomolecule?

- a) Carbohydrates, proteins, fats, and nucleic acids
- b) Water, minerals, ions, and salts
- c) Water, carbon dioxide, and salts
- d) Carbohydrates, proteins, and fats

What is the general formula for carbohydrates?

- a) $C_x(H_2O)_y$
- b) CH_xO
- c) $C_nH_{2n}O_2$
- d) $C_nH_2O_n$

Which of the following is a disaccharide?

- a) Glucose
- b) Sucrose
- c) Ribose
- d) Fructose

Polysaccharides are characterized by:

- a) Sweet taste and water solubility
- b) Composed of 2-10 monosaccharides
- c) Long chains of monosaccharides with no reducing properties
- d) Being aldoses or ketoses

What is the significance of monosaccharides like ribose and deoxyribose in cellular function?

- a) They serve as structural elements in RNA and DNA.
- b) They provide energy through breakdown.
- c) They support the synthesis of proteins and nucleic acids.
- d) They prevent the formation of ketone bodies in the blood.

Why is glycogen considered essential in animal metabolism?

- a) It forms the plant cell wall, providing structural support.

- b) It supports the synthesis of fats and amino acids.
- c) It prevents the incomplete oxidation of fats.
- d) It serves as a primary reserve food stored in the liver and muscles.

Which of the following groups of amino acids must be obtained from the diet because the human body cannot produce them?

- a) Alanine, arginine, asparagine
- b) Histidine, isoleucine, leucine
- c) Glutamic acid, glutamine, glycine
- d) Aspartic acid, cysteine, tyrosine

What is the primary function of tyrosine among amino acids?

- a) As a precursor to synthesize animal hormones like thyroxine and adrenaline
- b) Acting as the building block for protein synthesis
- c) Acting as a precursor for the plant hormone Indole Acetic Acid (IAA)
- d) Being essential for the synthesis of melanin pigments

Which category of proteins is formed by the combination of amino acids and nucleic acids?

- a) Simple proteins
- b) Conjugated proteins
- c) Derived proteins
- d) Fibrous proteins

Which type of protein exhibits a twisted structure and forms fiber-like arrangements?

- a) Primary structure
- b) Secondary structure
- c) Tertiary structure
- d) Quaternary structure

What is the primary characteristic of fibrous proteins?

- a) They are predominantly found in plants.
- b) They exhibit a twisted structure and form fiber-like arrangements.
- c) They are soluble in water, salt solutions, acids, or bases.
- d) They are formed by the combination of amino acids and nucleic acids.

Which function of proteins involves regulating glucose levels in the body?

- a) Acting as structural proteins for building and repairing tissues
- b) Providing energy fuel with a caloric value of 5.65 kcal per gram
- c) Acting as enzymes or biocatalysts to regulate life processes
- d) Functioning as hormones like insulin

Which category of lipids is primarily found in animal products like meat and dairy, as well as in some plant-based oils like coconut oil and palm oil?

- a) Simple lipids
- b) Complex or conjugated lipids
- c) Derived lipids
- d) Waxes

Which type of fatty acids generally have lower melting points and are often in liquid state (oil) at room temperature?

- a) Unsaturated fatty acids
- b) Saturated fatty acids
- c) Monounsaturated fatty acids
- d) Polyunsaturated fatty acids

Which complex lipid is a key component of cell membranes and white matter in nerve tissue?

- a) Glycolipids
- b) Phospholipids
- c) Lipoprotein
- d) Cholesterol

Which derived lipid acts as a precursor for sex hormones like progesterone, testosterone, and cortisol?

- a) Cholesterol
- b) Fatty acids
- c) Sterols
- d) Glycerides

Which type of RNA carries coded information to synthesize polypeptide chains?

- a) Messenger RNA (mRNA)
- b) Ribosomal RNA (rRNA)
- c) Transfer RNA (tRNA)
- d) Viral RNA

14. Which type of sugar is found in RNA nucleotides?

- a. Deoxyribose
- b. Ribose
- c. Glucose
- d. Fructose

Which component is present in both DNA and RNA nucleotides?

- a) Deoxyribose sugar
- b) Ribose sugar
- c) Phosphoric acid
- d) Thymine

Which of the following minerals contributes to the formation of chlorophyll pigment?

- a) Sodium (Na)
- b) Iron (Fe)
- c) Magnesium (Mg)
- d) Iodine (I)

Which trace element is essential for the hormone thyroxine and deficiency can lead to goiter?

- a) Copper (Cu)
- b) Iron (Fe)
- c) Iodine (I)
- d) Manganese (Mn)

Which characteristic of enzymes allows them to catalyze only a certain reaction?

- a) They are usually globular proteins
- b) They are highly specific
- c) They can include inorganic or organic substances for their activity

d) They are pH-specific

What is the primary biological function of water?

a) Provides energy

b) Facilitates heat loss

c) Acts as a solvent

d) Catalyzes chemical reactions

B. Very Short Questions:

What are biomolecules?

Define metabolism.

Define aldoses and ketoses.

Give an example of a monosaccharide and a disaccharide.

What is the primary role of amino acids in the body?

Which amino acid serves as the precursor for the plant hormone Indole Acetic Acid (IAA)?

What is the primary function of enzymes in the body?

Name one example of a fibrous protein and one example of a globular protein.

What is the primary role of antibodies in the body?

What is the primary difference between unsaturated and saturated fatty acids?

What is the primary function of triglycerides stored in adipose tissue?

What are the two types of pentose sugars found in nucleic acids?

Name one macro-element that contributes to maintaining the electrical potential across membranes.

C. Short Questions:

What is significance of telomeric region in chromosomes?

How do autosomes differ from sex chromosomes?

Explain the difference between oligosaccharides and polysaccharides in terms of their structure and properties.

Describe the role of carbohydrates in cellular metabolism with reaction.

Write differences between oligosaccharides and polysaccharides.

Distinguish between essential and non-essential amino acids.

Describe the primary structure of a protein and its significance in protein function.

Explain the difference between primary and quaternary protein structures, providing examples of proteins that exhibit each structure.

Explain the function of thrombin and fibrinogen in the process of preventing bleeding by clotting blood.

Describe the primary function of messenger RNA (mRNA) in protein synthesis.

Distinguish between RNA and DNA.

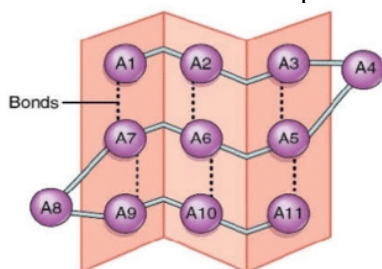
Describe the function of phospholipids in cellular structures.

Describe the functions of iron (Fe) in the human body.

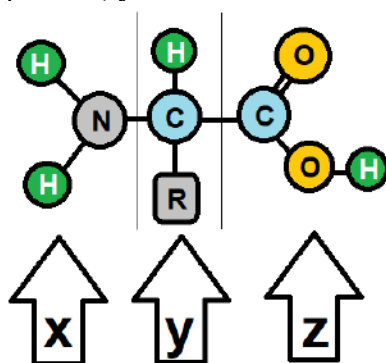
Design a dietary plan for a child's lunch to ensure they receive all essential nutrients. Consider incorporating a variety of food groups and justify your choices.

D. Diagrammatic Questions

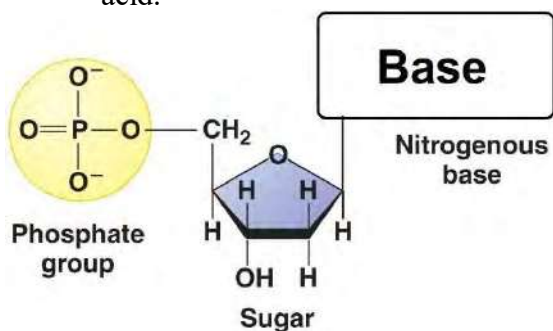
- a. Given is a structure of protein. Identify the type of protein structure.



- b. Schematic molecular structure of an amino acid is given below. Identify the labelled parts: x, y and z.



- c. Referring to the schematic structure of nucleotide, explain the structure of nucleic acid.



Project work: Identify and list the mineral-rich foods that your family regularly consume in their diet. Categorize them by mineral content, and provide a brief explanation of their health benefits.

Project work: Referring to textbook or internet or both, design a poster on a chart paper and colours to distinguish essential amino acids from non-essential amino acids.

Project work: Bring a variety of food items from home. Discuss in small groups to analyze the nutritional content of the foods using food labels or online resources. Categorize the foods based on the presence of carbohydrates, proteins, lipids, vitamins, and minerals. Discuss the results in your class with their significance.

Chapter 1.2

CELL

Let's discuss the following questions:

- Have you ever wondered how living organisms are structured and organized?
- What do you think all living things have in common, regardless of their size or appearance?
- Why do you think cells are considered the basic units of life?
- What, in cells, carry out vital functions to make it alive?

1.2.1 GENERAL INTRODUCTION

All living beings ever existed or existing are basically composed of a collection of special compounds called biomolecules packaged in a structure termed a cell. The cell is the basic building block of life, responsible for all necessary life processes. It is the smallest unit that can perform essential activities and is enclosed by a protective membrane. A cell can reproduce on its own and carries out vital functions like respiration, growth, and excretion. In multicellular organisms, the combined actions of cells drive life processes. In unicellular organisms, a single cell manages all life activities, making it the fundamental unit of life. The study of structure and function of a cell and its components is called Cytology, coined by Oskar Hertwig (1892).

1.2.2 PROKARYOTIC AND EUKARYOTIC CELL

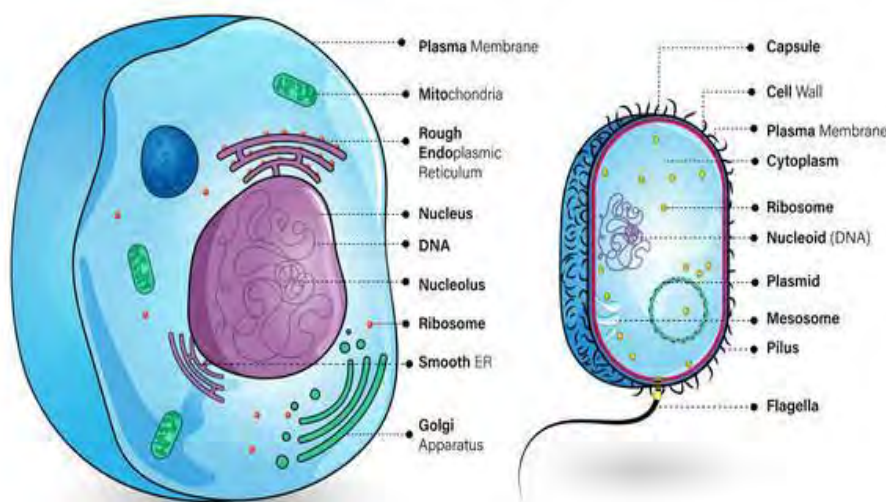


Fig: 1.2.1 Structure of (a) Eukaryotic Cell (b) Prokaryotic Cell

Dougherty (1957) recognized two types of cellular organization based on the nature of nucleus and cell organelles, and complexity of genetic material cells can be classified into two types: prokaryotic and eukaryotic cell.

1. Prokaryotic Cell:

A prokaryotic cell is a primitive cell that lacks organized nucleus and membrane-bound cell organelles. They have following properties:

- i. It lacks a definite nuclear membrane, membrane-bound organelles, a mitotic apparatus, nucleoli, and flagella with a (9+2) pattern of fibril arrangement.
- ii. It bears a naked circular DNA that fold into nucleoid.
- iii. Cell wall is composed of carbohydrates and amino acids, with murein or peptidoglycan.
- iv. Instead of mitochondria, plasma membrane possesses mesosomes which are the sites for respiration.
- v. Chlorophylls are located in lamellae rather than in membrane-enclosed chloroplasts.
- vi. It bears ribosomes of 70s type (50s + 30s).

For example, bacteria and cyanobacteria.

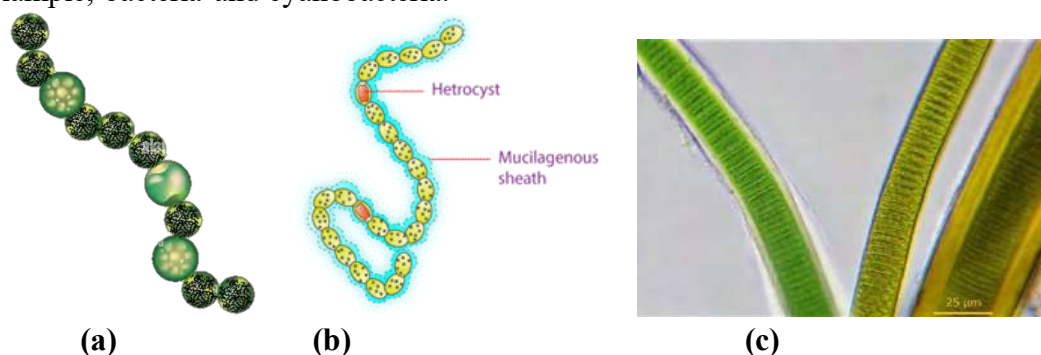


Fig: 1.2.2 Cyanobacteria (a. *Nostoc*, b. *Anabaena*, c. *Lyngbya*)

2. Eukaryotic cell

An eukaryotic cell is characterized by the presence of a well-organized nucleus and membrane-bound cell organelles such as mitochondria, endoplasmic reticulum, Golgi complex, centrosome, vacuoles, etc. They have following properties:

- i. Its nuclear material is enclosed by nuclear envelop forming a true nucleus.
- ii. Its DNA contains histone proteins.
- iii. Cell division, in eukaryotic cells, occurs with the help of mitosis, meiosis, or amitosis.
- iv. Its cell wall is mostly composed of cellulose and hemicellulose or in some cases, pectin or lignin in plantae. However, cell wall in fungi is composed of fungal cellulose or chitin.
- v. Its locomotory organ - Flagella - consists of (9 + 2) fibrillar arrangement.
- vi. The cells exhibit cytoplasmic streaming and carry out photosynthesis in membrane-enclosed chloroplasts.
- vii. Its cytoplasm comprises ribosomes of 80s type (60s + 40s), and chloroplast and mitochondria consist of ribosomes of 70s type (30s + 50s).

Examples of eukaryotic cells comprise a wide range of organisms, including plants, animals, fungi, and protists.

Activity 1.2.1

Design a table using colourful pens to compare the characteristics of prokaryotic and eukaryotic cells.

1.2.3 STRUCTURE OF EUKARYOTIC CELL

Shapes and sizes

The shape of cell is influenced by factors such as function, age, cell wall, external pressure, location, tension and viscosity. It may have different shapes like irregular, cylindrical, oval, plate-like, tubular, branched, etc. The size of eukaryotic cells can generally range from $1\text{ }\mu\text{m}$ - 1 mm long. The smallest cell is mycoplasma ($0.3\text{ }\mu\text{m}$) and the largest cell is an ostrich egg (around 15 cm).

A typical eukaryotic animal cell is composed of a jelly-like, translucent protoplasm enclosed by a plasma membrane. In plant cells, the plasma membrane is further surrounded by a rigid and porous cell wall made of cellulose. The fluid between the plasma membrane and nuclear envelope is called cytoplasm.

Parts of Eukaryotic Cells

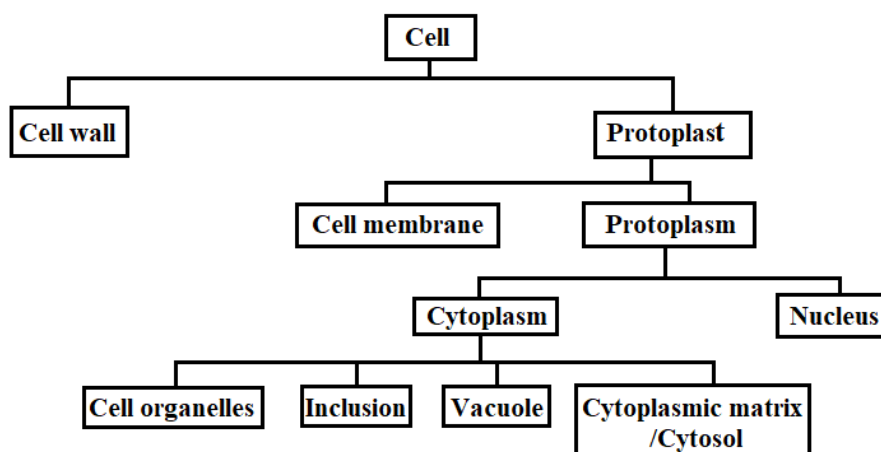


Fig: 1.2.3 Components of Eukaryotic cell

1. CELL WALL

The cell wall is the outermost protective layer, providing rigidity, and mechanical support to cells. It is present in plant cells, bacteria, cyanobacteria, fungi, and certain protists. However, the cell wall may be absent in certain lower plants and in cells involved in reproduction, such as plant gametes and zoospores. Notably, the cell wall is entirely absent in animal cells. The thickness of the cell wall may vary ($0.1 - 10\text{ }\mu\text{m}$). The discovery of the cell wall is attributed to Robert Hooke (1665).

The complex structure of the plant cell wall is divided into following different layers and structures:

- i. **Middle Lamella:** It is a thin layer between adjacent plant cell walls (formed during cell division) which is composed of pectates of calcium and magnesium. Its pectin layer is a hydrophilic colloidal substance that absorbs water and acts as a cementing material between cells.

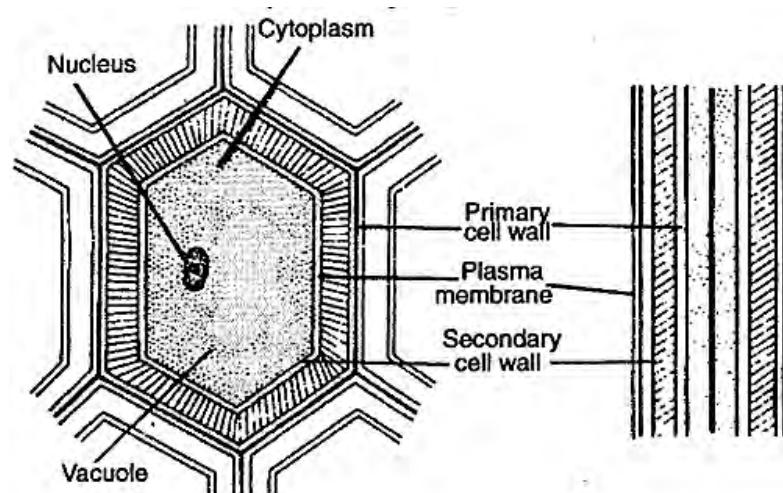


Fig: 1.2.4 Different layers in plant cell wall

- ii. **Primary Cell Wall:** It is a thin, elastic and permeable membrane basically composed of cellulose, hemicellulose, and pectic compounds. It is formed by protoplasm on either side of the middle lamella in a growing cell. Most leaves, fruits, cortex, and pith cells contain only the primary cell wall and middle lamella.
- iii. **Secondary Cell Wall:** It is a thick, rigid, and inelastic protective membrane composed of three concentric layers of microfibrils, chemically formed of lignin, cellulose, hemicellulose, and pectin of thickness 5-10 μm that lays down on the primary cell wall after its growth is complete. It is found in mature and specialized cells like tracheids, vessels, collenchymatous cells, and sclerenchymatous cells. Additional chemical substances like cutin, suberin, waxes, mucilage, and silica are deposited on the wall.
- iv. **Tertiary Cell Wall:** It is a very thin protective membrane composed of cellulose and xylan. It is found beneath the secondary cell wall, particularly in xylem tracheids of Gymnosperms and provides strength to the cell wall.
- v. **Plasmodesmata:** It is a small aperture between the primary cell wall and middle lamella that is connected to the endoplasmic reticulum. It permits the circulation of fluid and passage of solutes between cells forming bridges.

Functions of Cell Wall:

The functions of cell wall are:

- a. It provides rigid walls, offering mechanical strength to cells and the plant.
- b. It protects the inner cell contents from mechanical injuries and prevents the entry of germs.
- c. Its permeability allows exchange of essential molecules between the cell and its surroundings.
- d. It maintains the shape of cells, preventing undue expansion.
- e. The cell wall of root hairs aids in the absorption of water and minerals from the soil.
- f. Glycerolipid like Suberin (at root) and cutin (at cuticle) deposited on the cell wall prevent the loss of water from evaporation.
- g. It prevents cell bursting by maintaining a balance between intracellular osmotic pressure and the environment.
- h. It is involved in various enzymatic activities.

2. PROTOPLAST

A protoplast is a part of a cell when its cell wall is removed, leaving only the cell membrane and its contents.

3. PLASMA MEMBRANE

All living cells are enveloped by a thin, transparent and selectively permeable membrane called plasma membrane. It is an elastic, regenerative living structure. The term "cell membrane" was coined by Cramer and Nagelli (1855), but it was referred to as plasmalemma by Plowe (1931). Notably, the plasma membrane and all the membranes that cover different cell organelles within the cell share the same ultrastructure. It separates the cytoplasm from the surrounding cellular environment. Collectively, these membranes are referred to as biomembranes. This emphasizes the uniformity in the structural composition of cell membranes, both at the cell's outer boundary and within its internal organelles.

Plasma membranes are chiefly composed of lipids and proteins (i.e. lipoproteinous). The membrane contains three different classes of proteins, viz. structural proteins, enzymes (functional proteins), and carrier proteins.

Structural proteins are a major component of the cell membrane. Enzymes form the major component of many membranes and are catalytic proteins. Carrier proteins transport substances across the membrane against the concentration gradient. Lipid constitutes 20-40% of the membrane.

To explain the structure of plasma membranes different models have been developed. Most convincing two models are described below:

Structural models of plasma membrane

- a. **Sandwich Model:** This model was proposed by Danielli and H. Davson (1935) which is based on the physical and chemical properties of plasma membrane.

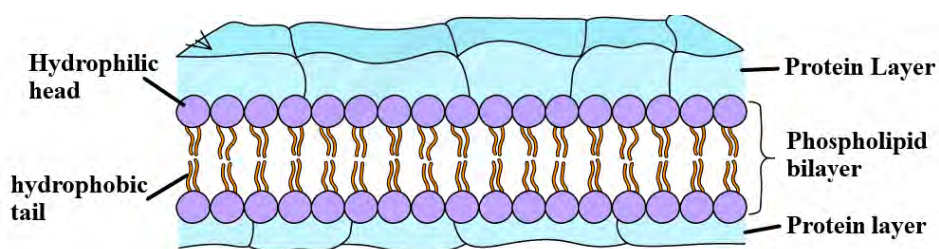


Fig: 1.2.5 Sandwich Model of cell membrane

Plasma membrane is basically a lipoproteinous trilaminar membrane distinctly divided into outer and inner denser protein monolayer and a middle phospholipid bilayer. It is called so because of the presence of the phospholipid bilayer between two protein monolayers. Here, protein molecules are globular that bear polar and non-polar side-chains and provide stability. Each phospholipid molecule is polar with hydrophilic and hydrophobic ends. Heads (glycerols) are directed in opposite directions, associated with proteins. Tails (fatty acids) of two layers face each other which is held together by weak Van der Waals force. It also bears microscopic pores of size 7 – 10 Angstrom (Å).

However, this model doesn't explain functional specificity and variability in biomembranes nor accounts for phenomena like active transport and movement of water-soluble substances.

- b. Fluid-Mosaic Model:** According to this model, protein is not found in a uniform layer but found in a mosaic pattern like icebergs in a sea. This model was proposed by Singer and Nicholson (1972).

The plasma membrane is composed of lipoproteins in trilaminar arrangement. It consists of a fluidly phospholipid bilayer, exhibiting two types of movements: transition and flip flop. Within this bilayer, there are globular proteins, which are further categorized as extrinsic (peripheral) or intrinsic (integral). Extrinsic proteins are positioned outside the bilayer, while intrinsic proteins are embedded with it. They are present in fluidly phospholipids bilayer either in partially or in completely suspended forms. They form channels for the passage of water, ions and other water soluble solutes. The phospholipid molecule is polar, with a hydrophobic tail and hydrophilic head of two fatty acid chains. So it is an amphipathic molecule. This amphipathic nature contributes to the formation of a water resistant barrier, with head and tail in opposite directions.

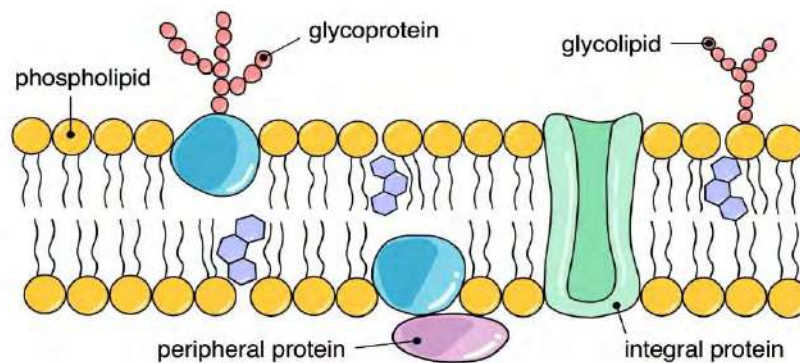


Fig: 1.2.6 Fluid mosaic model of plasma membrane

Functions of Plasma membrane

Following are the functions of plasma membrane:

- a. Plasma membrane provides shape and protects the cell from mechanical injury.
- b. It helps in transportation of materials by different processes like diffusion, osmosis, active transportation, endocytosis (taking in large solid or liquid materials), exocytosis (expelling large sized materials from the cell), etc.
- a. It also helps in cellular locomotion through pseudopodia movement (involving extension and folding of the plasma membrane like in amoeba, etc.) or undulatory movement (wave-like undulations of the plasma membrane like in fibroblast cells).
- b. The antigens present in cell membranes help in separation of blood groups.
- c. Microvilli is its modified form that helps in absorption of digested materials in the intestine.
- d. It serves as a site where different stimuli, like hormones and antigens, can be detected and recognized.

Activity: Exploring Plasma Membrane Models

Objective:

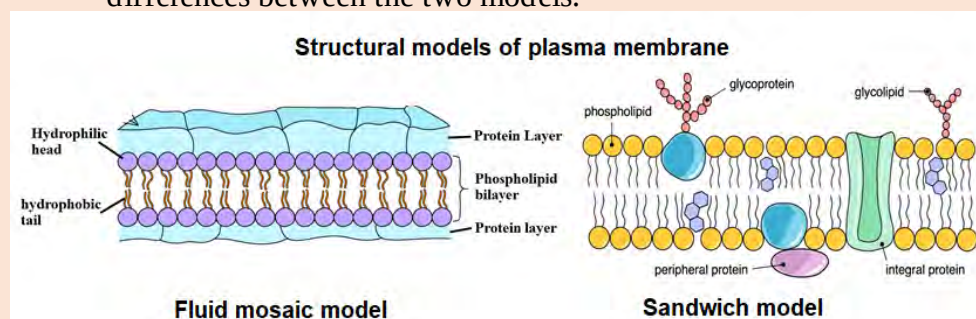
To understand the structure of the plasma membrane using the Sandwich and Fluid Mosaic models.

Materials Needed:

- Permanent color pens
- Transparency sheets
- Reference images of the Sandwich and Fluid Mosaic models

Procedure:

- Briefly introduce the plasma membrane and its importance.
- Explain the two models: Sandwich Model and Fluid Mosaic Model.
- Divide the class into two groups.
- Provide each group with transparency sheets and permanent color pens.
- Assign one group to create the Sandwich Model and the other to create the Fluid Mosaic Model using the provided resources
- Groups draw their assigned model on the transparency sheet.
- Ensure the Sandwich Model shows protein layers surrounding a phospholipid bilayer. While, the Fluid Mosaic Model illustrates the phospholipid bilayer with embedded proteins.
- Groups discuss their model's components and how they differ from the other model.
- Each group presents their model to the class.
- Conclude the session by summarizing the key concepts and highlighting differences between the two models.



4. PROTOPLASM

Protoplasm is the living colloidal mass of a cell, encompassing various cellular organelles. According to Huxley, it is 'a physical basis of life'. It is thick, translucent fluid containing lipids, carbohydrates, inorganic salts, and nucleic acids. The term 'protoplasm' was coined by Purkinje (1837). It comprises cytoplasm and nucleus.

$$\text{Protoplasm} = \text{Cytoplasm} + \text{Nucleus}$$

5. CYTOPLASM

Cytoplasm is a jelly-like, semi-fluid component of protoplasm that fills the space between the cell membrane and the nuclear membrane. It comprises cytosol, cell organelles, and cell inclusions. The cytoplasm maintains the cell's shape, stores necessary substances required by

organelles, and facilitates essential reactions within the cell. In plants, it is crucial for photosynthesis.

6. CELL ORGANELLE

The subcellular living membrane bound components having specific biological functions are called cell organelles.

7. MITOCHONDRIA

Mitochondria (G. *mito* = thread; *chondrion* = granule) are granular or filamentous cytoplasmic structures also known as "the powerhouse of the cell" as they give energy in the form of ATP during aerobic respiration to carry out basic activities of a cell. It was discovered by Kolliker (1880 AD) in the voluntary muscles of insects. The term mitochondria was given by Benda (1897).

Mitochondria are absent in prokaryotes but present in all eukaryotic cells except for mature mammalian red blood cells and sieve tubes in vascular plants. In prokaryotes, respiratory enzymes are on the plasma membrane instead of mitochondria. Mitochondria, shaped variably from rod-like to globular, change based on cell conditions. Sizes range from 1 μm in yeast to 20-40 μm in *Xenopus*. They are the largest organelles in animal cells and second-largest in plant cells, ranking third in overall cell structures after the nucleus and chloroplast. Mitochondrial number varies, being more abundant in growing, dividing, and metabolically active cells. Positioned strategically in metabolically active areas, mitochondria supply immediate ATP for cellular activities.

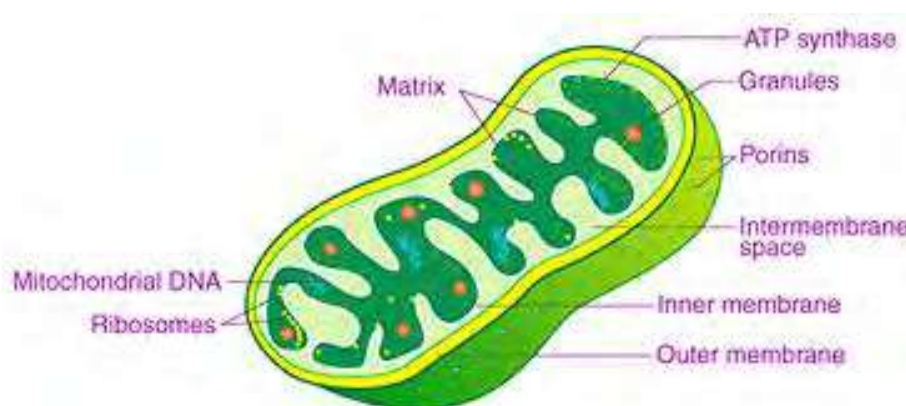


Fig: 1.2.7 Ultrastructure of a Mitochondrion

Structurally, mitochondria have two membranes (outer and inner), with the space between them which is called outer chamber. The inner chamber, or matrix, contains granules, ribosomes, and mitochondrial DNA. The enzymes for the Krebs cycle are located in the matrix. The outer membrane is smooth, while the inner membrane folds into cristae, increasing the surface area for cell respiration. The inter-cristae space within the folds is continuous with the intermembrane space. On the side of the inner membrane facing the matrix, numerous small tennis-racket-shaped particles, referred to as elementary particles, F_1 -particles, or oxysomes, are present. Each elementary particle comprises a head, stalk, and base. These particles play a crucial role in oxidation and phosphorylation reactions.

At the end of the F_1 -particles, there is an enzyme called ATPase or ATP synthetase that regulates the synthesis of ATP. Consequently, these particles are termed ATP particles that serve as the

functional units of mitochondria. While the chemical composition of mitochondria varies among animal and plant cells, they generally contain protein (65-70%), lipids (25-30%), RNA (0.5%), and a small amount of DNA.

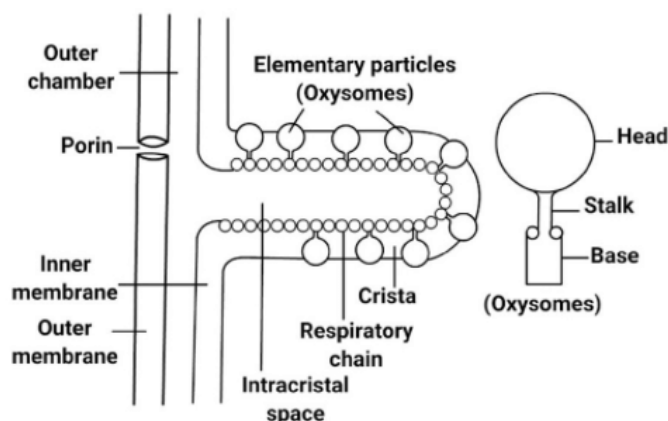


Fig: 1.2.8 Crista and a F₁ particle

Mitochondria possess the essential components for protein synthesis, including 70s ribosomes, self-replicating DNA molecules capable of forming RNA, and ATP molecules for energy. While mitochondrial DNA encodes information for about 30 proteins, insufficient for creating a new mitochondrion, the process relies on nuclear DNA, cytoplasmic enzymes, and other cellular molecules. Hence, mitochondria are considered semi-autonomous organelles.

Functions of mitochondria

1. Mitochondria are referred to as powerhouses or ATP factories, they are the key sites for ATP formation.
2. Intermediate products of cellular respiration contribute to the synthesis of steroids, cytochromes, chlorophyll, etc.
3. It is involved in the biosynthesis of certain amino acids.
4. It regulates calcium ion concentration within the cell.
5. Mitochondria contribute to yolk formation in ovum development.
6. It forms the middle piece of sperm during maturation.

8. PLASTIDS

Plastids are cellular organelles in plants and certain protozoans, like *Euglena*. The term plastid was coined by Haeckel (1866). Plastids are absent in bacteria, blue-green algae, fungi, and animals. In bacteria, chromatophore is present instead of plastid. Additionally, they are not found in the gametes and zoospores of plants. Plastids are classified as chloroplast (green coloured), chromoplast (coloured other than green) and leucoplast (colourless).

a. Chloroplast

Chloroplasts (G. *choloro* = green, *plastos* = formed), the most prevalent plastids, are crucial for plants as they facilitate photosynthesis, the process responsible for manufacturing complex organic food. It was discovered by Antonie Van Leeuwenhoek (1679) and the term "chloroplast" was introduced by Schimper (1883). These green plastids contain the pigment chlorophyll. They are widespread in photosynthetic cells of plants and some protists like *Euglena*, chloroplasts are absent in plant parts not exposed to light.

Chloroplasts exhibit diverse shapes, commonly biconvex or plano-convex in higher plants. Various shapes include filamentous, saucer-shaped, ovoid, discoid, spheroid, star-like, girdle-shaped, spiral ribbon-like, reticulate, or cup-shaped, depending on the plant cell. The size may vary from 2-3 μm in thickness and 5-10 μm in diameter and may be one (*Chlamydomonas*) to many (an intermodal cell of *Chara*) in number.

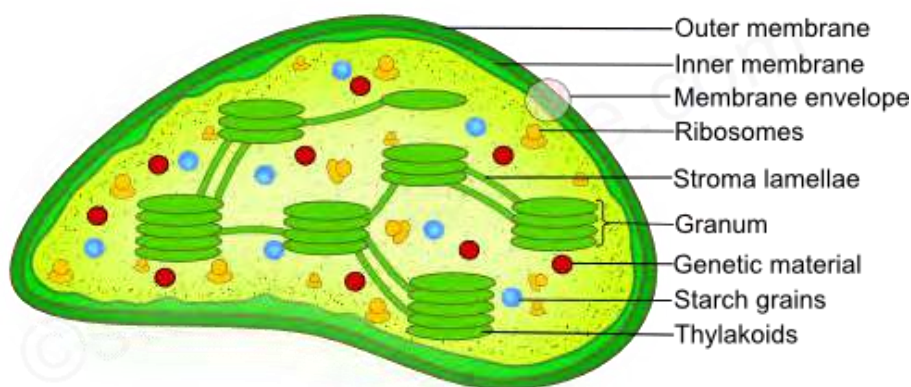


Fig: 1.2.9 An ultrastructure of Chloroplast

Structurally, chloroplast is composed of three main components: envelope, stroma and thylakoid. It is bounded by an envelope made of two membranes, outer and inner with an inter-membrane space. The inner membrane encloses a dense, colorless, granular ground substance called stroma or matrix. It is rich in proteins (over 50%), 70s ribosomes, circular and naked DNA molecules (0.5%), mRNA, tRNA molecules, water, minerals, and enzymes. The stroma is the site of the dark reaction of photosynthesis. Within the stroma, structures like grana and intergrana connecting membranes are embedded. Each granum consists of disc-shaped membranous sacs called thylakoids piled upon each other. Grana are interconnected by a network of membranous tubules known as intergrana or stroma lamellae. The thylakoid membrane contains all the enzymatic components required for photosynthesis, serving as the site for light reactions.

Similar to mitochondria, chloroplasts are semi-autonomous organelles with the ability to synthesize some proteins independently. However, for certain proteins, they rely on nuclear DNA and cytoplasmic ribosomes.

Functions of Chloroplasts:

1. Chloroplasts play a crucial role in photosynthesis, serving as the cell's kitchen.
2. They produce oxygen essential for the respiration of aerobic organisms.
3. They contribute to maintaining the balance of O_2 and CO_2 in the biosphere.
4. They mitigate global warming by reducing CO_2 concentration.
5. In algal forms, chloroplasts store starch in proteinaceous bodies called pyrenoids.
6. They are responsible for the natural green coloration of plant tissues.

b. Chromoplasts:

Chromoplasts (G. *chromo* = colour, *plastos* = formed) are colored plastids found in the non-green parts of plants such as flowers and fruits. They may develop from chloroplasts by replacing chlorophyll with other pigments or from leucoplasts by acquiring pigments like

carotenes or anthocyanin. Chromoplasts are angular or needle-shaped, lack lamellae and grana, and are enclosed by a double-layered membrane.

Types of Chromoplasts Based on Pigments:

- Phaeoplasts:** They are the type of chromoplast that contains brown pigments, specifically Xanthophyll and Fucoxanthin. They are found in diatoms, dinoflagellates, and brown algae.
- Rhodoplasts:** These chromoplasts contain red pigments R-phycoerythrin and R-phyococyanin and are present in red algae.
- Chromatophores of Blue green algae:** They bear C-phyococyanin, C-phycoerythrin, and chlorophyll-a and are found in blue-green algae.
- Chromatophores of photosynthetic bacteria:** They consist of purple-red carotenoid pigments. They are found in purple photosynthetic bacteria with **Function of Chromoplasts:**

Chromoplasts contribute to the vibrant colors of flowers and fruits, attracting insects and animals for pollination and the dispersal of seeds.

c. Leucoplasts:

Leucoplasts are colorless plastids found in storage organs where light is limited. They may be rod-like, spherical, or oval, enclosed by double-layered membranes, and contain a granular matrix. Leucoplasts transform into chloroplasts with a thylakoid structure when exposed to sunlight.

Types of Leucoplasts (Based on Stored Food)

- Amyloplasts:** They are found in potato tubers and grains of wheat and rice, synthesizing and storing starch.
- Elaioplast:** (Oleosome or Lipoplast): They store lipids (fat or oil) and are found in seeds of mustard, castor, groundnut, sunflower, cotton, etc.
- Proteinoplasts** or Aleuronoplasts: They are protein-storing leucoplasts mainly occurring in seeds with few thylakoids.

Function of Leucoplasts:

Leucoplasts primarily serve to store various reserve food materials like carbohydrates, lipids, and proteins.

Do You Know?

According to Schimper, different kinds of plastids can transform into one another.

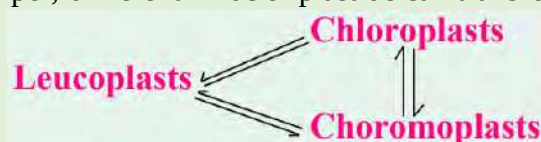


Figure 1.2.25 Interconversion of all three types of plastids

9. ENDOPLASMIC RETICULUM (ER)

The endoplasmic reticulum (ER) is a network of interconnected cisternae, tubules and vesicles present throughout the cytoplasm, especially in the endoplasm. It resembles a factory with winding pathways and chambers where proteins and lipids are synthesized, processed, packaged and transported. It is found only in eukaryotic cells, excluding germinal cells and

mature mammalian red blood cells. Its occurrence and development depend on the metabolic state and differentiation stage of cells, like it is less developed in spermatocytes, and well-developed in fully differentiated and metabolically active cells, like pancreas and liver. However, it is absent in embryonic cells,

ER was discovered by Garnier (1897) but its structural detail was reported by Porter, Claude and Fullam (1945), while the term 'Endoplasmic Reticulum' was coined by Porter (1953).

Types of Endoplasmic Reticulum:

The ER is classified into two types based on the presence or absence of ribosomes:

- a. **Agranular or Smooth Endoplasmic Reticulum (SER):** SER is located near cell membrane and lacks ribosomes on its surface. RER after losing ribosomes forms SER. It mainly comprises tubules. It is primarily found in cells like adipocytes, brown fat cells, interstitial cells (testes), cells of corpus luteum (ovaries), sebaceous cells, adrenocortical cells, muscle cells. It synthesizes and stores lipids.
- b. **Granular or Rough Endoplasmic Reticulum (RER):** RER is located near nucleus and possess ribosomes on its surface. RER formed from nuclear membrane. It mainly comprises cisternae. It is primarily found in protein forming cells like pancreatic acinal cells, goblet cells, plasma cells, Nissl's granules of nerve cells. It transports proteins.

Structure:

The endoplasmic reticulum (ER) comprises three main structures: cisternae, vesicles, and tubules.

1. **Cisternae:** They are flattened, sac-like, unbranched tubules located near the nucleus. They are interconnected, and often found in parallel bundles/stacks in cells like pancreas, notochord which have synthetic roles.
2. **Vesicles:** They are oval, membrane-bound vacuolar structures scattered in the cytoplasm, especially abundant in pancreatic cells.
3. **Tubules:** They are wider, branched and dynamic structures that form the reticular system along with cisternae and vesicles. It is associated with membrane movements, fission and fusion between membranes within the cell.

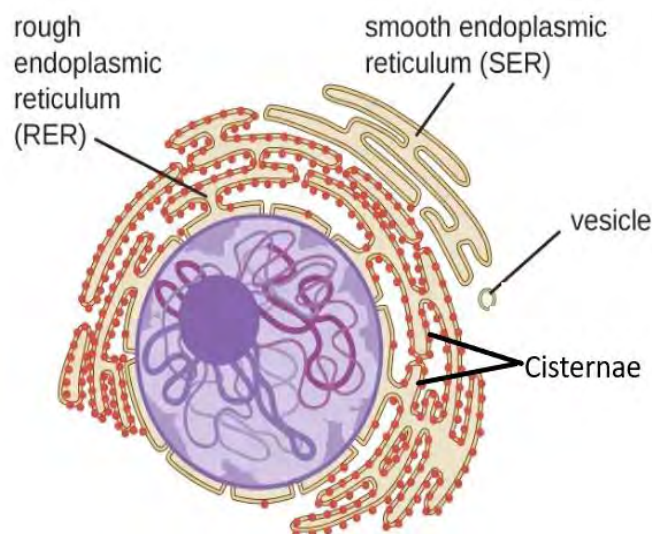


Fig: 1.2.10 Ultra structure of Endoplasmic Reticulum

Functions of Endoplasmic Reticulum (ER):

1. SER synthesizes lipids (Phospholipids, cholesterol, etc.) and phospholipids, and RER synthesizes proteins.
2. ER acts as an intercellular circulatory system that transports material by osmosis, diffusion, and active transport.
3. It functions as the cytoskeleton providing mechanical support to the cell.
4. ER membrane forms primary lysosome and nuclear envelope.
5. ER contributes to cell plate formation in plant cells during cytokinesis.
6. ER contains many enzymes to carry out many synthetic and metabolic activities such as glycogenolysis, detoxification, and sterol metabolism.
7. It facilitates transfer of information from nucleus to cell organelles.
8. It stores synthetic products like glycogen.
9. It helps in detoxification of xenobiotics.

10. GOLGI COMPLEX

The Golgi complex is a membrane-bound, cup-shaped cell organelle found near the nucleus that processes, packages, and transports proteins and lipids in eukaryotic cells. It was discovered by Camillo Golgi in nerve cells of cats and barn owls (1898). It is referred to as the 'traffic police' of the cell by Darnell (1986) because it helps in sorting the cell's proteins and membrane constituents, directing them to their destinations. It is also known as Lipochondria, Idiosome, or Dalton complex. It is present only in eukaryotic cells except in mature mammalian red blood cells, antherozoids of bryophytes and pteridophytes, and sieve tube cells. Depending on the cell type, functional state, and maturity of a cell, its shape and form may vary; therefore, it is also known as a Pleomorphic organelle. It is larger in mature, functional, and secretory cells like nerve cells, pancreatic cells, liver cells, and germinal cells; and smaller in non-secretory cells like muscle cells. In plant cells, the scattered subunits of the Golgi apparatus are known as Dictyosomes.

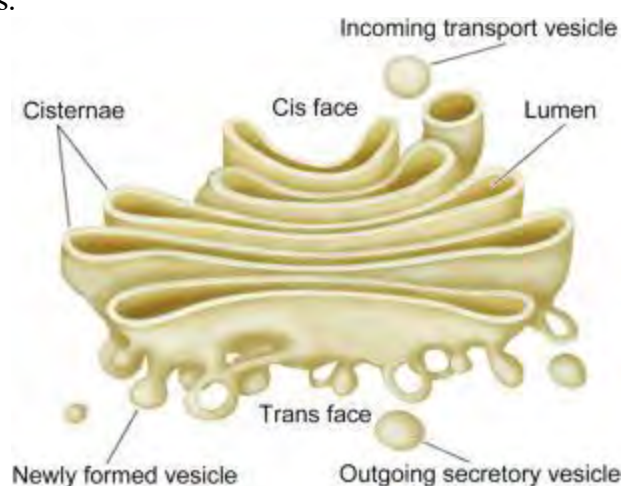


Fig: 1.2.11 Ultra Structure of Golgi complex

The Golgi body consists of four smooth membranous compartments: cisternae, vacuoles, and vesicles and tubules.

1. **Cisternae or flattened sac:** Cisternae are double-layered, flat, curved fluid-filled parallel sacs held in stacks. In each stack, cisternae are separated by a space which may

have fibrils. Each stack comprises 5-6 cisternae in animal cell and 20 or more cisternae in plant cell.

It is also known as saccules and are fenestrated and curved. The large concave face that faces cell membrane is known as trans/maturing face and a smaller convex face that faces nucleus is known as cis/forming face.

2. **Tubules:** The fenestrated cisternae give rise to a tubule, which is a network of associated vesicles towards the periphery and maturing face of the apparatus.
3. **Vesicles:** Vesicles are small sacs attached to the tips of tubules. They are associated with cisternae, present along the convex face. They are of two types, Smooth vesicles and coated vesicles.
4. **Golgian Vacuoles:** These are enlarged parts of cisternae formed from the concave face of the Golgi apparatus. These have glandular substances which contain hydrolyzing enzymes.

Do You Know?

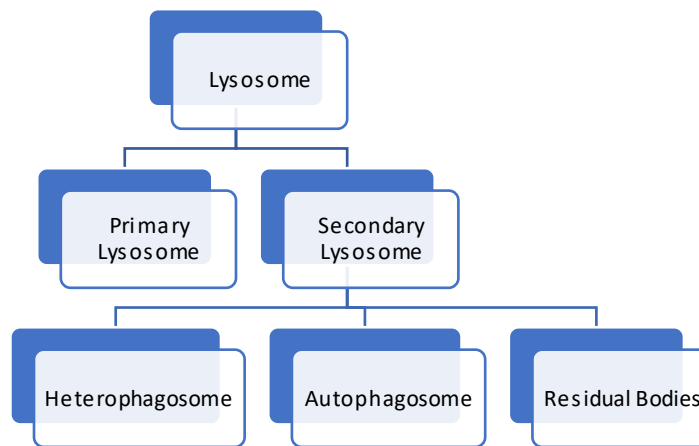
In plant cells, Golgi apparatus is made of a number of separate and scattered units known as dictyosomes. However, in animal cells it is made of a single compact/loosely stacked complex known as Golgi apparatus or Golgi complex.

Functions:

1. Golgi bodies transport and chemically modify cell materials such as proteins, lipids, and sterols.
2. It stores, condenses, and packages materials within the cell.
3. It is involved in cell secretion; vesicles containing secretory molecules pinch off and discharge contents to the cell's exterior.
4. They participate in cell plate formation during cytokinesis in plant cells; vesicles separate from the main body to form a new cell plate.
5. Golgi bodies contribute to the formation of primary lysosomes.
6. It plays a role in the synthesis of hormones in endocrine cells, e.g., thyroxine in thyroid gland cells.
7. They participate in the transformation of membranes and recycling of the plasma membrane.
8. It contributes to the biosynthesis of glycoproteins.

11. LYSOSOMES

Lysosomes (Gr. *Lyso* - digestive, *soma* - body) are microscopic, membrane-bound vesicles within the cytoplasm crucial for intracellular digestion. These pleomorphic structures contain up to 40 types of hydrolytic enzymes, mostly active at pH 5, and digest several biological materials (forming autophagosome), and, sometimes, own cell organelles causing death of the cell (autolysis). Therefore, they are also known as "suicidal bag". Lysosomes were discovered by Belgian biochemist Christian de Duve (1955) within rat liver cells. They are found in most eukaryotic animal cells (excluding mammalian red blood cells), certain fungi (e.g., yeasts), specific protists (e.g., *Euglena*), and meristematic cells (e.g., root tip cells of maize). Generally, they are spherical but irregular in plant root tip cells. They are found in a large number in phagocytes cells and cells of reticuloendothelial system (e.g., bone marrow, liver and spleen). On the basis of the nature of matrix, it is of following types:



1. **Primary Lysosomes:** Primary lysosomes are newly formed lysosome pinched off from the Golgi complex or granular endoplasmic reticulum. They contain hydrolytic enzymes that have not yet participated in any digestive process and are known as virgin lysosomes.
2. **Secondary Lysosomes:** Secondary lysosomes form when primary lysosomes fuse with other vacuoles containing extracellular or intracellular materials.
 - a. **Heterophagosomes:** They are the secondary lysosomes formed when primary lysosomes fuse with cytoplasmic vacuoles containing extracellular materials.
 - b. **Autophagosomes:** During events like growth, repair, tissue-differentiation, and starvation, lysosomes digest intracellular structures including mitochondria, ribosomes, peroxisomes and glycogen granules forming autophagosomes. The process of destroying cell organelles of own cell is known as autophagy. In fact, it is difficult to identify the nature of the secondary lysosome (i.e., heterophagosome or autophagosome), thus, the stage, in general, is termed digestive vacuole.
 - c. **Residual Bodies:** When food inside food vacuole is not completely digested, perhaps, due to absence of some enzymes, it forms whorls of grains/amorphous masses inside. The secondary lysosomes are called residual lysosomes. Typically, these residual bodies are removed from the cell by defecation/exocytosis. They are also known as tertiary lysosomes or telolysosomes.

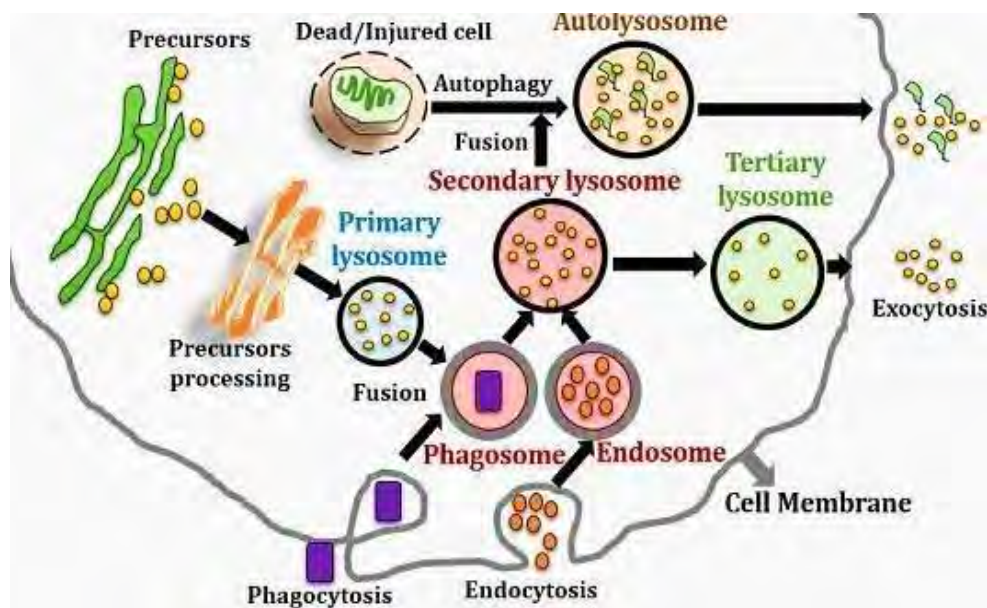


Fig: 1.2.12 Different types of lysosome and their origin

Functions of lysosomes:

1. The lysosomes digest extracellular food content such as bacteria, viruses of phagosomes/pinosomes forming heterophagosomes.
2. They also digest reserve food such as glycogen, proteins and lipids during starvation.
3. During autophagy, lysosomes digest various organelles like endoplasmic reticulum and mitochondria by forming autophagosomes.
4. During fertilization, lysosomes of cells like sperms release their digestive enzymes outside the cell to digest the membrane of the ovum for penetration.
5. Lysosomes initiate cell division by digesting repressor molecules.
6. DNase in lysosome can bring gene mutations, contributing to diseases like Leukemia (blood cancer).

12. RIBOSOMES

Ribosomes are tiny, compact, round and granular organelles crucial for protein synthesis. It was discovered by Claude (1943). Ribosomes are present in both prokaryotic (70s type) and eukaryotic cells (80s type), except in mature sperm and red blood cells. In prokaryotic cells, they are often free in the cytoplasm. Eukaryotic cells host cytoplasmic ribosomes in two forms: free and bound (on RER and outer nuclear membrane). Organellar ribosomes are also found inside certain cell organelles like mitochondria and plastids. The number of ribosomes depends on the cell's RNA content, with higher numbers in plasma cells, liver cells, meristematic cells, cancer cells, and endocrine cells. For example, *E. coli* has about 20,000-30,000 ribosomes.

Structure:

Ribosomes, oblate spheroids, consist of two subunits—one larger subunit (50s or 60s) and one smaller subunit (30s or 40s), joining only during protein synthesis. The larger subunit is dome-shaped, attached to the ER, and has various structural features. The smaller subunit is oval-shaped and fits like a cap. Ribosomes are composed of approximately 45% rRNA and 55% proteins. When a number of ribosomes attach each other like beads in a strand of mRNA, it is called polyribosome. Depending on sedimentation coefficient, ribosomes are of two types:

1. **70s type:** It consists of two sub-units, large 50s subunit and a small 30s subunit. It is smaller in size and can be found in bacteria, cyanobacteria, mitochondria, and chloroplasts.
2. **80s type:** It consists of two sub-unit, large 60s subunit and small 40s subunit. It is larger in size and is present in the cytoplasm of eukaryotic cells in fungi, protists, plants and animals.

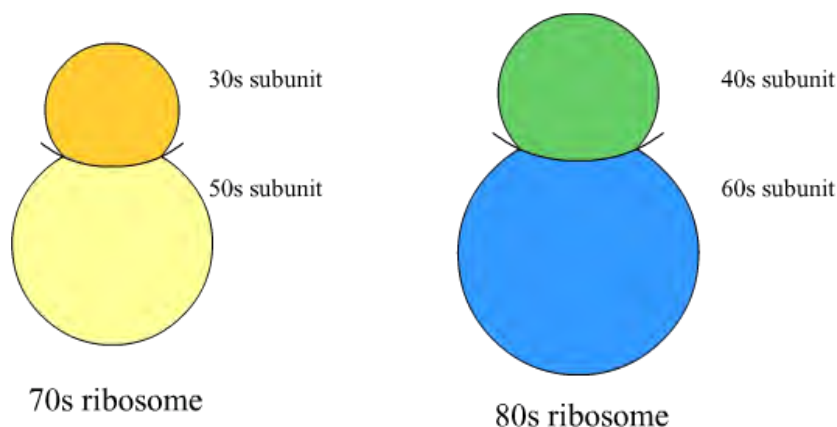


Fig: 1.2.13 Types of ribosome

Based on cellular composition, RNA is of three types:

- a) Ribosomal RN (rRNA): 50 - 80%
- b) Messenger RNA (mRNA) 5 - 10%
- c) Transfer RNA (tRNA) 10 - 20%

Ribosomal RNA (rRNA): Ribosomal RNA is the factory where proteins are synthesized. In eukaryotic cells, the 60s subunit contains around 35 different proteins and three different rRNAs. It is considered essential for mRNA to bind with ribosomes and carryout protein synthesis. It can also act as an enzyme (ribozyme).

Messenger RNA (mRNA): Messenger RNA is a linear molecule synthesized inside the nucleus by transcription from DNA. Its sequence is complementary to the template DNA strand. Messenger RNA carries genetic information from nucleus (chromosomal DNA) to cytoplasm for protein synthesis.

As mRNA reaches cytoplasm it combines with ribosomes to form polyribosomes or polysomes. Each polysome contains several ribosomes (normally five) which form a complex with mRNA.

Transfer RNA (tRNA): Transfer RNA (soluble RNA) molecule is relatively small molecule comprising 71-80 nucleotides. There are more than 20 species of tRNA corresponding to 20 amino acids present in protein structure. It is synthesized in nucleus from DNA template strand.

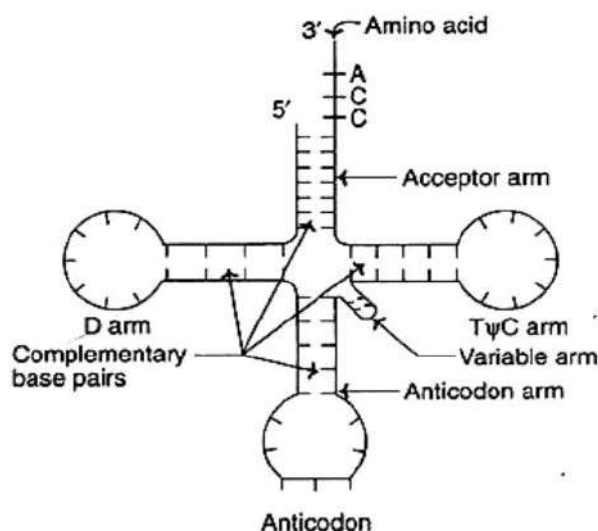


Figure 1.1.5 Structure of transfer RNA

Functions:

1. Ribosomes act as protein factories, being essential sites for protein synthesis.
2. Proteins synthesized by ribosomes contribute to cellular structure or act as enzymes, regulating cellular functions.
3. Free ribosomes produce intracellular enzymes, while bound ribosomes on RER synthesize enzymes for extracellular use.
4. Ribosomes temporarily store proteins and rRNA, contributing to protein synthesis.

13. CILIA AND FLAGELLA

The cilia (*L. cili* = eye-lash) and flagella (*L. flagellum* = little whip) are microscopic, contractile and hair-like or thread-like motile structures that originate inside the cell from the basal bodies but are present outside the cell. They aid in movement, locomotion, feeding, and circulation. Englemann (1868) first reported the presence of flagellum.

Occurrence

Cilia are present in all protozoans of the class ciliate, flame cells of flat worms, in some larval forms e.g. Bipinnaria larva of starfish, in some body structures e.g. wind pipe, fallopian tubes, etc., ciliated epithelium of the metazoa, etc. Flagella are found in all the protozoans of the class flagellate, choanocyte cells of sponges, gastrodermal cells of coelenterates, spermatozoa of metazoa and lower plants, zoospores of algae, gamete cells, etc.

Ultrastructure

Both flagella and cilia have similar structures: basal body, rootlets, basal plate, and shaft. In fact, term cilium is used when it is shorter than a cell (5 - 20 μm), while the longer extension is called flagellum (100 - 200 μm).

A cross-section of either organelle reveals a pair of central filaments surrounded by nine peripheral filaments, forming a 9 + 2 arrangement. This bundle of filaments is known as an axoneme or axial filament. It is encased in a double-layered protective coat, 90 angstroms thick, which is continuous with the plasma membrane. Each peripheral microtubule is a doublet, consisting of two submicrotubules, 'A' and 'B'. The 'A' microtubule has pairs of dynein arms, which can hydrolyze ATP. The central filaments are connected to the 'A' microtubules of the peripheral

filaments by radial spokes. The movement of cilia and flagella is powered by ATP, which diffuses from the cell cytoplasm.

Chemically, the central tubules are made of dynein protein, while the peripheral microtubules are made of tubulin protein. Dynein acts as an ATPase enzyme, breaking down ATP to release energy for the beating of cilia and flagella.

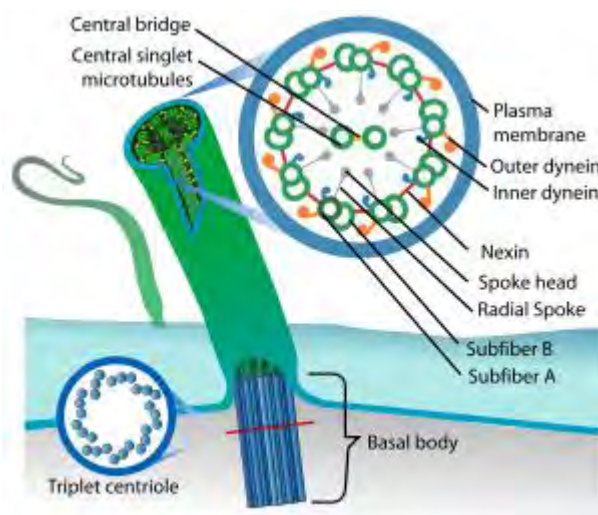


Fig. 1.2.14 Ultrastructure of a cilium/ flagellum

Functions

1. Cilia or flagella bring locomotion in organisms by their power strokes and return strokes.
2. Cilia of *Paramecium* and flagella of collar cells of sponges set up current in water allowing nutrition-and respiratory gas enter inside the body.
3. Ciliary movements in the respiratory tract help to eliminate solid wastes out of the body.
4. Cilia in kidney-nephrons cause movement of nephric filtrate.
5. Cilia push eggs out of the oviduct in amphibians and mammals.
6. Cilia help larval forms to disperse.

14. NUCLEUS

Nucleus (L., *nucleus* = kernel) is a double membrane bound protoplasmic body comprising genetic information which regulates all the cellular activities and carries the hereditary information of the cell. It is the largest cell organelle embedded in the cytoplasm. It was first discovered by Robert Brown (1833) in plant cells.

A true nucleus (Eukaryon) is found in all the eukaryotes except mature mammalian RBCs, sieve tube cells of phloem, tracheids and vessels of xylem. The prokaryotes have an incipient nucleus called nucleoid or prokaryon or genophore (the nucleus without nuclear membrane and nucleolus). Its shape and size varies. Generally, its shape depends upon the shape of the cell. However, it could be spherical, cuboidal, ellipsoidal, discoidal or even irregular. Its size depends upon nucleo-cytoplasmic index and the number of chromosomes present in the nucleus. In young cell, nucleus occupies 25% of cell volume while in mature cell, it occupies about 10% of cell volume.

Structure

The nucleus is made of the following four components:

- a. Nuclear membrane (karyotheca)
- b. Nuclear sap (nucleoplasm)
- c. Chromatin fibres and
- d. Nucleolus

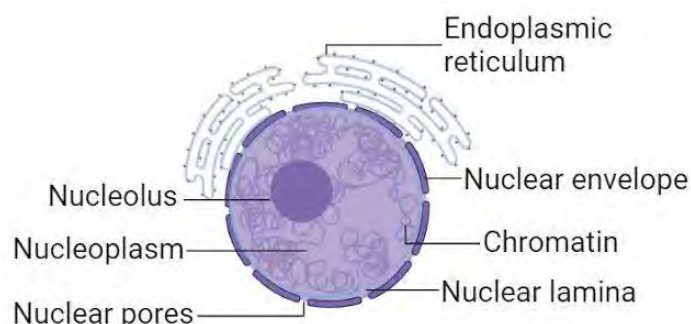


Fig: 1.2.15 Structure of nucleus (during interphase)

a. Nuclear membrane: Nuclear membrane is the outermost layer of the nucleus. It was discovered by Erclab (1845). It consists of two membranes with a fluid-filled space between them called the perinuclear space. The outer membrane is connected to the rough endoplasmic reticulum. Pores in the nuclear envelope enable the exchange of substances between the nucleus and the cytoplasm. This structure performs several functions, including controlling interactions between the nucleus and cytoplasm, permitting the passage of small molecules and ions, facilitating the uptake of large molecules through pinocytosis and phagocytosis, allowing the movement of ribosomal subunits, mRNA, tRNA, and proteins through nuclear pores, and maintaining the shape of the nucleus.

b. Nucleoplasm (Nuclear sap or karyolymph)

The space between nuclear envelop and nucleolus is filled with a transparent, homogenous, semi-fluid, gel-like, colloidal and slightly acidophilic ground substance called nucleoplasm. It constitutes water, nucleotides, sugars, minerals (Mn, Mg), ribosomes, enzymes, lipids, proteins, mRNA, tRNA, etc. which are essential for the synthesis and functioning of DNA, RNA, nucleoproteins and spindle fibres.

c. The chromatin fibres (Nuclear reticulum)

The nucleoplasm comprises thread-like, coiled and much elongated structures known as chromatin fibres (G. *chroma* = colour). Such chromatin fibres are observable only during interphase stage of cell division (mitosis and meiosis). When it becomes thick and ribbon-like in structure, it is called chromosomes. Chromatins are differentiated into two types:

- i. **Heterochromatin:** The condensed and darkly stained section of the chromatin is known as heterochromatin. It occurs around the nucleolus. Perhaps, it is metabolically and genetically inactive since it comprises relatively small amount of the DNA and large amount of the RNA.
- ii. **Euchromatin:** It is true and light stained chromatin located at the diffused region of the chromatin. It is metabolically and genetically active. It contains relatively large amount of DNA.

d. The Nucleolus

The nucleus contains one or more prominent, large, spherical and acidophilic dense granules known as the nucleoli (*sing.* nucleolus). Nucleolus, also called plasmosome, is generally associated with the nucleolar organizer region (NOR) of the nucleolar chromosome. Nucleolus is chemically composed of RNA and non-histone acidic proteins.

Nucleolus is the site of synthesis for ribosomal subunits. Additionally, it synthesizes and stores rRNA. It helps to form spindle fibers during cell division. It gets the ribosomal proteins from the cytoplasm that combines with rRNAs and ribosomal proteins to form ribosomal subunits.

Functions of nucleus

1. It controls all cellular activities.
2. It regulates the synthesis of structural proteins.
3. It controls cellular functions by controlling the synthesis of enzymatic proteins.
4. It comprises genetic information to carryout reproduction and development.
5. It helps to synthesize ribosomes.
6. It brings genetic variations bringing organic evolution.
7. It regulates cellular differentiation.

15. CHROMOSOMES

Chromosomes (L. *chrom* = coloured, *soma* = body) are thread-like nuclear component with special organization, individuality and function. E. Strasburger (1875) discovered thread-like structures which appeared during cell division and W. Waldeyer (1888) coined the term 'chromosome' to describe it that became intensely coloured after staining. Chromosomes are typically present in the nucleus and its shape changes from phase to phase in the continuous process of cell growth/division. They are composed of DNA and proteins (histones) with small amount of chromosomal RNA. Chromosomes carry genes, which are the units of heredity that encode instructions for the synthesis of proteins and determine various traits. The number of chromosome is constant for a particular species. However, based on the number of chromosomes present in a cell, cells can be classified into two types:

- a. Haploid
- b. Diploid

Haploid cell consists of one set of chromosome which is essential to carryout sexual reproduction. Diploid cell consists of a pair of chromosomes. In paired sets, one set is obtained from mother, which is called maternal chromosome and the other set is obtained from father and it is called paternal chromosome. In diploid cells of human, there are two distinct types of chromosomes:

- a. Autosomes (regulate cellular activity)
- b. Sex chromosomes (determine gender)

The electron microscopic structure of each chromosome comprises the chromonema, centromere, secondary constrictions, nucleolar organisers, telomeres and satellites.

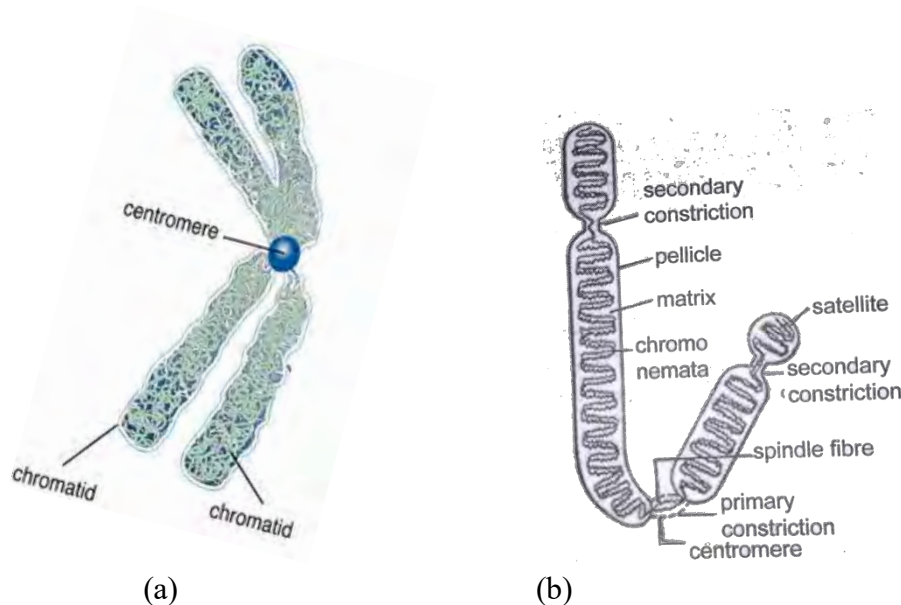


Fig. 1.2.16 (a) structure of Chromosome
(b) structure of chromosome during mitosis (anaphase stage)

a. Chromatid

During metaphase stage during mitosis, each chromosome comprises two identical structures called chromatids, each containing a single DNA molecule. These chromatids are attached at the centromere that separate during anaphase while moving to opposite poles.

b. Chromonema (ta)

During prophase stage of mitosis, chromosomes appear in the form of thin filaments called chromonemata (Vejdovsky: 1912). A chromonema is an early stage of a chromatid, so both terms refer to the same structure: a single linear DNA molecule with associated proteins. Chromonemata are the part of chromosomes that bear gene.

c. Chromomere

Chromomeres are regions of tightly folded DNA that appear like a cluster of bead of chromatin that can sometimes be observed on interphase. They are especially visible in polytene chromosomes (chromosomes which have undergone multiple rounds of DNA replication without cell division), where they align side by side to form chromosome beads. At metaphase, chromosomes are tightly coiled, and chromomeres are no longer visible.

d. Centromere (Primary constriction)

The chromosomes possess a constricted region called centromere or primary constriction where two sister chromatids are attached. The position of the centromere is constant for a particular chromosome.

The structure and function of the centromere is different from that of the rest of the chromosome. It is functional during cell division. **Kinetochore** is a trilaminar plate/disc situated upon the primary constriction or centromere.

The position of the centromere varies in different chromosomes based on which chromosomes are classified into four types. They are: (a) telocentric, (b) acrocentric, (c) sub-metacentric, and (d) metacentric chromosomes.

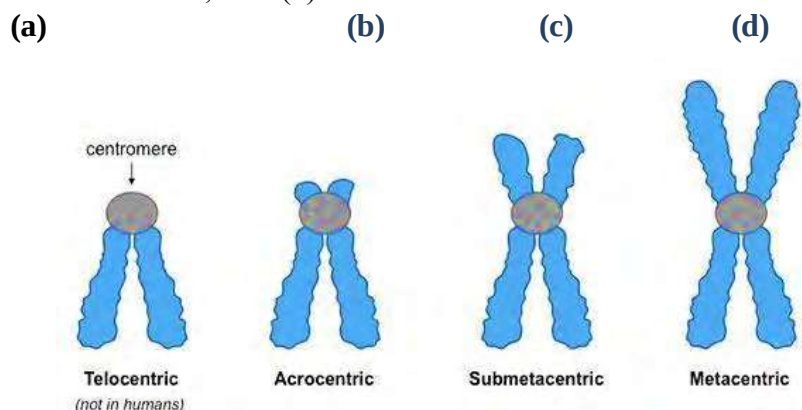


Fig. 1.2.17 Types of chromosome on the basis of position of centromere

e. Nucleolar organiser (secondary constriction I)

The constriction near one end of chromosome that induces the formation of nucleolus is called nucleolar organizer.

f. Secondary constriction (II)

In addition to the primary constriction or centromere, the arms of the chromosomes may show one or more secondary constriction (called secondary constriction II). These constrictions are different from nucleolar organisers (called secondary constriction I). It represents the site of breakage and subsequent fusion.

g. Satellite

Sometimes chromosomes possess round, elongated, knob-like extensions called satellites. It is the part of chromosome beyond the nucleolar organizer that does not change its shape and size. Chromosomes bearing satellites are called Sine Acid Thymonucleinico (SAT) - chromosomes (without thymonucleic acid or DNA).

h. Telomere (G., *telo* = for; *meros* = part)

The tips of chromosomes located at the terminal end after Secondary Constriction II are called telomeres. The telomeres are different in structure and composition from the rest of the chromosome. It has a unique property of preventing the ends of the chromosome from sticking together.

Functions of chromosomes

1. Chromatin fibers contain DNA which acts as a genetic material.
2. They control the synthesis of structural as well as enzymatic proteins.
3. The changes in DNA cause mutation.

Activity: Exploring Cellular Structures

Objective: Students will learn about various cellular structures, their features, and their functions through a creative and interactive group activity.

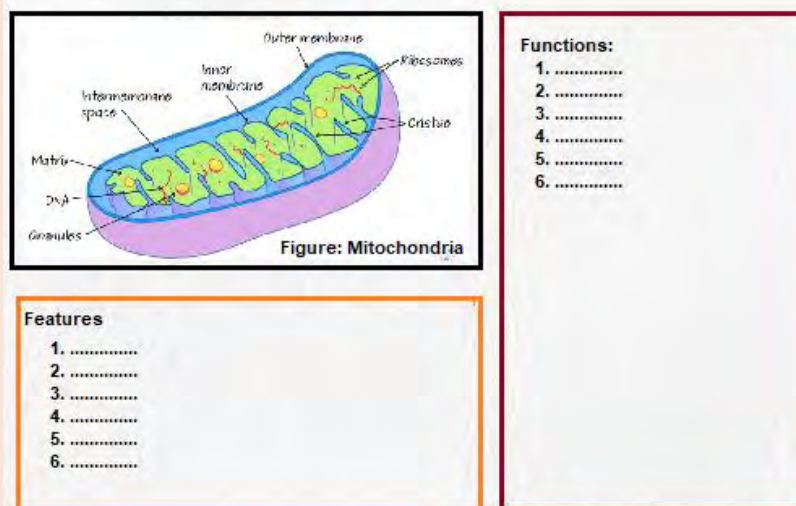
Materials Needed:

- Chart paper
- Color pens/pencils

- Cheat slips with names of cellular structures (e.g., cell wall, cell membrane, mitochondria, Golgi body, lysosome, plastid, vacuole, nucleus, etc.)

Procedure:

- Briefly introduce the topic of cellular structures.
- Explain the importance of understanding the different parts of a cell and their functions.
- Divide the class into small groups, each group consisting of 5-7 students.
- Assign each group to a bench.
- Provide a pool of cheat slips with names of various cellular structures.
- Ask each group to randomly select one cheat slip to determine which cellular structure they will work on.
- Each group receives chart paper and color pens/pencils.
- Instruct each group to:
 - draw an accurate and detailed image of their assigned cellular structure.
 - label all parts of the structure.
 - draw a table to list the features and functions of the structure.
- Each group presents their drawing and table and explains features to the class.
- Summarize the key points about each cellular structure discussed.
- Assign homework where students write a short report on any one cellular structure of their choice, including an illustration and a detailed explanation of its features and functions.
- Briefly explain the importance of cellular structures.
- Groups present their work to the class.
- Recap key points and discuss the structures.
- Give them assignment - 'Write a report on one cellular structure with illustration, features and functions'.



16. CELL INCLUSIONS

Due to metabolic activities in the cell, several non-living substances are produced. The metabolically inactive non-living substances such as proteins, amino compounds, starch grains, essential oils, latex, mineral crystals, cellulose, inulin, sugars, fats, oils, pigment, enzymes, etc.

present in the cytoplasm of the cell are known as cell inclusions or deutooplasmic bodies or ergastic bodies.

Cell inclusions can be divided into three categories:

1. Reserve materials
2. Secretory materials
3. Excretory materials

1. Reserve materials

The metabolic products stored in plant cells form the reserve food of the plant. They are either nitrogenous or non-nitrogenous and may remain in solid form or liquid form.

- a. **Nitrogenous reserve food materials:** Besides carbon, hydrogen and oxygen, these materials also possess some amount of nitrogen. Protein granules are the solid forms and amino acids are the liquid form of nitrogenous reserve food materials.
- b. **Non-nitrogenous reserve food materials:** These reserve food materials contain carbon, hydrogen and oxygen. The proportion of hydrogen and oxygen is found to be like in water (i.e. 2:1 in H₂O). They may or may not be soluble in water. They are the products of photosynthesis e. g. starch, cellulose, sugars, inulin, glycogens, etc.

2. Secretory materials

Some important chemical compounds which may not be related with nutrition are synthesized during plant metabolism. Such materials are called secretory materials. They may be of the following types:

- a. **Plant pigments:** Phycocyanin, phycoerythrin, carotenes, fucoxanthin, flavoxanthin, lutein, chlorophyll-a, chlorophyll-b, chlorophyll-c, etc. are some colour producing substances that are secreted. These are also known as plant pigments.
- b. **Enzymes:** These water soluble biocatalysts are the nitrogenous secretory products.
- c. **Nectar:** It is secreted by the glands known as nectaries.

3. Excretory materials

Excretory materials are the by-products obtained during plant metabolism which are of useless to plants. Such excretory products are given below:

- a. **Alkaloids:** These excretory compounds are composed of carbon, hydrogen, oxygen and nitrogen and occur in association with organic acids in various plant parts. For example, Quinine, nicotine, morphine, atropine, daturine, etc.
- b. **Organic acids:** These are the outcome of various chemical processes in living cells. For example, citric acid, tartaric acid, oxalic acid, malic acid, etc.
- c. **Gums:** These are the products obtained after the decomposition of cellulose (cell wall) which is soluble in water. They swell up in water forming a viscous mass.
- d. **Resins:** Resins are solid, brittle, non-volatile complex substances found in various parts of plants.
- e. **Tannins:** Tannins are non-nitrogenous, complex compounds, commonly found in unripe fruits. It is actually found dissolved in the cell sap of parenchymatous cells.
- f. **Essential oils:** The essential oils are found in fruits, flowers, and glandular leaves of plants such as lemon, Eucalyptus, etc.
- g. **Latex:** Latex is an emulsion of matrix in watery fluid. Starch grains, sugars, proteins, enzymes and alkaloids are dissolved in this fluid.
- h. **Mineral crystals:** Mineral crystals are present in parenchymatous cells of several plants in the form of silica crystals, calcium carbonate crystals, calcium oxalate crystals, etc.

EXERCISE

A. Tick the correct alternatives:

1. Which of the following is NOT a characteristic of prokaryotic cells?
 - a. Lack of organized nucleus
 - b. Presence of membrane-bound organelles
 - c. Naked circular DNA
 - d. 70s ribosomes
2. Which of the following organelles is not membrane bound?
 - e. Centriole
 - f. Chloroplast
 - g. Plastid
 - h. Ribosome
3. How would you describe the property of the cell membrane?
 - a. Semipermeable
 - b. Permeable
 - c. Nonpermeable
 - d. Impermeable
4. What term describes the protoplasmic connection between two cells?
 - a. Plasmodesmata
 - b. Semipermeable
 - c. Cell wall
 - d. None
5. According to the fluid-Mosaic Model, which type of proteins are embedded within the phospholipid bilayer?
 - a. peripheral proteins
 - b. Extrinsic proteins
 - c. Integral proteins
 - d. Globular proteins
6. Which process involves the expulsion of large sized materials from the cell through the cell membrane?
 - a. Endocytosis
 - b. Exocytosis
 - c. Osmosis
 - d. Diffusion
7. What enzyme is responsible for controlling the synthesis of ATP in mitochondria?
 - a. ATPase
 - b. ATP synthetase
 - c. Oxidase
 - d. Ribonuclease
8. Chromosomes with a centromere located near the middle are classified as?
 - a. Metacentric
 - b. Sub-metacentric

- c. Acrocentric
 - d. Telocentric
9. What is the primary function of mesosomes in prokaryotic cells?
- e. Photosynthesis
 - f. Respiration
 - g. Protein synthesis
 - h. Cell division
10. Which type of ribosome is found in the cytoplasm of eukaryotic cells?
- i. 70s
 - j. 80s
 - k. 60s
 - l. 30s
11. What type of endoplasmic reticulum (ER) is primarily involved in lipid synthesis?
- a. Granular Endoplasmic Reticulum (GER)
 - b. Rough Endoplasmic Reticulum (RER)
 - c. Smooth Endoplasmic Reticulum (SER)
 - d. Nuclear Endoplasmic Reticulum (NER)
12. Which structure in the Golgi complex is responsible for modifying, packaging, and transporting proteins and lipids?
- e. Lysosomes
 - f. Ribosomes
 - g. Cisternae
 - h. Tubules
13. Which of the following is NOT a function of lysosomes?
- a. Digestion of extracellular food content
 - b. Synthesis of lipids
 - c. Autophagy
 - d. Release of digestive enzymes during fertilization
14. Which pigment is found in chloroplasts?
- a. Carotene
 - b. Chlorophyll
 - c. Xanthophyll
 - d. Phycocyanin
15. Which type of plastid is involved in photosynthesis?
- e. Chromoplast
 - f. Leucoplast
 - g. Chloroplast
 - h. Amyloplast

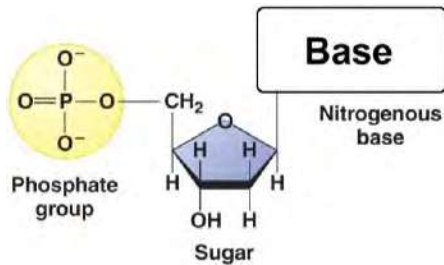
B. Answer the following questions:

1. Why is the cell considered as a basic unit of life?
2. What type of cell lacks a well-organized nucleus?
3. What type of ribosomes do prokaryotic cells have?
4. What is the primary composition of a plant cell wall?
5. What is the powerhouse of the eukaryotic cell?
6. Which type of protein is involved in transporting substances across the cell membrane?
7. Name the type of plastid that is colorless.
8. What pigment do phaeoplasts contain?
9. Which plastid is responsible for storing lipids?
10. Where are chromoplasts typically found?
11. What are the two main types of endoplasmic reticulum?
12. Name the primary function of Rough Endoplasmic Reticulum (RER).
13. What is the primary role of the Golgi complex in the cell?
14. What are the two types of ribosomes based on their sedimentation coefficient?
15. What do you mean by cell inclusions?
16. Write a brief note on fluid-mosaic model.
17. What is cyclosis?
18. Why mitochondrion is called the powerhouse of cells?
19. Name two semi-autonomous organelles.
20. Which organelle is called "suicidal bag"? Why is it called so?
21. What is the basic difference between ribosome and mitochondria?
22. Draw well labelled sketches of the prokaryotic and eukaryotic cells and point out their differences.
23. Give an account of the structure and function of mitochondrion.
24. Differentiate between leucoplasts and chromoplasts.
25. List two characteristics of prokaryotic cells.
26. What are mesosomes in prokaryotic cells and their function?
27. Describe the composition of the primary cell wall in plants.
28. What is the fluid between the plasma membrane and nuclear envelope in eukaryotic cells called?
29. Name the model that describes the plasma membrane as a mosaic of proteins in a fluid phospholipid bilayer.
30. List the three types of plastids.
31. What are the main components of a chloroplast's structure?
32. Explain the function of pyrenoids in algal chloroplasts.
33. What types of pigments are found in chromoplasts?
34. Describe the structure of the endoplasmic reticulum.
35. What distinguishes the Smooth Endoplasmic Reticulum (SER) from the Rough Endoplasmic Reticulum (RER)?
36. Explain the process of autophagy in lysosomes.
37. What is the significance of the nucleolus within the nucleus?
38. How does the Golgi complex contribute to the formation of primary lysosomes?
39. Write briefly about the structure of the nucleus.

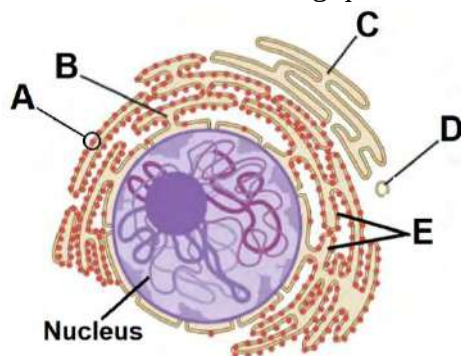
40. Name different types of plastids and describe their structure and function.

Describe the structures and functions of any two major cytoplasmic organelles of the eukaryotic cell.

41. Describe the structure of a nucleotide based on the diagram of a part of a DNA given below:



42. Below is an image of the nucleus with labelled peripheral structures. Refer to the image and answer the following questions.

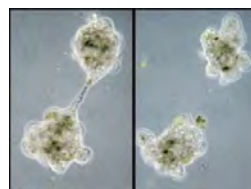


- Identify the labeled parts: A, B, C, D, and E.
- Write their functions.

Chapter 1.3

CELL DIVISION

Let's discuss the following questions:



- i. How do small creatures like protozoans reproduce?
- ii. How does a single-celled zygote develop into a full-grown organism?
- iii. What biological process enables wound healing?
- iv. Which type of cell division helps in evolution of the organism?

1.3.1 GENERAL INTRODUCTION

Cells typically go through a series of activities, including growth, essential functions for survival, and division to generate new cells. In fact, the growth and development of every living organism depends on the increment in the number or size of its cells. Cell division is that fundamental process in which a parent/mother cell divides into two or more daughter cells, ensuring growth, repair, and reproduction in living organisms. And a series of distinct events takes place in the cell leading to its division producing two daughter cells. It is crucial for the maintenance, growth, and repair of multicellular organisms.

Primitive protozoans and prokaryotes divide by a simple method of cell division that involves copying the cell's chromosomes, separating the copied DNA, and dividing the parent cell's cytoplasm. But in complex eukaryotic cells, division occurs involving intricate distinct phases, either maintaining the number of chromosomes or reducing their number in daughter cells. General growth and development of multicellular organisms require a diploid cell to divide into two diploid daughter cells which are genetically identical. On the other hand, sexual reproduction in developed organisms requires a diploid cell to divide into four haploid daughter cells.

In unicellular organisms, cell division is the means of reproduction by which the mother cell produces two or more cells. In multicellular organisms also, new individuals develop from a single cell, the zygote, by cell division. It also forms the basis of replacement of old and worn-out cells in the process of repair and regeneration. Cell division is thus central to the life of the cell and is essential for the perpetuation of the species.

The cell division is a process by which a mature cell divides to form new cells which resemble the mother cell in a number of characters. The division of the cell is achieved by two integral activities:

1. the division of the nucleus i.e. **karyokinesis**
2. the division of the cytoplasm i.e. **cytokinesis**

1.3.2 CELL CYCLE

All cells are reproduced by dividing the pre-existing cell. This process gives continuity to our life. The entire sequence that takes place during cell growth and cell division are collectively called cell cycle.

Basically, a cell cycle consists of the following three main cycles:

1. Chromosome cycle: In this process, a DNA molecule is replicated into two identical daughter DNA molecules.
2. Cytoplasmic cycle: In this process, cell growth and cytoplasm division takes place one after another.
3. Centrosome cycle: In this process, the centrosome is duplicated and divided and separated into two poles of the cell.

The above-mentioned cycles can be accumulated into the following broad two phases:

1. Interphase (L. *inter* = between; *phasis* = stage)

It is the stage between the end of one cell division and the beginning of the next cell division. This stage is also known as resting stage. The cell appear to be inactive; however, it is metabolically very active synthesizing a number of essential biomolecules required to carry out the next cell division.

Based on synthetic activities, interphase can be divided into three sub-phases which are briefly featured below:

Gap-one (G₁) or first growth phase:

During the gap-one (G₁) or first growth phase, the high rate of biosynthesis leads to the enlargement of the cell, driven by an active synthesis of RNA, proteins, carbohydrates, lipids, and amino acids for histone, as well as the formation of energy-rich compounds necessary for DNA synthesis. This robust biosynthetic process results in an increase in the number of nucleotides and organelles, but not in the DNA itself. The cell's metabolic activity and growth are sustained by this process, enabling it to meet the demands of cellular function and replication.

Synthetic phase or S-phase:

During the synthetic phase (S-phase), DNA molecules replicate, and most histone proteins and subunits of kinetochores are synthesized. This phase ensures the accurate duplication and distribution of genetic material to daughter cells, contributing to the maintenance of genetic integrity and stability.

Gap-two (G₂) or second growth phase:

During the gap-two (G₂) or second growth phase, significant protein and lipid synthesis occurs, along with the synthesis of spindle proteins and three types of RNA molecules using DNA. Additionally, this phase involves the repair of DNA double-strand breaks during DNA replication, as well as the synthesis and storage of ATP molecules. Furthermore, the duplication of mitochondria, plastids, and centrioles takes place, preparing the cell for subsequent mitotic division.

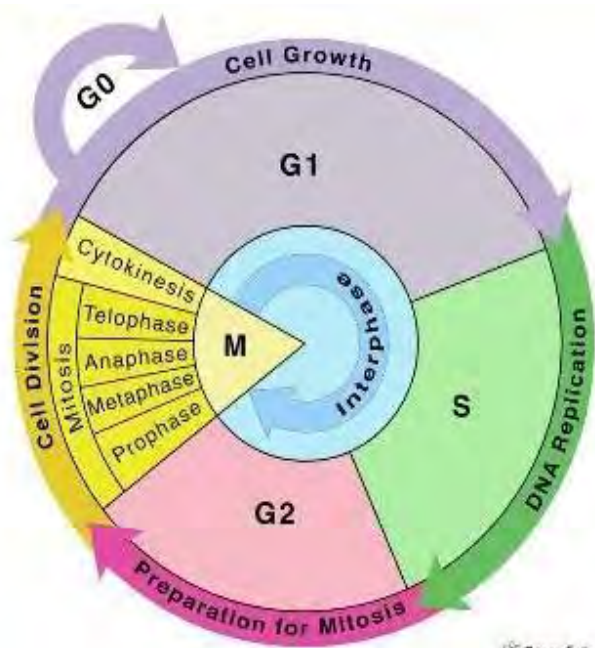


Fig. 1.3.1 Cell cycle

2. M-phase

The M-phase, or mitotic phase, follows interphase and includes mitosis and cytokinesis. Mitosis consists of prophase, metaphase, anaphase, and telophase, involving the division of nuclear material and distribution of identical genetic material to daughter cells. Cytokinesis, the division of cytoplasm and organelles, completes the process of cell division.

Table: 1.3.1 Cell cycle: Phases and events within cell.

Stage	Events within Cell
G ₁	The cell enters an intensive synthetic phase, producing essential structural and functional proteins, experiencing growth, and synthesizing RNA, lipids, and carbohydrates.
S	DNA replication occurs, along with the synthesis of protein (histone) molecules, resulting in each chromosome bearing two chromatids.
G ₂	Synthesis of various molecules, including RNA, proteins, and ATP, takes place. Additionally, mitochondria, plastids, and centrioles are duplicated.
M-Karyokinesis	Nuclear division progresses through four phases: prophase, metaphase, anaphase, and telophase.
M-Cytokinesis	Organelles and cytoplasm are equally distributed in each daughter cell, with animal cells undergoing cleavage/furrow and plant cells following the cell plate method.

G₀ - Phase:

In the G₀ phase, cells are inactive due to the unavailability of mitogens and energy-rich compounds. Despite their metabolic activity, they function as reserve cells poised to re-enter the cell cycle. The transition from G₁ to G₂ is linked to cell differentiation. Cell cycle durations vary based on cell type and external factors, with the G phase occupying 30-40%, the S phase 30-50%, the C phase 10-20%, and the M phase 5-10% of the total duration.

1.3.3 TYPES OF CELL DIVISION

The cells may divide by any of the following three methods:

1. Direct cell division or amitosis
2. Indirect cell division or mitosis
3. Reductional cell division or meiosis

1. DIRECT CELL DIVISION OR AMITOSIS (Greek, *amitos* = without thread; *osis* = state)

Simple organisms such as primitive protozoans and archaea reproduce through a basic form of cell division known as amitosis or binary fission. This asexual process entails duplicating the cell's chromosomes, separating the copied DNA, and dividing the parent cell's cytoplasm, ultimately creating two identical offspring cells. Examples of organisms that undergo this process include bacteria, amoeba, and Paramecium.

The following events occur in this process.

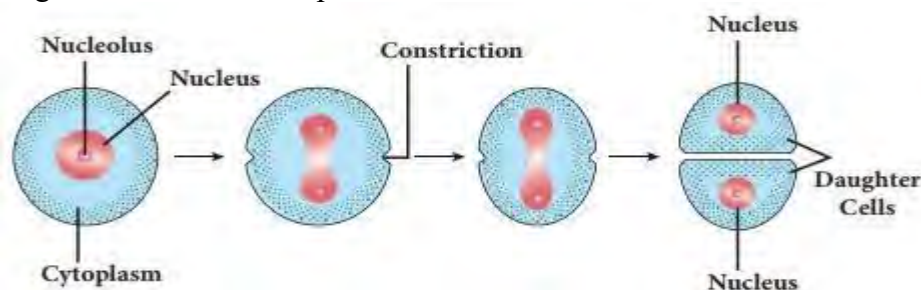


Fig. 1.3.2 Different stages of direct cell division

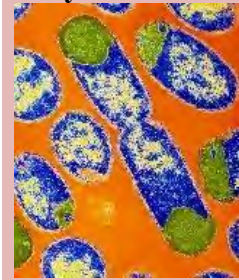
1. At first, the nucleus elongates setting constricts in the middle.
2. The elongated cell divides its nucleus into two daughter nuclei.
3. Simultaneously, cytoplasm divides into two poles giving rise to two approximately equal halves.

2. INDIRECT CELL DIVISION

Mitosis, also known as indirect cell division, ensures that daughter cells, resulting from the division of a mature cell, possess the same chromosome number as the mother cell. This process occurs in somatic cells during growth, germ cells in the gonads, meristematic cells in plants, and during embryonic development. The steps of mitotic cell division involve duplicating all cell contents, including chromosomes, and carefully controlled splitting to form two identical daughter cells.

The mitotic cell division is briefly described in the following steps:

Do you know?



Bacterial cells (*Escherichia coli*) divide every 20 minutes⁷; epithelial cells of intestine every 8-10 hours and tip cells of onion root divides every 20 hours.

A. Interphase

B. Mitotic phase

1. Karyokinesis
2. Cytokinesis

A. Interphase: It is the stage between two successive cell multiplications. During the stage, the cell is metabolically very active despite appearing restful. Key features of this stage include:

The following observations are characteristic of this stage:

- i. Chromosomes can be observed in diffused, long and coiled chromatin fibers.
- ii. Chromosomes form their exact copies.
- iii. Synthesis of protein and RNA occurs.
- iv. Duplication of cell organelles such as mitochondria, plastids, and centrioles takes place.

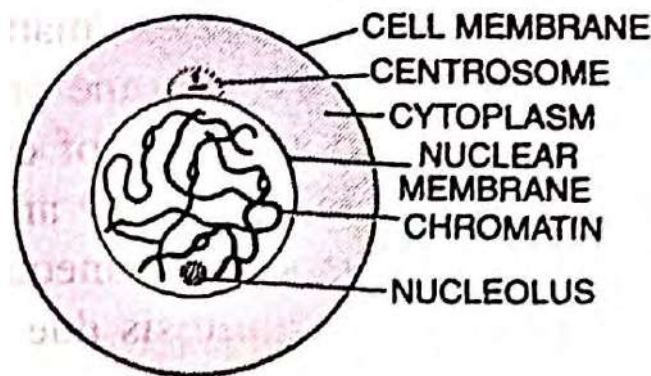


Fig. 1.3.3 Interphase

B. Mitotic phase

1. Karyokinesis: (Greek, karyon = nucleus; kinesis = movement)

The division of nucleus comprises four phases:

- a. **Prophase (G., 'pro' = first, 'phasis' = stage):** The initial visible step in nuclear division involves several changes which are characterized by following key events:
 - i. The nucleus becomes spheroid and viscosity of cytoplasm increases.
 - ii. DNA molecules condense to form elongated chromosomes which further shorten and thicken by the assistance of protein condensins.
 - iii. Each chromosome contains two sister chromatids connected at a point called centromere.
 - iv. In animal cells, two centrosomes (each with a pair of centrioles) start moving to opposite poles. Both centriole pairs radiate fine microtubular fibrils which is known as astral rays.

- v. By the end of this phase, nucleoli and nuclear membrane disintegrate and completely disappear; asters (centriole pairs with astral rays) lie at the region of future spindle poles.

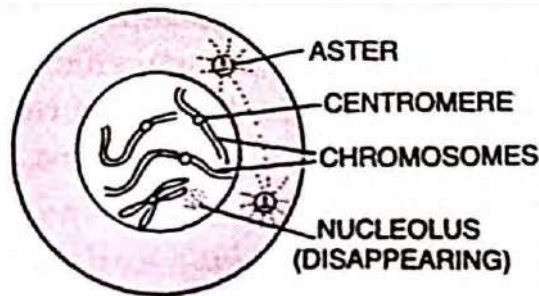


Fig. 1.3.3 Prophase

- b. **Metaphase (G., 'meta' = after, 'phasis' = stage):** Metaphase marks the initial visible step in nuclear division, characterized by the following key events:
- All chromosomes lie at equatorial region in a single alignment called metaphasic plate.
 - Each chromosome, at centromere, is attached to both spindle poles by Spindle fibers. This process of bringing the chromosomes to equator is called congression.
 - Smaller chromosomes lie towards the centre while larger ones lie at periphery.

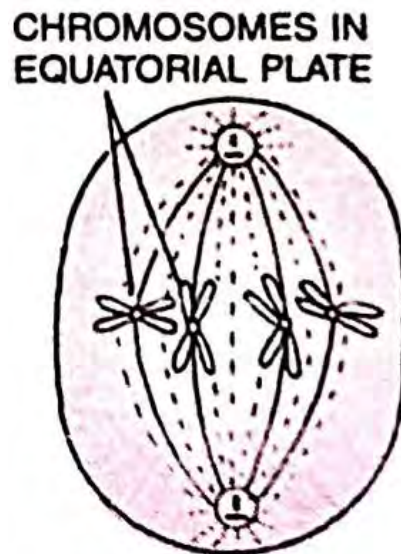


Fig. 1.3.3 Metaphase

- c. **Anaphase (G., ana = up; phasis = stage):** Anaphase, also known as migratory phase, is the shortest phase characterized by the following key events:
- The Centromere of each chromosome splits, forming two sister chromatids which later become daughter chromosomes.
 - These daughter chromosomes, each with a single chromatid, move towards opposite poles due to the contraction of spindle fibers and the stretch developed in the interzonal region.

- iii. During migration, the chromosomes appear like V, L, J and I in metacentric, submetacentric, acrocentric and telocentric chromosomes, respectively.
- iv. By the end of the phase, all daughter chromosomes reach opposite poles, ensuring the equal division of chromosome, and most spindle fibers disappear.

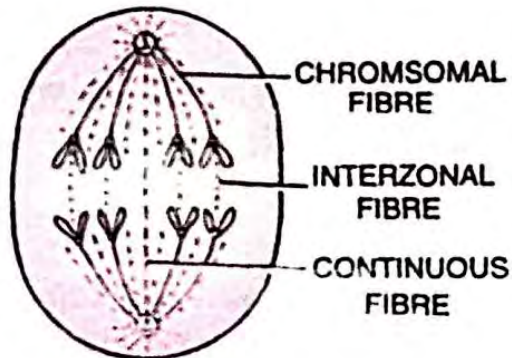


Fig. 1.3.3 Anaphase

- d. **Telophase** (G. 'telo' = end; 'phasis' = stage): Telophase, also known as the reorganization phase, is reverse of prophase. It is characterized by the following key events:
- i. Daughter chromosomes reach their respective poles, and as they do, they decondense through hydration and despiraling, transforming into long, thread-like chromatin fibers.
 - ii. Spindle fibers disappear while nucleolus and nuclear membrane reappear around each set of chromosomes.
 - iii. By the end of the phase, two daughter nuclei form at each pole.

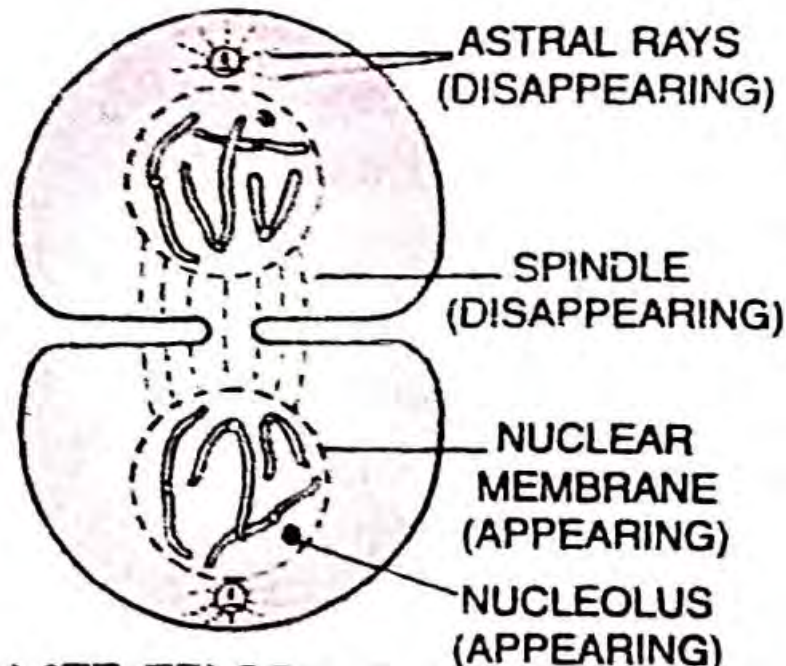


Fig. 1.3.3 Telophase

2. **Cytokinesis**: In this process, cytoplasm splits into two halves. It happens through the creation of a cell plate between two new daughter nuclei or through peripheral furrowing.

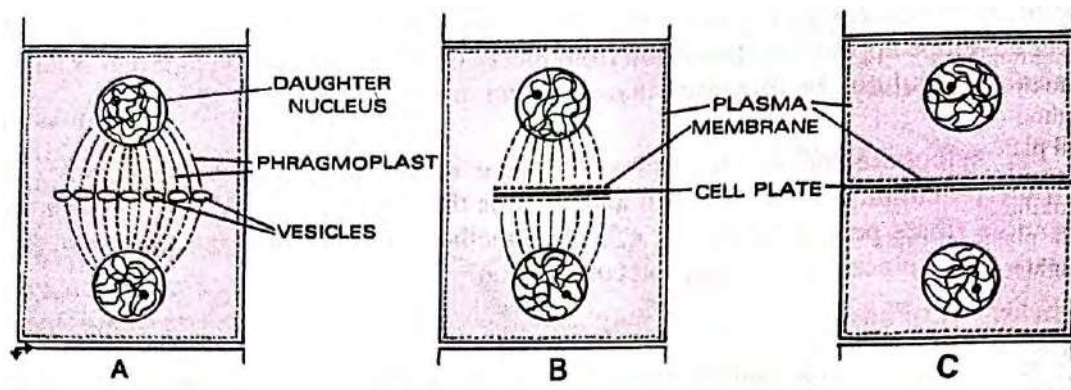


Fig. 1.3.4 Cytokinesis in animal and plant cell

- a. **Formation of cell plate:** In plant cells, cytokinesis involves the formation of a cell plate. Small granular bodies which are components of the Golgi complex and endoplasmic reticulum called phragmoplasts which gather at the cell's equator to form the cell plate.
- b. **Furrowing:** In bacteria, fungi, and animals, cytokinesis occurs through furrowing. Here, the gradual appearance of a peripheral cleavage furrow between the two daughter nuclei. The furrow deepens, and when its edges meet at the cell's center, the protoplasm divides into two daughter cells.

Fig. 1.3.3 Cytokinesis (Cell plate method in plant cells)

Significance of mitosis

1. Mitosis helps in growth of multicellular organisms from a zygote into an adult.
2. Mitosis is crucial for asexual reproduction in certain organisms, via fragmentation, budding, and stem cutting.
3. Mitosis ensures genetic stability by maintaining a consistent number of chromosomes in daughter cells.
4. Mitosis contributes to cell repair, regeneration, and heal wounds.
5. Mitosis controls cell size by inducing the division of overgrown cells.
6. Mitosis guarantees qualitatively and quantitatively genetic consistency between mother and daughter cells.
7. Uncontrolled mitosis causes cancer.

Activity: 1.3.1 Explore mitosis creating temporary and permanent slides.

Objective: Study of mitosis in onion root tips cells by preparing temporary slides and permanent slides.

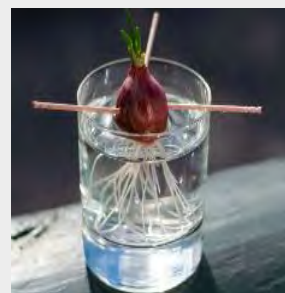
Part 1 | Growing Onion Roots | Day 1 – 5

Objective 1: Observe and document the growth of roots in an onion using a simple water-based method.

Materials: Fresh onion, toothpicks, transparent glass, water.

Procedure:

- Insert toothpicks around the middle of the onion.
- Place the onion, supported by toothpicks, in a half-filled glass of water.



Part 2 | Preparation and microscopic Observation of Onion Root Tip | Day 6

Objective 2: Prepare a temporary microscopic slide from a newly grown onion root, observe its cellular structure, and attempt to identify stages of mitosis.

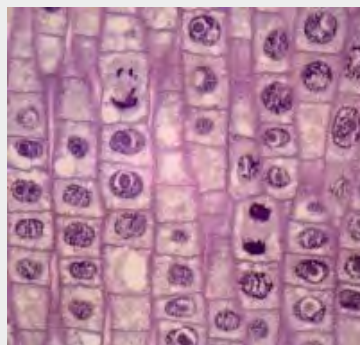
Materials: Just grown roots of onion, blade, microscope slides, coverslips, microscope, safranin.

Procedure:

- Gently pluck a young root from the just grown onion.
- Place a small section of the root on a watch glass.
- Add a few drops of safranin for a few seconds and wash with water.
- Cut a few thin slices (T/S) of the dyed root.
- Now, place them on a glass slide and cover with a coverslip.
- Observe under the microscope.

Observation:

Examine cells of the root tip under low (10x – 40x) and high (100x using immersion oil) magnifications.



- Note any visible structures, patterns, or characteristics.

3. REDUCTIONAL CELL DIVISION OR MEIOSIS (G., *meioun* = to lessen; *osis* = state)

It is the type of cell division in which a mature diploid mother cell divides into four haploid daughter cells. Since the number of chromosomes in daughter cells is reduced to half, it is also called reductional cell division. For the first time, meiosis was discovered and described by Oscar Hertwig in sea urchin eggs (1876).

Do you know?

Meiosis was first demonstrated by Belgian embryologist Edouard Van Benden (1883) in *Ascaris* roundworm eggs. The term "meiosis" was given by Farmer and Moore (1905).



Meiosis does not always occur in all cells, but in special types of cells like germ cells, pollen mother cells, megaspore mother cells when they are to undergo sexual reproduction. The cells that undergo meiosis are called meiocytes.

Interphase is observed prior to cell division, like in mitosis. However, G₂ phase is either short or absent in this type. Meiosis is a double cell division comprising: Meiosis I and meiosis II. The transition between these phases is short and without DNA replication. It is called **interkinesis**.

Meiosis I

Meiosis-I forms two daughter cells each bearing the half number of chromosomes than their mother cell.

It is divided into:

- A. Karyokinesis-I
- B. Cytokinesis-I.

A. Karyokinesis-I

It involves the division of nucleus in four distinct phases:

Prophase-I: This phase is complex and long which is simplified into five successive subphases.

- i. Leptotene or Leptonema
- ii. Zygotene or Zygonema
- iii. Pachytene or Pachynema
- iv. Diplotene or Diplonema
- v. Diakinesis

i. **Leptotene (G., 'leptos' = thin; 'tene' = thread):** Leptotene stage, also known as the thin-threaded stage, is characterized by following key events:

- b. The nucleus enlarges.
- c. The chromosomes become long and visible in the form of single-stranded threads called chromomeres due to condensation, thickening and shortening.
- d. The chromosomes' arrangement forms a bouquet at one side of the nucleus, known as the bouquet stage.
- e. The nuclear membrane and nucleolus remain intact.

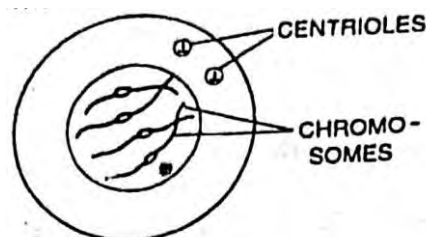


Fig. 1.3.3 Leptotene

- vi. **Zygotene (G., 'zygo' = yoke; 'nema' = thread):** Zygotene stage, also known as yoked-threaded or Zygonema stage is characterized by following key events:
 - a. Shorter, thicker, and coiled homologous chromosomes from the father and mother pair forming bivalents through a process called synapsis.
 - b. Asters continue to move away from each other.

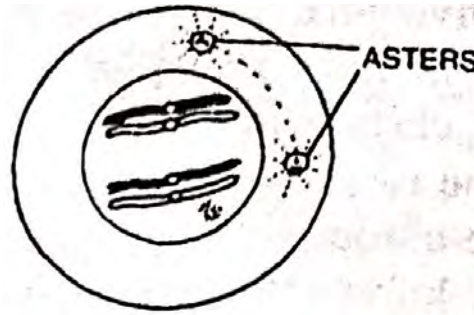


Fig. 1.3.3 Zygotene

- i. **Pachytene (G., 'pachys' = thick; 'nema' = thread):** The thick-threaded stage, also called pachynema, is relatively longer than Leptotene and Zygotene stages. It is characterized by following key events:
 - a. During this stage, the bivalents become shorter and thicker, and each homologous chromosome splits along its length, except in the centromere region forming two chromatids.
 - b. Each synaptonemal pair is called a bivalent or dyad because it comprises two visible chromosomes. Alternatively, it can be termed a quadrivalent or tetrad due to the presence of four visible chromatids. The two chromatids of the same chromosome are called sister chromatids.
 - c. Crossing-over occurs, involving the exchange of chromatid segments between non-sister chromatids of each tetrad, and the locations where crossing-over happens are termed chiasmata (singular: chiasma).

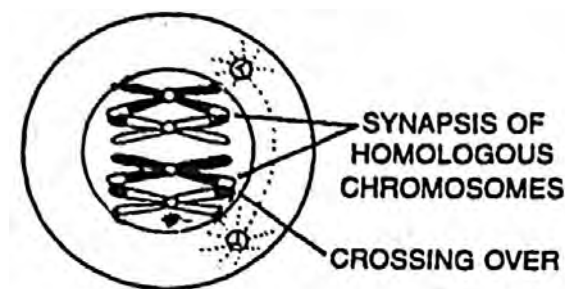


Fig. 1.3.3 Pachytene

- vii.
 - i. **Diplotene or Diplonema (G., "diplos" = meaning double and "nema" = thread)**
 Diplotene of Meiosis I is characterized by following key events:
 - a. Homologous chromosomes separate except in the region of chiasmata.
 - b. The nuclear membrane remains intact, while the nucleolus may either be small or start to degenerate.

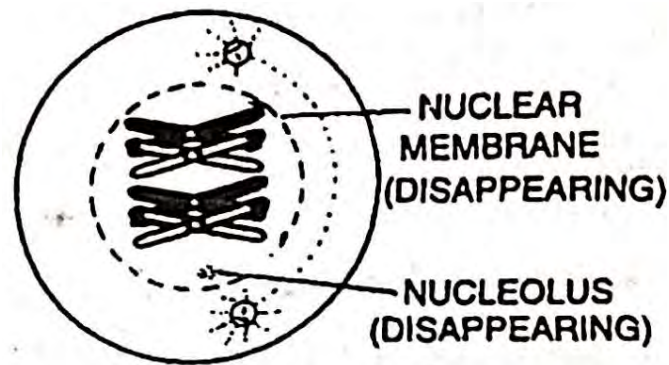


Fig. 1.3.3 Diplotene

- viii. **Diakinesis** (G., '*dia*' = across, '*kinesis*' = movement): In diakinesis stage, the final substage of prophase I in meiosis, the four parts of the tetrads are actually visible. This stage is characterized by following key events:
- Chromatids of a chromosome remain attached in the region of centromere.
 - The chromosomes bivalents move towards the periphery of the nucleus.
 - Chiasma shifts to the end of the chromosome. The process is known as terminalization.
 - Simultaneously the nuclear membrane and nucleoli disappear.
 - Spindle fibers start to develop.

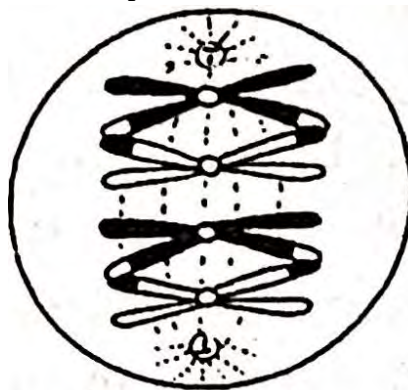


Fig. 1.3.3 Diakinesis

Metaphase-I

During the metaphase I stage of meiosis, the nuclear membrane and nucleolus disappear and the spindle fibers form. Homologous pairs or bivalents organize into two parallel equatorial or metaphase plates, with chromosomes or bivalents connected to the spindle fibers through their centromeres. The centromeres of bivalents are equally spaced from the equator and point toward the poles, while interzonal fibers form between the centromeres of bivalents.

- Nuclear envelope degenerates and spindle fibers appear.
- At this stage, bivalents get arranged on the equator.
- Chromosomes occur in bivalents having chiasmata.
- Chromosomes of a bivalent get attached to spindle fiber belonging to different poles.

Anaphase-I

After prophase I comes anaphase I stage which is characterized by following key events:

- ix. The centromere does not split, this keeps the two chromatids of each chromosome connected.
- x. Homologous chromosomes separate and move to opposite poles due to the contraction of spindle fiber and the repelling force between the bivalents as chiasmata break apart.
- xi. The homologous chromosomes moving to opposite ends are either from the father's (paternal) or mother's (maternal) side. This process is called **disjunction**.
- xii. By the end of the phase, two groups of chromosomes are formed, each containing half the number present in the mother cell.

Telophase-I

During telophase I phase of meiosis following key events take place:

- a. Each end of the cell receives one set of chromosomes with two chromatids, which then unwind into chromatin threads.
- b. The spindle fibers disappear.
- c. A nuclear membrane and a nucleolus reappear at the opposite poles, resulting in two daughter haploid nuclei.

Cytokinesis - I

All cells do not go through this stage. But when they do, animal cells form a “cell furrow” and plant cells form a “cell plate”. Each new cell, called a daughter cell, gets half the number of chromosomes as the original cell, known as the mother cell.

Interphase or Interkinesis

During interkinesis, the period between the first and second stages of meiosis, the cell focuses on protein and RNA production without synthesizing new DNA, known as the S-phase. This phase may vary in duration or may not occur at all. The cell prepares for the subsequent meiosis II division, ensuring the genetic material is ready for further division and the eventual production of four haploid cells from the two haploid cells produced in meiosis I.

Meiosis-II

This is also known as equational cell division because the number of chromosomes stays the same after the first stage of meiosis. It has two parts:

- (A) Karyokinesis-II
- (B) Cytokinesis-II.

A. Karyokinesis-II: This is divided into four phases.

1. Prophase-II:

During prophase II of meiosis, the chromatids become shorter, thicker, and more visible, with each chromosome having two chromatids attached at the centromere. Additionally, the nuclear membrane and nucleolus disappear, while spindle fibers appear. The chromatids are arranged at right angles to the spindle fibers from the first stage of meiosis.

2. Metaphase-II:

During metaphase II of meiosis, the nuclear membrane and nucleolus disappear, and chromosomes align along the middle of the cell. Each chromosome's centromere splits into

two, with each becoming the centromere for a chromatid. Additionally, each chromosome's centromere attaches to spindle fibers from both ends of the cell.

3. Anaphase-II:

During anaphase II of meiosis, the separation of the centromeres of sister chromatids takes place. This leads to the division of each chromosome's centromere by the contraction of the spindle fibers and the stretching of other fibers, sister chromatids move to opposite ends of the cell. This movement is facilitated by the spindle fibers, and the separated chromatids are now referred to as chromosomes

4. Telophase-II:

During telophase II of meiosis, chromosomes unwind, stretch out, and form a network of chromatin fibers at each end of the cell. Simultaneously, the spindle fibers disappear, and the nuclear membrane re-forms around the chromosomes, while the nucleolus reappears.

B. Cytokinesis-II

After Telophase II, the cell undergoes another division, forming a cell plate in plant cells or a cell furrow in animal cells. In meiosis, a diploid mother cell divides twice, producing haploid gametes with half the DNA of the mother cell.

Importance of Meiosis

1. Meiosis helps in formation of haploid gametes or spores which are essential for sexual reproduction.
2. It ensures a constant number of chromosomes in organisms, maintaining genetic balance.
3. It causes genetic variation. This happens through the exchange of genetic material between non-sister chromatids of similar chromosomes during crossing over.
4. It helps in gene segregation and independent assortment. This is due to the random distribution of chromosomes from the mother and father.
5. It can result in polyploid forms. If meiosis fails (disjunction disturbance), it can lead to cells with multiple sets of chromosomes.
6. It contributes to continuous variations. These variations are crucial for improving plant and animal breeds.
7. It reveals inter-relationships among sexually reproducing organisms. This is evident from the similarities in meiosis among these organisms.
8. It enables the alternation of generations. It allows for generations with one set of chromosomes and two sets of chromosomes in plants and animals.
9. It maintains the regularity of the reproductive cycle. It ensures a consistent cycle of reproduction in organisms.

Table: 1.3.3 Differences between mitosis and meiosis

Stage	Mitosis	Meiosis
General	Happens in body cells and germ cells during growth or gametogenesis.	Takes place in reproductive cells of gonads, known as meiocytes.
Prophase	Short phase with no sub-stages.	Prophase I lasts longer and has five sub-stages: Leptotene, Zygotene, Pachytene, Diplotene, and Diakinesis.
Metaphase	Chromosomes are double-stranded.	Chromosome pairs are in a four-part state in Metaphase I.
Anaphase	Each chromosome's two chromatids move to opposite spindle poles.	Each pair's two homologous chromosomes separate and move to opposite spindle poles.
Telophase	Always happens.	The first Telophase may not occur.
Cytokinesis	The division of cell contents to form two new cells begins in Anaphase or Telophase.	The cell divides exactly in half.
Interkinesis	Not applicable.	A rest period between Meiosis I and Meiosis II.
Significance	Daughter cells are genetically identical to the mother cell. The DNA amount is the same as in the mother cell.	Daughter cells are genetically different from the mother cells. The DNA amount is half that of the mother cell.

Project Work:

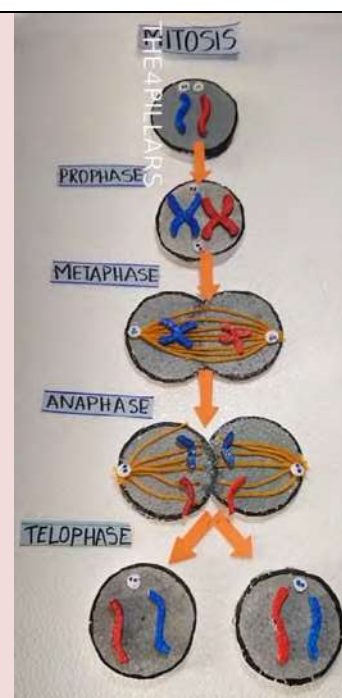
Group Model Creation of Cell Division Stages

Materials Required:

- Woolen thread
- Thermocol (Polystyrene)
- Chart paper
- Glue
- Color pencils
- Instructions:

Procedure:

- i. Divide the students into small groups, ensuring each group has access to the required materials.
- ii. Assign each group the task of creating a model depicting different stages of cell division using woolen thread on the provided chart paper.
- iii. Encourage collaboration within each group, as students use glue to secure the woolen thread on the chart paper and color pencils to label the stages.
- iv. Instruct groups to prepare a brief presentation explaining their model, focusing on the labeled components and stages of cell division.
- v. Facilitate a class session where each group presents their model to their classmates. Emphasize clarity and understanding during presentations.
- vi. Display all completed models on the classroom board. Engage the class in a discussion about the various approaches and details presented in each group's model.



EXERCISE

A. Tick the correct alternatives:

- Which of the following is a key difference between mitosis and meiosis?
 - Mitosis produces haploid cells, while meiosis produces diploid cells.
 - Mitosis involves one round of cell division, while meiosis involves two rounds.
 - Mitosis occurs in reproductive cells, while meiosis occurs in somatic cells.
 - Mitosis results in genetic variation, while meiosis results in genetic continuity.
- What is the main purpose of the cell cycle?
 - Repairing damaged cells
 - Allowing cells to grow and reproduce
 - Producing energy for the cell
 - Breaking down cellular waste
- How would you describe the phases and sub-phases of cell division?
 - The cell cycle, mitosis, and meiosis
 - Interphase, prophase, metaphase, anaphase, telophase
 - G1, S, G2, prophase I, metaphase I, anaphase I, telophase I, cytokinesis
 - Leptotene, zygotene, pachytene, diplotene, diakinesis
- What is a characteristic feature of mitotic cell division?
 - It produces gametes
 - It involves two rounds of division
 - It results in genetic variation
 - It produces genetically identical daughter cells
- Can you describe the role of centrioles in cell division?
 - They help in the formation of the mitotic spindle
 - They are responsible for cytokinesis
 - They aid in the separation of homologous chromosomes
 - They are involved in the synthesis of DNA
- How do you think changes in cell division could impact the growth and development of an organism?
 - By influencing the rate of tissue regeneration
 - By altering the patterns of gene expression
 - By affecting the stability of the genome
 - By modulating the efficiency of energy metabolism

B. Answer the following questions:

- Define cell cycle.
- What is mitotic cell division?
- What is meiosis?
- Name the phases of cell division.
- What is the difference between mitotic and meiotic cell division?
- What is the significance of mitotic cell division?
- Explain the difference between mitosis and meiosis in terms of the number of daughter cells and their genetic composition.
- How can one identify the phase of cell division through microscopic study?

9. Describe the phases and sub-phases of cell division in detail.
10. Compare the difference between mitotic and meiotic cell division in terms of their roles in an organism.
11. Explain the significance of meiotic cell division.
12. How can understanding the difference between mitosis and meiosis be applied in the field of genetics?
13. How can identifying the phase of cell division be useful in medical diagnosis and treatment?
14. How can knowledge of the phases and sub-phases of cell division be applied in the field of cell biology?
15. How can understanding the difference between mitotic and meiotic cell division be applied in the field of reproductive biology?
16. How can understanding the significance of mitotic and meiotic cell division be applied in the field of medicine?
17. Analyze the role of mitosis and meiosis in the life cycle of a sexually reproducing organism.
18. Evaluate the importance of being able to identify the phase of cell division in the context of cancer research.
19. Compare and contrast the roles of mitotic and meiotic cell division in the context of human health and disease.

Unit 2

FLORAL DIVERSITY



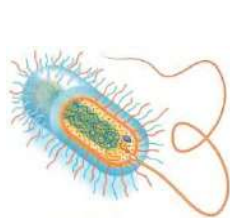
R.H. Whittaker
(1920-1980)

Robert Harding Whittaker was one of the foremost international scholars of ecology and evolutionary Biology of the 20th century. Whittaker played a leadership role in some of the most fundamentals in ecology of the 20th century. He was the first to propose the five kingdom taxonomic classification of the world's biota into the Monera, Protista, Fungi, Plantae and Animalia in 1969. He also proposed the Whittaker Biome classification, which categorized biome-types upon two abiotic factors: Temperature and precipitation. He was diagnosed with lung cancer and died on 20th October, 1980.

Chapter 2.1

Introduction to Floral Diversity

Observe the pictures and discuss the following questions:



(a)



(b)



(c)



(d)



(e)

- i. Identify the organisms.
- ii. What makes them differ from one another?
- iii. Name the kingdom to which the following organisms belong?
- iv. ii. Why is it important to classify living things?
- v. What do you think, how many types of plants are found in Nepal?

2.1.1 INTRODUCTION

The living species are the product of millions of years of organic evolution on earth. During this period many species appeared and disappeared. We are familiar with only a few species which inhabit or visit our surroundings. Even a short look at the small number of species around us at once shows diversity of life. A rose appears different from a lotus; a dog appears different from a cat. This simple instance is just a glimpse of the vast variety that exists in entire living world. The varieties of living things found on the earth are known as biodiversity or biological diversity. Biodiversity includes all the plants, animals, microorganisms and fungi. The study of varieties of plants from all sources is termed as floral diversity. It includes number of plants present, variation within and between species at the genetic level and role and function that plays in an ecosystem.

2.1.2 THREE DOMAINS OF LIFE

‘Domains’ are the top level classification that categorizes the life in the most general way. The three domain of life is a biological classification discovered by Carl Woese (1990). This classification system is also known as “Three Domains Classification” because it divides the life forms into three domains on the basis of differences of rRNA sequence. The domains of life are Archaea, Bacteria and Eukarya.

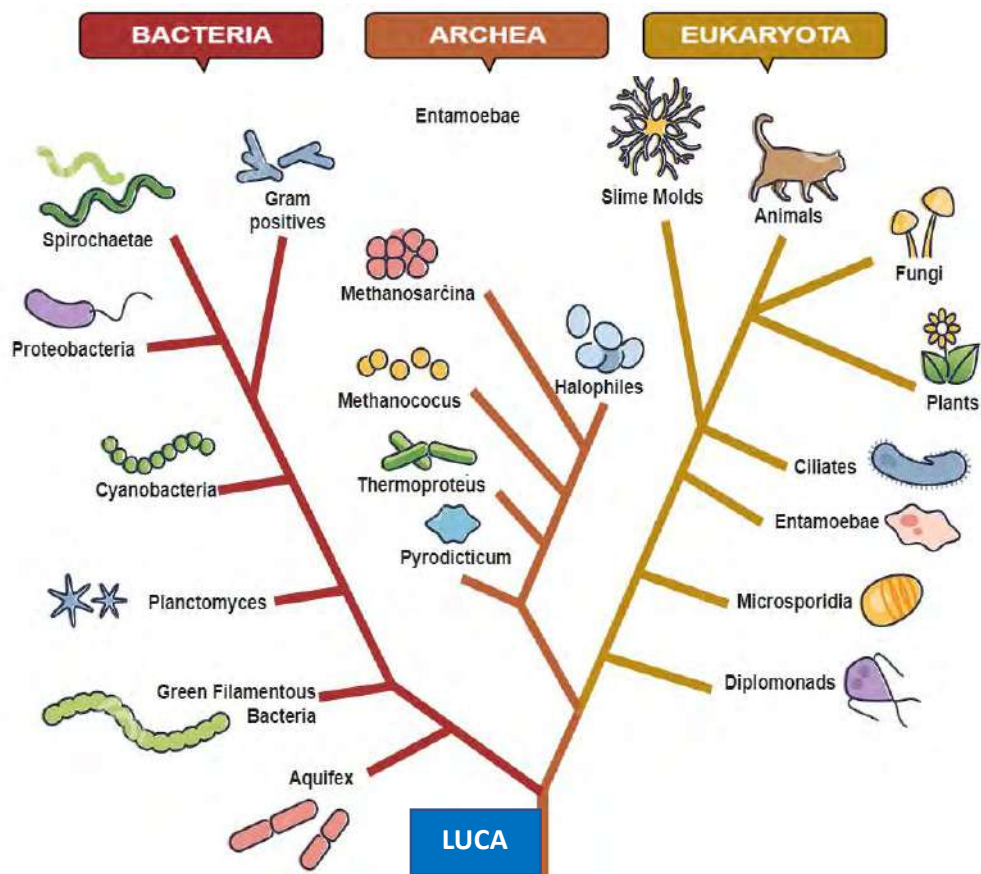


Figure 2.1.1 Phylogenetic tree

<i>Archaea</i>	<i>Bacteria</i>	<i>Eukarya</i>
1. They are early prokaryotes that live in extreme environments.	1. They are typical prokaryotes.	1. They are all eukaryotic organisms.
2. Cell walls is made up of polypeptide or pseudopeptidoglycan.	2. Cell wall is made up of peptidoglycan.	2. Cell wall is made up of polypeptide.
3. Hydrocarbon chain in cell membrane consist ether bond.	3. Hydrocarbon chain in cell membrane consist ester bond.	3. Hydrocarbon chain in cell membrane consist ester bond.
4. It includes archaeobacteria.	4. It includes Eubacteria.	4. It includes Protista, Fungi, Plantae and animalia.
5. They are unicellular.	5. They are unicellular, rarely multicellular.	5. They unicellular or multicellular.
6. Resistant to traditional antibiotics.	6. Sensitive to traditional antibiotics.	6. Resistance to traditional antibiotics.



Questions to think?

Why is Archaea domain considered closer to Eukarya than Bacteria?

2.1.3 BINOMIAL NOMENCLATURE

There are millions of plants and animals in the world. The plants and animals in our area are known by their local names. The same plants and animals are known by different common names in different languages, even within a country. This creates the confusion on recognizing the organisms. So, the standard method of naming the organisms is required. Carolous Linnaeus develops a system of scientific or technical names for animals and plants. The system is known as **binomial nomenclature**. In this system, each organism is given a name of two words. The first word indicates the genus or **generic epithet**. The second word refers to the **species or specific epithet**. For example: the scientific name of rice is written as *Oryza sativa*. In this binomial name, *Oryza* represents the genus and *sativa* indicate a particular species. These binomial nomenclatures ensure that a name has not been used for any other organism.

The binomial nomenclature (scientific name) are established on basis of certain principles and criteria developed by number of scientists belonging to International Code for Botanical Nomenclature (ICBN), International Code for Zoological Nomenclature (ICZN), International Code for Bacterial Nomenclature (ICBaN) and International Code of Viral Nomenclature (ICVN).

Some important rules of binomial nomenclature are as follows:

1. The Scientific name should be derived from Latin or Greek languages or should be Latinized.
2. The scientific name consists of two names, in which the first name denotes the generic name while second name denotes the specific name.
3. The generic name should always begin with capital letter while specific name should begin from small letter.
4. The scientific name should be written in italics if printed or computerized or should be separately underlined if handwritten.
5. The generic name is always single word and can be abbreviated by using only its first letter followed by dot if the generic name is mentioned earlier (like, *E. coli*) while specific name may be single or compound and never be used in abbreviated form. (like, *Hibiscus rosa-sinesis*)
6. The name of author is written either in full or in abbreviated form after the name of species. E.g. *Mangifera indica* L. Here 'L' indicates the name of author i.e. Linnaeus.

Activity 2.1

Write the common name and scientific name of any five organisms from each of the following groups: vegetables, fruits, wild plants, domestic animals and wild animals. Present your work in chart paper and show in class.

2.1.4 FIVE KINGDOM CLASSIFICATION SYSTEM

The five kingdom system for classification of living organisms was proposed by Robert H. Whittaker (1969). He divided all the organisms in five kingdoms i.e. Monera, Protista, Plantae, Mycota and Animalia on basis of following criteria:

1. Complexity of cell structure: Prokaryotic or eukaryotic

2. Complexity of organism's body or level of structural organization: unicellular or multicellular
3. Mode of obtaining nutrition: Autotrophic or heterotrophic
4. Ecological role: Producers, consumers or decomposers
5. Phylogenetic relationship: evolutionary history of an organism

Table 2.1.1: Characteristics of five Kingdoms

Characters	Monera	Protista	Fungi	Plantae	Animalia
Complexity of cell Structure	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Complexity of body	Unicellular/ Multicellular	Unicellular	Unicellular/ Multicellular	Multicellular	Multicellular
Mode of nutrition	Autotrophic/ Heterotrophic	Autotrophic/ Heterotrophic	Heterotrophic	Autotrophic	Heterotrophic
Ecological role	Producer/ Decomposer	Producer/ Consumer	Decomposer	Producer	Consumer
Examples	Bacteria, Cyanobacteria etc.	<i>Amoeba</i> , <i>Euglena</i> , <i>Paramecium</i> etc.	Mushroom, Yeast, <i>Mucor</i> etc.	<i>Spirogyra</i> , <i>Pinus</i> , Mustard etc.	Tiger, Starfish, Snail etc.

2.1.5 STATUS OF FLORA OF NEPAL AND WORLD REPRESENTATION

Nepal occupies about 0.1% of the global area but harbors 3.2% of floral diversity and 1.1% of faunal diversity. Nepal's unique geography with its dramatic changes in elevation along north-south transects, high variability in the physiographic and climatic conditions have resulted in rich diversity of flora and fauna.

Table: Status of Floral species diversity and world representation

S.N.	Group	Number of known species	% of known species in the world
1	Algae	1,001	2.5
2	Fungi	2,025	2.6
3	Lichens	771	2.3
4	Bryophyta	1,150	8.2
5	Pteridophyta	534	5.1
6	Gymnosperm	28	5.1
7	Angiosperm	6,973	3.2
Total		11,971	3.2

Source: GON, Ministry of forest and soil conservation, 2014

EXERCISE

A. Tick the correct alternatives:

- Which of the given domain is characterized by ancient bacteria that can live in extreme environments?
 - Archaea
 - Bacteria
 - Eukarya
 - Prokarya
- Who introduced five kingdom classification system?
 - G.J. Mendel
 - R.H. Whittaker
 - Charles Darwin
 - Carolus Linnaeus
- Use the rule of binomial nomenclature to determine which is the correct scientific name for the lion?
 - Panthera leo
 - Panthera Leo*
 - Panthera leo*
 - panthera leo
- If any organism has eukaryotic cells, lack of photosynthetic pigment and are consumers of an ecosystem, what kind of kingdom it should belong according to Whittaker classification?
 - Fungi
 - Plantae
 - Monera
 - Animalia

B. Answer the following questions:

- What are three domains of life? Explain.
- Bacteria and Archaea were kept in same kingdom in two kingdom classification system but now they are separated in two different domains. Why it became necessary to separate them?
- Differentiate between Common name and scientific name.
- What is binomial system of nomenclature? Mention its rules.
- Describe the criteria for development of five kingdom system of classification.
- The common name of cauliflower is simpler than its scientific name *Brassica oleracea*. Why is then simpler common name not used instead of the complex scientific name in Biology?
- Which organism is more complex among bacteria, mushroom and apple tree. Give reason.
- Explain the status of flora in Nepal and its world representation.

Project Work:

Write the name of different types of organisms found in your locality, identify and classify them into five kingdom and present your work in chart paper and discuss in class.

Chapter 2.2

FUNGI

Observe the picture and discuss the following questions:



(a)



(b)

- i. Have you ever seen white or grey woolly structure on stale bread or fruit?
- ii. What might be the cause of their spoilage?
- iii. Why do you think bakers usually add yeast to their dough?
- iv. Can you think any other examples of how fungi are used by humans?

2.2.1 GENERAL INTRODUCTION

Fungus (latin; fungour- to flourish) are non-green, nucleated, non-vascular thallophytes. They are eukaryotic organisms and include yeasts, moulds and mushrooms. The branch of Botany that deals with fungi is called mycology. The scientist who is concerned with fungi is called mycologist.

They grow in diverse habitats i.e. found in almost every available habitat on earth where organic material is present. They occur in air, water, soil and on animals and plants. They prefer to grow in warm and humid places. Fungi are multicellular except yeast. Except yeast, the body of fungus is made up of long, slender thread like structures called hyphae. The network of hyphae is known as mycelium. Some hyphae are continuous tubes filled with multinucleated cytoplasm called as coenocytic hyphae while other have septa or cross walls in their hyphae. The cell wall of fungi is made up of chitin.

Fungi are heterotrophic and absorb soluble organic matter from dead substrates and hence are called saprophytes. Some are parasites (e.g. *Fusarium*). They can also live as symbionts-in association with algae as lichens and with roots of higher plants as mycorrhiza. Reproduction in fungi takes place by vegetative, asexual and sexual method.



Questions to think?

Originally fungi were classified as plant, but now they have their own kingdom called fungi or Mycota. What might be the reason behind it?

2.2.2 CLASSIFICATION

On the basis of morphology of the mycelium, mode of spore formation and fruiting bodies Kingdom Mycota is classified into various classes.

1. Phycomycetes (The algal fungi)

Characteristics features of phycomycetes are as follows:

- They are found in aquatic habitats and on decaying wood in moist and damp places or as obligate parasites on plants.
- Thallus is mycelium. The mycelium is aseptate and coenocytic.
- Asexual reproduction takes place by the formation of spores which are produced inside sporangium. Terrestrial species produced aplanospores and aquatic species produced zoospores.
- The zoospores may be uniflagellate or biflagellate.
- The sexual reproduction may be isogamous or oogamous.

The class Phycomycetes is further classified into sub-classes, oomycetes and zygomycetes.

Oomycetes	Zygomycetes
1. Generally they are parasite.	1. Generally they are saprophytes, rarely parasites.
2. Asexual reproduction takes place by the formation of motile biflagellate zoospore.	2. Asexual reproduction commonly takes place by the formation of non-motile spores. Oidia and chlamydospores may be formed.
3. Sexual reproduction is by gametangial contact.	3. Sexual reproduction occurs by gametangial copulation or conjugation.
4. The fusion of male and female gametes produces oospore.	4. The gametangial fusion produces resting diploid spores, called zygospores.
Examples: <i>Albugo</i> , <i>Plasmopora</i> , etc.	Examples: <i>Rhizopus</i> , <i>Mucor</i> , etc.



a. *Mucor* growing on strawberry



b. *Albugo* on leaf

Fig: 2.4.1 Phycomycetes

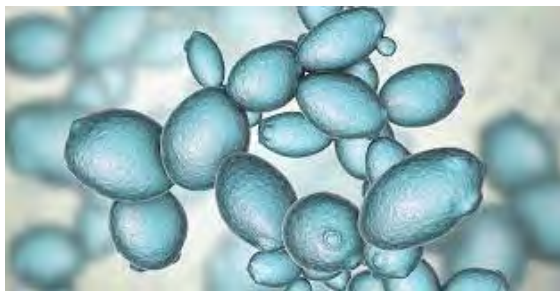
2. Ascomycetes (Sac fungi)

Characteristics features of ascomycetes are as follows:

- They are commonly known as sac-fungi due to presence of special sac like structure called ascus.
- Most of them are terrestrial and occur as saprophyte or parasite.

- c. They are multicellular, mycelium consists of septate hyphae but yeast is unicellular. Septa possess central pores.
- d. There is complete absence of motile structure in the life cycle.
- e. Asexual reproduction takes place by conidia produced by conidiophores. Conidia on germination produce mycelium.
- f. Sexual reproduction takes place by sexual spores called as ascospores produced in ascus.
- g. Asci may occur freely or grouped to form definite multicellular structure of fruiting body called ascocarp.

Examples: *Saccharomyces*(yeast), *Penicillium*, *Aspergillus*, *Claviceps*, *Neurospora*, etc.



a. *Saccharomyces* (Yeast)



b. *Aspergillus*

Fig: 2.4.2 Ascomycetes

3. Basidiomycetes (Club fungi)

Characteristics features of basidiomycetes are as follows:

- a. They are found in soil, on logs and tree stumps and in living plant bodies as parasites.
- b. Mycelium are filamentous, branched and septate hyphae. Each septum consists of a pore called dolipore.
- c. Mycelium are of two types: primary mycelium and secondary mycelium.
- d. Primary mycelium is monokaryotic, develops from the germination of basidiospores.
- e. Secondary mycelium is long lived and septate. They are dikaryotic, and formed by the fusion of primary mycelia.
- f. Vegetative reproduction takes place by fragmentation but the asexual spores are generally not found.
- g. The dikaryotic cell is formed during sexual reproduction.

Examples: *Agaricus* (Mushroom), *Ustilago* (smut), *Puccinia*, etc.



a. *Agaricus*



b. *Ustilago*

Fig: 2.4.3 Basidiomycetes

4. Deuteromycetes (Fungi imperfecti)

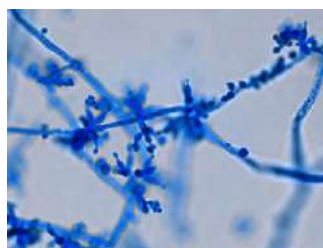
Characteristics features of deuteromycetes are as follows:

- They are commonly known as imperfect fungi because only the asexual or vegetative phases of these fungi are known.
- They are saprophytes or parasites.
- The mycelium consists of well developed, branched and septate hyphae.
- Asexual reproduction takes place by the formation of conidia.
- Sexual reproduction is absent.

Examples: *Alternaria*, *Trichoderma*, *Alternaria*, *Cladosporium*, etc.



a. *Alternaria*



b. *Trichoderma*

Fig: 2.4.4 Deuteromycetes

2.2.3 MUCOR

Systematic Position

Kingdom	: Mycota
Division	: Zygomycota
Class	: Phycomycetes
Order	: Mucorales
Family	: Mucoraceae
Genus	: <i>Mucor</i>

Occurrence

It is commonly known as black mould or bread mould. They are saprophytic and occur on bread, jam, jelly, cheese, pickle, leather, cattle dung, food stuffs and soil rich in humus.

Morphology

The vegetative bodies of *Mucor* consist of long, cylindrical, branched, coenocytic hyphae. The group of hyphae is known as mycelium. Mycelium consists of three types of hyphae:

- Submerged/sub-terranean hyphae: They are highly branched, smaller and penetrate the substratum spreading inside the body of substratum. They help in absorption of nutrients and fixation.
- Prostrate hyphae: They are highly branched and spread in all direction on the surface of substratum that helps to fix to the substratum.
- Aerial hyphae: They are aerial hyphae growing vertically from the prostrate hyphae. They bear sporangia at its tip so it is also known as sporangiophore. They help in asexual reproduction.

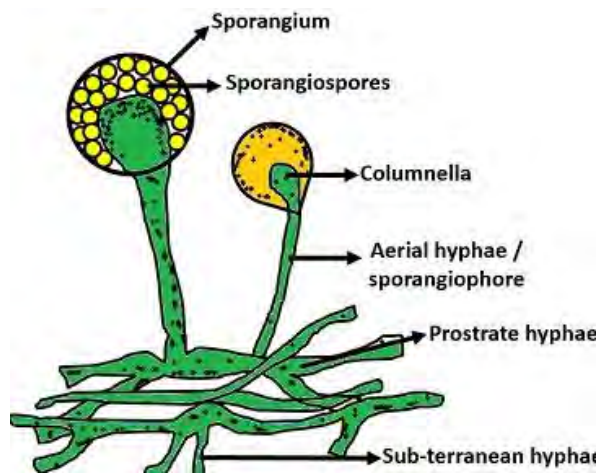


Figure 2.4.5 Morphology of vegetative body of *Mucor*

Reproduction

Mucor reproduce by vegetative, asexual and sexual method.

1. Vegetative reproduction:

It takes place by fragmentation. During unfavourable condition the hyphae are fragmented mechanically or by decay. On return of favourable condition, these fragments develop into new mycelium.

2. Asexual Reproduction:

Asexual reproduction takes place by non-motile structure known as sporangiospores, chlamydospores and oidia,

a. Sporangiospores or spores:

The reproduction by sporangiophore takes place during favourable condition. The spores are produced inside the sporangia which develop at the apices of special erect aerial hyphae called sporangiophores. The sporangium consists of two distinct region-the outer fertile region called sporangial proper and inner dome shaped sterile region called columella. The nuclei of sporangial proper divide mitotically for several times and form number of multinucleated sporangiospore.

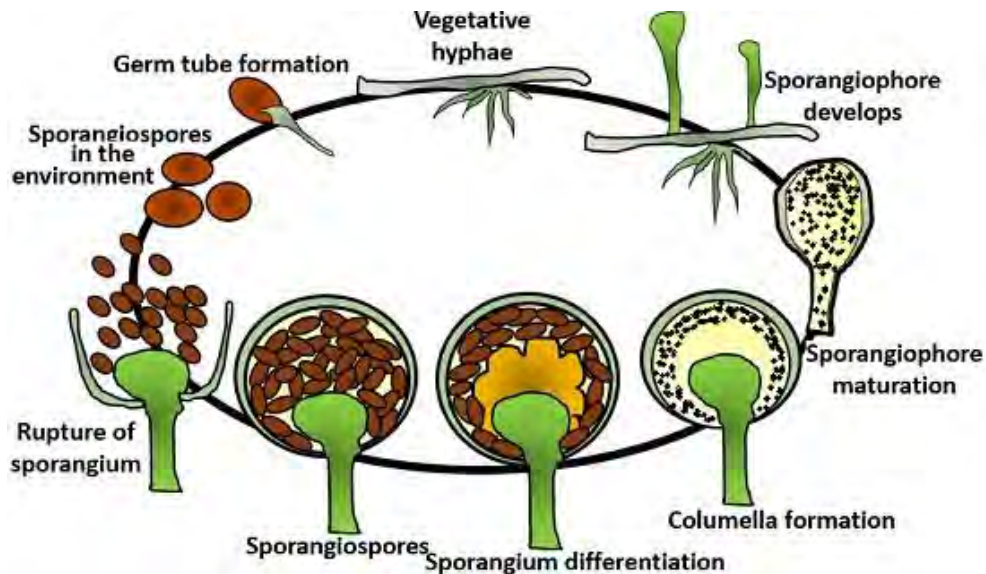


Figure 2.4.6 Reproduction by sporangiospore in *Mucor*

After maturation, the columella swells and the sporangial wall bursts so the sporangiospores are liberated out. On reaching a suitable substratum, they germinate to give rise to new mycelium.

b. Chlamydo spores:

They are formed during unfavourable condition. The protoplasm of hyphae collects at certain places, rounds off accumulates a lot of food materials and develops a thick wall to form chlamydo spores. During favourable condition, these chlamydo spores germinate to form new mycelium.



Figure 2.4.7 Chlamydo spore

c. Oidia:

Hyphae of certain *Mucor* when growing in a liquid medium rich in sugar, become septate. Then septate cells round off to form reproductive structures called oidia. They take part in fermentation and multiply by budding like yeast. When taken to solid medium, oidia produce new mycelia.

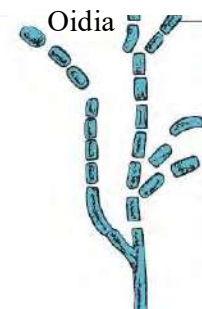


Figure 2.4.8 Oidia

3. Sexual Reproduction:

Sexual reproduction in *Mucor* takes place by conjugation (i.e. gametangial copulation) during unfavourable conditions. It takes place between the mycelia of two different mating types (i.e. heterothallic).

During sexual reproduction, two opposite strains of hyphae i.e. +ve strain and -ve strain come close together and develop short club-shaped protuberances called progametangia. They come in contact at the tip and septum appears in each progametangium that divides it into a basal suspensor and a terminal gametangium. After some time, the contact walls of the two gametangia dissolve and two gametes fuse together to form zygote having number of diploid

nuclei. The process is called conjugation. The zygote grows in size, become rounded and secretes a wall and this structure is known as zygosporangium.

The zygosporangium undergoes a resting for a while. It has dense cytoplasm containing a number of diploid nuclei, cell organelles and food reserve. After resting period, the zygosporangium germinates. Out of many diploid nuclei of zygosporangium only one is functional. This functional nucleus divides by meiosis into four haploid nuclei, among them three degenerate and one divides many times to form many nuclei of same strain. The protoplast of zygosporangium swells up, ruptures outer wall and comes out in the form of a vertical germ-tube, called promycelium. The tip of promycelium swells up and forms rounded germ sporangium which produces non-motile, uninucleate, haploid germ spores. The germ spores are liberated and on suitable substratum, they germinate to form new mycelium.

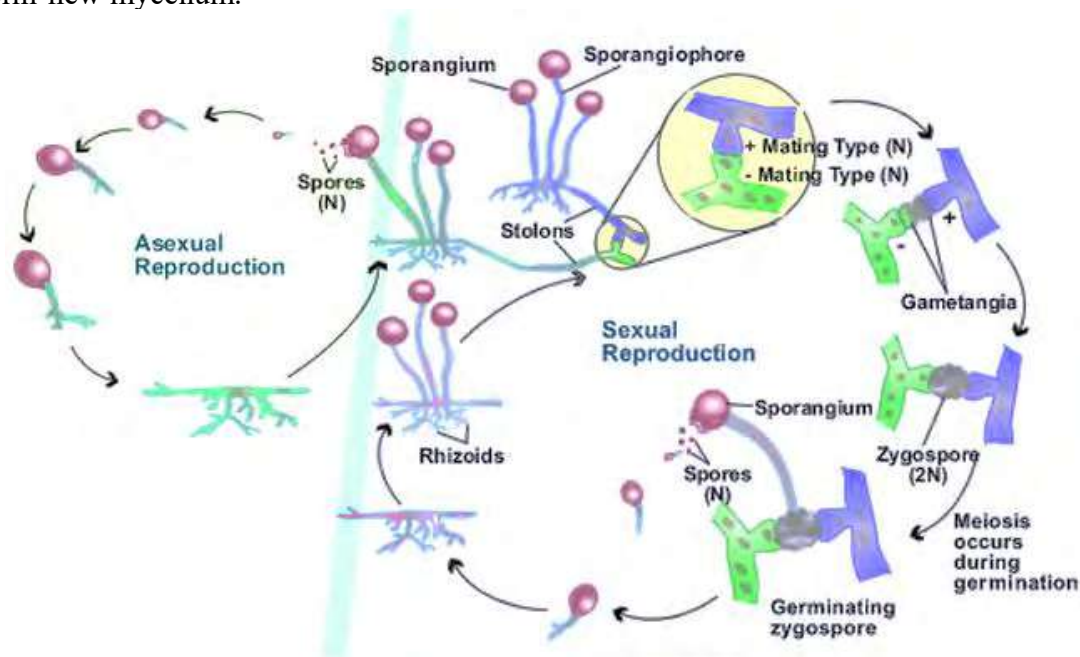


Figure 2.4.9 Life cycle of *Mucor*

Activity 2.2: To observe the *Mucor* growth on bread.

Material Required:

1. Bread slice
2. Plastic bag
3. Clear tape
4. Water
5. Magnifying glass or Microscope

Procedure:

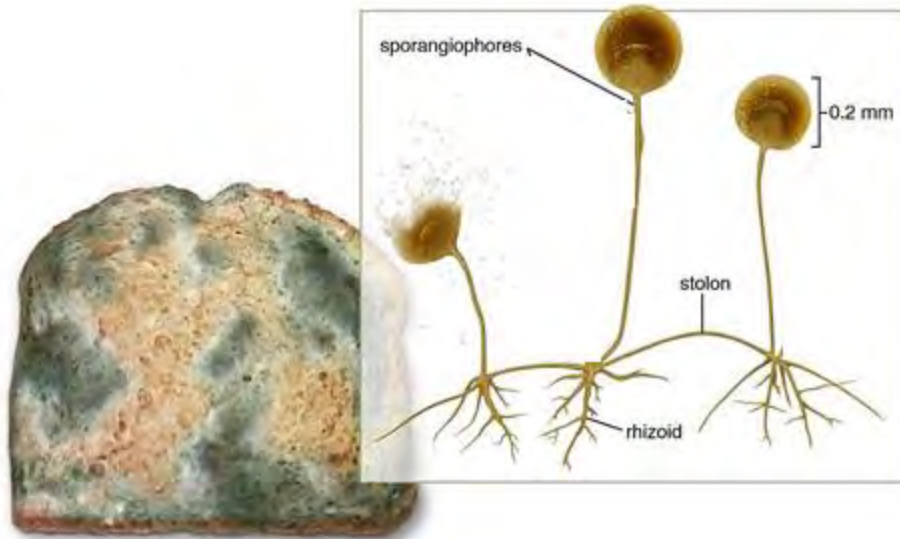
- Damp the bread with few drops of water.
- Place the damp bread in plastic bag and seal with tape.
- Place the bag in a warm area out of direct sunlight.
- Observe it daily until *Mucor* is seen.
- Use magnifying glasses or microscope (taking few threads from this mould and placing them on slide).

Observation:

Thread like structure with dark pin head is seen on the bread.

Description and Conclusion:

Describe the appearance like colour, texture, structure etc. and write it on practical sheet with diagram of *Mucor*.

**2.2.4 YEAST****Systematic Position**

Kingdom	: Mycota
Division	: Ascomycota
Class	: Saccharomycetes
Order	: Saccharomycetales
Family	: Saccharomycetaceae
Genus	: <i>Saccharomyces</i>

Occurrence

They are saprophytic fungi and are cosmopolitan in distribution. They grow on rotting fruits, cane juice, nectaries of flowers, sweets, decaying organic matter and milk products. Some yeast grows as parasites on plants and animals (e.g. *Candida albicans*).

Morphology

Yeast is non-mycelial unicellular fungi having oval or spherical cell. Sometimes, the yeast may form branched or unbranched temporary chain of up to 100 cells and this is known as pseudomycelium. Cell wall of each cell is thin, delicate and made of chitin. Cell membrane lies inner to cell wall. The cytoplasm is containing the cell organelles like mitochondria, endoplasmic reticulum, Golgi bodies, ribosome, and reserve food materials in the form of glycogen or fats. A large central vacuole surrounded by the membrane, tonoplast is present. Nucleus is attached at one end of a large central vacuole. Such type of vacuole is called nuclear vacuole.

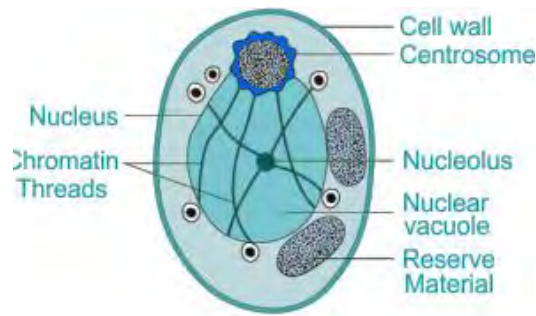


Figure 2.4.10 Structure of Yeast cell

Reproduction

Yeast reproduces by vegetative and sexual method.

1. Vegetative method:

Vegetative method in yeast takes place during favourable condition. It takes place by budding and fission method.

a. By budding:

It is the common method of reproduction in yeast, takes place during favourable condition i.e. in sugar solution.

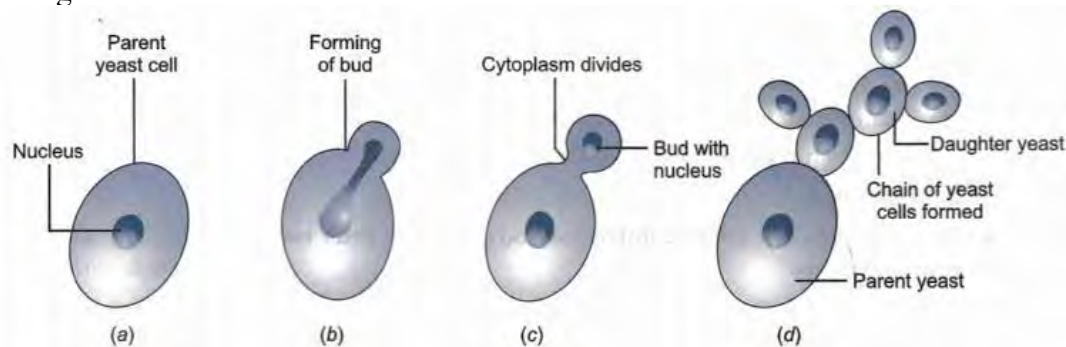


Figure 2.4.11 Budding in Yeast

During this process, a small bud like out growth appears at one end of the parent cell which gradually enlarges in size. The nucleus enlarges and divides amitotically into two daughter nuclei. One nucleus along with other cytoplasmic contents passes into the bud and the other remains in the parent cell. The vacuole almost disappears at this stage. Gradually the bud becomes almost of the same size as the parent cell. Wall formation occurs between the bud and mother cell. Then the bud behaves as a new individual. During rapid growth, the daughter cell also gives bud while still attached to the mother cell, this form false mycelium known as pseudomycelium.

b. By fission:

During this process, a somatic cell of yeast enlarges in size and its nucleus is divided into two daughter nuclei. Then a partition wall is formed at the middle of the cell dividing the parent protoplasm into two halves each having one nucleus. These halves then separate into two cells and lead an independent life.

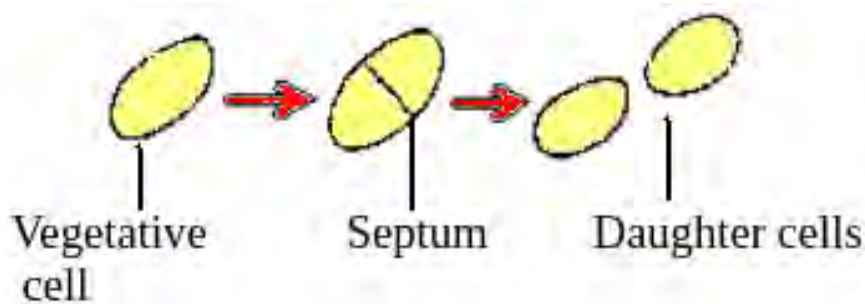


Figure 2.4.12 Fission in yeast

2. Sexual Reproduction:

It takes place during unfavorable condition. The sex organs are not formed in yeast and the sexual fusion occurs between two vegetative cells of opposite mating type, which behave as gametangia. It is known as conjugation. Depending upon the prominence of haploid or diploid phase, the sexual life cycle of yeast is of following types:

a. Haplobiontic life cycle:

This type of sexual life cycle occurs in *Schizosaccharomyces octosporus*. In this type of life cycle, the haploid phase is dominant than diploid phase.

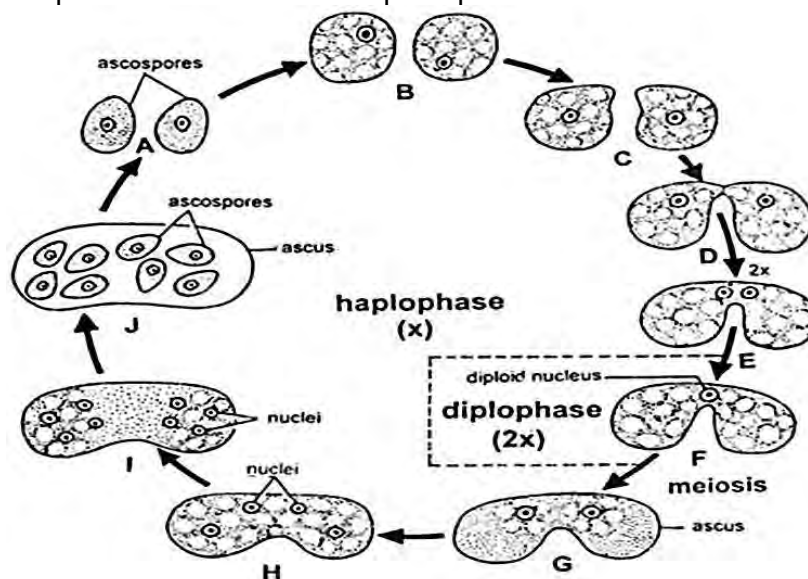


Figure 2.4.13 Haplobiontic life cycle of yeast

Two haploid cells of opposite strain come together and behave as gametangia. They develop an outgrowth toward each other and come in contact with each other. The contact wall dissolves and forms conjugation tube. The nuclei of two gametangia in the tube fuse to form a diploid zygote. The zygote grows and acts as an ascus. The diploid nucleus divides meiotically to form four haploid nuclei which further divide mitotically to form eight nuclei. Each nucleus develops into an ascospore within the ascus. After maturity, the wall of the ascus ruptures and the ascospores are liberated and act as haploid, uninucleate independent vegetative cell of yeast.

b. Diplobiontic life cycle:

This type of sexual life cycle occurs in *Saccharomyces ludwigii*. In this type of life cycle, the diploid phase is dominant than haploid phase.

During unfavourable condition, the diploid somatic cell directly behaves as ascus. The nucleus undergoes meiotic cell division to form four haploid somatic nuclei of two mating type

that develop into four ascospores. The ascospores of the opposite mating types undergo conjugation inside the ascus. The zygote cell formed within the ascus develops a germ tube. The germ tubes break the ascus wall and form a 'sprout mycelium'. The sprout mycelium produces several diploid somatic cells.

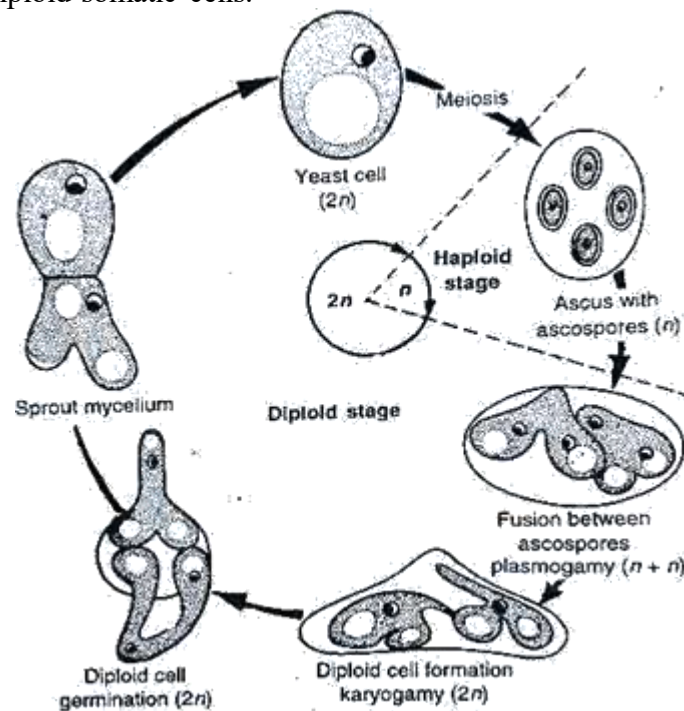


Figure 2.4.14 Diplobiontic life cycle of yeast

c. Haplodiplobiontic life cycle:

This type of sexual life cycle occurs in *Saccharomyces cerevisiae*. In this type of life cycle, both haploid and diploid phases are equally dominant in the life cycle.

During this type of life cycle, two haploid somatic cells unite to form diploid zygote. Zygote also behaves as diploid somatic cell and multiplies by budding to produce number of diploid somatic cells. Each of the diploid somatic cell behaves as ascus, nucleus of which divides meiotically to produce four haploid nuclei. Each of these nuclei organizes into ascospores. Ascospores, on liberation from ascus multiply by budding and produce haploid somatic cells.

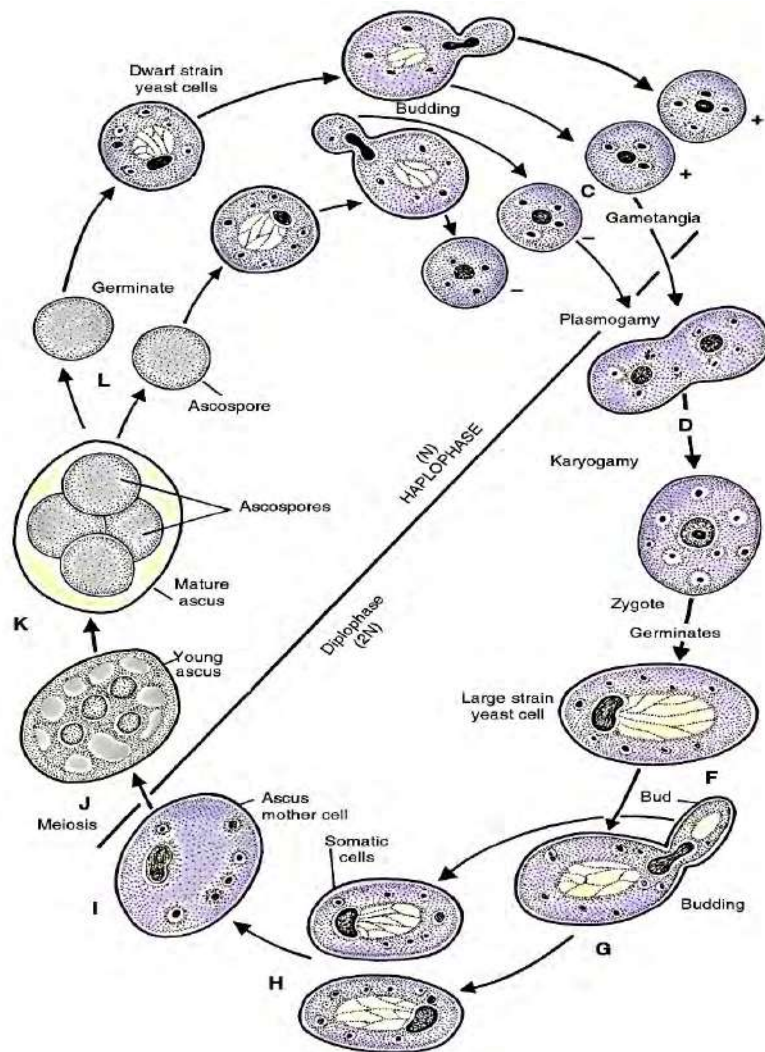


Figure 2.4.15 Haplodiplobiontic life cycle of yeast

2.2.5 INTRODUCTION OF MUSHROOM

Mushroom is saprophytic fungus grow on damp and dead organic substances such as humus, animal dung, damp rotten logs of wood, trunks of trees and meadows rich in decaying organic matter. The mushrooms are commonly seen growing on grasslands and other places rich in humus soil during rainy season.

The body of mushroom is divided into two main parts:

1. Mycelium or vegetative body
2. Basidiocarp or fruiting body

1. Mycelium or vegetative body:

It is comprised of profusely branched thread like structure known as hyphae growing in the substratum. It remains hidden under the soil. The network of hyphae forms the mycelium and fruiting body.

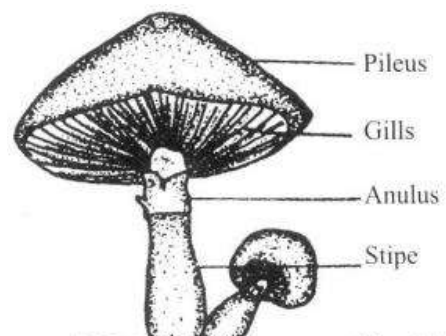


Figure 2.4.16 Structure of mushroom

2. Basidiocarp or fruiting body:

The fruiting body consists of a fleshy cylindrical stalk, known as stipe and an umbrella like head or cap called pileus. Stipe and pileus are made of interwoven mass of hyphae. During young stage, the fructification is the rounded and covered by thin membranous covering called velum. After growth of pileus, the velum is ruptured and remains attached to the stipe in the form of ring, called annulus. On the lower surface of the pileus, there is a large number of thin, vertical, plates like structures called gills or lamellae. It is the reproductive part which produces spores.

Activity 2.3:

The fruiting body of mushroom are collected carefully from cultivated farm and then preserved in 5% formalin solutions or even as over dry specimens. Study its parts and present in class. (Take precaution during collection).

Some mushrooms are edible while some are poisonous.

Poisonous Mushroom	Non-poisonous Mushroom
1. After cutting these mushroom turns either green or purple. 2. Poisonous mushrooms have bad odour. 3. It has bitter taste. 4. There is absence of worm. 5. The gills are attached to the stalk. 6. Annulus is commonly absent in fruiting body. Examples: <i>Pholiotina rugosa</i>, <i>Amanita phalloides</i>, <i>Cortinarius rubellus</i> etc.	1. After cutting these mushroom, does not turn green or purple. 2. Non-poisonous mushroom have pleasant odour. 3. It has sweet taste. 4. There may be presence of worms. 5. The gills are attached to the cap but not to the stalk. 6. Annulus is commonly present in fruiting body. Examples: <i>Agaricus bisporus</i>, <i>Pleurotus ostreatus</i>, <i>Volvariella volvacea</i> etc.

2.2.6 ECONOMIC IMPORTANCE OF FUNGI

Fungi have both useful and harmful effects in our daily life.

Useful Effects:

1. Medicinal value:

Different types of fungi are used in the production of numbers of drugs. Penicillin, claviformin and other antibiotic are extracted from *Penicillium* species. Vitamin B-complex, vitamin A and vitamin B-12 are obtained from *Saccharomyces cerevisiae* and *Eremothemium ashbyii* respectively. Different types of steroids are also synthesized from fungi.

2. Food value:

Fungi are used as food by humans from a long time ago. The fruiting bodies of mushroom are used as food due to their high protein content and have good amount of vitamins, minerals and very less amount of fat.

3. Industrial value:

Fungi are used in the production of different types of commercially important products such as alcoholic products (using yeast like, *Saccharomyces*, *Rhizopus*, *Penicillium* etc), bakery products (using yeast), Cheese (using *Penicillium* species), enzymes (like, amylase, cellulase, invertase etc.) and other organic acids (like; citric acid, fumaric acid, lactic acid, oxalic acid, etc).

4. Soil fertility:

Decomposition of litter and wood in the forest takes place by the different types of fungi. Fungi like *Fusarium*, *Chaetomium*, *Aspergillus*, etc can decompose the structural polymers such as cellulose, hemicellulose, lipid, protein, starch etc. By decomposing the organic matters, fungi help to increase minerals and other substances in the soil, hence the fertility of soil increases.

5. Plant Nutrition:

The mycorrhizal association of fungi and root of higher plants help in absorption of water and minerals.

6. Production of plant hormone:

Some soil funguses are used to produce plant hormone like Gibberellin.

7. Biological control:

Some fungi are used to control plant diseases in sustainable disease management systems. *Beauveria bassiana* is a naturally occurring fungus in soil has been use for control of soil borne insects like beetle etc.

Harmful Effects:

Fungi are directly or indirectly harmful to the human beings in various ways. They may cause diseases of plants, human beings, animals; spoilage of food, etc.

1. Plant diseases:

Fungi cause several diseases to varieties of economic value plants. Such as, club root disease in cabbage, wart disease in potato, damping off disease in various seedlings, red rots in sugarcane etc.

2. Rotting of fruit and food:

Poor storage of crops and fruits leads to the growth of fungi causing high economic losses like *Penicillium* species causes green rot on fruit, *Aspergillus* species cause black rot in fruit, *Aspergillus flavus* cause green rot in grains, etc. Fungi spoil the vegetables, dairy products, meat etc.

3. Human and animal diseases:

Certain fungi are parasite on human and animals causing infection of skin, hair or nails. Aquatic fungi live as parasite on egg and gills of fishes causing severe damage to them.

4. Damage of clothes:

Fungi can grow on wet clothes and shoes hence damage them. Clothes made from natural fibers such as cotton, wool, silk are more susceptible than those made from synthetic fibres.

5. Damage of paper and wood:

Many fungi destroy the paper of books and newspapers in moist conditions. The species of *Polyporus* cause the damage and decay the timber wood.

6. Mushroom poisoning:

Poisonous mushroom causes the different types of health hazards in human beings like diarrhea, vomiting, gastric disturbance and even death of person.



Questions to think?

Have you ever think, why we keep food in refrigerator?

EXERCISE

A. Tick the correct alternative.

- Which group of fungi includes 'club fungi'?
 - deuteromycetes
 - basidiomycetes
 - ascomycetes
 - phycomycetes
- Which nutrient is commonly obtained from yeast, making it a valuable dietary source?
 - vitamin C
 - riboflavin
 - sugar
 - fat
- In fungal organisms, what is the primary form of reserve food material storage?
 - starch
 - lipid
 - glycogen
 - protein
- Consider the statement 'The mode of nutrition in fungi is mainly saprophyte.' Evaluate the significance of this statement in the context of fungal ecology and nutrient cycling. Which of the following interpretation aligns best with the statement?
 - Fungi primarily obtain nutrients through photosynthesis
 - Fungi decompose dead organic matter to obtain nutrients
 - Fungi obtain nutrients by feeding on living organisms
 - Fungi rely completely on mutualistic relationships with other organisms for nutrition
- What does 'perfect stage' of a fungus indicate?
 - indicates that it can reproduce asexually
 - indicates that it perfectly healthy

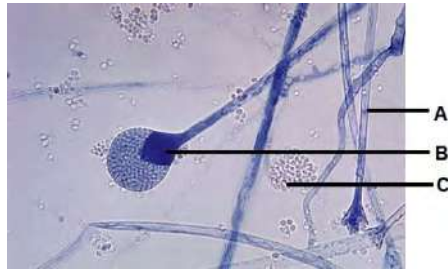
- c. indicates that it is able to form perfect sexual spores
 - d. all of the above
6. Which among the following is not a mode of asexual reproduction?
- a. Budding
 - b. Fragmentation
 - c. Zoospores
 - d. Zygosprores
7. How does *Mucor* contribute to the ecosystem?
- a. By producing oxygen
 - b. by decomposing organic matter
 - c. by fixing nitrogen
 - d. by pollinating plants
8. Observe the given diagram and find the correct labeled of A, B, C and D.



- a. A- pilus, B- annulus, C- stripe, D- gills
- b. A- pilus, B- gills, C- stripe, D- annulus
- c. A-stripe, B- hyphae, C- stripe, D- annulus
- d. A-pilus, B- gills, C-annulus, D- stripe

B. Answer the following questions:

1. Define the following terms:
 - a. mycelium
 - b. hyphae
 - c. ascus
 - d. coenocytic hyphae
2. Compare and contrast the Diplobiontic and haplobiontic life cycle of yeast, focusing on their key characteristics, reproductive strategies and ecological implication.
3. Justify the statement 'Deuteromycetes is known as fungi imperfecti.'
4. A grocery store has been experiencing spoilage issues with strawberries. Suggest the preventive measures the grocery store can implement to reduce the spoilage on strawberries.
5. Describe the structure of mushroom with necessary diagram.
6. Describe the vegetative structure of *Mucor* with necessary diagram.
7. Discuss the ecological importance of fungi and their interactions with other organism in ecosystems.
8. Observe the given diagram and answer the following questions:



- a. Name the organism shown in the diagram.
 - b. Label A, B and C.
 - c. Write the function of B and C.
 - d. Mention any one ecological importance of this organism.
9. There are several pairs of mushroom species that closely resemble each other, with one being poisonous and the other edible. Create a table comparing their key morphological characteristics that can be used to distinguish between them. Discuss the potential dangers of misidentifying these look-alikes.

Project Work:

Visit nearby mushroom cultivation farm and prepare a report on different cultivation methods of mushroom.

Chapter 2.3

LICHENS

Observe the picture and answer the following questions:



(a)



(b)

- i. Have you ever noticed such colorful patches growing on rocks or hanging beard like structures on the branches of trees?
- ii. What do you think, are they plants, animals or something else?

2.3.1 GENERAL INTRODUCTION

Lichen is an organism consisting of a fungus and algae, so closely associated with each other as to appear a single organism. Hence, the lichen is a dual or composite organism. The fungal partner of lichen is known as mycobiont and the algal partner is known as phycobiont. In lichen thallus (body), the fungal partner cover maximum volume of the body and provide habitat, water, carbondioxide, shape and colour to the lichens while the algal partner produced food through photosynthesis which is utilized by both of them. The study of lichen is called lichenology. The father of lichenology is Theophrastus.

2.3.2 CHARACTERISTICS FEATURES OF LICHEN

Following are the characteristics features of lichen:

1. They are dual organisms having symbiotic association of algae and fungi.
2. Lichen grows usually in moist, cold and moderate temperature. They grow on barks of trees, leaves, dead logs, bare rocks etc.
3. The growth of lichen is very slow; they can survive for many years.
4. The body is thalloid, irregularly shaped and often deeply pigmented due to algal partner. On the basis of nature of thallus and their attachment to the substratum, lichens are crustose (closely attached and embedded to the substratum), foliose (flat leaf like) and fruticose (branched, shrubby).
5. They are sensitive to air pollution and act as indicator of air pollution.
6. Lichen reproduces by vegetative, asexual and sexual method.

Examples: *Graphis*, *Phycia*, *Usnea*, etc.

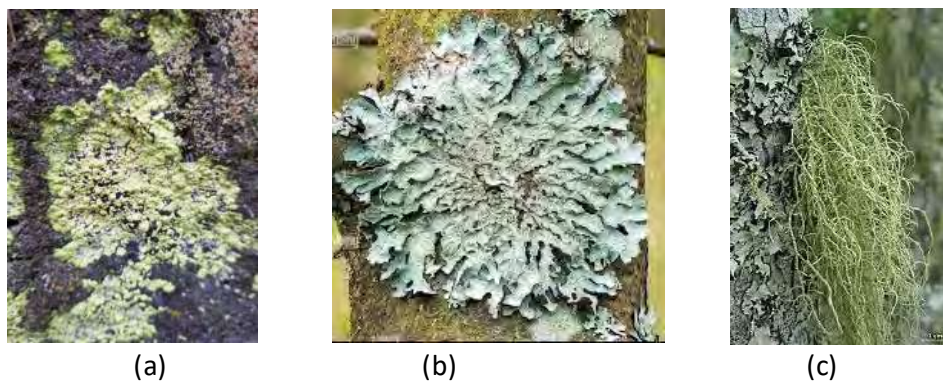


Fig: 2.3.1 Different types of lichens: a. Crustose b. Foliose c. Fruticose



Questions to think?

Lichens are not kept in any kingdom of five kingdom classification, why?

2.3.3 ECONOMIC IMPORTANCE OF LICHEN

Lichens have both positive and negative effect as mentioned below:

Positive effects

1. Source of food:

Lichens are the source of food for numerous minute organisms like mite, slugs, caterpillar etc. Certain species are also used by people for food.

2. Medical importance:

Several lichens are used in the treatment of various diseases like *Lobaria pulmonaria* (in the treatment of lung disease), *Xanthoria parietina* (treatment of jaundice) etc.

3. Pioneers of ecological succession:

Lichens are said to be the pioneers in establishing vegetation on bare rocky areas. They are the first members to colonize the barren rocky areas. They play an important role in nature in the formation of soil.

4. Bioindicator of air pollution:

Lichens are very sensitive to atmospheric pollutants such as sulphur dioxide. As the level of air pollution increases, their number decreases. It helps to predict the level of air pollution.

5. Industry :

Lichens are used to prepare different types of industrial products like dyes, cosmetics, perfumes, alcohol, litmus paper, etc.

Negative effect

1. Lichens growing on the walls of buildings can damage the plasters and shining beauty of buildings.
2. During dry season some species of lichens become so dry and inflammable that they catch fire and help in spreading forest fire.

3. The commercial value of glass and marble stone is reduced because of itching of their surface by lichens.
4. Certain lichens grow on perennial leaves of some economically important plant such as coffee, rubber, etc as parasite and may cause pre-mature leaf fall.

EXERCISE

A. Tick the correct alternative.

1. Which of the following pairs of organisms form a symbiotic relationship in lichen?
 - a. algae and fungi
 - b. algae and pteridophyte
 - c. fungi and higher plant
 - d. algae and bacteria
- b. What is the specific field of study that focuses on lichens?
 - a. Phycology
 - b. Mycology
 - c. lichenology
 - d. Bacteriology
3. Which of the following describes the body structure of lichen?
 - a. smooth and spherical
 - b. Cylindrical and transparent
 - c. rectangular and multicolored
 - d. irregularly shaped and deeply pigmented
4. Considering the symbiotic relationship between algae and fungi in lichens, which benefit does algae primarily provide to the association?
 - a. food
 - b. vitamins
 - c. growth substance
 - d. protection
5. Why are lichens often referred to as pioneers in ecosystem development?
 - a. because they are the primary producers in ecosystems.
 - b. due to their ability to rapidly reproduce and spread.
 - c. because they are the first organisms to colonize barren rocky areas.
 - d. because they are the dominant species in mature ecosystem.
6. Which of the following negative impacts is associated with lichens?
 - a. they enhance the aesthetic appeal of buildings.
 - b. they promote the growth of fruit trees.
 - c. they decrease the risk of forest fires during hot seasons.
 - d. they damage the plasters and appearance of buildings.

B. Answer the following questions:

1. Mention the characters of lichen.

2. Lichens are called as dual organism, give reason.
3. Define the terms 'phycobiont' and 'mycobiont' and describe their roles in lichen symbiosis.
4. What are the distinguishing characteristics of fungi and lichens?
5. Imagine you are a researcher studying air quality in a city with significant industrial activity. How could you use lichens as bioindicators to assess air pollution levels? Discuss the specific characteristics of lichens that make them sensitive to pollutants and explain how changes in lichen populations could indicate changes in air quality.
6. Write short notes on economic importance of lichens.

Chapter 2.4

ALGAE

Observe the picture and answer the following questions:



(a)



(b)

- i. You must have noticed a bluish-green scum in a pond, stagnant water or in overhead tanks that have not been cleaned for long. Can you predict it, what might be the cause of it?
- ii. What role do you think algae play?
- iii. Can you provide examples of algae?

2.4.1 GENERAL INTRODUCTION

The term algae (Latin- seaweeds) have been used in a broad sense to aquatic, photosynthetic organisms. The group algae include an enormous group of plants of great biological importance and most primitive plants. They show a great variety. Some are considered to be a link between prokaryotes and eukaryotes.

They are autotrophic, unicellular or multicellular, non-flowering and non-vascular plants. The algae are of great importance as primary producers of energy rich compounds in aquatic body. The branch of biology that deals with the study of algae is called **phycology or algology**. The person who is expert in algae is called phycologist. **F.E. Fritsch** is called father of phycology.

2.4.2 CHARACTERISTICS FEATURES OF ALGAE

Some of the basic features of algae are given below:

1. The algae are aquatic, both marine and fresh water, occur on and within damp soil and moist stones, wood as well as in association with fungi and certain animals.
2. The body of algae is not differentiated into roots, stems or leaves, so, the body of the alga is known as a **thallus**. This term is used even if the plant is unicellular (e.g. *Chlamydomonas*). The body or thallus of multicellular algae ranges from simple floating colony of cells (e.g. *Volvox*), to filaments (e.g. *Spirogyra*) to sheets of cells (e.g. *Ulva*).
3. The body is usually covered with mucilage.
4. The cell wall is made up of cellulose. s
5. Photosynthetic pigments are chlorophyll and carotenoids.
6. The common reserve food material is starch.

7. Reproduction takes place by vegetative, asexual and sexual method.
8. Vegetative reproduction is the most common type of reproduction. It takes place by fragmentation, budding, etc.
9. Asexual reproduction takes place by means of spores. The spores are motile or non-motile.
10. Sexual reproduction takes place by the fusion of gametes. It may be isogamous or anisogamous or oogamous.
11. An embryo stage is absent in life cycle of algae.

2.4.3 CLASSIFICATION

Algae are classified into different classes on the basis of photosynthetic pigments, storage material, thallus structure and method of reproduction. It is believed that red and brown algae evolved on a different pattern and green algae are the ones that gave rise to ancestors of land plants. Here features of three classes have been described:

1. Chlorophyceae (Green algae)

Green algae or chlorophyta (Greek: Chloros-green, phyton-plant) are cosmopolitan in distribution and occur in diverse habitats. They resemble land plants in their photosynthetic pigments and reserve food.

The general characters of green algae are as follows:

- a. Mostly they are fresh water and some grow on moist soil, wall and rocks.
- b. The plant body is unicellular or multicellular.
- c. Cell wall is made up of cellulose and pectin.
- d. Photosynthetic pigments are chlorophyll a, chlorophyll b, carotenes and xanthophyll.
- e. Reserve food material is starch.
- f. Reproduction takes place by vegetative, asexual and sexual method.

Example: *Spirogyra*, *Ulothrix*, *Chara*, *Chlamydomonas*, *Volvox*, etc.

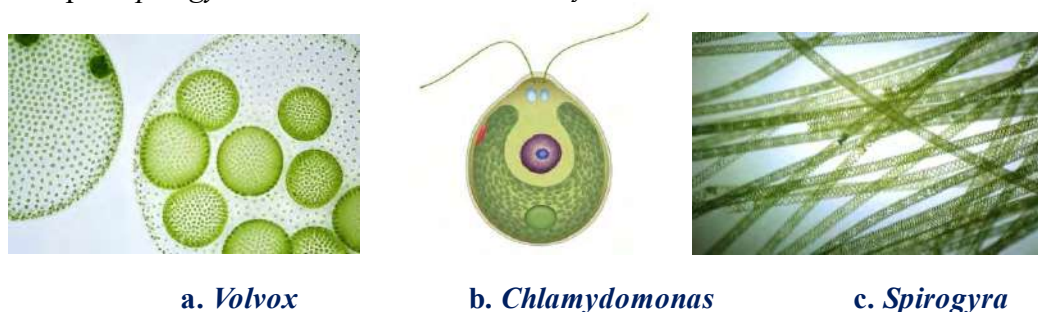


Fig: 2.4.1 Different types of green algae

2. Rhodophyceae (Red algae)

Red algae or rhodophyta (Greek: rhodon-rose, phyton-plant) are one of the oldest groups of eukaryotic algae commonly found in marine water. The red colour of rhodophyceae is due to presence of phycoerythrin.

The general characters of red algae are as follows:

- Mostly they are marine while a few are fresh water species.
- The plant body is unicellular, filamentous, parenchymatous or ribbon like.
- Cell wall is made up of cellulose, pectin and agar.
- Photosynthetic pigments are chlorophyll a, chlorophyll d, carotenoids and phycoerythrin.
- Reserve food material is floridean starch (similar to glycogen).
- Reproduction takes place by vegetative, asexual and sexual method.

Example: *Porphyridium*, *Porphyra*, *Ceramium*, etc.



a. *Porphyridium*



b. *Porphyra*



c. *Ceramium*

Fig: 2.4.2 Different types of red algae

3. Phaeophyceae (Brown algae)

Brown algae or phaeophyta (Greek: phaios-dusky, dark, brown; phyta-plant) are named due to their colour, which varies from brown to olive green. The brown colour of algae is due to the presence of large amount of fucoxanthin.

The general characters of brown algae are:

- They are mostly marine.
- The plant body is branched filamentous in lower form and parenchymatous structure in higher forms.
- The cell wall is made up of cellulose, pectin and alginic acid.
- Photosynthetic pigments are chlorophyll a, chlorophyll c, carotenoids and fucoxanthin.
- Reserve food material is laminarian starch and mannitol.
- Reproduction takes place by vegetative, asexual and sexual method.

Example: *Alaria*, *Fucus*, *Laminaria*, etc.



a. *Alaria*



b. *Fucus*



c. *Laminaria*

Fig: 2.4.3 Different types of brown algae

Activity 2.4:

Visit the nearby pond or lake and collect water samples containing algae. Place a small drop of water sample onto a glass slide and cover it with a coverslip. Observe the slide under the microscope. Write the morphology, cell structure etc. of algae and draw the picture on chart paper and present in class.

2.4.4 *SPIROGYRA*

Systematic Position

Kingdom	: Plantae
Division	: Algae
Class	: Chlorophyceae
Order	: Conjugales
Family	: Zygnemaceae
Genus	: <i>Spirogyra</i>

Occurrence

It is one of the common green algae found as free floating masses in the still water of reservoirs, tanks, pools, lakes, ditches, and slow running streams and rivers. Due to silky long filament and slippery nature, it is also known as pond scum or water silk.

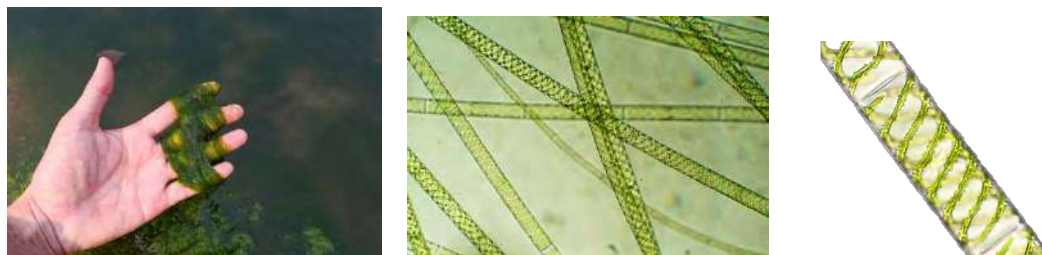


Fig: 2.4.4 (a) *Spirogyra* in habitat (b) *Spirogyra* filament under microscope (c) *Spirogyra* under high resolution

Plant body

The plant body is green, cylindrical thallus. It is thread like long unbranched filament. The filament is slimy due to presence of mucilage sheath. Each filament consists hundreds of similar cells placed end to end in a single row. The young filaments are attached to the substratum while the adult plants are free floating.

Cell structure

The cells of the filament are cylindrical in form and consist of two parts, the cell wall and the protoplast. The cell wall surrounds the protoplast and is protective in function. It consists of two layers; inner layer is made up of cellulose and forms a complete envelope around the protoplast while the outer layer is made of pectin substances. The protoplast is differentiated into plasma membrane, cytoplasm, nucleus, one or more chloroplast and a central vacuole. The

plasma membrane surrounds the cytoplasm. The cytoplasm is granular fluid mass and peripheral due to presence of large central vacuole. The single large nucleus remains suspended in the center of the vacuole by a number of cytoplasmic strands. The cytoplasm of *Spirogyra* consists of spirally arranged ribbon shape chloroplast. The number of chloroplast varies in number from one to sixteen in different species. In each chloroplast, nodules like protein bodies are present. These protein bodies store starch, and is known as pyrenoids.

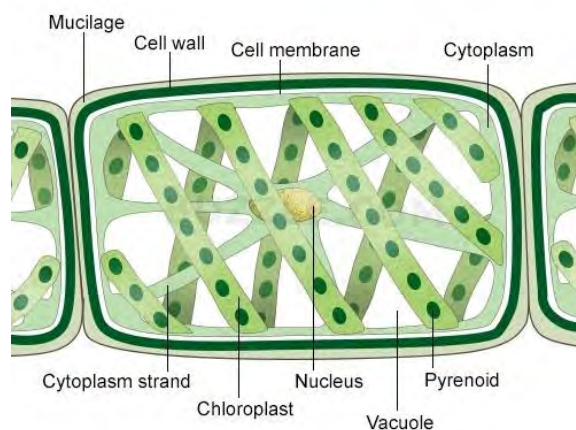


Fig: 2.4.5 Cell structure of *Spirogyra*

Reproduction

Spirogyra reproduces by vegetative, asexual and sexual method.

1. Vegetative method:

Vegetative reproduction takes place by fragmentation under favourable condition. It is the common method of reproduction. The dissociation of filament takes place by mechanical injury, death of intercalary cells, etc. Each fragment later independently forms long filament of *Spirogyra*.

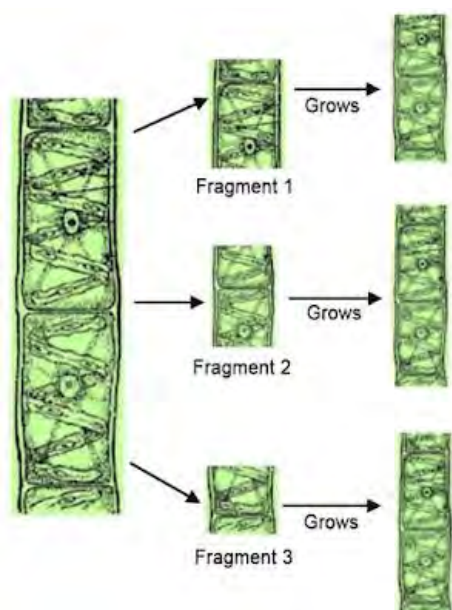


Fig: 2.4.6 Fragmentation in *Spirogyra*

2. Asexual method:

Asexual reproduction is less common in *Spirogyra*. It takes place by the formation of aplanospores, akinetes and azygospores. Under unfavourable condition, the protoplast of each vegetative cell shrinks and develops a wall around it to form aplanospores. Each aplanospore germinates to form a new filament. Akinetes are thick walled cells of filament formed by formation of additional wall under unfavourable condition. On return of favourable conditions, each akinete germinates into a new filament. Sometimes the gametes are failed to fuse in some species. These gametes round off and secrete a thick walled which surrounds them to form azygospores or parthenospores. Each parthenospore gives new filament during favourable condition.

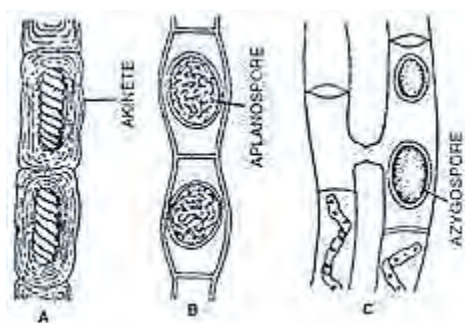


Fig: 2.4.7 Asexual reproduction in *Spirogyra* (A) Akinete (B) Aplanospore (C) Azygospore

3. Sexual reproduction

The *Spirogyra* shows conjugation type of sexual reproduction. Conjugation is an isogamous type. It involves the fusion of entire contents of the two morphologically similar unspecialized vegetative cells, known as gametangia. Sexual reproduction takes place towards the end of the growing season. It is of two types:

a. Scalariform conjugation (Ladder type):

It is the most common method and takes place at night between two different filaments (i.e. in heterothallic species of *Spirogyra*). In this process, two filaments of different strains come close and lie side by side. Both filaments get surrounded by common sheath of mucilage. Now, special conjugating cells of these two filaments develop small outgrowths known as protuberances or papillae in opposite direction. The papillae elongate and come in contact with each other. At the point of contact, the tips of these outgrowths dissolve by an enzyme, cytase and form hollow tubular structure called conjugation tube. At this stage it resembles as ladder. Hence, the conjugation is called scalariform (Gr. Scala=ladder; forma=shape). After the formation of conjugation tube, the protoplasm of one cell functions as male gametangium and other cell as female gametangium. The protoplasts of gametangium shrink to form gametes. The protoplasmic content of male gametangia moves towards the female gametangia through conjugation tube and fuse to form zygote. The zygote secretes wall around it, which is called zygospore. The cells of another filament remain empty.

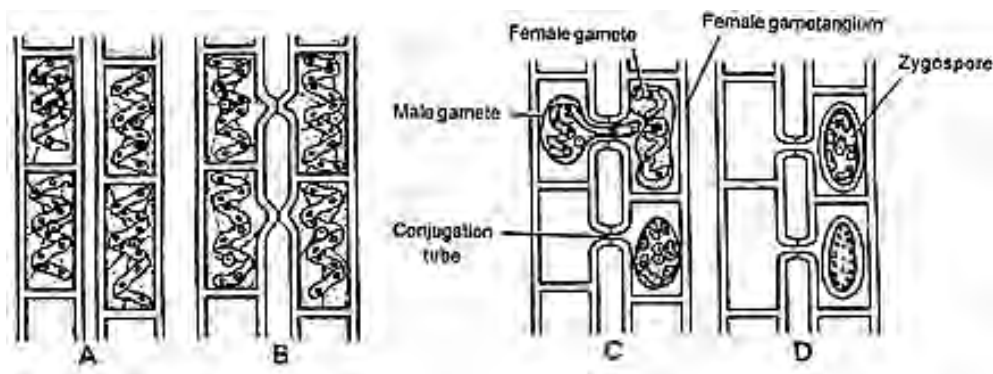


Fig: 2.4.8 Different stages of Scalariform conjugation in Spirogyra

b. Lateral conjugation

It is of rare type and involves the fusion of gametes from two adjacent cells of the same filament in monocious or homothallic species. It is of two types:

i. Indirect lateral conjugation:

Indirect lateral conjugation is the common method of lateral conjugation. In this conjugation, two adjacent cells of same filament function as male and female gametangium. The lateral outgrowth of the two adjacent cells forms papillae. The papillae grow in size and come in contact with each other. The common wall between them dissolves by enzyme and hollow tubular outgrowth is formed known as lateral tube. The protoplasmic content of one cell which functions as male gametangium behaves as male gamete and moves through the lateral tube to female gametangium which behaves as female gamete. The protoplasmic content of both male and female gametangia is fused to form diploid zygospore.

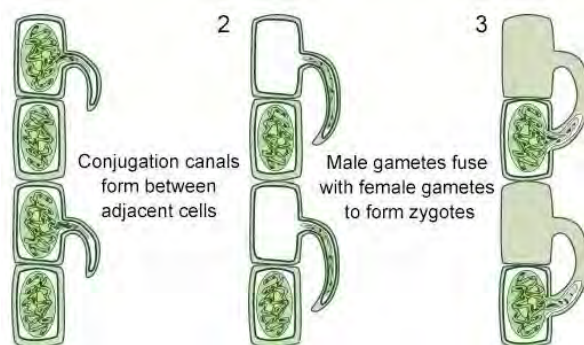


Fig: 2.4.9 Different stages of indirect lateral conjugation in Spirogyra

ii. Direct lateral conjugation

It is primitive type of conjugation occurring in few species. In this conjugation, the lower cell of the two adjacent cells gets enlarged and forms barrel shaped female gamete, while upper one behaves as male gamete. The male gamete develops pointed boring organ which creates pore mechanically or enzymatically on middle of the septum. The protoplasm of male gamete migrates through the pore and fuses with female gamete to form zygospore.

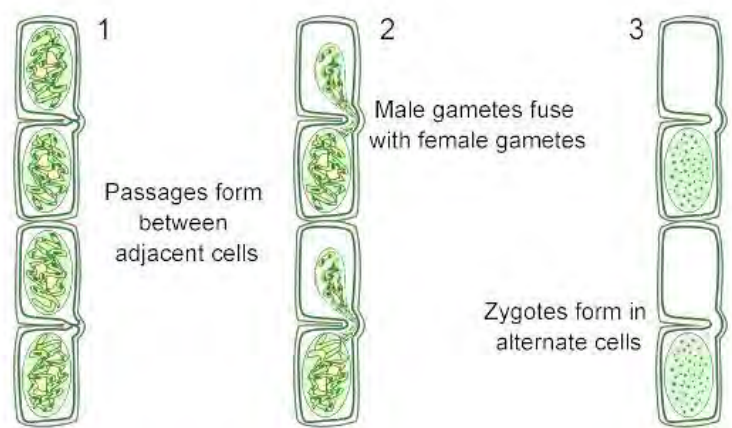


Fig: 2.4.10 Different stages of direct lateral conjugation in *Spirogyra*

Germination of zygospore

The zygospores are thick walled diploid resting spores of *Spirogyra*. The zygospores are released by destruction and decay of female cell of filament. It has three layered wall and resistant to unfavourable environmental condition. On return of suitable condition, the nucleus of zygospore divides meiotically to form four haploid nuclei. Out of four haploid nuclei, three nuclei degenerate and only one becomes functional. During germination, outer wall of spore absorbs water swells up and bursts, exposing inner layer as cylindrical germ tube. The germ tube divides transversally to form two celled structure. Lower cell acts as rhizoidal cell or holdfast that attached to substratum while upper cell divides repeatedly to form new filament. The filament gets detached from the substratum and becomes a free floating *Spirogyra*.

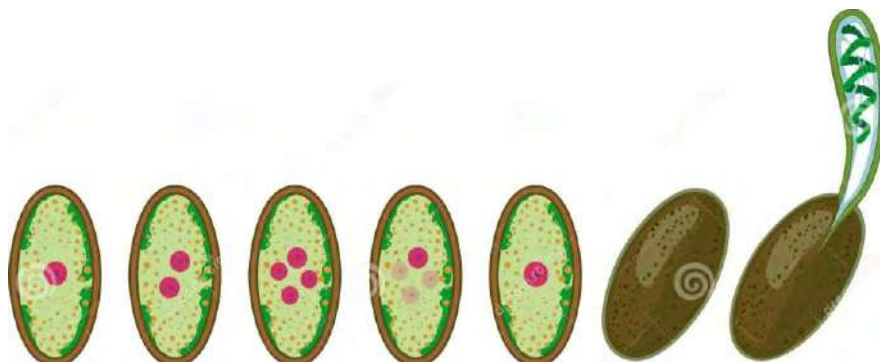


Fig: 2.4.11 Different stages of germination of zygospore in *Spirogyra*

2.4.5 ECONOMIC IMPORTANCE OF ALGAE

Algae have both positive and negative effect as mentioned below:

Useful activities:

1. **Food:** Algal species are becoming a popular food to the mankind because of its high nutritive value and more yield per unit area than conventional crops. Algae which are commonly used as food are: *Chlorella*, *Porphyra*, *Codium*, *Rhodomenia*, etc.
2. **Fooder:** Many algae become popular as fodder due to their vitamin and micronutrient in addition to their carbohydrate and protein content. The fat content of milk becomes

increased with the addition of sea algae as fodder. Algae commonly used as fodder are *Fucus*, *Laminaria*, *Alaria*, *Ascophyllum*, etc.

3. **Pisciculture:** Both floating and attached forms provide the primary food for fish and other aquatic animals. Species of the green algae, the diatoms and some blue-greens are most widely eaten up by the fishes.
4. **Industry:** Algae has been used to develop many products of commercial and pharmaceutical importance. Agar-agar obtained from *Gelidium* species are used in processed cheese, jam, jellies, tissue culture media etc. Carrageenan obtained from the cell wall of *Gigartina stellate* and *Chondrus* coagulate blood, cure cough and also use as a component of deodorants, cosmetics, toothpastes, etc. Chlorellin, an antibiotic is extracted from *Chlorella*. Various alga are rich source of iodine.
5. **Treatment of sewage plant:** Algae produce oxygen through the process of photosynthesis, which helps in the rapid decomposition of sewage.



Some species of *Chlorella* like *Chlorella vulgaris* can be used as a source of nutrition and oxygen by astronauts in space.

Harmful Effects

Some species of algae can be toxic to the environment. Some harmful effects are described below:

1. **Toxicity and parasitism:** *Gymnodinium veneficum*, *Prymnesium parvum* and other species may cause mortality in fish and in domestic animals that drinks water infested with these algae. *Cephaleuros* species of green algae cause 'red rust in tea' and cause heavy economic losses by seriously affecting the yield of tea.
2. **Fouling of ships:** Some algae like *Ulva*, *Enteromorpha* etc. are attached to the ship, and this is called fouling of ship. The fouling decreases the speed of the ship.
3. **Contamination of water supply:** Some algae contaminate the reservoirs of water supply of city that develops a foul odour in the water and makes the water unhygienic.

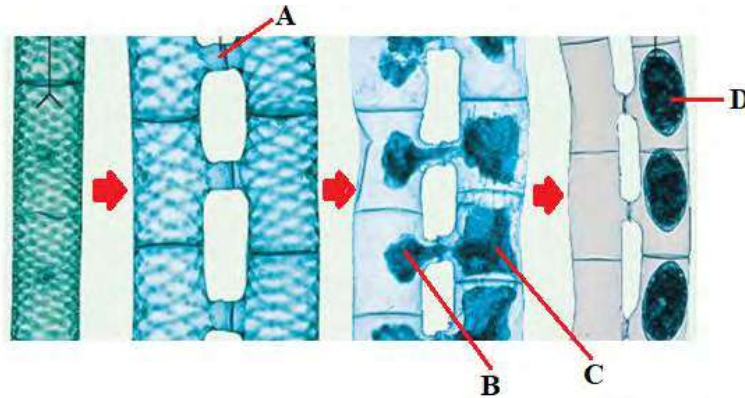
EXERCISE

A. Tick the correct alternatives.

1. What is the primary pigment responsible for the red color in red algae?
 - a. chlorophyll a
 - b. chlorophyll b
 - c. carotenoids
 - d. phycoerthyrin
2. Which of the following is a characteristic feature of algae?
 - a. Heterotrophic nutrition
 - b. Ability to conduct photosynthesis
 - c. Production of flowers and fruits
 - d. Presence of roots, stems and leaves
3. During rainy season the ground becomes slippery due dense growth of which organism?
 - a. fungi
 - b. Algae
 - c. mushroom
 - d. fern
4. Which of the following statements provides the most accurate explanation for the formation of the ladder-like structure in *Spirogyra*?
 - a. It is a result of asexual reproduction
 - b. It forms through direct conjugation
 - c. It arises from lateral conjugation
 - d. It occurs due to scalariform conjugation
5. Which of the following organisms is likely to exhibit a ribbon-shaped chloroplast?
 - a. *Spirogyra*
 - b. *Chlamydomonas*
 - c. *Riccia*
 - d. *Ulothrix*
6. In *Spirogyra*, pyrenoids are specialized structures found within the cell. Analyze the function of pyrenoids and determine their location in *Spirogyra* cell.
 - a. In the cell wall, supporting the structure of the organism
 - b. In the cytoplasm, facilitating metabolic processes.
 - c. In the chloroplast, aiding in photosynthesis
 - d. In the nucleus, controlling genetic material
7. What is the primary role of algae in aquatic ecosystems?
 - a. Providing habitat for fish
 - b. Reducing water pollution
 - c. Preventing algal blooms
 - d. Acting as a food source for herbivores
8. Which process is primarily involved in the sexual reproduction of *Spirogyra*?
 - a. Fragmentation
 - b. Conjugation
 - c. Somatogamy
 - d. Akinetes formation

B. Answer the following questions:

1. Differentiate between algae and fungi.
2. How does the role of green algae as producers contribute to the ecosystem's energy flow?
3. Mention the characteristics features of brown algae.
4. Describe the vegetative structure of *Spirogyra* with suitable diagram.
5. Describe the economic importance of algae.
6. Study the given diagram of and answer the following questions:



- a. Identify the process shown in the diagram.
 - b. Label A, B, C and D.
 - c. What is the role of B and C?
 - d. Explain how new filaments are formed from D.
7. Compare and contrast scalariform and lateral conjugation in *Spirogyra*.
 8. Explain the phenomenon of algal blooms and their ecological impact on aquatic ecosystems. Provide examples of factors that contribute to the formation of algal blooms and discuss potential consequences for biodiversity and water quality.

Chapter 2.5

BRYOPHYTA

Observe the picture and answer the following questions:



(a)



(b)

- Have you ever seen an old brick wall and rocky surfaces covered in green patches?
- Why do these plants grow on such surfaces?
- Do these plants have root, stem or leaves?
- Do these types of plants have any ecological role? Discuss.

2.5.1 GENERAL INTRODUCTION

Bryophytes (Greek, bryon-moss, phyton-plant) are essentially small plants from a few millimeters to a few centimeters. Bryophytes are photosynthetic, non-vascular, true embryophytes and were among the first plants that lived in the water and settled in terrestrial environment. They inhabit almost all ecosystems on the earth. The geographical ranges are wider than those of vascular plants due to the long distance dispersal of small spores, huge survival rate and settling specific microhabitats over the huge areas.

The bryophyte includes liverworts, hornworts and mosses. Bryophytes occupy a position between algae and pteridophyta. They are regarded as amphibians of plant kingdom. (because they are water dependent for fertilization while their vegetative structure is adapted to a terrestrial life). The branch of biology that deals with bryophytes is called bryology. A German botanist Johann Hedwig is known as father of bryology.

DID YOU KNOW?

During the First World War, mosses were used as bandages due to its antiseptic properties making its perfect application in cleansing and healing the wound.

2.5.2 CHARACTERISTICS FEATURES OF BRYOPHYTES

Some of the basic features of bryophytes are given below:

- Bryophytes usually grow on damp, moist and shady places. They form a green carpet on damp soil, rocks, walls and barks of trees.

2. The plant body lacks true roots, stems or leaves and may have root-like, stem like or leaf like structure. The plant body may be flat as in liverworts or tiny erect leafy structures on stalks, as in mosses.
3. The plant body of bryophytes is gametophyte since it produces gametes. It is an independent, autotrophic and haploid.
4. The plant body is attached to the substratum by unicellular or multicellular rhizoids.
5. The plant body is made up of simple parenchymatous cells. Vascular tissues are absent.
6. Reproduction takes place by vegetative and sexual method.
7. Vegetative reproduction takes place by fragmentation, adventitious buds, gemmae etc.
8. Sexual reproduction is oogamous type (i.e. female gamete is larger and im-motile whereas, male gamete is smaller and motile).
9. The male sex organ is known as antheridium that produces biflagellate male gamete called antherozoids while female sex organ is flask shaped archegonium that produces a single egg (oosphere).
10. The antherozoids are released in water and come in contact with archegonium and get fused with egg to form diploid zygote (oospore).
11. The zygote produces multicellular body called sporophyte. The sporophyte is parasitic over gametophyte for nutrition and attachment.
12. The sporophyte produces spores. On germination, these spores give rise to gametophytic stage.
13. The life cycle of bryophyte show alternation of generation.

2.5.3 CLASSIFICATION

The division bryophyta has been divided into three classes:

1. Hepaticopsida (Liverworts)

The name hepaticopsida comes from the word ‘hepatic’ which means liver. So, ‘Hepaticopsida’ literally means ‘class of liver like plants. The main characteristic features are given below:

- i. The plant body is gametophyte which is dorsoventral and may be thalloid or foliose (i.e. differentiated into leaves and stem like structures). Leaf, if present, are without mid-rib.
- ii. The ventral surface of thallus is provided with scales and rhizoids. Rhizoids are unicellular and unbranched.
- iii. Sex organs are borne on dorsal side of the thallus embedded in tissues.
- iv. The sporophyte may be simple, or differentiated into foot and capsule, or into a foot, seta and capsule.
- v. The sporophyte is completely dependent on gametophyte for its nutrition.
- vi. The columella is absent in the capsule.
- vii. Spores germinate to produce gametophytic plant body. A distinct protonema stage is absent.

Examples: *Marchantia*, *Riccia*, *Porella*, etc.

2. Anthocerotopsida (hornworts)

The name anthocerotopsida comes from the Greek word ‘Antho and ceros’ which means flower and horn respectively. So, ‘Anthocerotopsida’ literally means ‘class of horn like

structure that develop as part of sporophyte stage of the plant's life cycle. The main characteristic features are given below:

- i. The plant body is gametophyte which is dorsoventral flattened and thalloid.
 - ii. Rhizoids are unicellular and unbranched with smooth wall. Ventral scales are absent.
 - iii. Sex organs are present dorsally embedded in the thallus.
 - iv. The sporophyte is elongated, cylindrical and horn like structure. It is divided into foot, seta and capsule.
 - v. The sporophyte is parasite on gametophyte.
 - vi. The columella is present within the capsule.
 - vii. Mucilagenous cavities are present inside the thallus, which are invaded by nitrogen fixing cyanobacteria.
 - viii. Spores germinate to produce protonema stage and then to gametophytic plant body.
- Examples: *Anthoceros*, *Notothylas*, *Megaceros*, etc.

3. Bryopsida (Mosses)

The name bryopsida comes from the Greek word 'bryon' which means moss. The main characteristics features are given below:

- i. The plant body is gametophyte and is differentiated into spirally arranged leaves, axis and rhizoids.
 - ii. Rhizoids are multicellular, branched and have oblique septa.
 - iii. Sex organs are formed at apical portion of stem.
 - iv. The sporophyte is differentiated into foot, seta and capsule.
 - v. Sporophyte is parasite on gametophyte.
 - vi. The columella is present in the capsule and capsule contains ring of teeth like structure known as peristome.
 - vii. Spores germinate to produce protonema stage and then to gametophytic plant body.
- Examples: *Polytrichum*, *Funaria*, *Sphagnum*, etc.



a. *Marchantia*



b. *Anthoceros*



c. *Funaria* (Moss)

Fig 2.5.1 Different types of Bryophytes

2.5.4 MARCHANTIA

Systematic Position

Kingdom	: Plantae
Division	: Bryophyta
Class	: Hepaticopsida
Order	: Marchantiales
Family	: Marchantiaceae
Genus	: <i>Marchantia</i>

Occurrence

The thalli of *Marchantia* commonly grow upon moist, cool and shady places, generally found on soil, rocks, walls, log of wood, trunk of trees and near the bank of rivers and streams.

Plant body

The plant body of *Marchantia* is gametophytic thallus. The thallus is prostrate, dichotomously branched and dorsoventral. The thallus is dark green in colour and consists of distinct mid rib. The apex of each thallus has apical notch in which growing point is situated. Along the mid rib on the dorsal surface, special cup-shaped structure are found called as gemma cups which produce vegetative reproductive structures called gemmae.

The ventral surface of the thallus bears two types of structure – scales and rhizoids. The scales are multicellular arranged in row on each side of mid rib. Scales give protection to thallus. The rhizoids are unicellular, colourless and unbranched that help in fixation and absorption of water and minerals. The thallus is dioecious i.e. *Marchantia* has different male and female thallus.

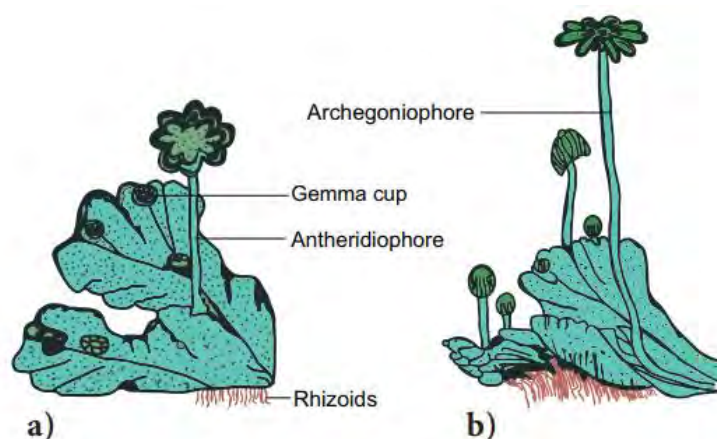


Fig 2.5.2 Structure of *Marchantia* a) Male thallus b) Female thallus

Reproduction

The reproduction in *Marchantia* takes place by vegetative and sexual methods.

1. Vegetative Reproduction

Vegetative reproduction takes place by various methods. Some methods are described below:

a. Fragmentation: The older parts of the thallus decay below the dichotomy and the lobes of thallus are separated from each other. On return of favourable condition these fragments develop into new thalli.

b. Gemma:

The most common method of reproduction in *Marchantia* takes place by special vegetative structures, the gemmae. Gemmae are produced in large number in gemma cup on the dorsal surface of thallus. Each gemma is multicellular, consist of unicellular stalk and multicellular discoid body. It has two notches on the lateral sides. The gemmae also possess mucilage cells, oil cells and rhizoidal cells. The majority of cells of gemma contain chloroplasts except oil cells and rhizoidal cells. The rhizoidal cells give rise to rhizoids. At maturity, the gemma breaks

its connection from the stalk and is carried away by water current, wind or animals. On reaching suitable substratum, each lateral notch gives rise to new thallus. Gemmae present on the male thallus give rise to male plants and those on the female thallus give rise to female plants.

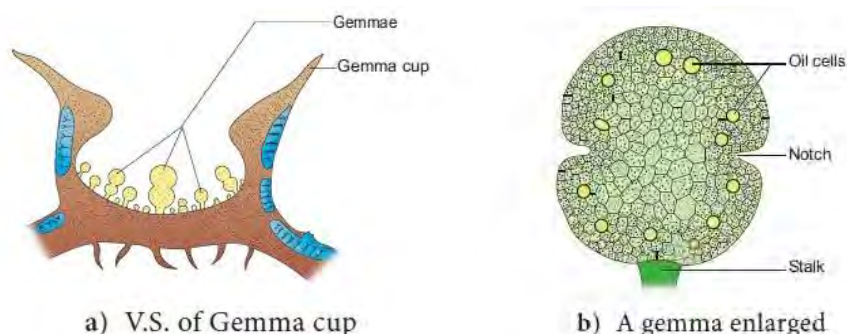


Fig 2.5.3 Reproduction in *Marchantia* by Gemma

2. Sexual Reproduction

Marchantia is dioecious. The sex organs are developed on special stalked receptacles called gametophores. The gametophore bearing male sex organ (i.e. antheridium) is called antheridiophore while the gametophore bearing female sex organ (i.e. archegonium) is called archegoniophore.

Antheridiophore has an erect about 2-3 cm long stalk. The top of antheridiophore flattened, slightly curved, 8-lobed disc, known as male receptacle. Each lobed disc consist of antheridial chambers and air chambers alternately. Each antheridial chamber consists of antheridium which is attached to the base by short multicellular stalk. Each antheridium consists of single layered oval body and a stalk. Inside the oval body, there is mass of androcytes which later develop into motile, biflagellated antherozoids (i.e. male gametes). After maturation, the antheridial wall absorbs water, ruptures and biflagellated antherozoids are liberated out into water.

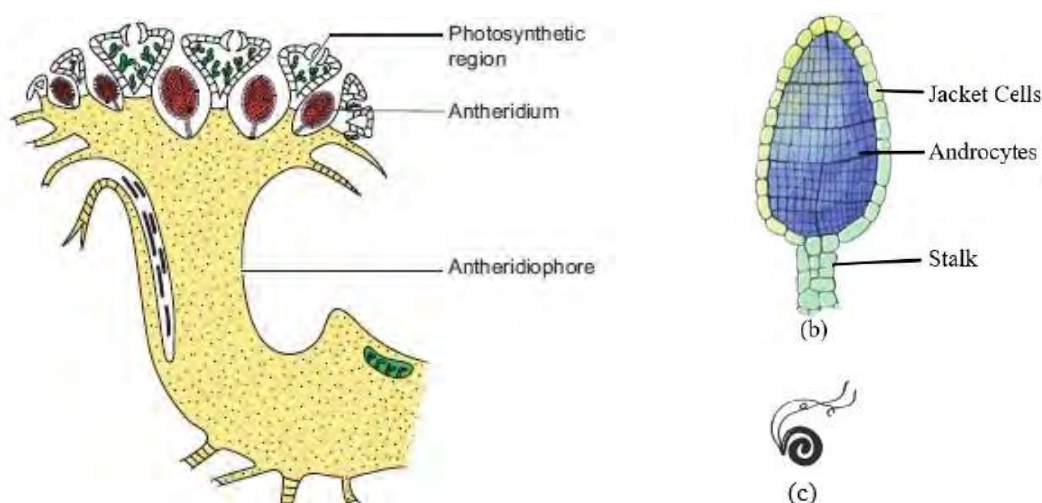


Figure 2.5.4 (a) L.S. of Antheridiophore (b) an antheridium (c) an antherozoid

Archegoniophore consists of long stalk and 8-lobed, umbrella shaped, female receptacles. Each receptacle consists of nine fingers like structure called rays. Female sex organs occur on ventral surface of lobes. Each patch contain 12-16 hanging archegonia. All archegonia are covered by protective layer called perichaetium or involucre. A mature archegonium is flask shaped structure with swollen base, venter and a long narrow, neck. Venter contains a large egg (oosphere) and a venter canal cell. Neck consists of 4-6 neck canal cells. The tip of archegonium is protected by four cover cells or lid cells.

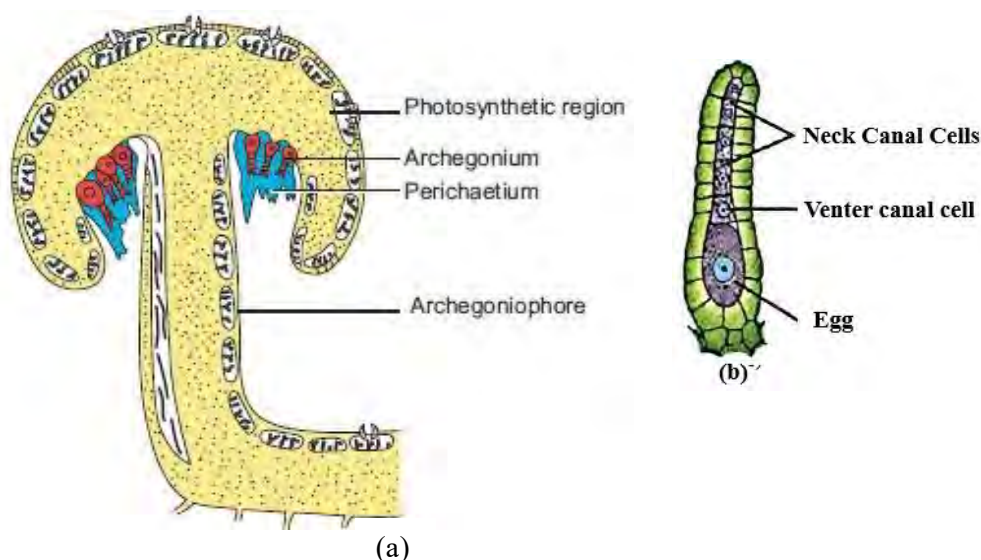


Figure 2.5.5 (a) L.S. of Archegonium (b) Archegonium

In a fully mature archegonium, the neck canal cells and venter canal cell disorganize to form a mucilage mass which absorbs water and swells up. It creates a pressure, results in the separation of cover cells. The passage is formed up to egg. Fertilization takes place in the presence of water. The antherozoids liberated from antheridium, swim through water and are attracted towards archegonium. Although many antherozoids enter the archegonium, only one fuses with the egg to form zygote.

The zygote represents the first stage of sporophytic generation. Zygote divides repeatedly to form embryo and embryo gives rise to multicellular sporophyte inside the venter of archegonium. Sporophyte is completely parasitic over gametophyte since it fully depends on



gametophyte for their nutrition. A mature sporophyte is differentiated into foot, seta and capsule. A foot is basal part, attached to the receptacle and absorbs nutrition from the gametophyte. Seta is short stalk that connects foot and capsule. The capsule is oval structure with single layer of jacket that encloses number of fertile spore mother cells and sterile elater mother cells. Each spore mother cell undergoes meiosis and forms four haploid spores. Some elater mother cells provide nutrients to the spore mother cells in early stage while some elater mother cells form elongated, narrow, spindle shaped structures called elaters. On maturation, the capsule wall ruptures and spores are dispersed with the help of elaters. The spores germinate to develop new gametophyte under favourable condition.



The bryophytes are used since from stone age when pre-historic man had made uses of feather moss for extinguishing fire, nappies etc. Nowadays, these plants have attracted environmentalists, botanists, industrialists, horticulturists and pharmacists only because of their useful characteristics. The economic uses of bryophytes are described in following two headings:

1. Ecological Importance

a. Bog succession:

The mosses play an important role in bog succession from water to climax forest. The bryophytes especially *Sphagnum* plants along with other hydrophytes form a dense surface covering over the water below. This covering gives the appearance of the soil from the surface. These areas are known as quacking bogs. Later on these bogs are converted into swamps. Ultimately these swamps are replaced by the forest growth.

b. Formation of soil:

Mosses along with lichens are supposed to be pioneers over the bare rocky surface. They grow on rocks and add organic matter to the substratum after their death that makes the rocks suitable for the growth of higher plants.

c. Food and shelter:

Numerous invertebrates eat bryophytes, lay their eggs on them or shelter in them. They form a vital part of the construction material of the nest of some birds.

d. Soil conservation:

Mosses grow in dense mats over the soil surface. They bind the soil particles and prevent soil erosion by running water.

e. Pollution:

The bryophytes are very sensitive to air pollution. Both alive and air dried mosses can absorb metals. The accumulation of heavy metal in mosses enables them to be used as atmospheric and aquatic pollution indicators.

2. Medicinal uses:

The bryophytes contain numerous potentially useful compounds so they help to cure ringworms, ash of moss is mixed with honey and fat to treat cuts, burn and wounds.

Liverworts are used for liver disease. Certain bryophytes are also used to obtain a number of antibiotic substances. *Sphagnum* is used in antiseptic absorbent bandage.

3. Packing material:

Most of the mosses are used as packing material after being dried. They make a fairly good packing material in the case of glass ware and other fragile goods.

4. A source of fuel:

The hardened and compact dark coloured rich in carbon formed by compression of dead remains of moss (*Sphagnum* species) accumulated year after year is called peat. These peats are dried, cut into pieces and used as fuel.

5. In experimental Botany:

The liverworts and mosses have played an important role as research tools in the various field of Botany such as genetics, experimental morphology and physiology.

6. Ornamental value:

Bryophytes have been used for green house crops, potted ornamental plants and in garden soil.

7. Industrial Uses:

Mosses are used to make carpets; peats are used to obtain alcohol, ammonium sulphate, paraffin, brown dye, tanning materials, etc.

EXERCISE

A. Tick the correct alternatives.

1. Which of the following best describes bryophytes?
 - a. Non-embryophytes
 - b. Tracheophytes
 - c. Non-vascular plants
 - d. spermatophytes
2. Which stage of the bryophyte life cycle is haploid?
 - a. Gametophyte
 - b. Sporophyte
 - c. Zygote
 - d. Sperm cell
3. What are the characteristics of the gametophyte of *Marchantia*?
 - a. Green and vascular
 - b. Independent and multicellular
 - c. Dependent and sporophyte
 - d. Foliose in nature
4. In the reproductive process of bryophytes, what is the primary mode of transport for male gametes?
 - a. Birds
 - b. Wind
 - c. Water
 - d. Insects
5. Which structure in bryophytes is primarily responsible for the continuation of the life cycle by producing the egg?
 - a. antheridium
 - b. sporangium
 - c. antheridiophore
 - d. archegonium
6. What is the primary role of mosses and lichens in the formation of soil over bare rocky surfaces?
 - a. Providing shelter for birds
 - b. Preventing soil erosion
 - c. Serving as indicators of pollution
 - d. Facilitating the growth of higher plants
7. What is peat, and how is it utilized?
 - a. Dried moss used as a packing material
 - b. Dense surface covering formed over water
 - c. Fuel obtained from compacted dead remains of moss
 - d. Ornamental plant used in greenhouses
8. In bryophytes, where are spores typically produced?
 - a. capsule seta
 - b. soot stalk

9. What biological process or event initiates the sporophytic generation in *Marchantia*, and why is it considered significant in the plant's life cycle?
 - a. The formation of spores enables dispersal to new environment, ensuring genetic diversity and colonization
 - b. The formation of zygotes marks the fusion of gametes, initiating the development of a new generation with a combined genetic makeup
 - c. The development of embryos represents the transition from the gametophytic to the sporophytic phase.
 - d. The emergence of sporophytes indicates the completion of fertilization, leading to the production of reproductive structures for future propagation.
10. The given picture is L.S. of mature antheridium as observed under microscope. What is A and B? How does B helps in reproduction process of *Marchantia*?



- a. A – antheridium cavity, B – air cavity, B produce male gamete
- b. A – archegonium, B – antheridium, B produce female gamete
- c. A – air chamber, B – antheridial chamber, B produce male gamete
- d. A – air chamber, B – antheridial chamber, B produce female gamete

B. Answer the following questions:

1. Define the following:
 - a. gemma
 - b. archegonium
 - c. antheridium
 - d. alternation of generation
2. Compare the characters of algae and bryophyte.
3. What is the dominant plant body in *Marchantia*, and why is this significant in the context of its reproductive biology and life cycle?
4. How does the designation of bryophytes as ‘amphibian plants’ reflect their ecological adaptations and reproductive strategies?
5. Give the characteristics features of bryophytes.
6. Describe the economic importance of bryophytes.
7. Explain how the presence or absence of certain bryophyte species can serve as indicators of environmental health and ecological changes in terrestrial ecosystems.
8. Alternation of generation occurs in the lifecycle of *Marchantia*. Elaborate it with justification.
9. Study the given thallus of *Marchantia* and answer the following questions:



- Identify whether the thallus is male or female? Provide reasons for your answer.
- Label A and B.
- Write the function of A and B.

Chapter 2.6

PTERIDOPHYT

Observe the picture and answer the following questions:



(a)



(b)



(c)

- Have you seen these plants? Can you name them?
- Are they produced flowers or fruits?
- Have you ever used these for anything, like decoration or medicine?
- Do you know which group of plants is considered to first terrestrial plants?

2.6.1 GENERAL INTRODUCTION

Pteridophyta (Greek; pteron-feather, phyta-plant), the name the given because of their feather like leaves. They are the cyptogams and first vascular plants. They are much advanced among non-flowering plant. The main plant body is sporophyte which produces spores. Mostly pteridophyta are herbaceous, but few of them are large tree which grow upto height of 30-40 feet. The study of pteridophyta is called pteridology. Theophrastus is called as father of pteridology.



a. Fern



b. *Equisetum*



c. *Selaginella*

Fig: 2.5.1 Different species of pteridophyta

2.6.2 CHARACTERISTICS FEATURES OF PTERIDOPHYTES

Some of the basic features of pteridophytes are given below:

- Pterodophytes grow in cool and shady terrestrial habitat. Few are aquatic.
- Adult plant body is sporophyte and truly differentiated into leaves, stem and roots.
- They are vascular plant having presence of both xylem and phloem tissue.
- Leaves may simple, minute and sessile or petiolate.
- The primary root is short lived which is replaced by adventitious roots.
- The stems are usually herbaceous and branched monopodially or dichotomously.

7. Reproduction is through spores which are formed in sporangia. Sporangia develop on special structures, such as sori on the ventral surface of fertile leaves (fern), cones or strobili (*Equisetum*) or sporocarps (*Marsilea*, *Azolla*).
8. Plants are homosporous (all spores are of same size and structure) or heterosporous (spores of two different sizes).
9. The germination of spore give rise to multicellular, autotrophic (independent) gametophytic structure known as prothallus.
10. The sex organs, antheridia (male reproductive organs) and archegonia (female reproductive organs) develop on the prothallus.
11. The male gamete, antherozoid and female gamete, egg fuse to form a diploid oospore (Zygote). The fertilization takes place with the help of water. The oospore gives rise to sporophytic generation.
12. Alternation of generation is present in the life cycle.

Example: *Dryopteris* (fern), *Lycopodium*, *Selaginella*, *Marsilea*, etc.

2.6.3 *DRYOPTERIS*

Systematic Position

Kingdom	: Plantae
Division	: Tracheophyta
Sub-division	: Pteridophyta
Class	: Pteridopsida
Order	: Filicales
Family	: Polypodiaceae
Genus	: <i>Dryopteris</i>

Occurrence

Dryopteris are found in moist and shady places. They are terrestrial plant, widely distributed all over the world.

Plant body

The plant body is perennial, evergreen, vascular sporophytic and is differentiated into root, stem and leaves.

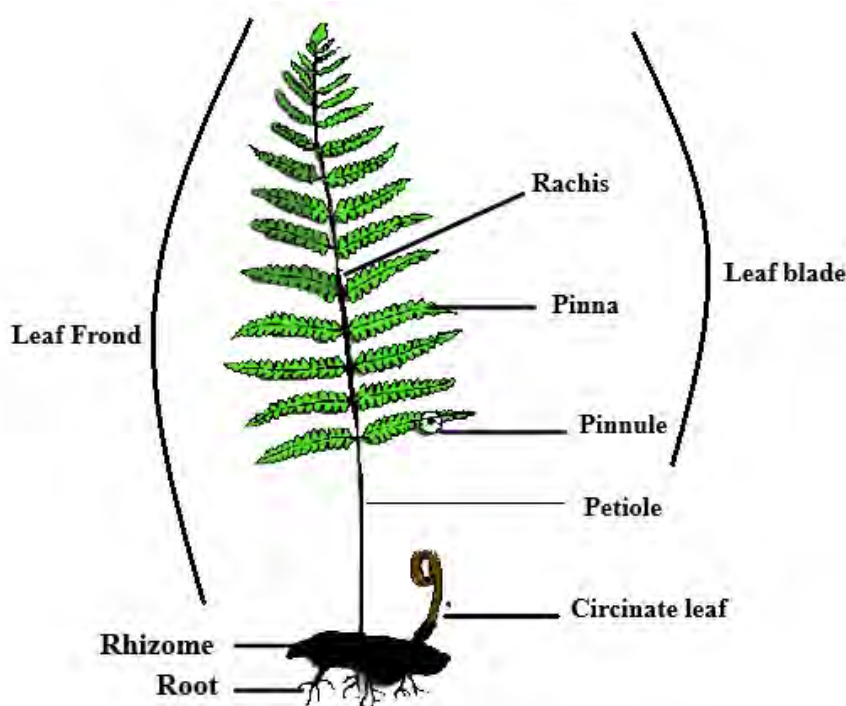


Figure 2.5.2 The plant body of *Dryopteris* (Fern)

The roots are adventitious that bear root hair and root cap. They arise from the basal portion of stem. The main function of root is anchorage and absorption of minerals from the soil. The stem is perennial, short, underground and modified into rhizome. It is covered with brown coloured scales called ramenta. The leaves are petiolate and pinnately compound that arise from the upper surface of rhizome. The leaf is known as frond. Each leaf is composed of numerous leaflets or pinnae. The pinnae are again divided into small pinnules. The leaf has long petiole which ends in a long rachis that bears pinnae. Mature leaves are of two types; the fertile leaf bearing sori called sporophyll and sterile leaf without sori called tropophyll. The young leaf is rolled up with the tip in the centre known as circinate leaf.

Reproduction

Reproduction in fern takes place by vegetative, asexual and sexual method.

1. Vegetative method:

It takes place by fragmentation. The older part of the stem dies and decays upto dichotomy and branches get separated. Then, each branch develops into new plant.

2. Asexual method:

It is the process of reproduction by the formation of spores. The plant body of *Dryopteris* is sporophyte. The spores are produced in sporangia which are found in sorus (pl. sori). The sori are found on ventral surface of sporophyll. Each sorus is covered by kidney shaped protective covering called indusium that contains numerous sporangia. Each sporangium has oval capsule and multicellular stalk. The capsule wall consists of two distinct region; thick walled region known as annulus and thin walled region known as stomium. The capsule consists of 12-16 diploid spore mother cells.

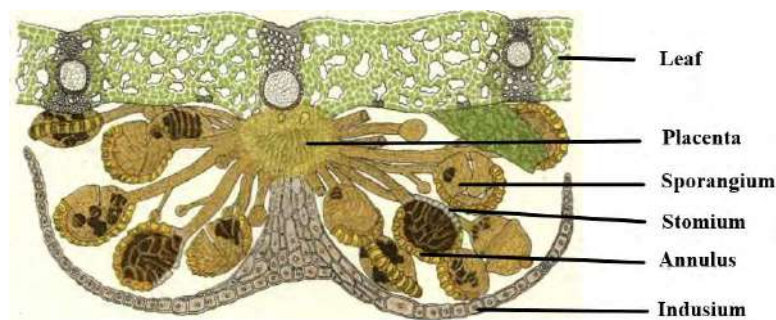


Figure 2.5.3 Internal Structure of Sorus

The spore mother cells undergo meiotic cell division to form 48-64 haploid spores. All the spores are of similar type hence, the plant is homosporous.

2. Sexual Reproduction:

After maturation of spores, the capsule wall breaks at stomium and spores are dispersed. After falling on a suitable soil the spores germinate to gametophytic stage known as prothallus.

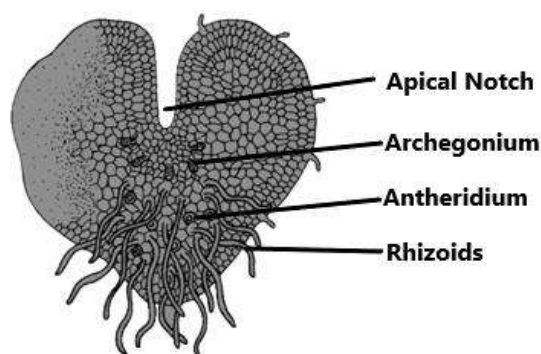


Figure 2.5.3 Structure of Prothallus

The prothallus is haploid, dorsiventrally flattened, multicellular, green, heart shaped structure. It is monoecious i.e. male and female reproductive organs are present on same thallus. At the anterior portion it consists of apical notch. Ventral surface bear rhizoids which help in anchorage and absorption of water and nutrients from the soil. It is independent and the mode of nutrition is autotrophic. The female sex organs are developed near the apical notch while the male sex organs are developed at posterior rhizoidal region.

An antheridium is a multicellular oval or rounded structure without stalk. It consists of androcytes which metamorphose into multiflagellate antherozoids or spermatozoids. The antheridial wall breaks when it absorbs water, then the antherozoids are liberated and are set free to swim in water.

An archegonium is flask shaped; consist of large basal venter and narrow neck. The venter consists of large egg cell and venter canal cell. The neck consists of binucleate neck canal cell.

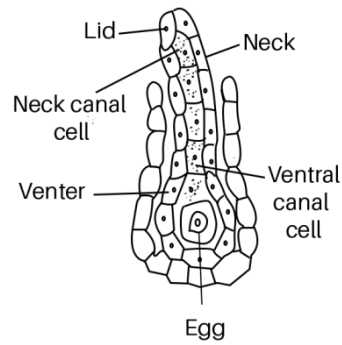


Figure 2.5.3 Structure of archegonium

After maturation of archegonium, venter canal cell and neck canal cell disintegrate to form a passage. The passage is filled with mucilage and malic acid. The malic acid of archegonium attracts the swimming antherozoids liberated from antheridia. Some of them enter the passage of archegonium, but only one antherozoid fertilize with egg to form diploid zygote (Oospore).

Although there are several archegonia in the prothallus only one is fertilized. The oospore is the beginning of sporophytic generation of fern plant. The zygote divides and redivides by mitotic cell division to form embryo, which later develops into sporophyte. Initially, the young sporophyte is fully dependent on prothallus. Once the roots are developed, the sporophyte becomes fully independent and then the prothallus disintegrates.

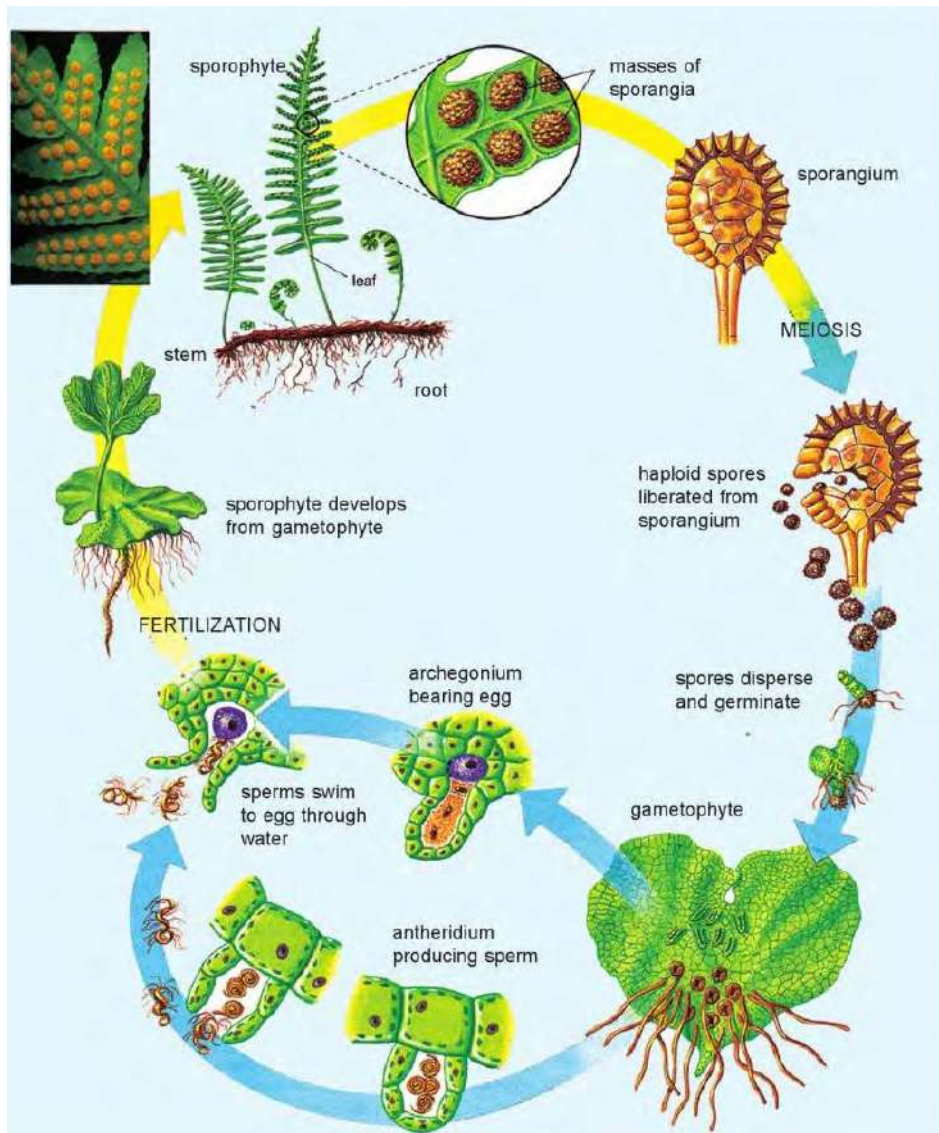


Figure 2.5.4 Life cycle of *Dryopteris* (fern)

2.6.4 ECONOMIC IMPORTANCE OF PTERIDOPHYTES

Pteridophytes are economically very important. Some are mentioned below:

1. **Ornamental value:**

Many ferns are grown as ornamental plants in gardens for their large, showy and graceful foliage.

2. **Food:**

Pteridophytes serve as a good source of animal food. The young leaf tips of ferns (like, - *Diplazium esculentum*), the circinate ptyxis are used as vegetable. The rhizome of many ferns are rich in starch, is used as food.

3. Soil Binding:

Pteridophytes prevent soil erosion by binding the soil even along hill slopes. Many pteridophytes species are used in soil conservation.

4. Medicines:

Some pteridophytes are of medicinal value. The spores of *Lycopodium* have been widely used in pharmacy as protective dusting powder. The foliage of *Lycopodium* is used as tincture, powder, ointment and cream as a stomachic and diuretic. Pteridophytes are used for the treatment of asthma, typhoid fever, etc.

5. As fossil fuels:

Ferns were the dominant plant millions of years ago. When they died, they formed thick layer of foliage and detritus, along with other trees and foliage. These layers are now in deep underground and converted into fossils fuels.

6. Forensic Investigation:

Moss spores are used in forensic investigations as finger print powder. It is also used as flash powder for photography.

7. Shelter for organisms:

Pteridophyte provides habitat for a variety of small organisms, such millipods, arthropods, larvae, bacteria and cyanobacteria. It also gives shelter to fish and frog eggs.

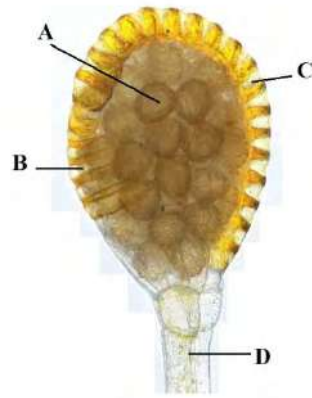
8. Nitrogen fixation:

Azolla (a water fern) has a symbiotic association with nitrogen fixing cyanobacterium. It is inoculated to paddy fields to function as biofertilizer.

EXERCISE

A. Tick the correct alternative.

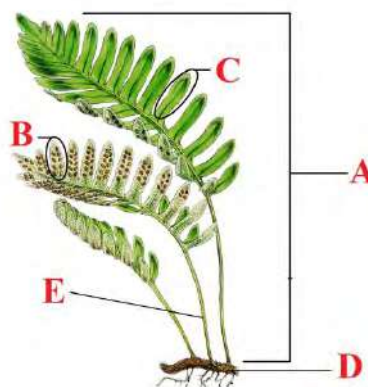
1. Which of the following statements accurately describes a key difference in the life cycles of pteridophytes and bryophytes?
 - a. pteridophytes have a dominant gametophyte generation, while bryophytes have a dominant sporophyte generation
 - b. pteridophytes have a dominant sporophyte generation, while bryophytes have a dominant gametophyte generation
 - c. pteridophytes produce seeds for reproduction, while bryophytes rely on spore dispersal
 - d. both pteridophytes and bryophytes have independent sporophytic generation.
2. In which of the following groups would you place a plant that produces spores, lacks seeds and has vascular tissue?
 - a. bryophyte
 - b. algae
 - c. pteridophyte
 - d. gymnosperm
3. What characterizes heterosporous plants in terms of spore production?
 - a. All spores are of the same size and structure
 - b. Spores may be of different types
 - c. Spores are produced only in cones (strobili)
 - d. Spores are produced only in sori
4. You are examining a plant specimen and notice that its rhizome is covered with a protective layer. Based on your observations, which of the following structures would you expect to find covering the rhizome of *Dryopteris*?
 - a. Flower
 - b. Thorns
 - c. Ramenta
 - d. spines
5. In fern, which of the following cell is binucleate?
 - a. Gametes
 - b. Neck canal cell
 - c. Venter canal cell
 - d. Spore mother cell
6. The structure of sporangium given below. Which part of the given diagram is responsible for breaking during the dispersal of spores?



- a. A
 - b. B
 - c. C
 - d. D
7. Which term describes the condition where both male and female reproductive organs are present on the same prothallus?
- a. Dioecious
 - b. Autotrophic
 - c. Monoecious
 - d. Heterosporous

B. Answer the following questions:

1. Define the following:
 - a. frond
 - b. sporangium
 - c. Prothallus
 - d. ramenta
2. Differentiate between bryophyte and pteridophyte.
3. What is alternation of generation?
4. Explain why ferns are classified as vascular cryptogams, providing examples of their vascular features and cryptogamic characteristics.
5. Demonstrate your understanding of the characteristic features of pteridophytes by listing them.
6. Study the given diagram of fern and answer the following questions:



- a. Label A, C, D and E.
 - b. Identified the specialized structure represent by B. Mention their function.
 - c. Write any two characters of fern leaf.
 - d. Name the structure that forms protective cover on D.
7. Explain the economic importance of pteridophytes.
 8. Illustrate your understanding of the structure and function of the prothallus in ferns by explaining it in detail, accompanied by a diagram.
 9. Describe the reproduction in *Dryopteris* with necessary diagram.

Project Work:

Create diagrams or models illustrating the alternation of generation in fern and discuss in class.

Chapter 2.7

GYMNOSPERM

Observe the picture and answer the following questions:



(a)



(b)

- i. Name the plant shown in the pictures.
- ii. What is the meaning of gymnosperm?
- iii. Have you ever seen the structure shown in second picture? What does it called?
- iv. Do you think cone produce seed?
- v. How are gymnosperm used in our daily life?

2.7.1 GENERAL INTRODUCTION

Gymnosperms (Greek: Gymnos-naked; sperma-seed) are naked seed plants because seeds are not enclosed in fruit. They are more ancient than the angiosperms in evolutionary terms. They were dominant in Jurassic and cretaceous period of Mesozoic era. Most of the gymnosperm have now become extinct.

The members are distributed throughout the temperate and tropical region of the world. They are widely distributed in the cold climates where snow, rather than rain, is the source of water. Gymnosperms are mostly perennial, xerophytic and evergreen plants. They are woody trees, shrubs and rarely climbers. Aquatic and herbaceous forms are totally absent. Theophrastus first used the word gymnosperm.

2.7.2 CHARACTERISTICS FEATURES OF GYMNOSPERM

Some of the basic features of gymnosperm are given below:

1. Gymnosperms are evergreen woody trees or shrubs.
2. They are perennial and show xerophytic adaptation.
3. The plant body is sporophyte and differentiated into root, stem and leaves.

4. The plant possesses well developed tap root system. In some cases the roots are symbiotically associated with algae (e.g. coralloid root of *Cycas*) or with fungus (e.g. mycorrhizal root of *Pinus*).
5. The stem is tall, erect, aerial, solid, woody, branched and covered with scaly bark.
6. In conifers two types of branches are present. The branches of limited growth (Dwarf shoot) and branches of unlimited growth (long shoot).
7. Leaves are dimorphic i.e. two types (foliage leaves and scale leaves).
8. Secondary growth occurs in roots and stems by the activity of cambium. Annual rings are distinct in most of the gymnosperm.
9. Gymnosperms are heterosporous, i.e. produces two types of spores (microspores and megaspores) inside sporangia.
10. The sporangia are developed on special leaf like structures, called sporophylls.
11. The sporophylls are aggregated to form cones or strobili. The cones are generally unisexual.
12. Pollination is anemophilous (i.e. pollination by wind).
13. Double fertilization is absent.
14. The life cycle shows alternation of generation. The sporophytic generation is dominant.

Examples: *Pinus*, *Cycas*, *Ginkgo*, *Taxus*, *Ephedra*, *Juniper*, etc.

2.7.3 STRUCTURE AND REPRODUCTION IN *PINUS*

Structure:

Pinus are large, perennial and evergreen tall tree. It is worldwide in distribution mostly confined to northern hemisphere. They are mostly present in the temperate regions. The plant body is sporophyte. The plant bears longer branches towards the base and progressively shorter branches towards the upper region, giving a pyramid like appearance. The plant body is divided into root, stem and leaves. It has tap root system with lateral roots. The lateral roots are well developed and spread over a large area. The root hairs are replaced by mycorrhizal roots in older lateral root. In **mycorrhizal** root, there is a symbiotic association with fungi. The root helps in absorption and fixation. The stem is cylindrical, erect and remains covered with bark. The main trunk is unbranched. It has branches confined to the apical region. These branches form a characteristics canopy i.e. pyramid like appearance. The branches are dimorphic (i.e. two types of branches) - Branches of unlimited growth or long shoots which contain apical bud and grow indefinitely; whereas Branches of limited growth or dwarf shoots which are devoid of any apical bud, thus are limited in their growth. There are two types of leaves, the scale leaves and the green foliage leaves (modified as **needles**). The scale leaves are small, membranous and brownish in colour and are protective in function. They present in both long and dwarf shoot. The foliage leaves are green and needle like present in dwarf shoot only. The dwarf shoot with cluster of foliage leaves are known as '**spurs**'. The number of needles in each spur varies from species to species. The foliage leaves helps in photosynthesis.

Reproduction:

Pinus are monocious (i.e. male and female reproductive organ developed in same individual). The male and female reproductive structures, known as cones or strobili develop on different branches of the same tree.

Male cone

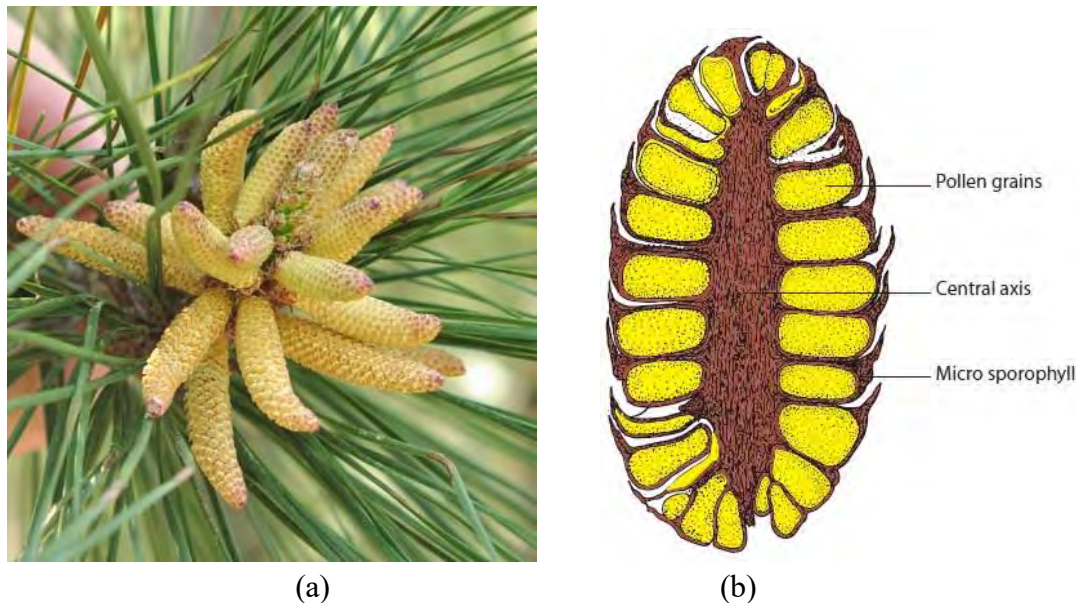


Figure 2.7.1 (a) Male cone (b) L.S. of male cone

The male cones are much smaller. They are produced in clusters near the tip of the long shoots. Each male cone is oval in shape and ranges from 1.5 cm to 2.5 cm in length. It consists of spirally arranged specialized leaves known as microsporophylls or stamens around the central cone axis. Each microsporophyll bears two sacs like microsporangia (pollen sac) on the ventral side. The microsporangia produce a large number of microspores (pollen grains). Each microspore or pollen grain is a rounded and yellow-coloured, light, uninucleate structure with two outer covering an inner intine and an outer exine. It has balloon like wings. The wings help in the dispersal of spores by wind.

Female cone

The female cones develop laterally in the axil of scale leaves. They are formed in clusters in place of long shoots. They are produced on the lower branches from those of the male cones. There may be one to four cones on each long shoot. Each cone consists of central axis bearing spirally arranged scales. The scales are of two types; bract scales and ovuliferous scales. The bract scales are thin membranous and are directly attached to the central axis. The ovuliferous scales are present on the ventral surface of each bract scale. Each ovuliferous scale bears two ovules (megasporeangia), situated side by side on upper side. The ovule (megasporeangium) is inverted (i.e. anatropous) has a mass of nucellar tissue surrounded by a single integument. The micropylar end of the ovule is directed towards the central axis. The diploid megaspore mother cell present in the nucellus of ovule undergoes meiosis and forms a linear tetrad of four megaspores. Upper three megaspores degenerate but the lowermost megaspore becomes functional. The functional megaspore (embryo sac) increases in size and occupies the major part of the nucellus. This functional megaspore develop into female gametophyte.



Figure 2.7.2 (a) Female cone (b) L.S. of female cone

Pollination and Fertilization

Microspore is the first cell of male gametophyte. It germinates inside microsporangium. It divides and forms 4-celled stage (2-prothelial cell, 1-antheridial cell and 1-tube cell). These 4-celled stage pollen grains released and pollination takes place. The pollination in *Pinus* is anemophilous (i.e. takes place by wind). At the time of pollination the ovule secrete mucilaginous fluid from the micropyle and pollen grains entangled on it. These pollen grains, then, draws into the pollen chamber and remain inactive for few months. Then, tube cell project to form pollen tube, which elongate towards the archegonium. The antheridial cell divides to form stalk cell and body cell. The body cell again divides to form two motile unequal male nuclei.

The functional megaspore is the first cell of the female gametophyte. Two to four cells of the female gametophyte at the micropylar end function as archegonial initials and form two to four flask shaped archegonia. Each archegonium consists of a large venter, a short neck and a very large egg or oosphere. The neck is without neck canal cells.

The fertilization takes place after about one year of pollination. The pollen tube containing two male nuclei elongates and penetrates the archegonium through micropyle and reaches up to the egg. One of the male nuclei fuses with the egg forming diploid zygote (oospore) and the remaining one get degenerated. The zygote is the first cell of sporophyte. The fertilized egg (Zygote) undergoes mitotic division and develops into embryo. After fertilization, integument and megasporangium are converted into seed coat and seed respectively. A mature embryo consists of radicle towards the micropylar end and plumule towards the inner side. It is surrounded by cotyledons. Some part of the ovuliferous scale fuses with the developing seed to form wing, which helps in dispersal in air. Seeds are generally dispersed by wind. Under favourable conditions, the seed germinates into new sporophyte.

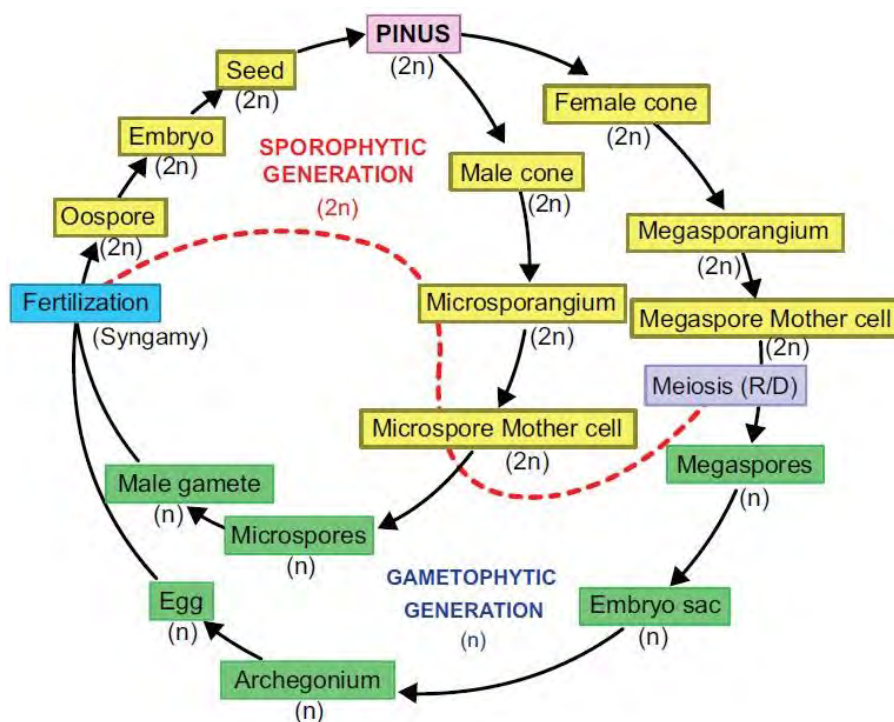


Figure 2.7.3 Life cycle of *Pinus*

2.7.4 ECONOMIC IMPORTANCE OF GYMNOSPERM

Gymnosperms are economically most important plants. The economic importances of gymnosperm are explained below:

1. Ornamental importance:

Species of *Cycas* are used for decoration purposes. Many gymnosperms are cultivated in the gardens as ornamental plants.

2. Source of food :

The cycads are used as food in many parts of the world. They are eaten as a source of starch which is obtained from stem or seed of cycads. Seeds of *Pinus gerardiana* (chilgoza) are edible.

3. Source of wood:

Many gymnosperm trees are of great importance for their light colour, straight grained and light weighed soft wood. The wood is used as timber as building materials, furniture, packing case, match box, pencils, railways sleepers, fuels, etc.

4. Medicinal importance:

Species of *Ephedra* yield ephedrine (alkaloid) which is used in treatment of asthma, cough, cold, bronchitis, etc. Anti-cancerous drug (taxol) is obtained from the bark of *Taxus*.

5. Industrial importance:

The gums obtained from *Cycas* are used as an adhesive. Tannin extracted from the bark of *Araucaria* is used in leather industry. The leaves of *Cycads* are used for preparing baskets, mats, hats, brooms, etc. Plywood is prepared from *Podocarpus*. Resins obtained from conifers are utilized commercially in manufacture of waterproof paints, sealing wax, etc.

EXERCISE

A. Tick the correct alternative.

1. Gymnosperms exhibit heterospory. What does this mean?
 - a. They produce seeds with varying sizes.
 - b. They have separate male and female cones.
 - c. They produce two types of spores.
 - d. They have both woody and herbaceous stems.
2. Which is the tallest known gymnosperm species?
 - a. *Pinus*
 - b. *Ginkgo*
 - c. *Sequoia*
 - d. *Ephedra*
3. What is the dominant generation in the life cycle of gymnosperms?
 - a. Gametophyte
 - b. Sporophyte
 - c. Zygote
 - d. Embryo
4. In gymnosperms, the term ‘megasporophyll’ refers to which of the following structures?
 - a. carpels
 - b. Stamens
 - c. leaves
 - d. Female cone
5. What is the primary mode of pollination in *Pinus*?
 - a. entomophily
 - b. hydrophily
 - c. anemophily
 - d. ornithophily
6. Coralloid roots, characterized by a symbiotic association with algae, are typically found in which of the following plant?
 - a. *Cycas*
 - b. *Pinus*
 - c. *Dryopteris*
 - d. *Lycopodium*

7. Ephedrine, a drug derived from *Ephedra*, is primarily used for the treatment of which medical condition?
 - a. Asthma
 - b. Hypertension
 - c. Allergies
 - d. diabetes
8. What is the first cell of the sporophyte generation after fertilization in gymnosperms?
 - a. Pollen grain
 - b. Zygote
 - c. Microspore
 - d. Megaspore
9. In the life cycle of gymnosperms, what structures are formed as a result of the transformation of integument and megasporangium after fertilization?
 - a. Seed coat and seed
 - b. Seed coat and ovule
 - c. Ovule and seed
 - d. Seed and seed coat

B. Answer the following questions:

1. Differentiate between:
 - a. Mycorrhizal and coralloid root
 - b. Long shoot and dwarf shoot
2. Describe in brief the general characteristics features of Gymnosperm.
3. Discuss the structural and functional differences between the two types of leaves found in *Pinus*.
4. How does the symbiotic relationship between plants and mycorrhizal fungi enhance nutrient uptake and overall plant growth in diverse ecosystems?
5. Compare and contrast the structural features and reproductive functions of the male and female cones in *Pinus*.
6. Explain the economic importance of Gymnosperm.
7. Describe the reproduction in *Pinus* with necessary diagram.

Project Work:

Prepare a report on diversity, distribution and ecological importance of gymnosperm in Nepal. Present your report in class.

Chapter 2.8

ANGIOSPERM

Observe the picture and answer the following questions:



(a)



(b)

- i. Why these plants are considered to be most advanced group?
- ii. How do you think these plants differ from non-flowering plants like ferns, bryophytes or algae?
- iii. What are plants that produce flowers called?
- iv. Why flowers are important in these plants?
- v. What do you know about the importance of flowering plants in ecosystem?

2.8.1 INTRODUCTION TO ANGIOSPERM

The term angiosperms (Greek; angios-enclosed, sperma-seed) means ‘enclosed seed’ because the ovules or seeds are enclosed within a hollow ovary. They are the most common among land plants and form the largest group of plant kingdom. These plants are found almost everywhere in all possible type of habitat and climate and may be annual, biennial or perennial herbs, shrubs, trees and climbers. Angiosperms show great diversity both in vegetative and in reproductive structures. They show variation in life span, size, form, habit, etc.

2.8.2 MORPHOLOGY OF ANGIOSPERM

Morphology is the study of forms and features of different plant organs like roots, stems, leaves, seeds, fruits etc. The body of a typical angiosperm is differentiated into an underground **root system** and an aerial **shoot system**.

The morphology of angiosperms is described in following headings:

1. Root
2. Stem
3. Leaves
4. Inflorescence

5. Flower
6. Fruit

1. THE ROOT

The root is generally non-green, underground and cylindrical part of the plant developed from the radicle of the embryo. It is negatively phototropic without nodes and internodes. The whole extent of the roots of a plant is called the root system. The development of the root system differs fundamentally in vascular plants and may be classified in two groups:

a. **Tap root system:**

The radicle elongates to form primary or main root which grows inside the soil. It produces number of lateral roots called as secondary roots, which further bear tertiary roots and rootlets. The primary root and its branches constitute the tap root system. Tap root system is generally found in dicot plants.

b. **Fibrous root system:**

In monocot plants, primary root arises from radicle, does not develop further and soon is replaced by many thin roots developed from the base of stem. It is known as fibrous root system. In some plants, such as grass, sugarcane, banyan tree, roots develop from part of plant other than the radicle and are called adventitious roots.

Morphologically roots have four distinct regions – Root cap, meristematic zone, elongation region and maturation region. **Root cap** is terminal cap like structure. It protects tender apex of root. Just behind the root cap a region of small and thin walled cells are found known as **meristematic zone**. They divide repeatedly and increase cell number. The newly formed cells lose the power of cell division but undergo rapid elongation and enlargement which are responsible for the increase in length of root. This region is known as **elongation region**. The cells adjacent to the elongation region gradually differentiate and become mature. This is known as

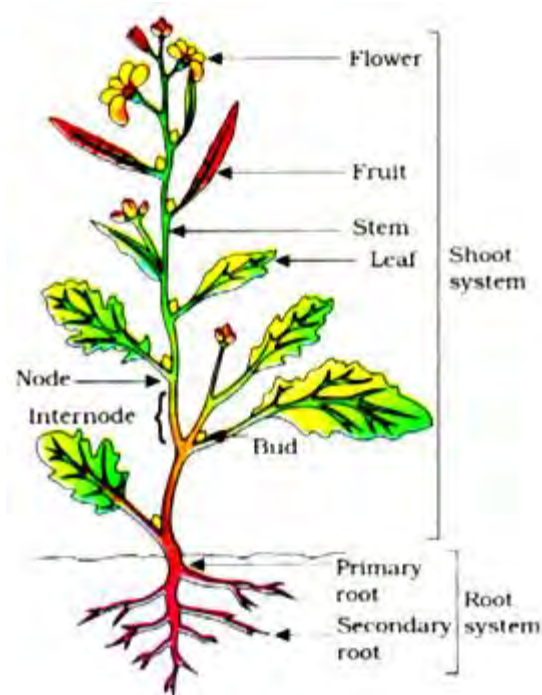


Figure: 2.8.1 Morphology of flowering plant

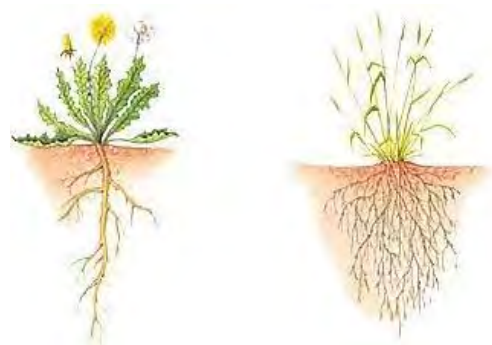


Figure: 2.8.2 Types of root system

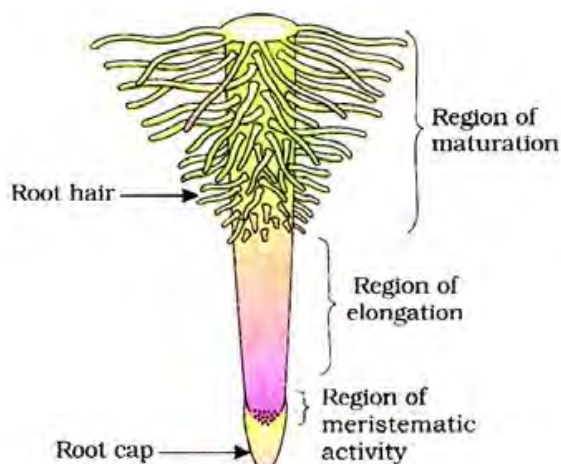


Figure: 2.8.3 Region of root

region of maturation. The epidermal cells of this region form thread like tubular structure called root hairs. These root hairs absorb water and minerals from the soil.

Functions of root:

- i. Roots support the aerial part of the plant and fix the plant in the soil.
- ii. They help in absorption of water and minerals.
- iii. Roots prevent soil erosion by holding it.
- iv. The respiratory root (pneumatophore) of mangrove helps in respiration.
- v. The assimilatory roots are green and prepare food for photosynthesis.
- v. Some roots helps in vegetative propagation.
- vi. The roots of certain plants are modified for storage of food.

2. THE STEM

The stem is the axis of aerial part of the plant. It shows positive phototropic and negative geotropic growth. Stem arises from plumule of embryo in a germinating seed. It has **nodes** and **internodes**. Branches, leaf, flower bud, fruits and bracts are developed from nodes. The portion between two nodes is known as internode. The stem is generally green during young stage and later often become woody and dark brown. The growing apex of the stem remains covered by a number of tiny leaves which arch over it. Buds are the stem's primary growing points which may be terminal or axillary. **Terminal buds** are located at the tip of the stem which help in increment of length of plant. The **axillary bud** is formed at the junction between a leaf and the stem. It produces the lateral branches. There are number of minute pores on stems that allow for gas exchange called as **lenticels**. The stem is covered by outer protective layer known as **bark**.

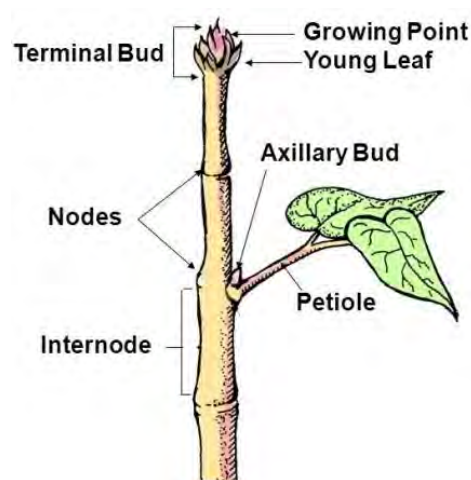


Figure 2.8.4 Morphology of stem

Functions of stem:

- i. The main stem is usually thick, aerial and stout and keeps the plant in erect position.
- ii. The stem conducts water and minerals from the root to the leaf. It also transports the prepared food from the leaf to the different parts of plant body.
- iii. Underground modified stem helps to store the food.
- iv. In fleshy stem of cactus help to store the water.
- v. The young green stem in certain plants are modified which helps in photosynthesis.
- vi. Thorns, the modified form of stem help to protect the plant from grazing animals.
- vii. Many aerial, sub-aerial and underground stem help in vegetative propagation.

3. THE LEAF

The leaf is a lateral generally flattened structure borne on the stem. The leaves develop from the nodes and have axillary buds in its axil. It is normally green in colour and its main function is photosynthesis. All the leaves of a plant are known as **phyllome**. Leaves originate from shoot apical meristem and are arranged in acropetal order.

Parts of leaf



Figure 2.8.5 Morphology of a typical leaf

A typical leaf consists of three main parts: leaf base, petiole and lamina. The leaves are attached to stem by leaf base and may bear lateral small leaf like structures called stipules. The leaf having stipule is called stipulate and leaf without stipule is called exstipulate. The petiole is the stalk of leaf that holds the blade to light. It connects the lamina with branch of stem. The leaf with petiole is called petiolate leaf while the leaf without petiole is called sessile leaf. The lamina or the leaf blade is the green flattened part of the leaf with network of veins. The lamina is the most important part of the leaf since this is the site of food manufacture for the whole plant. The vein that runs from petiole to the apex is called as mid rib or main vein. The mid rib produces thinner lateral veins which further give rise to veinlets.

The arrangement of veins and veinlets in the lamina of leaf is called as **venation**. When the veinlets form a network, the venation is called **reticulate venation** (e.g. leaves of dicot plant). When the veins run parallel to each other within a lamina, the venation is called as **parallel venation** (e.g. leaves of monocot plant).

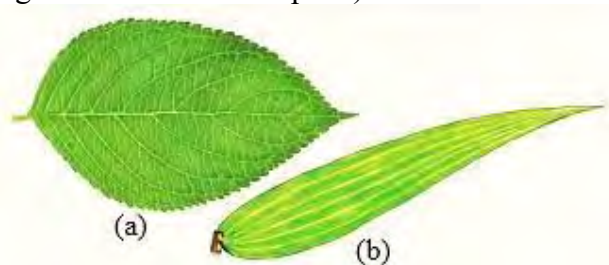


Figure 2.8.6 Venation (a) Reticulate venation (b) Parallel venation

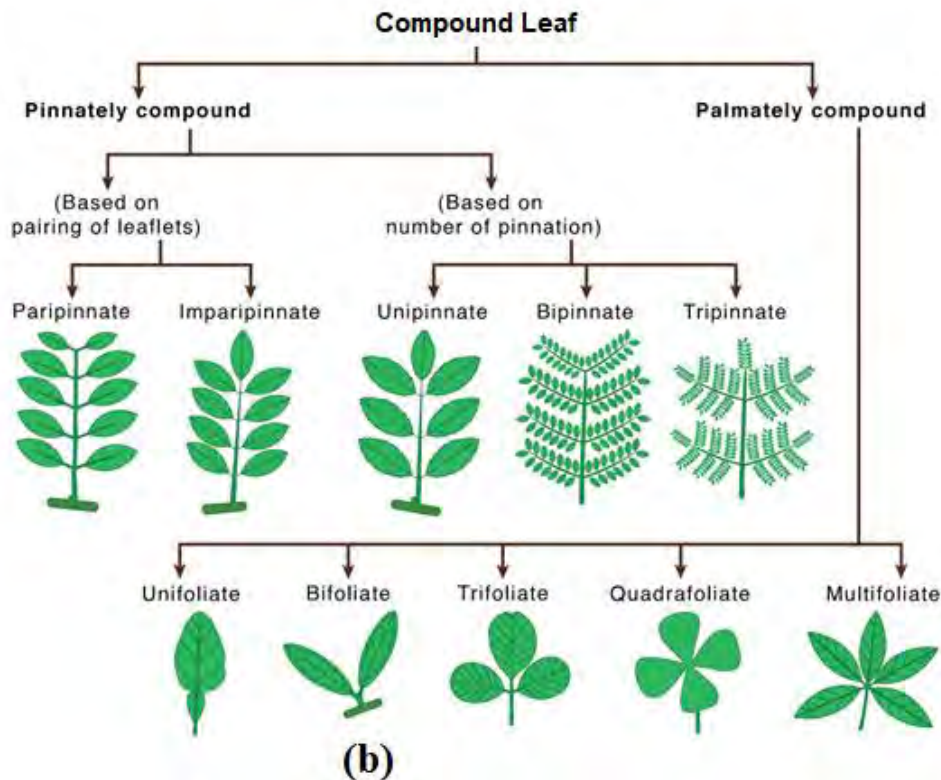
Types of leaf

A leaf which may be entire or incised to any depth but not down to the midrib or petiole is simple leaf. When the incisions of the lamina reach up to the midrib breaking it into a number of leaflets, the leaf is called compound leaf. The compound leaves are of two types i.e. pinnately

compound leaf (number of leaflets are present on a common axis) and palmately compound leaf (leaflets are attached at a common point).



(a)



(b)

Figure 2.8.7 Types of leaf (a) Simple leaf (b) Compound leaf

Phyllotaxy

Phyllotaxy is the arrangement of leaves on a stem or branch. The leaves are so arranged that they get appropriate amount of sunlight for photosynthesis. It avoids overcrowding of leaves at one place. It is basically of three types: alternate, opposite and whorled as shown below in the diagram.

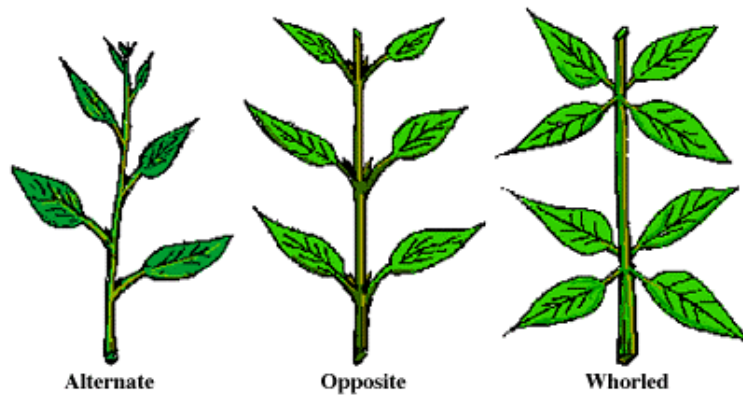


Figure 2.8.8 Arrangement of leaf

Functions of leaf:

- i. The main function of leaf is to manufacture food during the process of photosynthesis.
- ii. It helps in exchange of gases between atmosphere and the plant body.
- iii. It helps in transpiration i.e. removal of excess of water in the form of vapour from the aerial part of the plant.
- iv. Some modified leaves help to store the food.
- v. The leaves of *Bryophyllum*, *Begonia* etc. produce buds on their margin that develop into new plants.
- vi. The leaves provide protection to axillary bud.

4. THE INFLORESCENCE

The axis that bears flowers is called peduncle. Inflorescence is defined as the arrangement of flowers on floral axis or peduncle.

Depending on whether the floral axis terminates into a flower or shows continuous growth, the inflorescences are of two types:

a. Racemose:

In this type of inflorescence the main axis continues to grow and does not terminate in a flower. The flowers are developed laterally in acropetal manner (i.e. older flowers are arranged towards base and young flowers at tip) or centripetal manner (i.e. younger flowers are arranged at centre and older flowers are arranged in periphery).



(a)



(b)

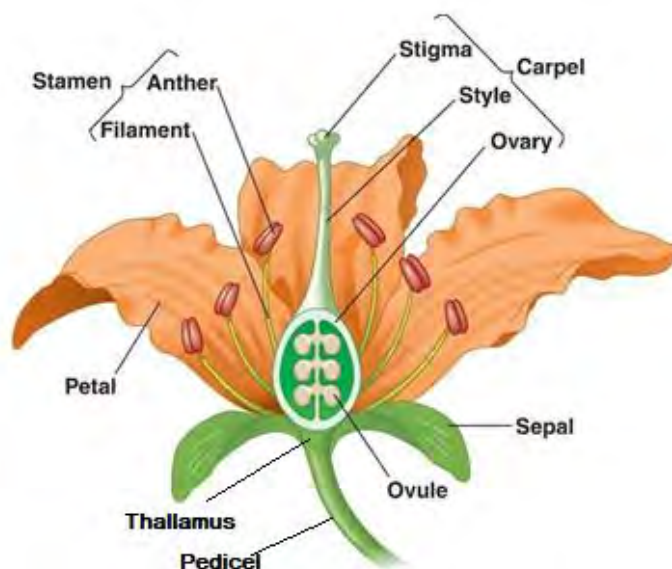
Figure 2.8.9 Inflorescence (a) Racemose (b) Cymose

b. Cymose:

In this type of inflorescence, the main axis terminates in a flower. The further growth occurs from nearby lateral branches which also end in flowers. The flowers are developed in a basipetal order (i.e. the older flowers are present at tip and young buds are arranged towards base).

5. THE FLOWER

Flower is a highly condensed and modified reproductive shoot. It is meant for sexual reproduction. The study of flower is called anthology. Bracts are modified reduced leaves present at the base of some flower. The flower with bract is called bracteate flower and the flower without bract is called ebracteate flower. The flower has short or long stalk known as pedicel. Flower with pedicel is called pedicellate but without pedicel is called sessile. The upper part of pedicel is swollen, spherical or conical in shape which is called thalamus or receptacle.



2.8.10 Structure of a typical flower

Symmetry of flower

The floral symmetry may be actinomorphic (radially symmetry), zygomorphic (bilateral symmetry) or asymmetric (irregular).

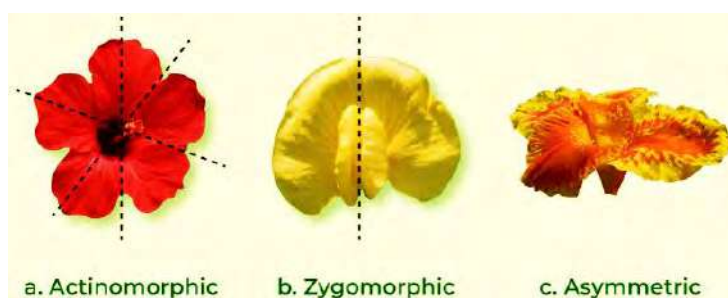


Figure 2.8.11 Symmetry of flower

Insertion of floral parts

Based on position of all four floral parts in respect of the ovary on thalamus, the flower are:

- Hypogynous flower: The ovary is superior i.e. calyx, corolla and androecium are situated below the ovary. E.g. mustard, brinjal etc.

- b. Perigynous flower: The thalamus grows upwardly and form a cup shaped structure. Gynoecium is situated in the centre and other parts of flower are located on the rim of the thalamus almost at the same level. The ovary is half inferior. E.g. rose etc.
- c. Epigynous flower: Ovary of a flower is fused with thalamus and other parts of flower are present above the ovary. The ovary is inferior. E.g. sunflower etc.

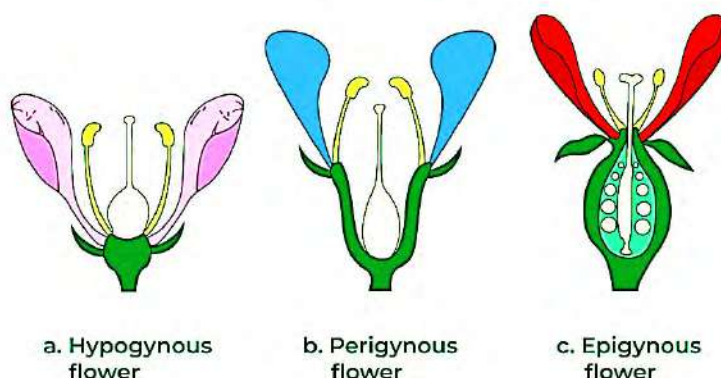


Figure 2.8.14 Insertion of flower

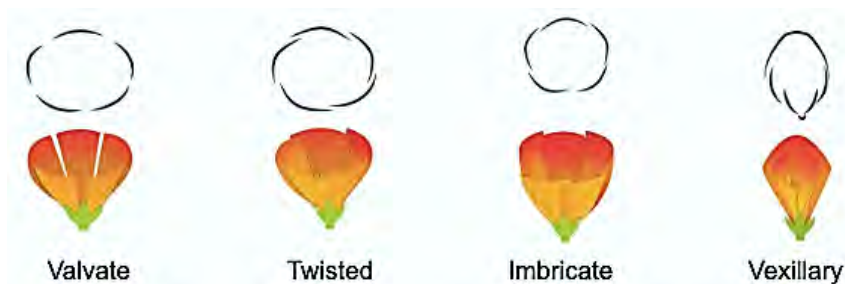
Parts of flower

A typical flower consists of four different types of whorls present on thalamus.

1. Calyx: The unit of calyx is called sepal. It is the outermost whorl, generally green in colour (sepaloid) or sometime colourful (petaloid) that protects the flower in bud condition. The sepals may be free (i.e. polysepalous) or fused (i.e. gamosepalous).
2. Corolla : The unit of corolla is called petal. It is variously coloured whorl of flower. Its bright coloured petals attract the insects which help in pollination. The free petals are termed as polypetalous and fused petals are termed as gamopetalous.

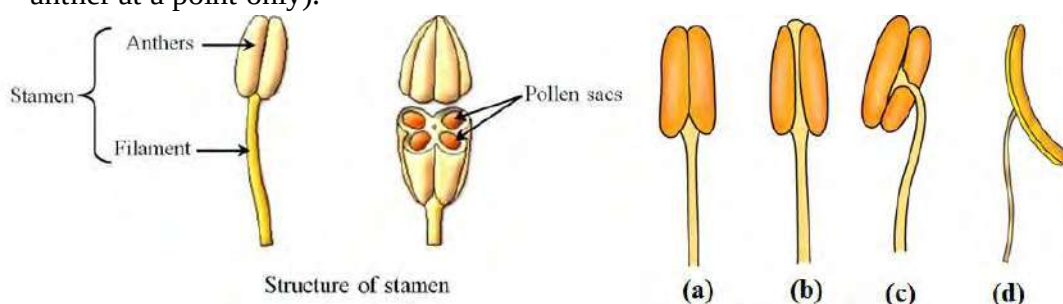
Calyx and corolla are accessory organs. In some flowers the calyx and corolla are not distinct and constitute single whorl known as **perianth**. The unit of perianth is termed as tepal. The mode of arrangement of sepals or petals in floral bud with respect to the other members of the same whorls is known as **aestivation**. Following are the major types of aestivation:

- a. Valvate – sepals and petals in a whorl just touch one another at the margin without overlapping. E.g. Mustard, Custard apple etc.
- b. Twisted – margin of adjacent sepals or petals overlap regularly. E.g. *Hibiscus*, Lady finger etc.
- c. Imbricate – sepals and petals overlap each other but not in any regular manner. E.g. Gulmohar, etc.
- d. Vexillary – Occurs in pentamerous flower. In this the largest one overlaps the two adjacent which in turn overlap two smallest anterior. It is also known as descending imbricate. E.g. pea, bean etc.



2.8.11 Types of aestivation

3. **Androecium:** The unit of androecium is called stamen. The stamens in a flower may be free (polyandrous) or united. The united stamens in one bundle (monadelphous), in two bundles (diadelphous) or in many bundles (polyadelphous). Stamens are sometimes attached to petals known as epipetalous. It is the male reproductive whorl of flower and consists of two parts i.e. anther and filament. The stamens may be syngenesious (i.e. anthers are united together but the filaments remain free) or synandrous (i.e. both anthers and filaments are fused throughout the whole length). Each anther is usually bilobed and each lobe has two chambers, the pollen sacs. The pollen grains are produced in pollen sac. The attachment of filament to anther lobe may be adnate (filament runs through the whole length of the anther from the base to the apex), basifixed (filament is attached to anther by its base), dorsifixed (filament is attached at the centre to the back of the anther) and versatile (filament attached to the back of the anther at a point only).



4. **Gynoecium :** The unit of gynoecium is called carpel/pistil. It is the female reproductive whorl of flower and consists of three parts i.e. stigma (receives pollen grains), style (connects ovary and stigma) and ovary (basal swollen ovule containing part). Each ovary bears one or more ovules attached to cushion like structure known as placenta.

Placentation

The arrangement of ovules within the ovary is known as placentation. The different types of placentation are:

Axile placentation: placenta is axial (around an axis) and the ovules are attached to it. Ovary is divided into many locules. E.g. tomato, lemon etc.

Marginal placentation: Ovary bears longitudinal placenta and the placenta bears one or two rows of ovules. E.g. pea, etc.

Parietal placentation: the ovules develop on the inner wall of the ovary or on parietal part. Ovary become bi or multilocular due to formation of a false septum. E.g. cucurbita, mustard etc.

Free central placentation: Ovules are borne on central axis and septa are absent. E.g. *Dianthus*, *Primula* etc.

Basal placentation: a single ovule is borne at the base of unilocular ovary. E.g. sunflower, marigold etc.

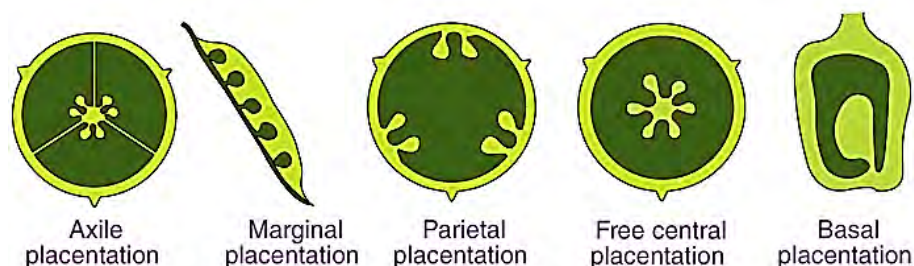


Figure 2.8.12 Types of placentation

Function of flower

- Male and female gametes are produced inside respective reproductive structures within a flower that later fuse to form zygote.
- After fertilization, the ovary develops into fruit.
- Flower provides nectar to attract pollinators like honeybees which later convert it into honey.
- Petals are brightly coloured and scented to attract animals and insects for pollination that ultimately helps in fertilization.
- Because of brightly coloured petals, human beings cultivate and use flowers for various occasions like wedding, funerals, expressing love etc.

6. THE FRUIT

Fruit is one of the characteristics of flowering plant. After fertilization, the ovule forms seed and ovary developed into fruit. So, fruit is defined as “**Matured or ripened ovary, developed after fertilization.**” Sometimes, a fruit is formed without fertilization of ovary; this type of fruit is called as **parthenocarpic fruit** which is seedless (e.g. seedless banana, seedless grapes etc). When only the ovary of the flower develops into the fruit, it is called **true fruit** (e.g. mango, litchi etc). In some cases the portions other than ovary, i.e. thalamus or calyx may also take part in the development of the fruit; these types of fruit are called **false fruit** (e.g. apple, pear etc.)

Parts of fruit

Generally, the fruit consists of two parts i.e. pericarp (develop from ovary wall) and seeds (develop from ovules). The pericarp may be dry or fleshy. When pericarp is thick and fleshy, it is differentiated into epicarp, mesocarp and endocarp. Epicarp is the outer part that forms the skin of fruit. Mesocarp is edible and fleshy part present inner to epicarp. Endocarp is innermost hard region that encloses the seeds.

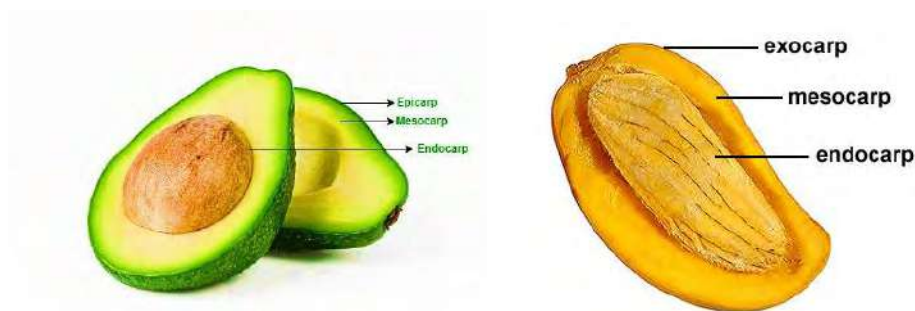


Figure 2.8.15 Parts of fruit

Types of fruit

The fruits are basically classified in following three types:

1. *Simple fruit*

A single fruit developing from the ovary of a flower. It may be dry or fleshy. Example: Pea, Mustard, rice, apple, lemon, etc.

2. *Aggregate fruit*

Number of simple fruits or fruitlets develop from an apocarpous pistil of a flower are collected together and form an aggregate fruit. The fruitlets of a group are collectively called etaerio. Example: strawberry, blackberry, Raspberry, custard apple etc.

3. *Multiple or Composite fruit*

The fruit formed by whole inflorescence are called multiple or composite fruits. Examples: pineapple, Jack fruit, mulberry etc.

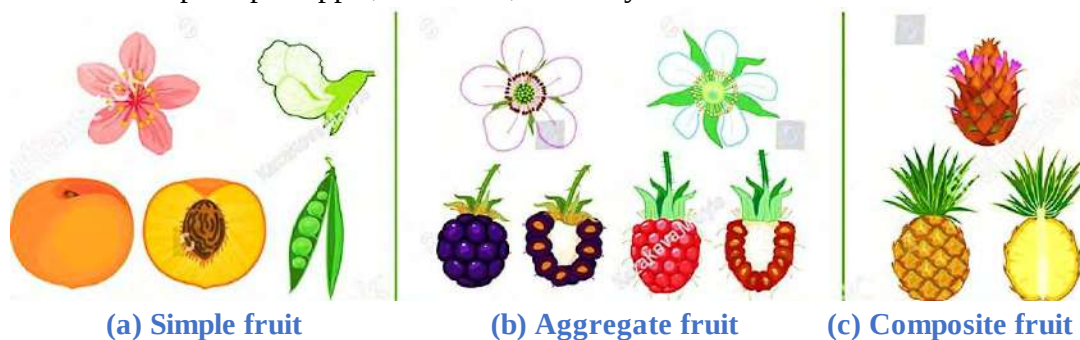


Figure 2.8.16 Types of fruit

Functions of fruit

- Fruit protects the seeds from unfavourable conditions.
- The presence of stored food attracts animals that help in dispersal of the seeds.
- The fleshy part of the fruit is responsible for storing the food.
- It provides nutrition to the developing seedling in some cases.

2.8.3 CONCEPT OF TAXONOMY

Taxonomy is the science of naming, describing and classifying organisms including all plants, animals and microorganisms, based on morphological, behavioural, genetic and biochemical variations. In short, taxonomy is defined as ‘the branch of biology that deals with identification, nomenclature and classification of organisms.

Identification is the process of finding the correct name and place of an organism in a system of classification. Nomenclature is the system of giving proper names or scientific names to all the organisms so that these can be easily distinguished from one another. Classification is the

system of grouping the organisms according to their resemblances or differences in characteristics. Carolus Linnaeus is considered as the father of taxonomy. He is the one who developed a procedure to name and organize species.

Systematics is the science that concerns with identification, nomenclature, description and classification of organisms based on unique properties of every species and groups of species at every level of classification from species to kingdom. It helps to understand the relationship among diverse species.

2.8.4 TAXONOMIC HIERARCHY

A taxon (plural: taxa) is a group of organisms that are classified as a unit. It means a category or taxonomic group of any rank like species, genus, family etc. Taxonomic hierarchy or hierarchical system was proposed by Linnaeus. It includes seven categories arranged in descending order from Kingdom to species. The arrangement of taxonomic categories in their proper order on the basis of their taxonomic ranks is called taxonomic hierarchy. There are seven obligate taxonomic categories in taxonomic hierarchy like kingdom, phylum/division, class, order, families, genus and species. These taxonomic categories are further classified as major categories (like- Kingdom, phylum/division, class, order and families) and minor categories (like-genus and species).

Taxonomic Categories

- Species:** It is the basic unit of taxonomy. It consist of closely resemble individuals which are genetically distinct, interbreed freely and produce fertile offspring.
- Genus:** It is the group of species which have common characters.
- Family:** It is the group of one or more genera having common characters.
- Order:** It is the group of family with common characters.
- Class:** It is the group of order with common characters.
- Phylum/Division:** It is the group of class with common characters. The term division is used for plant and the term phylum is used for animals.
- Kingdom:** Kingdom is the highest category in taxonomy hierarchy. It is the group of phylum/division having common characters.

Do you know ?

<u>Suffix for the plant taxa</u>	<u>Hierarchical Classification of Radish</u>
Division : phyta/spermae	Kingdom : Plantae
Class : opsida/nae	Division : Spermatophyta
Order : ales	Class : Dicotyledonae
Family : aceae	Order : Parietales
	Family : Brassicacea
	Genus : <i>Raphanus</i>
	Species : <i>R. sativus</i>
	Common name : Radish

2.8.5 CLASSIFICATION SYSTEM

Classification is defined as the system of grouping the organisms according to their resemblance or differences in characteristics. Organisms have been classified from different points of view at different times. The various types of classification are described below:

a. Artificial system:

It is based on one or a few easily observed characters (like habit, habitat, size, etc.) rather than on natural or evolutionary relationships. It is easier and quicker method of classification of organisms in the field. For example, the grouping of plants into herbs, shrubs and trees. There are many drawbacks in this system such as lack of detail information, heterogeneous grouping of organisms, separation of closely related organisms etc. Example: Linnaeus Classification.

b. Natural system:

It is based on large number of characters and utilizes all the information available at the time. This system of classification gives us a true idea about natural relationship existing among the organisms. This system of classification avoids the heterogeneous grouping of organisms. Example: Bentham and Hooker's classification system.

c. Phylogenetic system:

It is based on detailed characters of organisms as well as proper phylogenetic and evolutionary characters. It enables to determine the ancestors of any taxon. However, it seems a bit difficult to classify perfectly on the basis of evolutionary tendencies due to imperfection of fossil records. So, at present the organisms are classified partly according to natural and partly according to phylogenetic basis. E.g. Engler and Prantl's system of classification.

2.8.6 TAXONOMIC DESCRIPTION OF FAMILIES

To describe a flowering plant, various morphological features are used. The features should be brief, with semi technical terms and presented in a proper sequence. The families are described starting with its habit and habitat, morphological characters of root, stem, leaf and flower. Then after, a floral diagram and a floral formula are presented.

The symbols used in floral formula are given below:

Bracteate -	Br	Ebracteate -	Ebr
Actinomorphic -	$\oplus$	Zygomorphic -	$\%$
Unisexual, male -	σ	Unisexual, female -	♀
Bisexual -	$\sigma + \text{♀}$		
Calyx, sepals -	K	Corolla, petals -	C
Perianth, tepals -	P		
Androecium, stamens -	A	Gynoecium, carpels -	G
Inferior ovary -	<u>G</u>	Superior ovary -	<u>G</u>

Fusion of floral whorls is indicated by enclosing the figure within bracket. Sometimes stamens are fused with petals known as epipetalous and denoted as $\overbrace{\text{C A}}$.

1. Family : Brassicaceae (Cruciferae) – Mustard family

Habit and Habitat :

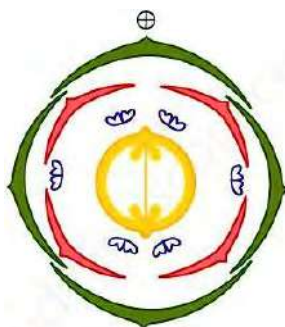
The members of this family are annual, biennial or perennial herbs with sulphur smelling. The plants may be cosmopolitan in distribution. Majority of them are common in north temperate region.

Vegetative characters:

- Root:** tap, branched, may be modified into fusiform (*Raphanus sativus* – radish) or napiform (*Brassica rapa* – turnip)
- Stem:** usually the stem is herbaceous; erect or prostrate, branched, solid, cylindrical, pubescent (hairy)
- Leaves:** Radical (arise from base of stem or underground stem) or cauline (attached directly to main stem nodes) or ramal (found on branches), simple, alternate, exstipulate, petiolate or sessile, lyrate, reticulate venation

Floral Characters

- Inflorescence:** Racemose
- Flower:** Mostly ebracteate, pedicellate, bisexual, complete, actinomorphic rarely zygomorphic, hypogynous
- Calyx:** 4 sepals, polysepalous, arranged in two whorls, petaloid or sepaloid, imbricate aestivation, inferior
- Corolla:** 4 petals, polypetalous and cruciform (arranged cross-like), valvate aestivation
- Androecium:** 6 stamens arranged in two whorls, tetradynamous (outer two stamens are short while inner four are long), anther bilobed, basifixed, introrse
- Gynoecium:** 2 carpels, syncarpous (carpels are united), unilocular in early stage and later becomes bilocular due to development of false septum, ovary superior, parietal placentation,
- Fruits:** siliqua or silicula,
- Pollination:** entomophilous (i.e. through insects)
- Floral Formula:** $\text{Ebr } \oplus \text{ } \text{♀} \text{ } K_{2+2} C_4 A_{2+4} \underline{G}_{(2)}$
- Floral Diagram:**



Economic Importance:

- Brassica campestris* (mustard) cultivated to extract the oils used for cooking, burning etc.
- The plants like turnip, radish, cabbage etc. are cultivated for vegetables.
- Seeds of some plants are used as condiments.

- iv. *Lepidium sativum* (chamsur) is used as vegetable as well as in the treatment of asthma, cough and bleeding piles.
- v. Some plants of this family are grown as an ornamental plant.

Some important plant of this family:

- a. Mustard – *Brassica campestris*
- b. Cauliflower – *Brassica oleracea* var. *botrytis*
- c. Cabbage – *Brassica oleracea* var. *capitata*
- d. Turnip – *Brassica rapa*
- e. Radish – *Raphanus sativus*

2. Family: Fabaceae (Leguminosae) – Legume family

Habit and Habitat : The members of this family may be herbs, shrubs, rarely trees. Usually the plants are cultivated for pulses and green manuring. They are cosmopolitan in distribution usually in temperate regions of both northern and southern hemispheres.

Vegetative characters:

- a. **Root:** tap root, branched, root bears nodules having nitrogen fixing bacteria.
- b. **Stem:** Herbaceous or woody, erect or climbing, branched, angular or cylindrical
- c. **Leaves:** Cauline or ramal, compound rarely simple, alternate rarely opposite or whorled, stipulate, petiolate, reticulate venation.

Floral Characters

- a. **Inflorescence:** Racemose
- b. **Flower:** bracteate or ebracteate, Pedicellate, zygomorphic, bisexual, complete, hypogynous
- c. **Calyx:** 5 sepals, gamosepalous, ascending imbricate or valvate aestivation
- d. **Corolla:** 5 petals (unequal), the uppermost largest petal (known as vexillum or standard), the two free lateral petals (known as wings or alae) and anterior two united petals (known as keel or carina), descending imbricate or vexillary aestivation
- e. **Androecium:** 10 stamens, diadelphous of 1+9, one stamen is free remaining nine in bundle partially fused, anther bilobed, basifixed or dorsifixed, introrse.
- f. **Gynoecium:** 1 carpel, unilocular, Ovary superior, marginal placentation
- g. **Fruits:** legume or pod
- h. **Pollination:** entomophilous
- i. **Floral Formula:** Br or Ebr % $\frac{\text{♂}}{\text{♀}}$ K₍₅₎ C₁₊₂₊₍₂₎ A₁₊₍₉₎ G₁
- j. **Floral Diagram:**



Economic Importance:

- i. The plants are cultivated for pulses and beans.
- ii. Many plants of this family are used as fodder.
- iii. Some plants like *Glycine max* are the source of edible oil.
- iv. The seeds of methi are commonly used as condiment in pickles.
- v. The roots of the plants of this family bear nodules which contain nitrogen fixing bacteria.

Some important plant of this family:

- a. Pea – *Pisum sativum*
- b. Soybean – *Glycine max*
- c. Cow pea (bodi) – *Vigna sinensis*
- d. Gram (Chana) – *Cicer arietinum*
- e. Black gram (maas) – *Phaseolus mungo*

3. Family: Solanaceae – Potato family

Habit and Habitat : The members of this family may be annual or perennial herbs, shrubs rarely trees. They are worldwide in distribution most commonly found in tropical and sub-tropical region of world.

Vegetative characters:

- a. **Root:** tap root, branched
- b. **Stem:** herbaceous rarely woody, erect or climbing, branched, cylindrical, solid or rarely fistular (hollow), pubescent or glabrous (smooth without hair), sometimes modified underground stem (like tuber in potato).
- c. **Leaves:** Cauline or ramal, exstipulate, simple rarely pinnately compound, alternate or opposite in floral region, rarely whorled, petiolate, reticulate venation.

Floral Characters

- a. **Inflorescence:** Cymose
- b. **Flower:** ebracteate, usually pedicellate, actinomorphic, bisexual, complete, hypogynous.
- c. **Calyx:** 5 sepals, gamosepalous, valvate or twisted aestivation.
- d. **Corolla:** 5 petals, gamopetalous, valvate aestivation
- e. **Androecium:** 5 stamens, epipetalous, anther dithecal, basifixed, introrse

- f. **Gynoecium:** 2 carpels, syncarpous, bilocular, Ovary superior and obliquely placed, axile placentation with swollen placenta
- g. **Fruits:** berry or capsule
- h. **Pollination:** entomophilous
- i. **Floral Formula:** $Ebr \oplus \text{♀} K_{(5)} C_{(5)} A_5 \underline{G_{(2)}}$
- j. **Floral Diagram:**



Economic Importance:

- i. The plant of the family are cultivated for vegetables.
- ii. Chillies are used as spices.
- iii. Some species are the source of valuable medicines.
- iv. *Petunia*, *Datura* etc. are grown as ornamental plants.

Some important plant of this family:

- a. Tomato – *Lycopersicum esculentum*
- b. Brinjal – *Solanum melongena*
- c. Potato – *Solanum tuberosum*
- d. Black night shade – *Solanum nigrum*
- e. Tobacco – *Nicotina tabacum*

4. Family: Liliaceae – Lily/onion family

Habit and Habitat : The members of this family annual, biennial and perennial herbs and shrubs. They are cosmopolitan in distribution mostly found in tropical and temperate region of the world.

Vegetative characters:

- a. **Root:** adventitious root
- b. **Stem:** herbaceous or woody, erect or climbing or sometimes modified into underground bulbs or rhizomes, branched, solid.
- c. **Leaves:** cauline or radical, exstipulate, usually simple, alternate or whorled, parallel venation, sessile with usually sheathing leaf base.

Floral Characters

- a. **Inflorescence:** racemose
- b. **Flower:** bracteate or ebracteate, pedicellate, atinomorphic rarely zygomorphic, bisexual, incomplete, hypogynous

- c. **Perianth:** 6 tepals arranged in two rows, gamotepalous rarely polytepalous, valvate or imbricate aestivation, sepaloid or petaloid
- d. **Androecium:** 6 stamens arranged in two rows, polyandrous, epiphyllous, anther ditheous, basifixed, introrse
- e. **Gynoecium:** 3 carpels, syncarpous, trilocular, ovary superior, axile placentation
- f. **Fruits:** fleshy berry or a capsule
- g. **Pollination:** entomophilous
- h. **Floral Formula:** $\text{Br} \oplus \text{P}_{(3+3)}^{\overline{\text{A}}_{3+3}} \text{G}_{(3)}$
- i. **Floral Diagram:**



Economic Importance:

- i. Some plants are grown as ornamental in the gardens.
- ii. *Asparagus* is consumed as vegetable.
- iii. Some plants are of great medical value used in treatment of rheumatism and gout.
- iv. *Aloe* are used to manufacture different types of cosmetic products.
- v. Garlic and some other plants are used in cordamnen.

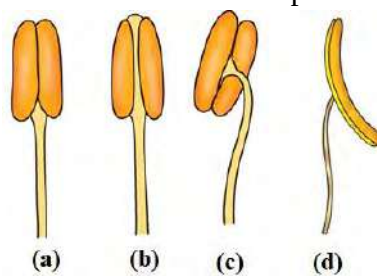
Some important plant of this family:

- a. Onion – *Allium cepa*
- b. Garlic – *Allium sativum*
- c. Asparagus (kurilo) – *Asparagus officinalis*
- d. Aloe – *Aloe vera*
- e. Lily - *Lilium*

EXERCISE

A. Tick the correct alternative.

1. Name the taxa formed by grouping of order.
 - a. Family
 - b. genus
 - c. Class
 - d. Phylum
2. Which botanical family does *Capsicum* belongs to?
 - a. solanaceae
 - b. liliaceae
 - c. compositae
 - d. leguminosae
3. What type of placentation is characteristic of the Solanaceae family?
 - a. Axile
 - b. Basal
 - c. Parietal
 - d. marginal
4. The tuber of potato is a modification of which of the following part?
 - a. Root
 - b. Stem
 - c. Fruit
 - d. seed
5. Name the type of fruit formed by whole inflorescence.
 - a. simple fruit
 - b. aggregate fruit
 - c. Composite fruit
 - d. None of above
6. Observe the given diagram and select the correct option.



- a. a- basifixed, b- adnate, c- versatile, d- dorsifixed
 - b. a- basifixed, b- versatile, c- adnate, d- dorsifixed
 - c. a- basifixed, b- adnate, c- dorsifixed, d- versatile
 - d. a- basifixed, b- dorsifixed, c- adnate, d- versatile
7. What is the scientific name of cabbage?
 - a. *Brassica campestris*
 - b. *Brassica oleracea*
 - c. *Raphanus sativus*
 - d. *Brassica rapa*

8. What is meant by a 'cruciform corolla' in botanical terms?
- A corolla with petals arranged in a circular pattern
 - A corolla with petals arranged in a star like shape
 - A corolla with petals arranged in the shape of a cross
 - A corolla with petals arranged in a spiral pattern

B. Answer the following questions:

- Define the following:
 - phyllotaxy
 - zygomorphic
 - complete flower
 - genus
 - taxonomy
 - perianth
- Differentiate between:
 - Tap root system and fibrous root system
 - Simple leaf and compound leaf
 - Cymose and Racemose
 - artificial and natural system of classification
- Describe the family solanaceae in semi-technical terms with floral formula and floral diagram with two scientific names of economically important plants of this family.
- Describe the family Liliaceae in semi-technical terms with floral formula and floral diagram with two scientific names of economically important plants of this family.
- Describe the floral characters of Fabaceae.
- What is placentation? Describe the different types of placentation.
- Explain the different region of root with diagram.
- Describe the morphology of leaf with diagram.
- Define the term inflorescence. Explain the different types of inflorescence.
- A group of botanists is conducting a study to classify the plant species found in particular region. They are debating whether to use an artificial system, a natural system, or a phylogenetic system for their classification. Which system would be most suitable for their study, and why?

Unit 3

Introduction to Microbiology



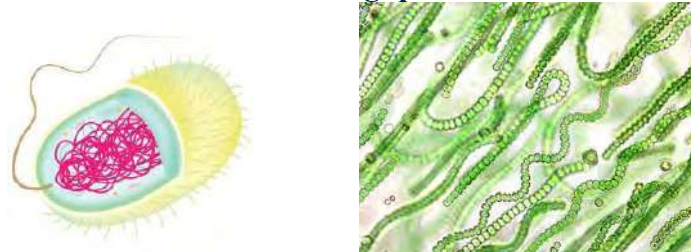
Antonie Van
Leeuwenhoek
(1632-1723)

Antonie van Leeuwenhoek is the somewhat improbable father of microbiology. A moderately educated owner of a textile business, he learned how to make his own unique microscopes which offered unparalleled magnification. Using these microscopes he became the first person to see and describe bacteria, among other microscopic discoveries. He made a number of crucially important scientific discoveries, including single-celled animals and plants, bacteria and spermatozoa.

Chapter 3.1

MONERA

Observe the pictures and discuss the following questions:



- Name the organisms given in the picture.
- In which kingdom do they belong?
- What type of cells (prokaryotic or eukaryotic) do they have?
- Are bacteria useful to us? Justify with an example.
- In which type of environment are bacteria found?

3.1.1 GENERAL INTRODUCTION

The kingdom Monera includes the most ancient, smallest, simplest form of life. All prokaryotes are included in this kingdom. Prokaryotes (Greek- Pro-before, karyon-nucleus) means the organisms lacking true nucleus. They exist everywhere on the earth even in thermal hot springs, supersaturated saline environment, within other living organism, deep within the earth, at the bottom of the ocean, etc. Bacteria were probably the earliest life forms on earth. A teaspoonful of soil may contain millions of bacteria.

Organisms present in this kingdom are microscopic, unicellular and consist of **prokaryotic** type of cell (i.e. cell lack true/organized nucleus and membrane-bound organelles) with rigid cell wall. They contain circular, naked DNA (i.e. without histone protein covering) in cytoplasm as genetic material. This also represents the nucleus and called as **nucleoid** or **incipient nucleus**. They are autotrophic as well as heterotrophic and are the major decomposers of an ecosystem. The sexual reproduction is absent.

Kingdom Monera is classified as follows:

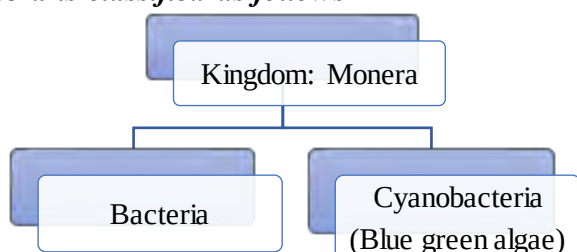


Figure 3.1.1 Classification of Kingdom Monera

3.1.2 BACTERIA

Bacteria are the simplest, minute, unicellular prokaryotes that can survive even in diverse environments. Bacteria are found in all possible habitats wherever life can exist. It was

discovered by Dutch naturalist Anton Van Leeuwenhoek in 1675. The branch of biology that deals with the study of bacteria is called bacteriology.

Bacteria are the smallest of all known cellular organisms. The average size of bacterial cells ranges from $0.5\mu\text{m}$ to $1.5\mu\text{m}$ in diameter. The shape of bacteria and forms of individual bacteria are usually constant while some can change their shape and size with changes in environmental conditions. This ability of organisms is known as pleiomorphism. For example; *Corenebacteria*, *Legionella pneumophila* etc.

On the basis of shape, bacteria are classified into following groups:

1. Cocci (Sing. Coccus)
2. Bacilli (Sing. Bacillus)
3. Helical bacteria
4. Filamentous bacteria

1. Cocci (Sing. Coccus)

These are spherical, oval or rounded in shape. They are non-motile as they lack flagella. They are found in different forms:

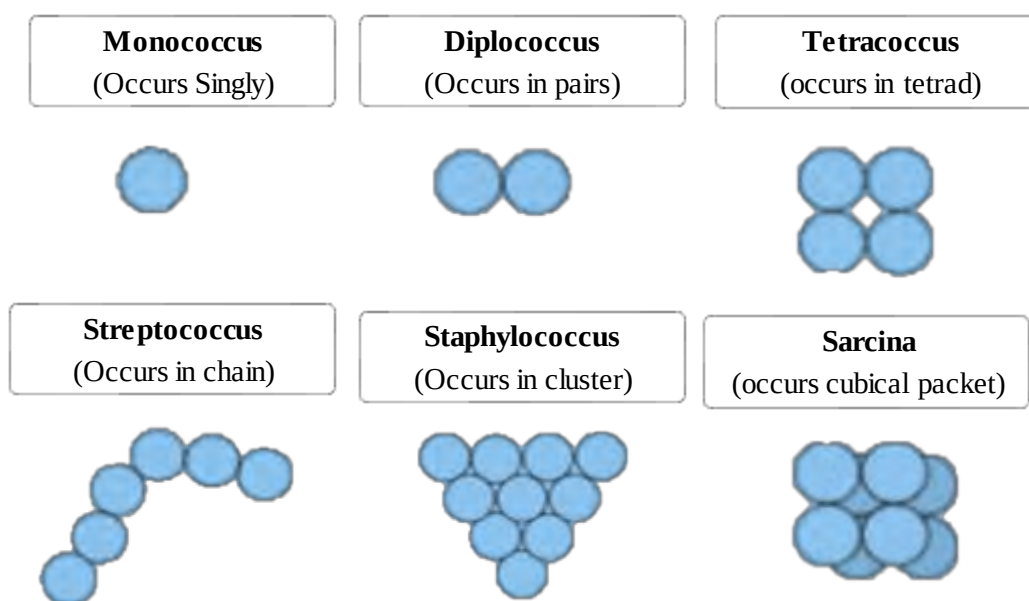


Fig:3.1.2 Different forms of Cocci bacteria

2. Bacilli (Sing. Bacillus)

They are elongated rod shaped or cylindrical bacteria. Some of them bear flagella. They are found in following different forms:

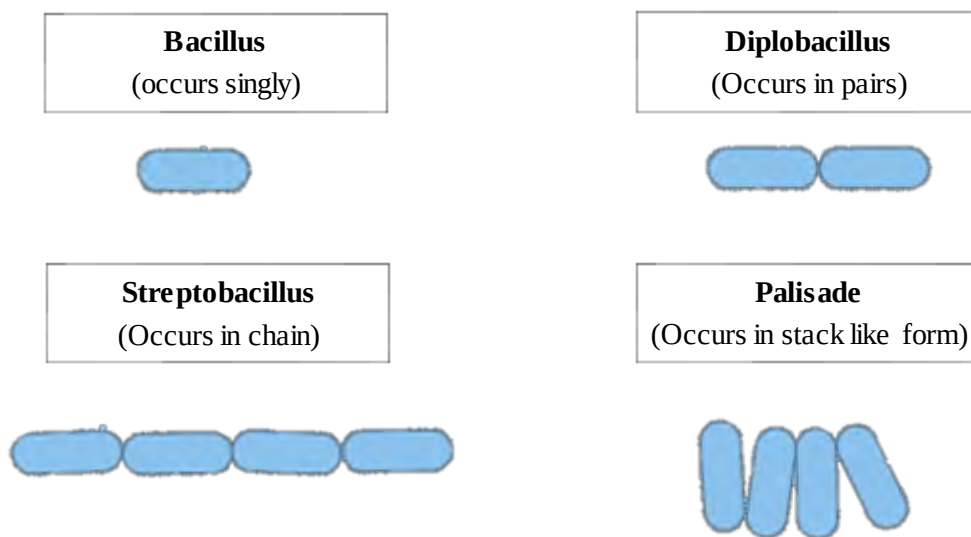


Fig:3.1.3 Different forms of Bacilli bacteria

3. Helical bacteria

They are found in two different forms:

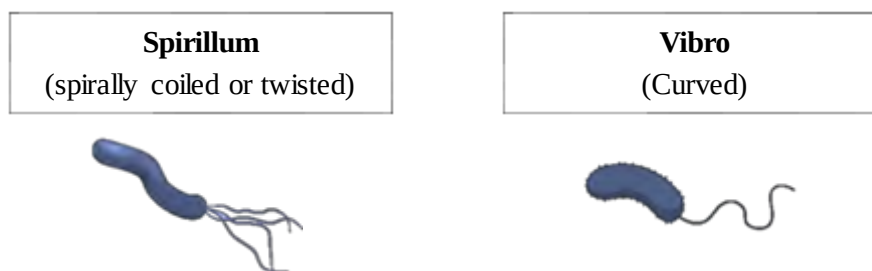


Fig:3.1.4 Different forms of helical bacteria

4. Filamentous bacteria

They are thread or filament -like structure.



Fig:3.1.5 Filamentous bacteria

Activity 3.1

Observe the chart showing the different forms of bacteria in a group. Discuss, draw and write the comments on their forms in a chart paper.

STRUCTURE OF BACTERIAL CELL

They usually have a simple structure without organized nucleus and membrane- bounded cell organelles such as mitochondria, golgi bodies, plastids, etc. A typical bacterial cell is

surrounded by a rigid, protective covering called cell wall which is made up of peptidoglycan, mucopeptide or murein. The cell wall gives proper shape and protects the cell against mechanical injury, chemicals and pathogens. Inner to cell wall, bacterial cell contains a thin, elastic, semi-permeable membrane called plasma membrane. The inner surface of the plasma membrane consists of several respiratory enzymes which help in respiration. In some bacteria, the plasma membrane gives rise to infoldings called **mesosomes** that play an important role during respiration and cell division. Externally, the cell wall is covered with a gelatinous substance called slime layer. In some bacteria, this slime layer forms a thick covering due to addition of amino acids, called **capsule**. The bacteria having capsule is called as capsulated bacteria. Capsule or slime layer protect the cells from chemicals and desiccation. In some bacteria, hair-like structures called pili are present on the cell wall that help in attachment with host.

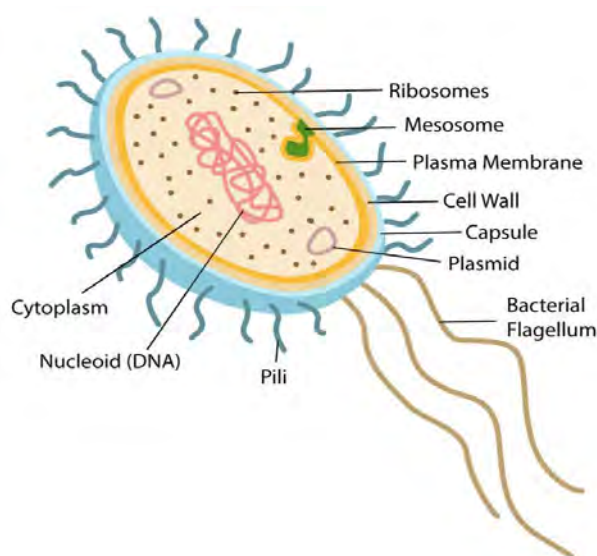


Figure 3.1.6 Structure of a typical bacterial cell

Inside the cell membrane granular, colourless fluids are present called protoplasm. It consists of 70s ribosome, gas vacuoles (present in aquatic form for floatation), reserve food materials (like, glycogen, lipid, protein etc.), centrally located circular double-stranded, naked DNA (incipient nucleus). Along with the normal DNA chromosomes, many bacteria also have extra-chromosomal genetic elements or DNA called plasmid. Photosynthetic bacteria consist of thylakoids called chromatophore which consists of photosynthetic pigments. The motile bacteria consists of fine, thread-like, protoplasmic attachments called as flagella. Flagella are absent in capsulated bacteria.

Activity 3.2 : TO OBSERVE THE BACTERIA IN CURD

Material Required:

1. Curd
2. Glass Slide
3. Cover slide
4. Microscope

Procedure:

- Take a small sample of curd and place it onto a clean glass slide.

- Spread the curd evenly across the slide to create a thin layer.
- Place a cover slip over the curd sample gently to avoid trapping air bubbles.
- Observe the slide in microscope. Start with the lowest magnification and gradually increase the magnification for a closer look at individual bacteria.

Observation:

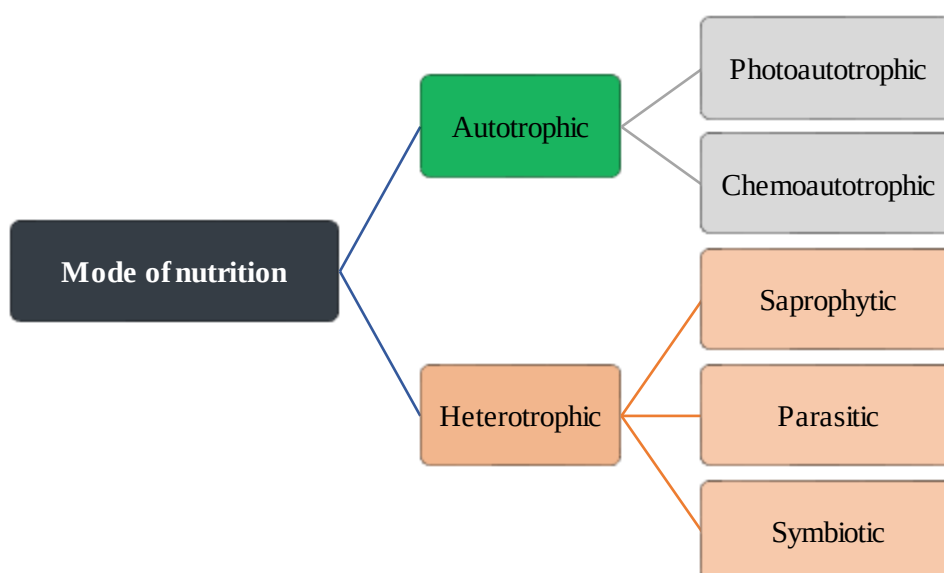
- Observe the curd sample under the microscope and note the characteristics of the bacteria such as size, shape and arrangement.
- The bacteria in curd are typically rod-shaped or spherical in shape and may appear singly or in a cluster.



Fig:3.1.7 Bacteria in curd as observed under microscope

3.1.3 MODE OF NUTRITION IN BACTERIA

Like other living organisms, bacteria also require nutrients and energy for their growth and development. The modes of nutrition in bacteria are autotrophic and heterotrophic.



3.1.8 Mode of nutrition in bacteria

Figure

1. Autotrophic Bacteria

A small group of bacteria show autotrophic nutrition. The bacteria that synthesize their own organic food from inorganic substances are called autotrophic bacteria. They utilize sunlight or chemical energy as a source of energy. Autotrophic bacteria are of two types:

a. Photoautotrophic bacteria: These bacteria utilize light energy to perform photosynthesis process. However, bacterial photosynthesis is different from green plant photosynthesis because water is not utilized as hydrogen donor so, oxygen is not evolved. This process is called anoxygenic photosynthesis. Instead of water they utilize hydrogen sulphide (H_2S), thiosulphate, hydrogen or other organic compounds.

b. Chemoautotrophic bacteria:

These bacteria utilize chemical energy to convert inorganic compound to organic compound and this process is called as chemosynthesis. They get energy from ammonia, nitrate, nitrite, ferrous iron, hydrogen sulphides and other inorganic compounds for the synthesis of their food. On the basis of chemical compounds they use as a source of energy, chemoautotrophic bacteria are grouped as nitrifying bacteria (utilize ammonia or nitrate), Sulphur bacteria (utilize Hydrogen sulphide), Iron bacteria (utilize ferrous compound), Hydrogen bacteria (utilize hydrogen), methane bacteria (utilize methane) etc.

2. Heterotrophic Bacteria

These are the bacteria which are unable to synthesize their organic food. They depend on other organisms for their nutrition. Most of the bacteria show heterotrophic mode of nutrition. Heterotrophic bacteria are of three types –

a. Saprophytic bacteria: The bacteria that obtain their nutrition from dead and decaying organic matter are called saprophytic bacteria. These bacteria breakdown the complex organic matter into simpler forms by secreting different types of digestive enzymes. The bacteria play an important role in the recycling of nutrients by decomposition. So, they are also called natural scavengers. They are the decomposers of an ecosystem. Some examples are: *Pseudomonas*, *Acetobacter*, *Clostridium*, etc.

b. Parasitic bacteria: The parasitic bacteria obtain their nutrition from living cell of other organisms. The parasitic bacteria may cause diseases (pathogenic) like *Mycobacterium tuberculosis*, *Clostridium tetani*, and *Salmonella typhi*.

c. Symbiotic bacteria: The bacteria that live in close association with other organism in such a way that both the partners get mutual benefit from this association are called symbiotic bacteria. Example: *Rhizobium* bacteria present in the root nodules of leguminous plant, *Escherichia coli* in the human intestine.



Questions to think?

Why the bodies of organism are preserved in ice?

Activity 3.3

Write the positive and negative effects of bacteria on chart paper and present in your class.

3.1.4 BACTERIAL GROWTH

In higher organisms growth refers to an increase in size and volume of organism but in bacteria growth refers to an increase in number. The growth of Bacteria takes place by binary fission. Binary fission is a form of asexual reproduction in single celled organisms by which one cell divide into two cells of the same size. A bacterial population grows in a geometric or exponential manner, with each generation producing 2 cells, 4 cells, 8 cells, 16 cells, 32 cells, 64 cells and so on. Bacteria need certain conditions to grow, and these conditions are not the same for all bacteria. Factors such as oxygen, pH, temperature and light affect the growth of microorganisms. Osmotic pressure, atmospheric pressure, and available moisture are some other additional factors that affect the growth of bacteria. The growth rate is also influenced by the composition of the growth medium. When the nutritive culture medium is inoculated with a given number of bacteria and incubated for a sufficient period, it gives a characteristic growth pattern of bacteria. The graphical representation of the number of living bacteria cells in a population over a period of time is called bacterial growth curve. The growth curve has four phases:

1. Lag phase

During this phase, the cells are metabolically active but not dividing. The cells prepare themselves for division by synthesizing enzymes and various other molecules.

2. Log phase (Exponential phase)

In this phase the bacterial cell divides continuously. The cells are most active metabolically in this phase. The cells are growing, dividing and increasing in number exponentially.

3. Stationary phase

The growth of bacteria reaches a state during which there is no net increase in bacterial population as the number of dividing cells is equal to the number of dying cells and this phase is called as stationary phase. This is due to depletion of nutrition and accumulation of toxic wastes products as a byproduct in log phase.

4. Decline phase (Death phase)

As the nutrition decreases and accumulation of toxic waste product increases, the number of dying cells begins to exceed the number of newly born cell during this phase.

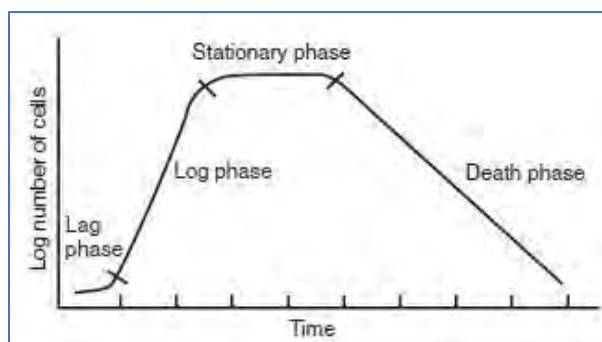


Figure 3.1.9 Bacterial growth curve

3.1.5 CYANOBACTERIA

Cyanobacteria or blue-green algae are a group of photosynthetic bacteria widely distributed in various aquatic habitats (fresh water and marine) and terrestrial habitat (moist soil). They may live singly or in colonies. They are one of the oldest life forms on earth. The red colour of red

sea is due to the abundance of the planktonic cyanobacteria. Most of the Cyanobacteria contain the green pigment chlorophyll (also some other pigments), which helps retain energy from the sun and allows these organisms to pursue an autotrophic mode of nutrition. Some cyanobacteria live in symbiotic association with other organisms.

They may be unicellular or multicellular. The multicellular forms are filamentous or colonial. Each cell is surrounded by a rigid cell wall which covered by mucilaginous sheath. The cell wall is followed by a plasma membrane made up of lipid and proteins. The cell lacks membrane-bound structures like mitochondria, Golgi bodies, chloroplast, etc. The photosynthetic pigments present in cell are chlorophyll a, carotene, xanthophyll and phycobillins and are present in chromatophore restricted to peripheral region of cytoplasm. At the centre of the cell there is presence of nucleoid that consists of DNA, RNA and protein. DNA is circular without histone protein. Flagella are absent.

The filamentous chain of cyanobacteria covered by a slimy sheath is called trichome. Some filamentous cyanobacteria (e.g. *Nostoc*, *Anabaena*, *Scytonema*) possess special types of cells in filaments called heterocysts that are the site of nitrogen fixation. Cell division takes place by amitosis and mitosis. The reproduction takes place by vegetative and asexual methods. Sexual reproduction is completely absent.

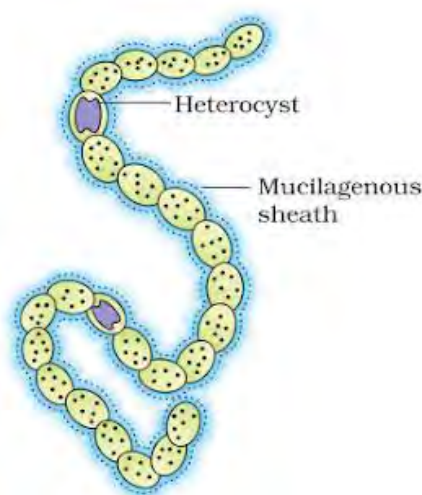


Table 3.1.10 Cyanobacteria (*Nostoc*)

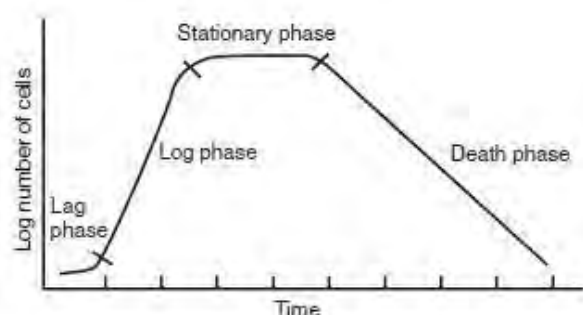
EXERCISE

A. Tick the correct alternative.

1. Name the site of respiration in bacteria.
 - a. mitochondria
 - b. chromatophore
 - c. cell membrane
 - d. mesosome
2. Which of the following genome is present in bacteria?
 - a. DNA without histone
 - b. DNA or histone
 - c. DNA and histone
 - d. Neither DNA nor histone
3. Which one of the following is absent in bacteria?
 - a. cell wall
 - b. Nucleoid
 - c. Ribosome
 - d. Golgi bodies
4. At which phase of bacterial growth does the rate of dying cells exceed the rate of newly born cells?
 - a. Lag phase
 - b. Decline phase
 - c. Log phase
 - d. Exponential phase
5. By studying the kingdom Monera, which of the following statement represents its characters?
 - a. They are multicellular with membrane bound organelles.
 - b. They have a true nucleus and can be found in specific environments.
 - c. They are unicellular with prokaryotic cells lacking a true nucleus and membrane bound organelles.
 - d. They primarily reproduce sexually and are essential for ecosystem balance.
6. Agricultural scientists are conducting a study to improve crop yield and soil health. They decide to introduce nitrogen-fixing bacteria into the soil to enhance nitrogen availability for the plants. Which of the following crops would be the most suitable for this considering its ability to form nodules with nitrogen fixing bacteria?
 - a. Cotton
 - b. Gram
 - c. Wheat
 - d. Mustard
7. How do bacteria contribute to ecosystem nutrient cycling and waste decomposition?
 - a. by breaking down complex organic matter into simpler forms that can be utilized by other organisms.
 - b. by releasing enzymes that convert inorganic nutrients into organic compounds
 - c. by producing oxygen through photosynthesis, which supports other organisms in the ecosystem
 - d. by forming mutualistic relationships with plants to enhance nutrient uptake

B. Answer the following questions:

1. Define plasmid.
2. What do you mean by naked DNA?
3. What types of bacteria are known as symbiotic bacteria? Give example.
4. Compare the characteristics features of Autotrophic and heterotrophic bacteria.
5. Explain the structural features of a bacterial cell with necessary labeled diagram.
6. Explain why blue green algae are classified within the Kingdom Monera rather than the Kingdom Plantae. Include specific characteristics of blue-green algae and compare both plant and bacteria to justify their placement in the Kingdom Monera.
7. Study the given bacterial growth curve and answer the following questions:



- a. Which phase of the bacterial growth curve is characterized by rapid cell division?
 - b. What happens during the lag phase of the bacterial growth curve?
 - c. In which phase there is balance between cell division and death?
 - d. Why the numbers of dying cells exceed the number of newly born cell during death phase?
8. Many organism die but do not remain same. Where does their body go? Do you think any organism have any role in disappearing their body?
 9. Describe the ecological roles and significance of organisms classified within the kingdom Monera, providing examples of their impact on ecosystems and human activities.

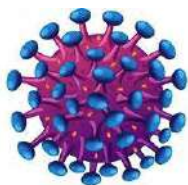
Project Work:

Divide students into groups and assign each specific type of bacteria (e.g. Cocci, Bacili, filamentous). Using various materials like clay, beads, colored papers, challenge them to create 3D modes representing the bacterial structure. Groups present their models, explaining their structure, functions etc.

Chapter 3.2

VIRUS

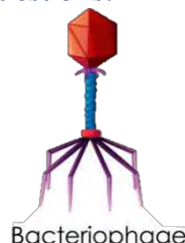
Observe the pictures and discuss the following questions:



HIV



Ebola Virus



Bacteriophage



Influenza

- Are they living or non-living?
- What is nature of virus if it is neither organism nor molecule?
- How do they differ from bacteria?

3.2.1 GENERAL INTRODUCTION

Viruses are ultramicroscopic intracellular parasites, which consist of a single nucleic acid, either DNA or RNA covered with a protein coat called capsid. Viruses do not consist of cellular organization. These are acellular pathogens. Hence, they are neither prokaryotes nor eukaryotes. Viruses crystallize like non-living things (chemicals) outside the host cell but show only living characteristics that is they replicate only inside the host cell. So, they are considered *midway/borderline between the living and nonliving things*. They may even be purified and crystallized like chemical substances. Viruses are completely devoid of the machinery for life processes so it requires the presence of host cell for its multiplication/replication. As they compulsorily need host cells to replicate or show their living characteristics, it is considered an obligatory parasite. In five kingdom classification of Whittaker virus doesn't get any defined place. A newly formed complete infectious virus particle is called **virion**.

Until the end of the nineteenth century, the history of viruses is just a part of the history of infectious diseases. The name 'virus' is coined by Beijerinck from Latin word meaning "venom" or similar poisonous fluid. The branch of Biology that deals with the study of viruses is called **virology**.

Viruses are ultramicroscopic acellular obligatory parasites having either DNA or RNA as a genetic material and can replicate only inside the living host cell.

Viruses have following characteristics:

- Viruses are **ultramicroscopic** intracellular parasites.
- They are **acellular** i.e. they do not have cellular level of organization.
- They are **obligate parasite** and can multiply only within living host cell as they lack enzyme system.
- Viruses do not have a system to produce ATP.
- They contain only a single type of nucleic acid, either DNA or RNA.
- The nucleic acids are enclosed by proteinous coat called **capsid**.

7. Viruses are **host specific** i.e. they infect only a single species and definite cells of the host organisms.
8. They can be crystallized and store like chemicals i.e. Outside the cell, they behave like inert chemicals.
9. They exhibit **mutation**.
10. They are infectious and are capable of spreading diseases.
11. They show an incubation period, like other parasites.
12. They do not show the biological process like respiration, excretion etc.
13. They have high specific gravity.

3.2.2 STRUCTURE

The shape and size of virus particles vary widely. The size of viruses ranges from 10-300 nm in diameter. The viruses may be rod-shaped, filamentous, roughly spherical, tadpole like etc.

Viruses are non-living objects, because they lack cellular organization and protoplasm. However, the structure of virus consists of two main types of chemicals viz. nucleic acid (about 6%) and protein (about 96%). Nucleic acid presents at the center and form **core**. Nucleic acid exists either in the form of DNA or RNA or both. DNA or RNA may be single-stranded or double-stranded. Single-stranded DNA and double-stranded RNA are characteristics never found in living system and, hence unique to the viruses.

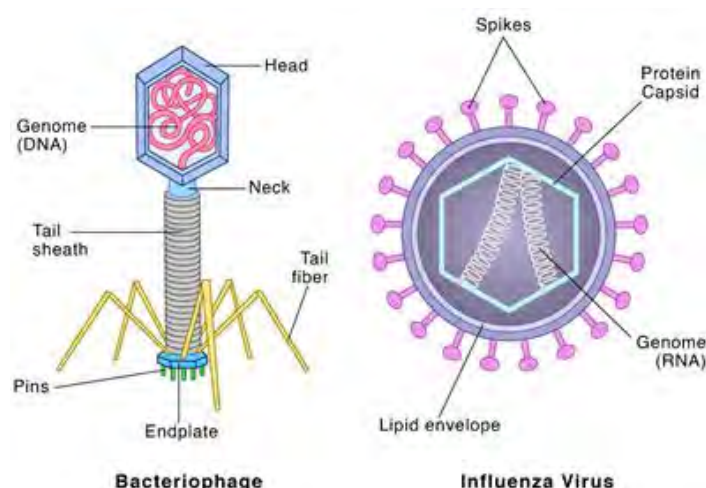


Figure 3.2.1 Structure of viruses

The protein molecule surrounds around the nucleic acid filament and forms the protective sheath called as **capsid**. This capsid is formed of identical repeated subunits called capsomeres. Size, shape, arrangement, and composition of sub-units are specific characteristics, i.e. fixed for each type of virus. The combined structure formed by the core and capsid is termed as **nucleocapsid**.

In some viruses, there is a thin envelope around the capsid that resembles typical cell membrane having a phospholipid bilayer. Viruses possess lysozyme in the region of their contact with host cell by the help of which they drill a hole in the host's cell.

3.2.3 ECONOMIC IMPORTANCE OF VIRUS

Viruses have both positive effects as well as negative effects:

Positive effects:

1. Viruses act as simple systems, which can be used as tools for research and analysis. Studies on recombinant DNA technology were developed using bacteriophages (Bacterial Viruses).
2. The lysogenic life cycle of certain viruses allows easy manipulation of the viral genome. Viruses are used as vectors to deliver therapeutic genes into humans in gene therapy.
3. They are also used to cure cancer in several ways like virotherapy and VDEPT (virus directed enzyme pro drug therapy).
4. Viruses are also the primary sources of vaccines used to prevent the viral infections.
5. Some of the viruses can also be used for the control of insect pests of our crop plants.
6. Some virus infected plant parts appear beautifully variegated. E.g. Tulip flowers.
7. Viruses may destroy the bacterial cells and make water free from bacteria.

Negative effects:

1. Viruses cause diseases in plants and animals including human beings.
2. Viruses cause danger to many biochemical industries especially bacteriophages that destroy the useful bacteria for such industries.
3. Viruses may be used as biological weapons.



Table: 3.2.1 Some common human diseases and the virus causing it

Name of Disease	Name of Virus
Chicken pox	Varicella Virus
Measles	<i>Polysona morbillorum</i>
Rabies	Rabies Virus
AIDS	HIV
Corona	Covid-19
Bird Flu	H ₅ N ₁ Virus/ H ₅ N ₈ Virus
Common Cold	Rhinovirus

EXERCISE

A. Tick the correct alternative.

1. Why are viruses considered obligate parasites?
 - a. They required a living host to multiply
 - b. They can survive independently outside a host
 - c. They possess their own enzyme system
 - d. They are capable of photosynthesis
2. What is the significance of the term ‘bacteriophage’?
 - a. It refers to a bacterium that infects higher plant cells.
 - b. It denotes a bacterium that infects an animal cell.
 - c. It represents a virus that infects a bacterium.
 - d. It describes an organelle of a bacterium.
3. Which statement is not true for viruses?
 - a. Viruses are made of proteins and nucleic acid.
 - b. Viruses can multiply only in living cells.
 - c. Viruses can grow in dilute sugary syrups in warm weather.
 - d. Viruses cannot use oxygen.
4. Which components are typically found in viruses?
 - a. DNA and protein
 - b. Proteins, RNA and DNA
 - c. RNA and DNA
 - d. Proteins and RNA or DNA
5. What is the primary component of the capsid structure found in viruses?
 - a. protein
 - b. proteins and carbohydrates
 - c. proteins and DNA
 - d. proteins and RNA

B. Answer the following questions:

1. Define virus and Explain why they are considered neither prokaryotes nor eukaryotes.
2. What is capsid?
3. Discuss the characteristics of viruses that place them midway between living and non-living things.
4. How do viruses differ from bacteria in terms of their cell structure, reproduction, and nuclear substance?
5. Describe the economic importance of the virus.
6. Explain the structure of the virus with an appropriate diagram.
7. How do viruses use lysozyme to interact with host cells, and what is its role in the infection process?

Project Work:

Prepare a report on any one viral disease (like, HIV/AIDs, Influenza, COVID-19 etc.) by including symptoms, transmission, preventive methods and societal, economic and healthcare impact. Present your finding in class.

Chapter 3.3

IMPACTS OF BIOTECHNOLOGY IN THE FIELD OF MICROBIOLOGY

Discuss the following questions in class:

- i. Have you ever heard of biotechnology? What do you think it involves?
- ii. Can you give some examples of products or services that you use in your daily life that might be influenced by biotechnology?
- iii. How do you think scientists can use microorganisms to help diagnose disease?

3.3.1 INTRODUCTION

The word biotechnology is derived from two words i.e. biology and technology. ***Biotechnology is the controlled use of biological agents, such as microorganisms or cellular components, for beneficial use.***

Microbes such as bacteria, fungi and viruses are found in nearly every environment and make up much of the biomass on earth. They have long been used by humans for several purposes. ***The use of microbes in biotechnology is known as microbial biotechnology.***

Microbial biotechnology is a dynamic field that provides a wide range of products and services to a diverse number of industries. These include food production, drug development, disease prevention and diagnostics, nutritional supplements, energy and alternative fuels, environmental monitoring and waste management, forensic sciences, and many more.

3.3.2 IMPACT OF BIOTECHNOLOGY IN THE FIELD OF MICROBIOLOGY

The use of microbial biotechnology is described below:

1. In Medicine:

The concept of microbial biotechnology is used in human and veterinary medicine by the following ways:

a. Antibiotics:

Antibiotics are substances obtained from microorganisms that help in controlling different types of diseases. They are obtained from different types of microorganisms.

b. Vaccines:

Vaccines are the substances derived from microorganisms used to immunize against disease. Vaccines are produced by using the concept of fermentation technology and recombinant DNA technology. The use of vaccines such as smallpox, polio, tetanus etc. led to the virtual elimination of these diseases in regions of the world where the vaccines have been deployed.

c. Gene therapy:

It is a technique that uses genes for the treatment of genetic disorders or chronic diseases. In this technique, new copies of genes are added or replaced by a defective or missing gene in a patient's cells by the use of genetic engineering.

d. *Molecular diagnosis:*

The early diagnosis of a disease is important to effectively treat the diseases. Recombinant DNA technology is used for isolation and identification of pathogens for easy, early, correct and quick diagnosis of many infectious diseases like AIDs, Cancer, hepatitis, smallpox, etc.

2. In Industries:

Microbial biotechnology is used to produce different types of industrial products as follows:

a. *Food production:*

By using the fermentation process different types of alcoholic, bakery and dairy products are obtained.

b. *Tea and tobacco industries:*

The leaves of tea and tobacco are treated with certain bacteria to remove bitterness of leaves, give flavor, colour and taste.

c. *Enzymes production:*

Certain type of bacteria are used to produced enzymes like proteases, pectinase etc.

d. *Biofuel production:*

Biofuel is produced by the use of microbial biotechnology which may be used instead of fossil fuels and are used as a renewable source of energy.

3. In Agriculture:

Micro-organisms are found in the soil and help to improve agricultural productivity in following ways:

a. *Biofertilizers:* Phosphate and nitrogen are important elements for the growth of plants. These elements are found naturally in the environment; however, plants have limited ability to extract them. Microbes, like *Penicillium bilaii* dissolve the phosphate in the soil and make available to the root of the plants. The bacteria like, *Rhizobium*, present in root nodules of leguminous plants convert the atmospheric nitrogen into nitrate which are absorb by the root of the plant. These processes take place naturally. However, Biofertilizers are made from these types of organisms when applied by either coating seeds, or putting directly into the soil.

b. *Bio-herbicides:* Weeds are the plants that compete with crops for water, nutrients, sunlight and space. It also harbors insect and disease. Some micro-organisms function as bio-herbicides because they possess invasive genes that can attack the defense genes of the weeds, thereby killing it. The advantage of using bioherbicides is that it cannot harm the environment and survive long enough for the next growing season.

c. *Improvement of variety:*

By transferring useful genes from microorganisms, improved varieties of crops are produced, enhancing various desirable traits. Improved varieties include the characters like high yielding, high nutrients content, disease resistance variety, pest resistance etc.

d. Development of GMO:

The genetically modified organism (GMO), also known as transgenic organisms are having foreign genes or foreign DNA.

4. In Environment field:

With recent advances in biology, materials, computing, and engineering, environmental biotechnologist now is able to use microbial communities for a wealth of services to society. These include detoxifying contaminated water, wastewater, sludge, sediment, or soil, capturing renewable energy from biomass, sensing contaminants or pathogens, and protecting the public from dangerous exposure to pathogens.

a. In waste disposal:

It includes treatment of domestic and industrial effluents or wastes by using microbes.

b. Bioremediation: One of the most beneficial uses of microbial biotechnology is bioremediation, which is the use of bacteria to clean up environmental contaminants. This process involves introducing a certain species of bacteria into contaminated sites to break down toxic substances. Example: genetically modified bacteria are used to clean up oil spills.

c. Bioindicator: Microbes are useful as bioindicators to detect the presence of environmental pollutants, such as heavy metals, and other hydrocarbons.

3.3.3 ETHICAL ISSUES OF MICROBIAL BIOTECHNOLOGY

Microbial biotechnology is a controversial topic because it comes with some concerns and issues. Ethical issues of microbial biotechnology include the availability and use of privileged information, the potential for ecological harm, access to new drugs and treatments, and the idea of interfering with nature. These issues include many defects and side effects of products, tools and techniques along with economic, and environmental loss and other negative impacts.

A huge risk of biotechnology in the field of medicine is its impact during clinical trials. Because of these risks, extensive research should be performed before even thinking of introducing to human. The technology may be often expensive compared to traditional treatments.

Another objection is that it interferes with nature and violates the natural integrity of species by deliberately bringing about genetic modification. Genetically modified plants have also reduced the need of fertilizers thus minimized the pesticides pollution to rivers and costal water resources. However the tools and products caused many defects in environment.

Legal and religious issues are being arises in the use of biotechnological techniques. Particularly in techniques such as stem cell technology, gene therapy, and human genome projects.

EXERCISE

A. Tick the correct alternative.

1. What is the term used to describe the utilization of living organisms in the creation of various products?
 - a. bioengineering
 - b. biotechnology
 - c. genome engineering
 - d. medical engineering
2. Which of the following is not the product of microbial biotechnology?
 - a. Insulin
 - b. antibiotic
 - c. Egg
 - d. growth hormone
3. Consider the application of transgenic technology in animal agriculture. Which of the following products can benefit from the genetic modifications made in animals?
 - a. milk
 - b. meat
 - c. eggs
 - d. all of the above
4. How are improved varieties of crops produced using microbial biotechnology?
 - a. by directly altering the DNA of plants to enhance traits
 - b. by using chemical fertilizers to increase crop yield
 - c. by transferring useful genes from microorganisms to enhance desirable traits.
 - d. by traditional breeding methods without any genetic modification

B. Answer the following questions:

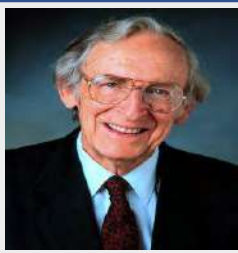
1. What is microbial biotechnology and how does it contribute to various industries?
2. Research the latest advancements in the field of bacterial research. How do these advancements have the potential to impact various fields like medicine, agriculture, or environmental science?
3. How do biofertilizers differ from chemical fertilizers in terms of their environmental impact and sustainability?
4. What are the ethical issues related to use of biotechnology?
5. Think about any areas of interest related to microbial biotechnology that you would like to explore further? Why?

Project Work:

Divide students into research teams, tasked with identifying the culprit bacteria using clues like symptoms, transmission mode, and potential sources. Team analyse information, propose hypotheses and present their finding, fostering critical thinking and scientific reasoning.

Unit 4

ECOLOGY



Eugene
Odum
(1913-2002)

Eugene Odum, a pioneering ecologist, shaped modern ecological understanding. His work emphasized ecosystems' holistic nature, studying how organisms interact with their environment. He introduces concepts like energy flow and nutrient cycling, pivotal to ecosystem dynamics.

His ideas changed how we study nature, inspiring people to protect the environment. His work reminds us that everything in nature is connected.

Chapter 4.1

ECOSYSTEM ECOLOGY

Discuss the following questions:

- I. What comes to mind when you hear the word 'ecosystem'?
- II. Can you name one example of natural ecosystem?
- III. How do you think living things in an ecosystem are connected?
- IV. What role do you think plants play in an ecosystem?
- V. Why might studying ecosystems be important for understanding the environment?

4.1.1 CONCEPT OF ECOLOGY

All the things of the world are classified into two major groups namely living and non-living things. The living things includes all types of life and is known as biotic component while non-living things includes soil, water, air, light, etc. and is known as abiotic components.

The inter-relationship between biotic and abiotic components as well as the relationship among the individuals of the biotic component is called ecology.

The word ecology (Greek; oikos-household, logos-study) was coined by Hanns Reiter (1885). Literally ecology means the study of organism at home. The 'home' includes the entire physical environment as well as other organisms that are there. Thus, **ecology is the branch of Biology that studies the interrelationships between organisms and their environment.**

Ecology is divided into two groups:

1. **Autoecology:** It is a study of relationship between individual species or its population and its environment.
2. **Synecology:** It is a study of relationship between the individual of different species or its population and its environment. It is concerned with the structure, nature, development and causes of distribution of population of different species.

4.1.2 ECOLOGICAL FACTORS

Any factor, abiotic or biotic, that influences the living beings are called as ecological factors or environmental factors. These factors either singly or in combination influence or determine the presence or absence, vigour or weakness and relative success or failure of various plant communities in a particular habitat. Ecological factors are classified into two groups:

1. Abiotic Factors:

The non-living things of the environment are known as abiotic factors. The abiotic factors that influence the living beings are grouped into three main groups: climatic factors, topographic factors and Edaphic factors.

a. Climatic factors :

It includes:

- i. **Sunlight** – It plays the most important role in an ecosystem. It is the primary source of energy for all living organisms in an ecosystem. It is necessary for photosynthesis, chlorophyll formation, stomatal movement, transpiration, etc in plants and locomotion, migration of organisms, pigmentation, metabolism, vision etc. in animals.
- ii. **Temperature** – It is another most important factor of an ecosystem. It plays a role in transpiration, respiration, photosynthesis, seed germination, flowering, growth and development etc. in plants and reproduction, colouration, hibernation, aestivation, thermal migration, etc. in animals.
- iii. **Pressure** – The atmospheric pressure varies at different places. The vegetation types and life also vary accordingly and thus the ecosystems are different at different places.
- iv. **Rainfall** – The vegetation types and its density depend on the quantity of rainfall. Heavy throughout the year favours evergreen forest while low rainfall retards the growth of plants and favours the xerophytic vegetation.
- v. **Humidity** – The amount of water vapour in the atmosphere is humidity. It directly influences the rate of photosynthesis, transpiration, absorption of water etc.

b. Topographic factors:

It is mainly concerned with surface features of the Earth and includes altitude, latitude, slope, steepness etc. The variation in these factors causes the variation in climatic factors.

c. Edaphic factors:

It is concerned with soil factors. It includes texture, organisms, temperature, pH, air, water etc of soil.

2. Biotic factors:

The living things of the environment are known as biotic factors. The biotic factor includes all types of life forms and is categorized in three groups on the basis of food relationship i.e. producer, consumer and decomposer.

- a. **Producers** – The green plants in the ecosystem are called producers. In a terrestrial ecosystem, main producers are herbaceous and woody plants while in aquatic

ecosystem the main producers are various species like phytoplankton, algae and higher plants.

- b. **Consumers** – All animals are called as consumers because they depend on plants for their food. They are heterotrophs. They are categorized into following groups:
 - i. Primary consumer: These organisms fully depend upon the producer for food. e.g. rat, rabbit, deer etc.
 - ii. Secondary consumer: These organisms depend upon the primary consumer for food. e.g. insects, frog, small fishes etc.
 - iii. Tertiary consumer: These organisms depend upon the secondary consumer for food. e.g. tiger, lion, snake, big fish etc.
- c. **Decomposers** – They obtain their food from dead and decaying body of organism. They convert the complex organic matter of dead and decaying matter into simple inorganic compounds. It includes bacteria and fungi.

4.1.3 SPECIES INTERACTION

The living organisms of an ecosystem form a biotic community. All the organism of a particular habitat influences each other directly or indirectly. Interaction is a necessity for any living being to survive. They can be either of the same species (intraspecific interactions), or of different species (interspecific interactions).

1. Positive Interaction

It is the type of interaction in which one or both partners are benefited and no one is harmed.

- a. **Mutualism (Symbiosis)**: It is the biotic interaction between two organisms of different species where both partners are benefited. The relationship is obligatory (i.e. they can not survive independently). Example: *Rhizobium* bacteria and leguminous plant, mycorrhiza etc.
- b. **Commensalism**: It is the biotic interaction between two organisms of different species where one partner is benefitted and other is neither benefited nor harmed. Example: epiphytes, Sucker fish and shark etc.
- c. **Protocooperation**: It is the biotic interaction between two organisms of different species where both partners are benefited but the relationship is not obligatory. Example: Flower and insect, birds and cattle etc.
- d. **Colonization**: It is the grouping of individuals of same species for better protection and food. Example: *Volvox*, *Nostoc* etc.
- e. **Social Organization**: It is the grouping of individuals of same species that show the division of labour. Example: honey bee, wasp, ants etc.

2. Negative interaction:

It is the type of interaction in which one partner is benefited and other is harmed.

- a. **Parasitism**: It is the interaction in which one organism, the parasite is benefited while the other organism, the host, is harmed. Example: mosquito and human, leech and cattle, etc.

- b. **Predation:** It is the interaction in which one organism kills and feeds on the other. Here one partner is benefited and other is harmed. Example: tiger and deer, frog and insect etc.
- c. **Competition:** It is the interaction between similar or different species for food, support, shelter, space etc. Here either of the organisms is harmed. Example: Lichens, herbs, birds etc.

4.1.4 CONCEPT OF ECOSYSTEM

In nature an organism does not exist in isolation, it is associated with organisms of its own and of different kinds as well as with the physical environment. If the organism is plant, it depends for growth on the aerial environment for light, temperature and carbon dioxide, on the soil environment for inorganic nutrients and water. If it is an animal it depends on the plants for food and shelter. If it is a microorganism it depend on the dead organic matter from plants and animals for its food, and releases the nutrients tied in the organic matter for the reuse of plants. Thus, there are continuous interactions among the organisms and between the organisms and the habitat resulting into an integrated, functional unit. This functional unit is known as ecosystem. It is the structural and functional unit of ecology. Thus, **ecosystem is defined as ‘the structural and functional unit of ecology where the living organisms interact with each other and the surrounding environment’**. The term ecosystem was coined by A.G. Tansley (1935). Ecosystem varies greatly in size from a small pond to a large forest or a sea. The ecosystem is divided into two basic categories: Aquatic Ecosystem and Terrestrial Ecosystem. Forest, grassland etc. are terrestrial ecosystem while pond, lake, river etc. are aquatic ecosystem.

STRUCTURAL AND FUNCTIONAL ASPECT OF POND ECOSYSTEM

Ponds are fresh water ecosystem. It is a small reservoir which may or may not dry up during dry season. It is self-sustaining and self-regulating.

Pond ecosystem consists of structural and functional components.

Structural components

Structural components are categorized into two main components: Abiotic component and Biotic component.

A. Abiotic component: Abiotic components of pond ecosystem are non-living things of pond and consist of water, dissolved minerals, oxygen, carbon dioxide, solar energy etc.

B. Biotic component: Biotic components of pond ecosystem are living beings of pond and are categorized into following groups:

1. Producers: The main producers in pond ecosystem are algae and other aquatic plants. The green plants can prepare their own food by the process of photosynthesis. In pond ecosystem, the producers are phytoplanktons which are minute microscopic floating or suspended plants like *Volvox*, *Spirogyra*, *Anabaena*, *Ulothrix*, etc. and larger plants known as macrophytes which may be floating, suspended or submerged like *Chara*, *Hydrilla*, *Marsilea*, *Eichornia*, *Lemna* etc.

2. Consumers: The consumers in pond ecosystem are categorized as primary, secondary and tertiary consumers. The primary consumers like tadpole, small fishes, etc. consume green plants and algae as their food. They are herbivorous of pond ecosystem. Secondary consumers like frog, big fishes, crabs etc. consume primary consumers as their food. These secondary consumers are consumed by tertiary consumers. The tertiary consumers are water birds, snake, crocodile etc.
3. Decomposers: When aquatic plants and animals die, a large number of bacteria and fungi attack their dead bodies and convert the complex organic substances into simpler inorganic compounds and elements. These micro-organisms are called decomposers.

Functional components

The functional aspect of pond ecosystem includes:

1. Flow of Energy
2. Flow of nutrients

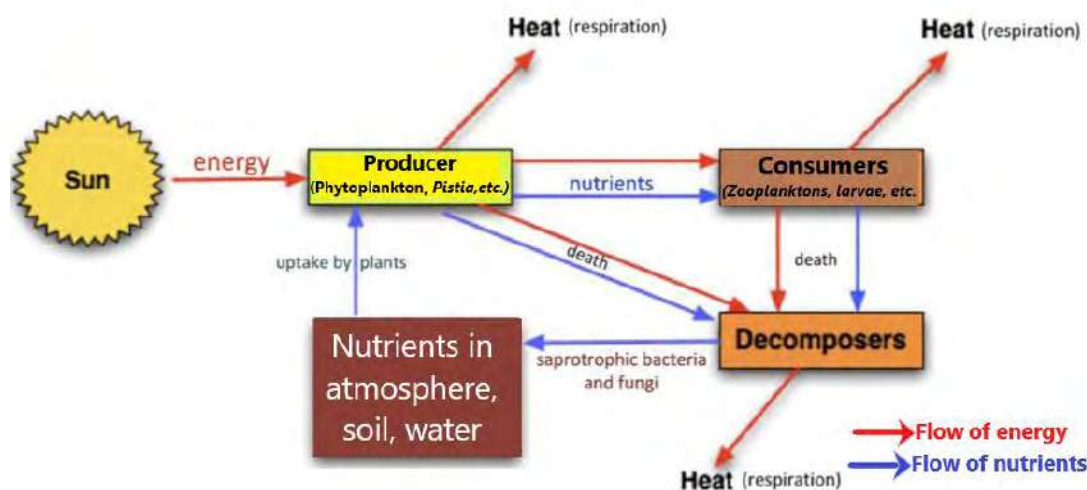


Figure: 4.1.1 Functional aspect of Pond ecosystem

The aquatic green plants of the pond ecosystem capture the solar energy and convert it into chemical energy of food and store in their body through photosynthesis. This process is called primary productivity. The primary consumers like tadpole, small fishes etc. of the pond ecosystem derive the energy by consuming plants or plants parts. These primary consumers are eaten by secondary consumers (like frog, crabs etc.) and then secondary consumers by tertiary consumers (like water birds, snake, etc.). In this chain of eating and being eaten, the aquatic green plants form first trophic level, primary consumers form second trophic level, secondary consumers form third trophic level and tertiary consumers form fourth trophic level. This linear arrangement of trophic levels is called food chain along which the energy flows. At each trophic level some energy is lost as heat and respiration so available energy decreases as one moves away from the first trophic level. The flow of energy is unidirectional. Also, organisms at each trophic level die and generate waste organic material. This constitutes detritus food chain. An ecosystem contains several food chains of each of the above types which are inter-linked forming a food web.

The nutrients in atmosphere, soil, water are utilized by aquatic green plants during photosynthesis, move from organism to organism through food chain and ultimately from all trophic levels, the decomposers break down the complex organic compounds and release nutrients back to atmosphere, water and soil again in a cyclic manner. This is known as biogeochemical cycling.

STRUCTURAL AND FUNCTIONAL ASPECT OF FOREST ECOSYSTEM

Forest ecosystem is the terrestrial ecosystem. Like other ecosystems, forest ecosystem also has two main components:

- A. Abiotic component
- B. Biotic component

A. Abiotic component: Abiotic components are the non-living things of forest ecosystem. The abiotic components of forest ecosystem are soil, moisture, air, sunlight, etc.

B. Biotic component: Biotic components are the living things of forest ecosystem. All the biotic components are grouped into following groups:

1. Producers: All the green plants of a forest are producers. They are the main sources of food for all the animals in forest ecosystem. The producers in the forest ecosystem are trees, shrubs, herbs, lichens, mosses and algae.

2. Consumers: They include all kinds of animals that cannot prepare their own food. On the basis of feeding habit, the consumers are divided into three types i.e. primary consumers, secondary consumers and tertiary consumers. Primary consumers take their food directly from producers. They may be grasshopper, rabbit, deer, monkey, birds and all herbivorous animals. Secondary consumers are wolf, jackal, frog etc which consume primary consumers. The animals like lion, tiger, hawks, etc are called as tertiary consumers as they obtain their food from secondary consumers.

3. Decomposer: They are micro-organisms like bacteria and fungi which attack dead bodies of producers and consumers. It converts complex organic compounds into simpler inorganic compounds and elements which are again utilized by producers in their nutrition.

Functional components

The functional aspect of forest ecosystem includes:

- 1. Flow of Energy
- 2. Flow of nutrients

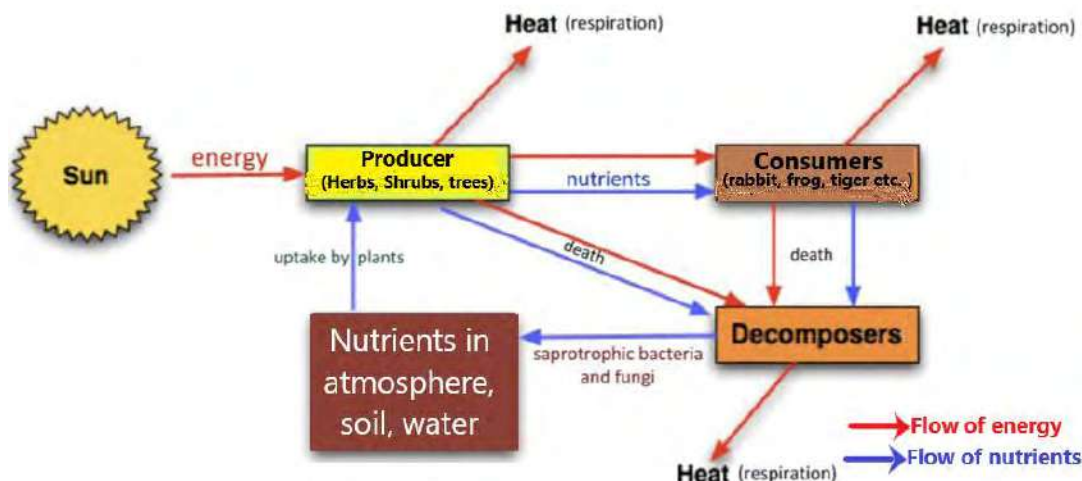


Figure: 4.1.2 Functional aspect of Forest ecosystem

The green plants of the forest ecosystem capture the solar energy and convert it into chemical energy of food and store in their body through photosynthesis. This process is called primary productivity. The primary consumer like grasshopper, rabbit, deer etc. of the forest ecosystem derive the energy by consuming plants or plants parts. These primary consumers are eaten by secondary consumers (like wolves, frog etc.) and then secondary consumers by tertiary consumers (like tiger, hawks etc.). In this chain of eating and being eaten, the green plant form first trophic level, primary consumer form second trophic level, secondary consumer form third trophic level and tertiary consumer form fourth trophic level. This linear arrangement of trophic levels is called food chain along which the energy flows. At each trophic level some energy is lost as heat and respiration so available energy decreases as one moves away from the first trophic level. The flow of energy is unidirectional. Also, organisms at each trophic level die and generate waste organic material. This constitutes detritus food chain. An ecosystem contains several food chains of each of the above types which are inter-linked forming a food web.

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4.1.5 TROPHIC LEVEL

The trophic level of an ecosystem refers to the position that an organism occupies in a food chain or food web. It indicates the organism's position in the transfer of energy and nutrients within the ecosystem. All green plants and photosynthetic bacteria prepare their own food through photosynthesis. So, producers belong to first trophic level. Similarly, primary consumers, secondary consumers and tertiary consumers form second, third and fourth trophic level respectively.

4.1.6 FOOD CHAIN AND FOOD WEB

In an ecosystem one can observe the transfer or flow of energy from one trophic level to other trophic level by the process of eating and being eaten. It forms a linear chain called food chain. There are basically three types of food chain in nature:

1. Grazing food chain:

The food chain that starts from the green plants and ends to carnivores (top consumer) by passing through herbivores.



Figure: 4.1.3 Grazing food chain

2. Detritus food chain:

The organic wastes and dead matter derived from grazing food chain are called as detritus. The food chain that starts with detritus is called detritus food chain.

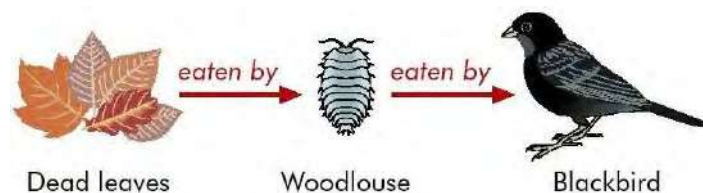


Figure: 4.1.4 Detritus food chain

3. Parasitic food chain:

This food chain starts either from producers or consumers. It goes from large organisms to smaller ones without killing. Parasites are present in one or more trophic level.

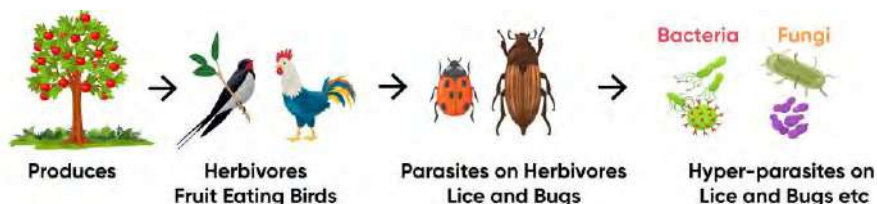


Figure: 4.1.5 Parasitic food chain

In an ecosystem, there is more than one food chain because most organisms feed on more than one organism. Even one organism may be eaten by several organisms. This form network of food chain called as **food web**.

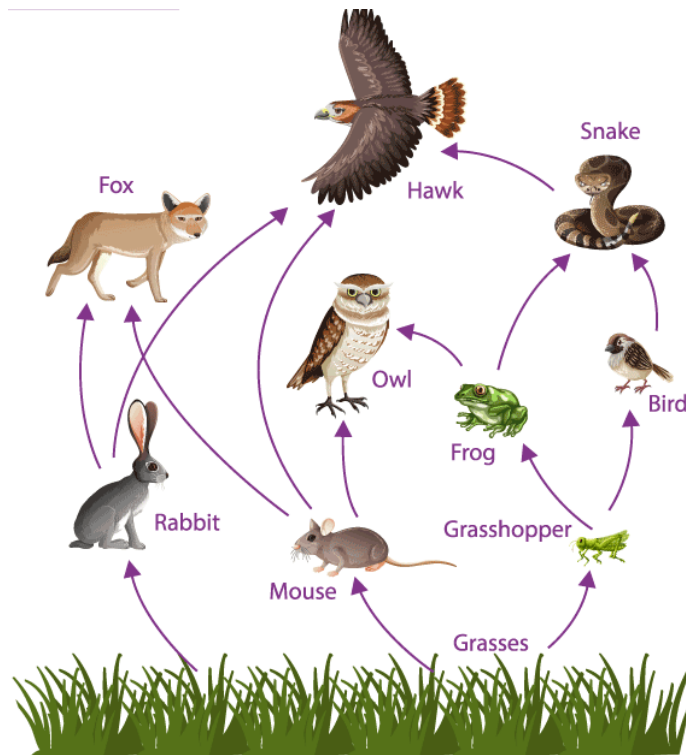


Figure: 4.1.6 Food web

4.1.7 ECOLOGICAL PYRAMID

At each step in the food chain a considerable fraction of the potential energy is lost as heat. As a result, organisms in each trophic level pass on lesser energy to the next trophic level than they actually receive. This limits the number of steps in any food chain. Longer the food chain the lesser energy is available for final members. Because of this tapering off of available energy in the food chain a pyramid is formed is known as ecological pyramid. It represents the relationship of organisms of different trophic levels. This relationship is expressed in terms of number, biomass or energy. **Ecological pyramid is defined as the graphical representation of different parameters like number, biomass or energy at different trophic level in the form of pyramid.** In ecological pyramid, producer level forms the base and successive levels make up the apex.

There are three types of ecological pyramid in an ecosystem:

1. Pyramid of number
2. Pyramid of biomass
3. Pyramid of energy

1. Pyramid of number

It shows the relationship between producers, herbivores and carnivores at successive trophic levels in terms of their number. **The graphical representation of the number of organisms at different trophic level in an ecosystem is called pyramid of number.**

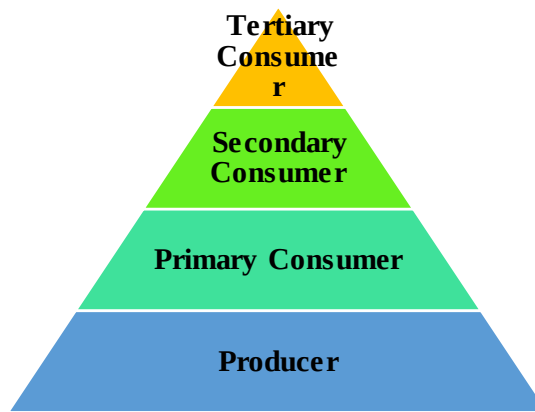


Figure: 4.1.7 Pyramid of Number in forest and pond ecosystem

The number of producers are found in large number than the consumers. So, the pyramid of numbers is usually upright except for some situations like that of the detritus food chain, where many organisms feed on one dead plant or animal.

2. Pyramid of biomass

The graphical representation of the biomass of organisms at different trophic levels in an ecosystem is called pyramid of biomass. In grassland and forest ecosystem the biomass of producers is maximum and decreases gradually in successive trophic level. So, the pyramid is upright. In pond ecosystem, producers are found in large number but they are smaller in size so biomass is least. The biomass of consumers increases gradually in successive trophic level. The pyramid of biomass in pond ecosystem is inverted.

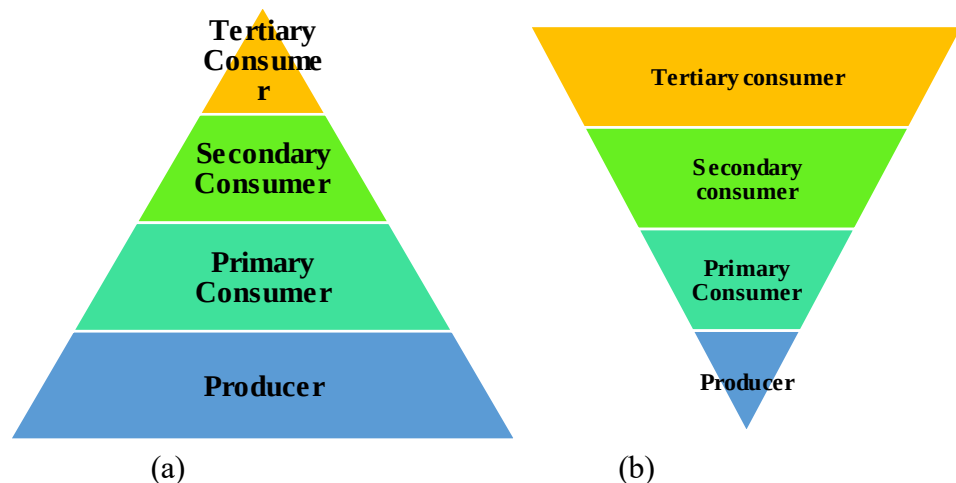


Figure: 4.1.8 Pyramid of biomass in (a) forest ecosystem (b) Pond ecosystem

3. Pyramid of energy

The graphical representation of the energy of organisms at different trophic levels in an ecosystem is called pyramid of energy. The pyramid of energy is always upright, can never be inverted, because the flow of energy in a food chain is always unidirectional. Producers trap solar energy during photosynthesis process for the preparation of organic matter. These organic matters are transferred to next trophic level. When energy flows from a particular trophic level to the next trophic level, some energy is always lost as heat at each step. So, the pyramid is upright.

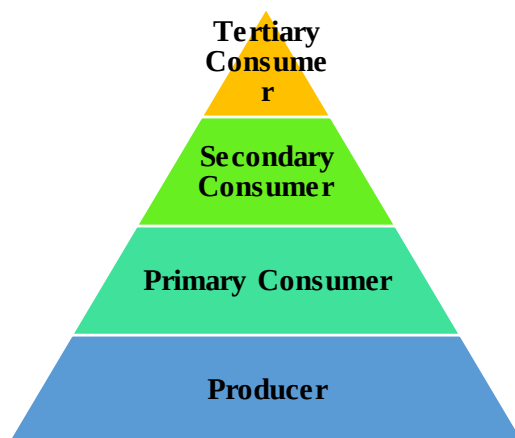


Figure: 4.1.9 Pyramid of energy in forest and pond ecosystem

4.1.8 PRODUCTIVITY

Productivity of an ecosystem refers to the rate at which biomass (organic matter) is produced within a given area over a specific period of time. It is measured in $\text{KJ/m}^2\text{year}$ (Kilo Joule per square meter per year).

The productivity is of following types:

1. **Primary productivity:** The rate at which producers within ecosystem synthesize organic compounds from inorganic molecules using solar energy. It is of two types:
 - a. **Gross primary productivity (GPP):** The total amount of organic of matter produced by producers though photosynthesis.
 - b. **Net primary productivity (NPP):** The amount of organic matter that remains after subtracting the energy used by producers for respiration from the gross primary productivity.
2. **Secondary productivity:** The rate of storage of energy in consumers is secondary productivity.

4.1.9 BIOGEOCHEMICAL CYCLE

You have already learnt that living organisms require several chemical elements for their life process. They may be used as part of their structural component or as parts of enzymes which influence various life processes. Nutrients are continuously exchanged between the organism and their physical environment.

The cyclic movement of inorganic nutrients or essential elements between abiotic environment and biotic communities is called biogeochemical cycle.

Biogeochemical cycle is of three types: hydrological cycle (water cycle), gaseous cycles (e.g. Carbon cycle, oxygen cycle, nitrogen cycle etc.) and sedimentary cycle (like, phosphorous cycle, calcium cycle, sulphur cycle, etc.).

CARBON CYCLE

Carbon is considered as building block of life as it is main component of biological compounds and many minerals. The carbon cycle is the biogeochemical cycle in which there is cyclic movement of carbon containing compounds in between biotic and abiotic components. The major source of carbon is the atmospheric CO_2 (0.03%) and dissolved state in water. It is also found in carbonate rocks.

Carbon cycle comprises the following process:

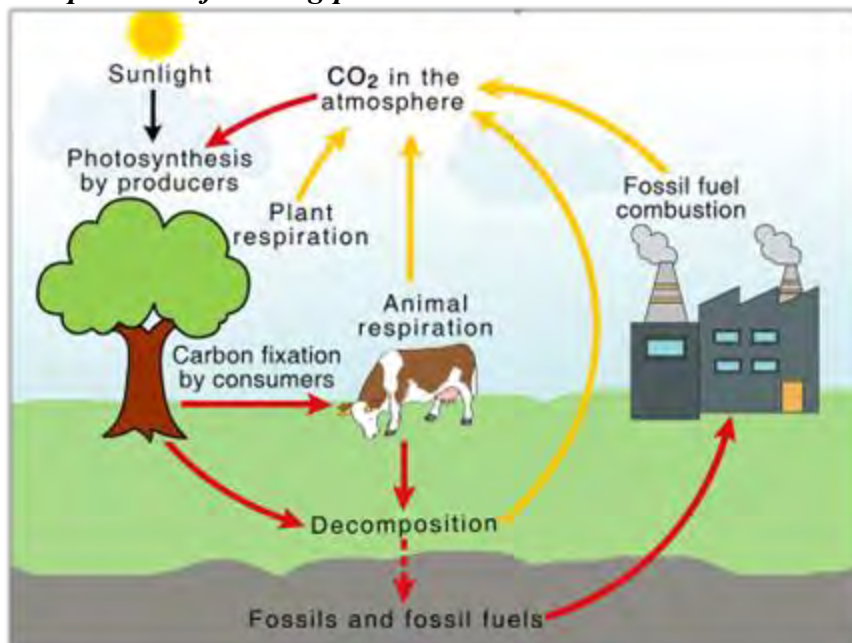


Fig: 4.1.10 Carbon Cycle

1. Photosynthesis

Carbondioxide of atmosphere and water is utilized by producers during photosynthesis to manufacture carbohydrate. The CO_2 thus fixed is partially used by the green plant for their own life processes and the rest is stored as their biomass which is available to the heterotrophs as food. In this way, carbon fixed by producers enters food chain and passes to consumers and decomposers.

2. Respiration

It is the process in which food is oxidized to liberate energy, CO_2 and water. Some amount of carbon of each trophic level is utilized for cellular respiration and rest of it is again stored as their biomass which may be consumed by another trophic level in food chain.

3. Decomposition

After the death of the organisms the decomposers break down the remaining dead organic matter and release the left over carbon back into the atmosphere.

4. Combustion (burning)

Under certain conditions dead bodies of organisms undergo partial decomposition to form fossil fuels. On burning, these fossil fuels release carbon dioxide to atmosphere. Forest also makes a large amount of fossil fuel. It acts like carbon reservoirs. They release CO_2 by forest fires and burning of firewood to the atmosphere.

NITROGEN CYCLE

Nitrogen is one of the essential components of different bio molecules like protein, nucleic acid, amino acid, vitamins etc. These molecules play vital role in living organisms. Nitrogen is abundant in atmosphere (about 78%). However, atmospheric nitrogen is not directly utilized by plants. It should be converted into nitrites, nitrates, ammonia, etc. and available in soil, for uptake by plants.

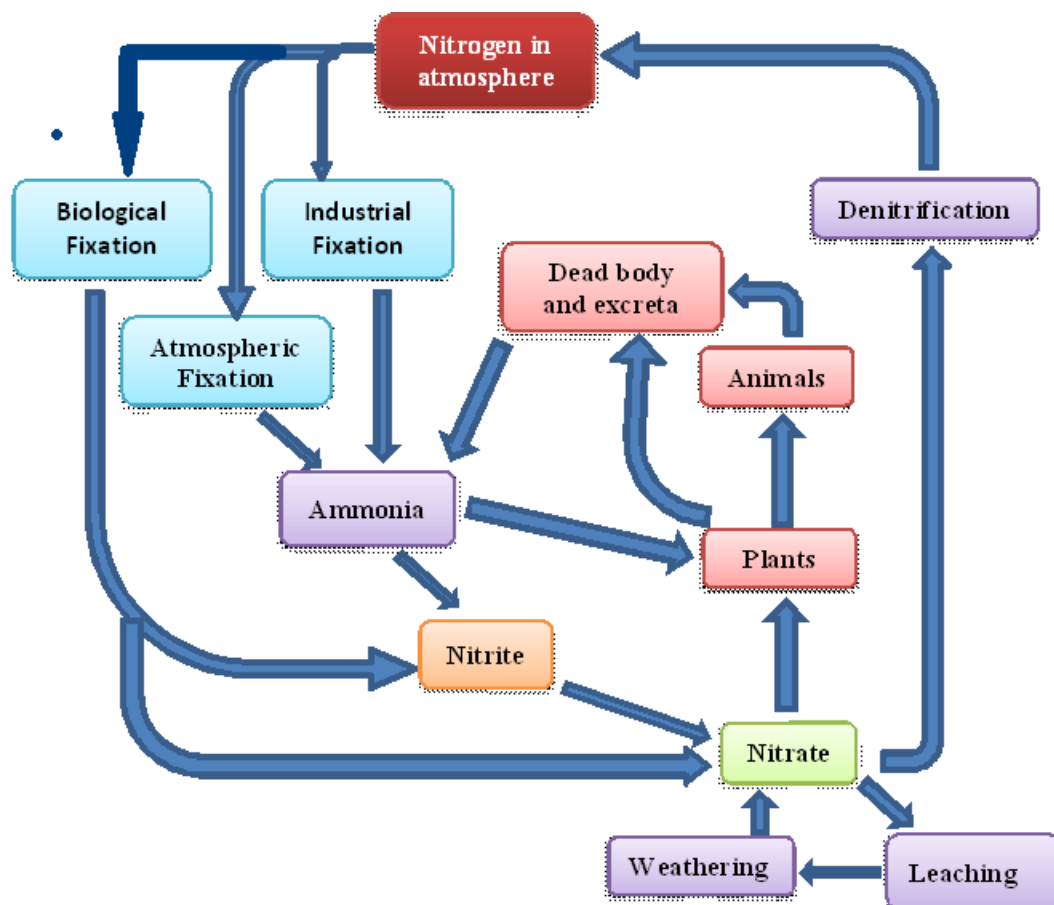


Fig: 4.1.11 Nitrogen Cycle

Nitrogen cycle consists of following steps:

1. Nitrogen fixation

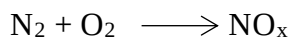
The conversion of free atmospheric nitrogen into biologically acceptable form or nitrogenous compounds is called as nitrogen fixation. This process is of three types:

a. Biological nitrogen fixation

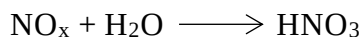
It is the process in which atmospheric free nitrogen is converted into nitrogenous compound by certain microorganisms. These microorganisms may be symbiotic like *Rhizobium* (present in root nodules of leguminous plant), *Nostoc*, etc. or free living like *Azobactor*, *Clostridium*, etc.

b. Atmospheric nitrogen fixation

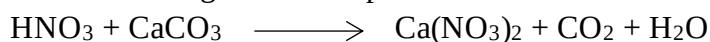
During lightening, the free atmospheric nitrogen reacts with oxygen present in atmosphere to form nitrogeneous oxides.



These oxides of nitrogen dissolve in moisture of atmosphere to form nitric acid.



The nitric acid so formed reacts with mineral compounds of the soil to form nitrates and other nitrogeneous compounds.



c. Industrial nitrogen fixation

In industries, free nitrogen and hydrogen gases react through the Haber's process to form ammonia. This ammonia serves as a crucial component in the production of nitrogen base fertilizers.

2. Nitrogen assimilation

In this process, plants uptake nitrogen from soil through their roots, utilizing it to synthesize organic compounds like amino acids, proteins, nucleic acids, etc. The nitrogen present in the compounds passes to animals in food chain. They form animal protein and nucleic acids.

3. Ammonification

When organisms die, nitrogen containing compounds within their dead bodies and excretory materials undergo conversion into ammonia by ammonifying bacteria. This process is termed as ammonification. The ammonifying bacteria are *Bacillus ramosus*, *B. vulgaris*, etc.

4. Nitrification

The process of conversion of ammonia into nitrites and later into nitrates is called nitrification. This process takes place by some nitrifying bacteria like *Nitrosomonas*, *Nitrobacter*, etc.

5. Denitrification

It is the process of conversion of ammonia and nitrates of soil into atmospheric free nitrogen. This is the process by which nitrogen compounds present in the soil make their way back to the atmospheric nitrogen. The process is carried out by certain bacteria known as denitrifying bacteria like *Bacillus denitrificans*, *Pseudomonas*, etc.

6. Sedimentation

Nitrogen of the soil is washed away to the sea and by leaching deep into the earth to form rock. This nitrogen is released only when the rocks are exposed and weathered.

4.1.10 CONCEPT OF SUCCESSION

Succession is like a natural makeover that happens in nature over time. Imagine you have a bare plot of land. At first, it might seem empty, but over time, different plants and animals come in and make it their home. This process of change from bare land to a thriving ecosystem is called succession. It helps the ecosystems grow and develop over time.

Succession is defined as *‘The gradual replacement of one type of biological community by the other community in a particular area over a period of time leading to the establishment of a stable and mature community, known as the climax community.’* The first biological community that develops in a bare area is called **pioneer community** while the final community which is more or less stable is called **climax community**.

Succession happens because nature is always changing. Succession generally occurs due to the development of bare area (by erosion, deforestation, fire, volcanic eruption etc.), biological interactions (competition and reaction, predation, aggregation, etc.) and climate change.

Types of Succession

There are two main types of succession:

1. **Primary Succession:** A succession that occurs in an area where there was no life before, such as bare rock, volcanic lava, etc. The pioneer species include lichens and mosses.
2. **Secondary Succession:** A succession that occurs in an area where soil already exists or the area where there is previous life but has been disturbed by landslide, fire etc. The pioneer species of the succession is either mosses or grasses.

Process of Succession

The various steps involved in succession are given below:

1. **Nudation:** It is the process of formation of bare area by natural causes (like landslide, volcanic eruption, flood etc.) or human causes (like deforestation, development work, forest fire, etc.).
2. **Invasion:** It is the successful establishment of a species in a bare area. It includes migration or dispersal of seeds, germination and formation of adult plants and finally increases in number of individuals.
3. **Competition and Coaction:** The increase in number of individuals starts the competition for resources like sunlight, water and nutrition. Individuals of a species affect each other's life in various ways is called coaction.
4. **Reaction:** It is the modification of environment through the influence of living organisms. Due to reaction, environmental condition changes so existing community is replaced by another new community. The replacement process is continuous until the development of climax community.
5. **Stabilization:** It is the stage in which a community becomes stable for that environmental condition for longer time.

EXERCISE

A. Tick the correct alternative.

1. What is the primary source of energy for all living organisms in an ecosystem?
 - a. Temperature
 - b. Pressure
 - c. Sunlight
 - d. Rainfall
2. What is the role of decomposers in ecosystems?
 - a. They convert inorganic compounds into organic matter.
 - b. They obtain energy from sunlight.
 - c. They convert dead and decaying matter into simple inorganic compounds.
 - d. They produce food through photosynthesis.
3. Which of the following is an example of mutualism?
 - a. Tiger and deer
 - b. Mosquito and human
 - c. *Rhizobium* bacteria and leguminous plant
 - d. Frog and insect
4. What is the term for the linear arrangement of trophic levels in an ecosystem where energy flows?
 - a. Energy web
 - b. Food web
 - c. Trophic hierarchy
 - d. Food chain
5. What is nudation in the process of succession?
 - a. The migration of seeds to a bare area
 - b. The establishment of a species in a bare area.
 - c. The modification of environment by living organisms.
 - d. The formation of a bare area by natural or human causes.
6. What is the first biological community that develops in a bare area called?
 - a. Climax community
 - b. Intermediate community
 - c. Pioneer community
 - d. Stable community
7. Which of the following best defines nitrogen fixation?
 - a. The conversion of atmospheric oxygen into nitrogenous compounds
 - b. The conversion of atmospheric nitrogen into biologically acceptable forms.
 - c. The conversion of soil nitrogen into atmospheric nitrogen.
 - d. The conversion of nitrogen compounds into atmospheric gases.
8. What is the role of nitrifying bacteria in the nitrogen cycle?
 - a. They convert atmospheric nitrogen into usable forms.
 - b. They convert ammonia into nitrites and nitrates.
 - c. They convert nitrites and nitrates into atmospheric nitrogen.
 - d. They convert organic nitrogen into ammonia.

B. Answer the following questions:

1. Who coined the 'ecology'? Define the term.
2. Explain the importance of sunlight in an ecosystem.
3. How does temperature affect plant and animal life in an ecosystem?
4. What role does rainfall play in determining vegetation types in an ecosystem?
5. Define positive interaction. Differentiate between mutualism and protocooperation.
6. Explain the concept of predation and provide an example.
7. How do intraspecific interactions differ from interspecific interaction?
8. What are the structural components of a pond ecosystem, and how do they contribute to its functioning?
9. What is succession? Describe the types and process of succession.
10. What is biogeochemical cycle? Describe nitrogen cycle in detail.

Chapter 4.2

ECOLOGICAL ADAPTATION

Look at the pictures and discuss the following questions:



- i. Can you identify the given plant.
- ii. Name the climatic condition to which the given plant belongs to?
- iii. Discuss some characters of these plants that make them to adapt in the given environment.

4.2.1 CONCEPT OF ADAPTATION

There are millions of species on Earth. They can be found in a wide range of natural environments. The environment is constantly changing. This changing environment ensures that the species that are capable of adapting survive and an advantage over organisms that do not adapt. The competition caused by adaptations is critical to the evolution process. The changes in the structure of organisms aid in their survival in an environment.

Ecological adaptation refers to the process by which organisms adjust to their environment in order to survive and reproduce successfully. This adaptation can occur through various mechanisms, including physiological, behavioral, and morphological changes. The ultimate aim of all adaptations is to make the individual fit to obtain food and space for its survival, opportunities for its reproduction and rearing of young ones.

Plant life, like animals, is dependent on a variety of basic survival needs. Light, air, water, nutrients, soil and a proper climate are all required for growth. However, not every habitat provides the necessary needs. As a result, to live in such conditions, plants have evolved specific physiological, behavioral, and morphological adaptation.

On the basis of their water requirement and nature of habitat, the plants have been classified as follows:

1. Hydrophytes
2. Mesophytes
3. Xerophytes

4.2.2 HYDROPHYTES

Plants which grow in wet places or grow either partially or completely submerged in water are commonly referred to as hydrophytes or aquatic plants. Examples: *Hydrilla*, *Pistia*, *Eichornia*, *Lemna*, etc.



Hydrilla



Pistia



Eichornia

Fig: 4.2.1 Hydrophytes

According to their distribution in a fresh water body, there are five categories of hydrophytes:

a. Free-floating

These are the aquatic plant that float freely on water surface. They remain in contact with water and air, nut not soil. Example: *Pistia*, *Eichornia*, *Lemna*, etc.

b. Rooted with floating leaves

These are the aquatic plants whose roots are fixed in mud but leaves have long petioles which keep floating on the water surface. Rest of the plant body is submerged in water. Example: *Marsilea*, *Trapa*, etc.

c. Submerged floating

These are the aquatic plants that remain in contact only with water. They are not rooted in the mud and being completely submerged in water. Example: *Najas*, *Ceratophyllum*, etc.

d. Rooted submerged

These are the hydrophytes that remain completely submerged in water, but rooted in the soil. Example: *Hydrilla*, *Chara*, etc.

e. Rooted emergent

These hydrophytes grow in shallow waters and require excess of water but their shoots are partly or completely exposed to air. The root system is completely under water, fixed in soil. Example: *Sagittaria*, *Ranunculus*, *Typha*, etc.

Adaptation of hydrophytes

Different parts of various hydrophytes shows following specialized features:

- Roots: Roots may be completely absent or are poorly developed. Root hairs and root caps are usually absent. However, in free-floating plants the root hairs and root caps

develop prominently. In *Eichornia*, root caps are replaced by ‘root pockets’. Roots of hydrophytes are generally fibrous, short, unbranched or poorly branched.

- b. Stems: In free-floating forms, stem is slender, horizontally floating, short, thick and spongy, while in submerged, stem is long, slender, spongy and flexible.
- c. Leaves: The leaves are generally thin, small and translucent in submerged hydrophytes while large, flat and with waxy coat on entire surface in floating hydrophytes.
- d. Flowers and reproduction: The flowers are not common in submerged form. They are usually produced on the surface of water or above it. Pollination and dispersal are performed by water, insects and birds. Vegetative reproduction is common.
- e. Anatomical Adaptation: Aerenchyma in submerged leaves and stem is well developed. Mechanical tissue and vascular tissues are poorly developed. The cuticle is absent or poorly developed. Stomata are completely absent in submerged leaves while present on the upper surface of floating forms.
- f. Physiological adaptation: The aquatic plants exhibit a low compensation point and low osmotic concentration of cell sap. Nutrients are absorbed by the submerged plants through the general plant surface. The gases are exchanged from the water through the surface cells (epidermis). Transpiration is absent in submerged hydrophytes however, emergent and free-floating plants have excessive rate of transpiration.

4.2.3 XEROPHYTES

Xerophytes are plants that have adapted to survive in dry or arid environments where water availability is limited. Xerophytes are characteristic plants of desert and semi-desert regions, yet they can grow in mesophytic conditions where water available is in sufficient quantity. Example: *Opuntia*, *Aloe*, *Begonia*, *Agave*, etc.



Opuntia



Aloe

Fig: 4.2.3 Xerophytic plant

According to their adaptations to arid or dry environments, there are three categories of xerophytes:

a. Ephemerals

They are xerophytic plants that complete their life cycle in short period of time when sufficient moisture is available. They are also called ‘drought evaders’ or ‘drought escapers’. Since these plants avoid dry seasons. Example: *Solanum xanthocarpum*, *Tephrosia purpurea*, etc.

b. Succulent

They have specialized tissues for water storage that can store large amounts of water during periods of rainfall or high humidity. In these plants, the succulence, i.e. development of water storing parenchymatous tissues may occur in roots, stems or leaves. The rest of the plant body other than succulent organ is generally reduced. Example: *Aloe*, *Asparagus*, *Begonia*, *Agave*, etc.

c. True xerophytes or drought resistant

The plants which have the ability to maintain growth under critical dry conditions and high temperature are true xerophytes. The plants are woody trees, shrubs or herbs. Example: *Acacia nelotica*, *Nerium*, etc.

Adaptation of Xerophytes:

The xerophytic plants show following adaptations:

- a. Root: They have well developed root system that can penetrate deep into the soil to access moisture. Root hairs are concentrated in abundance near the tips of growing rootlets.
- b. Leaves: The leaves, if present, are modified to minimize the rate of transpiration. The modification in leaves may vary from species to species. There are small sized, rolling and folding of leaf blades or delicate leaves which are shed under conditions of less supply of water. The leaves surfaces are generally shining and glazed to reflect light and heat.
- c. Stems: The stem of some xerophytes are hard and woody while some plants have succulent type of stem. In some it may modified into thorns.
- d. Flower and reproduction: The flower is generally reduced. It generally develop during high moisture availability, such as after rainfall. In some xerophytes the flowers have fleshy structure that can store water. Pollination takes place by wind or gravity. Vegetative propagation is more common.
- e. Anatomical adaptation: The leaves have heavy cuticular and epidermal layer and waxy coating on its surface to reduce the transpiration. The stomata are sunken type. Conducting and mechanical tissues are well developed.

EXERCISE

A. Tick the correct alternative.

1. What type of leaves do submerged hydrophytes typically have?
 - a. large, flat and with a waxy coat
 - b. Thin, small and translucent
 - c. Broad, with prominent veins
 - d. Needle like and succulent
2. Name the category to which the given plant belong to?



- a. Submerged floating
 - b. Rooted submerged
 - c. Free floating
 - d. Rooted emergent
3. How do xerophytic leaves minimize the rate of transpiration?
 - a. By increasing the size of leaf blades
 - b. By reducing the concentration of waxy coating on leaf surfaces
 - c. By developing shiny and glazed leaf surfaces
 - d. By increasing the density of stomata
 4. Which category of xerophytes completes its life cycle in a short period of time when sufficient moisture is available?
 - a. Succulent
 - b. True xerophytes
 - c. Ephemerals
 - d. Drought resistant
 5. What is the another term used to describe ephemerals?
 - a. Drought avoiders
 - b. Moisture evaders
 - c. Drought escapers
 - d. Water seekers
 6. Which of the following is an example of a plant belonging to the category of ephemerals?
 - a. *Aloe*
 - b. *Acacia nelotica*
 - c. *Solanum xanthocarpum*
 - d. *Begonia*

B. Answer the following questions:

1. What is ecological adaptation? Why is it important for species survival?
2. How do plants adapt to environments where not all necessary needs are provided?
3. Explain the anatomical and physiological adaptations of hydrophytes to their aquatic environment.
4. How do ephemerals adapt to an dry environment?
5. Explain the concept of xerophytes and their adaptations to arid environments.
6. What distinguishes true xerophytes from other categories in terms of their adaptation to arid conditions?

Chapter 4.3

ECOLOGICAL IMBALANCES

Look at the pictures and discuss the following questions:



(a)



(b)

- How do they affect environment?
- How do they affect the organism?
- What are the ways to prevent the effect caused by above activities?

Ecological imbalance refers to a disturbance in the natural equilibrium of an ecosystem. In a balanced ecosystem, various species and environmental factors interact in a way that maintains stability and sustains life. However, when this balance is disrupted, it can lead to negative consequences for the environment that may include loss of biodiversity, spread of invasive species, climate change, etc. Some factors that causes ecological imbalance are described as follows:

4.3.1 GREENHOUSE EFFECT AND CLIMATE CHANGE



Figure 4.3.1 Greenhouse effect

The greenhouse effect is the natural process that traps the sunlight increasing warmth of earth's surface. The sun releases the energy in the form of radiation. Some of these radiation passes through and the Earth's surface absorbs this energy, causing it to warm up. The Earth's warm surface then radiates back the energy out in the atmosphere. Some gases in the atmosphere

known as greenhouse gases trap those energy and radiate it back to the earth surface. These trapped heats contribute the overall warming of the planet.

The greenhouse effect in the atmosphere is caused by some gases called as greenhouse gases. Water vapor is the most abundant greenhouse natural gas in the atmosphere. Human activities do not significantly affect the amount of water vapor in the atmosphere. Carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) are the other major greenhouse gases emitted by human activities like deforestation, burning fossil fuel, agricultural activities, and waste disposal etc. Such activity has enhanced greenhouse effect by increasing concentration of greenhouse gases causing global warming.



Questions to think?

Why Venus is the hottest planet of our solar system?

Consequences of greenhouse effect:

Positive consequences:

1. Evolution of new species due to climate change caused by greenhouse effect.
2. Tropical plants can be grown in other region by making artificial greenhouse.
3. Off-season fruits, vegetables, flowers, etc. can be grown by making artificial greenhouse.

Negative consequences:

1. Thermal expansion of ocean and melting sea level increases ocean level.
2. Extreme weather events can be caused like frequent and intense heat waves, high rain fall, floods, storms and draught.
3. Species distribution and migration pattern may alter.
4. New pests and diseases emerge.
5. Many species become vulnerable to extinction.
6. Number of invasive species increases.

Mitigating greenhouse effect

1. Reduction of emission of greenhouse gases and switching to alternative sources of energies than burning fossil fuel can help to reduce greenhouse effect.
2. Forest plays crucial role in sequestering carbon dioxide. Afforestation, reducing deforestation and sustainable management of forest are important steps to mitigate climate change.
3. Electric or low emission vehicles should be prioritized.

4.3.2 OZONE LAYER DEPLETION

Ozone is a molecule that contains three oxygen atoms. It forms a layer which is called ozone layer in the stratosphere in the atmosphere. The ozone layer absorbs radiation from the sun preventing it from reaching the planet's surface. Most importantly it absorbs portion of UV light which has been linked for many harmful diseases like skin cancer, cataracts and harm to crops and marine life.

Ozone molecules are constantly formed and destroyed at any given time. Ozone layer depletion is the thinning of ozone layer of earth's atmosphere.

The main cause of ozone layer depletion is release of certain human made chemicals which are known as ozone layer depleting substances (ODS). This includes chlorofluoro carbon (CFC) which is used in refrigerator, air conditioner and aerosol propellants. Halons used in fire extinguisher are another potent cause of ozone layer depletion. Industrial chemicals, such as methyl bromide and carbon tetrachloride, also contribute to ozone depletion.

These ODS molecules, when reach stratosphere are broken down by UV radiations and bromides and chlorides are released. Those compounds act as a catalyst in a chain reaction that destroys ozone.

A single chlorine atom can destroy over 100,000 ozone molecules before it is removed from the stratosphere.

Consequences of ozone layer depletion

With thinner layer of ozone, more ultraviolet rays reach to the earth's surface which can lead to

1. Increased risk of diseases like skin cancer and cataract.
2. UV rays suppress the immune system of human and other animals.
3. UV radiation can harm plants, including reduced photosynthesis, stunted growth, and decreased crop yields. This can affect agricultural productivity and biodiversity in terrestrial ecosystems.
4. It can influence atmospheric circulation pattern and contribute to climate change.
5. The consequences of ozone layer depletion, such as healthcare expenses, loss of productivity, and damage to crops and infrastructure, can impose significant economic burdens on societies and nations

Mitigation of ozone layer depletion

Ozone layer depletion can be controlled by following ways:

1. By reducing the use of CFCs.
2. By increasing the use of alternative source of energy instead of fossil fuels.

4.3.3 ACID RAIN

Acid rain refers to precipitation that has become acidic due to presence of certain chemical compounds such as sulfuric and nitric acid. Rain naturally has acidic pH due to presence of carbon dioxide. But acid rain has much lower pH typically ranging from 4 and 5.

Causes

Air emission: The main cause of acid rain is the emission of gases containing sulfur dioxide (SO₂) and nitrogen oxides (NO_x). These gases are emitted by burning of fossil fuel like coal and oil in power plants, factories and vehicles. These gases travel in atmosphere and react with water vapor to form sulfuric or nitric acid. These acids mix with cloud droplets or rain and forms acidic precipitation.

Acid rain has several adverse effects on

1. Surface water: lower pH of surface water can damage fishes and other aquatic life.
2. Soils: Soil chemistry is altered by acid rain, resulting to the death of existing microorganisms. This changes the chemical and biological properties of soil.
3. Forest and Plants: Acid rain can damage the leaves of plants and hinders growth. It can degrade the essential nutrients in soil making plants difficult to survive.
4. Human health effects: Exposure of acid rain to human can cause irritation to skin and eyes, dental damage and erosion, cause lung disease like asthma and bronchitis etc.
5. Others: Acid rain can damage quality of monuments, building, statues etc. specially made of rocks such as lime stone and marble. It also increases corrosion of metals.

Control measures

1. Reducing emission: The only measure to control acid rain is to reduce emission of oxides of nitrogen and sulfur from power plants, factories and vehicles. Strick regulations on emission, switching to alternative source of energy, investing in renewable source of energy helps in achieving less emission.
2. Liming lakes and ponds: Acidity of ponds and lakes can be neutralized by treating with lime or lime stone to minimize the impact on aquatic life after acid rain.
3. Awareness: Being responsible citizen we should be aware of harmful effect of acid rain and unethical wastes containing oxides of nitrogen and sulfur from industries.

4.3.4 BIOLOGICAL INVASION

The process of introduction, establishment and spread of species to a new environment where it is not native is called biological invasion. Those organisms which live naturally in a particular area and have been present there for long time playing important role in local ecosystem are known as native species. Those organisms which have been introduced to new environment are called exotic or alien species. Exotic species may or may not cause the problems to local ecosystem. Those exotic species that start to spread causing problems for the local environment are known as Invasive alien species.

Invasive species possess certain better features which are superior to native species become more competent in that environment. Some feature are given below

1. Fast growth and reproduction: Invasive species often have high reproductive rate and allows them to colonize rapidly in new areas.
2. Adaptive to wide range of environmental conditions: Invasive species often can tolerate and sustain in various environment. That allows them to spread in various environment that may not be suitable to other native species.
3. Few natural predators and diseases: Invasive species often lack predators and diseases in the new environment that allows them to spread unchecked.
4. Aggressive competitors: Invasive species are aggressive competitors for resources like food, water and space. This can reduce population of native species.
5. Efficient dispersal: Invasive species maintain efficient mechanism to disperse their propagules to new environment. For example they produce seeds with wings or hooks which can be easily carried out by wind or animals.

The main reason behind the spread of invasive species is believed to be human activity often unintentional. Some key causes are

1. Globalization and increase trade: With increase in trade and travel in the interconnected world, opportunities of movement species or its propagules have been increased. For example this can occur to ballistic water, contaminated goods, vehicles etc.
2. Accidental release: Sometimes due to careless or lack of awareness invasive species are released in the new environment. For example pet trade, escape of animals from farm, introducing new plants for cultivation etc.
3. Land use change: Human activities that modify natural habitat can make them more susceptible to invasion.
4. Climate change: Change in climatic condition of the area can allow new species to enter that can disrump established ecosystem and make vulnerable to invasion

Impact of invasive species

Although introduction of invasive species increases the number of species in that area instantly but causes many negative impacts in that area. Some of the negative impacts are as follows:

1. Disturb ecosystem: Invasive species can disturb balance in existing ecosystem by many ways. They may result in loss of native species, can become new predator in the ecosystem, may carry new diseases, can alter microbial community and physical structure of the habitat which becomes unsuitable to native species.
2. Economic damage: They have significant negative impact on economy. They reduce agriculture yield, investment on controlling invasive species increase the cost, decrease scenery of lakes and ponds, damage infrastructures etc.
3. Health: Invasive species can introduce, transmit and cause new diseases. Some invasive species can cause allergic reactions.
4. Loss of biodiversity: The overall impact of the consequences is loss of biodiversity. The loss of biodiversity have severe impact on disturbing natural process that keep ecosystem healthy and functioning.

Management of invasive species

1. Prevention: The best way to deal with invasive species is to prevent them to introduce in the new environment. This can done by proper inspecting cargo, regulating import of live plants and animals etc.
2. Early detection and rapid control: Early detection may make it possible to eradicate it completely before proper establishment.
3. Control measures
 - a) Mechanical control: This includes physically removal of invasive species
 - b) Chemical control: These include using herbicides or pesticides to kill invasive species. However, this method should be used cautiously to avoid harming native species and environment.
 - c) Biological control: This includes introduction of natural enemies of the invasive species such as parasite or predators.

4. Public education and awareness: Educating and awaking public may help in early detection and prevention of spread of invasive species. This also include avoid introducing invasive species and reporting sighting of invasive species to authorities.

Examples of invasive species in Nepal

S.N.	Scientific name	Common name
1	<i>Mikania micrantha</i>	Lahare Banmara
2	<i>Ageratina adenophora</i>	Banmara
3	<i>Lantana camera</i>	Kirne kada
4	<i>Parthenium hysteropgorous</i>	Paati jhaar
5	<i>Eichhornia crassipes</i>	Jal Kumvi
6	<i>Oncorhynchus mykiss</i>	Rainbow trout
7	<i>Pomacea spp</i>	Golden apple snail



Figure: 4.3.2 Some invasive species (a) *Lantana camera* (b) *Parthenium hysteropgorous* (c) *Oncorhynchus mykiss*

EXERCISE

A. Tick the correct alternative.

- Which of the following is greenhouse gas?
 - Oxygen
 - Carbondioxide
 - Hydrogen
 - Calcium
- What role do forest play in mitigating the greenhouse effect?
 - Forest release large amount of greenhouse gases into the atmosphere.
 - Forest has no impact on greenhouse effect.
 - Forest help sequester carbon dioxide from the atmosphere.
 - Forest contributes to the emission of methane and nitrous oxide.
- What is the composition of an ozone molecule?
 - One oxygen molecule
 - Two oxygen molecule
 - Three oxygen molecule
 - Four oxygen molecule
- What is one measure to control acid rain?
 - Increasing emission of sulfur dioxide and nitrogen oxides.
 - Reducing emission of oxides of nitrogen and sulfur.
 - Adding more carbon dioxide to the atmosphere.
 - Using more coal and oil in power plants and factories.
- What is the term used to describe the process of introduction, establishment, and spread of species to a new environment where it is not native?
 - Environmental migration
 - Biological invasion
 - Ecosystem transplantation
 - Natural colonizaation
- How can the spread of invasive species be managed?
 - Promotion of their introduction into new environements.
 - Prevention of their introduction.
 - Encouragement of their rapid expansion.
 - Ignoring their presence in ecosystems.

B. Answer the following questions:

- What are the primary greenhouse gases responsible for the greenhouse effect, and how do human activities contribute to their increase in concentration?
- What measures can be taken to mitigate the greenhouse effect?
- What is ozone layer depletion? What are the consequences of ozone layer depletion?
- Explain the process of formation of acid rain.
- Define biological invasion and differentiate between native, exotic and invasive species.
- What are the control measures for biological invasions?

Unit 5

Vegetation

Jean-François
Dobremez

Jean-François Dobremez (1941-2009), a distinguished French ecologist, left an indelible mark on Nepal's ecological understanding and biogeography. He delineated four belts and 11 bioclimatic zones, identified 75 vegetation types, and 118 ecosystems. His research laid the foundation for conservation efforts in Nepal, preserving its rich biodiversity. Dobremez's extensive field expeditions between 1969 and 1974, spanning over 15,000 kilometers, involved French researchers and Nepalese botanists, enriching Nepal's ecological knowledge.

Chapter 5.1

VEGETATION

Discuss the following questions:

- i. Have you ever visited a local park or botanical garden? Do you think why are they established?
- ii. What benefits do they bring to the community?
- iii. What's the purpose of seed banks?
- iv. How do they help us and the environment?

5.1.1 INTRODUCTION

Vegetation refers to the plant life or the collection of plant species in a particular region or habitat. It encompasses all types of plants, ranging from small mosses and ferns to large trees. Natural vegetation is a plant community that grows without human intervention, obtaining everything it needs from its environment and remaining untouched by human activities for a considerable period, often referred to as virgin vegetation.

The natural vegetation in Nepal is influenced by its climate, altitude and slope of the region. Although cultivated crops and fruits are part of vegetation, they are not considered natural vegetation.

IMPORTANCE OF VEGETATION

The importance of vegetation lies in its various essential roles in the biosphere:

- a) Vegetation plays a key role in regulating biogeochemical cycles, like water cycle, carbon cycle, and nitrogen cycle.
- b) Vegetation significantly affects properties of soil like volume, chemistry, and texture. These, in turn, affect the productivity and structure of the vegetation.
- c) Vegetation serves as a habitat for wildlife and provides energy for a diverse range of animal species on Earth.
- d) For humans, vegetation is crucial for food, shelter, and medicines.
- e) Vegetation helps reduce erosion by intercepting rainfall, decreasing overland flow, and improving the infiltration of water into the soil.

5.1.2 TYPES OF VEGETATION IN NEPAL

In Nepal, there are different kinds of natural vegetation, and their diversity and distribution depend on factors like the shape of the land, climate, soil, and altitude.

There are six main types of natural vegetation (Dobremez) in Nepal based on altitude (bioclimatic zones):

- a) **Tropical Forest:** It is found at altitudes below 1000 m in the Terai and Shiwalik (Churia) hills. It covers about 14% of Nepal's area. Dominant trees include *Shorea*

robusta (Sal), *Bombax ceiba* (Simal), *Terminalia alata* (Saaj), *Dalbergia sissoo* (Sisau), and *Pinus roxburghii* on higher Churia hills.

- b) **Subtropical Forest:** It is located at altitudes between 1000 to 2000 m, mainly in the northern Shiwaliks. Key trees include *S. robusta* (Sal), *Castanopsis indica* (Dhale katus), *Ulmus nepalensis* (utis), *Pinus roxburghii* (chir pine), *Acacia catechu* (khayar), *Quercus semicarpifolia* (oak), *Dalbergia latifolia* (satisal), etc.
- c) **Temperate Deciduous forest:** It is found at altitudes between 2000 to 3000 m, north of the Sub-Tropical Evergreen forest. Trees like *Castanopsis indica* (kattus), *Schima wallichii* (chilaune), *Macaranga Nepalensis* (malato), *Pinus spp.*, *Fagus sylvatica* (beech), *Ulmus americana* (elm), *Rhododendron arboreum* (rhododendron), etc., are present.
- d) **Temperate Coniferous evergreen forest:** It exists at altitudes between 3000 to 4000 m in the Mahabharat ranges. This forest type, situated above the temperate forest, includes trees like cones, laliguras, *Betula utilis* (bhojpatra), pine, *Abir spp.* (fir), and *Quercus leucotrichophora* (oak).
- e) **Alpine Vegetation:** It grows at altitudes between 4000 to 5000 m in the Himalayan region, where the climate is cold and dry. Trees are absent, and only thorny bushes are found. It includes: *Rhododendron lepidotum* (sunpaati), *Caltha palustris* (caltha)
- f) **Tundra vegetation:** It is found at altitudes above 5000 m in the higher Himalayan regions covered with snow, forming a cold desert area. This area contains vegetation such as lichens and mosses.

PRESENT STATE OF VEGETATION IN NEPAL

A joint five-year survey conducted by the Department of Forest Research and Survey and the National forest Products Survey Project in between 2067 to 2071 BS, has come up with following findings:

1. Roughly 44% of Nepal's landmass is occupied by forest.
2. Forest roughly occupies 5.96 million hectares of landmass of the country.
3. Protected forests in Nepal make up about 12.1% of the total, and conserved forests account for around 21.4%.
4. Approximately 5.1% of Nepal's forests are classified as production forests.
5. Between 2000 and 2005, Nepal lost about 2,640 square kilometers (1,019 square miles) of forest, with an annual deforestation rate of about 1.4%, equivalent to an average loss of 530 square kilometers (205 square miles) each year.
6. A 2010 study estimated that 39.1% of Nepal is covered by forests, and agriculture occupies 29.83% of the land.
7. Patch and edge forests, constituting 23.4% of the national forest cover, show interactions with surrounding living things.
8. Core forests make up 79.3% of protected areas and 63% of the area outside protected areas.

5.1.3 CONCEPT OF *IN-SITU* AND *EX-SITU* CONSERVATION

Natural vegetation conservation refers to the preservation and protection of indigenous plant species, ecosystems, and habitats in their natural state. It involves efforts to maintain the diversity, health, and balance of plant communities and their associated fauna, often through the implementation of various strategies such as protected area designation, habitat restoration, sustainable land management practices, and biodiversity conservation initiatives. The goal of natural vegetation conservation is to safeguard ecosystems from degradation, habitat loss, and extinction, ensuring their long-term survival and ecological function for future generations.

Types of Conservation

- a. ***In-situ* conservation:** This strategy focuses on the protection of rare, endangered, and threatened species of plants and animals in their own natural habitat. For example, national parks and other protected areas.
- b. ***Ex-situ* conservation:** This strategy focuses on the protection of rare, endangered, and threatened species of plants and animals outside their natural habitat. It focuses on the organisms which are at the verge of extinction. For example, botanical gardens, zoos, conservation efforts in places like seed bank, safari parks, Elephant Breeding Center, Gharial Conservation and Breeding Center, and Vulture Conservation and Breeding Center, etc.

CONCEPT OF *IN-SITU* (PROTECTED AREAS) CONSERVATION

Protected or conservation areas are special places that get extra care because they are important for nature, the environment, or culture. There are different kinds of these areas, and how much protection they get depends on the rules of each country or international groups.

A protected area is a specific space on the map that is clearly marked, known, and taken care of through laws or other effective methods. The goal is to keep nature safe for a long time, along with its ecosystems and cultural values. These areas usually include places like national parks, wildlife reserves, natural forests, conservation areas, community forests, religious forest, and lease-hood forests.

Protected areas of Nepal

Nepal's protected areas mainly cover forested land across different elevations, including the Terai, Himalayan foothills, and mountains, to safeguard biodiversity. Nepal, situated in the central part of the Himalayas, spans 7,181 km. Altitudes range from 67 m in the southeastern Terai to 8,848 m at Sagarmatha (Mt. Everest).

Botanists have identified 1,120 species of non-flowering plants and 5,160 species of flowering plants. Zoologists have documented 151 mammal species, 844 bird species, 100 reptile species, 43 amphibian species, 185 freshwater fish species, and 635 butterfly species. Recognizing the significant biodiversity, the government of Nepal established a network of 20 protected areas since 1973, including ten national parks, three wildlife reserves, six conservation areas, and one hunting reserve. In 2017, Shuklaphanta and Parsa wildlife reserves were upgraded to National Parks.

National Parks in Nepal:

1. Chitwan National Park
2. Bardia National Park
3. Langtang National Park
4. Sagarmatha National Park
5. Rara National Park
6. Shey-Phoksundo National Park
7. Khaptad National Park
8. Makalu-Barun National Park
9. Shivapuri National Park
10. Banke National Park
11. Shuklaphanta National Park
12. Parsa National Park



Fig: 5.1.1 Chitwan National Park

Wildlife reserve

1. Koshi Tappu wildlife reserve

Conservation areas

1. Annapurna Conservation Area
2. Kanchenjunga Conservation Area
3. Manaslu Conservation Area
4. Blackbuck Conservation Area
5. Api Nampa Conservation Area
6. Gauri Shankar Conservation Area

Hunting Reserve

1. Dhorpatan hunting reserve

Ramsar sites

The following Ramsar sites were declared between 1988 and 2008.

1. Bishzari taal
2. Ghodaghodi taal (declared in 2003, far SW terai harbours Cotton Pygmy goose)
3. Gokyo Lake Complex
4. Gosaikunda
5. Jagdishpur Reservoir
6. Koshi tappu Wildlife Reserve
7. Mai Pokhari
8. Phoksundo Taal
9. Rara Taal
10. Lake Cluster of Pokhara Valley

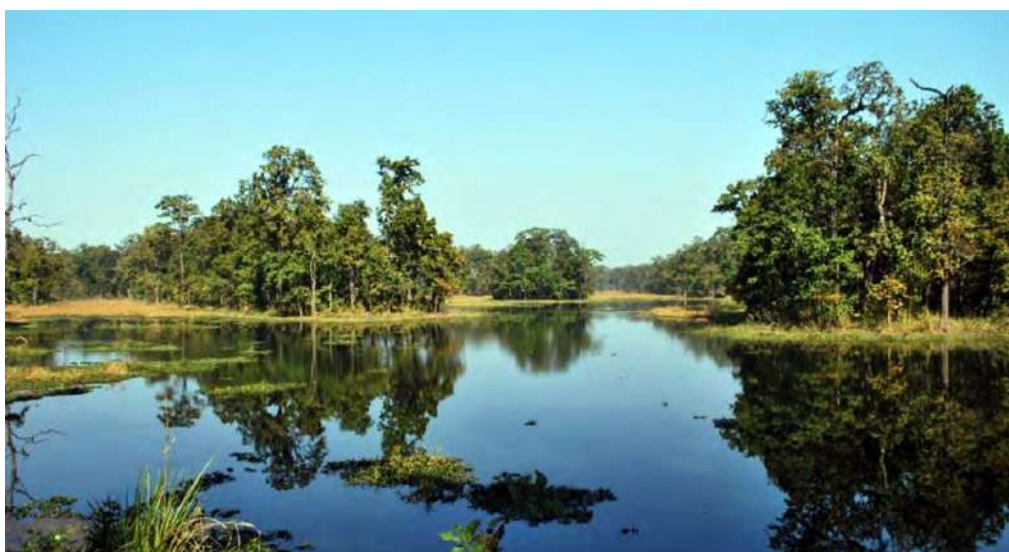


Fig: 5.1.2 Bishazari Tal

BOTANICAL GARDEN (*EX-SITU* CONSERVATION)

Botanical gardens are large areas dedicated to growing various types of plants for scientific and educational purposes. The idea of botanical gardens dates back to Theophrastus, but modern botanical gardens have evolved significantly. In addition to outdoor plants, they now include greenhouses, research laboratories, libraries, and herbariums with documented collections of different plant species. The International Association of Botanic Gardens (IABG), established in 1962, plays a crucial role in coordinating research and facilitating the exchange of plant materials.

Importance of Botanical Gardens:

- a) Botanical gardens provide living plant materials essential for systematic studies.
- b) They cultivate important plants from the local area.
- c) Botanical gardens maintain records of the local flora.
- d) They supply seeds and materials for various botanical research activities.
- e) Botanical gardens grow and preserve rare and endangered plant species.

- f) They cultivate and maintain plants that wouldn't naturally grow during certain seasons by regulating greenhouse temperatures.

Botanical gardens (BG) in Nepal

- a) Brindavan Botanical Garden, Hetauda
- b) Devariya Botanical Garden, Kailali
- c) Dhanushadham Botanical Garden, Janakpur
- d) Dhitachaur Botanical Garden, Jumla
- e) Daman Botanical Garden, Makwanpur
- f) Dhakeri Botanical Garden, Banke
- g) Mai pokhari Botanical Garden, Ilam
- h) Mulpani Botanical Garden, Salyan
- i) National Botanical Garden, Godawari
- j) Tistung Botanical Garden, Makwanpur
- k) World peace Botanical Garden, Pokhara



Fig: 5.1.3 National botanical garden, Godawari, Lalitpur

SEED BANK (*EX-SITU* CONSERVATION)

A seed bank or germplasm bank is a location where specific conditions are upheld to safeguard seeds from various plant species, whether they are wild or cultivated. The main goal is straightforward: to secure the long-term preservation of a wide variety of plants for future generations.

Originally, they were created for important food crops, but now they also store seeds of many endangered wild plants. These seeds can stay dormant for thousands of years if kept at a low temperature (below -5°C) and humidity.

They include major crop plants such as cereals, soyabean, cotton and many vegetable species. A challenge in a seed bank is making sure the seeds stay alive. Periodic tests are conducted on seed samples to check their ability to sprout. If the germination capability drops below an acceptable level, around 85%, new seeds are produced by growing the stored seeds and then harvesting them for storage.

The importance of seed bank

The undeniable and significant threat of species extinction, caused by both natural factors and human activities, poses a serious risk to our planet. Once a species disappears, it is lost forever. Seed banks play a crucial role in addressing this threat, particularly for plants. They are integral to a strong seed system that ensures food security.

1. The importance of seed banks includes preserving the genes necessary for plant breeders to enhance crop yield, disease resistance, drought tolerance, nutritional quality, and more.
2. Additionally, seed banks help prevent the loss of genetic diversity in rare plant species, contributing to the conservation of biodiversity outside their natural habitats (*ex-situ*).

5.1.4 NATURAL ENVIRONMENT: VEGETATION AND HUMAN ACTIVITIES

The natural environment is everything around us that happens without human influence. It includes plants, animals, soil, rocks, air, and natural events. The place we live in, called the ecosystem, provides important services for us and other living things, like clean air and water. However, humans are affecting the environment a lot by things like too many people, pollution, using too much of certain resources, and cutting down too many trees. These changes are causing problems like climate change, soil erosion, bad air, and a shortage of clean water.

People's actions, like building cities, farming, putting up factories, and constructing things, have a big impact on the plants that grow in an area. These human activities change how plants are spread out in different places.

DEFORESTATION

Cutting down a lot of trees, known as deforestation, is a significant human activity that has a big effect on plants. This happens when forests lose their trees. It causes problems like soil erosion and brings negative changes to the entire environment. Right now, about 100 thousand hectares of forests are getting cut down each year. If we keep doing this, Nepal might have no forests left in about 20-25 years.

CAUSES OF DEFORESTATION

1. The escalation of human and livestock populations has intensified the demand for food, space, and natural resources derived from forests.
2. The heightened need for timber and fuel wood has led to the degradation of numerous areas, with an estimated annual destruction of approximately 1000 square km of forest land for fuel wood purposes.
3. Overgrazing of forest trees by domesticated animals has further exacerbated the impact on vegetation.
4. Agricultural expansion is encroaching upon forested areas, resulting in the displacement of natural woodland.

5. Deforestation is driven by infrastructure development such as road construction, dam projects, urbanization, and mining activities.

HAZARDS OF DEFORESTATION

Forests are really important for the environment. When we cut down too many trees (deforestation), it can lead to several problems:

1. Deforestation makes soil erosion worse, and a lot of soil (about 240 million cubic meters) gets washed away every year in Nepal.
2. Good soil with important nutrients is lost due to erosion, making the land less productive and fertile.
3. It messes up the climate, the balance of oxygen and carbon dioxide, and even rainfall. This harms the environment.
4. Animals lose their homes because of the loss of forest trees.
5. Deforestation and soil erosion can cause floods and landslides to happen more often.
6. There's less wood, herbs, and other forest products because of deforestation. This shortage affects people and industries that rely on these products, causing problems for the economy of Nepal.

FOREST CONSERVATION OR FOREST MANAGEMENT

There are different ways to protect and take care of the forests:

1. Afforestation or Reforestation: Planting new trees, both by the government and local communities, on a larger scale can help.
2. Community Forests: Local communities manage and look after these forests to meet their own needs.
3. Private Forests: People who own land are encouraged to plant trees on their property, and they get help and resources to do it.
4. Modern Pest Control Techniques: Using new methods to control pests helps save the forest without disturbing the natural balance.
5. Agroforestry: Growing trees along with crops on less productive farmland.
6. Strip Plantation: Planting trees along roads, canals, and rail lines.
7. Alternative Energy Sources: Using different sources of energy instead of cutting down trees.
8. Herbal Farming: Growing more herbs to meet the demand.
9. Public Awareness Programs: Teaching people about the importance of forests.

EXERCISE

A. Tick the correct alternatives:

1. What does the term "vegetation" refer to in a general sense?
 - a. Animal life
 - b. Plant life
 - c. Soil composition
 - d. Atmospheric conditions
2. Why cultivated crops and fruits are not considered part of natural vegetation?
 - a. They are too small
 - b. They are not found in Nepal
 - c. They require human intervention
 - d. They are not useful for wildlife habitat
3. At what altitude range does the Temperate Coniferous Evergreen Forest grow in Nepal?
 - a. 1000 to 2000 m
 - b. 2000 to 3000 m
 - c. 3000 to 4000 m
 - d. 4000 to 5000 m
4. What is the primary goal of *In-situ* conservation, such as national parks in Nepal?
 - a. To promote agriculture
 - b. To protect endangered species in their natural habitats
 - c. To facilitate botanical research
 - d. To establish zoological gardens
5. According to the joint survey conducted between 2067 to 2071 BS, what percentage of Nepal's landmass is covered by forests?
 - a. 29.83%
 - b. 44%
 - c. 39.1%
 - d. 12.1%
6. How does deforestation contribute to soil erosion?
 - a. By promoting soil fertility
 - b. By decreasing overland flow
 - c. By enhancing water infiltration
 - d. By worsening soil erosion
7. What is the primary purpose of botanical gardens in Nepal?
 - a. To cultivate crops
 - b. To serve as wildlife reserves
 - c. To preserve genes of endangered species
 - d. To provide timber resources
8. What is the primary role of seed banks in preserving plant species?
 - a. To promote seed production
 - b. To ensure a constant supply of herbs
 - c. To safeguard seeds outside their natural habitats
 - d. To facilitate soil erosion

9. How does deforestation affect the climate?
 - a. It has no impact on climate
 - b. It improves rainfall patterns
 - c. It leads to ecological imbalances
 - d. It enhances oxygen levels
10. Which conservation method involves growing trees along with crops on less productive farmland?
 - a. Afforestation
 - b. Community Forests
 - c. Agroforestry
 - d. Modern Pest Control Techniques

B. Answer the following questions:

1. Define vegetation. Write one essential role of vegetation in the biosphere.
2. What is the altitude range of Alpine Vegetation in Nepal?
3. What is the main influence on the natural vegetation in Nepal?
4. What role does vegetation play in erosion control?
5. What is the primary goal of *In-situ* conservation?
6. Which bio-climatic zone in Nepal is characterized by Subtropical Forest?
7. What is the significance of protected areas in Nepal for biodiversity?
8. Describe the importance of vegetation in influencing soil characteristics.
9. List and briefly describe the types of natural vegetation in Nepal based on altitude.
10. Discuss the economic importance of vegetation in relation to the world economy.
11. Describe two types of conservation methods.
12. Briefly explain the importance of botanical gardens.
13. Differentiate between *in-situ* and *ex-situ* conservation of biodiversity.
14. Explain the concept of seed banks and their importance.
15. What is deforestation? Describe the causes, consequences of deforestation in the context of Nepal and suggest possible mitigating measures.

Project Work

1. Prepare a research-based report on national and international efforts on nature conservation. Use trustworthy online sources, news articles, and magazines to discover how our world is being protected. And present in your class to inspire each other.
2. Plan a field trip together to visit a nearby botanical garden or seed bank (if there's one nearby). During the trip, observe and learn about ex-situ conservation efforts firsthand. Pay close attention to how plants' genetic resources are collected, preserved, and used to conserve biodiversity and promote sustainable agriculture.

Unit

6

Introduction to Biology



Aristotle
(384-322)

Aristotle was a renowned ancient Greek philosopher who dedicated himself to unraveling life's mysteries, becoming the first genuine scientist in history. Aristotle's pioneering contributions spanned philosophy and science, where he introduced formal logic and delineated the relationships between various scientific disciplines. Aristotle's groundbreaking works include animals' classification (in book "History of Animals"), binomial nomenclature. His profound impact on science endures, making him a revered figure in human history.

Chapter 6.1

INTRODUCTION to BIOLOGY

Discuss the following questions:

- i. Why did early scientists find the study of life so intriguing, leading to the creation of biology?
- ii. What makes biology important in our daily lives?
- iii. How has our knowledge of living things influenced fields like medicine and agriculture?
- iv. How does biology contribute to solving global challenges?
- v. Can we understand biology without knowledge of other branches of science?

6.1.1 GENERAL INTRODUCTION

We are accompanied by plenty of living creatures found on the earth. Many of them are harmless and useful while some are harmful. There is a science that studies all forms of such lives known as biology (Greek: '*bios*' – life, '*logos*' - knowledge). Thus, it is also known as life science.

The major contributions in the development of biology were made by Hippocrates (460-320 BC), Aristotle (384 - 322 BC), Theophrastus (370 - 285 BC), Robert Hooke (1635 - 1703 AD), Carolus Linnaeus (1707 - 1778 AD), Charles Darwin (1809 - 1882 AD), Gregor John Mendel (1822 - 1884 AD) and many other biologists.

Do you know?

- The term 'Biology' was coined by **Lamarck** and **Treviranus** (1802).
- The father of biology is **Aristotle**.
- The father of zoology is **Aristotle**.
- The father of botany is **Theophrastus**.
- The father of medicine is **Hippocrates**.

The three main branches of biology which deal with the different aspects of living science are:

1. **Botany** (Greek: '*botanē*' = herbs, '*logos*' - knowledge/study) - It is the branch of biology that deals with the study of plants.
2. **Zoology** (Greek: '*zōion*' = animal, '*logos*' - knowledge/study) - It is the branch of biology that studies about animals.
3. **Microbiology** (Greek '*mikros*' - small or slight, '*logos*' - knowledge/study) – It is the branch of biology that studies tiny living creatures that cannot be observed by our naked eyes.

6.1.2 BRANCHES OF BIOLOGY

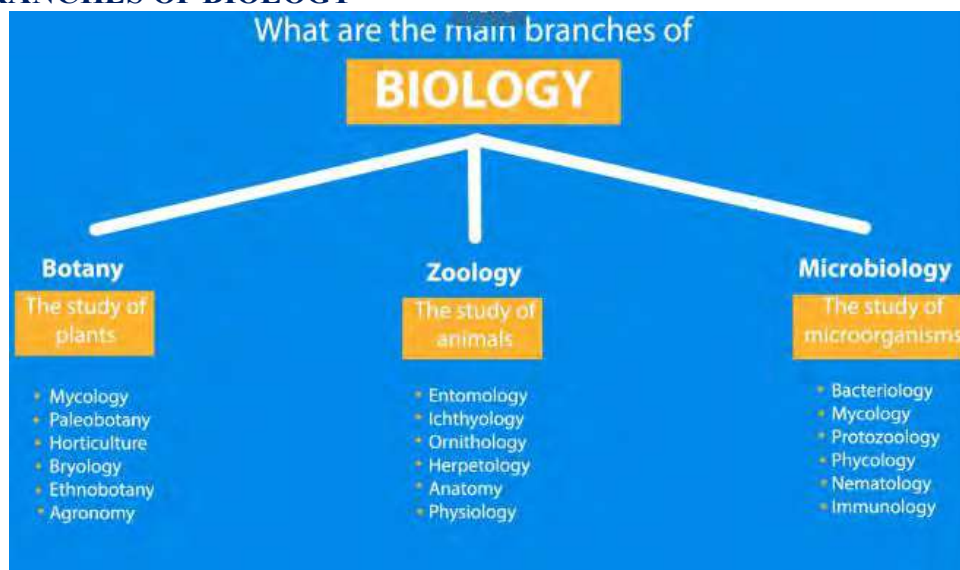


Figure 6.1 Branches of Biology

Table 6.1 Branches of Biology

Name of the branches	Deals with the study of
Anatomy	internal structures of organisms
Physiology	functions and processes that occur within living organisms
Morphology	external features of organisms
Paleontology	Fossils of organisms
Ethnobiology	combination of biology and anthropology
Cytology	structure and functions of cells and cell organelles
Histology	structure and functions of tissues
Embryology	formation and development of embryo
Genetics	hereditary characters and their inheritance
Evolution	changes in organisms in the course of time
Ecology	relationship between living organisms and environment
Taxonomy	identification, nomenclature and classification of organisms
Biochemistry	chemistry of living organisms
Biotechnology	technique to modify organisms and their products for human benefit
Genetic engineering	producing desirable genotypes by the combination of different genes
Limnology	freshwater and their inhabitants
Karyology	nucleus
Biogeography	geographical factors influencing the distribution of organisms

Branches of Zoology

Table 6.2 Branches of Zoology

Name of the branches	Deals with the study of
Entomology	insects
Ichthyology	fishes
Ornithology	birds
Herpetology	reptiles
Protozoology	protozoans (unicellular organisms)
Parazology	porifera or sponges
Cnidology	coelenterates
Helminthology	helminth worms
Araeneology	spiders
Aphidology	aphids
Malacology	mollusks
Ichthyology	fishes
Batreology	frogs
Ophiology	snakes
Saurology	lizards
Mammalogy	mammals
Anthropology	human evolution and their culture
Euthenics	development of human race through laws of heredity
Ethology	animal nature or behavior of animals

Branches of Botany

Table 6.3 Branches of Botany

Name of the branches	Deals with the study of
Bacteriology	bacteria
Virology	virus
Phycology	algae
Mycology	fungi
Bryology	bryophytes
Pteridology	pteridophytes
Pomology	fruits and fruit yielding plants
Anthology	flowers
Floriculture	cultivation of plants for flowers
Horticulture	art of cultivating fruits, vegetables, ornamental plants, etc.
Agronomy	agriculture focusing on the practice of crop production and soil management

Branches of Zoology Related to the Medical Science

Table 6.4 Branches of Zoology related to Medical science

Name of the branches	Deals with the study of
Epidemiology	epidemic diseases
Immunology	defense and resistance against diseases
Helminthology	helminthic parasites
Parasitology	parasites
Enzymology	enzymes
Cardiology	heart
Hematology	blood
Osteology	bones
Endocrinology	endocrine glands and hormones
Nephrology	kidney and its functions
Neurology	brain and nerve functions
Pathology	diseases caused by organisms

6.1.3 RELATION OF BIOLOGY WITH OTHER SCIENCE

The exploration of life science involves knowledge of other basic sciences like Physics and Chemistry. The combination of these disciplines contributes to a comprehensive perspective.

Relation with Chemistry

The physiological processes of plants and animals are intricately linked with chemical reactions. Biochemistry, situated at the intersection of Biology and Chemistry, is the discipline that addresses this intersection. Biology is related with Chemistry, because of the following reasons:

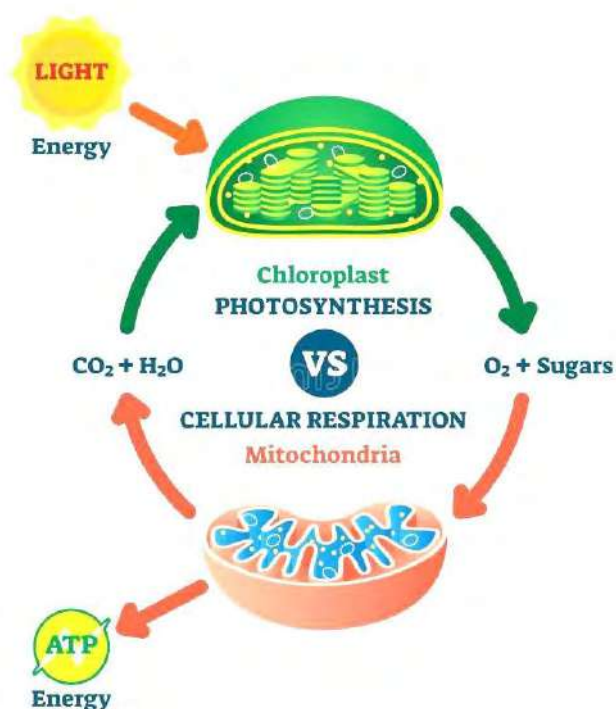


Figure 6.2 Photosynthesis vs. Cellular respiration

- Living organisms contain both organic and inorganic compounds, which play a crucial role in shaping various life processes.
- Energy is transferred within the body through organic chemicals like glucose.
- Chemical changes are integral to metabolic pathways, including photosynthesis, respiration, and metabolism.
- Genetic materials such as DNA and RNA are composed of chemicals.
- Enzymes and hormones secreted in animals are exclusively chemical in nature.

Relation with Physics

Biology is related with the Physics, because of the following reasons:

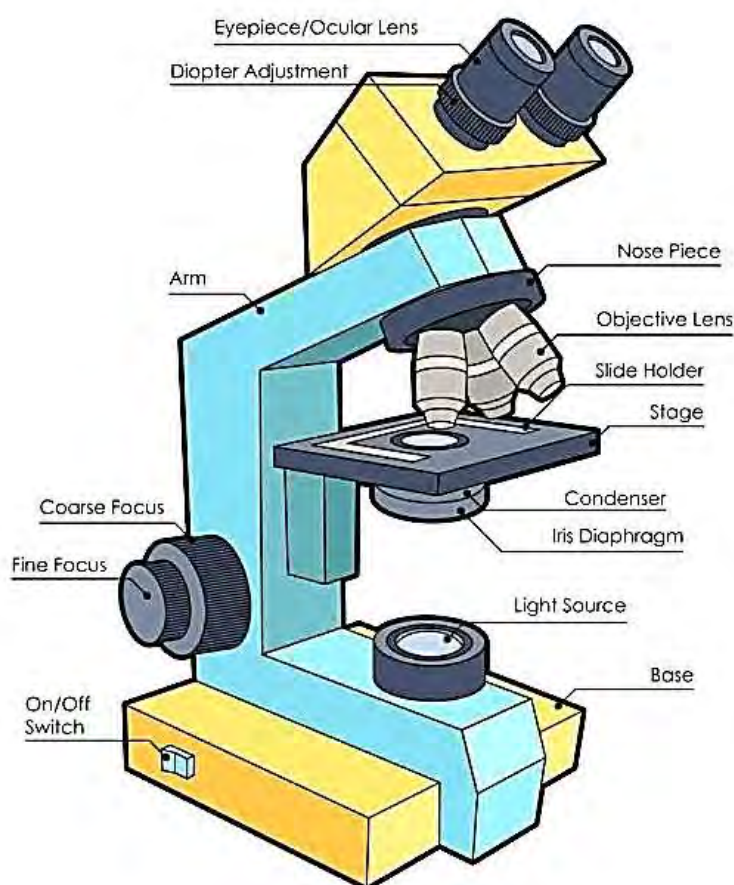


Figure 6.3 Compound Microscope

- Some life processes such as sap movement, diffusion, mineral transport, etc. rely on physical phenomena.
- Many tools in biology, such as microscopes, chromatography, X-ray diffraction, etc. use physical principles.
- The physiological activities of plants depend on factors like light intensity and energy.
- Working of eyes is based on the principle of optics.

Relation with Geography

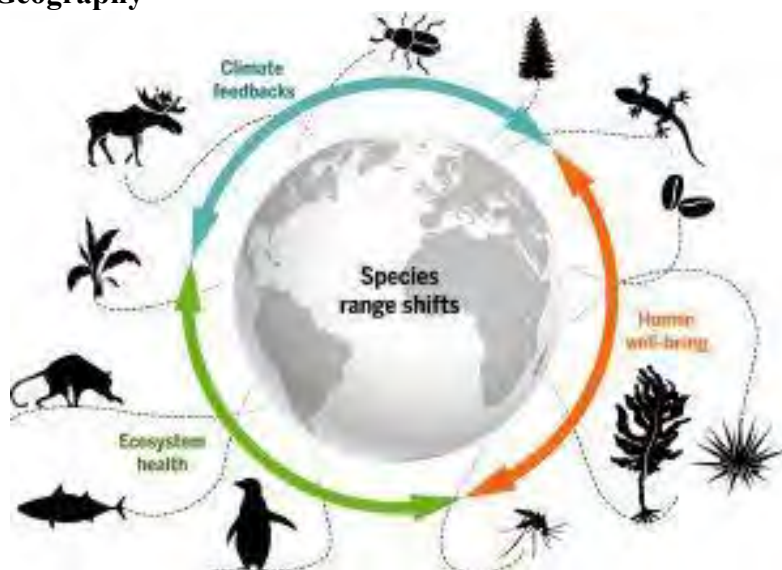


Figure 6.4 Relation of Biology with Geography

The distribution of animals, plants is influenced by various geographical factors like altitude, temperature, climate, landscape, and more in different locations and evolutionary history. Understanding biogeography helps explain why certain species are found in specific regions and how they have evolved and dispersed over time.

Relation with Mathematics

Biology and mathematics are connected because data obtained from research works can be analyzed using statistical tools. The relationship between biology with statistics, and mathematics is called biostatistics and biometrics. Biology is related with Mathematic, because of the following reasons:

- Mathematics is used in biology for analyzing data and modeling biological systems.
- Statistical analysis is important to interpret experimental results and draw conclusions in fields like genetics and ecology.
- Mathematical models are used to describe population growth, gene frequencies, and ecological interactions.

Relation with Sociology

Sociology is the study of society, social relationships, and social behavior. Sociologists seek to understand social processes, structures, and issues by analyzing social interactions, cultural norms, and societal changes. Biology is related to sociology as animals live in social groups. The relation with sociology includes:

- Animal behavior depends on social interactions.
- Many animals follow social patterns and customs, showing their social nature.
- Biological and medical research includes sociological insights to ensure ethical practices.
- Studying human behavior and social systems involves understanding biological principles.
- Sociobiologists and social scientists use biology to explain social behaviors and relationships.

Activity 6.1

Design a poster showing different branches and scopes of biology and discuss in your class.

6.1.4 SCOPES OF BIOLOGY



Figure 6.5 Scopes of Biology

Biology is very important as it helps us to understand nature and living things and adjust to our surroundings. Its application extends far beyond basic scientific research, impacting crucial sectors like health, genetics, nursing, agriculture, environmental science, and conservation. The diverse scopes of biology underscore its importance in addressing societal challenges and advancing technological innovations that benefit both humans and the environment. Some important scopes of biology can be discussed under following heads:

1. In the Field of Health, Disease and Medicine:

Biology provides essential knowledge for understanding human health, disease mechanisms, and developing medical treatments. It helps to maintain health and control epidemic diseases, offering insights into controlling and curing diseases transmitted by parasites like *Anopheles* (malaria), sandfly (kala-azar), *Tse-tse* (sleeping sickness), and housefly (typhoid). Advancements in medical technology often involve testing drugs and vaccines on animals.



Figure 6.6 Vaccine

2. In the Field of agriculture:

Agriculture is a part of applied biology. The development of hybrid plants through biological knowledge has significantly increased agricultural productivity and resilience. Understanding biology helps to know the economic importance of various organisms in croplands ecosystem such as earthworms improve fertility and porosity of soil which is beneficial for plants. Similarly, insects like bees help pollinate flowers, bacteria break down dead animals and plants, enriching the soil with nutrients that plants absorb. Various pests destruct our cultivated crops. Biological knowledge aids in developing integrated pest

control strategies. Similarly, biology provides knowledge on soil microbiology, soil ecology, sustainable agriculture or developing good agricultural practices.

3. In the Field of Industry:



Figure 6.7 Apiculture

Various biological products like foods, antibiotics, medicinal herbs, coral, pearl, honey, wax, silk, lac, turtle shell, bones, feathers, tusks, leather, and fur are in high demand. Biological knowledge of producing these items can help increase their availability.

4. In the Field of Forestry:



Biology is pivotal in forestry, aiding our understanding and management of forests and wildlife. Forest ecology delves into how organisms interact with their environment, crucial for wildlife habitats. Recognizing floral diversity is key for preserving plant species vital for wildlife. Microbiology uncovers how microorganisms support soil health, benefiting both forests and wildlife. Conservation biology ensures sustainable practices, safeguarding wildlife habitats within forests. These biology scopes empower foresters to protect forests and wildlife, benefiting ecosystems and human communities alike.

EXERCISE

A. Tick the correct alternative.

- Which of the following broadly describes biology?
 - Macrobiology
 - Biotechnology
 - Biochemistry
 - Life Science
- Why is biochemistry considered at the intersection of Biology and Chemistry?
 - It studies the geological aspects of living organisms.
 - It explores the relationship between animals and their environments.
 - It addresses the chemical processes within living organisms.
 - It focuses on the classification of different species.
- What is the study of plants called in biology?
 - Zoology
 - Botany
 - Microbiology
 - Biotechnology
- Which branch of biology does ichthyology deal with?
 - fruit
 - heart
 - disease
 - fish
- Why do biologists focus on finding solutions to challenges such as radiation dangers and hunger?
 - To control the population increase.
 - To understand the origin of life.
 - To address environmental pollution.
 - To enhance human well-being and solve global issues.
- Which branch of zoology focuses on the study of insects?
 - Ichthyology
 - Ornithology
 - Entomology
 - Anthropology
- If a scientist is studying the internal structures of plants, which branch of biology are they likely specializing in?
 - Morphology
 - Anatomy
 - Physiology
 - Histology
- Which branch of biology involves the study of geographical factors influencing the distribution of organisms?
 - Bioinformatics
 - Biogeography
 - Biostatistics
 - Biometrics
- What field of biology is associated with the study of health and disease control?
 - Biotechnology
 - Paleontology
 - Microbiology
 - Epidemiology

10. Which tool mentioned in biology relies on physical principles?
 - a. X-ray diffraction
 - b. DNA sequencing
 - c. Gene editing
 - d. Microarray analysis
11. Which area of agriculture involves the role of earthworms in soil improvement?
 - a. Apiculture
 - b. Horticulture
 - c. Agronomy
 - d. Vermiculture

B. Answer the following questions.

1. Define biology and describe its scopes.
2. Describe how biology is related to chemistry.
3. Explain one way in which biology is connected to physics.
4. How does geography influence the distribution of plants and animals?
5. What role does mathematics play in biology?
6. Discuss one important scope of biology related to agriculture.
7. Biology is an interdisciplinary subject that cannot be studied alone. Justify the statement with relevant examples.
8. List and briefly explain three major branches of biology, outlining what each branch focuses on.
9. Explain the difference between anatomy and physiology in biology.
10. What does the branch of ecology study, and why is it important?
11. How does biology contribute to the protection of forests and wildlife?
12. Write a brief overview on the scope of biology, highlighting its diverse areas of study and applications.
13. Match the branches of biology listed in Column A with their corresponding descriptions or focuses listed in Column B. Choose the correct answer from the list of options provided.

A	B
Ecology	Study of plant life and organisms
Genetics	Investigates heredity and variation in organisms
Microbiology	Focuses on the function and mechanisms of living organisms
Physiology	Study of interactions between organisms and their environment
Botany	Examines microorganisms like bacteria, viruses, and fungi
	Study of parasites

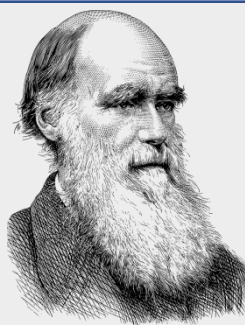
Project work:

Collaborate in your team to explore various branches of biology with their applications through research and prepare a power point presentation. Present the findings to the class.

Unit

7

Evolutionary Biology



Charles
Darwin
(1809-1882)

Charles Darwin (1809-1882), a renowned English naturalist, left an indelible mark on the scientific world through his pioneering theory of evolution by natural selection. His groundbreaking book, "*On the Origin of Species*" (1859), revolutionized biology by proposing that species adapt and evolve over time, driven by natural selection favoring advantageous traits. Additionally, his publication "*The Descent of Man*" (1871) extended these ideas to human evolution, solidifying his contributions as a cornerstone of modern biology.

Chapter 7.1

LIFE AND IT'S ORIGIN

Discuss the following questions:

- i. Was primitive Earth livable?
- ii. Have you ever wondered how the first life originated on Earth?
- iii. Do you think living organisms change over a long period of time?
- iv. How did human beings evolve to present day forms?
- v. What could be the causes for the drastic variation in organisms?

7.1.1 ORIGIN OF EARTH AND PRIMITIVE ATMOSPHERE

Scientists believe that our planet, Earth, came into existence approximately four and a half billion years ago. During its formation, the entire solar system emerged from the condensation of cosmic dust and gases (According to *Dust and cloud hypothesis*). At its birth, it was incredibly hot that everything existed as gases, making it impossible for any form of life to exist.

Due to the extreme temperature, elements existed as individual atoms. Intense heat broke the bonds apart quickly and atoms couldn't bond together. These elements included carbon, silicon, oxygen, sulphur, chlorine, phosphorus, sodium, calcium, potassium, and iron.

Over time, Earth gradually cooled down, taking about 100 million years to transition into a molten core. During this cooling process, the elements began to separate based on their density, forming distinct layers within the Earth:

- i. The heaviest elements, like iron (Fe), nickel (Ni), zinc (Zn), and sodium (Na), sank to the very centre, forming the Earth's core.
- ii. Lighter elements, such as aluminium (Al), silicon (Si), phosphorus (P), and sulphur (S), flowed to create the mantle and crust of Earth.
- iii. The lightest elements, like helium (He), hydrogen (H), oxygen (O), nitrogen (N), and carbon (C), remained closer to the surface forming atmosphere.

7.1.2 ORIGIN OF LIFE

The origin and history of life on Earth have led to various theories over time. Some of the theories are discussed below:

1. **Theory of special creation:** It suggests that all living beings, including plants and animals, were created by a supernatural power or God.
2. **Cosmozoic theory (Interplanetary/Panspermia):** The theory was proposed by Richter (1865) and it suggests that life might have arrived on the Earth via meteorites from another planet in the form of spores, also known as theory of Panspermia.

3. **Theory of spontaneous generation (Abiogenesis):** It suggests that living organisms were thought to have originated from inanimate matter such as toad frog snake arose from mud, sweat gave rise to parasites, plant juice gave rise to aphids etc.
4. **Theory of biogenesis:** This theory claims that life originated from preexisting life. Scientists like **Lazzaro Spallanzani (1729–1799)**, **Francesco Redi (1621-1697)** and **Louis Pasteur** conducted many experiments to support this idea.

Pasteur sterilized a flask containing hay infusion/broth by boiling it and closed the flask with a swan-necked tube. The experiment was left for 18 months. He didn't find any tiny life forms inside. But when he opened the flask by breaking its neck, tiny life forms quickly appeared. From this, he thought that these tiny life forms didn't come from the hay infusion itself but came from the air around it.

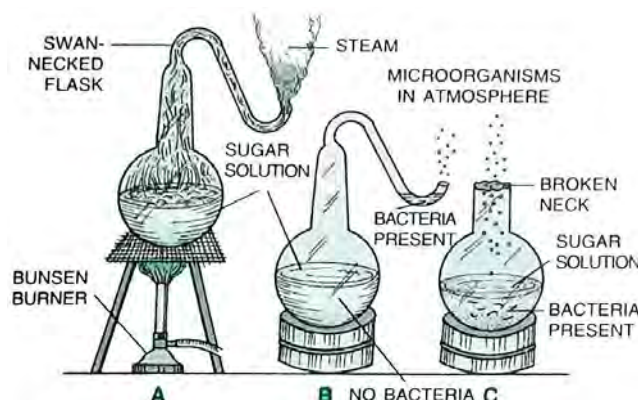


Figure: 7.1.1 Louis Pasteur's experiment to refute Abiogenesis

7.1.4 THEORY OF BIOCHEMICAL ORIGIN OF LIFE (*Oparin-Haldane Theory*)

This is the modern and widely accepted explanation for how life began. Russian scientist Alexander Ivanovich Oparin proposed it in 1923. It was further supported by J. B. S. Haldane in 1929. They believed that life spontaneously started from nonliving substances in Earth's ancient oceans around 3.3 billion years ago.

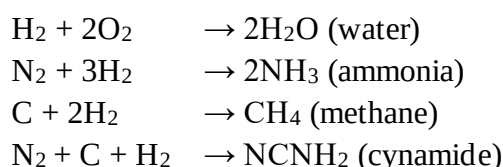
This theory can be studied under following headings:

- A. **Chemogeny**
- B. **Biogeny**
- C. **Cognogeny**

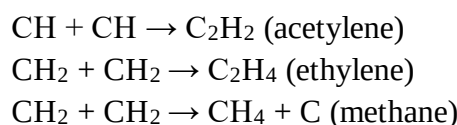
A. CHEMOGENY

It is the formation of complex organic molecules from simpler inorganic molecules in the oceans by chemical reactions. Following are the steps involved in the synthesis of complex organic molecules:

- i. **Formation of water, ammonia, methane, and cyanide:** In the early days of Earth, elements like carbon, hydrogen, nitrogen, and oxygen (not in free states) were abundant, but they were in a gaseous state due to the high temperatures. As the Earth's surface cooled down over time, these elements began to combine with each other, eventually forming important molecules such as water, ammonia, methane, and cyanamide. These molecules played a crucial role in the origin of life on Earth.



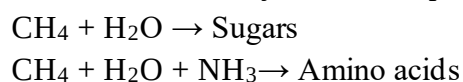
- ii. **Formation of Hydrocarbons:** As the Earth's surface cooled to around 100°C or lower, highly reactive free radicals CH and CH₂ combined to create various types of hydrocarbons like acetylene, ethylene, methane. Meanwhile, liquefaction and solidification of gases occurred to form water that precipitated on Earth's surface forming ocean supporting further chemical reactions.



- iii. **Formation of Oxy- and Hydroxyl Derivatives of hydrocarbons:** These hydrocarbons reacted with superheated steam, forming molecules like aldehydes and ketones.



- iv. **Formation of Carbohydrates, Amino Acids, and Fatty Acids:** Through processes like condensation, polymerization, oxidation, and reduction, complex molecules like simple sugars, amino acids, and fatty acids were produced.



- v. **Formation of Purines, Pyrimidines, and Nucleotides:** These molecules further reacted and aggregated in hot water to form new complex organic compounds, such as purines, pyrimidines, and nucleotides.

Energy for these reactions came from ultraviolet (UV) radiation (from the sun), electrical energy (from lightning), and heat energy (from volcanoes) and the high temperature of the primitive Earth.

These reactions were believed to have occurred in hot seawater, which was rich in primary organic compounds. This marine environment is often described as the "**hot dilute soup/primordial soup/prebiotic soup**" by *Haldane*. Notably, the early Earth's atmosphere lacked free oxygen – thus was reducing in nature.

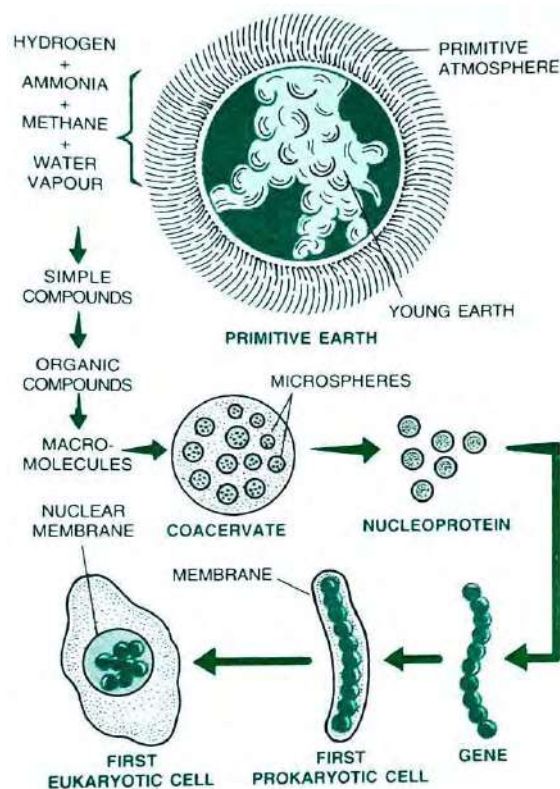


Figure: 7.1.2 Origin of life according to biochemical origin of life

B. BIOGENY

This phase involves the formation of complex, self-reproducing biological molecules from complex organic molecules in three distinct phases.

- 1. Formation of Nucleic Acids:** It is believed that sugars, phosphates, purines, and pyrimidines combined to create nucleotides. These nucleotides then joined together to form nucleic acids like DNA and RNA. This event marked a significant step in the origin of life since nucleic acids could replicate themselves, indicating the beginning of life.
- 2. Formation of Coacervates:** Nucleic acids and other macromolecules bounded by water in the primitive ocean formed colloidal structures known as coacervates. These coacervates consisted of nucleic acids and enzymatic proteins, called nucleo-proteins, with the ability to self-duplicate. They acted as intermediaries between molecules and living organisms.
- 3. Formation of Primary Organisms:** Coacervates absorbed organic materials from the oceanic soup and started replicating. They grew in size and number, creating anaerobic chemoheterotrophs, *proto-cells*, or the *first cells*. Oparin referred to them as *protobionts* or *ebionts*. These first cells eventually gave rise to prokaryotic cells such as bacteria, cyanobacteria, and blue-green algae.

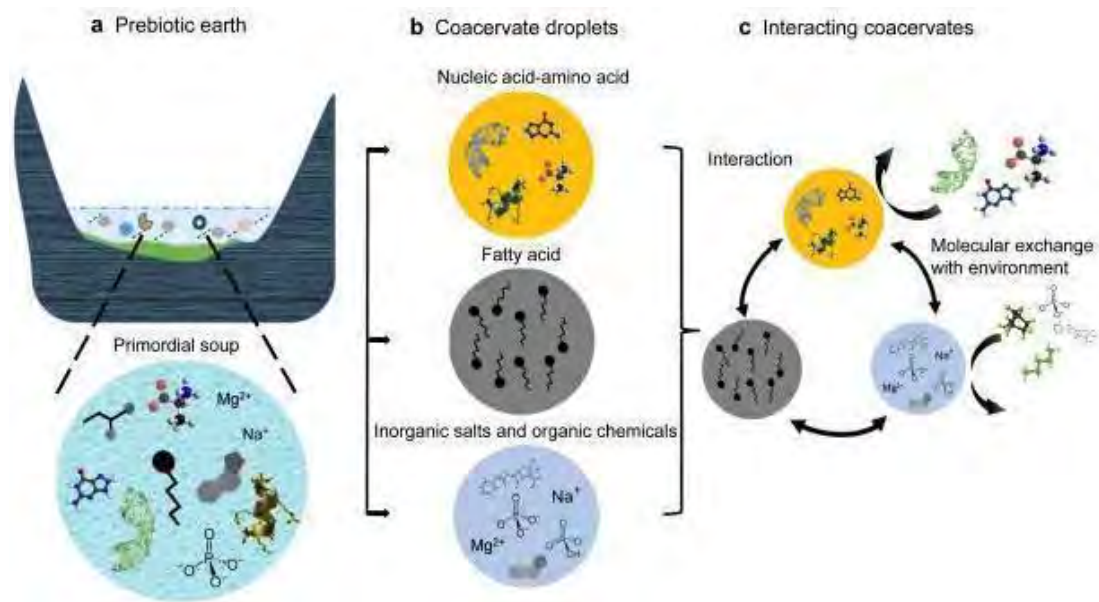


Figure: 7.1.3 Coacervate

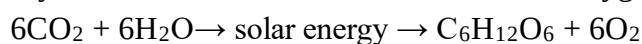
C. COGNOGENY

This phase involved the diversification and differentiation of simple life into protozoa, metazoa, and metaphyta. Due to shortage of food and space in the sea, these organisms adapted to different feeding habits and became parasitic, saprophytic, chemosynthetic, or photosynthetic.

- 1. Origin of Autotrophs:** As the number of anaerobic heterotrophs in the ocean increased, they consumed organic nutrients, leading to a shortage of natural food sources. In response, some prokaryotes developed enzymes to synthesize simple carbohydrates from inorganic substances, initiating **chemoautotrophism**. Sulphur bacteria, nitrifying bacteria, etc. performed this type of nutrition. This sequence of events marked the progression from simple molecules to the emergence of autotrophic life forms.



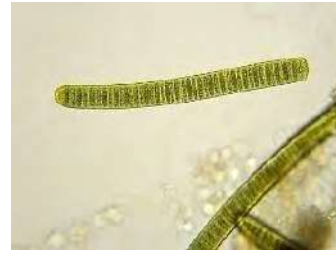
In the meantime, some prokaryotes developed bacteriochlorophyll from Mg and Porphyrin of the ocean water. Bacteriochlorophyll underwent further molecular changes to form chlorophyll. This enabled them to turn inorganic compounds into carbohydrates by capturing solar energy. This process is known as **photoautotrophism** that evolved autotrophs. Cyanobacteria are considered to be the first oxygen-producing aerobic bacteria.



(b)



(a)



(c)

Figure: 7.1.4 Cyanobacteria (a) in pond, (b) photoautotrophic (c) under microscope

ii. Origin of Eukaryotes

Cyanobacteria or blue-green algae like algae at that time played a crucial role in introducing oxygen into Earth's atmosphere through photosynthesis. This transformed the primitive atmosphere, which lacked oxygen, into an atmosphere with abundant oxygen (oxidizing atmosphere). The prokaryotes developed true nucleus and membrane bound cell organelles and transformed into eukaryotes. This change also led to the development of aerobic respiration and the formation of the ozone layer. The presence of free oxygen and the ozone layer allowed life to transition from water to land.

The unicellular eukaryotes evolved into multicellular eukaryotes over the course of time with increased complexity.

7.1.5 Miller-Urey EXPERIMENT

In 1953, *Stanley L. Miller* and Professor *Harold C. Urey* conducted an experiment that supported *Alexander Oparin's* biochemical concept for the origin of life. They recreated conditions resembling early Earth in their laboratory.

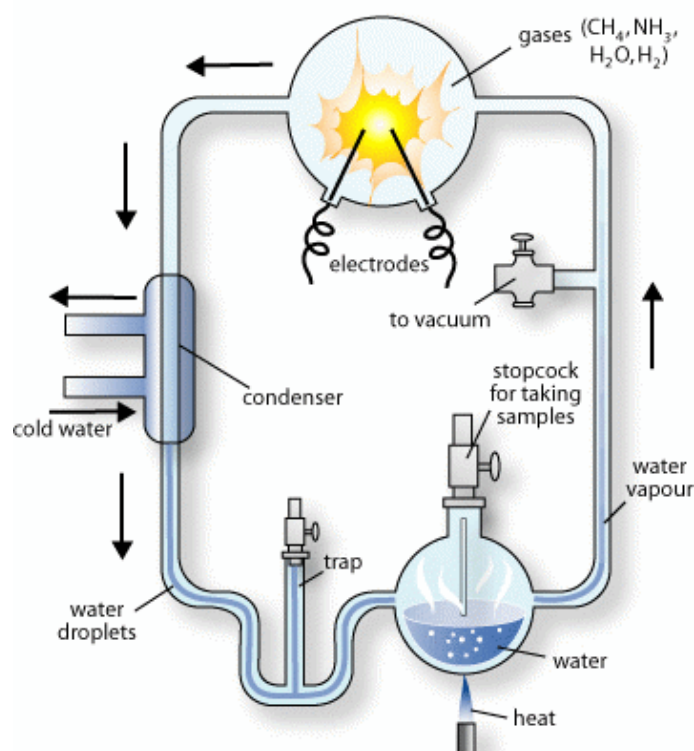


Figure: 7.1.5 Miller-Urey Experiment

Experiment

- The apparatus was constructed using glass tubes and a flask, as shown in the figure. The apparatus consisted of two glass chambers: a water chamber and a gas chamber.
- The water in the flask was heated to generate steam, facilitating the circulation of water vapour within the chambers.
- The gas chamber contained a mixture of gases—hydrogen, methane, and ammonia in the proportion of 2:2:1.
- Energy was introduced into the closed chamber through heating, electric discharge from electrodes, and UV radiation.
- A condenser was used to cool the resulting mixture. The entire setup was operational for a week.

Observation

The products condensed and gathered within a designated chamber.

Result

The obtained products contained numerous organic compounds like amino acids (glycine, alanine, aspartic acid, etc.), aldehydes, simple sugars, ribose, etc.

Conclusion

The chemical reactions utilized the energy from electric sparks and led to the formation of amino acids and other organic compounds. This supports *Oparin's* idea about the origin of life.

Do You Know?

About three billion years ago (Cambrian period) there were flat rock formations made by layers of microorganisms, like bacteria and algae, in shallow water like coastal areas or

ancient seabeds. These formations, known as stromatolites, are one of the oldest forms of life on Earth. The microorganisms trap and bind sediments (like sand and mud) to form these layers. Over time, minerals in the water stick to these layers, making them hard and rock-like.

Scientists believe they might hold clues about how life started on Earth.



Shark Bay, Western Australia



Stromatolite

EXERCISE

A. Tick the correct alternative.

- a) Which elements formed the Earth's core according to the Dust and cloud hypothesis?
 - a. Aluminium, silicon, phosphorus, sulphur
 - b. Iron, nickel, zinc, sodium
 - c. Helium, hydrogen, oxygen, nitrogen
 - d. Carbon, silicon, oxygen, sulphur
2. According to the Theory of biogenesis, where did life originate from?
 - a. Supernatural power
 - b. Inanimate matter
 - c. Pre-existing life
 - d. Another planet
3. Which theory is widely accepted as the modern explanation for the origin of life on Earth?
 - a. Theory of special creation
 - b. Theory of spontaneous generation
 - c. Theory of cosmogeny
 - d. Theory of biochemical origin of life
4. During which phase of the origin of life does the formation of complex organic molecules from simpler inorganic molecules primarily occur?
 - a. Chemogeny
 - b. Biogeny
 - c. Cognogeny
 - d. Photosynthesis
5. What is the main source of energy for the chemical reactions involved in the formation of complex organic molecules during chemogeny?
 - a. Geothermal heat

- b. Solar radiation
 - c. Volcanic eruptions
 - d. Atmospheric pressure
6. In which phase of the origin of life do nucleic acids like DNA and RNA first form?
- a. Chemogeny
 - b. Biogeny
 - c. Cognogeny
 - d. Photosynthesis
7. What process enabled the transition of simple molecules to autotrophic life forms during the origin of life?
- a. Chemosynthesis
 - b. Photosynthesis
 - c. Oxidative phosphorylation
 - d. Fermentation
8. Which gases were used in the Miller-Urey experiment to simulate the atmosphere of early Earth?
- a. Oxygen, nitrogen, carbon dioxide
 - b. Hydrogen, methane, ammonia
 - c. Helium, argon, neon
 - d. Carbon monoxide, sulfur dioxide, nitrogen dioxide
9. What was the main observation from the Miller-Urey experiment?
- a. Formation of rocks
 - b. Production of metals
 - c. Synthesis of organic compounds
 - d. Generation of volcanic ash

B. Answer the following questions:

1. How old is the Earth believed to be according to scientists?
2. What were the conditions like during the early formation of Earth, and why was it impossible for life to exist?
3. What does the theory of special creation propose regarding the origin of living beings?
4. Explain the Theory of biogenesis and provide the names of at least two scientists who contributed to its validation through experiments.
5. Describe the Theory of spontaneous generation (Abiogenesis) and provide an example of an experiment conducted to refute it.
6. What is the Oparin-Haldane Theory of biochemical origin of life? Briefly explain its main concepts.
7. Describe the main steps involved in the Miller-Urey Experiment.

Chapter 7.2

EVIDENCE OF EVOLUTION

7.2.1 CONCEPT OF ORGANIC EVOLUTION

Evolution (L. *evolvere* = unrolling/unfolding) is a gradual and orderly change from one state to another. Charles Darwin defined it as "descent with modification". It's important to note that evolution isn't about changes happening to one individual during its lifetime; rather, it's about how entire groups of organisms change over many generations.

Simple organisms in the past evolved to present-day complex organisms adapting to Earth's changing environment. Evolution can also be defined as a slow, continuous, and irreversible journey from primitive life forms to today's advanced organisms. The father of organic evolution is Charles Darwin. The term 'evolution' was coined by Herbert spencer.

PATTERN OF EVOLUTION

- a) **Microevolution** involves small scale changes in gene frequencies in a population by factors like natural selection, genetic drift, etc. For example, Peppered moths evolving darker coloration due to pollution.
- b) **Macroevolution** involves large evolutionary patterns leading the formation of new species by phenomena like adaptive radiation, speciation, etc. For example, Darwin's finches evolving different beak shapes for varied diets.
- c) **Progressive evolution** shows an evolutionary trend in organisms from simple to complex. For example, Whales evolving from land-dwelling mammals.
- d) **Retrogressive evolution** involves a reversal evolutionary trend in organisms from complex to simple. For instance, evolution of small sized reptiles from giant reptiles. For example, Transition from giant dinosaurs to small lizards.
- e) **Convergent evolution** involves evolution of similar characters in organisms from different ancestors. For example, the development of fusiform type of body by Palaemon (arthropod), shark (fish), and a dolphin (mammal).
- f) **Divergent evolution** occurs when a common ancestor gets diversified to different forms. It is also known as adaptive radiation. For example, African *cichlid* fish diversifying jaw shapes due to varied diets.
- g) **Parallel evolution** refers to the process in which two related species, independently, evolve similar characters over the long time after they diverged from their common ancestor. For example, Marsupial mammals in Australia and placental mammals evolved independently but in parallel lines due to adaptation to their similar ways of life.

7.2.2 EVIDENCES OF ORGANIC EVOLUTION

Evidence supporting the theory of organic evolution comes from diverse fields such as morphology, paleontology, geology, embryology, biogeography, biochemistry, and genetics. Collectively, these lines of evidence offer a compelling narrative of the interconnectedness and gradual change within the biological world:

- i. Evidences from morphology, comparative anatomy and vestigial organs
- ii. Evidences from palaeontology
- iii. Evidences from embryology
- iv. Evidences from biochemistry and comparative physiology

1. EVIDENCES FROM MORPHOLOGY, COMPARATIVE ANATOMY AND VESTIGIAL ORGANS:

A comparative analysis of morphological and anatomical structures in different groups of animals provides important evidence in favour of organic evolution.

Diverse animal groups present distinct categories of organs—homologous, analogous, vestigial, and atavism providing evidential support for evolutionary processes.

- a. **Homologous Organs:** Homologous organs are the organs which have similar origin and design but different functions. For example, the forelimbs of a whale (flippers), bat (wings), bird (wings), horse, and man. Despite their different functions—swimming, flying, running, leaping, and grasping—the forelimbs share a common structure, known as the pentadactyl pattern, featuring similar bones like humerus, radio-ulna, carpals, metacarpals, and phalanges. Additionally, the arrangement of muscles, heart, nerves, and blood vessels follows a similar pattern. The presence of homologous organs suggests a shared evolutionary ancestry.

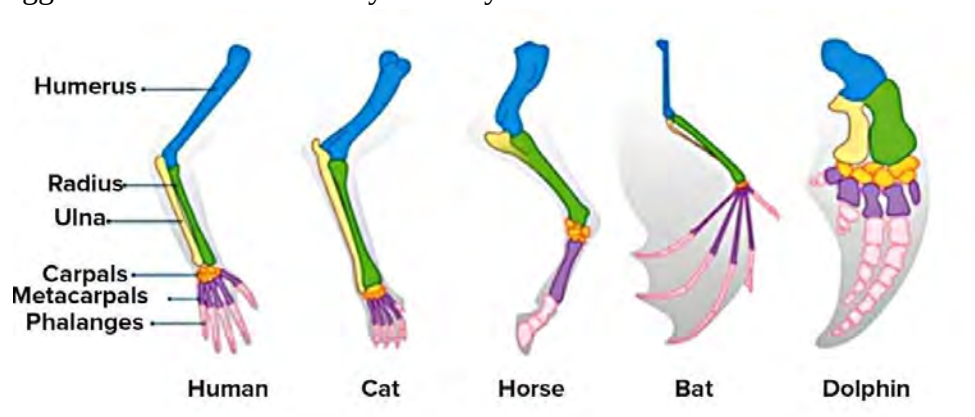


Figure: 7.2.1 Homologous organs

- b. **Analogous Organs:** Analogous organs, despite different origins, serve similar functions. For example, the wings of a butterfly and bird. Wings of butterfly are membranous but wings of birds have feathers on arm bones. Despite these structural differences, both facilitate flight. Similarly, fins of fish and flippers of whales; sting of honey bees and sting of scorpions are analogous organs. This highlights their adaptability, even with different evolutionary backgrounds.

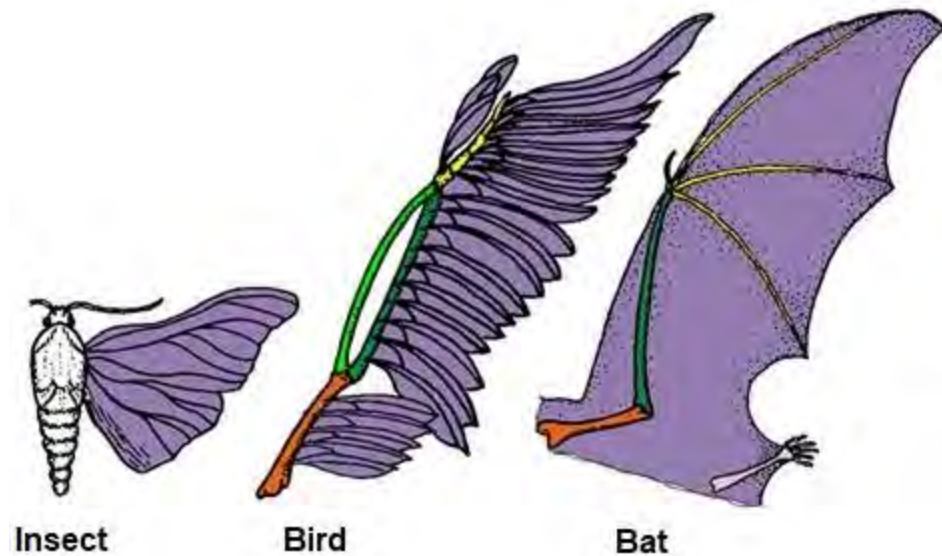


Figure: 7.2.2 Analogous organs - forelimbs of (a) frog, (b) lizard, (c) bat, (d) human, (e) cat, (f) whale, (g) bat

Activity 7.1

Enlist differences between homologous organ and analogous organ with examples on a chart paper and present in the class.

- c. **Vestigial Organs:** Vestigial organs, non-functional and practically useless, were likely functional in ancestors but have diminished over time due to changing needs. Examples in humans include the vermiform appendix, wisdom teeth, pointed canines, and more. The appendix, once a functional caecum aiding in cellulose digestion, indicates herbivorous ancestry in primates. The presence of vestigial organs supports the concept of organic evolution, implying a transformation from herbivorous ancestors to omnivorous modern humans.

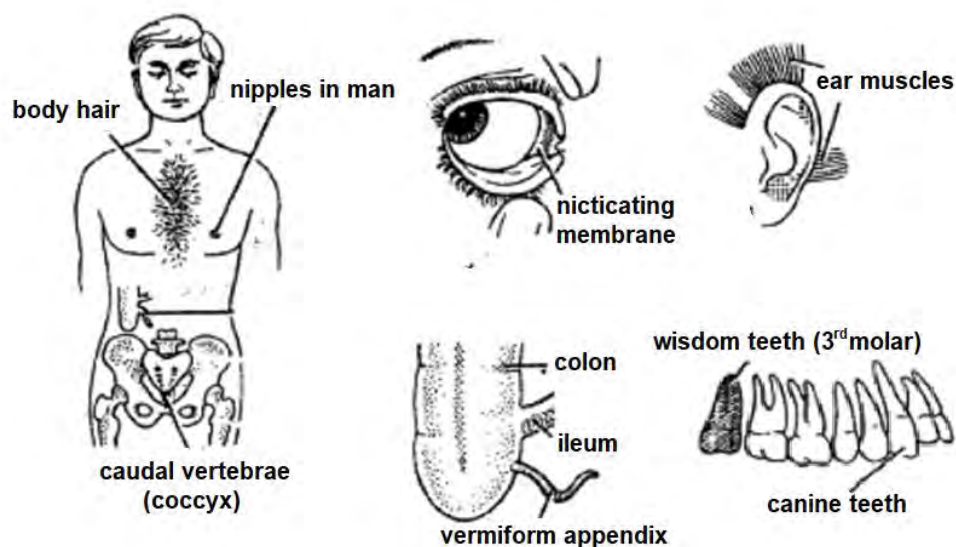


Figure: 7.2.3 Vestigial organs

- d. **Atavism (Reversion):** Atavism is the sudden appearance of ancestral characteristics lost during evolution. Examples include a human baby with a tail or an extra digit in a horse; long and canine teeth represent carnivorous ancestors; large and thick body hair reflect our relationship with apes and extra nipples (more than two). This indicates that individuals showing atavism have evolved from ancestors in whom these characteristics were fully developed providing evidence for evolutionary processes.

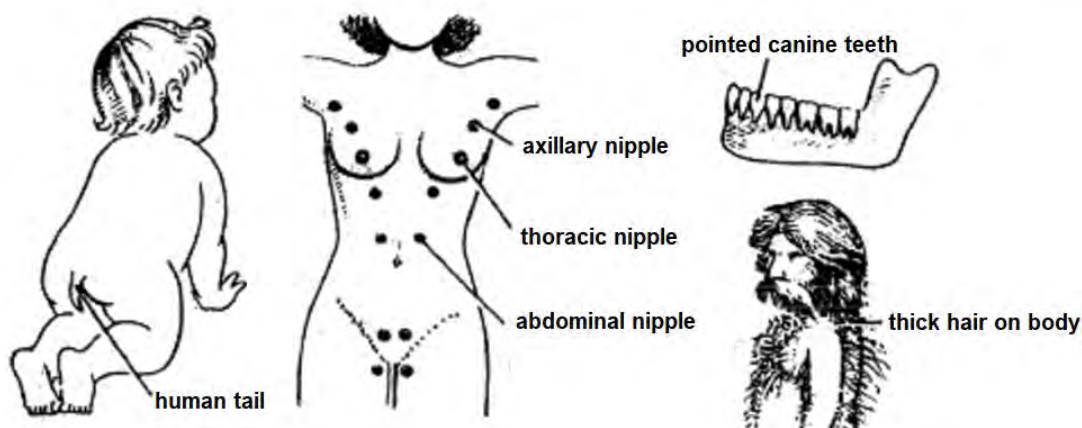


Figure: 7.2.4 Atavism

2. EVIDENCES FROM PALAEONTOLOGY:

Palaeontology, the study of fossils, focuses on the examination of fossils, which are the remains, impressions, or entire organisms of plants and animals from past geological periods. These artifacts provide direct evidence of evolution. Fossilization is the process through which fossils are formed. The fossil record indicates a gradual evolution from simpler to more complex forms.

Branches of Paleontology:

Palaeontology can be divided into two primary branches:

- i. **Palaeozoology:** The study of animal fossils.
- ii. **Palaeobotany:** The study of plant fossils.

Do You Know?

The pioneer of palaeontology was Leonard da Vinci, but modern palaeontology was formally established by George Cuvier.

Fossilization Process: Fossilization is the process by which the remains of organisms from the past become fossilized. It involves the burial of the entire organism or its parts in sand or mud. The ocean is an ideal environment for fossilization due to the inhibitory effect of saltwater on decay.

After an organism's death, its soft tissues decompose, and the hard parts settle at the bottom, eventually being covered by sand. This sedimentation continues over time, preserving older fossils in deeper layers and more recent ones closer to the surface.

Types of Fossils:

Fossils are categorized based on the preserved parts of the organism:

- i. **Intact Fossils:** Entire organisms or parts preserved in original condition, often in cold or dry regions. Example: woolly mammoth found in Siberia
- ii. **Petrified Fossils:** Preservation of hard parts like bones, teeth, and exoskeleton through mineralization.
- iii. **Moulds/Casts Fossils:** Impressions left behind by organisms as surrounding materials harden, creating exact replicas. Example: Trilobite fossils
- iv. **Compression Fossils:** Common in plant fossils, where a thin carbon film remains, outlining the organism.
- v. **Imprints or Impressions:** Fossils in the form of footprints, wing prints, skin prints, or impressions of crawling creatures. Example: Dinosaur foot prints
- vi. **Pseudofossils:** Mineral formations resembling plant remains but, are not true fossils.

Significance of Paleontology:

1. It helps in understanding the evolutionary history (phylogeny) of organisms.
2. It provides the proof of existence of diverse groups of organisms at different time periods.
3. While studying fossils from older to recent strata of rocks simple to complex forms of life are observed.
4. Fossil records also indicate that complex life forms of today originated from simpler forms of the past.

Do You Know?

How are fossils dated?

Relative Dating:	Absolute Dating (Radiometric Dating):
i. Stratigraphy: This method examines the layer of rock (strata) for fossils to determine the tentative age of fossils. It is based on the principle of superposition that states younger layers superimpose the older layers. ii. Biostratigraphy: It uses the known ages of the index fossils to date the rock layers in which fossils are found.	i. Carbon-14 Dating: It measures the decay of radioactive carbon isotopes in organic material. This method is suitable for dating fossils up to about 50,000 years old. ii. Potassium-Argon Dating: It measures the decay of potassium-40 into argon-40, with a half-life of 1.3 billion years. It is used for dating ancient volcanic rocks and fossils. iii. Uranium-Series Dating: It relies on the decay of uranium isotopes. It is useful for dating older fossils and materials with ages ranging from a few thousand to several hundred thousand years.

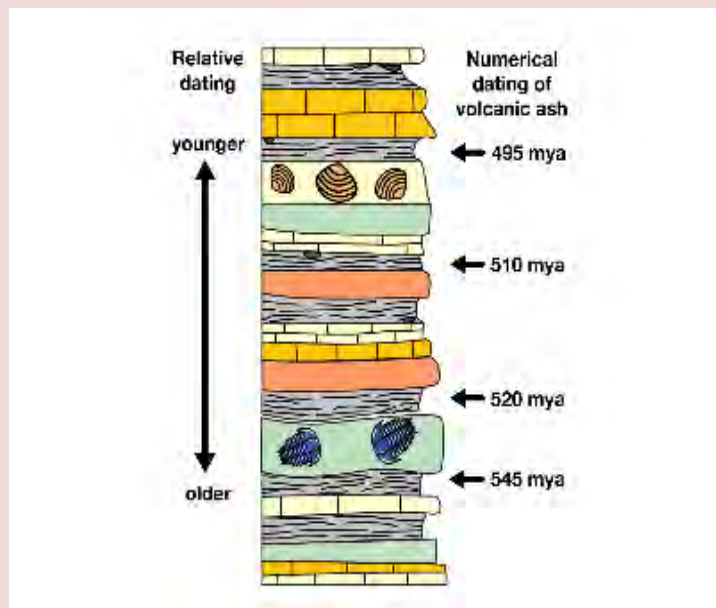


Figure: 7.2.5 Formation of fossils and multiple strata of fossils

Activity 7.2

"Building a Fossil Record - Understanding Relative Dating"

Objective:

To help students grasp the concept of dating fossils using everyday objects.

Materials Required:

- Pens or pencils
- Books or notepads

Steps:

- Place the book and pen one above another alternatively as shown in the figure.
- As layers (sediment) build up, pens (organisms) get buried.
- Assume that each layer is formed at a different time period.
- Discuss how formation of sedimentary rock preserves organisms of different time periods.



Connecting Links:

Undeniably, fossils are the most convincing evidence to support organic evolution. Fossils of organisms that connect organisms of two different groups-primitive and advanced possess characteristics of both, bridging the gap between them. Such organisms are called connecting links. Some examples are listed in the table below:

Between	Connecting link
Living and nonliving	Virus
Plants and animals	<i>Euglena</i>
Protozoa and Porifera	<i>Proterospongia</i>
Mollusca and Annelida	<i>Neopilina</i>
Annelida and Arthropoda	<i>Peripatus</i>
Reptiles and Aves	<i>Archaeopteryx</i>
Non chordata and chordate	<i>Balanoglossus</i>
Cartilaginous and bony fishes	<i>Chimaera</i>
Fishes and Amphibians	<i>Protopterus</i> (Lung fish)
Reptiles and mammals	<i>Platypus</i> and <i>Echidna</i>

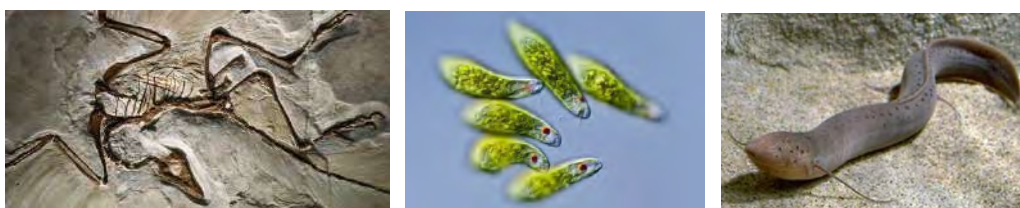


Figure: 7.2.6 Archaeopteryx, Euglena and Lungfish

Archaeopteryx, a fossil found in Jurassic period rocks, serves as a link between reptiles and birds, suggesting that birds might have evolved from reptiles.

Table: 7.1 Characteristic features of Archaeopteryx

Features	Reptile	Bird
Beak and Jaw	Heavier jaw, teeth present	Lighter beak, no teeth
Forelimbs and Claws	Claws on wings, reptilian structure	Wing structure with adapted flight feathers
Scales and Feathers	Reptilian scales	Flight feathers and avian characteristics
Tail	Long, bony tail with vertebrae	Feathery tail shorter than reptilian tails
Skeletal Structure	Vertebrae structure resembling reptiles	Hollow bones, characteristic of avian skeletons
Wings	Wings with claws and a reptilian appearance	Wings adapted for flight, with flight feathers and shape
Eyes and Vision	Eye structure resembling reptiles	Binocular vision for depth perception, common in birds

Geological Time Scale and Eras:

Geologists construct a geological time scale, a chronological record of Earth's history, based on fossil types and radioactive dating. This scale divides geological history into six eras: Archeozoic, Proterozoic, Paleozoic, Mesozoic, and Cenozoic, each characterized by specific life forms, geological disturbances, and climatic changes.

Following an in-depth examination of sedimentary rock strata in various parts of the world, geologists have categorized geological history into the following eras:

Archeozoic era	-	Age of primitive life.
Proterozoic era	-	Age of early life.
Paleozoic era	-	Age of ancient life.
Mesozoic era	-	era of middle age
Cenozoic era	-	Age of modern life

Phylogeny of horse

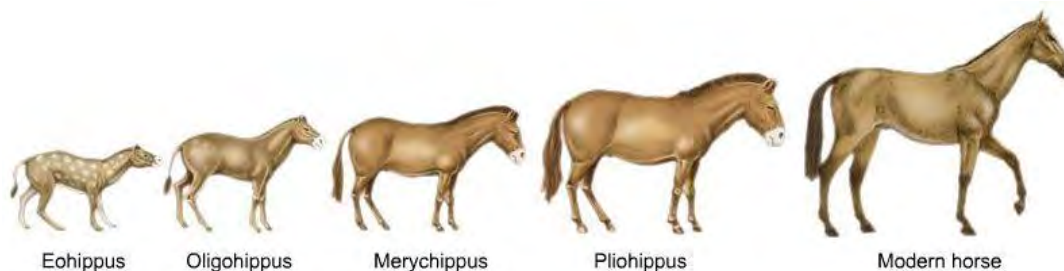


Figure: 7.2.7 Evolution of horse

The horse's genealogy stands as one of palaeontology's most extensively scrutinized. Commencing approximately 60 million years ago in the Eocene Epoch, the inaugural horse ancestor emerged. This creature, denoted scientifically as *Hyracotherium* but more commonly recognized as *Eohippus* or the 'dawn horse,' stood at around a foot in height, similar to a fox, and primarily consumed plants. Sporting 44 teeth, with moderately adapted cheeks for grinding, it exhibited four toes with a splint on the front foot and three toes with two splints on the hind foot. The ancestral lineage likely progressed through *Eohippus*, *Mesohippus*, *Miohippus*, *Parahippus*, *Merychippus*, and *Pliohippus*, culminating in the modern *Equus*, representative of contemporary horses. Throughout this evolutionary trajectory, following changes occurred to form the modern horse:

- Increase in body size,
- Lengthening and increased mobility of the neck,
- Reduction in the number of toes from four to one,
- Elongation of the anterior portion of the skull,
- Extension of the distal parts of limbs, elevating the wrist and ankle,
- Specialization of teeth (molars and premolars) for grinding grasses, and
- Fusion of metatarsals and metacarpals

3. EVIDENCES FROM EMBRYOLOGY

Embryology involves studying the embryonic stages of animals or how animals grow from eggs to adults. This field provides strong evidence supporting the theory of organic evolution, and here's how:

- a. **Early Developmental Similarities:** In the beginning, all multicellular animals start as a single cell known as a zygote. This cell progresses into morula, blastula, and gastrula stages, forming three germinal layers—ectoderm, mesoderm, and endoderm. These early developmental stages share striking similarities across various animals.
- b. **Comparing Vertebrate Embryos:** The embryos of fish, frogs, tortoises, pigeons, rabbits, and humans resemble each other significantly during their early stages of development. Even organs like the kidney, heart, and arteries follow a similar fundamental pattern in their development, indicating a common ancestry among vertebrates.
- c. **Recapitulation Theory (Biogenetic Law):** According to Ernst Haeckel's recapitulation theory, "every organism during its development repeats the evolutionary history of its race". Comparing vertebrate embryos further emphasizes this idea. For example, a tadpole of frogs resembles a fish-like ancestor, and the larva of *Herdmania* shows characteristics of its chordate ancestry. These traits include having a notochord, a well-developed nervous system, and a tail. However, when *Herdmania* develops into adulthood, it loses the notochord, tail, and experiences a significant reduction in its nervous system. This transformation shows the larva's resemblance to the ancestral characteristics.

Thus, Haeckel concluded "Ontogeny (developmental history of an organism) recapitulates (repeats) its phylogeny (ancestral history)". It means, an organism repeats its ancestral history during its development.

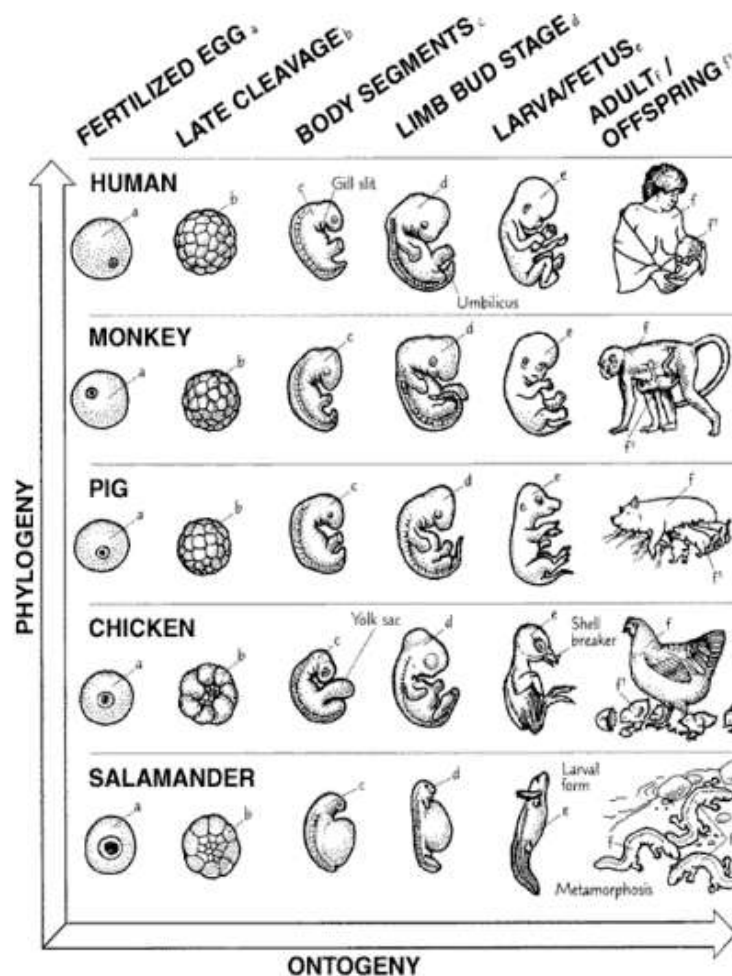


Figure: 7.2.8 Embryological study of various organisms

4. EVIDENCE FROM BIOCHEMISTRY AND COMPARATIVE PHYSIOLOGY

The strongest evidence supporting the idea that all living organisms share a common ancestor lies in the remarkable similarities found in their biochemistry and physiological functions.

- a. **Chemical Composition Resemblance:** All living beings share a common chemical composition, they are essentially composed of elements like Carbon (C), Hydrogen (H), Oxygen (O), and Nitrogen (N). These elements combine to form crucial organic compounds like Carbohydrates, fats, and proteins. Protoplasm, the fundamental substance of all living beings, also shares the same composition. Chromosomes and genes, DNA and RNA that store genetic information are coded in the arrangement of bases, sugar and phosphate molecules. Therefore, based on their chemical composition, it's reasonable to infer that all living organisms may have originated from a common ancestor.
- b. **Serological (Precipitation) Tests:** Serum is the liquid component of blood separated after blood clotting.

When antigens from one animal are injected into another, antibodies are produced, leading to an antigen-antibody interaction and the formation of a white precipitate known as precipitin. This reaction, observed in serological tests, helps determine the relationship between different animals. By comparing the amount of precipitate formed with diluted antigens, scientists can assess the closeness of the organisms. This technique has been

crucial in clarifying phylogenetic uncertainties, such as the classification of the king crab (*Limulus*), where antigens from various arthropods were tested against *Limulus* serum, confirming its placement in the Arachnida class. Similarly, comparative serological tests have resolved uncertainties among mammals, such as the relationship between whales and fishes. Despite morphological similarities, serological tests show that whale serum proteins are most like those of even-toed hoofed mammals, suggesting their evolution from a primitive artiodactyla stock. Comparative serology among primates, including man, anthropoid apes, monkeys, lemurs, and dogs, revealed an increasing order of precipitate formation, indicating the closest relationship between man and anthropoid apes.

- c. **Enzymes and Hormones:** Remarkable similarities in digestive enzymes such as Trypsin, Lipase, amylase, etc. and hormones are observed in large groups of animals. This further supports organic evolution.

EXERCISE

A. Tick the correct alternative.

- Which scientist is often regarded as the father of organic evolution?
 - Herbert Spencer
 - Charles Darwin
 - Louis Pasteur
 - Gregor Mendel
- What is microevolution primarily concerned with?
 - Formation of new species
 - Small-scale changes in gene frequencies
 - Evolutionary trends from simple to complex
 - Adaptation to changing environments
- Which type of evolution involves a reversal from complex to simple organisms?
 - Progressive evolution
 - Retrogressive evolution
 - Convergent evolution
 - Divergent evolution
- What type of organs share a similar origin but serve different functions?
 - Analogous organs
 - Vestigial organs
 - Homologous organs
 - Atavistic organs
- What term describes the sudden appearance of ancestral characteristics lost during evolution?
 - Adaptation
 - Vestigiality
 - Atavism
 - Convergence
- Which branch of paleontology focuses on the study of animal fossils?
 - Palaeozoology
 - Palaeobotany

- c. Micropaleontology
 - d. Paleoclimatology
7. What type of fossilization involves the preservation of hard parts like bones and teeth through mineralization?
 - a. Intact fossils
 - b. Petrified fossils
 - c. Moulds/Casts fossils
 - d. Compression fossils
 8. What is the term for fossils that are the impression left behind by organisms when surrounding materials harden?
 - a. Compression fossils
 - b. Petrified fossils
 - c. Moulds/Casts fossils
 - d. Pseudofossils
 9. What field of study provides strong evidence supporting the theory of organic evolution by comparing the early stages of animal development?
 - a. Palaeontology
 - b. Embryology
 - c. Biochemistry
 - d. Comparative physiology
 10. What is the primary function of serological tests in understanding evolutionary relationships between different organisms?
 - a. Determining the age of fossils
 - b. Analyzing the chemical composition of organisms
 - c. Observing early developmental similarities
 - d. Assessing the closeness between organisms
 11. Which theory, proposed by Ernst Haeckel, suggests that the developmental history of an organism repeats its ancestral history?
 - a. Recapitulation Theory
 - b. Ontogeny Theory
 - c. Phylogenetic Theory
 - d. Evolutionary Recapitulation
 12. What type of evidence supporting organic evolution is derived from the remarkable similarities found in digestive enzymes and hormones across large groups of animals?
 - a. Comparative serological tests
 - b. Fossil records
 - c. Chemical composition resemblance
 - d. Embryological studies

B. Answer the following questions.

1. Provide an example of convergent evolution.
2. List three features of Archaeopteryx that exhibit bird-like characteristics.
3. Name one connecting link between:

- a. reptiles and mammals
 - b. reptiles and aves
 - c. annelida and arthropoda
 - d. fishes and amphibians
4. What are vestigial organs, and how do they provide evidence for organic evolution?
 5. Explain the significance of fossils in understanding the evolutionary history of organisms.
 6. Describe the process of fossilization and the different types of fossils that are formed.
 7. What are connecting links in the context of organic evolution, and why are they significant?
 8. Explain the characteristic features of Archaeopteryx and its role as a connecting link between reptiles and birds.
 9. How does embryology provide evidence for organic evolution, particularly concerning the recapitulation theory?
 10. Describe the key evolutionary changes that occurred in the lineage leading from *Hyracotherium* to modern *Equus*.

Chapter 7.3

THEORIES OF EVOLUTION

7.3.1 INTRODUCTION

Like groups of animals and specific types of creatures, life forms have changed slowly and gradually over a long time. Scientists have come up with different ideas to explain how this happens. Let's explore the main ideas from Darwin and Lamarck about how life evolves.

- i. Lamarckism (Theory of inheritance of Acquired characters)
- ii. Darwinism (Theory of Natural Selection)
- iii. Modern Synthetic Theory (Neo-Darwinism)

7.3.2 LAMARCKISM (Theory of Inheritance of Acquired Characters)



Jean Baptiste de Lamarck, a pioneering French biologist (1744 - 1829), introduced a groundbreaking concept in 1809, known as the "Inheritance of Acquired Characters." His theory proposed that organisms evolve gradually in form and structure over time, due to the influence of the environment. His book '*Philosophie Zoologique*,' proposed a foundational concept in evolutionary biology.

The foundation of Lamarckism rests on essential concepts, serving as the core ideas of this theory. Lamarckism comprises four fundamental postulates:

- i. **Tendency to increase in size:** According to Lamarck, Living organisms and their component parts tend to develop and expand in size and structure over time. He believed that increase in size of an organism is due to internal vital force and growth is delimited by life itself.
- ii. **Direct environmental influence:** Any changes in the environment might cause a species to require alteration in their specific organs or traits for survival. For example, to combat new predators, a species might need to develop distinct characteristics, initiating evolutionary changes.
- iii. **Use and Disuse of Organs:** As per the needs, a species may undergo changes in character or organs across generations. The more these features or organs are utilized, they get more developed. If an organ becomes unnecessary, a species gradually ceases to use it, leading to a decline in its function and structure.
- iv. **Inheritance of Acquired character:** New traits or changes acquired by any individuals during their lifetime are transmitted from one generation to the next, ensuring the changes within the species. This transmission guarantees that subsequent generations inherit the same set of changes, making them a consistent feature of the species. In this way, a new species different from their original ancestors emerges.

EXAMPLES IN SUPPORT OF LAMARCKISM

Lamarckism is regarded as the initial theory of evolution, forming the basis for subsequent evolutionary studies. Following examples are in the favour of Lamarckism:

1. Giraffe's Evolution:

Lamarck used the evolution of giraffes as a prime example aligning with his postulates. Ancestors of giraffes resembled horses, relatively smaller in size. Changes in the environment led to the disappearance of small trees, leaving only taller trees as food sources. This urged giraffes to develop longer necks and limbs to reach leaves. Over generations, this feature strengthened through consistent use, ultimately creating the current giraffe species.

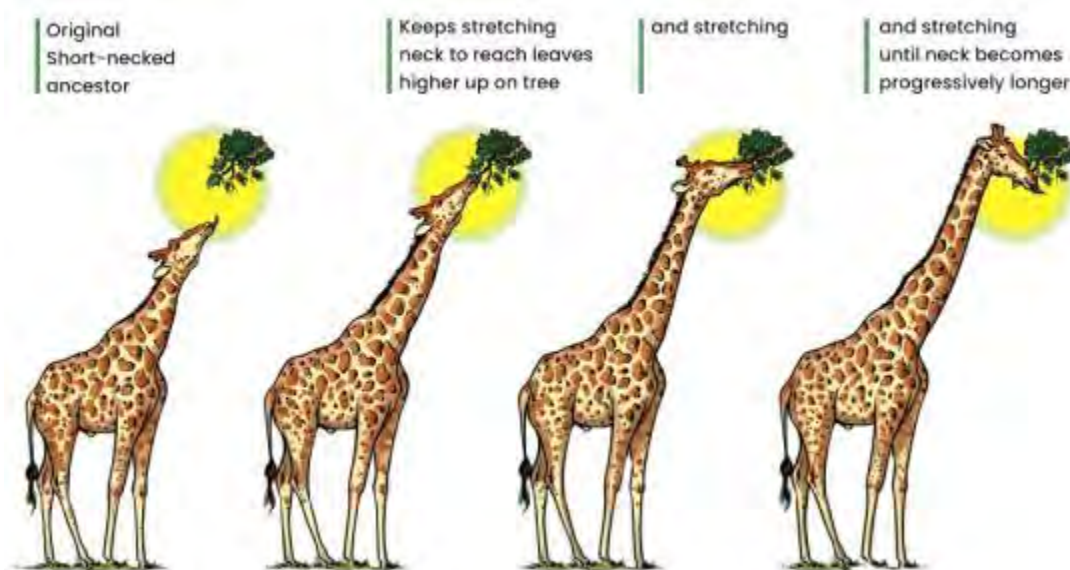


Figure: 7.3.1 Evolution of Giraffe based on Lamarckism

2. Duck's Evolution: Ancestors of ducks were initially non-aquatic, surviving on land. Moving to water environments demanded enhanced swimming capabilities. Descendants developed a web-like structure between their toes through repeated use.

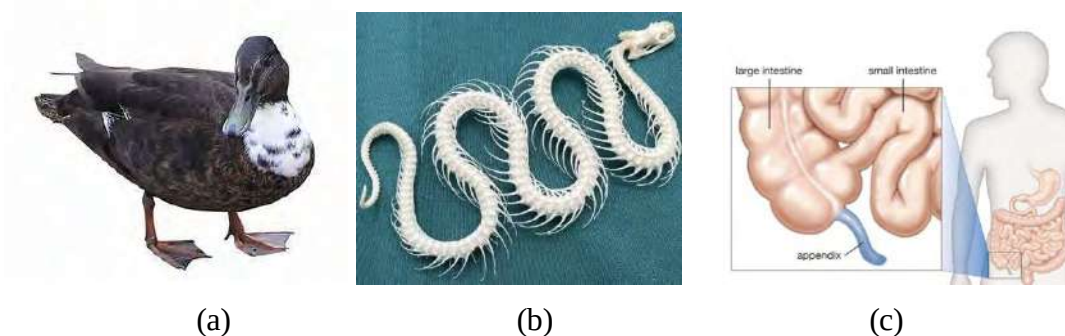


Figure: 7.3.2 a. duck with webbed toes, b. snake, c. appendix in human

3. Snake's Evolution: Snakes initially had limbs and resided on land. However, a reduced need for limbs led to their weakening and eventual disappearance after many generations. This loss of limbs was inherited, resulting in the creation of a new snake species.

4. Human Appendix Evolution: Ancestor humans had a more developed and useful appendix that was essential in digestion of cellulose in plants. However, as humans changed their feeding habit, the appendix's usage reduced, resulting in its current diminished state.

CRITICISMS OF LAMARCKISM

Lamarck's theory faced criticism and lacked widespread support from scientists.

- i. Evidence does not always support the tendency of organisms to increase their size. There have been some cases where size gets reduced. For example, primitive trees are larger whereas shrubs, herbs, and grasses that emerged later are smaller.
- ii. It is clearly illogical to accept that organisms can gain new organs just by their need or will.
- iii. It was observed that mutilations, like lost limbs or fingers, are not passed onto offspring.

Weismann's Tailless Mice Experiment: Scientist August Weismann conducted a five-generation experiment involving 68 white mice, surgically cutting their tails. Surprisingly, no tailless or shorter-tailed mice were born in subsequent generations. Weismann's experiment provided strong evidence against the inheritance of acquired characteristics, especially if changes occurred in somatic cells. However, he proposed the theory of Continuity of germplasm, which implies that heritable traits get transferred through germ cells in the ovaries and testicles.

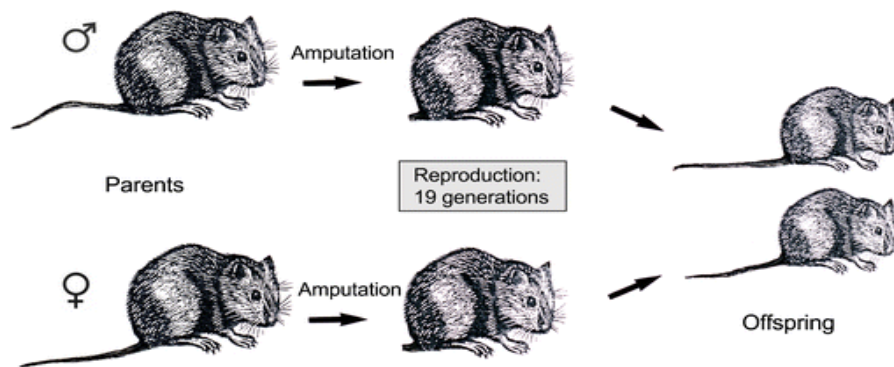


Figure: 7.3.3 Weismann's Tailless Mice Experiment

- iv. Contrary to Lamarck's idea of improved organs through continuous use, it was noted that organs, such as eyes, developed defects instead.

Neo-Lamarckism emerged as a response, reevaluating the theory. Recent research highlighted that body traits result from interactions between hereditary factors and environmental conditions that influence evolution.

According to the germplasm theory, organisms have two types of cells –

- i. somatic cell (somatoplasm)
- ii. germinal cells (germplasm)

Only changes that happen in the germinal cells can be passed down to offspring. This means that if something changes in the somatic cells, like the body cells, it usually won't be passed on to the next generation.

7.3.3 DARWINISM (Theory of Natural Selection)

Darwinism is a theory of organic evolution propounded by Charles Darwin as an explanation of changes in living beings that is driven mainly by natural selection. Darwin's meticulous research and observations, primarily conducted during his journey aboard HMS Beagle from 1831 to 1836, laid the foundation of this theory in the field of modern evolutionary biology. Exploring diverse regions like the Galápagos Islands, South America, and Australia, the systematic arrangement of flora, fauna, and geological formations, shaped his later discoveries. Darwinism is based on several facts and observations. The five fundamental facts are:

- a. Enormous fertility
 - b. Struggle for existence
 - c. Variation and heredity
 - d. Natural selection
 - e. Origin of species
- a) **Enormous fertility:** All living things have an extraordinary ability to reproduce in geometric ratio. This type of reproductive potential can be observed in nature in various organisms:
- i. An oyster lays around 80 million eggs in a year.
 - ii. A starfish produces about a million eggs every season. If all of them survive and continue to reproduce, a single species will fill all the sea after a few generations.
 - iii. Paramecium divides three times within 48 hours.
 - iv. A salmon produces 28 million eggs in a single breeding season.
 - v. A slow breeding elephant couple, in 800 years, can give 29 million offsprings.
- b) **Struggle for existence:** Darwin observed three types of struggle for existence:
- i. **Intraspecific struggle:** This is the struggle between individuals of the same species for food, shelter, breeding place, etc. For instance, dogs compete with one another for flesh.
 - ii. **Interspecific struggle:** This is the struggle between individuals of different species. For example, both leopards and wolves hunt rabbits. Elephants, rhinos and deer sometimes wander into farmland nearby national parks for food, which can cause problems for farmers. At the same time, people clear forests to make space for farms, which affects the habitat of these animals. This competition for land and food shows how humans and wildlife struggle for survival.
 - iii. **Environmental struggle:** This is the struggle against environmental challenges like floods, droughts, cold and other natural disasters.



(a)



(b)



(c)

Figure: 7.3.4 a. Intraspecific, b. Interspecific and c. Environmental struggles

- c) **Variations and heredity:** Competition among organisms has driven them to adapt to their surroundings, aiming for better access to resources and increased chances of survival. This

process brings variation which can be: useful, useless or harmful. Harmful variations cause individuals less capable in the struggle for survival, while useful ones are quite significant that help the organism fit the environment. Useless variations are not significant from an evolutionary point of view. Beneficial variations are passed down to the next generation, making them better suited to their environment.

- d) Natural selection (Survival of the Fittest):** The organisms which are provided with useful or favorable variation would survive because they are fit to face environmental challenges, whereas unfits get destroyed. The organisms which sort out useful variations are said to be the fittest. But it was unknown how only useful variations are sorted out by the organisms for which Darwin said that these variations are sorted out by nature. This is natural selection. Herbert Spencer first used the phrase 'survival of the fittest' for this phenomenon.
- e) Origin of species (Speciation):** The useful variations acquired by organisms as result of natural selection are passed down to offsprings that become prominent over the generations. Improvements in the organisms in successive generations gradually diverged from their parents, resulting in the emergence of more adapted and better organized organisms which are identified as a new species.

EXAMPLES OF NATURAL SELECTION

a) Evolution of Giraffe

Originally, there were giraffes with both short and long necks. With the scarcity of leaves on the lower branches of trees, they were forced to reach the higher branches favouring the survival of the long necked giraffes. This phased out the giraffes with short necks as they could not reach higher leaves. Thus, the giraffes with longer necks were selected by nature that survived and reproduced to the present day giraffes.



Figure: 7.3.5 Evolution of Giraffe based on Darwinism

- b. Resistance of mosquito to pesticides:** Mosquitoes make people sick by spreading diseases like malaria. So, an insecticide called DDT (banned now) was used to kill mosquitoes effectively. But now, it is not effective because some mosquitoes have developed a special ability to survive the DDT. This shows how nature picks the mosquitoes that can survive and pass their abilities onto their offspring.
- c. Industrial melanism:** In Britain, peppered moths (*Biston betularia*) in industrial areas were of two types: light-colored and black (due to pigment melanin). Before industrial pollution, light-colored moths were common as they could blend with the surrounding pale tree trunks and protect themselves from their predators like birds. But with industrial

pollution, the color of tree trunks turned black making the light-colored moths conspicuous and visible to predators. This resulted in declination in their number but favoured black-colored moths.

CRITICISM OF DARWINISM

Darwin's theory of natural selection was widely accepted, given its logical basis and strong support. However, some objections were later raised:

- i. Darwinism lacked the knowledge of heredity and could not explain how variation occurred.
- ii. It could not justify the inheritance of small variations which are not useful in organisms.
- iii. It could not explain over specialization of some organs like elephant's tusk and antlers of deer.
- iv. Darwin's theory explained survival of the fittest but not how the fittest initially emerged.
- v. It didn't account for the presence of vestigial organs.
- vi. The distinction between somatic and germinal variations was not addressed.

MODERN SYNTHETIC THEORY (NEO-DARWINISM)

Modern Synthetic Theory is a modified form of Darwin's theory of natural selection which is often called Neo-darwinism. The fundamental concept of this theory is based upon Dobzhansky's book 'Genetics and the Origin of Species'. A number of biologists such as Fischer, Huxley, Ernst Mayr, Haldane, Sewall Wright, Hugo de Vries, etc. contributed to the development of this theory. G. L. Stebbins (1971) discussed this theory in his book 'Process of Organic Evolution' encompassing five fundamental processes like gene mutation, chromosome mutation, genetic recombination, natural selection, and reproductive isolation.

Modern Synthetic Theory can be described under following points:

- i. Mutation
- ii. Genetic recombination
- iii. Gene migration
- iv. Genetic drift
- v. Reproductive isolation
- vi. Natural selection

These points are briefly explained below:

i. Mutation: Mutation refers to sudden inheritable changes in genetic composition of organisms. Mutations lead to variations within a population, playing a crucial role in driving evolution. They are considered a source of organic evolution because they can replace old genes with new ones, resulting in changes and contributing to the evolutionary process.

Dutch botanist Hugo de Vries first proposed this idea after studying Evening primrose plants (*Oenothera spp.*) in 1901. He suggested that new species form due to sudden changes caused by mutations. There are two main types of mutations:

- a. **Chromosomal mutation:** This type of mutation involves alteration in the structure or the number of chromosomes. For example, a part of a chromosome may break off and reattach to another chromosome (translocation), or an entire chromosome may be duplicated or lost (duplication or deletion).

- b. **Gene Mutation:** Gene mutations affect the DNA sequence within a gene, altering the genetic information. Gene mutations can be of several types, such as substitutions (one base is replaced by another), insertions (extra base pairs are added), or deletions (base pairs are removed).

ii. Genetic Recombination: Genetic recombination involves the reshuffling and recombination of genes among different organisms, creating new genetic constitution from existing genotypes. This process primarily occurs in sexually reproducing organisms by following ways:

- i. crossing over in meiosis
- ii. independent assortment of genes during gamete formation
- iii. random fusion of gametes in fertilization

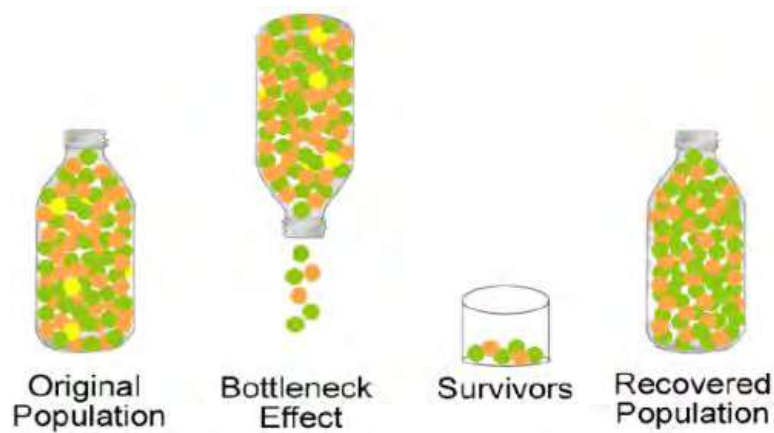
Genetic recombination is a major source of observable genetic variation within a population. This phenomenon adds new alleles and their combination to the gene pool, playing a significant role in the evolution and formation of new species.

iii. Gene Migration: Migration is the process of movement of individuals from one place to another. When such migrated individuals breed within a new population, new alleles or genes are added in the local gene pool of the host population. It leads to evolution.

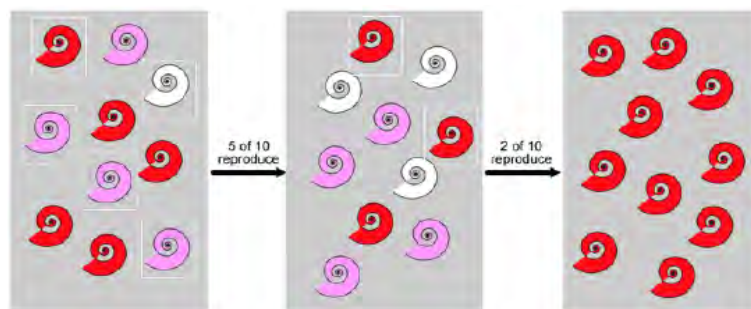
iv. Genetic Drift (Sewall Wright Effect): Genetic drift is the change in gene frequencies in a population randomly by chance, not due to natural selection. This happens in all populations; however it's most noticeable in small, isolated groups. Sewall Wright, an American geneticist, describes this process as a significant force in evolution.

Bottlenecks and founder effects are two examples of Genetic drift.

- a. **Bottleneck effect** is a genetic phenomenon that occurs when a large population is drastically reduced in size due to a catastrophic event, such as a natural disaster or disease outbreak. As a result it can cause a substantial loss of genetic diversity in small populations, affecting their ability to adapt to environmental changes. Later when population expands, gene frequencies distinctly differ from the one before catastrophe.
- b. **The founder effect** is a genetic phenomenon that occurs when a new population is established by a small number of individuals from a larger population. These founding individuals carry limited genetic diversity. As a result, the new population formed from the separated individuals will have different gene frequencies from that of the parent population. For example, in Galápagos Islands, a small number of finches arrived from the mainland and established a new population. Due to the limited genetic diversity of the founding individuals, the new finch populations on different islands evolved distinct beak shapes and behaviors adapted to their specific island habitats.



Bottleneck effect



Founder's effect

Figure: 7.3.5 Bottleneck effect and Founder's effect

- v. **Reproductive Isolation:** Isolation is the separation of organisms from their original population that prevents interbreeding between different groups. Isolation can result from various factors: physical barriers (geographical, ecological, etc.) and biotic barriers (physiological, behavioural, genetic, etc.). Dobzhansky (1930) introduced the term 'isolating mechanism' to define the phenomena by which two related populations residing in a particular area remain distinct. There are two main types of isolation, viz. geographical isolation and reproductive isolation.

Geographical Isolation occurs when a population is divided into separate groups by geographical barriers like mountain, rivers, glacier, ocean, forests, desert, etc., preventing interbreeding and leading to the formation of new species over time. It could be due to independent evolution that accumulated in the gene pools. Thus, new species have been formed by geographical isolation.

Reproductive isolation is the separation that prevents interbreeding between the populations of different species. It ensures the maintenance of species' characteristics and potentially gives rise to new species. Reproductive isolating mechanisms are of two types: Premating isolation and Postmating isolation. Premating isolation prevents interspecies mating and fertilization while postmating isolation prevents reproduction in interspecies offspring.

- vi. **Natural Selection:** This process actually means ‘differential reproduction’ in which some members of a population produce a large number of progeny while others produce less or none. The organisms which are physically, physiologically and behaviorally better adapted to the surrounding survive and reproduce. The better adapted organisms transfer their successful characters to the upcoming generation. Those who are not well adapted fail to reproduce and die in the process of natural selection. In this way, natural selection leads to the change in allele or gene frequencies.

EXERCISE

A. Tick the correct alternative.

- Which of the following is NOT one of the fundamental postulates of Lamarckism?
 - Tendency to increase in size
 - Direct environmental influence
 - Inheritance of acquired character
 - Struggle for existence
- According to Lamarck, what happens to organs that are used frequently?
 - They disappear over time
 - They become more developed
 - They remain unchanged
 - They develop defects
- Which experiment provided strong evidence against the inheritance of acquired characteristics?
 - Miller-Urey Experiment
 - Weismann's Tailless Mice Experiment
 - Louis Pasteur's experiment
 - Evidences from embryology
- Which of the following is NOT one of the five fundamental facts of Darwinism?
 - Enormous fertility
 - Survival of the fittest
 - Struggle for existence
 - Use and disuse of organs
- What process describes the change in gene frequencies in a population randomly by chance, not due to natural selection?
 - Mutation
 - Genetic recombination
 - Gene migration
 - Genetic drift
- Which type of isolation occurs when a population is divided into separate groups by geographical barriers?
 - Reproductive isolation
 - Postmating isolation
 - Geographical isolation
 - Premating isolation

B. Answer the following questions.

1. What is the primary concept of Lamarckism regarding environmental influence?
2. What theory did Charles Darwin propound to explain organic evolution?
3. Describe the concept of "use and disuse of organs" in Lamarckism with an example.
4. What criticism did Weismann's experiment provide against Lamarckism?
5. Explain the postulates of Lamarckism and provide examples for each postulate.
6. Name the type of struggle that occurs between individuals of the same species.
7. Explain the concept of "enormous fertility" in Darwinism with an example.
8. What is the main cause of the decline in light-colored peppered moths during the industrial revolution?
9. Which process describes the random change in gene frequencies in a population?
10. How does natural selection lead to the origin of new species?
11. Describe the three types of struggles for existence as observed by Darwin.
12. What prevents different species from interbreeding despite living in the same area?
13. Explain Lamarck's concept of the use and disuse of organs and how it contributes to evolutionary changes within a species.
14. Describe one example from nature that supports Lamarckism, highlighting how environmental factors influence evolutionary adaptations in a species.
15. Discuss the criticisms faced by Lamarckism and provide examples or evidence that contradict Lamarck's proposed mechanisms of evolution.
16. What is genetic recombination and how does it contribute to evolution?
17. Differentiate between chromosomal mutation and gene mutation with examples.
18. Explain the concept of neo-Lamarckism and how it addresses some of the limitations of classical Lamarckism. Provide examples or evidence supporting the neo-Lamarckian perspective on evolution.
19. Explain Darwin's concept of "Survival of the fittest" and how it contributes to the process of natural selection.
20. Describe one example of natural selection in nature, highlighting how it influences the evolution of a species.
21. Discuss the role of mutation in driving evolution according to the Modern Synthetic Theory (Neo-Darwinism).
22. Compare and contrast Darwinism with Lamarckism, focusing on their key principles and how they explain the mechanisms of evolution.
23. Explain the concept of genetic drift and provide examples of bottlenecks and founder effects, highlighting their significance in the evolution of populations.
24. What is the bottleneck effect, and how does it impact genetic diversity?
25. Explain the founder effect with an example.
26. What are the main criticisms of Darwin's theory of natural selection?

Chapter 7.4

HUMAN EVOLUTION

7.4.1 INTRODUCTION

For many years, people didn't have any idea where modern humans, *Homo sapiens sapiens*, came from. Many anthropologists believe that modern humans might have evolved from primitive eutherian mammals during the cretaceous period. These early mammals were terrestrial, insect-eating, and shrew-like. They were the ancestors from which other mammal species evolved. Among these mammals, the first primates, resembling present-day tree-shrews, evolved during the Paleocene epoch of the tertiary period in the Cenozoic era. Primates further evolved into two suborders: Prosimii and Anthropoidea. Among them Prosimians include some animals such as Tree-shrews, Lemurs, Tarsiers etc. Evolution of modern human from anthropoid ancestry is outlined in the chart given below:

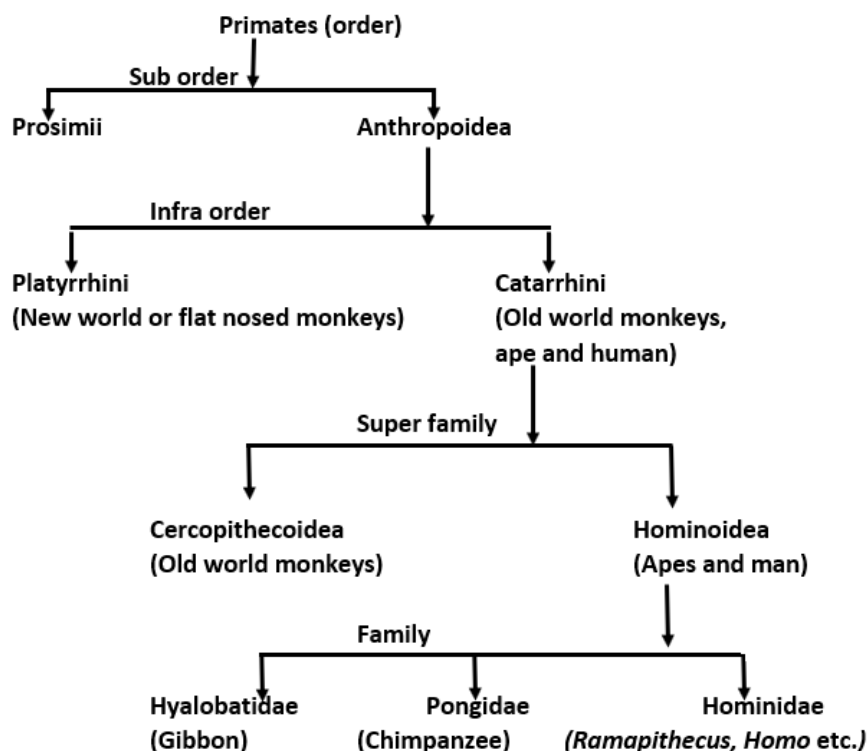


Figure: 7.4.1 Flowchart of Human evolution

Platyrrhini or new world monkeys had primitive dentition similar to prosimians. They had flat noses with widely separated nostrils, long prehensile tails, and did not use their limbs for grasping. Catarrhini or old world monkeys had dentition more similar to humans than prosimians. They had narrow noses with closely placed and downward nostrils, short non-prehensile tails, and used their limbs to grasp. Catarrhini diverged into two groups:

Cercopithecoidea (old world monkey) and Hominoidea (ape and man). Hominoidea further evolved into 3 families in the Miocene epoch of Tertiary period in Cenozoic era, viz. Hylobatidae, Pongidae and Hominida. The first two families constitute apes of various sizes such as Gibbon, Gorilla, chimpanzee, etc. Whereas, the Hominids are believed to be the ancestor of humans as they have some characteristics like erect body posture, long and stout hind limbs, bipedalism, mostly terrestrial, well-developed brain, etc.

Thomas Huxley in his study claimed humans to have a very close relationship with apes. He even concluded in his book '*Man's Place in Nature*' (1863) that humans might have evolved from apes. It was further supported by Charles Darwin (1871) in his book '*Descent of Man*' (1871). Later, a pre-human fossil was discovered after 1925 showed it to be around 2 million years old suggesting all primates like monkeys, apes and humans share a common ancestor. Now, scientists agree that humans originated in central Asia around 24-36 million years ago from some sort of ape-like ancestor.

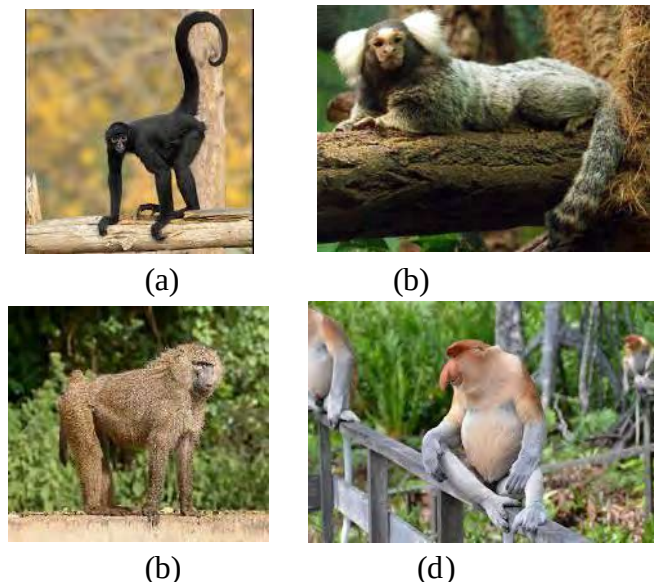


Figure: 7.4.2 (a) Spider monkey, (b) Marmoset, (c) Baboon, and (d) Proboscis monkey

7.4.2 DIFFERENCES BETWEEN PLATYRRHINI AND CATARRHINI

Platyrrhini (New World Monkeys)	Catarrhini (Old World Monkeys)
They bear flat noses.	They bear narrow noses.
Their nostrils are widely separated and outwardly directed.	Their nostrils are close and downwardly directed.
They are small to medium-sized primates.	They are medium to large-sized primates.
They have long prehensile tails.	They have short prehensile tails.
Their limbs are not well adapted for grasping.	They have limbs well adapted for grasping.
They possess 36 teeth with dental formula 2/2, 1/1, 3/3, 3/3.	They possess 32 teeth with dental formula 2/2, 1/1, 2/2, 3/3.
Their molar teeth possess 3 cusps.	Their molar teeth possess 4 - 5 cusps.

They show less developed and unspecialized brains.	They have developed a specialized brain and are capable of expressing emotions by facial gestures.
They are native to Mexico, Central and South America.	They are native to Asia and Africa.
For example, Spider monkey, Marmoset, etc.	For example, Baboons, Proboscis monkeys, etc.

7.4.3 APES AND MAN

Human beings and ape have the following similar characteristics:

There exists a close relationship between apes and man some of which are listed below:

- Both lack a tail.
- Both bear larger brains, cranial cavity and efficient memory.
- Both exhibit prominent brow ridges above the eyes.
- Both can communicate by producing sounds by vocal means.
- Both have highly developed facial musculature to express emotion/feelings such as anger, surprise, pleasure and laughter using facial gestures.
- Both have a tendency to live as couples. In fact, females undergo periodic menstruation.

These resemblance shown by apes and men, suggests them to be 'cousins' descended from common ancestors.

Table:7.4.1 Differences between Ape and Man

Ape	Man
Their posture is less erect.	Their posture is fully erect.
They possess conspicuous brow ridges.	They possess less conspicuous brow ridges.
They have a well-marked chin.	They bear prominent chins.
They are herbivorous.	They are omnivorous.
They are quadrupedal.	They are bipedal.
Their jaws are protruded.	Their jaws are not protruded.
Their canine teeth are projected.	Their canine teeth are not projected.
There is small diastema between incisors and canines.	There is no diastema.
Their arms are longer than their legs.	Their legs are longer than their arms.
Their pollex (thumb) and hallux (great toe) are opposable.	Their vertebral column has four curves.
Their vertebral column has one curve.	Their Pollex is opposable, but not the hallux.
Their cranial capacity is under 450 cc.	Their cranial capacity is about 1450 cc.
The sole of their foot does not lie flat on the ground while walking.	The sole of their foot lies flat on the ground while walking.
They lead chiefly arboreal life.	They lead terrestrial life.
Apes cannot make and employ tools, neither can use spoken and written language to communicate.	They have the ability to make and use tools, speak and write to communicate.

Ape-like human ancestors underwent several modifications during the course of evolution to develop into present day humans which are summarized below.

- i. Walking on two legs (bipedal locomotion) and not using the forelimbs for walking on the ground.
- ii. Losing the ability to opposably use the big toes.
- iii. Adopting an upright posture by developing the lower back curve.
- iv. Growing a larger and more complex brain.
- v. Decreasing the size of eyebrow ridges, canine teeth, and incisor teeth.
- vi. Developing a distinct chin.

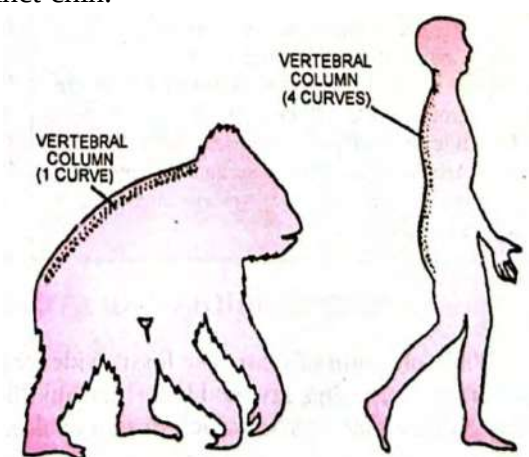


Figure: 7.4.3 Vertebral column in Apes and Man

7.4.4 POSITION OF MODERN MAN IN ANIMAL KINGDOM

Position of modern man in animal kingdom

Kingdom	- Animalia
Phylum	- Chordata
Subphylum	- Vertebrata
Class	- Mammalia
Order	- Primates
Family	- Hominidae
Genus	- <i>Homo</i>
Species	- <i>sapiens</i>
Subspecies	- <i>sapiens</i>

7.4.5 EVOLUTION OF MODERN MAN

The palentological evidence suggests that man originated in Central Asia, China, Java and India (Shivalik Hills). An established theory suggests *Dryopithecus* to be one of the oldest fossils that later evolved into apes and man. The origin and evolution of man can be understood in the following major headings:

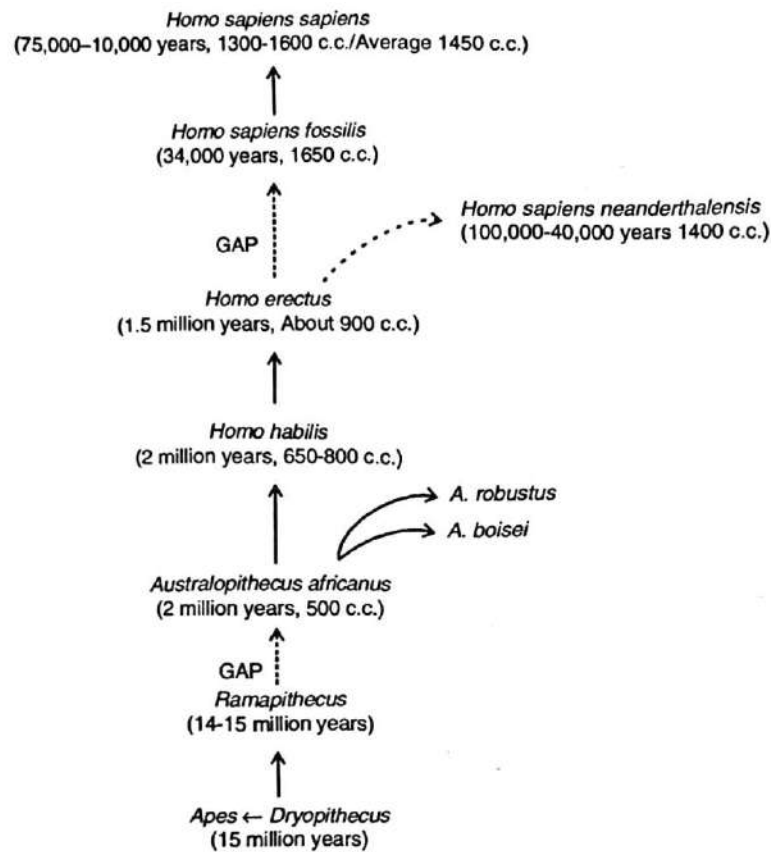


Figure: 7.4.4 Timeline of evolution of man (with cranial capacity)

1. *Dryopithecus* or *Proconsul*

The fossil of *Dryopithecus africanus*, that lived 15 million years ago, was discovered from Miocene rocks of Lake of Victoria, Africa and Europe by Leakey. It is regarded as a common ancestor of man and apes.

Its characteristic features are listed below:

- i. They were hairy and looked more like an ape but walked like a gorilla and chimpanzee.
- ii. They were arboreal that fed on leaves and soft fruits.
- iii. They had round forehead like modern man but canine teeth were like apes.
- iv. They had forelimbs that were weaker and shorter than hind limbs.
- v. The characteristics shown by the fossils indicates that they are not the direct ancestor of humans.



Figure: 7.4.5 Figure Proconsul

2. *Ramapithecus*

It is believed that in the late Miocene epoch, *Dryopithecus* gave rise to *Ramapithecus* which was on the direct line of human evolution. Thus, it appeared about 14 - 15 million years ago. Its fossil was discovered from Pliocene rocks of Shivalik Hills (India) by Edward Lewis and from Africa by Leaky. Its teeth were found in Dang valley, now preserved in the Natural History Museum, Kathmandu. *Ramapithecus* is assumed to be in the direct line of human evolution according to fossil records.

Some of its characteristic features are listed below:

- i. They were hairy and looked more like a man but walked like gorillas and chimpanzees.
- ii. They had small canine teeth but large molar teeth. It suggests, like modern man, *Ramapithecus* ate hard nuts and seeds.

(There is a GAP between *Ramapithecus* and *Australopithecus* which is not described, yet).

3. *Australopithecus* (First ape man).

Australopithecus evolved as the first human-like form that existed around 2 million years ago. The fossil of *Australopithecus* (African Ape man) was discovered by Raymond Dart in South Africa from the Pleistocene rock. *Australopithecus* was of two species: *A. africanus* and *A. robustus*.

Some of the characteristic *A. africanus* are listed below:

- i. They had erect posture more like a man and walked upright without chin
- ii. They had an ape-like brain (500 cc) and man-like teeth with brow ridges projected over the eyes.
- iii. Evidence suggests them to have hunting life and used stones, sticks, bones as hunting weapons.
- iv. Their canine teeth were smaller than that of apes
- v. They were omnivorous but mainly fed on fruits.

It is believed that *Australopithecus africanus* later gave rise to *Homo habilis*.

Do You Know?

Donald Johanson discovered a 3.2 million years old skeleton of a female human ancestor of *Australopithecus* - Lucy (*A. afarensis*).

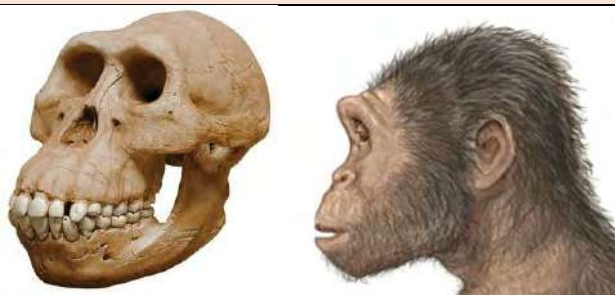


Figure: 7.4.6 *Homo habilis* (Handyman).

4. *Homo habilis* (the tool maker)

Louis Leakey and his wife Mary Leakey discovered the fossils of *Homo habilis* from pleistocene rocks in East Africa. They are also called 'Able or Skillful man' or 'the tool maker'. They are believed to have lived in Africa about 2 million years ago.

Some of its characteristic features are listed below:

- They were 4.5 feet tall with erect posture more like a man and were omnivorous.
- Its brain capacity was between 650-800 c.c.
- H. habilis* (*habilis* = mentally able or skillful) were the first to make tools mainly out of chipped stones.

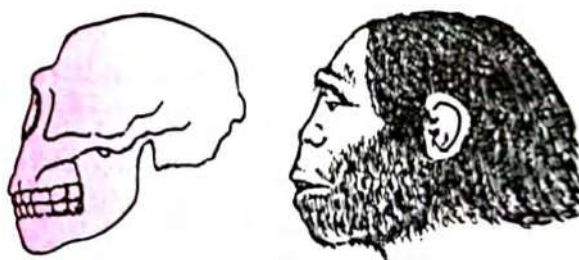


Figure: 7.4.7 *Homo habilis*

5. *Homo erectus* (Erect man)

They appeared about 1.5 million years ago in the middle pleistocene. *H. erectus* evolved from *H. habilis*. They had erect posture with 900 cc of cranial capacity. They had protruding jaws, projecting brow ridges and small canines and large molar teeth. They might have consumed meat. They made more elaborate tools of stones and bones, hunted big game and perhaps knew and used fire. Two fossils of similar type were discovered at Java (Africa) and Peking (China).

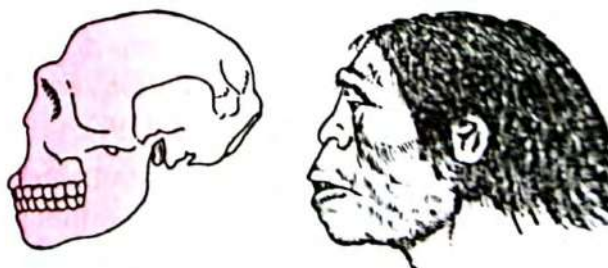


Figure: 7.4.8 *Homo erectus*

H. erectus includes Java man, Peking man and Heidelberg man.

(i) Java man (*Pithecanthropus* or *Homo erectus erectus*): Eugene Dubols discovered its fossil from pleistocene rocks in central Java (Island of Indonesia) and named it *Pithecanthropus erectus*. They existed 50,000 years ago.

Some of its characteristic features are listed below:

- They had a brain of 900 c.c. capacity.
- They were taller than 5 feet.
- They lacked a distinct chin but had eye ridges.

- iv. They are believed to be the first prehistoric man to use fire for hunting, defense and cooking food.
- v. They were omnivorous in their feeding habit, having meat as the chief diet.

(ii) Peking Man (*Sinanthropus* or *Homo erectus pekinensis*)

Peking men were very similar to Java men. Their fossils were recovered by W.C. Pel from the limestone caves near Peking and named them *Sinanthropus*. Later, Mayer renamed it *H. erectus pekinensis*.

Some of its characteristic features are listed below:

- i. They were around 5 feet tall.
- ii. Their bodies were lighter and weaker than Java men.
- iii. They had a brain of 900 -1200 c.c. capacity.
- iv. They had undeveloped chin but had developed eye ridges.
- v. They used relatively sophisticated sharp tools made of stones for hunting animals for food and defence. They were cannibals too.

(iii) Heidelberg man (*Homo erectus heidelbergensis*)

The fossil (jaw) of *H. erectus heidelbergensis* was discovered in Heidelberg, Germany. It is supposed to be the ancestor of Neanderthal man.

Some of its characteristic features are listed below:

- i. They had massive and heavily built jaws with moderate size teeth.
- ii. They lacked chin but had developed eye ridges.

(There is another GAP of fossil record of around 50,000 years)

6. Neanderthal Man (*Homo sapiens neanderthalensis*)

They are considered a primitive form of modern man that thrived in Europe, Asia and North America between 1,00,000 - 40,000 years ago. Fossils of Neanderthal man were recovered from Neanderthal Valley (Germany) from the late Pleistocene epoch by Carl Fuhlrott. Later many other fossils were excavated in various parts of the world by different palaeontologists. It is considered that *H. sapiens neanderthalensis* did not evolve into *H. sapiens*, which implies they might have vanished due to extreme cold weather.

Some of its characteristic features are listed below:

- i. They were like modern men with tallness of around 5 feet and faces projecting slightly forward.
- ii. They walked upright and had low brows, receding jaws, and high domed heads.
- iii. Their cranial capacity was 1400 c.c. like a modern man.
- iv. Neanderthals were cave dwellers, skilled hunters (all time predators) and were adapted to a cold environment and harsh climate. They had fashioned the skin into clothing.
- v. They were omnivorous and cannibals.
- vi. They used to light fire in natural caves at night for heat and light.
- vii. It is believed that they buried their dead with flowers and tools. And they may have religion.

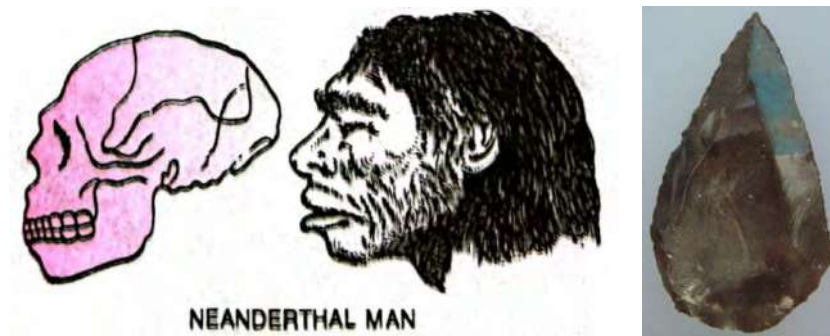


Figure: 7.4.9 Neanderthal man (skull, face) and stone tool

7. Cro-Magnon man (*Homo sapiens fossilis*).

They are considered the early form of modern humans that thrived around 34,000 years ago in the Holocene epoch. They were more developed than Neanderthal man. Their fossils were first discovered in 1868 from Cro-Magnon rocks of France by Mac Gregor. Thus, they are called Cro-Magnon man. Thus, it is regarded as the most recent ancestor of modern man. It became extinct about 10,000-11,000 years ago.

Some of its characteristic features are listed below:

- i. They were similar to modern men in terms of size and appearance.
- ii. Their faces had jaws that were not projected forward.
- iii. They had moderate brow ridges, strong jaws and dentition like man, and a well-developed chin.
- iv. They were around 5 feet tall with broad forehead and raised narrow nose and prominent chin.
- v. They could walk and run faster.
- vi. They were cave dwellers and had left a few beautiful murals of animals on the cave's wall.
- vii. They used to live in families and were good at making tools and even ornaments, not only of stones and bones, but also of elephant tusks. Its tools included spears, bows and arrows.
- viii. Their cranial capacity was 1600 c.c. which is more than modern man. Thus, it was believed that they were more intelligent and cultured than the man of today.
- ix. They were unaware of agriculture, domestication and socialization by then.

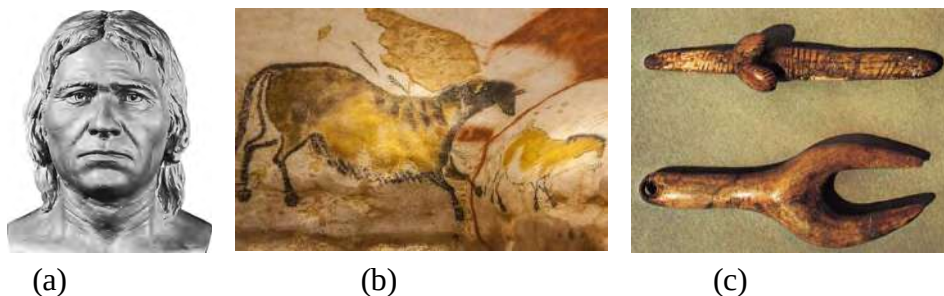


Figure: 7.4.10 (a) Cro-Magnon man (b) Cave painting (Lascaux cave, France) (c) weapons

8. The Living Modern Man (*Homo sapiens sapiens*)

Further evolution of man after Cro-Magnon was of culture rather than of anatomy. During the ice age between 75,000-10,000 years ago modern *H. sapiens* appeared in the region around Caspian and Mediterranean seas. Then, they spread all over the world to become a dominating species. Around 18,000 years ago prehistoric cave art developed, one of which can be observed at Bhimbetka rock shelter in Raisen district of Madhya Pradesh, India. *H. sapiens sapiens* appeared in the Holocene epoch. Their lifestyle evolved from cave dwelling and hunting type to crop raising type in around 10,000 years with which human settlements started.

Morphologically, they were similar to modern man in all aspect however following morphological evolution are distinctly observed in modern man:

- Modern men have slight raises in the skull cap.
- Their skull bones are thinner.
- There is slight reduction in cranial capacity which is about 1450 cc.
- They developed four curves in the vertebral column.

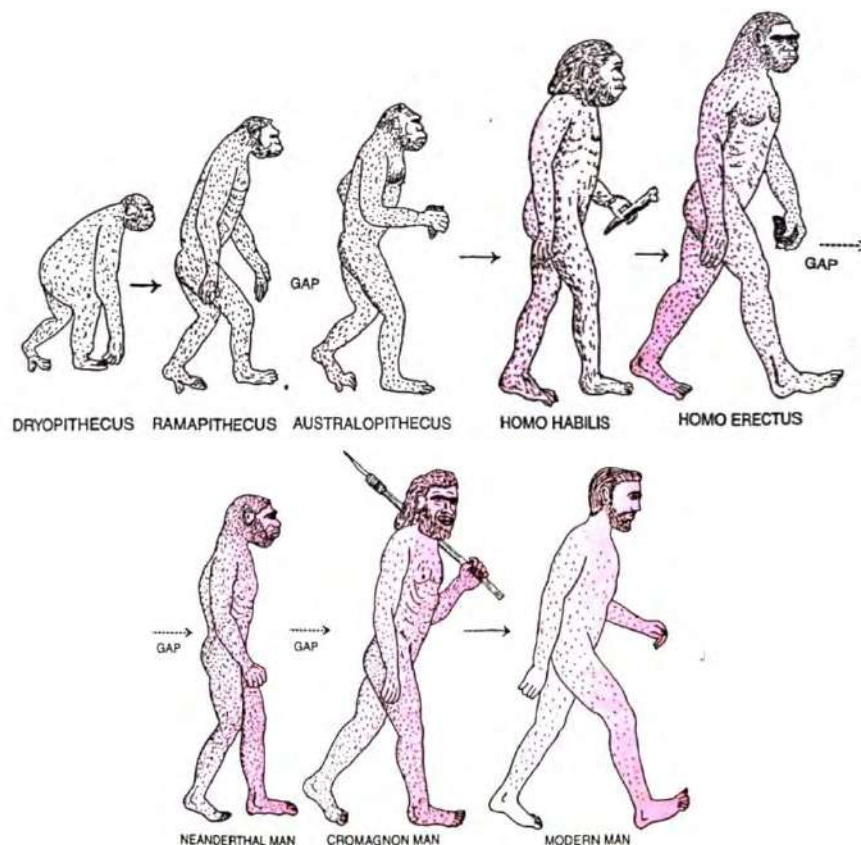


Figure: 7.4.11 Evolution of modern human

Activity:7.1

Conduct research using reliable resources on the internet and reference books to track the evolution of modern human evolution. Design a poster or a powerpoint slide in a group and present it in your class.

EXERCISE

A. Tick the correct alternative.

1. Which epoch of the Cenozoic era saw the evolution of the first primates resembling present-day tree-shrews?
 - a. Miocene
 - b. Paleocene
 - c. Pleistocene
 - d. Eocene
2. What is the characteristic feature that distinguishes *Platyrrhini* (New World Monkeys) from *Catarrhini* (Old World Monkeys)?
 - a. Tail length
 - b. Dentition
 - c. Brain size
 - d. Limb adaptation
3. Which feature is a distinguishing characteristic of *Platyrrhini* (New World Monkeys)?
 - a. Narrow noses with closely placed nostrils
 - b. Short, non-prehensile tails
 - c. Long, prehensile tails
 - d. Dentition with 32 teeth
4. Which of the following primates is classified under the suborder Prosimii?
 - a. Gibbon
 - b. Lemur
 - c. Baboon
 - d. Gorilla

B. Answer the following questions:

1. What is the dental formula for *Catarrhini*?
2. Compare the nasal structure and dental characteristics of *Platyrrhini* and *Catarrhini*.
3. Describe two similarities and two differences between apes and modern humans.
4. Explain the significance of the fossils of *Dryopithecus* and *Ramapithecus* in understanding human evolution.
5. Describe the main characteristic features of *Australopithecus* and its importance in human evolutionary history.
6. Discuss the key differences between Neanderthal Man and Cro-Magnon Man, highlighting their respective contributions to human evolution.
7. Trace the evolutionary lineage from *Dryopithecus* to *Homo sapiens sapiens*, detailing the major milestones and characteristic adaptations that occurred during this journey.
8. Compare and contrast *Homo habilis* and *H. erectus* in terms of their physical characteristics, behavior, and cultural advancements.

Project work

Design an evolutionary tree of human evolution in a chart paper and label them using different colors.

Unit

8

Faunal Diversity



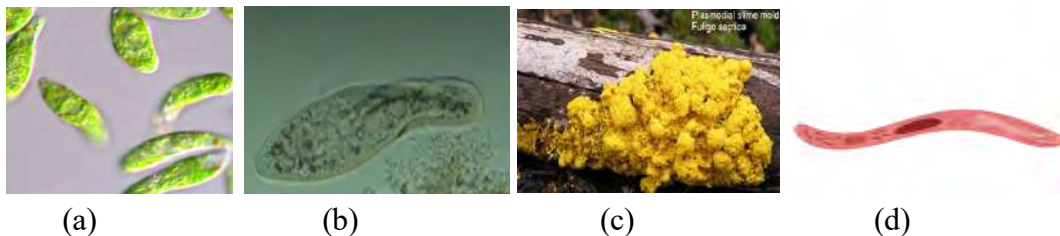
Ernst
HAECKEL
(1834-1919)

Ernst Haeckel (Ernst Heinrich Philipp August Haeckel) was a German biologist, physician, naturalist, philosopher and artist, born on February 16, 1834 in Potsdam, Germany. He is famous for his contributions made to the biological sciences. He did research work in the field of zoology and taxonomy of radioloria, Porifera and annelida. He also proposed that the phylum monera and kingdom protista be included to the classification of living beings. Ernst Haeckel was greatly inspired by Charles Darwin and his book “origin of species”.

Chapter 8.1

PROTISTA

Observe the pictures given below and discuss the following questions.



- What could be the organisms shown above?
- Have you ever seen these organisms anywhere else?
- Are they unicellular or multicellular?
- Which kingdom do they belong to?
- Are they beneficial or harmful to us?

8.1.1 GENERAL INTRODUCTION

The organisms shown in the picture above are *Euglena*, *Paramecium*, *Fuligo* and *Plasmodium* respectively. *Euglena* is a microscopic, unicellular and flagellate organism primarily found in freshwater. *Paramecium* is also a microscopic and unicellular ciliate found in freshwater rich in decaying organic matter. *Fuligo* is a fungi like unicellular organism which can be seen in decaying woods. Similarly, *Plasmodium* is an intracellular blood parasite. *Euglena* exhibits both autotrophic and heterotrophic mode of nutrition as it can prepare its own food and sometime derives food from other micro-organisms whereas *Paramecium* is a heterotrophic because it derives food from other microorganism or organic substances. These organisms belong to the kingdom protista.

8.1.2 OUTLINE CLASSIFICATION OF PROTISTA

Kingdom protista (Gr; protistos, first of all) was proposed by Ernst Haeckel in 1866. Later, an American taxonomist Robert Harding Whittaker broadly divided all the living beings of this universe into five kingdoms in 1969 basically on the basis of phylogenetic relationship among them.

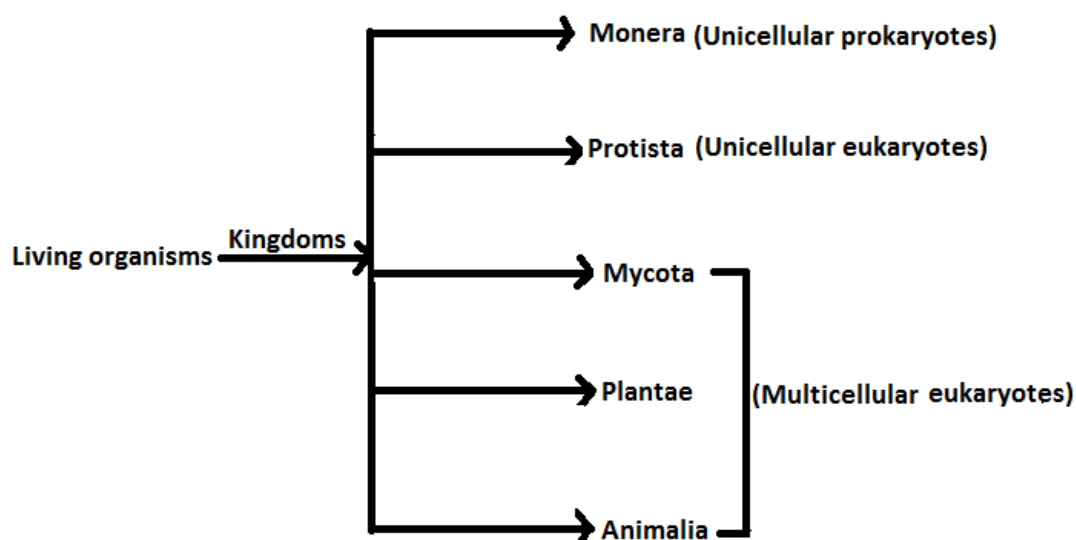


Figure 8.1.1 Five kingdom classification

Protistans consist of microscopic, single-celled and primitive eukaryotic organisms. This group includes diverse living organisms that are plant-like, such as golden algae and diatoms, animals like such as *Paramecium* and *Amoeba*. Some of them are both plants and animals like such as *Euglena* and *Astasia* and some of them are fungi like such as *Fuligo*, *Protostelium*, etc.

CHARACTERISTICS FEATURES OF KINGDOM PROTISTA

Organisms belonging to the protista have following features:

1. They are usually aquatic and some of them are also found in moist soil.
2. They are simple, microscopic and unicellular eukaryotes. Some protist like *Volvox* is colonial.
3. They have protoplasmic or acellular level of body organization.
4. Cell body is externally covered by cell membrane or cell wall and some of them are without any outer covering.
5. They have either single nucleus (monomorphic) or two nuclei (dimorphic condition) in *Paramecium* or many nuclei (coenocytic condition) in *Opalina*.
6. Their locomotion takes place with the help of pseudopodia, flagella and cilia. In some forms, there may not be locomotory organs.
7. Mode of nutrition is different among them. They show holophytic or holozoic or mixotrophic or saprozoic or parasitic mode of nutrition.
8. Digestion of food particles takes place inside the cell (intracellular digestion).
9. Respiration and excretion take place through general body surface.
10. Reproduction takes place asexually by binary fission, multiple fission, cyst formation, sporulation etc. Sexual reproduction takes place by conjugation and fusion of gametes (syngamy).

Some protistans are planktons. Planktons are those creatures which are free swimming on the surface of water. They are autotrophic plant like, called phytoplankton (Diatoms) and heterotrophic animal like, called zooplankton (paramecium).

CLASSIFICATION OF PROTISTA

Kingdom protista is further divided into 3 groups:

Group A: Photosynthetic protists

Group B: Consumer-decomposer protists

Group C: Protozoan protists

1. Group A: Photosynthetic protists

They can further be divided into three phyla:

Phylum 1: Pyrrophyta

- i. They are aquatic, mostly found in marine water; commonly called dinoflagellates.
- ii. They are unicellular, motile, and photosynthetic.
- iii. Some of them are bio-luminiscent glowing in dark because of presence of phosphorescence. Example: *Noctiluca*
- iv. Body is externally covered by theca or lorica.
- v. They reproduce only by asexual method.

Example: *Noctiluca*, *Gymnodinium*

Phylum 2: Chrysophyta

- i. They are unicellular and some occur in colonial form, found mostly in marine water.
- ii. Their cell body is covered by hard siliceous shell called frustula.
- iii. Reproduction takes place by sexually and asexually both. Binary fission is common.
- iv. They include diatoms and golden brown algae. Diatoms are important food source to animals.

Example: *Navicula*, *Triceratium*



(a)



(b)

Figure 8.1.2 (a) *Navicula* (b) *Noctiluca*

Phylum 3: Euglenophyta

- i. They are motile, free living flagellate protists found in freshwater and damp soil.
- ii. Their body shape is maintained by plasma membrane and pellicle.
- iii. They move with the help of flagella.
- iv. Some of them have chlorophyll and are photosynthetic. Their reserve food is called Paramylum.
- v. Near the base of flagellum lies light sensitive spot called eye spot.

- vi. They behave as both plants and animals hence show mixotrophic mode of nutrition.
- vii. They reproduce asexually by longitudinal binary fission.

Example: *Euglena*, *Peranema*, *Trachelomonas*

2. Group B: Consumer decomposer protists or slime moulds

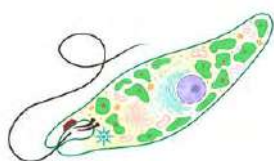
- i. These organisms are also called **protistan fungi** as they resemble both amoeboid protozoans and fungi.
- ii. They don't have chlorophyll and hence can't produce their own food. They derive their food from decaying organic matter.
- iii. They reproduce by sexually and asexually both.

They are of two types

Type 1. Plasmodial or true or acellular slime moulds

- i. They are found in decaying leaves and wooden log.
- ii. Their outer covering is plasma membrane.
- iii. They are free living irregular shaped mass of slimy protoplasm.
- iv. Their vegetative stage is called Plasmodium, represented by a large sized multinucleated structure.

Example: *Tubifera*, *Physarum*



(a)



(b)

Figure 8.1.3 (a) *Euglena* (b) *Physarum*

Type 2. Cellular slime moulds

- i. Cellular slime moulds are found on upper layer of moist soil rich in decaying organic matter.
- ii. Their feeding stage is single-celled amoeboid stage.
- iii. When there is scarcity of food, they aggregate but retain their individuality and reproduce by spore formation.

Example: *Dictyostelium*, *Acytostelium*

3. Group C: Protozoan protists

- i. They are aquatic and terrestrial both. Most of them are parasitic. Some of them are either free living or commensal or saprophytic.
- ii. They are simplest, primitive, acellular and microscopic animalcules.
- iii. They are solitary or colonial having protoplasmic body organization.
- iv. Body is covered by cell membrane, pellicle and shells.
- v. They have varied body shape such as spherical, oval, elongated and flattened.

- vi. Cytoplasm is differentiated into ectoplasm and endoplasm.
- vii. Number and shape of nucleus also vary among protozoans.
- viii. Nutrition is holozoic and digestion is intracellular.
- ix. Respiration takes place by diffusion through general body surface.
- x. Excretion also occurs through general body surface or through cell anus (cytopyge).
- xi. Amount of salt and water in the body is maintained by contractile vacuole. The process is called osmoregulation.
- xii. Reproduction takes place by asexually and sexually both. Asexual reproduction by fission, budding, or sporulation and sexual reproduction by gamete formation.
- xiii. Encystment usually occurs in unfavourable condition.

Protozoan protists can be divided into four classes on the basis of their locomotory organelles:

Class 1: Flagellata or mastigophora

- i. Body is externally covered by Pellicle.
- ii. Their locomotion takes place through flagella.
- iii. They have single nucleus.
- iv. They are either free living or parasitic.

Examples: *Leishmania*, *Trypanosoma*, *Giardia* etc.

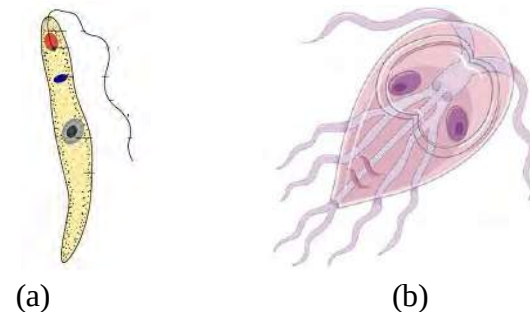


Figure 8.1.4 (a) *Leishmania* (b) *Giardia*

Class 2: Rhizopoda or Sarcodina

- i. Body is irregular shaped and externally bounded by plasma membrane.
- ii. They have pseudopodia for locomotion.
- iii. They are solitary, free living or parasitic.
- iv. Asexual reproduction takes place by fission.

Examples: *Amoeba*, *Entamoeba* etc.

Class 3: Sporozoa

- i. Their body is externally covered by pellicle.
- ii. They reproduce asexually and sexually.
- iii. They are endoparasites.

iv. They have no locomotory organelles.

Examples: *Plasmodium*, *Babesia*, *Monocystis* etc

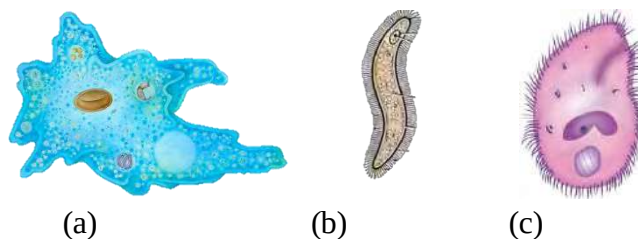


Figure 8.1.5 (a) *Amoeba* (b) *Monocystis* (c) *Balantidium*

Class 4: Ciliata

- Body shape is fixed because of the presence of pellicle as external covering.
- They move with the help of cilia.
- They are either free living or parasitic.
- Reproduction by asexually and sexually both.

Examples: *Paramecium*, *Balantidium*

Activity 8.1

Prepare a power point presentation on the classification kingdom Protista. Present it in the class and discuss.

8.1.3 *Paramecium caudatum* (SLIPPER ANIMALCULE)



- Have you seen the above organism before? What is its shape?
- Where can it be found?
- Is it multicellular or unicellular?
- What might be its locomotory organelles?
- Is it free living or parasitic?

A unicellular, free living and microscopic animalcule called *Paramecium* is shown in the figure mentioned above. It is found in freshwater rich in decaying organic matter. Its shape is like the sole of slipper, hence called slipper- animalcule. *Paramecium* moves with the help of minute cytoplasmic hair like projections arising from the general body surface called cilia.

Classification

Kingdom	:	Protista
Phylum	:	Protozoa

Class	:	Ciliata
Genus	:	<i>Paramecium</i>
Species	:	<i>caudatum</i>
Common name:		Slipper animalcule

Habit and Habitat

Among the several species, *Paramecium caudatum* is a most common which is found in freshwater like pond, streams, ditches, lakes which are rich in decaying organic matter. They are abundantly found in stagnant water and slow running streams. *Paramecium* is a free living unicellular microscopic ciliate moving with the help of cilia. It is also called infusorian animalcule as it is found in infusion of decaying animal and vegetable matter.

Activity 8.2

Objective: To identify the various parts of *Paramecium*

Apparatus required: Permanent slide of *Paramecium*, microscope

Procedure:

- i. Fix a permanent slide of *Paramecium* under a microscope.
- ii. Observe the slide.
- iii. Note down the structures seen on the chart paper. (Take the help of your teacher, if necessary).
- iv. Search on the internet more about *Paramecium*.
- v. Draw a labelled diagram and discuss.

Conclusion

A. External structure (Morphology)

a. Shape and size

Paramecium caudatum has slipper shaped or spindle shaped cell body so it is commonly called the 'Slipper Animalcule'. Its body is asymmetrical due to the presence of obliquely situated oral groove. Body is elongated and blunt at the anterior end, wider just below the middle region and somewhat pointed at the posterior end. Its ventral side is flat and marks the oral surface and dorsal side is called the aboral surface.

It is a microscopic organism and visible to the naked eye as a whitish or greyish spot. Among the several species, *Paramecium caudatum* is the largest measuring about 170µ-290 µ in length.

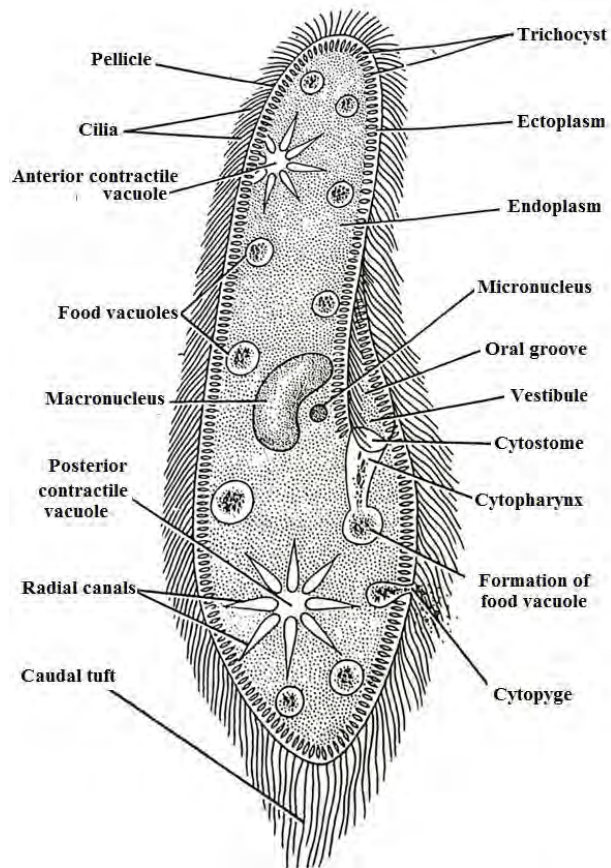


Figure 8.1.6 *Paramecium caudatum*

b. Pellicle:

Body of *Paramecium* is externally covered by a thin, double layered, elastic and gelatinous protective membrane called pellicle. Elastic nature of pellicle facilitates the organism to squeeze or pass through narrow places. Under high power microscope, the pellicle consists of regular series of hexagonal shaped depressions and from the centre of each hexagonal shape emerges out a cilium. The anterior and posterior margin of the hexagonal depressions have opening for the discharge of trichocyst.

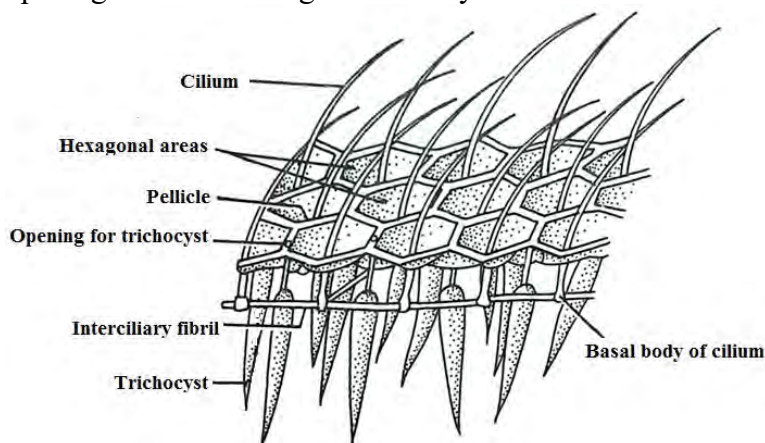


Figure 8.1.7 Surface view of small area of pellicle of *Paramecium*

c. Cilia:

The whole body of *Paramecium* is covered by numerous tiny hair like projections called cilia. Cilia are uniform sized and arranged in longitudinal rows except at the posterior end, where they are the long tuft, forming caudal tuft. Each cilium arises from a spherical basal granule or kinetosome lying just below the pellicle in ectoplasm.

Cilia are used by the organism for locomotion, food capturing and also as sensory receptors which respond to external stimuli. Caudal tuft helps to change the direction while swimming.

B. Internal structure

a. Cytoplasm

Cytoplasm of *Paramecium* is clearly differentiated into two regions.

- Ectoplasm: It is a thin, peripheral, clear and dense region of cytoplasm which includes trichocyst, basal bodies and fibrils.
- Endoplasm: It is the large central, granular and semifluid region which contains cell components such as nucleus, contractile vacuole, food vacuoles, mitochondria, golgibodies, ribosomes etc.

b. Trichocyst:

Trichocysts are small, peculiar, rod-like or oval shaped organelles found in ectoplasm beneath the pellicle alternating with basal bodies. They lie right angle to the body surface and open by small pores on the ridges of hexagonal areas of pellicle. Each trichocyst consists of an elongated shaft and a terminal pointed tip, called spike covered by a cap like structure. Trichocyst is filled with a refractive dense fluid having a swelling substance. Discharge of trichocyst is triggered by external stimuli such as touch, chemical, temperature, electric current etc.

Trichocysts are discharged as long, sticky threads in response to stimuli. At the moment of stimulation, the ectoplasm quickly contracts, separating the cap and spike of trichocyst. Consequently, water enters the sac of trichocyst and substance in the sac swells by absorbing water to form a filamentous spike for discharging out. A discharged trichocyst has an opaque spike like the inverted nail with a cap, attached to a long striated shaft. Shaft can't be seen in undischarged trichocyst.

Function: Trichocysts help to attach on solid object or substratum. They also help in offence and defence in some ciliates.

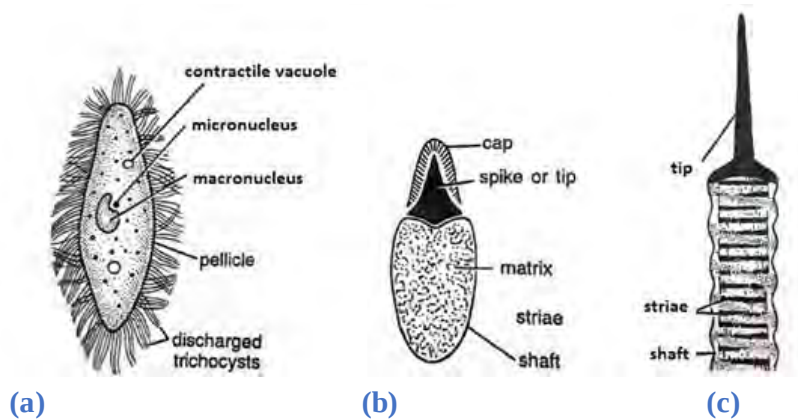


Figure 8.1.8 (a) *Paramecium* with discharged trichocyst (b) Undischarged trichocyst (c) discharged trichocyst

c. Nucleus:

Paramecium caudatum possess two types of nuclei and this is called nuclear dimorphism. Larger, bean shaped nucleus is called **macronucleus** or **meganucleus**. Its function is to regulate the metabolic activities of its cell. It is also called **somatic** or **vegetative nucleus**. Similarly, the small and spherical shaped nucleus lying close or at the concavity of macronucleus is called **micronucleus**. Micronucleus controls the reproductive activity of *Paramecium* and so it is also called generative nucleus.



Questions to think?

What will happen to *Paramecium* when micronucleus is removed from its cell body?

d. Contractile vacuole:

Unlike *Amoeba*, there are two large liquid filled contractile vacuoles in *Paramecium*, each fixed at the anterior and posterior position closer to aboral surface in endoplasm. Contractile vacuoles open outside through permanent pore in pellicle on aboral surface. Sometimes, they may disappear temporarily. Each contractile vacuole is surrounded by about six to ten long, narrow tubular structures called radiating canals or radial canals. The radial canals communicate with the interior part of body from where they take up excess water and pour into the central vacuole. When the vacuole becomes fully turgid then it contracts and discharges its content through permanent pore in the pellicle. Posterior contractile vacuole contracts more frequently than the anterior contractile vacuole. Since, more water enters this vacuole as it is nearer to the cytopharynx. Function of contractile vacuole is osmoregulation i.e. maintaining water and salt in the body.

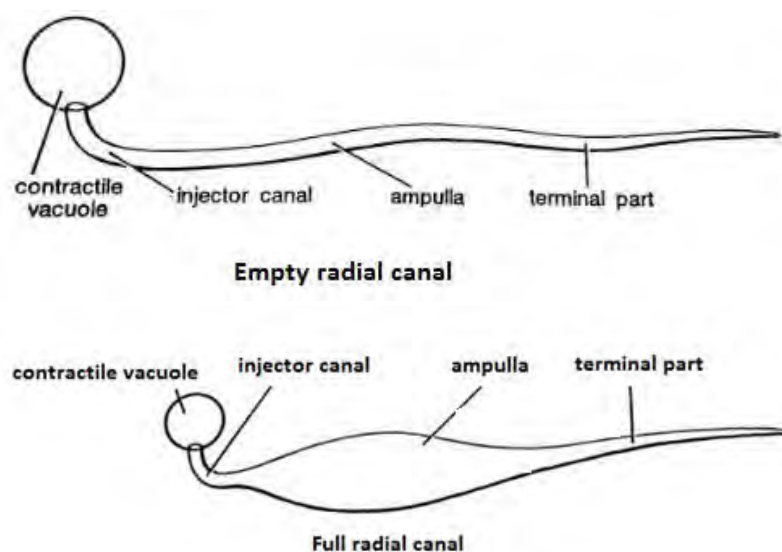


Figure 8.1.9 Radial Canal

e. Food vacuole:

Food vacuoles are also called gastroles which are roughly spherical, non-contractile structures with variable numbers and size. They are found embedded in endoplasm. Food vacuoles contain ingested food particles such as bacteria, small amount of fluid along with digestive enzymes bounded by a thin membrane. They are seen, moving with the streaming cytoplasm (cyclosis) in the clockwise direction throughout the body. During the course of movement, food particles are digested, absorbed and assimilated.

f. Oral groove:

Oral groove is a large oblique depression on the ventro-lateral side of the body, making the body of *Paramecium* asymmetrical shaped. Oral groove posteriorly leads into a short conical funnel shaped depression called vestibule. Vestibule leads posteriorly into cytopharynx through a fixed oval shaped opening called cytostome (cell mouth). Cytopharynx runs obliquely downward and form new food vacuole at its proximal end. Several rows of cilia are found lining the oral apparatus and beating action of these cilia help in collecting and passing down food particles. The food particles are finally trapped in food vacuole.

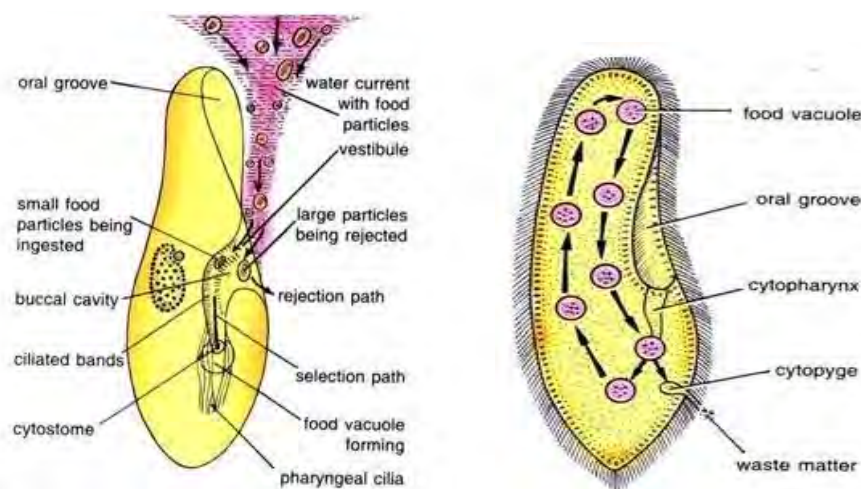


Figure 8.1.10 (a) Food particles with water current into the oral groove (b) Cyclosis

g. Cytophyge (cell anus):

At the time of egestion, a minute opening on the pellicle on ventral surface is visible, just behind the cytostome called cytophyge. Cytophyge is also called anal spot or cytoproct. This is used for expelling out undigested food particles.

Project Work:

Prepare a model of *Paramecium caudatum* with the help of locally available materials such as clay, thermocol etc.

Reproduction

Reproduction is the life process in which living beings produce offspring of their own kind for the continuation of their generation.

In *Paramecium*, asexual reproduction takes place by transverse binary fission and sexual reproduction takes place by various methods such as conjugation, endomixis, autogamy etc.

Transverse binary fission

This type of reproduction takes place during favourable condition at the availability of food, suitable temperature etc. *Paramecium caudatum* divides 2-3 times a day by this process. Entire process completes in about 1-2 hours. In transverse binary fission, *Paramecium* divides in such a way that plane of division is right angle to the axis of the body. In this process, division of nucleus (karyokinesis) is followed by the division of cytoplasm (cytokinesis). Following events occur for the completion of transverse binary fission:

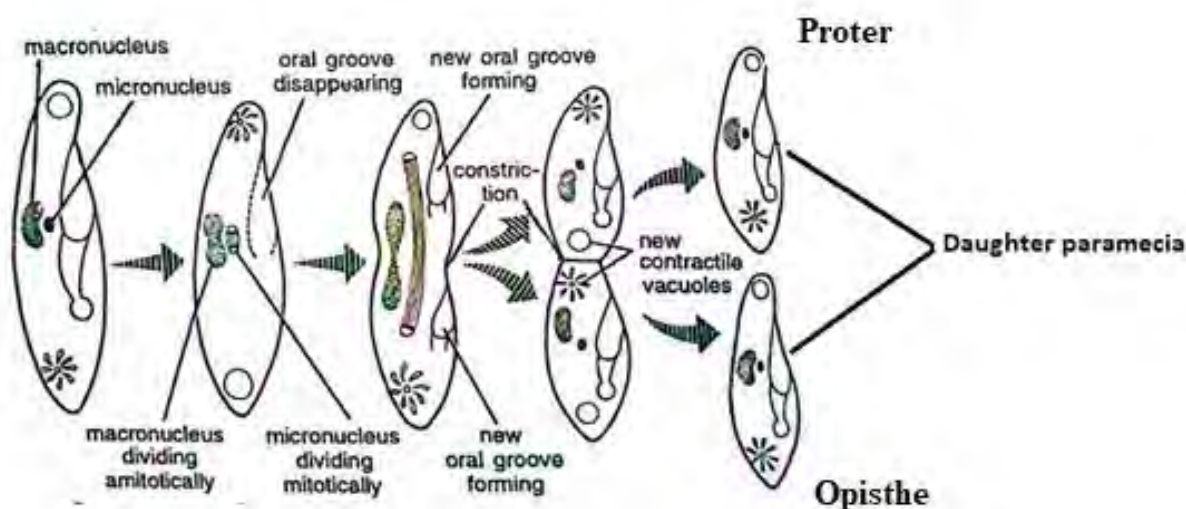


Figure 8.1.11 Transverse binary fission in *Paramecium*

- Paramecium* stops feeding and its oral groove or buccal structure also disappears.
- At that time, micronucleus divides by mitosis to form two daughter nuclei and each move towards the opposite end.
- Simultaneously, macronucleus becomes elongated and constricted at the middle to divide by amitosis. Daughter macronuclei also move to the opposite pole.
- Now, two oral grooves start to form, one at the anterior half and another at the posterior half on the ventral side.
- Each half develops a new contractile vacuole at the required position. Buccal structures also start to reappear.
- Meanwhile, a transverse constriction or furrow appears at the middle region which deepens and finally cytoplasm is also divided to form two daughter *Paramecia*.
- Anterior daughter *Paramecium* is called **proter** and posterior one is called **opisthe**.

Daughter *Paramecia* produced by this process are called clone because they are genetically similar. After many generations, the rate of binary fission becomes slow and may stop. So, they should be rejuvenated frequently by conjugation.

Conjugation

It is the simplest method of sexual reproduction in which temporary union of two *Paramecia* of same species but different strain takes place to exchange their genetic materials. It is a significant process that should occur frequently between transverse binary fissions because after many generations (about 300 asexual generations), *Paramecium* is unable to reproduce

asexually. *Paramecia* undergoing conjugation are morphologically similar but physiologically different, called **pre-conjugants**. Factors which induce conjugation are:

- i. Insufficient supply of food or starvation.
- ii. Being genetically and physiologically weak and small due to continued binary fission.
- iii. Sudden darkness or fall in temperature in some species.
- iv. A specific protein present in cilia of mating individual.

Events that occur in conjugation

1. Two *Paramecium caudatum* of different strain or mating type come in contact ventrally and unite by their oral grooves.
2. Buccal structures disappear and feeding is also stopped.
3. At the point of contact, pellicle and ectoplasm also dissolve forming protoplasmic bridge between them and *Paramecia* at this moment are called **conjugants**.
4. The macronucleus degenerates into pieces and absorbed by cytoplasm. Meanwhile, micronucleus grows first and divides by meiosis to yield four haploid daughter micronuclei.
5. Out of four daughter micronuclei, three get degenerated and remaining one divides by mitosis to produce two unequal sized pronuclei or gametic nuclei.
6. Among two pronuclei, smaller sized and active nucleus behaves as migratory or male gametic nucleus whereas larger sized and passive nucleus behaves as stationary or female gametic nucleus.
7. Each migratory or male gametic nucleus moves from one conjugant to another through protoplasmic bridge and fuses with stationary or female gametic nucleus.
8. Now, zygote nucleus or synkaryon is formed. This phenomenon of complete fusion of two nuclei from different individual is also called amphimixis.
9. After 12- 48 hours of union of two individuals, they become separated and now called ex-conjugants.
10. In each ex-conjugant, zygote nucleus divides thrice by mitosis to produce eight nuclei. Out of them, four nuclei become enlarged to form macronuclei and remaining four become micronuclei.
11. Among four micronuclei, three micronuclei get degenerated.
12. Now, remaining micronucleus of each ex-conjugant divides mitotically and transverse binary fission in *Paramecium* occurs to produce two daughter *Paramecia*, each with two macronuclei and one micronucleus.
13. The daughter *Paramecium*, so produced, again divides by binary fission to produce two *Paramecia*, each with one micronucleus and one macronucleus.
14. In this way, altogether eight daughter *Paramecia* are produced at the end which are genetically different.

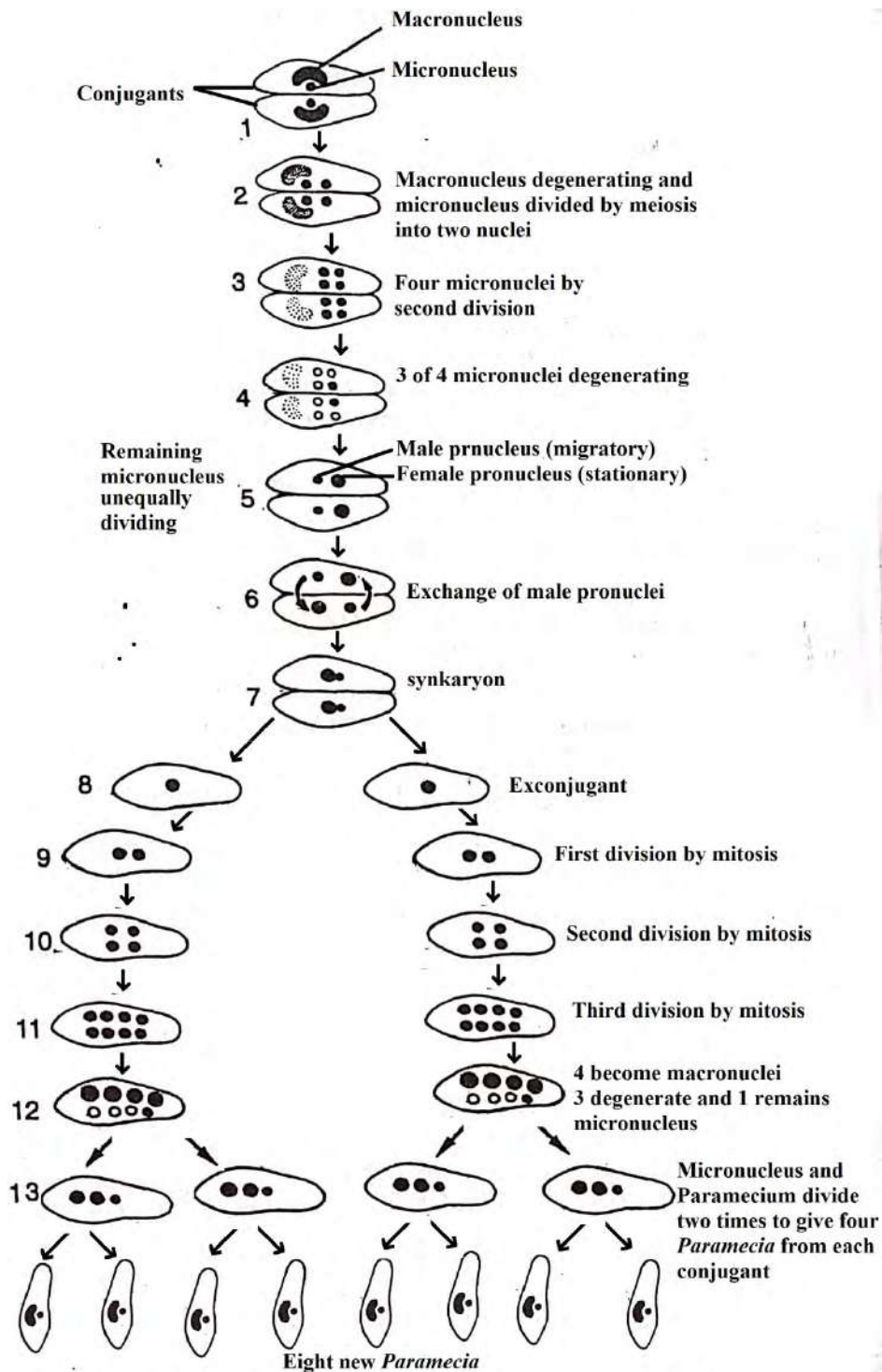


Figure 8.1.12 Conjugation in *Paramecium*

Significance of conjugation

- Conjugation brings nuclear re-arrangement or re-organization which is essential for the continuation of binary fission.
- Conjugation is the means of rejuvenation maintaining vitality and genetic vigour in offsprings.
- It brings about the replacement of macro or meganucleus with the material from zygote nucleus.

- iv. Conjugation brings variation in offsprings.
- v. In conjugation, *Paramecium* multiplies significantly, as eight offsprings are produced at the end.

Do you know?

Autogamy: It is the process of nuclear re-organization and fusion within a single individual of *Paramecium aurelia*, also called self-conjugation.

Endomixis: It is also a process of nuclear re-organization but without fusion in *Paramecium aurelia*.

Activity 8.3

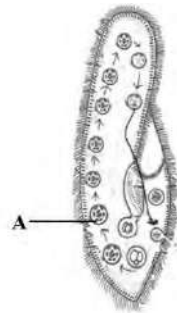
Enlist the differences between transverse binary fission and conjugation on chart paper or prepare power point presentation and present them in the class for discussion.

EXERCISE

A. Tick the correct alternative.

1. Which of the following is a bioluminescent protist?
 - a. *Physarum*
 - b. *Dictyostelium*
 - c. *Noctiluca*
 - d. *Leishmania*,
2. In which of the following mixotrophic mode of nutrition is found?
 - a. *Amoeba*
 - b. *Euglena*
 - c. *Plasmodium*
 - d. *Entamoeba*
3. Which of the following is a fungus like protistan?
 - a. *Foligo*
 - b. *Peranema*
 - c. *Giardia*
 - d. *Monocystis*
4. What is the cell anus of the protozoans called?
 - a. cytoproct
 - b. cytopharynx
 - c. cytostome
 - d. cyclosis
5. In protozoans, which of the following perform osmoregulation?
 - a. food vacuole
 - b. contractile vacuole
 - c. nucleus
 - d. oral groove

6. Which of the following protozoan move by flagella?
 - a. *Leishmania*
 - b. *Plasmodium*
 - c. *Paramecium*
 - d. *Babesia*
7. *Paramecium* is the inhabitant of fresh water where there is regular inflow of water current with food particles into the body from outside. Which of the following structure is responsible for maintaining osmotic balance in the body?
 - a. mitochondria
 - b. food vacuole
 - c. contractile vacuole
 - d. caudal tuft
8. Which process is responsible for the movement of part A in the given diagram?



- a. cyclosis
 - b. osmoregulation
 - c. cytokinesis
 - d. endomixis
9. What may happen when macronucleus in paramecium is eliminated?
 - a. it will not able to reproduce.
 - b. it will die soon.
 - c. osmoregulation will be disturbed.
 - d. No cyclosis
10. What is the function of contractile vacuole in paramecium?
 - a. thermoregulation
 - b. hormonal regulation
 - c. osmoregulation
 - d. digestion
11. How many radiating canals are found in paramecium?
 - a. 2-5
 - b. 6-10
 - c. 11-15
 - d. 6-15
12. How many daughter Paramecia are formed after each conjugation?
 - a. four
 - b. eight

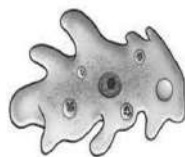
- c. twelve
 - d. two
13. What will happen when *Paramecium* can't perform conjugation?
- a. *Paramecium* becomes stronger.
 - b. *Paramecium* becomes weaker.
 - c. fusion of meganuclei
 - d. rejuvenation occurs.
14. Which type of digestion is found in *Paramecium*?
- a. extracellular
 - b. intracellular
 - c. both extracellular and intracellular
 - d. oral digestion
15. Which of the following is the external protective cover in *Paramecium*?
- a. pellicle
 - b. plasmalemma
 - c. cell membrane
 - d. cuticle
16. Which organelle is used for locomotion in *Paramecium*?
- a. cilia
 - b. flagella
 - c. pseudopodia
 - d. setae
17. Which of the following part help in feeding in *Paramecium*?
- a. cytoproct
 - b. oral groove
 - c. caudal tuft
 - d. radial canal

B. Answer the following questions:

1. In which group of Protista do following organisms belong to? Write any four differences between these groups.

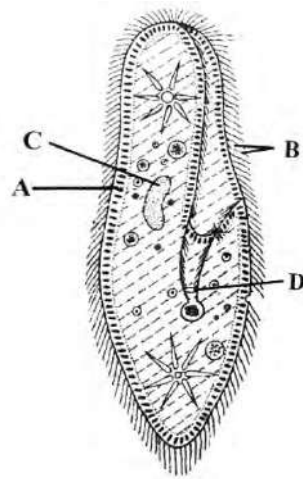


A

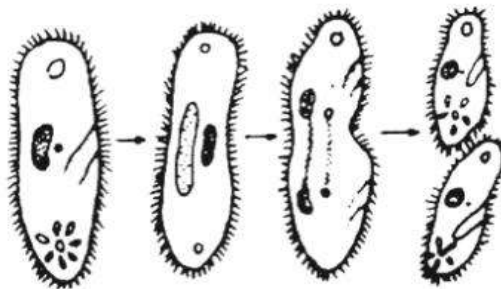


B

2. What are the slime moulds? Enlist their characters.
3. Observe the diagram given below and answer the following questions:



- i. Identify the parts A, B, C and D.
 - ii. What is the function of C and B?
 - iii. B is long at the posterior end. Write its function?
4. Draw neat and labelled diagram *Paramecium caudatum*.
 5. What are trichocysts? Discuss its working mechanism.
 6. What are the significances of conjugation in *Paramecium*?
 7. The process of maintenance of salt and water in the body is called osmoregulation. Which organelle in paramecium helps in this process? Describe briefly.
 8. *Paramecium* shows nuclear dimorphism which indicates it has two types of nucleus called macronucleus and micronucleus. What differences are found in micronucleus and macro nucleus?
 9. Observe the diagram given below and answer the following question



- i. Which method of asexual reproduction is shown in the diagram?
 - ii. In which condition does this process occur?
 - iii. Briefly describe this process.
10. Why *Paramecium* is called slipper animalcule? Describe the external features of *Paramecium caudatum* with well labelled diagram.
 11. Which method of reproduction is adopted by *Paramecium* during unfavourable condition like scarcity of food, sudden fall in temperature etc? Describe with necessary diagram.

Chapter 8.2

Plasmodium vivax

8.1.4 *Plasmodium vivax*

Let's discuss the given questions.

- i. What do you know about malaria?
- ii. Why is malaria a significant health problem globally?
- iii. What do you think about the strategies to prevent malaria?

Plasmodium is a protozoan parasite that causes dreadful disease called malaria in human beings and other animals. There are more than fifty known species of *Plasmodium*, causing such disease in man and other animals like lizards, birds and other mammals. So, they are commonly called malarial fever parasites. Among them, four species of *Plasmodium* namely *Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale*, *Plasmodium falciparum* are most common to human beings causing different types of malaria.

Classification

Kingdom : Protista
Phylum : Protozoa
Class : Sporozoa
Genus : *Plasmodium*
Species : *vivax*

Common name: **Malarial parasite**

Habit and habitat:

Plasmodium vivax is distributed in the temperate or warmer region of the world such as Nepal, India, and Sri Lanka, Bangladesh etc. It is an intracellular blood parasite in human, thriving in RBC and liver cells but it is extracellular in female *Anopheles* mosquito living in gut and salivary glands. Female *Anopheles* mosquito is also called **vector** since it is the carrier of *Plasmodium* parasite from malaria infected person to healthy person. *Plasmodium vivax* causes tertian malaria in human which is characterized by a 48-hour cycle between the first malaria fever and subsequent recurrence of chills and fever.

Do you know?

In the past, it was believed that the cause of malaria is bad air or foul gases of marshy areas and hence the name malaria (Gr; mala=bad; aria=air) was given. Later in 1880, Charles Laveran reported for the first time that blood of malarial patient contains *Plasmodium* as parasites. But it was in mystery for a long time that how these parasites were transmitted to human beings. Then, Patrick Mason in 1894 suggested that there is role of mosquitoes in the transmission of this disease from person to person.



Figure 8.1.13 Female *Anopheles* mosquito

Structure:

Among the several stages of *Plasmodium vivax* in its life cycle, trophozoite is the mature and adult form which lives in RBC of human. It is somewhat spherical or amoeboid shaped, uninucleated and vacuolated cell filled with granular cytoplasm. Under the electron microscopy, it shows following major structural details:

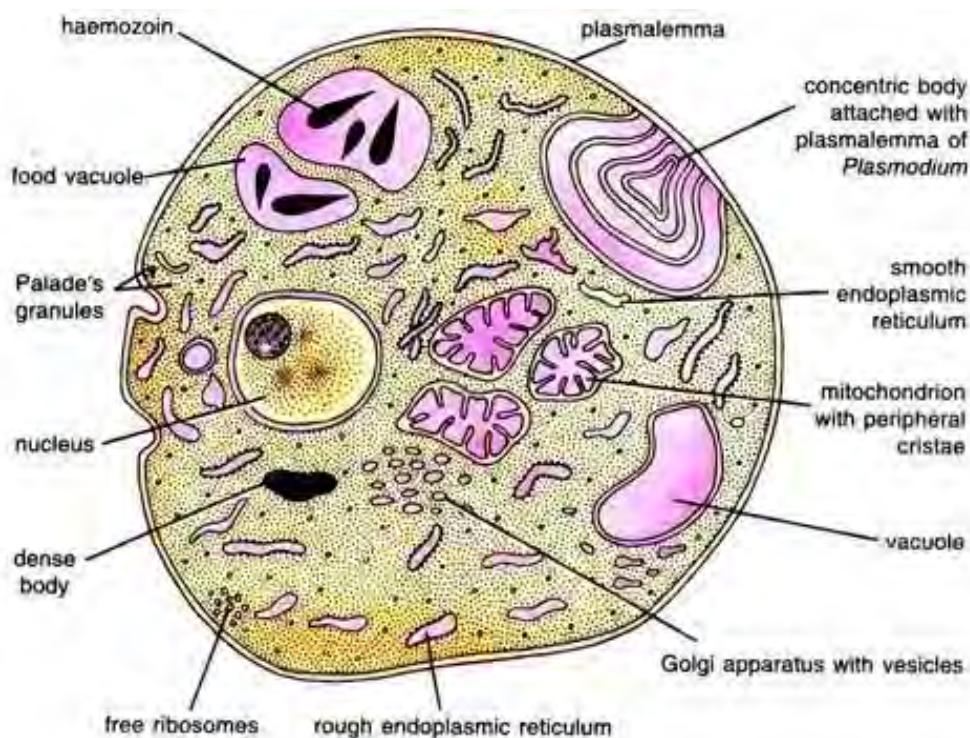


Figure 8.1.14 A mature trophozoite of *Plasmodium*

- i. It is externally covered by double layered membrane called plasmalemma.
- ii. Nucleus is large and eccentric, surrounded by double layered nuclear membrane with RNA particles. Nucleoplasm contains a nucleolus, granules and fine fibrils.
- iii. Food vacuoles containing hemozoin are also found scattered in cytoplasm.
- iv. The endoplasmic reticulum is in the form of simple vesicles of variable shape and the vesicles may be rough or smooth.
- v. Several mitochondria are found in cytoplasm they are externally bounded by double layered membrane with peripheral cristae.

- vi. Concentric body is found in cytoplasm which seems to be developed from plasmalemma.
- vii. There are no locomotory organs and contractile vacuoles in it.

Life cycle

An organism which harbors parasites is known as host. *Plasmodium vivax* is the digenetic parasite; completing its life cycle in two hosts: **Female *Anopheles* mosquito** and **human**. In this case, humans suffer from malaria but mosquitoes are not harmed.

Female *Anopheles* mosquito is considered primary host as sexual phases of life cycle of the parasites are passed in it whereas human is referred secondary host in which *Plasmodium* completes its asexual cycle.

The female *Anopheles* mosquito is also called a vector as it transmits malarial parasites from one host to another.

1. Asexual life cycle of *Plasmodium vivax* in human

a. **Infection or inoculation of sporozoites**

The infective female *Anopheles* mosquito carries infectious stage of *Plasmodium vivax* called sporozoite in its salivary gland. When it bites a healthy person for sucking blood, large numbers of sporozoites are inoculated along with saliva. It pours saliva at the time of blood sucking because it contains anticoagulants which prevent the clotting of blood so that it is able to suck blood continuously. Structure of a sporozoite under electron microscopy is given below:

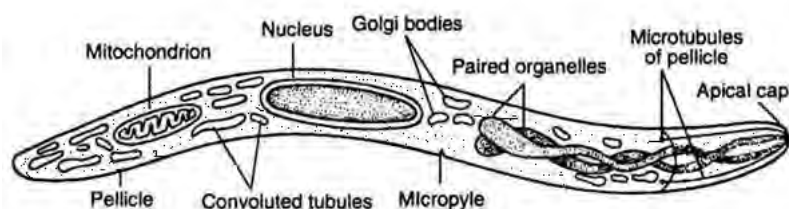


Figure 8.1.15 Structure of sporozoite

- i. Sporozoite is a microscopic, unnucleated, and sickle shaped structure with somewhat tapering ends. It measures about 12 μ length and 1 μ width.
- ii. It is externally covered by a thin, firm and elastic membrane called pellicle.
- iii. It shows wriggling movement because of the presence of longitudinally arranged contractile microtubules.
- iv. Paired organelles which secrete lytic juice, open into apical cap at the anterior end. Lytic juice helps in the penetration of targeted cells of host.
- v. Similarly, convoluted tubules of unknown function, a centrally placed large prominent nucleus and a mitochondrion are also found embedded in the cytoplasm.

Project work

Mention differences between trophozoite and sporozoite of *Plasmodium vivax* on the chart paper. Present it in the class and discuss.

b. Schizogony in liver

After the sporozoites are inoculated into the human blood by mosquito, they disappear from blood stream after half an hour and enter hepatic or liver cells. Sporozoites penetrate liver cells with the help of lytic enzymes secreted by paired organelles and multiply there asexually by a process called schizogony. The daughter cells so formed are known as merozoites. Liver schizogony can be discussed in following headings:

i. Pre-erythrocytic schizogony (First schizogony in liver cells)

After the entry of sporozoite in liver cell, it grows in size and shape, becomes spherical to form schizont. Schizont divides by schizogony (multiple fission) to form thousands of un-nucleated cells called cryptomerozoites. Now, liver cells rupture and cryptomerozoites are released into liver sinusoids.

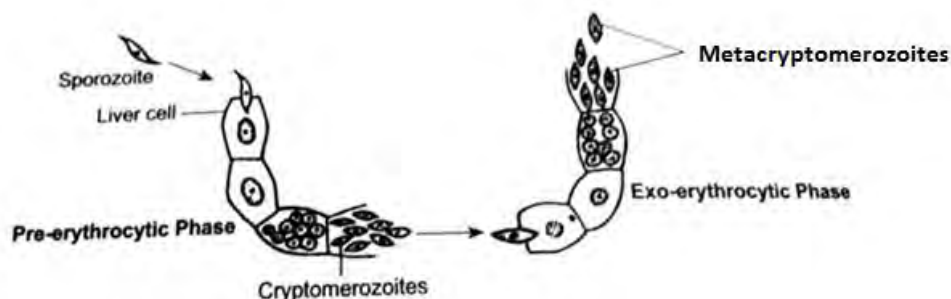


Figure 8.1.16 Schizogony in liver

ii. Exo-erythrocytic schizogony (Second schizogony in liver cells)

From liver sinusoids, Cryptomerozoites enter fresh liver cells; grow into circular schizonts which feed on the liver content. They undergo series of schizogony there and finally produce thousands of metacryptomerozoites which are released by the bursting of the liver cells. Metacryptomerozoites are of two types: smaller and more numerous micro-metacryptomerozoites enter blood and attack RBCs. Larger and fewer macro-metacryptomerozoites again attack fresh liver cells.

Do you know?

The time period between initial sporozoite infection and first appearance of parasites in blood is called pre-patent period. It is about 8 days in *Plasmodium vivax*.

c. Schizogony in RBC or erythrocytic schizogony

After entering the blood stream, micro-metacryptomerozoites invade RBCs and pass through several stages that are discussed below:

i. Micrometacryptomerozoites feed nutrients from RBC; and get vacuolated and rounded to become young trophozoite.

- ii. As the trophozoite grows, a central large non-contractile vacuole pushes the nucleus and cytoplasm towards the peiphery. This stage seems to be a ring with a gem like form called **signet ring stage**. Digestive enzymes of the parasite break down haemoglobin into protein and hematin. Protein is used as food by trophozoite and hematin forms a toxic malarial pigment called **haemozoin** which is yellowish brown coloured fine granules.
- iii. The signet ring later develops into **amoeboid stage** having pseudopodial processes. Small red eosinophilic granules appear in cytoplasm of RBCs called schuffner's dots and RBC becomes enlarged and pale yellow at this time.
- iv. Amoeboid stage after active feeding changes into an enlarged and rounded structure called **schizont**. It undergoes schizogony in which nucleus divides mitotically into 12- 24 nuclei and each remaining in the periphery and surrounded by cytoplasm to form oval shaped merozoites. The peripheral arrangement of the merozoites with central mass of unused cytoplasm, and haemozoin resembles like the arrangement of petals in rose and hence this stage is named as **Rosette stage**.

The red blood cells rupture to release large number of merozoites in blood plasma. These merozoites, again, attack fresh RBC and finally repeat the cycle in RBC. One Erythrocytic schizogony cycle completes in 48 hours.

d) Post erythrocytic schizogony

Sometimes, some merozoites may again attack liver cells and undergo schizogony which is referred as post-erythrocytic schizogony.

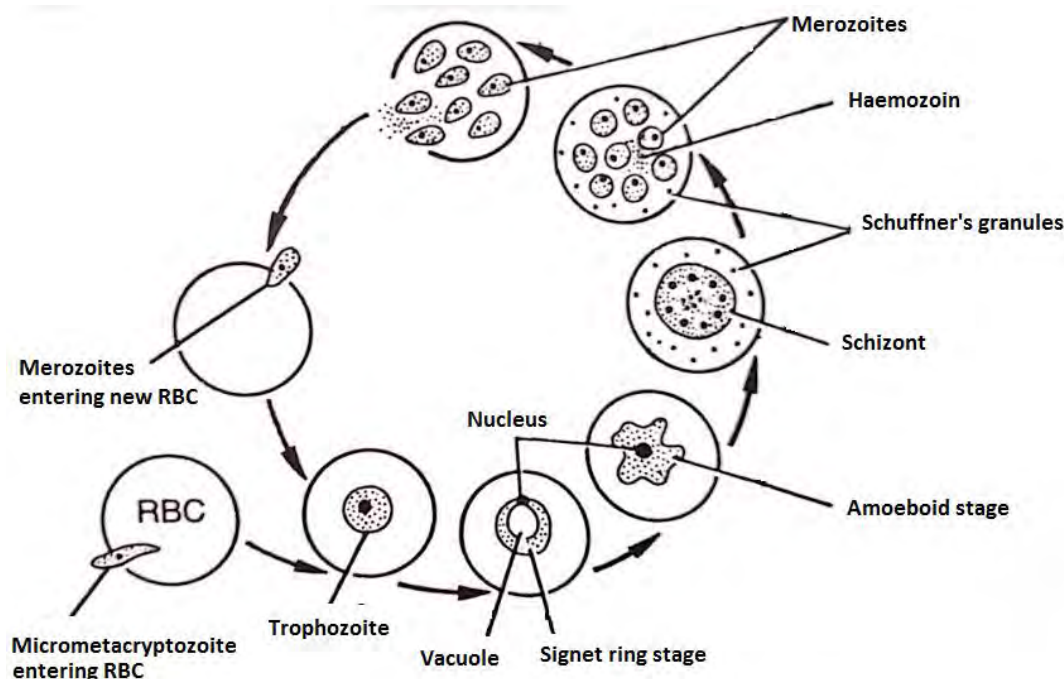


Figure 8.1.17 Schizogony in RBC

Do you know?

Release of haemozoin toxin and merozoites to the blood plasma by the rupture of RBC causes malaria fever in which the patient suffers from chills, shivering, high temperature and

convulsion with profuse sweating. It comes at the interval of every 48 hours i.e at the completion of one erythrocytic cycle which releases merozoites and haemozoin in blood plasma.

Incubation period is the time period between the entry of pathogen and appearance of first symptom. For *Plasmodium vivax* it is 14 days in average.

e. Formation of gametocytes

After the many generations of schizogony in RBCs, some merozoites slowly increase in size producing large amount of haemozoin and transform into specific structures called gametocytes. Gametocytes are of two types: - macrogametocytes and microgametocytes.

Macrogametocytes are called female gametocytes which are less numerous, larger with small compact nucleus and food laden cytoplasm.

Microgametocytes are called male gametocytes which are more numerous, smaller with clear cytoplasm and large central nucleus.



Questions to think?

Why should some merozoites be transformed into gametocytes after the many generations of erythrocytic schizogony?

These gametocytes do not develop further but remain inactive in human blood for several weeks. They get either degenerated in human blood or sucked up with blood by female *Anopheles* mosquito to continue their sexual cycle.

2. Sexual phase of *Plasmodium vivax* in female *Anopheles* mosquito

a. Sucking up blood by the mosquito

Female *Anopheles* mosquito sucks blood of malaria infected person with gametocytes and other phases of this parasite in RBCs. In the alimentary canal of mosquito, Gametocytes remain undigested because they have developed adaptation against digestive enzymes of the mosquito.

b. Gametogony (Development of gametes)

Gametogony is the process of development of male and female gametes from gametocytes. Microgametocytes give rise to the formation of male gametes or microgametes. In this process, microgametocytes in the stomach of mosquito undergo ex-flagellation process, which is favoured by the sudden fall in temperature as the microgametocytes are transferred from warm blooded human to cold-blooded mosquito. During this process, nucleus of microgametocyte divides by mitosis and produce about 6-8 haploid nuclei which lie in the periphery of cytoplasm and then cytoplasm along with each nucleus is projected out in the form of flagellar structure. Each projection separates as a mature and motile male gamete.

Similarly, macrogametocyte undergoes some structural re-organization and grows into a non-motile gamete called female gamete or ovum.

Do you know?

According to Bano (1959), only the zygote in *Plasmodium* is diploid, while all stages of life cycle, including gametes, are haploid. It is so because the zygote initially divides by meiosis.

c. Fertilization and ookinete formation:

The macrogamete or female gamete develops a small protuberance or outgrowth called receptive cone which is to receive micro-gamete or male gamete at the time of fertilization. Many microgametes approach the female gamete but only one of them is able to enter the macrogamete or ovum by penetrating the receptive cone. Fertilization takes place to form zygote and this process is also called syngamy.

**Questions to think?**

What is the difference between syngamy and synkaryon?

Zygote remains rounded and motionless for about 24 hours and then gets elongated to become a motile worm like (vermiform) structure called ookinete or vermicule which measure about 15μ - 20μ in length and 3μ in breadth.

d. Encystment and sporogony

Ookinete penetrates the wall of stomach of mosquito and it remains attached beneath the outer epithelial layer of stomach. Then, it becomes spherical and undergoes encystment by developing a thin, elastic, membranous cyst wall. The cyst wall is secreted by ookinete itself and with some tissues of stomach of mosquito. The encysted ookinete is now referred as oocyst. About 50 or more oocysts can be seen on the stomach of an infected mosquito.

Sporogony is the process of asexual multiplication to form sporozoites in the oocyst. In this process, the nucleus first divides by meiosis and, subsequently, by mitosis to form several haploid daughter nuclei. Meanwhile, cytoplasm also develops many large vacuoles making it sponge like appearance. Numerous cytoplasmic masses are also formed that take up individual nuclei. Then, each cytoplasmic mass along with a daughter nucleus and vacuoles give rise to a slender, spindle shaped haploid cell called a sporozoite. A mature oocyst may contain about 10,000 sporozoites. Each sporozoite is a sickle shaped structure which is pointed at the ends and broad at the middle bearing a large prominent nucleus with other cell organelles in cytoplasm. By the rupture of mature oocyst, sporozoites are released into haemocoelom or body cavity of the *Anopheles* mosquito, from where they reach the salivary gland and enter the duct of hypopharynx to be discharged with saliva while biting a healthy human. Then, another asexual phase of life cycle continues in human.

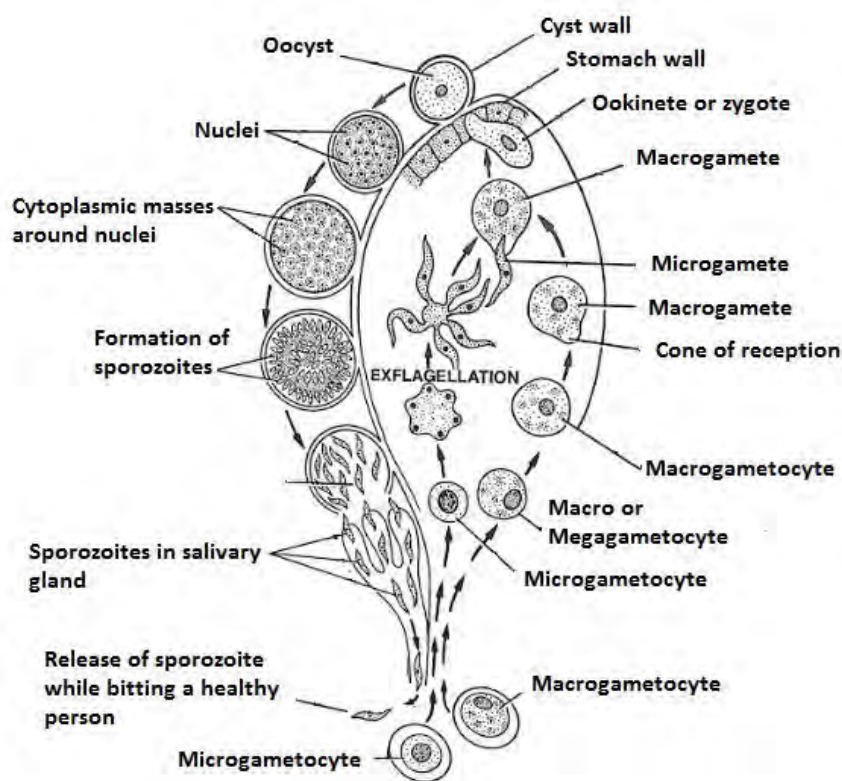


Figure 8.1.18 Sexual Cycle of *Plasmodium vivax* in mosquito

8.1.5 Concept of *Plasmodium falciparum*

Plasmodium falciparum is worldwide in distribution. It is mainly distributed in tropical, subtropical and warmer regions of the world. It causes malignant tertian malaria or pernicious malaria fever almost continuously or at the interval of about 2 days. It causes a serious condition in human called **Blackwater fever** which is characterized by the complete destruction of RBCs and haematuria (discharging the characteristic black or dark coloured urine). It is most dangerous species of *Plasmodium* that causes cerebral malaria. Death rate is higher in the infection of *P. falciparum*.

Incubation period for this disease is about 12 days in average. Pre-patent period is about 5 days due to the absence of exo-erythrocytic schizogony. In the signet ring stage, a small ring is situated at the edge of RBC with two chromatin dots. Trophozoite is small as compared to that of *Plasmodium vivax* and sometimes there are two trophozoites in one RBC. Schizont is very small measuring 5 μ diameter. Haemozoin is black coloured and RBCs are not enlarged but get shrunk and greenish coloured. No schuffners dots are seen but **maure's dots** are found in RBC. Schizonts in RBC form 8-36 merozoites which are not seen in peripheral blood and gametocytes are crescentic shaped.

Comparative study of four species of *Plasmodium* infecting human beings.

S.N.	Characters	<i>P. vivax</i>	<i>P. malariae</i>	<i>P. ovale</i>	<i>P. falciparum</i>
1.	Type of malaria fever and its effects	Benign tertian Low death rate	Quartan severe	Ovale or mild tertian severe	Malignant tertian. Death rate high

2.	Distribution	Worldwide specially in tropical, subtropical and warmer temperate regions	Worldwide, in tropical and subtropical region	Africa, in tropical region	Worldwide specially in tropical, subtropical and warmer temperate regions
3.	Incubation period	14 days	18-24 days	14 days	12 days
4.	Duration of erythrocytic cycle	48 hours	72 hours	48 hours	38-48 hours
5.	RBC of host	Enlarged and red schuffners dots seen	Not enlarged, ziemanns dots seen	Slightly enlarged, schuffners dots seen	Not enlarged, greenish Maurers dots seen

8.1.6 Economic importance of *Plasmodium*

Plasmodium vivax has no any harmful effect inside the body of *Anopheles* but it is pathogenic to human being causing a disease, **Benign tertian malaria**. The symptoms in the case of *P.vivax* appear after 14 days of initial infection. This time is utilized by the parasite to establish malarial symptoms. For this, large number of parasites continues their life cycle in the RBCs. When all the schizonts in RBC burst and made free, merozoites along with haemozoin are released in to the plasma inducing fever to the person because haemozoin is a toxin. Each attack of fever consists of three stages:

- i. **Cold stage:** In this stage, patient feels much cold with shivering and chattering teeth.
- ii. **Hot stage:** As the cold stage or chill subsides, the body temperature increases up to 106°F with a terrible headache.
- iii. **Sweating stage:** Patient sweats profusely in this stage due to lowering of temperature. Temperature becomes normal until the next attack of fever (in 48 hours).

Other symptoms of malaria are anaemia, haemolysis, splenomegaly (enlargement of spleen) etc.

Control measures of mosquito

1. Adult mosquitoes can be destructed by various methods like manual killing, using traps, fumigation, spraying insecticides etc.
2. Swampy areas, marshes, stagnant water such as pools ponds ditches should be removed from human dwelling areas as they are the breeding places of mosquito.
3. Open drains should be closed.
4. Tin cans, bucket, unused tyre, barrels etc. should be removed because they serve as breeding places for mosquito.
5. Bushes and shrubs should be cleared off.
6. Destructing the breeding places, such as water reservoir of mosquito by spraying oil, kerosene, and other chemicals.
7. Biological control of mosquito can be done by the help of predator fishes like *Gambusia*, trout, stickle back in ponds, pools, ditches and other water reservoirs.

Activity 8.4

Prepare a power point presentation on the disease 'Malaria' by visiting a nearby hospital and searching on the internet. Present it in the class and discuss.

EXERCISE

A. Tick the correct alternative.

- Which of the following organism is the carrier (vector) for *Plasmodium*?
 - male *Anopheles*
 - male *Culex*
 - female *Culex*
 - female *Anopheles*
- Which of the following statement is correct for the life cycle of *Plasmodium vivax*?
 - Sexual phase of *Plasmodium* passes in human.
 - Merozoites are formed in *Anopheles* from sporozoites.
 - Plasmodium vivax* is transmitted from infected person to healthy person by direct touching.
 - Asexual reproduction of *P. vivax* occurs in liver and RBC but sexual reproduction in *Anopheles*.
- Which of the following is the infective stage of *Plasmodium*?
 - signet ring
 - trophozoite
 - sporozoite
 - amoeboid
- What is the function part X in the given diagram?



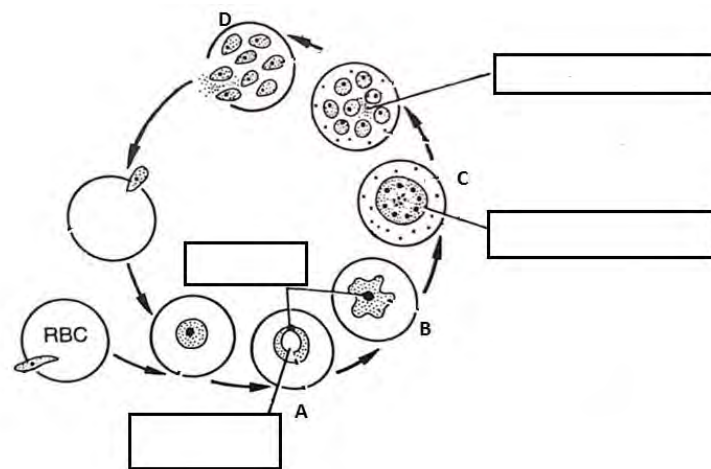
- secretion of lytic juice
 - wriggling movement
 - feeding
 - unknown function
- In malaria, which event is related directly to the periodic fever and chills in erythrocytic schizogony?
 - invasion of RBCs by merozoite
 - haemoglobin digestion by parasite
 - bursting of RBCs and release of merozoites with haemozoin
 - formation of gametocytes
 - In which of the following, pre-erythrocytic phase of *Plasmodium* occur?
 - white blood cells
 - plasma
 - red blood cells
 - liver cells

7. Who discovered the relationship between malaria and mosquito?
 - a. Laveran
 - b. Patric manson
 - c. Golgi
 - d. Ronald ross
8. In which of the following does ex-flagellation occurs?
 - a. macrogametocyte
 - b. microgametocyte
 - c. sporozoite
 - d. ookinete
9. In *Plasmodium*, zygote after about 24 hours transforms into a motile worm like structure called....
 - a. oocyst
 - b. ookinete
 - c. sporocyst
 - d. syngamous
10. In which stage schuffners dots are found in the parasite?
 - a. sporozoite
 - b. trophozoite
 - c. amoeboid
 - d. schizont
11. The fish which is commonly used to kill mosquito larva is
 - a. rahu
 - b. naini
 - c. grass carp
 - d. *Gambusia*
12. Which of the following is the correct sequence in the sexual cycle of *Plasmodium*?
 - a. sporozoite - gametocytes – zygote – ookinete – oocyst
 - b. oocyst- sporozoite - gametocytes – zygote – ookinete
 - c. gametocytes – zygote – ookinete – oocyst- sporozoite
 - d. ookinete – oocyst- sporozoite – gametocytes – zygote
13. Which of the following is the diploid form in the life cycle of *Plasmodium*?
 - a. trophozoite
 - b. sporozoite
 - c. zygote
 - d. merozoite

B. Answer the following questions.

1. Define schizogony. Explain various types of schizogony in the life cycle of *Plasmodium vivax* with necessary diagram
2. *Plasmodium* is a digenetic parasite that completes life cycle in two hosts. The asexual phase of life cycle passes in human being. Now, identify the organism in which it completes its sexual life cycle. Also, explain how it completes sexual cycle in this organism.

3. Draw neat and labelled diagram of sporozoite.
4. Swarnim said that a spherical shaped, mature, adult and vacuolated form of *Plasmodium* is sporozoite. Is it true? Give reason.
5. Describe liver schizogony with required diagrams.
6. Malaria is a dreadful communicable disease with worldwide distribution. Can it be prevented? Support your answer with some points.
7. Briefly describe the species of *Plasmodium* that causes blackwater fever.
8. How encystment and sporogony occurs on the wall of stomach of *Anopheles*?
9. Compare and contrast the forms of *Plasmodium vivax* which are characterized as feeding stage and infective stage.
10. What is erythrocytic schizogony? Describe its stages in life cycle of *Plasmodium*.
11. Study the given diagram and answer the following questions.



- i. Which phase is shown in the figure?
- ii. Label the stage A, B, C and D.
- iii. Copy the diagram and fill up the boxes.

Chapter 8.3

ANIMALIA

8.2.1 SOME TERMS USED IN BIOLOGY

1. **Level of organization:** Depending upon the number and degree of complexity or specialization of cells present in an animal, following body organizations are found in animals:
 - i. Cellular level of body organization: In primitive multicellular organisms like sponges, there is no co-ordination among the cells and cells are not organized to form tissues. Individual cell performs its own function. This is cellular level of body organization.
 - ii. Tissue level of body organization: In coelenterates, certain cells are organized together to form tissues which is called tissue level of body organization. Example: Nerve cells forming nerve net in *Hydra*.
 - iii. Organ-system level of body organization: In multicellular animals from platyhelminthes to chordates, tissues are aggregated into organs and organs are co-ordinated or associated to form a particular system performing specific function such as digestion, circulation, respiration etc.
2. **Body plan:** body plan in animals can be divided into following types:
 - i. Cell aggregate plan: In this, body consists of aggregation of many cells where individual cell functions independently. There is no tissue formation in this type of body plan. It is only found in porifera phylum.

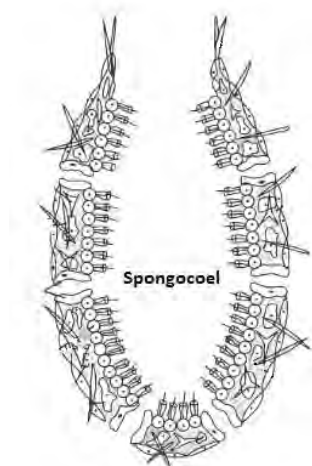


Figure 8.2.1 Cell aggregate body plan in sponges

- ii. Blind sac plan: Body contains a single cavity which blindly ends at the posterior side. There is a single opening at the anterior end. It is found in coelenterates and some platyhelminthes.

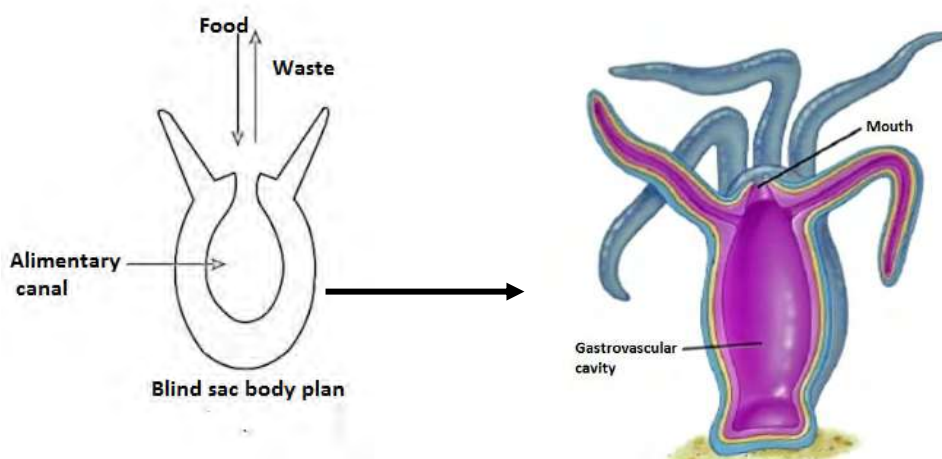


Figure 8.2.2 Blind sac body plan in *Hydra*

- iii. **Tube within tube plan:** This type body plan consists of two tubes, one of which is formed by body wall and within it lies another tube of digestive tract. Digestive tract is a complete tube with openings at both ends. Animals from nemathelminthes phylum up to chordata have this type of body plan. It is of following types:

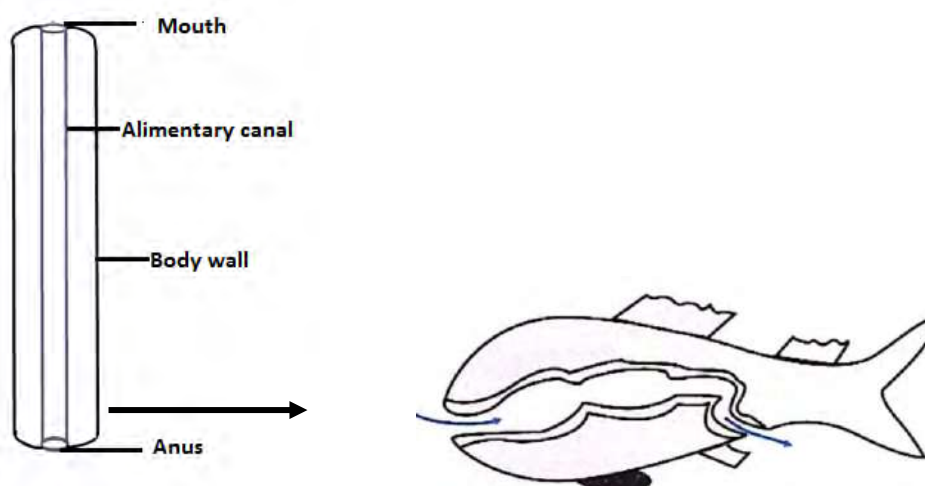


Figure 8.2.3 Tube within tube body plan in fish

- a. **Protostomic plan:** In the embryo, Mouth develops before the anus. Example: roundworms, annelids, arthropods, molluscs and such animals are called protostomes.
- b. **Deuterostomic plan:** Anus develops before the mouth in embryo. Example: echinoderms and chordates and these animals are called deuterostomes.

3. Body symmetry

- i. **Asymmetrical body:** When the body of an animal cannot be divided into two similar halves through any plane, it is called an asymmetrical body. Example: *Amoeba*, most of the sponges etc.

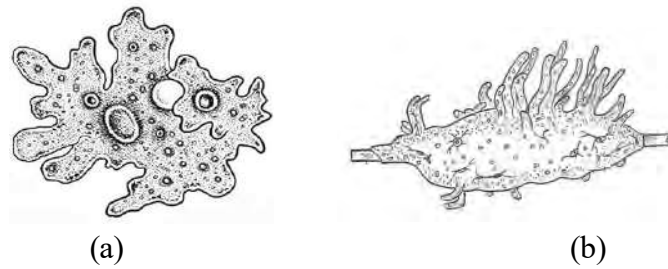
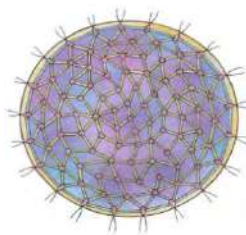
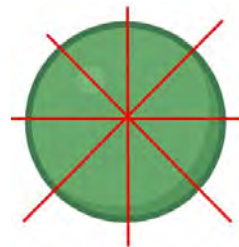


Figure 8.2.4 (a) Asymmetrical body of *Amoeba* (b) Asymmetrical body of *Spongilla*

- ii. Symmetrical body: An animal's body is said to be symmetrical if it can be divided into two similar halves through one or more planes. It is of following types:
- Spherical symmetry: In this type of symmetry, body shape is spherical and body can be divided into two similar halves in any plane that runs through the centre of organism. Example: *Volvox*, *Streptococcus*



Volvox



Streptococcus

Figure 8.2.5 Spherical symmetry in animals

- Radial symmetry: In this, body can be divided into roughly two equal halves by any one of many vertical planes passing through the central axis. Generally, these animals are cylinder like in form and similar parts of the body are arranged equally around the axis. Example: most of the coelenterates and adult echinoderms.

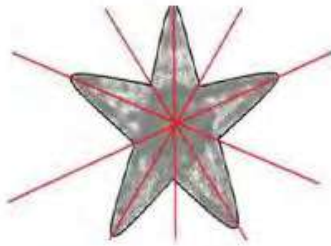


Figure 8.2.6 Radially symmetrical animals

- Bilateral symmetry: In this type of symmetry, only one median vertical plane divides the whole body into two equal halves. From the phylum Platyhelminthes to Chordata, all animals show bilateral symmetry with few exceptions in molluscs and echinoderms.

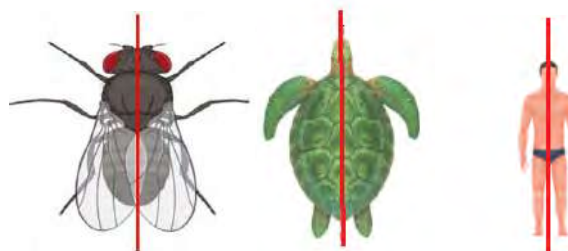


Figure 8.2.7 Bilaterally symmetrical animals

- d. Biradial symmetry: In this type of symmetry, Animals body show a combination of both bilateral and radial symmetry. Example: comb jellies.

4. Body cavity (coelom)

The large fluid filled space between gut (alimentary canal) wall and body wall is called coelom. On the basis of presence or absence of coelom in the body, animals are of following types:

- i. Acoelomate: Some animals like sponges, coelenterates, and platyhelminthes donot have coelom and hence they are called acoelomate animals.
- ii. Pseudocoelomate: Coelom derived from blastocoel of the embryonic stage is called pseudocoelom. This type of coelom is enclosed by ectoderm and endoderm. Animals in Aschehelminthes only are acoelomate.
- iii. Eucoelomate or coelomate: This is the true coelom which is enclosed by mesodermal cells from both sides. It is of following types:
 - a. Schizocoel: Coelom formed by splitting of mesoderm layer in the embryonic stage. It is found in annelida, arthropoda, mollusca and higher chordate.
 - b. Enterocoel: In ehinoderms and hemichordate, mesodermal pouches develop from larval archenteron and then fuse to form coelom. It is called enterocoel. Example: Echinoderms and protochordates.
 - c. Haemocoel: It is the modified form of coelom in arthropods, mollusca and some annelids in which coelom is greatly reduced and filled with blood.

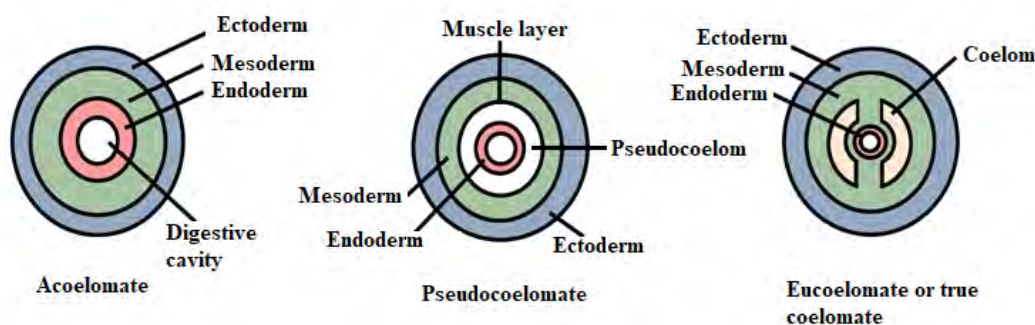


Figure 8.2.8 Different types of coelom

5. Segmentation:

Segmentation is the division of body of an animal into linear series of similar parts or sections.

- i. Unsegmented body: Animals such as sponges, coelenterates, nemathelminthes, mollusca, echinoderms have no segmentation of their body.
- ii. Metameric segmentation: It is the division of body in specific pattern, into many linear series or segments where all segments are interdependent, work together and of same stage of maturation. Example: annelida, arthropoda and chordata.
- iii. Psedosegmentation: Body with many independent and false segments where growth of body takes place by a type of budding or strobilization and all segments are not in the same stage of maturation. Example: tapeworms

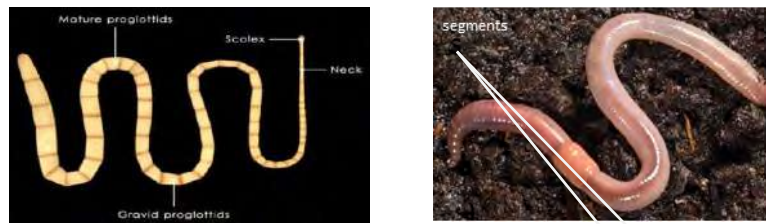


Figure 8.2.9 Segmentation

Activity 8.5

Visit your biology laboratory, observe and list down all the museum specimens there. Classify them to different groups on the basis of their body plan, symmetry and segmentation.

Do you know?

Diploblastic: Body is developed from two germ layer in the embryonic stage; ectoderm and endoderm. Example: Porifera and coelenterata.

Triploblastic: Body is developed from three germ layer in the embryonic stage; ectoderm, mesoderm and endoderm. Example: All animals except sponges and coelenterates.

Anterior end: Front or head end of an animal.

Posterior end: Rear or tail end of an animal.

Dorsal surface: Body surface facing towards the sky.

Ventral surface: Body surface that faces towards the earth.

Lateral side: Either sides of an organism, away from central axis.

Dorso-lateral side: Towards the dorsal surface and sides of the body

Ventro-lateral side: Towards the ventral surface and sides of the body

Mid-dorsal side: Middle region of dorsal surface.

Mid-ventral side: Middle region of ventral surface.

Freshwater organism: Organisms living in river pond lakes pools (less salty water).

Marine organism: Organism that lives in sea water (salty water).

Amphibious animal: Animal which lives in land and water both.

Solitary animal: Animal that lives alone.

Colonial animal: Animal that lives in group or colony where work is divided among the members.

Gregarious animal: Animal that lives in groups independently.

Sedentary: Animal is normally fixed to the substratum. Sea anemone

Free swimming: Animal that swims freely in water.

Pelagic: Animal residing in upper surface of water.

Benthic: Animal living in bottom of water sources.

Lentic: Standing water such as ponds, lakes etc.

Lotic: Running water such as river, stream etc.

Warm-blooded (homeothermic): Body temperature remains constant.

Cold-blooded (Poikilothermic): Body temperature changes according to the surrounding.

Flagellum: A hair like structure arising from cell body. It is present in bacteria, euglena etc.

Cilia: Minute hair like cytoplasmic processes. locomotory organs of *Paramecium*

Pseudopodia: Locomotory organ of *Amoeba*

Setae: Locomotory organ of Earthworm.

Parapodia: Locomotory organ of *Nereis*.

Appendages: Lateral outgrowths arising from body. Example: legs, tentacles, antennae etc.

Muscular feet: Locomotory organs of molluscs. For example: apple snail (*Pila*), garden snail (*Helix*) etc.

Tube feet: Locomotory organ of echinodermata. Example: Starfish, Sea cucumber etc.

Fins: Locomotory organ of fishes.

Limbs: Locomotory organs of tetrapods such as amphibians, reptiles, aves and mammals.

Holozoic nutrition: Mode of nutrition in organisms in which they engulf solid or liquid food which is not prepared by them as found in green plants.

Holophytic nutrition: Mode of nutrition in organisms in which they prepare food themselves.

Mixotrophic nutrition: Organism showing both autotrophic and heterotrophic nutrition. Example: *Euglena*

Saprotrophic: Organisms feeding on dead and decaying organic matters,

Intracellular digestion: Digestion takes place inside the cell.

Extracellular digestion: Digestion takes place outside the cell i.e in alimentary canal.

Anaerobic respiration: Respiration which takes place in the absence of oxygen.

Aerobic respiration: Respiration which takes place in the presence of oxygen.

External gills: Gills on the outer body surface but not enclosed by body wall. Example: amphibian larva and some larval fishes.

Internal gills: Gills inside the body developed as pharyngeal outgrowth.

Tracheae: Respiratory organ in the body of some arthropods. Example: insects

Book lungs: Respiratory organ in some arthropods such as spider and scorpion

Pulmonary sac: Respiratory organ of terrestrial molluscs. Example: *Pila*

Open circulation: Blood remains in blood sinuses or cavities, there is no veins and capillaries.

Closed circulation: Blood flows within blood vessels.

Myogenic heart: Heartbeat originates from specialized nodule tissue of heart itself.

Neurogenic heart: Heart beat originates from a nervous tissue situated near the heart.

Contractile vacuole: Osmoregulatory organelle in protozoans.

Flame cells: Excretory organs of platyhelminthes.

Nephridia: Excretory organ in phylum annelida.

Malpighian tubules: Excretory organ in most of the insects.

Green gland or coxal glands: Excretory organs of crustaceans.

Organ of Bojanus: Excretory organ of mollusca.

Monoecious/hermaphrodite/bisexual: Both male and female sex organ present in the same body.

Unisexual/dioecious: Male and female are separate.

Oviparous: Egg laying animals

Viviparous: Animals giving direct birth to the young

Ovoviviparous: Animal giving birth to immature youngones.

Sexual dimorphism: Condition in which male and female are distinct by their morphology.

Protandry: Condition in which male reproductive organ mature earlier than female reproductive organ. Example: Earthworm

Protogyny: Female reproductive organ matures earlier than male reproductive organ. Example: Human

External fertilization: Fertilization takes place outside the body of female.

Internal fertilization: Fertilization takes place inside the body of female.

Direct development: No larva in the life cycle

Indirect development: Larval stages in the life cycle

Retogressive metamorphosis: Larva is more advanced than adult. Example: *Herdmania*

Ureotelic animal: An animal which excretes urea as chief nitrogenous waste. Human, frog etc.

Uricotelic animal: An animal which excretes uric acid as chief nitrogenous waste. Bird, land reptiles etc.

Ammonotelic animal: An animal which excretes ammonia as chief nitrogenous waste. Freshwater bony fishes, tadpole etc.

Aminotelic animal: An animal which excretes excess amino acid. Starfish, *Unio*

8.2.2 PHYLUM PORIFERA

The name porifera (L; porus-pore; ferro-to bear) was coined by Robert grant. The evidence of their animal nature was given by John Ellis in 1765 in which he found water currents. Porifera are commonly called sponges. Branch of biology which deals with the study of porifera is called parazoology.



Sycon
(urn or crown sponge)



Hyalonema
(glass rope sponge)



Chalina
(Finger sponge)

Figure 8.2.10 some poriferans

General characters

1. Porifera are all aquatic animals, which are mostly found in marine water and few of them are found in freshwater.
2. They are primitive and first multicellular organisms having cellular grade of body organization.
3. Adult body is sessile and sedentary, found attached on substratum.
4. Body shape is vase or cylinder like, tubular, cushion like, branched tube like.
5. Their body is either asymmetrical or radially symmetrical.
6. They are diploblastic i.e. developed from two germ layers in embryonic stage. Their body wall consists of outer pinacoderm (dermal epithelium) and inner choanoderm (gastral epithelium) with non-cellular gelatinous mesenchyme layer in between. Mesenchyme is composed of skeletal elements and amoeboid cells.
7. Body is perforated by many pores where smaller pores are called ostia and larger pores are called oscula. Water enters the body through ostia and exits through osculum. This

phenomenon is called water canal system. Its advantages for sponges are to help in feeding, respiration and excretion.

8. Internal hollow cavity of body is called spongocoel which is lined by choanocytes. Choanocytes are flagellated collar cells.
9. Their skeleton is formed of either spongin fibres or silicious spicules or calcareous spicules.
10. They have no alimentary canal and digestion takes place inside the cell (intracellular digestion).
11. Respiratory, excretory and nervous system are absent. Respiration and excretion take place through general body surface.
12. Nervous and sensory cells are not differentiated. Individual cell responds to stimuli.
13. They are hermaphrodite but there always occur cross fertilization.
14. They reproduce asexually by budding, gemmule formation and regeneration.
15. Sexual reproduction takes place by the fusion of sperms and ovum and fertilization is internal. There is holoblastic cleavage of zygote and development is indirect with free swimming ciliated larva called parenchymula or amphiblastula larva. The larva finally settles on a substratum and undergoes metamorphosis to spend sedentary mode of life.

Unique features: primitive multicellular animals, cellular grade of body organization, numerous pores in the body, presence of water canal system, adult form fixed or attached on substratum, internal hollow cavity is spongocoel, skeleton in the form of calcareous or silicious spicules or spongin fibres, parenchymula or amphiblastula larva

Classification

Based on the types of skeleton found, following are the classes of porifera:

Class 1: Calcarea (L; calcareous-limy) or calcispongiae

- i. They have calcareous (made from calcium carbonate) spicules as skeleton which are monaxon, tetraxon and triradiate.
- ii. Body shape is vase like or cylindrical.
- iii. They are found in shallow marine water.
- iv. They are smaller sized and dull coloured sponges.
- v. They are solitary or colonial.

Example: *Sycon* (vase sponge), *Grantia*, *leucosolenia*, *Clathrina*

Class 2: Hexactinellida (Gr; hex- six; actin-ray) or hyalospongiae (Gr; hyalos- glassy; spongos - sponge)

- i. They have six rayed silicious (made from silica) spicules as skeleton which are triaxon.
- ii. They are found in deep marine water.
- iii. Body shape is like cup and vase.
- iv. They are moderate sized and commonly called glass rope sponges.
- v. Most of them are solitary.

Example: *Euplectella* (venus flower basket), *Hyalonema* (glass rope sponge), *Pheronema* (bowl sponge), *Farnera* etc.

Class 3: Demospongiae (Gr; demos-frame; sponges- sponge)

- i. They have skeleton in the form of sponging fibres or silicious spicules with sponging fibre or no skeleton. Spicules are never six rayed.
- ii. They are mostly found in marine water. Few of them are found in fresh water such as *Spongila*, *Ephydatia*.
- iii. Body shape is vase or cup or cushion like.
- iv. They are more numerous and mostly large sized sponges.
- v. They are solitary or colonial.

Example: *Euspongia* (bath sponge), *Chalina* (mermaids' sponge), *Phyllospongia* (leaf sponge), *Cliona* (boring sponge), etc.

8.2.3 PHYLUM COELENTERATA

Leukart created the phylum coelenterata (Gr; koilos-cavity; enteron-intestine) and Hatschek named them as cnidarians. They are commonly called cnidarians or stinging animals as they specialized stinging cells or nematocyst (Cnidoblast or nematoblast) in their body.



Hydra (freshwater polyp)



Aurelia (jelly fish)



Gorgonia (sea fan)

Figure 8.2.11 some coelenterates

General characters

1. They are all aquatic, mostly found in marine water; few of them are found in fresh water such as *Hydra*.
2. Level of body organization is cell-tissue grade because some cells are aggregated to form tissue and there is no formation of organs and system.
3. They are either solitary or colonial and sedentary; found attached on substratum like rocks stone and hard objects. Some of them are free swimming.
4. They are diploblastic i.e developed from two germ layers. Their body wall consists of outer ectodermal layer and inner endodermal layer of cells with gelatinous mesogloea in between. Composition of mesogloea varies which may be either acellular or cellular with connective tissue.
5. They are acoelomate animals.
6. The shape of the body is hollow tube-like, umbrella- like or large bell-like.
7. The mouth and margin of the bell are surrounded by slender and short tentacles.
8. Tentacles help in capturing and ingestion of food and also in locomotion in some forms. Stinging cells or cnidoblasts help in paralyzing prey and also in defence.

9. They exhibit unique phenomenon of polymorphism in which main forms or zooids are polyps and medusa. Polyp is the asexual zooid found attached on substratum while medusa is free swimming having role in sexual reproduction.
10. Exoskeleton is made up of either chitin (in perisarc) or calcium carbonate (in corals).
11. There is an internal hollow cavity inside the body called gastrovascular cavity or coelenteron which is lined by gastrodermis. This cavity opens anteriorly by an opening called mouth and ends blindly at the posterior side.
12. They are carnivorous animals. Digestion is both extracellular and intracellular.
13. Respiratory, circulatory, excretory systems are absent. Respiration takes place through general body surface.
14. They have radial or biradial symmetry about a longitudinal oral-aboral axis.
15. They have primitive and diffused type of nervous system in which nerve cells form a network called nerve net on either side of mesogloea in epidermis and gastrodermis but no central nervous system in them.
16. Sensory organs are ocelli (light receptor); statocyst (maintaining orientation) in free swimming forms.
17. They are hermaphrodite or unisexual. Reproduction takes place asexually and sexually both.
18. Asexual reproduction takes place by budding, fragmentation and regeneration.
19. Sexual reproduction occurs by fusion of gametes. Fertilization is external. Development is indirect with a free-swimming ciliated planula larva.

Unique features

First tissue graded animals, diploblastic, presence of nematocysts (stinging cells), internal hollow cavity is coelenteron, incomplete alimentary canal, polymorphism, carnivorous, coral forming animals, larva is planula

Classification

Phylum coelenterata is classified into three classes on the basis of composition of mesogloea and body forms.

Class 1: Hydrozoa

- i. Most of them are found in marine water and some of them in freshwater.
- ii. They occur as either polyp form (*Hydra*) or both polyp and medusa form (*Obelia*). Mostly, they exhibit alternation of generation.
- iii. There is non-cellular mesogloea in between ectoderm and endoderm.
- iv. Few of them contribute to the formation of coral reef.
- v. They are colonial or solitary and free swimming or sessile forms.

Example: *Hydra* (freshwater polyp), *Obelia* (sea fur), *Physalia* (portuguese man of war), *Porpita*, *Tubularia* etc.

Class 2: Scyphozoa

- i. They are all solitary forms and found exclusively in marine water.

- ii. Polyp stage is absent or reduced and medusa stage is dominant. Some of them exhibit alternation of generation.
- iii. Medusae are large bell or umbrella shaped and free swimming with marginal tentacles.
- iv. Gelatinous mesogloea contains amoeboid cells.
- v. They don't form corals.

Example: *Aurelia* (jelly fish), *Pericolpa*, *Lucernaria*, *Rhizostoma*

Class 3: Anthozoa

- i. They are both solitary or colonial forms and all found in marine water.
- ii. There is only polyp stage but no medusa stage and hence alternation of generation is absent.
- iii. Mesogloea is well developed that contains amoeboid cells and fibres.
- iv. Gastrovascular cavity is further divided by septa or mesenteries.
- v. They have major role in the formation of coral reef.

Example: *Tubipora* (organ pipe coral), *Alcyonium* (soft coral), *heliopora* (blue coral), *Gorgonia* (Sea fan), *Metridium* (sea anemone) etc.

8.2.4 PHYLUM PLATYHELMINTHES

The word platyhelminthes (Gr; platys-flat; helminthes-worms) was first proposed by Gegenbaur for flatworms. Their body is compressed dorsoventrally and show bilateral symmetry. They are the first animals which have developed organ system.



Figure 8.2.12 some flatworms

General characters

1. They are mostly parasitic, living inside the organs such as liver, intestine, blood etc. of animals. Few of them are free living or commensal found in freshwater sea and moist places.
2. Their body is bilaterally symmetrical and dorso-ventrally flattened. Ventral surface bears mouth and genital openings.
3. They have organ-system grade of body organization.
4. Body is vermiform (worm like), elongated ribbon or leaf like.
5. They are microscopic or small to moderate sized and some are long ribbon measuring 13 metre length in average.
6. They are first triploblastic animals i.e. body is developed from three germ layers.
7. Body is covered with syncytial and ciliated epidermis in free living forms but parasitic forms have cuticle as outer layer and without epidermis.

8. Muscular layer of mesodermal origin lies below epidermis that consists of longitudinal, circular and oblique muscles.
9. Parasitic forms have spines, hooks, suckers, adhesive secretions for attachment on host.
10. These animals lack coelom (acoelomate) and spaces between the organs are filled with mesodermal parenchymatous tissue.
11. Digestive system is incomplete and branched without anus. In tapeworms, digestive system is totally absent.
12. Respiratory, circulatory and skeletal systems are absent.
13. Excretion takes place through special structures called protonephridia or flame cells.
14. Nervous system is primitive consisting of a pair of cerebral ganglia and longitudinal nerve cords connected each other by transverse commissures giving ladder like appearance.
15. Sense organs are simple eye spots or photoreceptor in free living forms but usually absent or reduced in parasitic forms.
16. They are mostly hermaphrodite and very few of them are unisexual. Fertilization is internal which may be self or cross.
17. Parthenogenesis and polyembryony commonly occurs in parasitic forms.
18. Reproduction occurs by sexually and asexually both. Asexual reproduction takes place by regeneration and sexual by fusion of gametes.
19. Development is direct and indirect both. Indirect development is found in endoparasites with many larval forms.

Unique features

Dorsoventrally flat body, mostly endoparasites, presence of hooks and suckers in parasitic forms, first triploblastic animals, excretion by flame cells, alimentary canal incomplete or absent, mostly hermaphrodite

Classification

Phylum platyhelminthes is divided into three classes on the basis of their habitat and digestive tract.

Class 1: Turbellaria

- i. They are mostly free living, found in freshwater, marine water and moist land.
- ii. Body is unsegmented, flat, and covered with ciliated cellular layer or syncytial epidermis. Cuticle is absent.
- iii. Suckers are absent.
- iv. Alimentary canal is incomplete with eversible pharynx..
- v. Touch receptor, chemoreceptor, and photoreceptor are commonly found in free living forms.
- vi. Mostly hermaphrodite. Reproduction occurs by sexual and asexual method. They have remarkable power of regeneration.

Example: *Planaria*, *Bipalium*

Class 2: Trematoda

- i. They are commonly called flukes, found as ectoparasites and endoparasites in the body animals.
- ii. Their body shape is usually leaf like and dorso-ventrally flattened.
- iii. Outer covering of body wall is cuticle.
- iv. Digestive tract is incomplete with branched intestine.
- v. Suckers are usually present to attach with host.
- vi. They are mostly hermaphrodite.
- vii. Development is direct in ectoparasites and indirect in endoparasites.

Example: *Fasciola* (Liver fluke), *Schistosoma* (blood fluke), *Diplozoan*, *Gyrodactylus* etc.

Class 3: Cestoda (cestos-girdle; eidos-form)

- i. They are commonly called tapeworms found as endoparasites in the intestine of vertebrates.
- ii. Body is pseudosegmented, elongated, flat and ribbon like.
- iii. Body segments are called proglottids which are immature anteriorly, matured at the middle and gravid posteriorly. Each mature proglottid is hermaphrodite.
- iv. Head or scolex is provided with hooks and suckers.
- v. Alimentary canal and sense organs are absent.
- vi. Complicated life cycle involving two vertebrate hosts and embryo is with hooks.

Example: *Taenia* (tape worm), *Echinococcus* (dog tapeworm), *Hymenolopis* (dwarf tape worm) etc.

8.2.5 PHYLUM ASCHELMINTHES

Grobben introduced the term Aschelminthes (Gr; askos-cavity; helmins-worm) in the place of older name nemathelminthes. This phylum includes varieties of animals which are either free living or parasitic or epizoic.



Ascaris



Mermis



Trichinella

Figure 8.2.13 some nematodes

General characters

1. They are found in aquatic and terrestrial habitat and also as parasites of plants and animals. Some of them are free living forms.
2. They are bilaterally symmetrical, triploblastic, unsegmented, thread like worms having organ system grade of body organization.
3. Body is slender, vermiform and usually cylindrical in outline with indistinct head.
4. They are pseudocoelomate i.e. coelom is derived from blastocoel.
5. Body wall consists of outermost protective cuticle layer, syncytial epidermis without cilia and a layer of longitudinal muscle. Cuticle layer sheds off periodically.

6. Alimentary canal is straight and complete with mouth, pharynx, intestine and anus.
7. There are no circulatory and respiratory organs. Transport of materials occurs with the help of pseudocoelomic fluid and respiration occurs through general body surface by diffusion in free living forms. Parasitic forms respire anaerobically.
8. Excretion occurs through a system of canals or tubes; renette cells and protonephridia in some cases.
9. Nervous system consists of ganglionated nerve rings around pharynx and a number of longitudinal nerve cords.
10. The sensory organs are in the form of papillae, eye spots, bristles and pits.
11. They are mostly unisexual with sexual dimorphism and having relatively simple reproductive organs. Males are usually smaller.
12. They do not reproduce asexually but sexual reproduction takes place by the fusion of sperms and ovum.
13. Fertilization is internal. Eggs are shelled and life cycle is either simple or complicated, usually with no larval forms.

Unique features

Body is thread like, usually cylindrical in outline, pseudocoelomate, first animals with complete alimentary canal, excretion through renette cells (H-shaped excretory canal), distinct sexual dimorphism, No asexual reproduction

Classification

Phylum nemathelminthes is divided into two main classes based on the presence or absence of phasmids (caudal sense organs).

Class1: Phasmida (Secernentea):

- i. This class consists of many parasitic forms. Free living forms largely inhabit soil.
- ii. They usually possess pore like amphids in the lateral lips.
- iii. There is the presence of paired phasmids in the caudal region.
- iv. Only anterior testis is found.
- v. There is well developed excretory system with renette cells.
- vi. Presence of glandular tail.

Example: *Ascaris* (round worm), *Wuchereria* (filarial worm), *Loa loa* (eye worm), *Ancylostoma* (hook worm) etc.

Class: 2 Aphasmda (Adenophorea)

- i. They are mostly free living found in water and soil. Some of them are parasitic.
- ii. Various shaped amphids are found behind the lips.
- iii. There are no phasmids in the caudal area.
- iv. Paired testes are present.
- v. Excretory system is absent or reduced.
- vi. Presence of non-glandular tail.

Example: *Mermis*, *Enoplus*, *Dorylaimus*, *Trichinella* etc.

8.2.6 PHYLUM ANNELIDA (L., ANNULUS-RING, EIDOS-FORM)

The term annelida was coined by Lamarck for segmented worms which are regarded as first higher non- chordates.



Figure 8.2.14 some annelids

1. They are mostly aquatic, found in both marine water and freshwater, some of them are terrestrial and burrowing form.
2. They are sedentary or free living and some of them are parasitic.
3. Body is elongated, vermiform, bilaterally symmetrical and triploblastic.
4. There is organ system level of body organization.
5. They have metamerically segmented body in which external segmentation corresponds internal segmentation. Segments are also called somites or metameres which are separated externally by grooves and internally by septa.
6. Their body wall consists of outermost non-living cuticle secreted by underlying epidermis and innermost layer of circular and longitudinal muscle fibres.
7. They have schizocoel i.e. true coelom which is divided by septa into coelomic chambers and leeches are haemocoelomate.
8. Locomotary organs are segmentally repeated chitinous bristles called setae or lateral fleshy outgrowth called parapodia or suckers in some forms.
9. Digestive system is straight tube like and complete. Digestion is extracellular.
10. There is closed type of blood vascular system. Blood is red because of haemoglobin or erythrocrutorin dissolved in plasma.
11. Respiration takes place through general body surface or through gills of parapodia and head.
12. Excretory organs are segmentally arranged coiled tube-like structures called nephridia.
13. Nervous system consists of a nerve ring and double ventral nerve cord bearing ganglia and lateral nerves.
14. Sensory organs are touch receptor, taste buds, statocyst, photoreceptors and eyes.
15. They are mostly monoecious i.e. hermaphrodite. Some of them are unisexual too.
16. Asexual reproduction by regeneration is common and sexual reproduction takes place by the fusion of gametes.
17. Development is direct in hermaphrodite annelids. Indirect development is present in unisexual forms with a free-swimming larval form called trochophore larva.

Unique features

Metamerically segmented body, schizocoelomate and some haemocoelomate, locomotory organs are setae, parapodia and suckers, closed circulatory system, excretion through nephridia, haemoglobin in plasma, Larva is trochophore if present.

Classification

Class 1. Polychaeta (Gr; polys-many; chaite-hairs)

- i. Mostly marine and some are found in fresh water.
- ii. Distinct head with eyes, palps and tentacles.
- iii. Locomotary organs are fleshy lateral outgrowth called parapodia.
- iv. Clitellum is absent.
- v. Sexes are separate.
- vi. Fertilization is external, and presence of trochophore larva.

Example: *Nereis* (sand worm), *Aphrodite* (sea mouse), *Glycera*, *Arenicola* (lug worm) etc.

Class 2. Oligochaeta (Gr; oligos-few; chaite-hairs)

- i. Mostly terrestrial and some of them are found in freshwater.
- ii. Head is indistinct and without eyes and tentacles.
- iii. Locomotary organs are setae embedded in skin. No parapodia.
- iv. Presence of glandular clitellum that forms cocoon.
- v. Hermaphrodite and fertilization is external that takes place in cocoon.
- vi. Direct development i.e. no larval stages.

Example: *Pheretima* (Earthworm), *tubifex* (sludge worm), *Lumbricus*, *Megascolex* etc.

Class 3. Hirudinea

- i. They are both terrestrial and aquatic, mostly ectoparasitic or blood feeding (sanguivorous).
- ii. Body is elongated, dorsoventrally flattened or cylindrical.
- iii. Both anterior end and posterior end of the body bear suckers used to adhere on host skin and locomotion. (No parapodia and setae)
- iv. Coelom is greatly reduced and filled with botryoidal tissue and blood.
- v. Clitellum is developed temporarily only, during breeding season.
- vi. Body consists of usually 33 segments and each segment is further sub-divided superficially into annuli.
- vii. Hermaphrodite, internal fertilization and direct development.

Example: *Hirudinaria* (cattle leech), *Piscicola* (fish leech), *Hirudo* (medicinal leech), *Haemopsis* etc.

Class 4. Archiannelida

- i. They are exclusively marine and primitive worms of about a dozen genera.
- ii. Body is small and elongated with distinct internal segmentation. External segmentation is faint.
- iii. No parapodia or setae.
- iv. Sexes are usually separate and larval form is called trochophore.
- v. Prostomium bears 2 or 3 tentacles.

Example: *Polygordius*, *Dinophilus*, *protodrilus* etc.

8.2.7 PHYLUM ARTHROPODA

Arthropoda (Gr; arthros-jointed; podo-foot) is the largest phylum of animal kingdom which consists of more than 800000 species found in all types of habitat. These animals comprise about 80% of all known animals.

General characters

1. They are the most diversified animals inhabiting the land, water and air. They are mostly free living and some of them are parasites of both plants and animals.
2. Body is bilaterally symmetrical, triploblastic and metamerically segmented.
3. Body segments bear jointed appendages which are variously modified such as jaws, antenna, gills etc. Legs are adapted for walking, swimming, food capturing, tearing of food, defense etc.
4. They have organ system level of body organization.
5. Their coelom is true but reduced and filled with blood called haemocoelom.
6. Body is externally covered by thick chitinous and tough layer of cuticle which act as exoskeleton, secreted by underlying epidermis. Cuticle cast off periodically during growth and development and this process is called moulting or ecdysis.
7. Body is distinctly divided into three regions-head, thorax and abdomen. However, head and thorax is fused to form cephalothorax in some cases such as prawn, spider.
8. Muscular layer is not continuous but lie as separate bundles below epidermis which allows rapid contraction during movements.
9. Respiratory organs are booklungs and trachea in terrestrial forms and gills in aquatic forms. Some of them also respire through general body surface.
10. Digestive system is complete with mouth and anus at the opposite ends. Mouth is surrounded by a number of appendages called mouth parts which are adapted variously for biting, chewing, sucking etc.
11. Excretion takes place through malpighian tubules or coelomoducts or green glands or coxal glands.
12. They have open type of circulatory system which consists of dorsally placed heart, arteries and blood sinuses or lacunae. There are no veins and capillaries.
13. Nervous system is typically annelidan type that consists of dorsal brain with nerve ring and ganglionated ventral nerve cord with lateral nerves.
14. Sensory organs are simple eyes, compound eyes, antenna, hairs, statocyst, and auditory organs. These organs perceive stimuli like light, chemical, touch, sound etc. and also help in maintaining body posture during locomotion.
15. Compound eye is composed of many visual units or lenses called ommatidia and such eye can detect very slowly moving object.
16. They are usually unisexual and well-marked sexual dimorphism is found in most cases.
17. Fertilization is mostly internal. Development is direct and indirect both. Parental care is also found in some arthropods.
18. Parthenogenesis occurs in some cases.

Unique features

Most diversified, Presence of jointed appendages, metamerically segmented, haemocoelomate, shedding off outer cuticle frequently, body divided into head, thorax and abdomen or cephalothorax and abdomen, open circulatory system, compound eye, larval form in the most.

Classification

Classification of phylum arthropoda is controversial and complicated which is divided into seven subphyla but the true arthropods belong to the three sub-phyla namely trilobitomorpha, chelicerata and mandibulata. Among them, trilobitomorpha is not mentioned here as it comprises extinct arthropods.



Limulus



Spider



Shrimp



Dragon fly

Figure 8.2.15 some arthropods

Sub-phylum: Chelicerata (Gr; chele-claw; keros-horn)

Body is divided into cephalothorax and abdomen, presence of six pair of appendages in total and absence of antenna are the main features. This subphylum consists of two classes:

Class 1: Merostomata (Meros-thigh, stoma mouth)

- i. All found in marine water, simple eyes in median position and compound eyes are placed laterally.
- ii. They have 5-6 pairs of abdominal appendages; with book gills for respiration.
- iii. Excretion takes place by coxal glands.
- iv. Abdomen ends at sharp telson.

Example: *Limulus* (king crab or horse shoe crab; a living fossil)

Class 2: Arachnida

- i. They are mostly terrestrial, few are aquatic.
- ii. They have only simple eyes.
- iii. Cephalothorax is with a pair of chelicerae, a pair of pedipalpi and four pair of walking legs. No appendages from abdomen.
- iv. Excretion occurs by coxal glands and malpighian tubules.
- v. Respiration by tracheae and book lungs or book gills.
- vi. They have no antenna and wings.
- vii. They are carnivorous and hence predator.

Example: *Aranea* (spider), *Palamnaeus* (scorpion), ticks, mites etc.

Sub-phylum: Mandibulata (L; mandibula-mandible; ata-group)

They are both terrestrial and aquatic, body divided as head, thorax and abdomen or cephalothorax and abdomen, presence of compound eyes and 3-5 pairs of appendages in head. This subphylum consists of three classes:

Class: 3 Crustacea (L; crusta-shell)

- i. They are mostly aquatic and few are terrestrial (wood louse), respire by gills.
- ii. Body is divisible as cephalothorax and abdomen where cephalothorax is covered by hard carapace and segmented abdomen by sclerites.
- iii. Head is five segmented and each segment bears biramous (two branched) appendages.
- iv. Sexes are separate with sexual dimorphism.
- v. Development is direct and indirect both.

Example: *Palaemon* (prawn), *Cancer* (crab), lobster, shrimp, copepod, water flea etc.

Class 4: Myriapoda (Gr; myrios- terrestrial; podos-foot)

- i. They are exclusively terrestrial and air breathing forms.
- ii. Body is divisible into head and trunk. Trunk is many segmented and each segment bear paired jointed legs.
- iii. They have a pair of antennae, three pair of jaws and more than 11 pair of legs.
- iv. Breathing occurs through trachea. Trachea opens outside through small pores called spiracles.
- v. They excrete through malpighian tubules.
- vi. Sexes are separate.

Example: *Julus* (millipede), *Scolopendra* (centipede), *Spiroboleus*, *Pauropus* etc.

Class 3: Insecta (L; insectus- cut or divided)

- i. They are mostly terrestrial, aerial and air breathing forms.
- ii. Body is divisible into head thorax and abdomen.
- iii. Head bears paired compound eyes, antennae, mandibles and two pairs of maxillae.
- iv. Mouth parts are modified according to their feeding habit.
- v. There is three pair of walking legs arising laterally from thorax and wings are two pair or 1 pair or absent.
- vi. Respiration occurs by branched tracheae which open externally through spiracles.
- vii. Excretion by malpighian tubules.
- viii. Sexes are separate, fertilization is internal and development is direct and indirect both. Indirect development with larval forms and metamorphosis. Direct development with immature young one resembling adult is called nymph.

Example: *Pieris* (butterfly), *Bombyx* (silkworm), *Melanopus* (grasshopper), *Periplaneta* (cockroach), *Apis* (honey bee), *Musca* (house fly) etc.

8.2.8 PHYLUM MOLLUSCA

The term 'mollusca' was first applied by Aristotle to cuttle fish and is derived from latin word 'mollis' which means soft body. Phylum mollusca is the second largest phylum which comprises more than 100000 species. Among them 80000 species are gastropods.

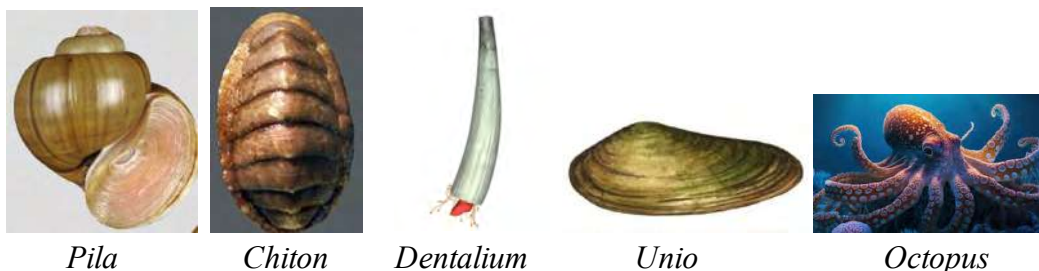


Figure 8.2.16 some mollusks

General characters

1. They are mostly found in aquatic habitats, especially marine water, a few are freshwater forms and some are terrestrial. Most of the members of the phylum mollusca are free living and there are some parasitic forms (some gastropods).
2. Body is soft, unsegmented (except monoplacophora), and bilaterally symmetrical and some are unsymmetrical.
3. Body is usually protected by exoskeleton in the form of calcareous shell. Skeleton may be internal or absent.
4. Their body can be divided into head, foot, mantle and visceral mass.
5. Head is distinct with mouth, eyes, tentacles, and other sensory organs except in pelecypoda and scaphopoda.
6. Ventral surface consists of flat or plough like muscular foot which is variously modified for creeping, burrowing and swimming in water.
7. Mantle or pallium is a thick glandular fold of body wall on the dorsal surface.
8. Visceral mass consists of vital organs in compact form within the shell.
9. Alimentary canal is simple with anteriorly situated mouth and posterior anus. But in gastropods, scaphopods and cephalopods, intestine become U-shaped bringing the anus in anterior position. Radula or rasping organ in buccal cavity is usually present.
10. Circulatory system is open type (exception cephalopods) in which heart is with one or two auricles and one ventricle. Blood contains copper based respiratory pigment called haemocyanin.
11. Respiratory organs consist of numerous gills (branchiae) or ctenidium in aquatic forms, pulmonary sac or lungs in terrestrial forms.
12. Excretion occurs through a pair of metanephridia or kidneys.
13. Nervous system comprises paired ganglia (cerebral, pleural, pedal, visceral), connectives and nerves.
14. Sense organs are eyes, statocyst, osphradium (detect water chemistry) and tentacles.
15. They are usually dioecious and some are hermaphrodite too.
16. Fertilization is internal or external. Development is either direct or indirect with larva.

Unique features

Soft bodied animals, calcareous exoskeleton in the form of shell or internal skeleton or absent, body divisible into head, mantle, visceral mass, ventral foot, open circulatory system, respiratory pigment haemocyanin, respiration through gills or ctenidia in aquatic and through lungs in terrestrial forms, osphradium as chemoreceptor

Classification

Mollusca phylum is classified into six classes according to the symmetry, nature of foot, shell, mantle, gills, radula etc.

Class 1: Monoplacophora (Gr; monos-one; placo-plate)

- i. All marine forms.
- ii. Body is bilaterally symmetrical, internally segmented and with dome shaped mantle.
- iii. They have single limpet shaped flat shell and their foot is broad, flat and ventral.
- iv. Head is without eyes and tentacles.
- v. Sexes are separate.

Example: *Neopilina*

Class 2: Amphineura (Gr; Amphi-both; neuron-nerve)

- i. They are all found in marine water.
- ii. Their body is dorso-ventrally flattened with shell and foot. Some of them are worm like without shell and foot.
- iii. Shell, if present, consist of 8 plates.
- iv. They have small head without eyes and tentacles.
- v. Radula, mantle and gills are present.

Example: *Chiton*, *Neomenia*

Class 3: Scaphopoda (Gr; scapha-boat; podos-foot)

- i. They are exclusively marine forms.
- ii. Body is bilaterally symmetrical, enclosed within tusk-shaped shell opening at both ends.
- iii. Head is vestigial or not distinct, eyes and gills are absent.
- iv. Mouth is with filamentous tentacles and presence of radula.
- v. Foot is conical used for digging.

Example: *Dentalium* (Elephant tusk shell), *Cadulus*

Class: 4 Gastropoda (Gr; gaster-belly; podos-foot)

- i. They are found in marine water, freshwater, land and also as parasitic form in echinoderms.
- ii. Body is unsegmented and asymmetrical.
- iii. Shell is present or absent or in reduced form. Shell is univalved and spirally coiled.
- iv. Head is distinct with eye tentacles and mouth.
- v. Muscular foot is broad and flat on ventral side.
- vi. Buccal cavity is with radula and anus is anteriorly situated.
- vii. Respiration by ctenidia (gills) or pulmonary sac or through general body surface.

Example: *Pila* (apple snail), *Helix* (garden snail), *Limax* (slug) etc.

Class 5: Pelecypoda or Bivalvia (Gr; pelekys-hatchet, podos-foot)

- i. Mostly marine, a few are freshwater forms.

- ii. Body is bilaterally symmetrical, laterally compressed with bivalve shell.
- iii. Head is indistinct without tentacles, eyes, pharynx and radula.
- iv. Foot is hatchet or plough shaped.
- v. Some of them form pearl.

Example: *Unio* (freshwater mussel), *Pecten*, Pearl oyster etc.

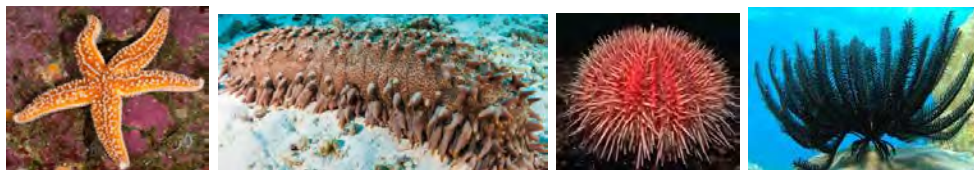
Class 6: Cephalopoda (Gr; kephale-head; podos-foot)

- i. They are extremely found in marine water.
- ii. Body is elongated and bilaterally symmetrical and divisible into head and trunk.
- iii. Shell is external, internal or absent.
- iv. Head bears eyes, mouth, tentacles and radula.
- v. Suckers are found in arms or tentacles encircling mouth.
- vi. Sexes are separate.

Example: *Sepia* (cuttle fish), *Loligo* (squid), Octopus (devil fish), *Nautilus* etc.

8.2.9 PHYLUM ECHINODERMATA (Gr; echinos-hedgehog or spiny, derma-skin)

The term echinodermata literally means spiny skinned and was first introduced by Klein in 1734 for “sea urchins”. Because of their radial symmetry, they were kept with coelenterates in a single group ‘radiata’ for a long time. Later, they were recognized as distinct group by Leuckart in 1847. All the animals of phylum echinodermata form a peculiar group of invertebrates, living at the bottom of sea by creeping slowly, though some can swim.



Star fish

Sea cucumber

Sea urchin

Feather star

Figure 8.2.17 some echinoderms

General characters

1. They are exclusively found in marine water, mostly in sea bottom and hence called ‘benthic invertebrates’.
2. The shape of the body varies among the species, which are cylindrical or elongated, globular, star like, discoidal, or flower like.
3. They are triploblastic and have organ grade of body organization.
4. Adults have pentamerous radially symmetrical body and larvae are bilaterally symmetrical.
5. They are enterocoelomate animals.
6. They have no definite head. Body surface is divided into oral and aboral surface where oral surface is marked by five symmetrically radiating areas called ambulacra and five alternating interambulacra.
7. Body wall consists of outermost epidermis, dermis, muscular layer and innermost epithelial layer (ciliated cuboidal).
8. Many of them bear pincer like pedicellaria with spine on body surface; pedicellaria clear body by removing debris and other things which are attached on the body.

9. Endoskeleton consists of calcareous ossicles or plates of mesodermal origin in dermis.
10. Water vascular system or ambulacral system of coelomic origin, consisting of canals filled with water-like fluid connected with tube feet and madreporite.
11. Tube feet are the locomotory organ which consists of ampulla, podium and sucker.
12. Alimentary canal is either straight or coiled and mouth is present on the oral surface and anus usually on the aboral surface.
13. Circulatory system is open type which includes haemal and perihemal systems with sinuses but without heart. A true blood vascular system is lacking.
14. Excretory system is entirely absent. However, nitrogenous wastes are expelled out by papulae and tube feet in some forms.
15. Nervous system is primitive or poorly developed with a circum-oral ring and radial nerves. Brain is absent.
16. Sexes are separate with few exceptions. Reproduction occurs both sexually and asexually. Asexual reproduction takes place by regeneration.
17. Fertilization is external. Development is indirect with larval forms.
18. Larvae are free swimming and bilaterally symmetrical, get metamorphosed into radially symmetrical adult. Some echinoderms are viviparous.

Unique features

All marine animals, skin with calcareous spine, enterocoelomate, presence of water vascular system, some with pincer like pedicellaria on body surface, locomotion by tube feet, excretory system lacking, absence of brain and heart, larva bilaterally symmetrical but adult radially symmetrical, well-marked regeneration power

Classification

Phylum echinodermata is divided into two subphyla: Eleutherozoa and Pelmatozoa

Subphylum: Eleutherozoa (eleutheros-free; zoon-animal): They are free living forms and further divided into four classes on the basis of body shape:

Class 1: Asteroidea

- i. They are commonly called starfishes or sea star.
- ii. They have five arms, not distinct from central disc.
- iii. Presence of tube feet with suckers, and pedicellaria.
- iv. Their larvae are called bipinnaria and brachiolaria.

Example: *Asterias* (sea star), *Solaster* etc.

Class 2: Ophiuroidea (Gr; ophis-snake; oura-tail; eidos-form)

- i. They are commonly called brittle star.
- ii. Their body is also star like but arms are sharply marked off from the central disc.
- iii. Pedicellaria is absent, tube feet without suckers.
- iv. Larva is called ophiopluteus.

Example: *Ophioderma*, *Ophiura* etc.

Class: 3 Echinoidea (Gr; echinos- hedgehog; eidos-form)

- i. They are commonly called sea urchins.

- ii. Body is discoidal, or oval and without arms
- iii. Pedicellaria are present and 3-jawed.
- iv. Their biting and chewing apparatus is called 'Aristotle lantern'.
- v. Larva is called echinopluteus.

Example: *Echinus* (sea urchin), *Echinocardium* (heart urchin), *Clypeaster* (sand dollar)

Class: 4 Holothuroidea (Gr; holothurion- sea cucumber; eidos-form)

- i. They are commonly called sea cucumber.
- ii. Body is elongated in oral- aboral axis having mouth at the one end and anus at the other end.
- iii. Mouth is surrounded by tentacles.
- iv. Tube feet are present for locomotion cloaca contains respiratory tree.
- v. Larvae are called auricularia and doliolaria.

Example: *Holothuria* (sea cucumber), *Cucumaria* (sea cucumber)

Sub-phylum: Pelmatozoa (Gr; pelmatos-stalk; zoon-animal): They are stalked and there is only one class.

Class: 5 Crinoidea

- i. They are commonly called sea lilies or feather star.
- ii. Body is attached to substratum by an aboral stalk most of the time. But feather star is free swimming.
- iii. Mouth and anus on the oral surface.
- iv. Pedicellaria, spines and madreporite are absent and tube feet without suckers.
- v. Larva is called doliolaria.

Example: *Antedon* (feather star), sea lilies etc.

Project work

Collect different type of small invertebrates found in your locality (take precautions at the time of collection). Classify them into different phylum according to their external features. Now, prepare a report or power point presentation and present in the class.

8.2.10 PHYLUM: CHORDATA (Gr; chorde-string or cord; ata-bearing)

Phylum Chordata is the last major group of kingdom animalia which was created by Balfour in 1880. The term 'chordata' is derived from two Greek words 'chorde' means string or cord and 'ata' means bearing. It indicates that these animals have a common characteristic which is a stiff supporting rod like structure on the back called notochord. (Gr; noton-back; L; chorda-cord). Notochord is found in all the member of this phylum at some stage of their life. Following are the major characters of phylum chordata:

1. **Presence of notochord:** An elongated, flexible and supporting rod like structure present in mid dorsal line from head to tail. It lies beneath the nerve cord and above the alimentary canal. It persists throughout the life in lower chordates (protochordates) but embryonic notochord is replaced by vertebral column in the adult of higher chordates (vertebrates)

2. **Dorsal tubular nerve cord:** A longitudinal hollow nerve cord of ectodermal origin extends lengthwise of the body above notochord. In vertebrates, its anterior region form brain which is protected by cranium and posterior part form spinal cord which is protected by vertebral column.
3. **Presence of pharyngeal gill slits:** Series of paired gill slits present on the lateral wall of pharynx at some stages of development in all chordates. In primitive chordates and lower aquatic vertebrates, gill slits or gill clefts remain throughout the life for breathing but disappear in the adult of higher vertebrates.

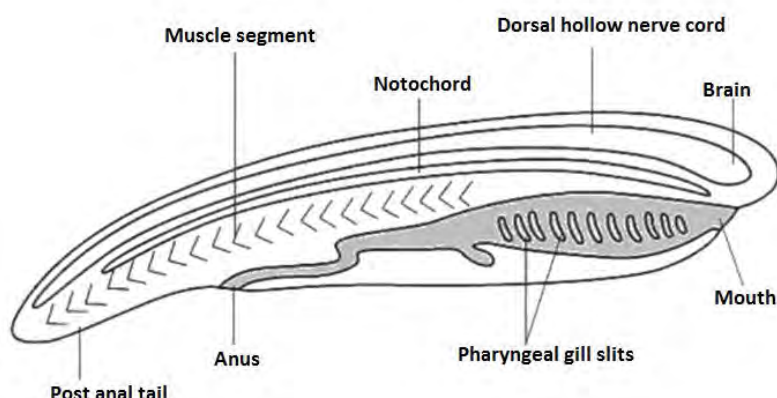


Figure 8.2.18 A chordate's body plan

Other general characters:

4. They are aquatic, terrestrial and aerial. Mostly free living and very few are parasitic.
5. They are triploblastic, metamerically segmented and bilaterally symmetrical.
6. They have schizocoel or true coelom formed by splitting of mesoderm in the embryonic stage. Enterocoelom is found in proto chordates.
7. Exoskeleton is often present and well developed and endoskeleton is cartilaginous or bony in majority of them
8. There is complete alimentary canal with digestive glands.
9. Circulatory system is closed type, consists of ventrally located heart and all types of blood vessels.
10. Some of them have post anal tail beyond anus.
11. Respiratory system is well developed consisting of gills or lung or moist skin.
12. They have kidneys for excretion.
13. They have well developed nervous system
14. Majority of them have well developed sensory organs such as eye, auditory organ, olfactory organs, taste receptors etc.
15. Sexes are separate. Mostly direct development and some of them have indirect development.

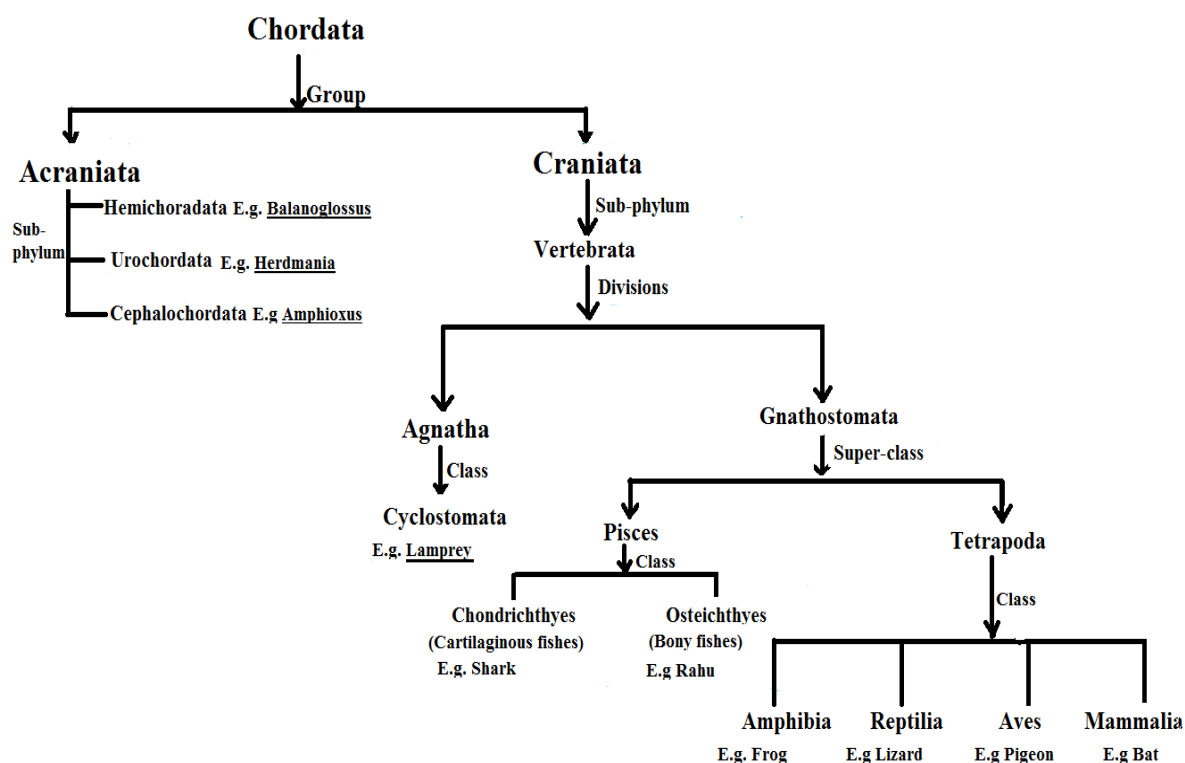


Figure 8.2.19 classification of chordata

Phylum Chordata consists of four sub-phyla which are Hemichordata, Urochordata, Cephalochordata and Vertebrata. First three sub-phyla are primitive chordates which are exclusively marine, relatively small and without vertebral column and also called protochordates. They also lack cranium and hence placed in group acraniata. Last sub-phylum vertebrata consist of animals which are more advanced and specific over these protochordates and hence called Euchordates. Their notochord is replaced by vertebral column in adult and have cranium and hence placed in the group craniata.

1. Hemichordata (Gr; hemi-half; chorde-cord):

- They are exclusively marine, solitary or colonial and mostly tubicolous (living inside self-constructed tube).
- Body is soft and worm like.
- Notochord is present at the anterior region of the body.
- Their body is divided into three regions- proboscis, collar and trunk

Examples: *Balanoglossus*(tongue worm or acorn worm), *Saccoglossus* etc.

2. Urochordata (Gr;oura-a tail; chorde-cord) or Tunicata

- They are also exclusively marine found at all depth and commonly called as “tunicates”
- Notochord and nerve cord are present only in larva but absent in adults.
- They show retrogressive metamorphosis as the larval form is more advanced than adult.
- Adult body is mostly sedentary, enclosed within leathery test or tunic.

Example: *Herdmania* (sea squirt), *Ascidia* etc.

3. Cephalochordata (Gr;kephlae-head; chorde-cord)

- i. They are also marine forms and widely distributed in shallow water, commonly called “Lancelets”.
- ii. Body is transparent, segmented, slender and fish like.
- iii. Notochord and nerve cord are present along the length of the body throughout the life.
- iv. They are mostly burrowing and sedentary, some are free swimming.

Example: *Branchiostoma* (lancet)



Balanoglossus



Herdmania



Branchiostoma

Figure 8.2.20 some cephalochordates

4. Vertebrata (L; vertebratus-jointed)

A vertebrate can be defined as an animal of phylum chordata having bony or cartilaginous endoskeleton that consists of cranium enclosing brain and a vertebral column enclosing a nerve cord.

General characters:

1. Lower vertebrates are aquatic and higher vertebrates are terrestrial.
2. Body is usually divisible into head, neck, trunk and post-anal tail.
3. Their exoskeleton consists of protective scales, feather, hair found in skin. Nail, claws, hoof, horn etc. are also found.
4. Skin or integument is differentiated into epidermis and dermis along with cutaneous glands.
5. Notochord in the early embryonic stage is replaced by cartilaginous or bony vertebral column in adult.
6. Endoskeleton is either cartilaginous or bony where muscles are attached.
7. They have well developed organ systems.

Sub-phylum vertebrata is further divided into two divisions:

Division 1. Agnatha (Gr; a-not; gnatha-jaw): Division agnatha comprises jawless vertebrates which consists of only one class called cyclostomata (Gr; cyclos-circular; stoma-mouth).

Characters

- i. They are exclusively aquatic forms, mostly found in marine water. Mostly parasitic or scavengerous.
- ii. Body is elongated and eel-shaped.

- iii. Their appendages are unpaired.
- iv. Skin is soft, smooth and slimy without scales.
- v. Mouth is circular and suctorial.
- vi. They have single nostril and 5-16 pairs of gills.
- vii. Heart two chambered.
- viii. Sexes are separate or united, gonad single and fertilization is external.

Example: *Petromyzon* (lamprey), *Myxine* (hag fish) etc.



Figure 8.2.21 *Petromyzon*

Division 2: Gnathostomata (Gr; gnatha-jaw; stoma-mouth; ata-form): This division constitutes jawed vertebrates. It has two super classes; Pisces and Tetrapoda

Super class 1: Pisces (L; piscis-fish)

It includes all the fishes which are essentially aquatic having 3 main characters such as body streamlined and covered with scales, respiration by gills, paired fins for locomotion.

Characters:

1. They are always aquatic, freshwater or marine form.
2. Body is streamlined or spindle shaped and divisible into head, trunk and tail. Neck is absent.
3. Locomotion takes place by paired pectoral and pelvic fins; unpaired median dorsal fin and tail fin. Muscular tail acts as propeller and rudder.
4. Body is externally covered by waterproof dermal scales with some exceptions.
5. Their endoskeleton is either bony or cartilaginous.
6. Respiration mainly takes place through gills and gills are naked or covered by operculum. Presence of 5-7 pairs of gill slits.
7. Alimentary canal is a complete tube terminating into cloaca or anus.
8. Their heart is 2 chambered with blood vessels and blood. RBC nucleated.
9. They are poikilothermic i.e. body temperature gets fluctuated according to surrounding environment.
10. Kidneys are mesonephric and excretion is ammonotelic or ureotelic.
11. Nervous system comprises brain, spinal cord and nerves where cranial nerves are 10 paired. Sensory organs are nasal sac for olfaction, auditory apparatus, lateral line system etc.
12. Sexes are separate and fertilization is external or internal. Female is oviparous (eggs large and yolky) or ovoviviparous and development is usually direct.

Unique features

Exclusively aquatic, gill breather, body covered by waterproof scales, locomotion by fins, heart two chambered, poikilothermic, cranial nerves 10 pairs

Super class pisces is broadly divided into 2 classes.

Class 1: Elasmobranchi or Chondrichthyes (Gr; chondros-cartilage; ichthys-fish)

- i. They are marine and predatory fishes.
- ii. Skin is tough with minute placoid scales and some naked with mucous glands.
- iii. Tail is heterocercal.
- iv. They have cartilaginous endoskeleton.
- v. Their mouth is ventral in position.
- vi. Respiration occurs through 5-7 pairs of gills and gill slits are not covered by operculum.
- vii. They have no swim bladder
- viii. Fertilization is internal; male has claspers at the base of pelvic fins to transfer sperm into the genital tract of female. They are ovoviviparous.

Example: *Scoliodon* (dog fish), *Trygon* (sting ray), *Torpedo* (electric ray), *Chimaera* (rat fish) etc.

Class 2: Osteichthyes (Gr; osteon-bone; ichthys-fish)

- i. They are found inhabiting in freshwater, marine water and brackish water.
- ii. They have chiefly bony endoskeleton and hence called as bony fishes.
- iii. Tail is homocercal.
- iv. Freshwater bony fishes have swim bladder connected with alimentary canal which helps in floating or buoyancy.
- v. Their mouth is terminal or sub terminal in position.
- vi. Scales are ganoid, cycloid, or ctenoid and few are naked.
- vii. They respire through 4 pairs of gills supported by bony arches, covered by operculum. Some of them have air bladder and lung for respiration.
- viii. Fertilization is external, male has no copulatory organ.
- ix. Mostly oviparous.

Example: *Labeo* (rahu), *Cyprinus* (carp), *Cirrhinus* (naini), *Hippocampus* (Sea horse), *Exocoetus* (flying fish), *Anguilla* (eel) etc.



Common carp



Scoliodon



Trygon

Figure 8.2.22 some fishes

Super class 2: Tetrapoda (Gr; tetra-four; podos-foot)

Tetrapoda includes animals having two pair of limbs arising from the trunk. They are mostly terrestrial and some of them exhibit amphibious mode of life. Super class tetrapoda consist of following classes:

1. Amphibia (Gr; amphi-dual; bios-life)

- i. They spend dual mode of life i.e. living in land and water both.
- ii. Their body is mainly divisible into head and trunk. Some of them have neck and tail.

- iii. They have two pair of pentadactylous or five toed limbs. Some of them are without limbs.
- iv. Skin is soft moist, glandular and with chromatophore (pigmented cells).
- v. Exoskeleton is entirely absent but endoskeleton is bony with dicondylic skull.
- vi. Alimentary canal is complete; mouth is wide and bounded by jaws. Tongue is often protrusible.
- vii. They respire through skin or lung or lining of buccal cavity. In some forms external gills in larva persist in adults.
- viii. They have three chambered heart with an additional chamber; sinus venosus. Presence of renal portal system and hepatic portal system.
- ix. Kidneys are mesonephros and excretion is urecotelic in adults.
- x. Brain is poorly developed with 10 pairs of cranial nerves.
- xi. Nasal chambers, single ear ossicle (columella) and lateral line system as sensory organs.
- xii. Sexes are separate.
- xiii. Fertilization is external, male without copulatory organs. Female are oviparous and egg are laid in water which hatch out into larva which is completely aquatic and respire through external gills.

Unique features

Need water for reproduction, locomotion by limbs, body without hard exoskeleton, respire through lungs, skin and buccal cavity, heart 3-chambered, kidney mesonephric, poikilothermic, cranial nerves 10 pairs, external fertilization, indirect development

Example: *Rana tigrina* (frog), *Bufo* (toad), *Triton* (newts), *Salamandra* (salamander), *Siren* (mud eel), *Hyla* (tree frog), *Rhacophorous* (flying frog), *Ichthyopis* etc.



Hyla



Salamander



Ichthyopis

Figure 8.2.23 some amphibians

Class 2: Reptilia (L; repere-to crawl)

- i. They are predominantly land dwellers, crawling and some are burrowing forms.
- ii. Body is bilaterally symmetrical and divisible into head, neck, trunk and tail.
- iii. Skin is dry without any glands and is covered by exoskeleton such as horny epidermal scales, shields and scutes.
- iv. They have two pair of lateral limbs arising from trunk which are pentadactyle and digits are with horny claws. Snake and some lizards are without limbs.
- v. Mouth is terminal in position and jaws are with simple conical teeth.
- vi. Endoskeleton is bony and skull is monocondylic.
- vii. Presence of 3-chambered heart with the exception in crocodile (4-chambered). RBCs are oval and nucleated.
- viii. Lungs are the respiratory organs.
- ix. They have metanephric kidney and excretion is urecotelic.

- x. Brain is more advanced than in amphibians and cranial nerves are 12 pairs.
- xi. Jacobson's organs are present which detect smell.
- xii. Fertilization is internal and mostly oviparous.
- xiii. Eggs are large and yolk; protected by shells which are laid on land.
- xiv. Development is direct. Young develop inside embryonic membrane called amnion, chorion, yolk sac and allantois.



Crocodile



Snake



Tortoise

Figure 8.2.24 some reptiles

Unique features

First land vertebrates, body covered by dry horny scales, body divided into head, neck, trunk and tail, two pair of limbs (exception snake), heart-3 chambered, respiration by lungs, metanephric kidney, fertilization internal, young develop in embryonic membrane, 12 pair of cranial nerves.

Class 3: Aves

- i. They are bipedal, feathery and warm blooded (homeothermic) animals which maintain a constant body temperature and able to fly.
- ii. Body is streamlined or spindle shaped and divisible into four distinct regions: head, neck, trunk and tail.
- iii. They have two pair of limbs arising from trunk where fore-limbs are modified into wings. Most of them can fly except flightless birds (e.g., Ostrich). Legs are modified for various purposes like walking, hopping, grasping, perching, wading and swimming. Legs are externally covered by horny epidermal scales.
- iv. They have uropygium gland (preen gland or oil gland) at the base of the tail, no other skin gland is present.
- v. The upper and lower jaws are modified into toothless beak. Beaks are adapted to various ways of feeding; seed-picking, fruit-scooping, flesh-tearing, nectar-sipping, wood-chiseling etc.
- vi. Their endoskeleton is bony and the long bones are hollow with air cavities (pneumatic) to reduce weight. Bone marrow is absent. The skull is monocondylic, i.e., with one occipital condyle. Sternum is with a mid-ventral keel for the attachment of large flight muscles.
- vii. The alimentary canal is complete and opens posteriorly by cloacal aperture. Alimentary canal contains additional chamber such as crop and gizzard. The crop stores and softens the food but gizzard crushes or grinds the food into fine particles.
- viii. Respiratory organs are lungs which are spongy and non-elastic. Air sacs are connected to lungs. Voice is produced by a special organ called the syrinx.

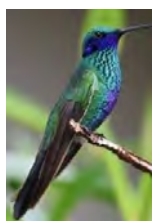
- ix. Birds have four-chambered heart. Renal portal system is reduced. RBCs are oval, nucleated and biconvex structure.
- x. Excretion occurs through metanephric kidney. They are uricotelic animals. Urinary bladder is absent.
- xi. They have well developed brain than the reptiles. Cranial nerves are 12 pairs.
- xii. They have good sense of vision but poor smelling power except kiwi which has good sense of smell. Eyes of bird contain nictitating membrane, sclerotic plate and vascular pecten. Presence of ear opening and middle ear is with single ossicle.
- xiii. Sexes are separate and sexual dimorphism is well marked. Female has a single and functional left ovary and oviduct.
- xiv. All birds are oviparous. Eggs are larger, yolky and protected in hard calcareous shell. Four embryonic membranes - chorion, amnion, allantois and yolk sac are found.
- xv. They are most beautiful creatures showing migratory, courtship, nest building, parental care and territorial behaviour.

Unique features

Feathers covered body, jaws modified as beak, presences of preen gland, forelimbs modified into wings, lungs with air sac, pneumatic bones, single ovary, urinary bladder absent, yolky eggs



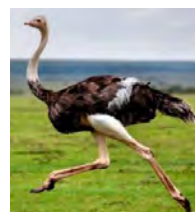
Pigeon



Humming bird



Duck



Ostrich

Figure 8.2.25 some birds

Do you know?

Rhea Americana or American Rhea or South American Ostrich is the only bird that has urinary bladder.

Class 4: Mammalia

- i. They are mostly terrestrial, hair-covered, air breathing, and warm-blooded animals.
- ii. Body is conspicuously divisible into head, neck, trunk and tail.
- iii. They have two pair of pentadactylous limbs, each with 5 or fewer digits and limbs are adapted for walking, climbing, burrowing, swimming or flying. Hind limbs are absent in some aquatic forms such as whale and dolphins.
- iv. Exoskeleton includes horns, hairs, spines, scales, claws nails, hoofs etc.
- v. Skin contains sweat gland and sebaceous gland, mammary glands. Mammary glands are non-functional in males.

- vi. Diaphragm is a muscular partition that separates posterior abdominal cavity from anterior thoracic cavity.
- vii. Endoskeleton is thoroughly ossified, skull is dicondylic, with tympanic bulla and dentary.
- viii. They have complete alimentary canal terminating into anus. Teeth are heterodont, thecodont and diphyodont.
- ix. Respiration is always pulmonary.
- x. Heart is four chambered and absence of renal portal system. RBC non-nucleated.
- xi. Chief excretory organs are a pair of metanephric kidney and excretion is ureotelic.
- xii. Brain is highly developed with 12 pairs of cranial nerves.
- xiii. Sense organs are well developed; eye protected within eye lid, ear opening protected by pinna and middle ear with ear ossicles (malleus, incus and stapes) and inner ear consist of spiral cochlea.
- xiv. Sexes are separate with distinct sexual dimorphism where male has erectile copulatory organ called penis and testis within scrotum pouch, and eggs are small with little yolk.
- xv. Fertilization internal. They are all viviparous except some. Development is uterine in which foetus is attached to the wall of uterus of mother by placenta for nutrition and respiration. Embryonic membranes are amnion,chorion and allantois.

Unique features

Body covered by hair, sweat and sebaceous gland in skin, ear with pinna and three ear ossicles, dentition well developed, presence of diaphragm, mostly viviparous, mammary glands in female for breast feeding



Horse



Bat



monkey



Whale

Figure 8.2.26 some mammals

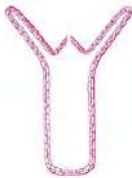
Activity 8.6

Divide the student of your class in five groups where each group is going to perform task on individual class of vertebrates. Observe the vertebrate animals around you. Mention the class, characters, scientific name, common name, economic importance of animals you observed on the chart paper and present it. (Take the help of your teacher if required)

EXERCISE

A. Tick the correct alternative.

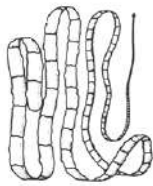
1. Which of the following is a freshwater sponge?
 - a. *Sycon*
 - b. *Spongilla*
 - c. *Hyalonema*
 - d. *Euspongia*
2. The body plan shown in the figure is found in.....



- a. *Hydra*
 - b. *Ascaris*
 - c. cockroach
 - d. earthworm
3. *Hyalonema* is commonly called....
 - a. bath sponge
 - b. urn sponge
 - c. vase sponge
 - d. glass rope sponge
 4. Water canal system is the unique character of phylum.....
 - a. protozoa
 - b. porifera
 - c. coelenterate
 - d. echinodermata
 5. The internal hollow cavity of a poriferan animal is
 - a. coelom
 - b. coelenterons
 - c. spongocoel
 - d. schizocoel
 6. Which of the following animal is commonly called a freshwater polyp?
 - a. *Obelia*
 - b. *Metridium*
 - c. Jelly fish
 - d. *Hydra*
 7. In sponges, a larva is.....
 - a. planula
 - b. hydrula
 - c. miracidium
 - d. amphiblastula
 8. Nematocyst is found in.....
 - a. nemathelminthes
 - b. coelenterate

- c. platyhelminthes
 - d. annelida
9. Which of the following animals are called cnidarians?
- a. sponges
 - b. coelenterates
 - c. echinoderms
 - d. mollusca
10. Diffused type of nervous system is found in.....
- a. *Hydra*
 - b. tapeworm
 - c. earthworm
 - d. leech
11. Which of the following animals show polymorphism?
- a. coelenterates
 - b. platyhelminthes
 - c. arthropods
 - d. mollusks
12. Metagenesis is the characteristic feature of
- a. porifera
 - b. protozoa
 - c. coelenterata
 - d. nemathelminthes
13. Identify the larval form of coelenterate.
- a. trochophore
 - b. planula
 - c. amphiblastula
 - d. parenchymula
14. What are the excretory organs of platyhelminthes?
- a. renette cells
 - b. flame cells
 - c. nephridia
 - d. coxal glands
15. Planaria is
- a. parasite
 - b. free-living
 - c. commensal
 - d. predator
16. Which of the following is acoelomate?
- a. tapeworm
 - b. earthworm
 - c. roundworm
 - d. leech
17. Pseudocoelom is only found in the phylum....
- a. cnideria
 - b. platyhelminthes

- c. nemathelminthes
 - d. annelida
18. Which of the following phylum consists of diploblastic animals?
- a. Porifera
 - b. Coelenterata
 - c. Platyhelminthes
 - d. both porifera and coelenterata
19. *Ascaris lumbricoides* is
- a. Digenetic
 - b. monogenetic
 - c. phylogenetic
 - d. morphogenetic
20. Which of the following disease is caused by the animal shown in the figure?



- a. taeniasis
 - b. liver rots
 - c. pleurosis
 - d. schistosomiasis
21. Locomotion in *Nereis* takes place by.....
- a. setae
 - b. parapodia
 - c. suckers
 - d. cilia
22. Excretory organs of annelida are.....
- a. nephridia
 - b. green glands
 - c. kidney
 - d. ctenidia
23. Which of the following animal is commonly called sea mouse?
- a. *Nereis*
 - b. *Arenicola*
 - c. *Aphrodite*
 - d. *Tubifex*
24. In archiannelida, locomotory organs are
- a. setae
 - b. parapodia
 - c. suckers
 - d. absent
25. Which of the following phylum is the largest in animal kingdom?
- a. annelida
 - b. arthropoda

- c. mollusca
 - d. echinodermata
26. Cephalothorax is the structure in which.....
- a. head and thorax are separated
 - b. head and abdomen fused
 - c. head and thorax fused
 - d. thorax and abdomen fused
27. Which of the following arthropod is also called a living fossil?
- a. spider
 - b. *Limulus*
 - c. *Spirobolus*
 - d. lobster
28. The periodic shedding of outermost layer of skin is called
- a. instar
 - b. moulting
 - c. polymorphism
 - d. apolysis
29. Compound eyes consist of a number of
- a. eyes
 - b. ommatidia
 - c. appendages
 - d. antenna
30. How many legs are there in prawn?
- a. 5
 - b. 6
 - c. 7
 - d. 8
31. Which of the following is the terrestrial crustacean?
- a. prawn
 - b. lobster
 - c. spider
 - d. wood louse
32. *Scolopendra* is
- a. carnivorous
 - b. hervivorous
 - c. omnivorous
 - d. detrivorous
33. Soft bodied animals are
- a. molluscs
 - b. echinoderms
 - c. arthropods
 - d. pisces
34. The dorsal glandular fold of the apple snail s called.....
- a. ctenidia
 - b. osphradium

- c. mantle
 - d. hard cover
35. Which of the following animals are called benthic invertebrates?
- a. sponges
 - b. coelenterates
 - c. mollusca
 - d. echinoderms
36. The animals which are exclusively marine belong to the phylum.....
- a. porifera
 - b. coelenterata
 - c. echinodermata
 - d. annelida
37. What is the common name for the animal shown in figure?



- a. Freshwater mussel
 - b. *Dentalium*
 - c. apple snail
 - d. elephant tusk shell
38. Locomotory organs of mollusca are
- a. tube foot
 - b. appendage
 - c. muscular foot
 - d. parapodia
39. In echinoderms, locomotion takes place by.....
- a. appendage
 - b. muscular foot
 - c. Tube foot
 - d. cilia
40. Which of the following organ is the rasping organ in mollusca?
- a. mantle
 - b. radula
 - c. stomach
 - d. osphradium
41. Identify the respiratory pigment found in the given animal.



- a. haemoglobin
- b. myoglobin

- c. erythrocrurin
 - d. haemocyanin
42. Water vascular system is the unique characteristic of some invertebrates. In which of the following phylum these animals belong to?
- a. porifera
 - b. coelenterata
 - c. mollusca
 - d. echinodermata
43. Which of the following animal is also called feather star?
- a. *Ophioderma*
 - b. *Antedon*
 - c. *Echinus*
 - d. *Asterias*
44. In vertebrates, heart is located.....
- a. laterally
 - b. dorsally
 - c. ventrally
 - d. posteriorly
45. Which of the following vertebrate is jawless?
- a. dogfish
 - b. hagfish
 - c. trout
 - d. carp fish
46. Which of the following animal is poikilothermic?
- a. dog
 - b. cow
 - c. frog
 - d. pigeon
47. In which class of vertebrates does the given animal belong to?



- a. pisces
 - b. amphibia
 - c. reptilia
 - d. mammals
48. How many pairs of cranial nerves are there in amphibians?
- a. 10
 - b. 11
 - c. 12
 - d. 13
49. Which of the following statement is true for the reptilians?
- a. their skin is moist with mucous glands.

- b. their skin is moist and shiny.
 - c. their body is covered with dry horny epidermal scales.
 - d. they have sweat gland in skin with horny scales
50. Which of the following type of kidney is found in reptiles?
- a. pronephric
 - b. mesonephric
 - c. metanephric
 - d. enteronephric
51. Which of the following animal has dicondylic skull?
- a. frog
 - b. lizard
 - c. monkey
 - d. frog and monkey
52. In birds, sound is produced by.....
- a. larynx
 - b. syrinx
 - c. vocal cord
 - d. vocal sac
53. Left ovary is not found in.....
- a. crow
 - b. rabbit
 - c. toad
 - d. frog
54. Which of the following is true for the diaphragm?
- a. The diaphragm is the unique muscle found in mammals.
 - b. The diaphragm is the unique structure present in all vertebrates
 - c. The diaphragm is an exclusive respiratory muscle in humans
 - d. The diaphragm is the membrane that regulate the pressure within circulatory system
55. How many chambered heart is found in crocodile.....
- a. 2
 - b. 3
 - c. 4
 - d. 5
56. Sweat gland and sebaceous glands are only found in
- a. pisces
 - b. amphibians
 - c. aves
 - d. mammals

A. Answer the following questions:

1. Compare and contrast *Hydra* and *Sycon*.
2. Mention any six unique features of porifera phylum. Classify this phylum with examples.
3. In which phylum, metagenesis occurs? Also mention any six unique features of this phylum.

4. In the biology laboratory, a student observes *Ascaris* of both sexes. How can he distinguish male and female *Ascaris*?
5. What do you mean by mouth parts? Give the meaning of cephalothorax? Write any four peculiar features of arthropoda?
6. Classify the phylum mollusca with two characters and examples of each class.
7. What are the three main features of phylum chordata.
8. Why hag fish is not a true fish? Give reason.
9. Complete the following table:

Phylum	Coelom type	Alimentary canal	segmentation	Excretory organ
Platyhelminthes			pseudosegmentation	
Annelida		complete		Nephridia
Nemathelminthes				

10. Write any four differences between spider and prawn.
11. What are the unique features of aves?
12. Echinoderms are the unique animals among invertebrates. Justify the statements.
13. Identify the following animals and write any three differences between them.



A



B

14. How do you differentiate millipede from centipede?
15. Mention any 5 characters of osteichthyes and chondrichthyes.
16. What are the differences between pigeon and bat?

Chapter 8.4

EARTHWORM

Pheretima posthuma

Observe the animal given below and answer the following questions.



- What might be its phylum and scientific name?
- This animal always keeps skin moist? Why?
- Is it free living or parasitic?
- What might be its white coloured thick band near the anterior end of body?
- Is it beneficial for us? How?

8.3.1 GENERAL INTRODUCTION

Systematic position

Kingdom	: Animalia
Phylum	: Annelida
Class	: Oligochaeta
Genus	: <i>Pheretima</i>
Species	: <i>posthuma</i>
Common name	: Earthworm

The animal shown in the diagram is earthworm belonging to the phylum annelida and its scientific name is *Pheretima posthuma*. Earthworms are found under the soil in moist burrow. They have not developed any special respiratory organs like lungs, gills or other structures and hence they respire through moist skin. They maintain skin moist with the help of mucous glands present in their skin. Such type of respiration is called **cutaneous respiration**. They are **free living** and **omnivorous** animals. They feed on soil rich in decaying organic matter, dried leaves, insect larva, protozoans, arthropod exoskeleton etc. Nearer to the anterior end, their body contains a ring or belt like conspicuous glandular tissue called **clitellum** which forms cocoons. Earthworms are useful in agriculture as they help to increase the fertility of soil by their movements and excreta, hence considered friend of farmers.

8.3.2 HABIT AND HABITAT

Earthworms are terrestrial, living in burrows and moist soil rich in decaying organic matters. They are mostly found under the soil in irrigated farmlands, garden, lawns etc. They are free living and nocturnal animals. At night time, they come out of their burrow for searching food, finding new habitat and for reproductive activities. Similarly, they are seen in large number on the earth surface during rainy season as it is their breeding season and burrows are full of water due to heavy rainfall. Earthworm makes burrow by excavating and engulfing soil with its

anterior end and moving down progressively. It derives food from decaying organic matter present in the soil and discharge the undigested content along with the soil as faecal matter in the form of “worm casting”. Although they are hermaphrodite, self-fertilization does not occur. Hence, there always occurs copulation between two mature worms. In earthworm copulation is for the exchange of sperm between two mature worms. Fertilization is external that takes place in cocoon and development is direct. Earthworms also have capacity to reproduce asexually by regeneration.

8.3.3 EXTERNAL FEATURES (MORPHOLOGY)

Activity 8.7

Objective: To identify the external parts of an earthworm

Apparatus required: dissecting tray, forceps, needle

Procedure:

- i. Take a freshly caught or preserved specimen of earthworm. (Kill the freshly caught earthworm by dipping it in formalin)
- ii. Then, Keep it on dissecting tray.
- iii. Point out its external parts with the needle. (Take the help of your teacher if required)
- iv. Note down all the structures on white board.
- v. Now discuss its external characteristics and draw its well labeled diagram.

Conclusion

1. Shape, size and colour

Body of *Pheretima* is vermiform, elongated, cylindrical and bilaterally symmetrical. It is pointed anteriorly and more or less blunt posteriorly. A mature earthworm measures about 15 cm in length and 0.3-0.5 cm in diameter. Body colour of earthworm is shining deep brown because of the presence of porphyrin pigment in the body wall. This pigment also protects the body from the harmful effect of solar radiations. Dorsal surface is darker than ventral surface and carries dorsal blood vessel as a median line from the anterior end to the posterior end.

2. Segmentation

Body of earthworm is soft which is divided into 100-120 similar segments called somites or metameres. Segments are separated externally by grooves and internally by septa. Segmentation is true because external segmentation corresponds with internal segmentation which is called metamerism, hence its body is metamerically segmented.

3. Prostomium and peristomium

The anterior part of the earthworm is not differentiated as a distinct head and without sense organs like eyes, tentacles. The first segment of the earthworm in which mouth is situated called peristomium (peri-around; stoma-mouth).

From the peristomium arises anteriorly, a fleshy lobe-like structure called the prostomium (pro-before; stoma-mouth). Prostomium is also called the boring organ and it is tactile organ too.

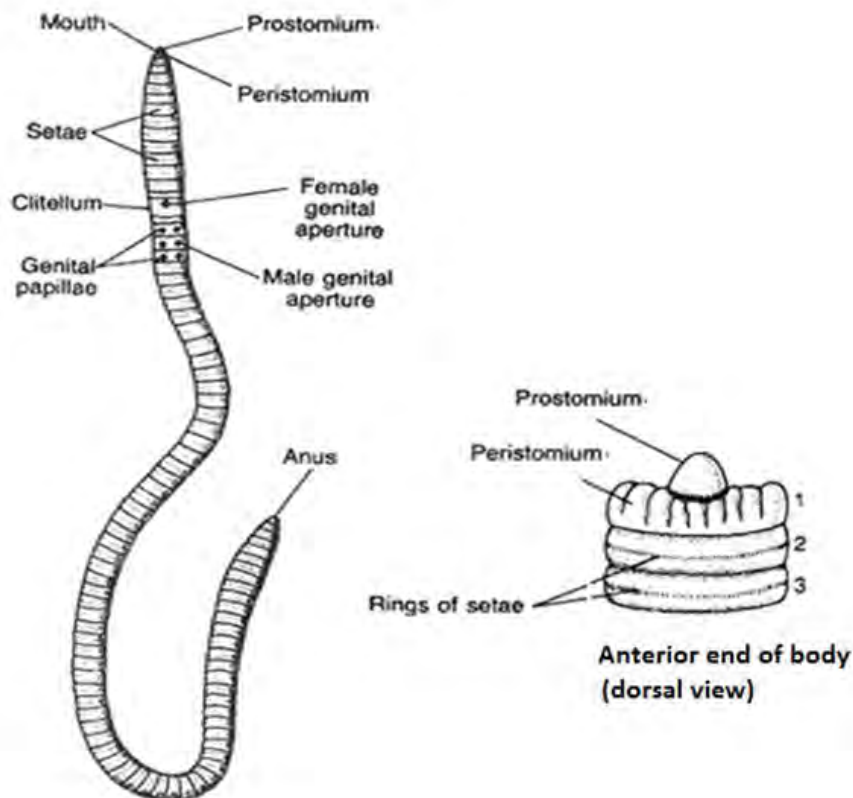


Figure 8.3.1 *Pheretima posthuma* (a) Ventral view (b) dorsal view of anterior end of body

4. Clitellum or Cingulum

There is a prominent, thick and circular band of glandular tissue in mature worm surrounding 14th, 15th and 16th segment which is called clitellum or cingulum. Clitellum consists of albumen secreting cells, mucous secreting cells and cocoon forming cells. Clitellum divides the body into: pre-clitellar region (from the 1st to the 13th segment), clitellar region (from the 14th to the 16th segment) and post-clitellar region (from the 17th up to the last segment).

5. Setae

All segments except first, last and clitellar segments bear a ring of chitinous and backwardly directed bristles called setae. Setae are found embedded in the body wall, arranged in the row at the middle of each segment. Their number ranges from 80-120 per segment and arrangement is called perichaetine. A seta has a light-yellow colour, and shape like elongated 'S' with a swollen middle part called nodulus. Locomotion takes place in earthworm with the help of setae. Movement of setae is controlled by some special muscles called protractor and retractor muscles of the body wall.

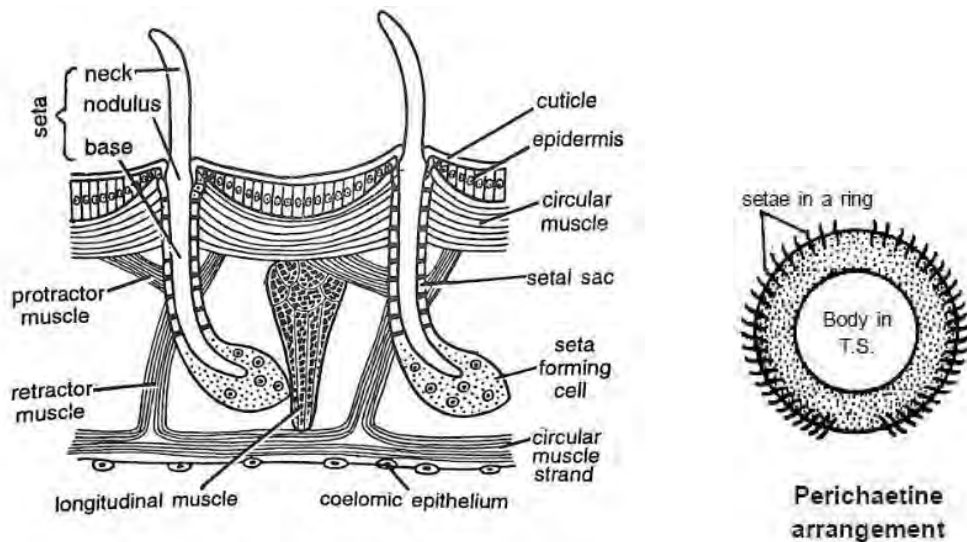


Figure 8.3.2 T.S of body wall through setae

6. External apertures or openings

There are several openings or apertures on the body wall of earthworm which are listed below :

- i. **Mouth:** It is a crescent shaped and anterior most opening situated in the first segment called peristomium. It is ventrally located.

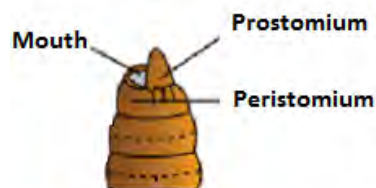


Figure 8.3.3 location of mouth

- ii. **Spermathecal pores:** There are altogether four pairs of small apertures of spermathecae (sperm storing sacs) and each pair situated at the intersegmental groove of 5th and 6th, 6th and 7th, 7th and 8th, 8th and 9th in ventro-lateral position.
- iii. **Nephridiopores:** A large number of very minute openings of integumentary nephridia are found scattered throughout the body of earthworm except first two segments. These openings are used for the removal of metabolic nitrogenous wastes extracted from blood capillaries.
- iv. **Dorsal pores:** These minute apertures are found along the mid-dorsal line in the inter-segmental groove from 12th and 13th segment onwards except the last groove. They are the opening of coelomic chambers through which coelomic fluid oozes, making body moist.

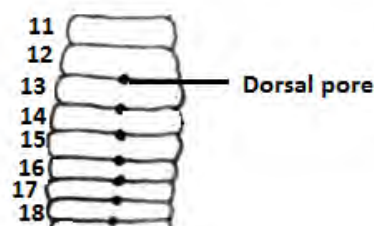


Figure 8.3.4 location dorsal pores

- v. Female genital aperture: A single median aperture or opening of common oviduct lying on the ventral surface of 14th segment called female genital opening which is used for discharging out ova.
- vi. Male genital apertures: There is a pair of crescentic openings situated on the ventro-lateral surface of 18th segment which are called as male genital openings. They are used to discharge sperms during copulation by earthworms.
- vii. Anus: It is a vertical slit like opening at the posterior most segment of the body called pygidium or anal segment. It is the last part of alimentary canal through which faecal matters are discharged.

7. Genital papillae

Genital papillae are two pairs in number and structurally; they are prominent rounded elevations, each pair in the 17th and 19th segment; each in ventro-lateral position. These papillae are used for the attachment of two mature worms during copulation.

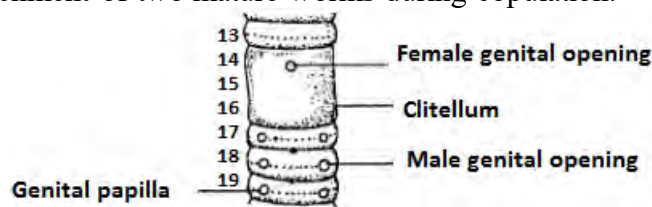


Figure 8.3.5 apertures in 13th to 19th segments magnified

Body wall of Earthworm

Body wall of earthworm is thin, soft, elastic and moist which is composed of four layers. These layers are cuticle, epidermis, a well-developed muscular layer and a thin parietal layer of coelomic epithelium from outside.

1. Cuticle:

Cuticle is a thin, elastic, non-living and finely striated layer which forms the external protective covering of the body. It is composed of two layer of collagen fibres mixed with a polysaccharide and small amount of gelatin. It is secreted by underlying epidermis. Cuticle also consists of numerous pores through which epidermal glands and nephridia open out.

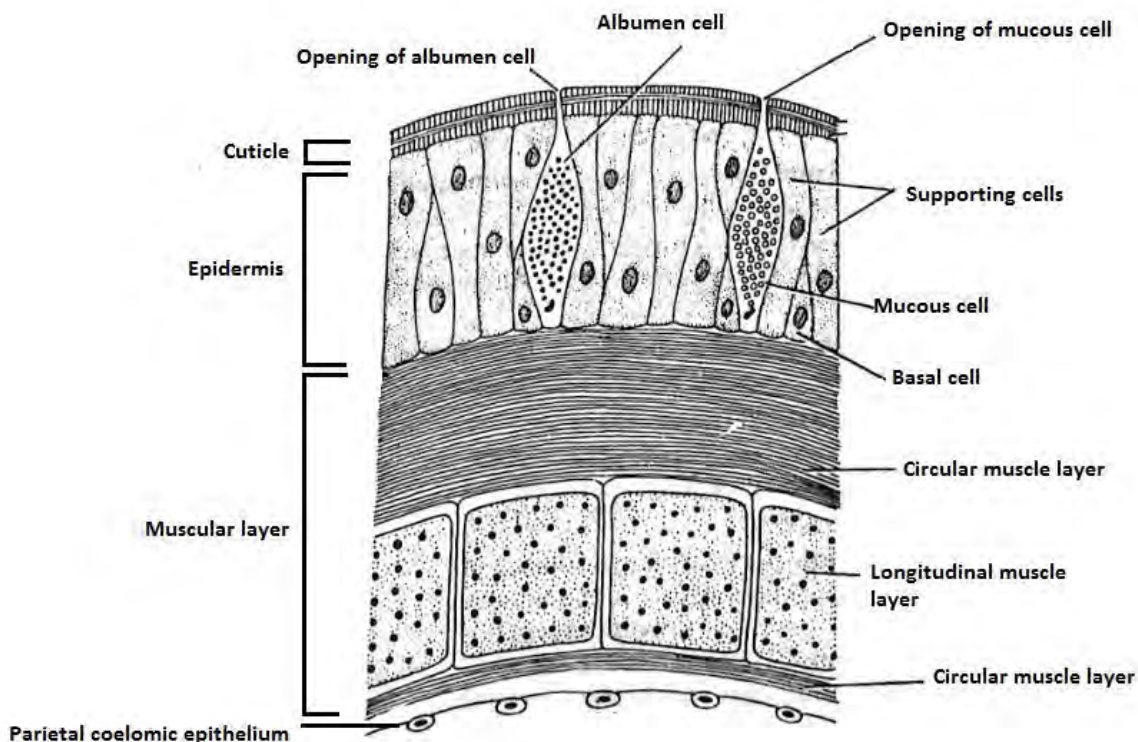


Figure 8.3.6 T.S of body wall of earthworm

2. Epidermis:

This is a single layer of epithelial cells lying just below cuticle resting on basement membrane. The constituent cells are of different types: supporting cells, gland cells, basal cells, sensory receptor cells.

- **Supporting cells** form the major bulk of epidermis and secrete cuticle.
- **Gland cells** comprise mucous cell and albumen cell which secrete mucus and albumen respectively. These secretions make skin moist, slippery and also help in cementing the wall of burrows.
- **Basal cells** are small and conical shaped present between gland cell and supporting cells at the lower end. These cells replace worn out gland cells and supporting cells and hence called **replacing cells**.
- **Sensory cells** are also found in clusters with hair like processes at the outer end and they are photo, chemo and touch receptors.

3. Muscular layer:

Muscular layer lies just below the epidermis. It consists of outer thin layer of circular muscle fibres (around the body) and inner thick layer of longitudinal muscle fibre (along the length of body).

- Circular muscle layer is thin and contains scattered granules of porphyrin pigment which imparts brown colour to the skin.
- Longitudinal muscle layer is thicker and lies in the form of parallel bundles separated by connective tissue and strengthened by collagen fibres.
- There is another thin strip of circular muscle lying below the layer of longitudinal muscles.

Circular muscles and longitudinal muscles are opposite in function i.e. contraction of one cause relaxation of other and vice versa.

4. Parietal coelomic epithelium:

It is a thin and single layer of flattened squamous epithelial cells that forms the outer envelope of coelom.

Coelom in earthworm

Earthworm has true coelom or schizocoel which is the cavity between alimentary canal and body wall and is formed by splitting of mesoderm in the embryonic stage. Coelom of earthworm is divided into a number of coelomic chambers by the intersegmental muscular septa. Septa are absent up to the 4th segment and present behind it. The first septum is thin and lying in between 4th and 5th segment. Similarly, there is only a single septum between 8th and 10th segments. Septa from 4th /5th upto 13th /14th are without perforations whereas septa from 14th /15th up to the last are with sphinctered openings.

Coelom in earthworm is filled with an alkaline, whitish or colourless fluid that contains salts, proteins, water and coelomic corpuscles. Coelomic corpuscles are of four types:

i. Phagocytes or amoebocytes or granulocytes:

They are the largest and more numerous cells. They are nucleated cells having amoeboid shape. They are called phagocytes since they eat/engulf bacteria.

ii. Mucocytes:

They are elongated cells which have broad fan like structure at one end and narrow nucleated part at the other end.

iii. Circular nucleated cell:

These cells are less numerous, round shaped, nucleated and filled with clear cytoplasm.

iv. Chloragogen cell:

They are star shaped and small sized cells. They become deep yellow coloured when stained in iodine solution. They are excretory in function and remove waste from coelomic fluid. They are analogous to the liver of higher animals as they store reserve food material in the form of glycogen.

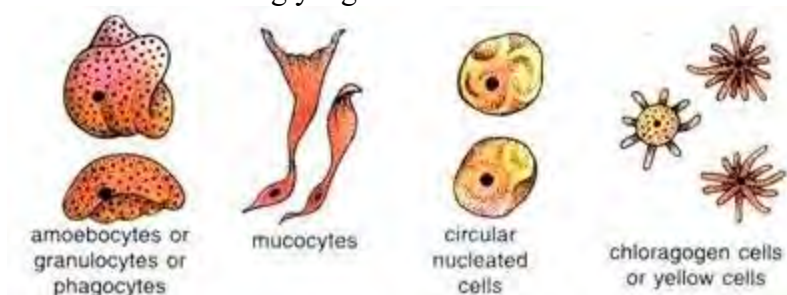


Figure 8.3.7 Coelomic corpuscles

Function of coelomic fluid

- Coelomic fluid act as hydroskeleton making body turgid and stiff that aids in locomotion.
- Coelomic fluid oozes out through dorsal pore which makes skin moist for cutaneous respiration.
- It also acts as antiseptic protecting skin from microbial infection.

8.3.4 DIGESTIVE SYSTEM

Let's discuss the given questions.

- i. What process actually occurs in the process of digestion?
- ii. Do earthworms have complete or incomplete alimentary canal? Why?
- iii. What is the feeding habit of earthworm?

Digestive system is the complex system of organs chiefly concerned for the conversion of complex food particles into simpler forms by the action of digestive organs and digestive glands. This system also performs the absorption of nutrients from the digested food and elimination of undigested food particles in the form of faeces. Digestive system can be broadly divided into **alimentary canal** and **digestive glands**.

Alimentary canal: In earthworm, it is a long, complete and straight tubular structure of varying diameter extending from mouth to anus; also called gastrointestinal tract. It consists of following parts:

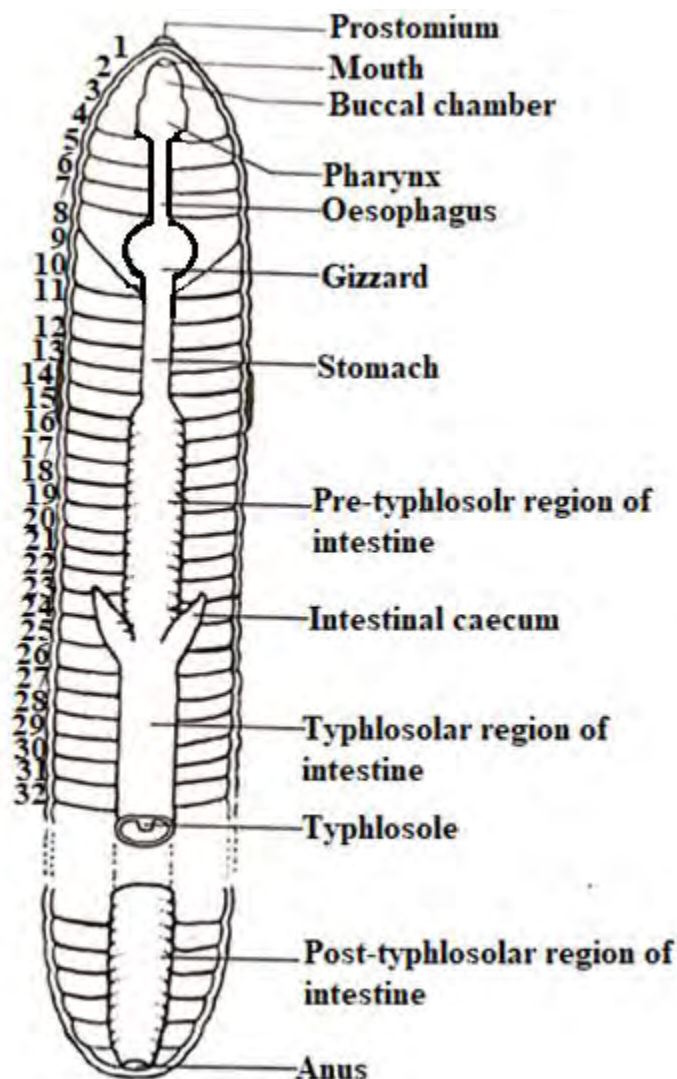


Figure 8.3.8 Alimentary canal of *Pheretima posthuma*

1. Mouth and buccal chamber (1st - 3rd segment) :

Mouth is the crescentic opening, lying below the prostomium at the ventral position in the first segment. It posteriorly leads into a short, narrow and thin walled protrusible chamber or cavity called buccal chamber. Buccal cavity extends up to the middle of 3rd segment. The innermost epithelial layer of buccal chamber is thrown into longitudinal folds.

2. Pharynx (3rd – 4th segment):

Buccal chamber is followed by a wide, pear-shaped muscular structure called pharynx. Pharynx and buccal cavity are separated by a transverse constriction or groove. Pharynx extends from the middle of 3rd segment up to 4th segment

Histologically, dorsal part or the roof of pharynx seems thicker and forms pharyngeal bulb. Similarly, its lateral wall is projected as horizontal fold or shelves; dividing the lumen (hollow cavity) incompletely into the dorsal salivary chamber and ventral conducting chamber. Pharyngeal bulb contains salivary glands composed of chromophil cells which secrete saliva and pour into salivary chamber. Saliva contains mucus and proteolytic enzymes. Mucus lubricates food and proteolytic enzymes digest protein. Ventral conducting chamber simply serves as the passage of food particles.

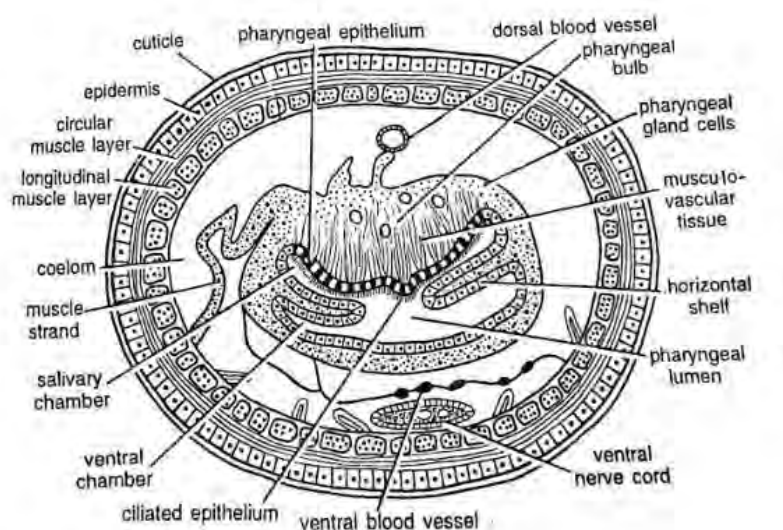


Figure 8.3.9 T. S. of body wall of earthworm through pharynx

Pharynx remains connected with the body wall by muscular strands. Contraction and relaxation of these muscles help to compress and dilate the lumen of pharynx and this process facilitates in sucking and pumping of food particles.

3. Oesophagus (5th - 7th segment):

Pharynx is followed posteriorly by a short narrow and thin-walled tubular structure, oesophagus. It extends from 5th to 7th segment. Oesophagus doesn't contain any glands. Food passes downwards through it by peristalsis.

4. Gizzard (8th or 8th to 9th segment):

Gizzard is a distinct, oval, hard, thick-walled and highly muscular organ. It is located in 8th or 8th to 9th segment and chiefly composed of thick layer of circular muscles. Lumen of gizzard is internally lined by cuticle. The function of gizzard is to grind or crush the food particles into fine state, thus acts as 'grinding organ'.

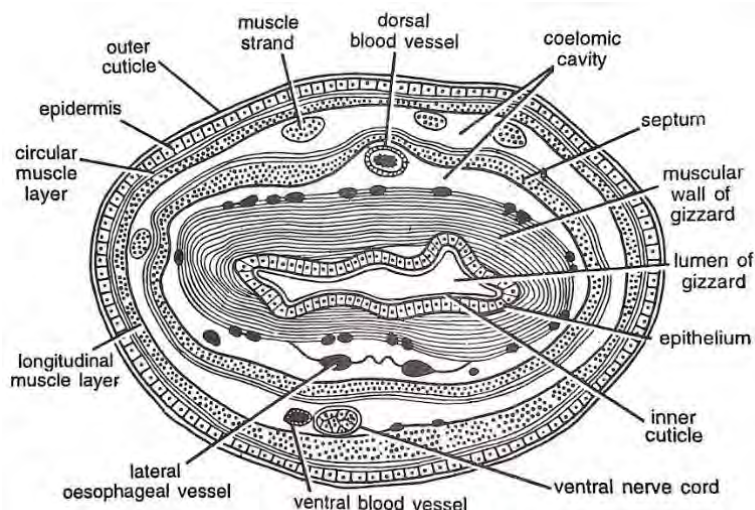


Figure 8.3.10 T.S of earthworm through gizzard

5. Stomach (9th to 14th):

Gizzard leads into a short, narrow and thin-walled tube called stomach; extending from 9th to 14th segment with a sphincter at both ends. Its inner layer is highly vascular and glandular and thrown into internal transverse folds.

Calciferous glands are found in the epithelial lining of stomach that produces Ca and CO₂. These glands excrete excess Ca and CO₃ ion in calcite form.

6. Intestine (15th onwards):

Stomach is followed by a long, wide and thin-walled tubular structure called intestine. It extends from 15th segment up to the last segment. It appears beaded in structure because of circular constrictions corresponding to the septa.

Intestine is divisible into 3 regions: pre-typhlosolar region, Typhlosolar region and Post-typhlosolar region.

i. Pre-typhlosolar region:

This region of intestine extends from 15th to 26th segment. Its inner wall is glandular, highly vascular and internally folded to form minute processes called villi. In the 26th segment, from the intestine arises a pair of lateral and upwardly directed conical outgrowths called intestinal caeca and each extends up to 23rd segment. These structures secrete amylase enzyme. They are also vascular and possess villi like processes.

ii. Typhlosolar region:

This is the second part of intestine which is characterized by the presence of a typhlosole. Typhlosole is a highly vascular, glandular and dorsal median longitudinal fold that extends from 27th segment onwards except last 25 segments. It is regarded as well-developed and largest villi. It has main role in the digestion and absorption of food.

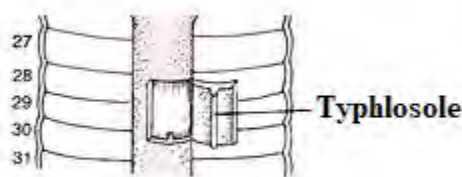


Figure 8.3.11 Intestine of earthworm cut open to show typhlosole

iii. Post-typhlosolar region:

Post typhlosolar region is the last part of the intestine, also called rectum. It is thin-walled vascular and comprises about last 25 segments. This region is devoid of typhlosole, villi and gland cells but its inner layer is longitudinally folded. It contains small pellets of mud as faeces.

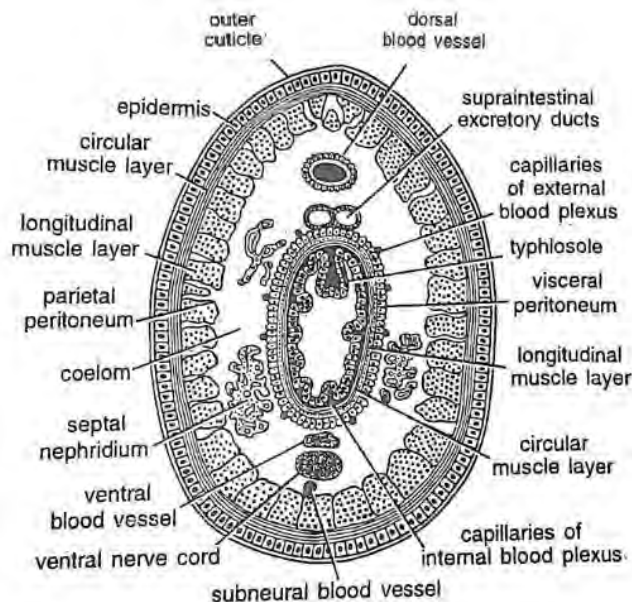


Figure 8.3.12 T.S of earthworm through typhlosolar region

7. Anus:

Post typhlosolar region opens externally by a circular opening at the centre of last segment. Faecal matter (worm casting) is discharged through it.

Activity 8.8

Visit the biology laboratory with your biology teacher and dissect the earthworm to identify its different parts of alimentary canal. Draw a labelled diagram of it on the chart paper and discuss.

PHYSIOLOGY OF DIGESTION

The process of conversion of complex food particles into simpler absorbable or diffusible forms is digestion. This process is carried out by the organs and glands in the digestive tract. It involves both mechanical and chemical processes. Mechanical process is simply the conversion of larger food particles into smaller forms so that enzymes thoroughly act on it. Whereas the chemical process is the chemical conversion of complex organic compounds such as different types of carbohydrates, protein, fat into glucose, galactose, amino acid, fatty acid and glycerol etc. as end products. Physiology of digestion can be discussed under following heads:

1. Food:

Earthworm is omnivorous and detritivorous. It feeds on soil rich in decaying organic matter such as decayed leaves, nematodes, protozoan, insect's egg, larva and other micro-organisms. It can directly feed on leaves, grasses, algae etc.

2. Feeding:

At the time of feeding, buccal cavity is protruded or everted out and the soil with food is drawn into the mouth by sucking and pumping action of the pharynx. It is aided by the muscles around the pharynx.

3. Digestion:

Ingested foods into the buccal cavity do not undergo digestion. Now, the food is passed into the pharynx which receives secretion of salivary glands. Salivary secretion contains mucus and proteolytic enzymes which lubricate food as well as digest proteins into proteoses and peptones. Now, food passes into gizzard through oesophagus by peristalsis. Gizzard acts as grinder because of its contractile muscular wall and cuticle lined lumen. It grinds or pulverizes the larger food masses into the fine powdered form. Food now reaches into the stomach where further digestion of protein by proteolytic enzymes occurs. Semi digested food, now passes into the intestine and gets digested completely. Such food is subjected to the action of various enzymes secreted by intestine and intestinal caeca.

- i. Amylase: This enzyme acts upon the carbohydrates to convert them into simple sugar like glucose, fructose etc.
- ii. Protease: It hydrolyses proteins or proteoses and peptones into amino acid.
- iii. Lipase: It digests fats and converts into fatty acid and glycerol.
- iv. Chitinase: It digests chitin found in exoskeleton of arthropods.
- v. Cellulase: This enzyme digests cellulose.

4. Absorption and egestion

Nutrients from digested food are absorbed by the intestinal villi, particularly by the typhlosole. After absorption, they are passed into blood capillaries in the intestinal wall and transported to the various parts of the body. Hence, intestine is the site for both the digestion and absorption of food. Undigested food materials and soil are discharged out through the anus in the form of small rounded pellets of mud called worm casting.

8.3.5 EXCRETORY OR NEPHRIDIAL SYSTEM

Let's discuss the given questions.

- i. What is excretion?
- ii. Why do animals excrete?
- iii. Is earthworm ammonotelic, ureotelic or uricotelic? Why?
- iv. What is the excretory organ of earthworms?

In the body of living beings, various waste products are generated due to metabolic activities. Such wastes should be eliminated for maintaining healthy and stable internal environment of the body. Excretion is the process of expulsion of metabolic wastes, especially nitrogenous wastes produced inside the body. Earthworm is an ureotelic and ammonotelic animal. Excretion is performed by segmentally arranged, microscopic, long, thin and much convoluted tubular units called nephridia. Nephridia of earthworm are small; called micronephridia unlike those of leech and *Nereis* which are larger, called meganephridia.

According to the location of nephridia in the body of earthworm, they are distinguished into 3 types: pharyngeal, integumentary and septal nephridia.

1. **Pharyngeal nephridia:** 4th 5th and 6th segment.
2. **Integumentary nephridia:** Entire body wall except first few segments.

3. **Septal nephridia:** Attached to both the faces of each inter-segmental septum from 15/16 segment upto the last.

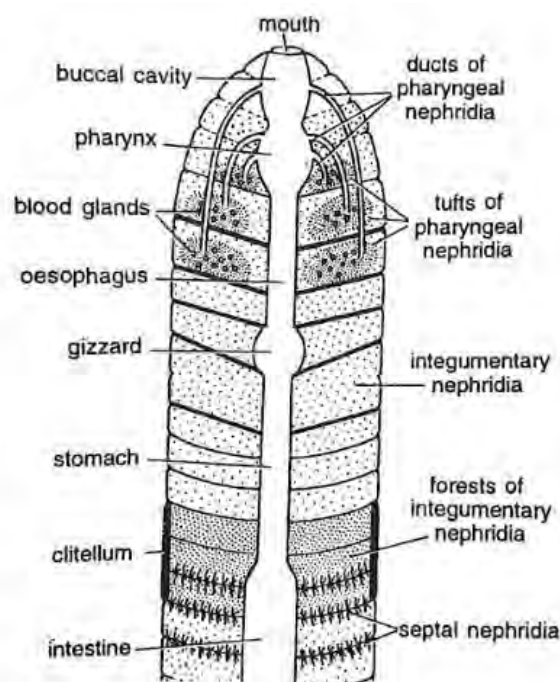


Figure 8.3.13 excretory system in earthworm

1. Pharyngeal nephridia

Pharyngeal nephridia are found as paired tufts on the both side of pharynx and oesophagus in the 4th, 5th and 6th segment. Each tuft comprises hundreds of coiled branched tubules along with blood glands. In each tuft, a single thick-walled common duct is formed by the union of the terminal duct of all nephridia. This nephridial duct from each tuft runs anteriorly parallel to the ventral nerve cord. Ducts of 4th and 5th segments open into pharynx while those of 6th segment open into buccal chamber or 2nd segment. Pharyngeal nephridia are enteronephric nephridia or endonephric as they pour waste into the alimentary canal i.e. pharynx and buccal cavity through the common nephridial duct. These nephridia are closed type i.e. without nephrostome and they extract waste from only capillaries.

2. Integumentary nephridia

These nephridia are found distributed on the entire inner surface of body wall except first two segments. About 200-250 nephridia are found in each segment except clitellum region. Each segment of clitellar region contains about 2000-2500 integumentary nephridia. So the clitellar region is also called “forest of nephridia”. Integumentary nephridia are microscopic, V-shaped and without nephrostome or any opening into coelom. Hence, they are closed type nephridia. The terminal duct of each nephridium opens exteriorly through the minute opening called nephridiopore on the outer surface of the body wall. These nephridia discharge wastes directly to the outside and hence called exonephric or ectonephric nephridia. These nephridia also extract wastes from capillaries only.

3. Septal nephridia

Septal nephridia are the largest and considered as the most advanced or typical nephridia of earthworm with the nephrostome. They are found attached to both the faces of each intersegmental septum behind 15th segment. Altogether 80-100 septal nephridia are found on each septum except 15th segment which contains only 40-50. Septal nephridia remain

suspended freely in coelomic chambers. They are called enteronephric since they also discharge wastes into the gut. Each septal nephridium consists of 3 parts:

i. Nephrostome or nephridiostome

It is the proximal, ciliated funnel like structure, communicating with coelom. Nephrostome consists of an oval shaped pore bounded by ciliated upper lip and lower lip. Upper lip consists of about eight ciliated marginal cells and a large central cell and lower lip is lined with about four ciliated compact cells. Continuous beating movement of these cilia helps to extract nitrogenous wastes from coelomic fluid.

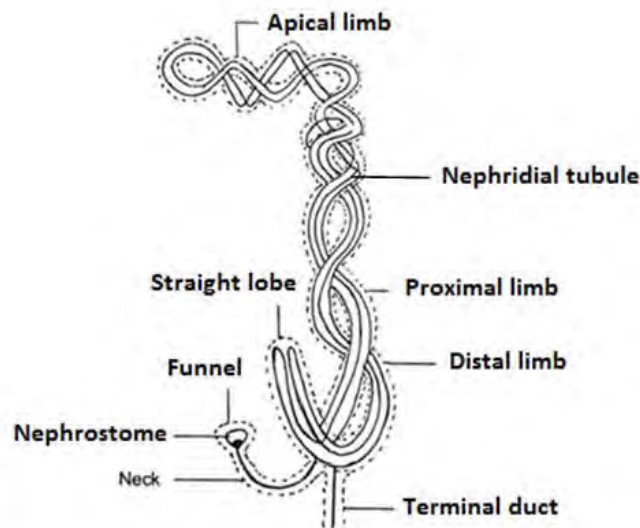


Figure 8.3.14 A septal nephridium in earthworm

ii. Body

A short, thin and ciliated tube called neck connects the nephrostome with the main body of nephridium. Body consists of two parts- a short straight lobe, and a long-twisted loop with a narrow apical lobe. Twisted lobe consists of a proximal limb and a distal limb which are spirally twisted upon each other. Number of twists varies from 9-13. Proximal limb is joined to the neck.

iii. Terminal duct

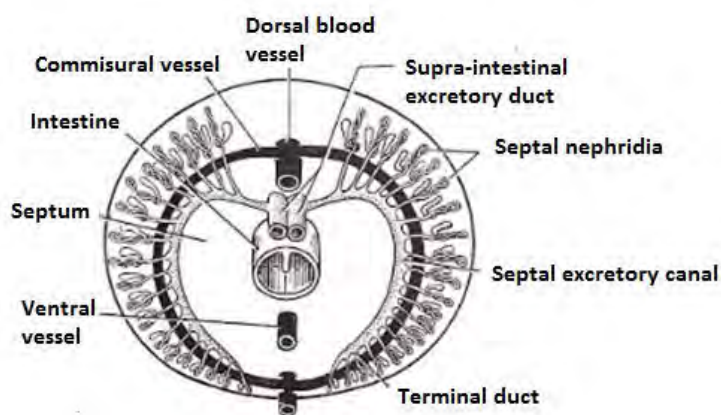


Figure 8.3.15 T.S. of Terminal duct

Distal limb of body of nephridium posteriorly gives off a short and narrow duct called terminal duct. Terminal ducts of all septal nephridia open into the septal excretory canals of either side.

There are two supra intestinal ducts extending length wise from 15th segment up to the last segment dorsally above the intestine. Each septal excretory canal leads into supra-intestinal excretory ducts of its own side. Finally, supra-intestinal excretory ducts open into the lumen of intestine in each segment through narrow ductules, each having a sphinctered opening.

The lumen of nephridium contains ciliated canals, which are four within straight lobe, three in proximal limb and distal limb each, two in apical lobe, and one in neck and terminal duct.

In this way, wastes collected by septal nephridia are discharged first into septal excretory canals through terminal ducts and then passed to supra-intestinal excretory ducts, from where wastes are passed into the intestinal lumen and expelled out through the anus.

Physiology of excretion

In general, earthworm excretes 40% ammonia, 50% urea, 0.6% amino-acid and remaining other compound in excretory fluid. A well-fed earthworm excretes comparatively more ammonia in excretory fluid whereas starved one excretes more urea. Gland cells in pharyngeal and integumentary nephridia extract nitrogenous wastes and water from the blood. Integumentary nephridia discharge waste directly to outside through the pores in their body surface. Pharyngeal nephridia discharge waste to the alimentary canal from where wastes are expelled out through anus. Septal nephridia have ciliated nephrostome. Continuous beating of cilia extracts wastes from the coelomic fluid which is later poured into alimentary canal and eliminated with faeces.

Do you know?

In earthworm, ammonia is converted into urea in chloragogen cell which is released into either coelomic fluid or blood.

8.3.6 NERVOUS SYSTEM IN EARTHWORM

Nervous system is responsible for regulating and coordinating various activities of the body in proper way. It has main role in responding stimuli, maintaining internal environment of the body and coordinating various functions of the body. Nervous system in *Pheretima* is well developed and concentrated type. It is divisible into central nervous system, peripheral nervous system and sympathetic nervous system

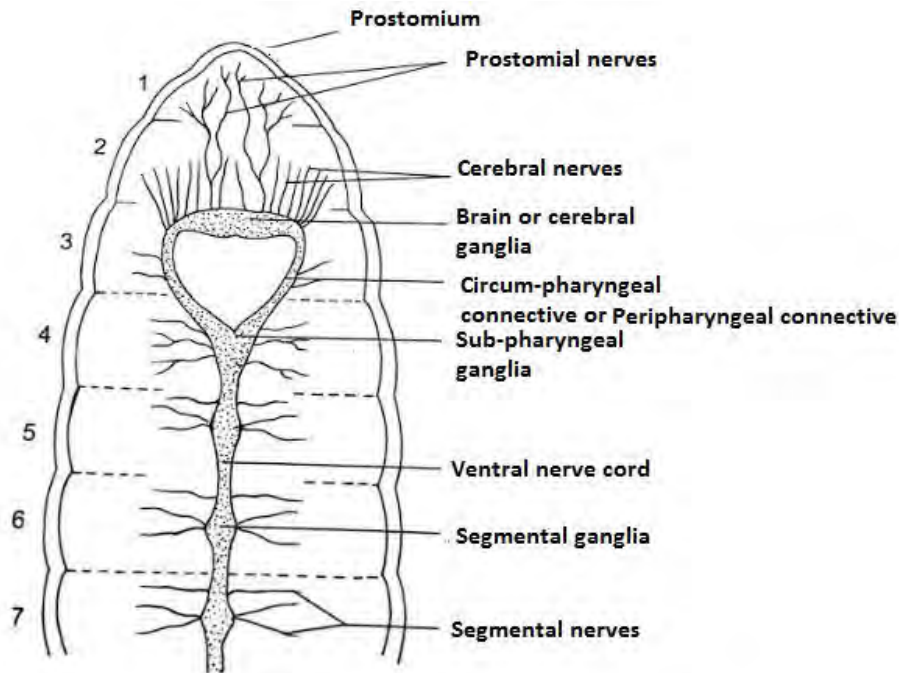


Figure 8.3.16 Nervous system of earthworm

1. Central nervous system (CNS)

Central nervous system is formed by an anteriorly situated **nerve ring** and a rod like **ventral nerve cord** arising posteriorly from it.

a. Nerve ring:

Nerve ring is situated around the pharynx in 3rd and 4th segment. It is formed by a pair of fused supra pharyngeal ganglia, a pair of circum pharyngeal connective and a pair of fused sub-pharyngeal ganglia. Supra-pharyngeal or cerebral ganglia are also called brain which are white coloured and pear-shaped structures lying dorsally in the groove between the buccal cavity and the pharynx. From the either side of cerebral ganglia arises laterally a thick and

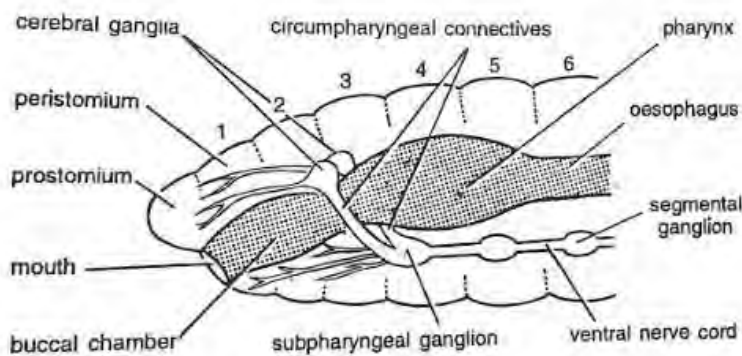


Figure 8.3.17 Nervous system of earthworm in lateral view

strong circum or peripharyngeal connective. These connectives encircle pharynx and meet at the ventral side with sub-pharyngeal ganglia in 4th segment.

b. Ventral nerve cord:

Ventral nerve cord is a long rod like structure arising from sub-pharyngeal ganglia. It runs posteriorly along the mid-ventral line up to the last segment of the body. While passing, it gets slightly enlarged or swelled in each segment forming segmental ganglion. Ventral nerve cord

is actually double, though it appears single externally. Hence, it is formed by the fusion of two longitudinal rod like structures; right longitudinal cord and left longitudinal cord. It means a segmental ganglion is also formed by the fusion of a pair of ganglia, one belonging to each cord of double ventral nerve cord. Histologically, ventral nerve cord is composed of nerve cells and nerve fibres. The ventral nerve cord is enclosed in a sheath composed of three layers-Outer **visceral peritoneum**, middle layer of **longitudinal muscle fibres** and inner thick fibrous layer of **epineurium**

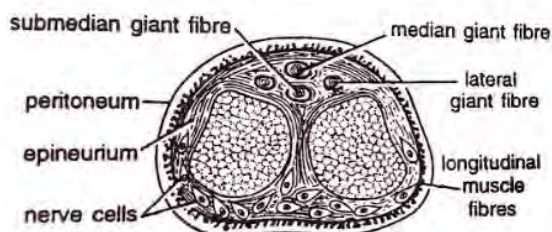


Figure 8.3.18 T.S of ventral nerve cord

2. Peripheral nervous system

The peripheral nervous system is formed by the several nerves which arise from central nervous system. From each cerebral ganglion arise about 8 to 10 nerves innervating the prostomium and buccal chamber. Two pairs of nerves arising from circum-pharyngeal connectives supply the first segment and buccal cavity. Similarly, three pairs of nerves from sub-pharyngeal ganglia supply the various structures present in 2nd, 3rd and 4th segment. From each segmental ganglia arises laterally three pairs of nerves called segmental nerves; one pair anteriorly and next two pairs posteriorly. Segmental nerves innervate the wall of alimentary canal, body wall and other visceral organs of respective segments. All the nerves are of mixed type functioning as both afferent and efferent nerves.

3. Sympathetic nervous system

Sympathetic nervous system consists of an extensive nerve network or plexus spreading beneath the epidermis and within the muscles of body wall, on the wall of alimentary canal and other visceral organs. These plexuses are finally connected with the circum pharyngeal connectives.

Activity 8.9

Visit the laboratory with your biology teacher and dissect the freshly preserved earthworm to identify its nerve ring, ventral nerve cord and nerves. Draw a labelled diagram of it on the chart paper. Present in the class for discussion.

SENSE ORGANS IN EARTHWORM

Sense organs are simple and well developed in earthworm which consists of single cell or group of ectodermal cells. They are of following types:

i. Epidermal receptors:

They are scattered throughout the epidermis layer of body wall and more abundant in lateral side and ventral surface. The outer margin of these receptor cells consists of hair like processes and inner margin is with nerve fibre. These receptors respond to touch and chemical stimuli.

ii. Buccal receptors:

These receptors are found in the buccal cavity which gives the sensation of taste and smell.

iii. Photo receptors:

These receptors are found only in the dorsal surface and more abundant in prostomium and peristomium. They are absent in clitellum. Their number is gradually reduced towards posterior side. Such receptors help the animal to judge intensity of light falling on the body.

8.3.7 REPRODUCTIVE SYSTEM

Reproduction is the life process in which living beings produce offspring of their own kinds for the continuation of their generation. Earthworm is a hermaphrodite (monoecious) animal bearing both male and female reproductive organs in the same body. But self-fertilization doesn't occur because they are protandrous animal. Protandry is the condition where male reproductive organs mature earlier than the female reproductive organs. So, cross fertilization takes place by the process of copulation between two sexually mature worms which is followed by cocoon formation.

Activity 8.9

Observe the reproductive system of earthworm.

Objective: To identify the different reproductive organs of earthworm

Materials required: Dissecting tray, forceps, needle, and blade

Procedure:

- i. Take a preserved earthworm
- ii. Pin down it on the tray by dorsal surface facing upwards
- iii. Make a longitudinal incision in the mid-dorsal line from 25th segment up to the anterior end.
- iv. Release the flaps of body wall from the septa with needles and pin down them
- v. Identify the reproductive organs and note the segments in which they lie. (Take help of your teacher)
- vi. Draw and list down the organs in chart paper

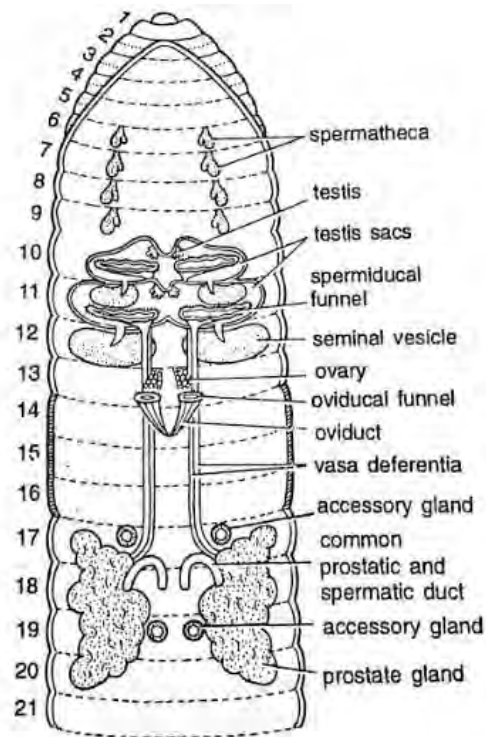


Figure 8.3.19 Reproductive system of earthworm

A. Male reproductive organs:

1. Testes

There are two pairs of very minute, white and lobed structures called testes. Each pair of testes is present in the 10th and 11th segment. Each testis lies ventro-laterally on the either side of ventral nerve cord. They are attached to the anterior wall of respective testis sacs. Each testis consists of a narrow compact base from which arises 4-8 finger like processes containing round ball of cells called spermatogonia. Spermatogonia shed off into the testis sac and passed into seminal vesicles for maturation i.e. to transform into spermatozoa.

2. Testis sacs

Testis sacs are wide, white and thin-walled and fluid filled sacs which enclose testes in 10th and 11th segment. They are situated ventro-laterally below the alimentary canal. Each testis sac also encloses a pair of ciliated spermiducal funnels. Testis sac of 11th segment is larger. Testis sacs communicate with seminal vesicles by narrow ducts.

3. Seminal vesicles

There are two pairs of white coloured large sac like structures, each pair lying in 11th and 12th segment called as seminal vesicles. Seminal vesicles of 12th segments are comparatively larger and not enclosed within testis sac. Seminal vesicles are developed as outgrowth of septum and hence called septal pouches. Seminal vesicles of 11th segment communicate with testis sac of 10th segment and seminal vesicles of 12th segment communicate with testis sac of 11th segment.

4. Spermiducal funnel/spermatid duct

Spermiducal funnels are two pair of cup like structures and having ciliated and folded margin. Each of them is lying below each testis i.e. in the 10th and 11th segment. They

are also enclosed within testis sacs. The mature sperm from the seminal vesicles move back to the testes sacs and then enter through the spermiducal funnel into the vasa deferentia.

5. Vasa deferentia

Each spermiducal funnel posteriorly leads into a slender and internally ciliated thread like structure called sperm duct or vas deferens. Two vasa deferentia of same side run downward very closely on the either side of nerve cord along the ventral body wall. They reach up to the 18th segment and join with the prostatic duct.

6. Prostate glands

They are a pair of dirty white coloured, flat, solid, irregular shaped and lobulated structures on either side of the alimentary canal extending from about 16th to 21st segment. Each gland consists of mainly two parts: a big glandular part with many lobules and a small non-glandular part composed of many small ductules. Small ductules get united together and finally form prostatic duct. A prostatic duct and two vasa deferentia of same side remain separated inside a muscular sheath, forming a single tube which emerges out from prostate gland. The single tube that emerges out of each prostate gland is called common **prostatic and spermatic duct**. Common **prostatic and spermatic duct** of either side, after emergence, gets curved down and opens exteriorly by male genital opening in 18th segment. Prostate glands secrete prostatic fluid of unknown function.

7. Accessory glands

Accessory glands are rounded white masses which are altogether 2 pair in number, each pair situated in 17th and 19th segment, one on either side of nerve cord. These glands open outside ventrally by minute ducts on the two pair of genital papillae. The secretion of accessory glands helps to unite worms during copulation.

B. Female reproductive organs

1. Ovaries

In the 13th segment, there is a pair of small, white, lobulated ovaries hanging down from the intersegmental septum of 12th and 13th segment, each on the either side of ventral nerve cord. Each ovary is a compact structure with finger like processes in which ova of various stages are found in linear sequence. Larger sized or mature ova are found at the distal part whereas immature ones at the proximal part.

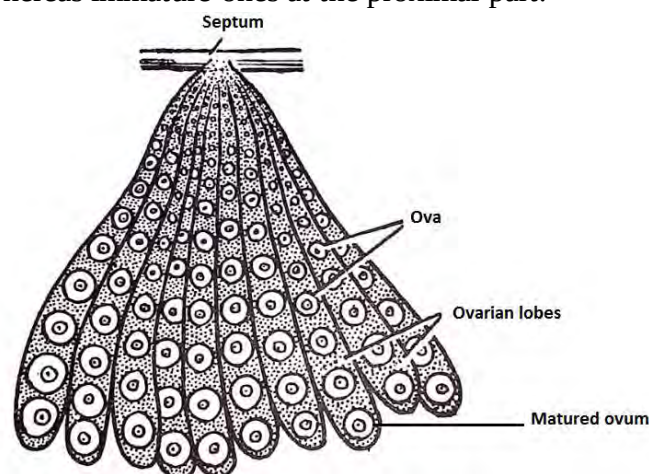


Figure 8.3.20 Ovary of earthworm

2. Oviducal funnel

Oviducal funnel are large, saucer shaped structures with much folded and ciliated margin. They lie below each ovary in 13th segment.

3. Oviducts

Each oviducal funnel posteriorly continues into a short conical and internally ciliated tube called oviduct. Two oviducts run posteriorly by penetrating the septum between 13th and 14th segment and finally unite to form a common oviduct. Now, common oviduct opens mid-ventrally to the exterior by a single opening in 14th segment which is called female genital opening.

4. Spermathecae

There are altogether four pairs of small flask shaped structures called spermathecae in the segments 6th, 7th, 8th and 9th in ventro lateral position. Each spermatheca has a broad pear shaped part called ampulla and a short narrow neck with a blind caecum or diverticulum on its side. After copulation, the sperms are received and stored in the diverticulum. Ampulla provides nourishment to maintain live condition of sperms until the ovaries mature. Each pairs of spermathecae opens outside through spermathecal pores situated ventrolaterally in the groove between segment 5/6, 6/7, 7/8 and 8/9.

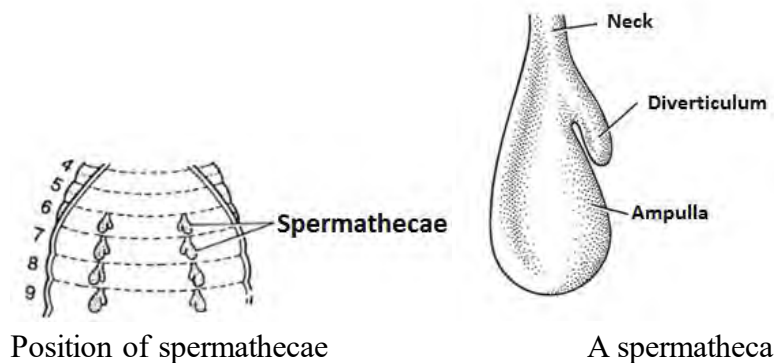


Figure 8.3.21 Spermathecae

8.3.8 COPULATION AND COCOON FORMATION

Copulation:

In earthworms, copulation generally takes place during rainy season in the month from July to October at night time which lasts for about an hour. At this time, two sexually mature earthworms attach themselves by their ventral surfaces with their anterior end facing opposite

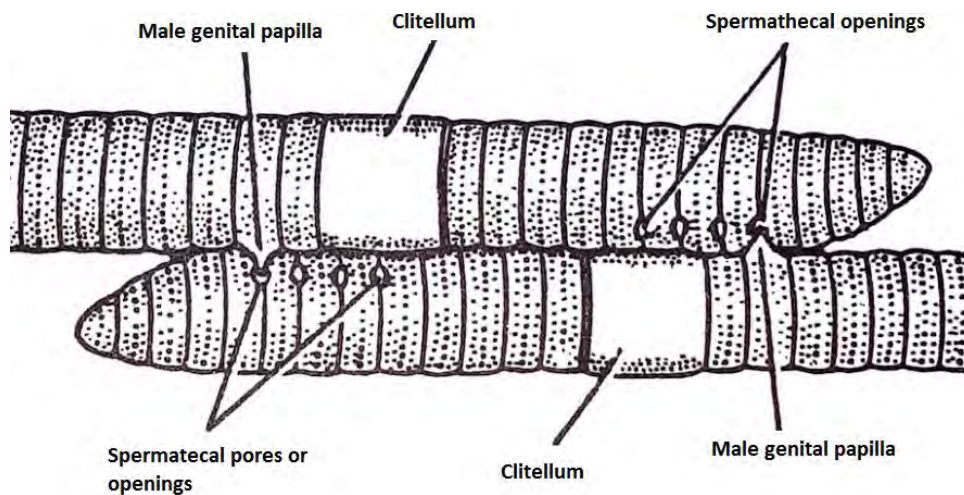


Figure 8.3.22 coplato in earthworm

direction. In this condition, Male genital opening of one worm lies opposite to spermathecal pore of another worm. The area of male genital opening of each worm is raised into an elevated structure called the papilla which act as the copulatory organ and is inserted through spermathecal pore of another worm for the transfer of sperm. In this way, mutual transfer of sperms and prostatic fluid between copulating worms takes place and they become separate. Sperms are received and collected in spermathecae and maintained live until female reproductive organ matures.

Cocoon formation:

Cocoon formation takes place after the process of copulation, when ovaries become mature. The clitellar gland consists of mucous secreting gland, cocoon forming gland and albumen secreting gland. After the ovaries become mature, clitellum secrete a gluey or sticky substance which gets hardened on exposure of air to form a circular band or girdle around it. When the membranous girdle is formed, earthworm withdraws itself backwards from the girdle and several unfertilized ova are laid into the girdle through the female genital opening. As the girdle passes over the spermathecal pores, sperms from spermathecae are also shed off into the girdle. The girdle is finally thrown off from the anterior end and both ends of girdle or cocoon are closed due to its elastic wall. In this way, a light-yellow coloured, oval or rounded cocoon is formed which contains fertilized eggs along with nutritive albuminous substance secreted by albuminous gland. Many cocoons are formed in succession after each mating.

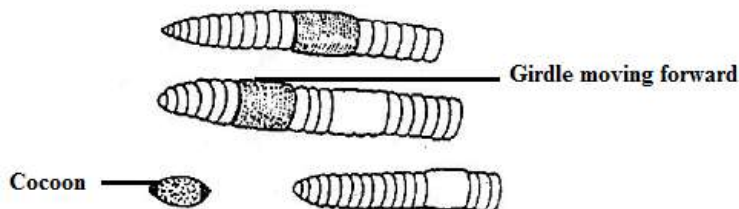


Figure 8.3.23 Cocoon formation in earthworm

Fertilization is external and takes place in cocoon when it is deposited on land. Among many fertilized eggs in a cocoon, only one fertilized egg develops into new youngone. Cleavage of zygote is holoblastic, unequal and development is direct. A young earthworm thus formed escapes from cocoon in about 15-20 days.

8.3.9 ECONOMIC IMPORTANCE OF EARTHWORM

Beneficial

1. Earthworms are food for many animals like birds, lizards frogs snakes and aquarium fishes. Similarly, they are used as fishing baits by fisherman or anglers.
2. Earthworms make soil porous, loose and fertile by their continuous movement and castings or excreta in soil. So physical and chemical characteristics of soil is improved which is beneficial for farmers.
3. Nowadays, earthworms are widely used in vermi-composting i.e. used to prepare compost manure from organic residues.
4. In the ancient times, they were used to prepare medicines of piles, jaundice, rheumatic fever, gallstone, infertility etc.
5. Earthworms can be considered as representative invertebrate specimen and dissected in the biology laboratory to study their anatomy and physiology.

Harmful

1. Many burrows formed by earthworm causes seepage and loss of water from irrigated land resulting reduced crop yield.
2. Loose soil formed by earthworm is easily eroded by water from sloping land.
3. Earthworm come out from the burrow on the earth surface with several parasites like *Amoebotania*, gapeworm, nematodes etc. and germs like bacteria viruses in their body which may infect other animals.
4. Some species of earthworm damage the roots of cultivated plants such as paddy, betelvine etc.

EXERCISE

A. Tick the correct alternative.

1. Which pigment imparts glistening brown colour of body of the earthworm?
 - a. porphyrin
 - b. prophyrin
 - c. melanin
 - d. haemoglobin
2. In which of the following structure, mouth is located?
 - a. prostomium
 - b. pygidium
 - c. peristomium
 - d. clitellum
3. Which of the following segmentation is found in the body of earthworm?
 - a. pseudosegmentation
 - b. metameric segmentation
 - c. superficial segmentation
 - d. internal segmentation
4. At the time of mating between mature earthworms, mutual exchange of sperm occurs, which surface of their body comes in contact to facilitate this exchange?
 - a. dorsal
 - b. mid-dorsal
 - c. ventral

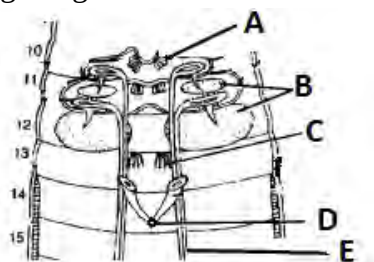
- d. anterior
- 5. Which part of earthworm responsible for storing fertilized ovum?
 - a. ovary
 - b. spermatheca
 - c. cocoon
 - d. testis
- 6. In which segment, seminal vesicles are present?
 - a. 10th and 11th
 - b. 11th and 12th
 - c. 9th and 10th
 - d. 9th and 11th
- 7. How is the excretory system of earthworm responsible for making soil fertile?
 - a. by the secretion of enzymes that make down organic substances in soil
 - b. through the production of coelomic fluid that neutralizes soil pH.
 - c. through the expulsion of nitrogenous wastes into soil
 - d. by the discharge of mucus
- 8. Which part is mainly responsible for the crushing of food in the digestive system of earthworm?
 - a. Pharynx
 - b. intestine
 - c. Stomach
 - d. gizzard
- 9. In which segment nerve ring is situated?
 - a. 2nd and 3rd
 - b. 3rd and 4th
 - c. 4th and 5th
 - d. 1st and 2nd
- 10. Which type of feeding habit is found in earthworm?
 - a. omnivorous
 - b. hervivorous
 - c. omnivorous and detritivorous
 - d. carnivorous
- 11. What are the locomotory organs of earthworm?
 - a. setae
 - b. parapodia
 - c. sucker
 - d. cilia
- 12. Which of the following is exonephric nephridia?
 - a. septal
 - b. pharyngeal
 - c. integumentary
 - d. both pharyngeal and integumentary
- 13. Which of the following process best describes absorption in the alimentary canal of earthworm?

- a. wall of gizzard possesses villi which absorb nutrients.
 - b. absorption occurs in the stomach through specialized cells
 - c. nutrients are mainly absorbed in the typhlosole of intestine
 - d. absorption of nutrients occurs in pharynx
14. Which of the following part of earthworm is called the forest of nephridia?
- a. prostomium
 - b. clitellum
 - c. pygidium
 - d. peristomium
15. Which of the following cells are called yellow cells?
- a. granulocytes
 - b. chloragogen cells
 - c. circular nucleated cells
 - d. mucocytes
16. Earthworm exhibits a unique reproductive feature called cocoon formation in its life cycle. Which of the following is true for cocoon?
- a. cocoon stores unfertilized ova.
 - b. cocoon stores fertilized ova.
 - c. cocoon forms ova.
 - d. cocoon makes sperm mature.
17. What is the location of dorsal pores?
- a. behind 10th segment
 - b. behind 12th segment
 - c. before 13th
 - d. in 14th
18. Which of the following nephridia extract waste from coelomic fluid?
- a. septal nephridia
 - b. pharyngeal nephridia
 - c. integumentary nephridia
 - d. protonephridia
19. Nephridia are the excretory organs of earthworm with or without nephrostome. which of the following type nephridia are characterized by the presence of nephrostome?
- a. pharyngeal
 - b. septal
 - c. integumentary
 - d. protonephridia

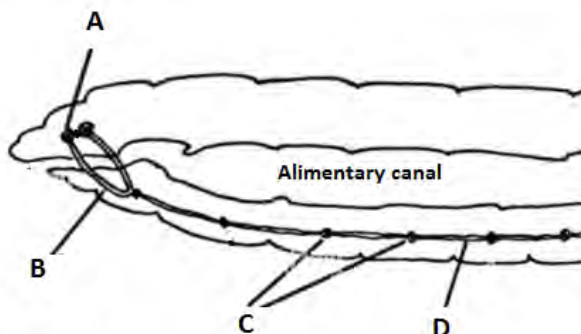
B. Answer the following questions.

1. Write short note on habit and habitat of *Pheretima posthuma*.
2. What is morphology? Mention the morphological features of earthworm.
3. Draw neat and labelled diagram of T.S of body wall of earthworm through setae.
4. Earthworm is omnivorous and detritivorous. Describe the process of digestion of food in its digestive tract.
5. Write a short note on the central nervous system of earthworm.
6. How do you differentiate septal nephridia from pharyngeal nephridia?

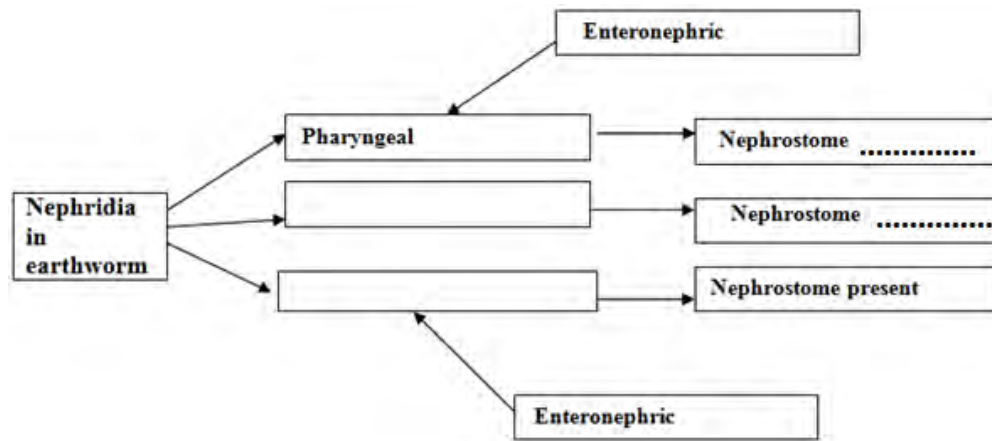
7. Observe the diagram given below and answer the following questions.



- i. Identify the parts A, B, C, D and E.
 - ii. In which part, maturation of sperms take place?
 - iii. What is the function of part C and E?
8. Draw neat and labelled diagram of T.S of body wall of earthworm through pharynx.
 9. What are the four differences between male reproductive system and female reproductive system of earthworm?
 10. What is typhlosolar region in the intestine of earthworm? How is it different from post typhlosolar region?
 11. Saumyata claimed that earthworm is a hermaphrodite animal which perform self-fertilization and there is no need of copulation. Is she true? State your opinions.
 12. How does copulation and cocoon formation take place in earthworm? Describe the process.
 13. Draw well labelled diagram of T.S. of body wall of earthworm through gizzard.
 14. What are the economic importances of earthworm?
 15. Observe the given diagram and answer the following question.



- i. Which system is shown in the figure and write its function.
 - ii. Identify the parts A, B, C and D.
 - iii. Mention the segment from which D starts and terminates.
16. What is coelom? What are the constituents of coelomic fluid in earthworm?
 17. Describe the body wall of earthworm with well labelled diagram.
 18. Complete the given concept map.



19. The process of conversion of complex food particles into simpler diffusible form is digestion. What are the organs involved in this process? Briefly describe them.
20. Why earthworm is called proterandrous animal? What are the various organs involved in reproduction in earthworm? Discuss.
21. Which nephridium is most advanced in earthworm? Why? Describe its structure with labelled diagram.
22. In earthworm, nervous system is well developed and concentrated type. Describe various organs involved in this system.

Chapter 8.5

FROG

Rana tigrina

Observe the animal given below and answer the following questions.



- What are its unique external features?
- What is the significance of its moist skin?
- It is mostly aquatic and found in damp places. Why?
- It is not seen in extreme hot or cold environment? Why?
- What might be its economic importance?

8.4.1 GENERAL INTRODUCTION

Systematic position

Kingdom	-Animalia
Phylum	-Chordata
Group	- Craniata
Sub-phylum	-vertebrata
Division	-Gnathostomata
Super-class	-Tetrapoda
Class	-Amphibia
Genus	- <i>Rana</i>
Species	- <i>tigrina</i>
Common name	- Bull frog

Rana tigrina is a common frog species found in Asian countries such as Nepal, India, Bangladesh, China, Sri Lanka etc and is commonly called “Bull frog” or “Asian bull frog”. This species belongs to Ranidae family and distinguished by its characteristic green colouration with black blotches, larger size, conical snout, mid-dorsal white line, vocal sacs (in male for croak) etc. It is found in moist habitats such as forest, farmlands, urban areas although prefer to live in freshwater bodies like pond, lake, river etc. Frogs are cold blooded and they hide in moist burrow to protect from extreme cold days of winter and hot days of summer. Now, its scientific name has been changed to *Hoplobatrachus tigerinus*. In some countries, they are commercially farmed or hunted for meat. Frogs are the natural predator of insects or pest that can damage our cultivated crops. They have been used in medical and scientific research for centuries because of their physiological similarities to higher vertebrates.

Why is it selected for study?

- i. It is easily available, inexpensive and non- poisonous.
- ii. Bull frog is better known than the toad.
- iii. Its size is appropriate for handling and dissecting in the laboratory.
- iv. It can be kept alive for few days without feeding.
- v. Its life cycle is short simple and can be easily observed.
- vi. It is a sample representative of vertebrates and basically its anatomy is similar to other higher vertebrates including human.

Do you know?

Some species of Frogs were previously used in the pregnancy test. Injection of women's urine into the African clawed frog *Xenopus* resulted production of ova which was the proof of pregnancy.

8.4.2 HABITAT AND HABIT

Rana tigrina is commonly found in water or on damp soil. It lives most of the time in moist land rich in green vegetation near fresh water or found swimming in pond, ditches, rivers lakes, streams. It frequently visits water bodies to keep its skin moist for cutaneous respiration. It can escape from enemies by immediately diving into water. While living near aquatic habitat, it can easily access food since plenty of insects, worms, slugs, small frogs etc. are found there. Moreover, it needs water for reproductive activities, and all its embryonic stages including the larval stage are passed in water.



Figure 8.4.1 Frog near water

Rana tigrina is a non-poisonous, solitary, harmless and normally silent animal without any armatures. It is a free living, predaceous and cannibalistic animal. Generally, its presence is only detected after it is being disturbed on the banks of ponds, streams, pools, or in the paddy field. Frog is active at the day time and hence called **diurnal** animal. In breeding season, males are gathered in shallow water in paddy field or ponds and croak.

i. Locomotion:

In frog, locomotion takes place by leaping on the land and swimming in the water. It has strong and long hind limbs which are contracted in 'Z' shaped manner and short forelimbs in upright position during the resting posture. When leaping, it extends hind limbs and leaves the land quickly; throwing body up into the air and body is supported by fore limbs at the time of landing. A frog may leap about 1.5 meter at a jump. While swimming, hind limbs provide powerful backward thrust with their broad webbed toes spreading apart for propelling forward. Left and right fore limbs also support and are moved alternately while swimming.

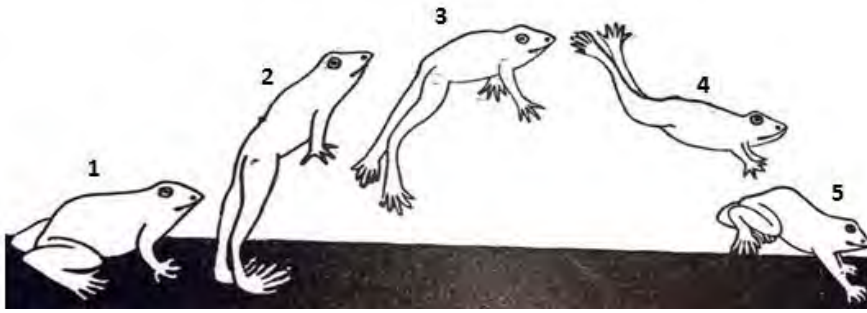


Figure 8.4.2 Stages of body posture while leaping on land

ii. Feeding:

Adult frog is carnivorous and its food chiefly consists of living insects, worms, slugs, small fishes, tadpole etc. It quickly shoots out its protrusible and sticky tongue for capturing prey and whole food is, then swallowed without chewing. It prefers to hunt live prey and discards motionless or dead prey as food. Frog is a glutton and hence feed excess; becomes fatty, accumulates reserve food material such as glycogen and fat before going to hibernation.

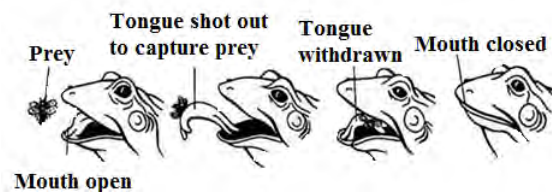


Figure 8.4.3 process of feeding in frog

iii. Hibernation and aestivation:

Frogs are poikilothermic or cold blooded animals and their body temperature changes according to the temperature of surrounding environment. Their body temperature may fall abruptly in winters which may threaten life. To protect from such a harsh situation, they remain hidden or dormant inside the moist burrow or under soft damp bottom mud. This phenomenon is called hibernation or 'winter sleep'. This duration lasts for about 3 months. At the time of hibernation, nostrils and mouth remain closed and stops feeding, excretion, become metabolically inactive, breathe only by cutaneous respiration and survive on reserve food such as glycogen and fat stored in their body. During summer also, they remain inactive or become dormant under the mud to escape from extreme high temperature of the environment, which is called aestivation. Aestivation lasts for about 15 days. During this period, they occasionally come out in search of food. Aestivation is commonly called summer sleep.

iv. Croaking:

It is the characteristic sound produced by male frogs during breeding season, also called sex call or mating call. It is heard louder and produced only by male frogs to attract female frogs for mating purpose. Males have a pair of bluish skin patches or folds on the throat region, called vocal sacs which are used to croak.

v. Breeding

Rainy season (July to September) is breeding season for frog in which males gather in shallow water and start producing croaking sound to attract female frog. While mating, male mounts on the back of female and grasps the female firmly with the help of nuptial pad or copulatory pad developed on its first or index finger of fore limbs. This sexual embrace is also called false copulation or amplexus. Hence, there is no true copulation or mating in frogs. Meanwhile, female frog gets stimulated and starts laying eggs in water through cloaca. Mass of eggs intermingled with gelatin like material on the water surface is called spawn. Male discharges seminal fluid or milt containing sperms over the cluster of eggs or spawn. Thus, fertilization is external, taking place in water, which in turn forms zygotes. Then, zygotes develop into free swimming and completely aquatic tadpole within about 15 days. Tadpole after few weeks gets metamorphosed into amphibious adult.



Figure 8.4.4 A male frog croaking by inflating vocal sacs

vi. Camouflage:

Frogs can change their body colour according to the surrounding where they are living so that they are not easily noticed by enemies. This is called camouflage. Change in colour occurs due to the dispersion of amoeboid pigmented cells called chromatophores found in dermis of skin.

vii. Ways of protection from enemies

Enemies of frog are snakes, human beings, birds such as crane, hawk, eagle, crow etc. Similarly, small frogs are also eaten up by larger frog. Human beings also kill large number of frogs for dissection in laboratory to study their anatomy. Ways adopted by frogs to protect themselves from enemies are:

- a. They can change its body colour according to the surrounding so that enemies can't detect it easily.
- b. Frog suddenly ejects urine, when tried to catch.
- c. They have slippery skin because of the presence of mucous glands due to which they can't be easily caught by enemies.
- d. They have habit of living near fresh water sources and quickly dive into the water on arrival of enemies.

8.4.3 EXTERNAL FEATURES (MORPHOLOGY)

Activity: 8.10

Objective: To find out the external characteristics of frog

Apparatus required: dissecting tray, forceps, needle

Procedure:

- Take a freshly preserved or chloroformed frog.
- Put it on dissecting tray.
- Observe its structure thoroughly. Use needle to point out structures.
- Note down its all part.
- Identify more with the help of your teacher
- Draw its labeled diagram and discuss.

Conclusion

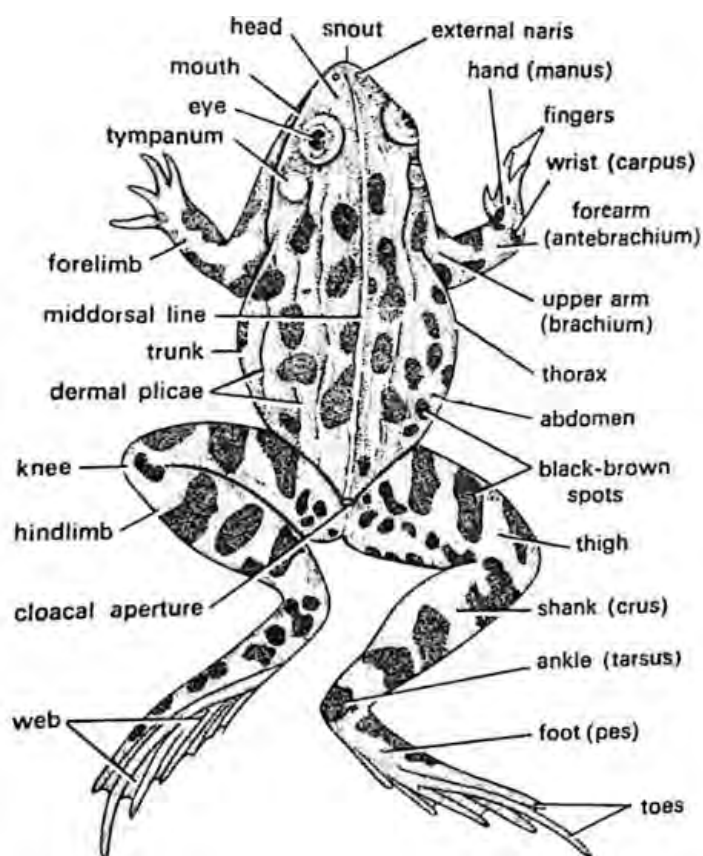


Figure 8.4.5 Morphology of Frog

1. Shape, size and colour:

Body of adult frog is somewhat spindle shaped which is pointed anteriorly and rounded at the posterior side. It has dorso-ventrally flattened and bilaterally symmetrical body (body can be divided into similar halves by a single plane). The size of a fully-grown adult is about 18cm length and 8 cm width. Skin is thin, moist, slimy and smooth without any hard scales or exoskeleton. Skin of frog is slippery because of the presence of mucus gland. Frog never drinks water but absorb it through skin. Moist skin also serves as respiratory surface in frog. Dorsal side of frog is green colored with black or brown spots but its ventral surface is pale yellow or

whitish coloured. A light yellow or white coloured thick line runs mid-dorsally from the tip of snout to the cloacal opening at the back.

2. Division of the body

The body of an adult frog is divisible into head and trunk with limbs. Neck and tail are absent.

i. Head:

The head is flat and roughly triangular in outline, with a short and less blunt anterior snout. A wide transverse opening is situated at the anterior end of the snout, called mouth. There are two small openings lying dorsally above the mouth called external nostrils or external nares which serve in breathing. A pair of spherical and bulging eyes, each situated at the dorso-lateral position on the top of the head. Bulging eye helps to see all possible direction in the absence of neck. Each eye has thick and pigmented upper eye lid and a thin and semitransparent lower eyelid. Upper eyelid is immovable whereas lower eye lid is movable. Both the eyes of frog have nictitating membrane (plica semilunaris) arising from the lower eyelid, which protect eyes in water from foreign substances and also prevent drying of eye in terrestrial habitat. In front of eyes lie a light coloured brow spot which represents vestigial pineal eye. Just behind the eye on each side, a circular and pigmented tympanum is present which receives sound waves but external ear is absent in frog. In male frogs, two bluish and wrinkled vocal sacs are present on the undersurface of throat, used to produce croaking sounds in the breeding season for attracting female frog.

ii. Trunk:

Trunk is a flat and oval structure which is joined directly with the head. During resting or squatting condition, posterior side of trunk, in the middle is slightly raised forming hump which is also called sacral prominence. There is a small circular opening called vent or cloacal aperture at the posterior end of trunk between hind limbs. This aperture is the common for discharging out faeces, urine and gametes.

There are two pairs of limbs arising laterally from the trunk. Anterior pair is called forelimbs, which arise just behind the head. Each forelimb consists of proximal upper arm (brachium), fore arm (antebrachium), wrist (carpus) and hand (manus) bearing 4 fingers or digits where thumb is externally invisible or rudimentary. Fingers of forelimbs are without fold of skin or web between them. In the case of male frog, base of index or first finger is thickened to form nuptial pad or amplexuary pad or copulatory pad to hold the female frog firmly during amplex or copulation. Posterior pair is hind limbs which are comparatively much longer and powerful than fore limbs. Each hind limb consists of proximal thigh, middle shank, a long ankle or tarsus and large foot bearing five fingers with a fold of skin in between, called webbed toes used in swimming. Undersurface of digits of forelimb and hind limb contains small and round pads called sub-articular pads which are shock absorber and also aid in gripping and climbing surfaces.

Sexual dimorphism

Sexual dimorphism is the condition or phenomenon in which male and female of same animal species are distinguished by observing their external features. Sexual dimorphism is relatively more distinct in the breeding season in *Rana tigrina*. In copulating frogs, upper one is male and the lower one is female.

Table: Difference between male frog and female frog

Male frog	Female frog
1. They are generally smaller and darker.	1. They are relatively larger and less dark.
2. They have nuptial on the base of index finger in breeding season.	2. They are without nuptial pads.
3. They croak loudly as they develop vocal sac in breeding season.	3. They do not croak hence without vocal sac.
4. Their body is slimmer or thin.	4. They have large belly with eggs inside in breeding season.



Bufo bufo (common toad)



Rana tigrina (frog)

Figure 8.4.6 Toad and frog

Table: Difference between toad and frog

Toad (<i>Bufo</i>)	Bull frog (<i>Rana tigrina</i>)
1. Toad is mostly terrestrial and goes to water only for breeding.	1. Frog is mostly aquatic and lives near water.
2. It is poisonous due to the presence of parotid gland just behind the head on either side.	2. It is non-poisonous.
3. It is active at night and hence called nocturnal animal.	3. It is active at day and hence called diurnal animal.
4. Skin of toad is dry, rough and with warts or tubercles.	4. Skin of frog is moist smooth and slippery.
5. Its snout is more rounded and broader.	5. Its snout is relatively narrower or somewhat tapered.
6. Hind limbs are comparatively shorter with rudimentary web between toes.	6. Hind limbs are comparatively longer with well-developed webbed toes as they are skilled swimmer
7. Locomotion mostly occurs by walking or crawling rather than jumping because of its shorter and stubby limbs.	7. Frog actively leaps on land and swims in water because of its well-developed limbs.
8. Both jaws are devoid of teeth.	8. Only upper jaw is provided with teeth.
9. Vocal sacs are not present in toad.	9. Only male has developed vocal sacs in the throat region.
10. It lays eggs in long chains.	10. It lays eggs in cluster.

8.4.4 DIGESTIVE SYSTEM OF FROG

Let's discuss given questions.

- What is the digestive system?
- What are the end products of carbohydrate, protein and fat digestion?
- What is the feeding habit of frog?

Digestion is the process of conversion of complex food particles into simpler forms. For this, various organs are co-ordinating or working together called digestive organs forming a complex system called digestive system. Mainly two processes involve in the process of digestion which are mechanical and chemical. Mechanical process is the conversion of larger food particles into smaller or fine state whereas chemical process is the conversion of complex organic compound in food into simpler forms. Digestive system in frog can be discussed under two headings:

A. ALIMENTARY CANAL

In frog, alimentary canal is a complete, long and coiled tube of varying diameter extending from mouth to cloaca. Alimentary canal includes the mouth, buccal cavity, pharynx, oesophagus, stomach, small intestine, large intestine and cloaca.



Figure 8.4.7 Mouth open to show the parts of buccal cavity

- Mouth:** The alimentary canal starts with a wide opening called mouth. It is a transverse gape bounded by upper and lower jaws covered by immovable lips. Upper jaw is immovable but lower jaw is partially movable which can be moved up and down for closing and opening mouth respectively.
- Bucco-pharyngeal Cavity:** Mouth posteriorly leads into a wide and spacious cavity called oral cavity or buccal cavity. In frog, due to the absence of neck, its buccal cavity and pharynx are not distinct and hence called bucco-pharyngeal cavity. Bucco-pharyngeal cavity serves as the common passage of food and air. Posterior part of buccal cavity is often called as pharynx. The bucco-pharyngeal cavity is internally lined by ciliated columnar epithelium with mucus secreting cells or goblet cells. The function of mucus is to lubricate the food particles for swallowing easily. There are no salivary glands. Structures present in bucco-pharyngeal cavity are:

i. Teeth:

The upper jaw is provided with a row of closely set, small, conical and backwardly pointed teeth over the premaxillae and maxillae bones. Teeth on premaxilla and maxilla are called premaxillary and maxillary teeth respectively. The lower jaw does not bear teeth. Besides, there are two more patches of teeth, each patch lying on the either side of the median line of the roof of the buccal cavity called vomerine teeth.

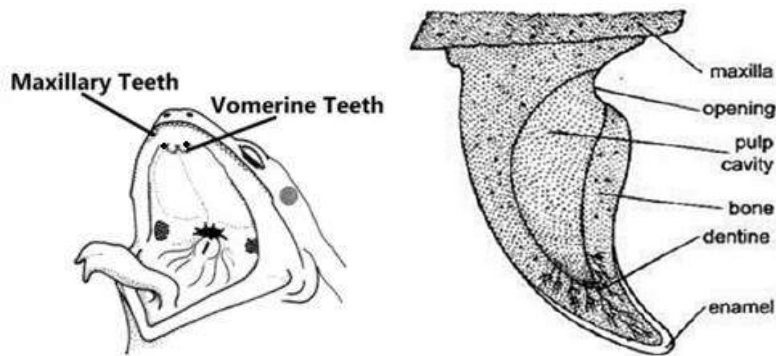


Figure 8.4.8 (a) The upper jaw showing teeth (b) A maxillary tooth in V.S.

They are found on the vomer bone. Teeth in frog are not used for chewing purpose instead they are used to hold the prey inside the buccal cavity after the food is captured by tongue. The teeth are homodont i.e. similar shaped. They are curved backwards and directly attached to the jaw bones called acrodont condition. Old and worn out teeth are being continuously shed off during the life span and replaced by new ones and hence called polyphyodont. Each tooth is conical shaped consisting of mainly two parts: - base and crown. The broad bony base is attached to the jaw bone. The crown is primarily composed of dentine and traversed by numerous fine branching canals called canaliculi. Tip of the crown is coated with a very hard and shining white substance called enamel (secreted by ameloblast cell). The internal cavity of tooth is called pulp cavity which is filled with a highly vascular and nutritive tissue, odontoblast cells (dentine secreting cells) and nerves.

ii. Internal Nostrils:

The buccal cavity in its roof near vomerine teeth contains paired openings called internal or posterior nostrils which communicate with external nostrils.

iii. Tongue:

Tongue is large, thick, fleshy and protrusible structure lying on the floor of buccal cavity. It is attached anteriorly to the inner border of lower jaw; free and notched (bifid) posteriorly. Its upper surface bears taste buds in the form of small papillae. Secretion of tubular lingual glands and intermaxillary gland inside buccal cavity make the tongue adhesive. Such a sticky tongue can be thrown out and retracted suddenly by frog to capture live prey.

iv. Bulgings of Orbits:

The roof of buccal cavity just behind the vomerine teeth contains two large, soft, oval and cushion like areas the bulgings of orbits and eyeballs. While swallowing food, eyes are depressed, pushing the food backward.

v. Eustachean openings:

Openings of Eustachian tube into the buccal cavity, each situated at the postero-lateral side of roof of bucco-pharyngeal cavity. They communicate with the middle ear.

vi. Vocal sacs opening:

In male frog, there are two openings of vocal sacs, each present in the angle of two jaws on the floor of bucco-pharyngeal cavity. Vocal sacs amplify the sound at the time of croaking.

vii. Glottis and gullet:

Glottis is a median longitudinal slit like aperture in the posterior side of buccopharyngeal cavity, just behind the tongue. It opens while breathing so that air is passed to lungs and closes at the time of swallowing food.

Similarly, Bucco-pharyngeal cavity posteriorly leads into the oesophagus through a transverse opening called gullet.

viii. Fossae and prelingual elevations

Fossae are three in number which are minute pits or depressions at the apical part of upper jaw, just below the maxillary teeth. Front end of lower jaw contains three small elevations, called prelingual elevations.

Prelingual elevations fit into fossae to close the mouth tightly.

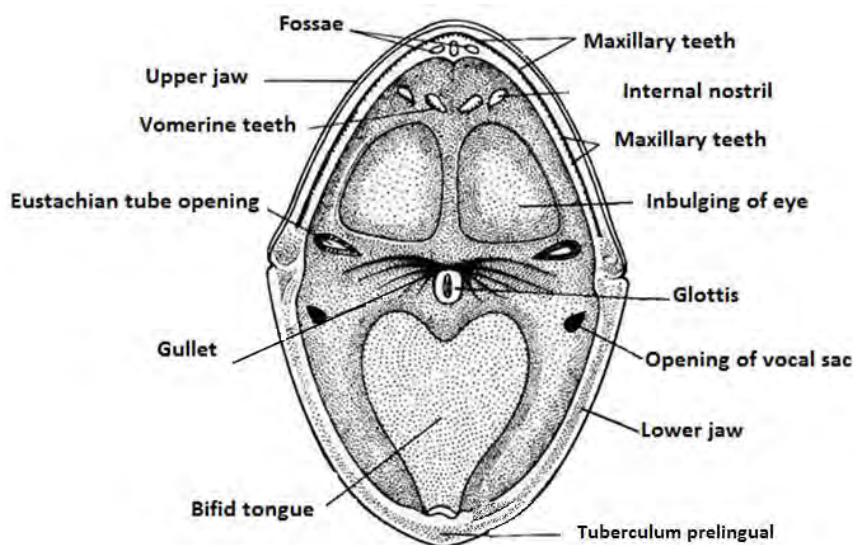


Figure 8.4.9 structures in buccal cavity of frog

3. Oesophagus:

Buccopharyngeal cavity leads behind into a short, and stretchable muscular tube called oesophagus. Its inner lining is thrown into a large number of longitudinal folds for the sufficient distension of the oesophagus during the passage of the ingested food to the stomach. It abruptly leads into the stomach as there is no distinct demarcation between the oesophagus and stomach. Its inner wall also contains peptic glands and goblet cells.

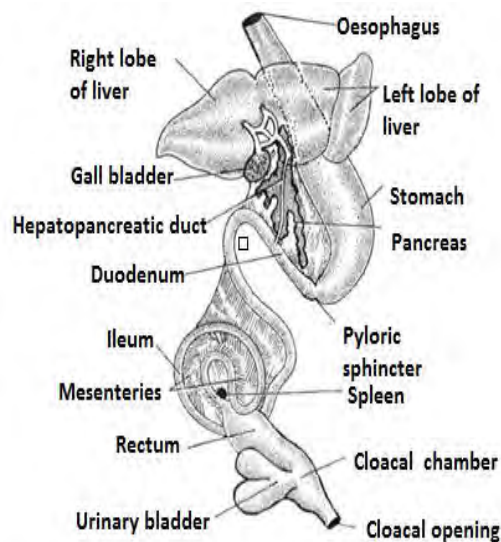


Figure 8.4.10 Alimentary Canal of Frog

4. Stomach:

Stomach is a J-shaped muscular sac like structure situated in the left side of the body cavity or the coelom and attached to dorsal body wall by a mesentery called mesogaster. It is divided into two regions – the anterior large and wider region is called cardiac stomach and the posterior short narrower region is called pyloric stomach. The internal lining (mucous epithelium) of the stomach is thrown into numerous longitudinal folds which may allow the expansion of the stomach whenever required. Its mucous epithelium also possesses multicellular gastric glands which secrete pepsinogen enzyme, and unicellular oxyntic cells that secrete hydrochloric acid. Stomach also contains goblet cells which secrete mucus for lubricating food. The pyloric end of stomach is constricted externally and its opening into small intestine is internally guarded by a muscular ring or flap like sphincter or pyloric valve. This valve checks reverse flow of food from the intestine into the stomach. Function of stomach is to store food for few hours and also digest the food.

5. Intestine: It consists of two parts-

- a. **Small Intestine:** The small intestine is the long-convoluted tube of 30 cm length in the form of several loops, supported by a fan-like membrane, the mesentery. Small intestine is the main site of digestion and absorption of food.

Small intestine consists of **duodenum** and **ileum**.

i. Duodenum

The anterior part of the small intestine which curves upwards to form a U shaped with the stomach is called the duodenum. The internal mucous lining of duodenum is provided with low transverse folds. In the duodenum, opens a common hepato-pancreatic duct from liver and pancreas, draining the bile and pancreatic juice respectively.

ii. Ileum

The remaining part of small intestine continues as a long, narrow and much twisted tubular part called ileum. The internal mucous layer of

ileum forms a number of longitudinal folds. True villi, glands and crypts are absent.

- b. Large intestine: The ileum opens into a short and dilated tube of about 4 cm called large intestine or rectum which leads behind into cloacal chamber. Its inner layer is with goblet cells and forms numerous low longitudinal folds. This part absorbs water and stores faeces.
6. Cloacal chamber and cloaca: Rectum is followed by a small terminal sac-like structure, called cloacal chamber. This sac also receives the opening of ureters. Cloacal chamber opens exteriorly through a vent or cloacal opening situated at the posterior most end of the body.

Activity: 8.11

Objective: To identify various parts of buccal cavity in frog

Apparatus required: dissecting tray, forceps, needle, chart paper

Procedure:

- i. Take a freshly preserved or chloroformed frog in dissecting tray.
- ii. Lay down it by facing ventral surface up.
- iii. Open its mouth and observe. Note down the structures in buccal cavity (take help of teacher if required).
- iv. Draw well labelled diagram in chart paper and discuss.

B. DIGESTIVE GLANDS

In addition to the gastric glands and the intestinal glands, two large digestive glands namely liver and pancreas are also found in frog.

1. Liver:

Like other vertebrates, liver in frog, is the largest gland situated in the anterior body cavity close to the heart and lungs. It is reddish brown coloured and lobulated gland consisting of three lobes: - the right, median and the left lobe. The left lobe is again subdivided into two lobes. A spherical, thin-walled, large and greenish sac called gall bladder is present ventrally between the right and left lobe of liver. It serves as a reservoir for the bile juice constantly secreted by the hepatic cells. The bile passes into the gall bladder through hepatic ducts. Cystic duct from gall bladder and some hepatic ducts from liver get united to form a common bile duct which passes through the pancreas and opens into the duodenum. The common bile duct receives the fine ducts from the pancreas while passing on its way to open into duodenum. Bile lacks digestive enzymes.

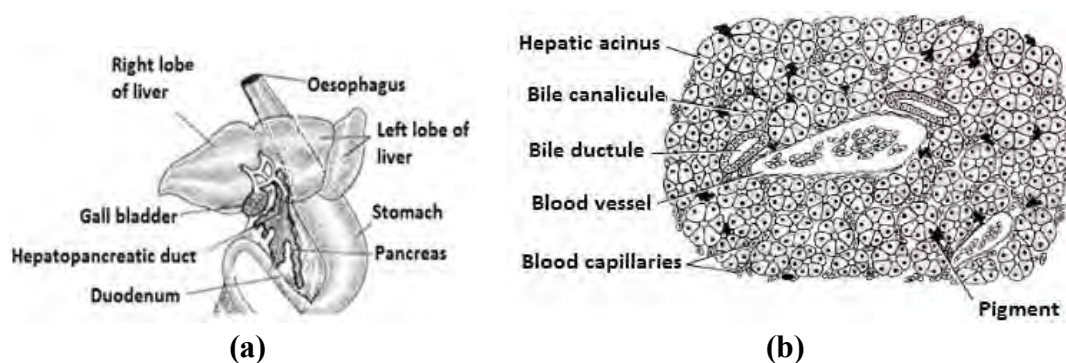


Figure 8.4.11 (a) Liver of frog showing its lobes (b) T.S. of liver of frog

Histologically, frog's liver is composed of numerous lobules or hepatic acini and these lobules are separated from each other by the presence of connective tissue containing bile capillaries, hepatic ducts, blood capillaries and sinusoids. Each lobule or hepatic acinus consists of numerous polyhedral, glandular hepatic cells; each containing a nucleus and cytoplasm with protein granules, droplets of fats, glycogen and often black or dark brown pigment granules. Hepatic cells secrete bile juice which is poured into canalicule. These canaliculi unite to form bile ductule which again unite, re-unite and finally form bile or hepatic ducts. The liver receives blood from the hepatic artery and the hepatic portal vein.

Functions

The liver performs the following important functions:

- i. It secretes green coloured alkaline bile juice containing bile salts, bile pigments, cholesterol, water etc. Bile juice reduces acidity of food, provides suitable medium for the activation of pancreatic enzymes and emulsifies fats. Conversion of larger fat globules into smaller forms by the action of bile juice is called emulsification.
- ii. Liver is an important organ of metabolism of carbohydrate, protein and fats. Glucose absorbed from the wall of alimentary canal, if excess, is converted to glycogen by the process of glycogenesis in liver. Similarly, glycogen may be converted to glucose, if required, by the process of glycogenolysis. Formation of new glucose (gluconeogenesis) from non-carbohydrate compounds such as amino acid and glycerol also takes place in liver.
- iii. Liver performs the function of de-amination and detoxification. As the amino acids can't be stored in the body of animals, metabolism of amino acid produces ammonia as by-product, called deamination. Ammonia is highly toxic, reacts with carbon dioxide in liver to convert into less toxic urea by the process of detoxification.
- iv. It also removes some other excretory products such as bilirubin and biliverdin formed by break down of old RBCs, which are discharged with bile into the intestine and expelled with the faeces.
- v. In an embryo, RBCs are formed in liver but in an adult old and worn out RBCs are destroyed in liver.
- vi. Kupffer cells are the phagocytic cells which destroy harmful microbes such as bacteria.
- vii. It stores copper and iron and fat-soluble vitamins.
- viii. Fibrinogen and prothrombin are synthesized in liver which are essential blood clotting factors.
- ix. Liver also secretes heparin which prevents clotting of blood in blood vessels.

2. Pancreas:

It is an irregularly branched, flat and cream coloured gland of exocrine and endocrine nature, which is held in position by mesentery between the stomach and duodenum. It is traversed by the common bile duct into which the ducts from pancreas also open to form a hepatopancreatic duct.

Histologically, exocrine part of pancreas consists of many pancreatic lobules or acini embedded in connective tissues. Connective tissue also contains pancreatic ducts, blood vessels, lymph vessels and nerves. Each acinus consists of secretory cells of columnar type around a central cavity or lumen. Secretory cells are with a large nucleus and filled with non-granular cytoplasm. These cells secrete pancreatic juice containing digestive enzymes which is poured into central lumen or ductule. Acini unite with each other through their ductules, which in turn unite to form the larger ducts and finally form the pancreatic ducts. The pancreatic ducts open into the bile duct from liver to form hepatopancreatic duct.

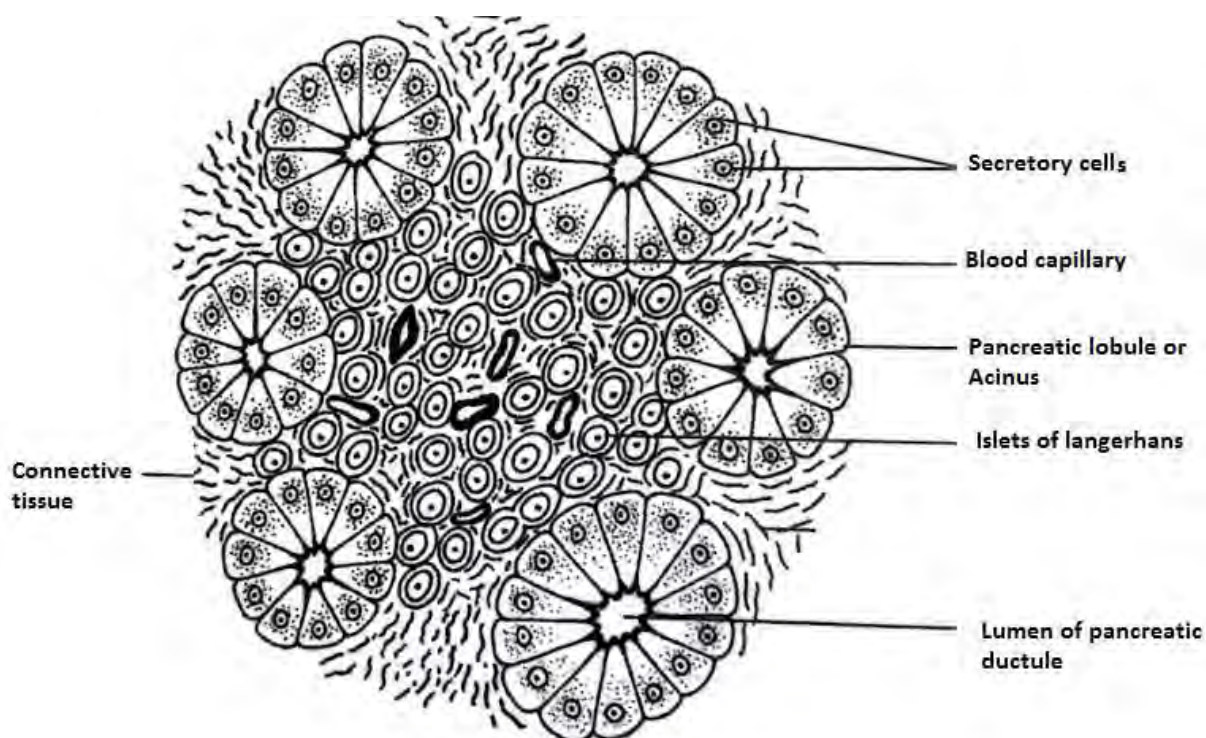


Figure 8.4.12 T.S. of pancreas of frog

Similarly, Endocrine Part consists of a compact group of specialised cells in the connective tissue amongst the acini, known as pancreatic islets or islets of Langerhans. The cells in islets are chiefly alpha Cells, beta Cells and delta Cells which secrete hormones which are directly poured into blood capillaries.

Functions of pancreas

- i. Pancreatic juice secreted by exocrine gland contains digestive enzymes such as trypsinogen, amylase, and lipase which digest protein carbohydrates fat respectively.
- ii. Alpha cells secrete glucagon which converts glycogen into glucose. Beta cells secrete insulin which converts excess glucose to glycogen as reserve food materials. Delta cells secrete somatostatin which regulates secretory activity of alpha and beta cells.

Histology of alimentary canal in frog

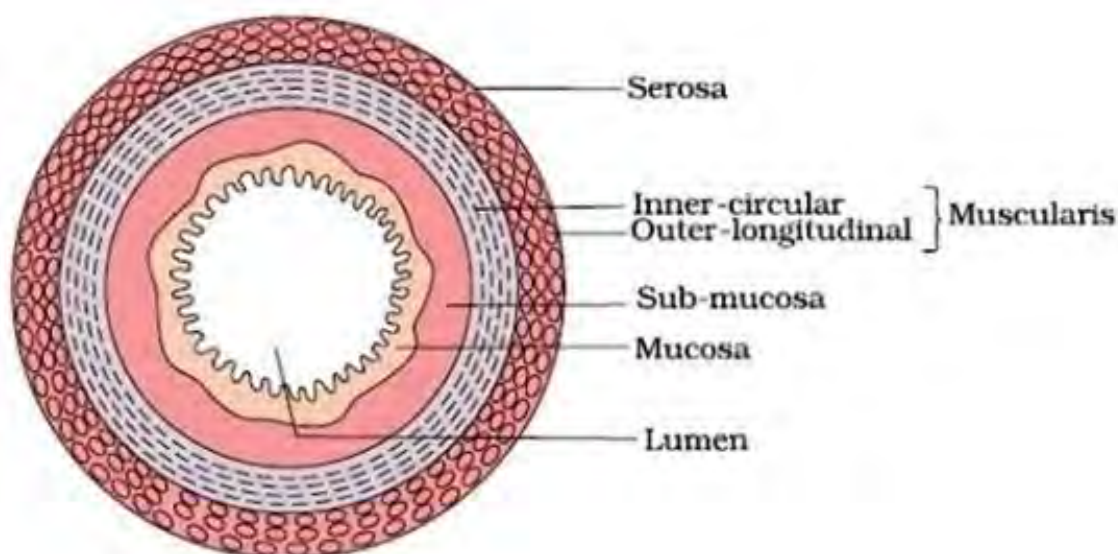


Figure 8.4.13 T.S. of alimentary canal (schematic)

1. **Serosa (visceral peritoneum):**
It is composed of single layer of squamous epithelium. This layer is replaced by fibrous layer called tunica adventitia in oesophagus.
2. **Muscularis:**
It is made up of muscles - outer longitudinal muscle fibre and inner circular muscle fibres. These muscles are smooth muscles which create peristalsis in alimentary canal. This layer is thicker in stomach.
3. **Submucosa:**
This layer is mainly composed of loose connective tissue which contains elastic fibers, fat, blood vessels, and lymph vessels and nerves
4. **Mucosa:**
This is the innermost layer of alimentary canal which is variously modified and folded and with different types of glands. This layer is mainly concerned with secretion, digestion and absorption of nutrients from the digested food. Mucosa consists of lamina

propria (loose connective tissue), muscularis mucosa (in some parts) and innermost folded layer of columnar epithelial cells.

C. PHYSIOLOGY OF DIGESTION

1. Process of capturing food and ingestion:

Frog is a carnivorous; especially insectivorous animal that feeds on insects, earthworms, spiders, snails, fishes and smaller frogs which are captured with the help of sticky and protractible tongue. Mode of catching prey is remarkable. While feeding, the frog sits at a suitable place frequented by insects. When any prey comes close to it, it opens its mouth and suddenly flicks out its sticky tongue and strikes the prey. The prey soon comes in contact with the tongue and gets attached. Now, the tongue is withdrawn into the buccal cavity.

Once the prey is captured and brought into the buccal cavity, it is seized and killed with the help of hook-like and pointed maxillary and vomerine teeth. Teeth do not chew the food but food is moistened by mucus secreted by goblet cells found in the inner lining of buccal cavity. From the buccal cavity food is pushed back by the beating of cilia on the inner wall of buccal cavity and with the help of inbulging of eyeball. Then, contraction of the pharyngeal wall and by peristalsis in oesophagus, food gets passed through oesophagus, down into the stomach.

2. Digestion of Food:

Food contains complex organic substances which are not of immediate use as they are insoluble and can't diffuse or absorbed through the inner lining of the alimentary canal. Such complex foodstuffs are subjected to the physical and chemical changes to transform them into soluble and absorbable form. The physical change or mastication of food is brought about by the peristaltic movements of the alimentary canal, while the chemical changes are brought about by the enzymes or biological catalysts. Enzymes are complex proteins having specific property. In the digestive tract, several glands are present which produce various enzymes and they always act at the optimum body temperature. Proteolytic enzymes digest proteins, amylolytic enzymes digest carbohydrates and lipolytic enzymes digest fats.

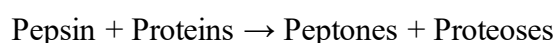
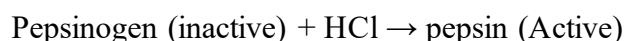
i. Digestion in buccal cavity and oesophagus:

There is neither mechanical nor chemical digestion in the buccal cavity as the buccal cavity is devoid of digestive glands. From the buccal cavity, the prey is directly pushed into oesophagus where it undergoes physical changes to some extent due to constant peristaltic movement of its wall. The inner lining of oesophagus secretes mucus and an inactive pepsinogen enzyme. No digestion occurs in oesophagus. Mucus simply makes the food moist or slippery to pass down easily.

ii. Gastric Digestion:

Food reaches the stomach and stays there for about 2-3 hours; its wall shows a series of peristaltic movements which brought about the churning of food and mix the food thoroughly with gastric juice secreted by the gastric glands; situated in the inner layer (internal lining) of stomach. Here, secretion of gastric juice is under the influence of gastrin

hormone which is produced by the stomach wall as soon as the food reaches to stomach. Gastric glands consist of multicellular peptic glands secreting a pro-enzyme called pepsinogen and unicellular oxyntic cells secreting hydrochloric acid. The gastric juice secreted by the gastric glands contains a large amount of water, inactive pepsinogen enzyme and hydrochloric acid. Inactive pepsinogen changes into active pepsin, if mixed with hydrochloric acid (HCl). Pepsinogen secreted by oesophagus also becomes active by HCl in stomach. Hydrochloric acid prevents the bacterial decomposition and dissolves the inorganic salts as well as makes the food soft. The pepsin acts on proteins of food and changes them into peptones and proteoses.



Now, Food takes the form of a thick creamy acidic fluid called chyme. Peristalsis in the stomach wall forces the chyme to pass in small amount at a time through the pyloric opening into the duodenum. To conclude, three functions of stomach are: Storage of food, mechanical mixing and chemical modification of food.

iii. Intestinal Digestion:

As the acidic chyme enters duodenum, wall of duodenum is also stimulated and secretes two hormones namely secretin and cholecystokinin which diffuse into the blood and reach the pancreas and liver respectively. Then, secretin stimulates the pancreas to secrete pancreatic juice and cholecystokinin activates the gall bladder to release the bile juice.

Bile and pancreatic juices are poured into the duodenum through the common hepatopancreatic duct. Meanwhile, the intestinal mucosa layer also secretes the intestinal juice called succus entericus under the influence of enterocrinin hormone. All the three substances get mixed up with the food in the intestine.

Bile contains no digestive enzymes. It is alkaline because it contains certain inorganic salts like sodium bicarbonate, sodium glycocholate and sodium taurocholate which not only neutralise the acidity of the chyme but also activates pancreatic juice as the pancreatic juice acts only in alkaline medium. Bile juice mechanically breaks down larger fat into small globules, called emulsification.

Pancreatic Juice contains powerful enzymes such as amylase (amylolysin), trypsinogen, chymotrypsinogen and lipase (steapsin). All of them act in alkaline medium and hydrolyse carbohydrates, proteins and fats. Trypsinogen is an inactive enzyme or pro-enzyme and gets activated by enterokinase enzyme found in succus entericus. Trypsin is also called autocatalyst as it activates more trypsinogen and chymotrypsinogen to form trypsin and chymotrypsin respectively.

Trypsin and chymotrypsin acts on proteins, peptones and proteoses hydrolysing them into simple amino acids.

Amylase acts on starches changing them into maltose, and lipase acts on emulsified fat to form fatty acids and glycerol.

Trypsinogen (inactive) + Enterokinase → Trypsin (active)

Trypsin + Protein + proteoses and peptones → Smaller polypeptides + Amino acids

Amylopsin + Starch → Maltose (Disaccharides)

Steapsin + Emulsified fats → Fatty acids + Glycerol.

Succus Entericus is also an alkaline fluid containing many enzymes such as enterokinase, peptidases (erepsin), lipase, maltase, sucrase (invertase), lactase, ribonuclease and deoxyribonuclease.

Peptidases + Polypeptides → Aminoacids

Lipase + Emulsified fat → fatty acid and glycerol

Maltase +maltose → glucose + glucose

Sucrase + sucrose → glucose + fructose

Lactase+ lactose → glucose + galactose

Similarly, Ribo-nuclease and deoxyribonuclease change the nucleic acids into nucleotides which are used in the synthesis of DNA, RNA and ATP. In this way, food is thoroughly digested with the help of enzymes. Consequently, all the proteins are changed into amino acids, carbohydrates into glucose and simple sugars and fats into glycerol and fatty acids.

3. Absorption of nutrients:

Absorption is that process by which the digested food is passed into blood stream. It occurs either by active transport or by passive transport. Absorption is mainly carried out in the duodenum and ileum as their inner layer is very much suited i.e. modified as absorptive surface or villi (singular; villus). Each villus is richly supplied with blood capillaries and lymph vessel or lacteal. Water, mineral salts and other nutrients are passively absorbed through the mucosa. The amino acids, glucose and fructose are absorbed by the diffusion through mucosa and passed into the blood capillaries and finally reach the liver through the hepatic portal vein. The glycerol and fatty acids pass into lymph vessels called lacteals. The glycerol can be absorbed easily as it is soluble in water, whereas the fatty acids cannot be absorbed as they are insoluble in water. So, before absorption the fatty acids mix with bile salts to make themselves water soluble substance called micelles. The micelles now enter intestinal mucosa cell where they are converted to chylomicrons which enter to lymph ducts or lacteals.

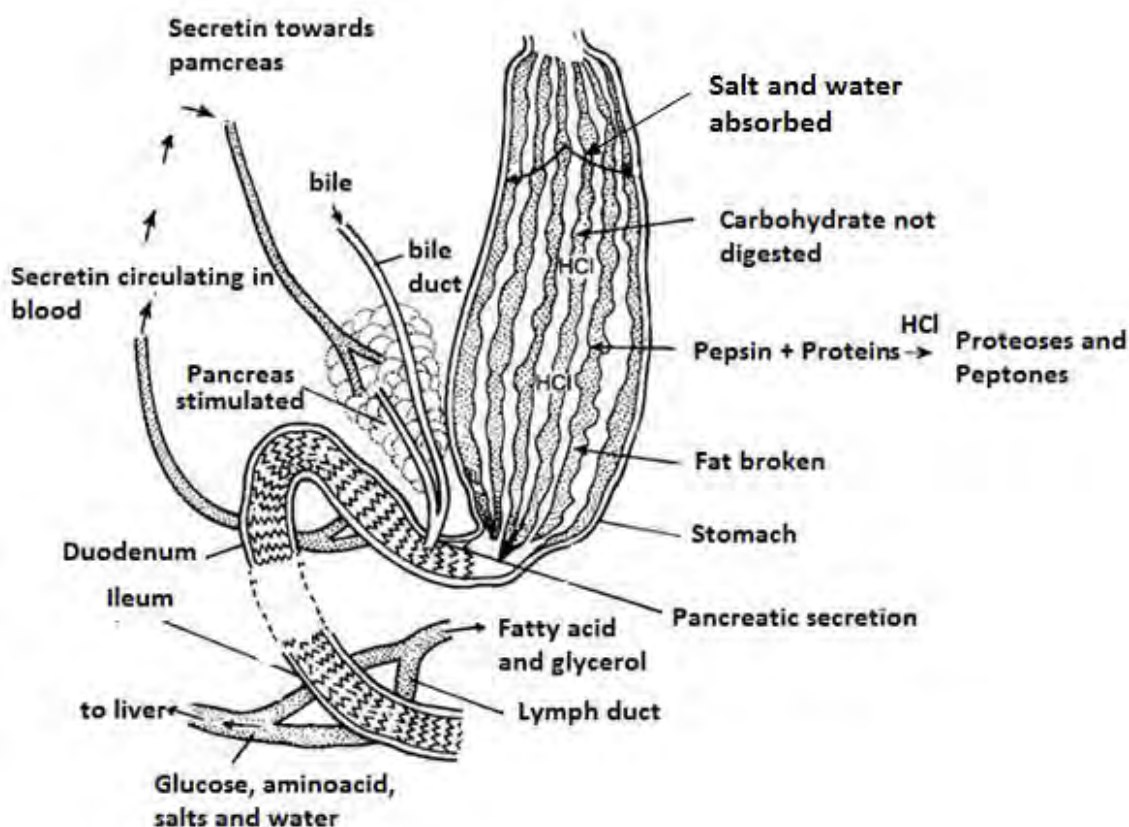


Figure 8.4.14 Digestion and absorption of nutrients

4. Assimilation:

Assimilation is the process in which absorbed nutrients are utilized by the body. Nutrients are utilized by body as per need such as synthesizing enzymes, amino acid, repairing cells and tissues, stored as reserve food material for future use, running metabolic activities etc. Similarly, Glucose is transported by the blood into the cells and tissues where glucose burns with oxygen or oxidizes to release energy, carbon dioxide and water.

5. Egestion of undigested Food:

After the completion of digestion and absorption in small intestine, undigested food enters rectum by peristalsis for storage and formation of faeces. Undigested food particles, old epithelial cells, leucocytes, bile pigments and large number of bacteria forms faecal matters which are discharged through the cloacal aperture.

EXERCISE

A. Tick the correct alternative.

1. Frog lives inside or near the ponds ditches pools etc. because.....
 - a. it can escape from enemies easily
 - b. to complete its life cycle
 - c. to take bath for maintaining body temperature
 - d. to make skin moist for cutaneous respiration
2. Larva of frog is.....
 - a. Terrestrial
 - b. Aquatic
 - c. Amphibious
 - d. tree dweller
3. Skin of frog is slippery because of the presence of in its skin.
 - a. mucus gland
 - b. sweat gland
 - c. sebaceous gland
 - d. harderian gland
4. The respiration which takes place through moist skin is called
 - a. pulmonary respiration
 - b. cutaneous respiration
 - c. branchial respiration
 - d. buccal respiration
5. Adult frog is
 - a. carnivorous
 - b. omnivorous
 - c. herbivorous
 - d. detritivorous
6. How does the croaking sound produced by frog contribute to its behaviour or environment?
 - a. to communicate distress.
 - b. To scare off predator
 - c. To pass through water
 - d. Use this sound as mating call
7. How is the metabolic rate in frog affected at the time of hibernation?
 - a. Metabolic rate increases significantly.
 - b. Metabolic rate unchanged
 - c. Metabolic rate decreases feebly
 - d. Metabolic rate decreases significantly
8. Which of the following statement is correct representing the nature of frog's teeth, and how do they contribute to feeding habit?
 - a. Teeth are sharp and numerous in both jaw for grinding food.
 - b. Teeth are sharp, numerous present in lower jaw for capturing prey
 - c. Teeth are sharp backwardly directed numerous in upper jaw implying for holding prey
 - d. Molar teeth on the backside of buccal cavity for grinding hard prey

9. Pancreas has main role in digestion by secreting various enzymes. One of the enzymes listed below is not pancreatic secretion and identify it.
- lipase
 - trypsinogen
 - amylase
 - pepsinogen
10. The function of bile juice is to emulsify.....
- protein
 - fat
 - carbohydrate
 - aminoacid
11. In liver carbohydrate is stored in the form of.....
- glucose
 - glycogen
 - aminoacid
 - Fat
12. Hepatopancreatic duct plays important role in the digestion by serving as a channel for the delivery of pancreatic juice and bile juice which are important for digestion of nutrients. Opening of this duct lies in the gastrointestinal tract. Into which part of gastrointestinal tract, hepatopancreatic duct open?
- stomach
 - large intestine
 - duodenum
 - ileum
13. Pharynx posteriorly opens into oesophagus by an opening called.....
- glottis
 - gullet
 - internal nares
 - pyloric opening
14. Trypsinogen is activated by.....
- enterokinase
 - trypsin
 - HCL
 - amylase
15. Lipid in the alimentary canal of frog is digested and converted to fatty acid and glycerol. Fatty acid should be transported from intestine by the body. Lacteals or lymph ducts play important role for doing so. Which of the following best describes for this?
- Fatty acids are transported as fat-soluble vitamins
 - Fatty acids are transported as chylomicrons
 - Fatty acids are transported by sodium co-transport mechanism
 - Water soluble vitamins

B. Answer the following questions:

- 1) Write short note on habit and habitat of frog.
- 2) In which part, body of frog is divisible? Briefly describe.
- 3) What do you mean by sexual dimorphism? Briefly discuss this phenomenon in *Rana tigrina*.
- 4) Frogs are poikilothermic animals. How do they cope with the change in season?
- 5) Discuss the feeding habit of frog.
- 6) What are the parts of alimentary canal of frog? Enlist them and discuss in brief.
- 7) In frog, buccal cavity is often called buccopharyngeal cavity. Why?
- 8) Briefly describe the various structures present in buccal cavity?
- 9) How does the process of digestion occur in various parts of alimentary canal in frog? Discuss.
- 10) How does gastric digestion occur in frog?
- 11) How are nutrients absorbed from the wall of intestine of frog?
- 12) Draw neat and labelled diagram of buccal cavity of frog.
- 13) What is the function of teeth in frog? Describe its structure.
- 14) Describe the liver of frog with its function.
- 15) Why pancreas is called compound gland? Discuss its structure and function.

8.4.4 BLOOD VASCULAR SYSTEM

To keep a cell alive, it requires some essential substances such as regular supply of water, oxygen and nutrients etc. Likewise, metabolic wastes produced by the cell should also be eliminated from it. Metabolic wastes produced in tissues such as urea, uric acid, carbon dioxide, excess water etc. should be transported to the excretory organs for their elimination. Blood vascular system is the organ system that is responsible for the transportation of both useful and harmful substances to the required sites within the body. Specific organs such as heart, blood vessels and blood form blood vascular system or circulatory system in frog.

Activity: 8.12

Objective: To identify the heart and its external feature.

Apparatus required: dissecting tray, forceps, needle, blade, magnifying glass

Procedure:

- Lay down a chloroformed or freshly preserved frog in dissecting dish ventro-dorsally i.e. ventral surface facing up.
- Fix the frog by pinning through the limbs.
- Dissect open the body cavity and identify heart.
- Observe with the help of magnifying glass.
- Draw and note down the external features for discussion.

Conclusion:

A. HEART

1. External features

The heart of a frog is a dark red colored and conical muscular organ with a broad anterior side and somewhat tapered posterior side. It is protected dorsally by vertebral column and ventro-laterally by the pectoral girdle. It lies mid-ventrally in the anterior body cavity in between two lungs, just anterior to the liver. It is enclosed within a delicate, thin and transparent two layered sac called the pericardium. The outer layer is parietal pericardium and inner layer is known as visceral pericardium. A space or cavity between these two layers is called the pericardial cavity which is filled with a pericardial fluid. The pericardial fluid maintains the heart moist, reduces friction and allows its free movements; also protect from the shocks, and mechanical injuries.

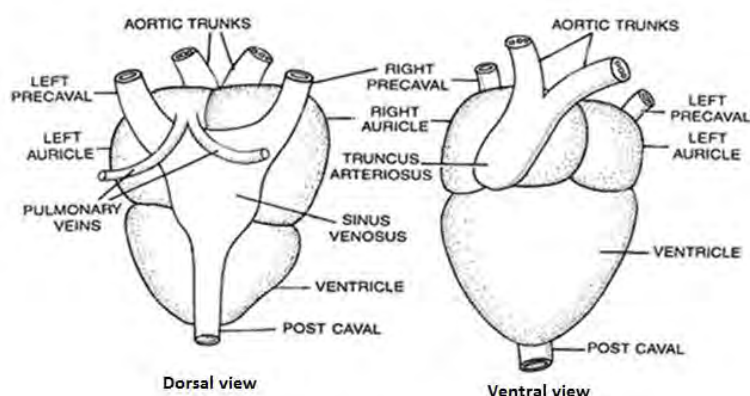


Figure 8.4.15 External Structure of heart of frog

When the pericardium is removed and observed thoroughly, the heart consists of three chambers where two anterior chambers are called auricles or atria and a posterior pink coloured conical chamber is called ventricle. In addition to the auricles and ventricle, frog has two additional chambers known as sinus venosus and truncus arteriosus. Sinus venosus present dorsally and truncus arteriosus present ventrally.

On the dorsal side, heart shows a thin walled, dark coloured and triangular chamber which is called sinus venosus. Sinus venosus is formed by the union of three caval veins in which two are anterior precavals and one is posterior post caval. Sinus venosus receives impure blood from various parts of body through precaval and postcaval veins to pour into right auricle. Two pulmonary veins from lungs also unite and open into the left auricle of the heart.

On the ventral side, there is a tubular structure arising from the anterior margin of ventricle on the right side called truncus arteriosus. It runs anteriorly and divides into two branches called right aortic trunk and left aortic trunk. Each aortic trunk further gives off three branches namely- carotid arch, systemic arch and pulmo-cutaneous arch. Right and Left auricles are separated externally by a faint inter-auricular groove and two auricles are separated from the ventricle by a transverse groove called coronary sulcus.

2. Internal structure

The internal structure of heart can be observed and studied by removing its ventral wall. It shows that it is a hollow conical muscular organ with two thin walled auricles and a thick-walled ventricle.

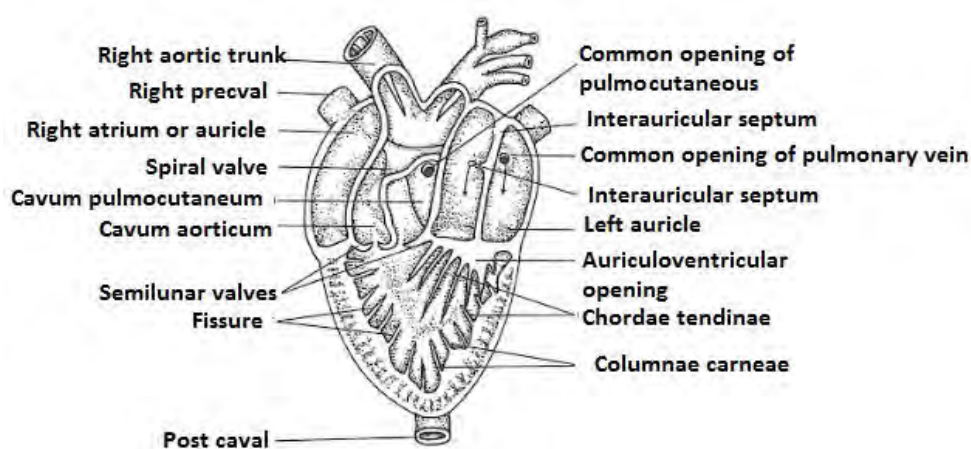


Figure 8.4.16 Internal Structure of heart of frog

Right and left auricles are separated from each other by a thin and vertical inter auricular septum. The right auricle is larger and receives blood from sinus venosus through a transverse oval shaped sinu-atrial opening, guarded by valve formed of two flaps like structures. Sinu-atrial or sinu-auricular opening is situated medially near interauricular septum. The common opening of pulmonary veins is situated in the left auricle near the septum but it is without valve. Both the auricles open into a single ventricle by a common wide auriculo-ventricular aperture, which is guarded by valve made up of four flaps; one dorsal, one ventral and two lateral in position. The free edges of these flaps project into the ventricle and are supported by fine contractile but tough thread-like structures known as chordate tendineae. The chordae tendineae regulate the movement of the auriculo-ventricular valve to allow the blood to pass

from the auricles into the ventricle but prevent the backward flow of blood from ventricle into the auricles.

The wall of ventricle is thick hence highly muscular and spongy and its inner surface contains numerous ridges and strands called the columnae carneae. The spaces between these strands are called fissures. Ventricle on the right side opens into truncus arteriosus on the ventral side. A row of three semilunar valves is present at the opening where ventricle opens into truncus arteriosus. These valves allow the flow of blood into the truncus arteriosus from the ventricle.

Truncus arteriosus is further divisible into a proximal or basal muscular part called conus arteriosus and the distal thinwalled bulbous aretriosus. The inner hollow cavities inside the conus arteriosus and bulbous arteriosus are called pylangium and synangium respectively. A row of the three semilunar valves separates the pylangium from the synangium. The pylangium is further divided incompletely into two chambers by a vertical and spirally twisted valve called spiral valve. The right chamber is the cavum aorticum and the left chamber is called the cavum pulmocutaneum. The spiral valve is attached dorsally but its ventral edge is free. In the cavum pulmocutaneum lies a common opening of pulmocutaneous arches. This opening is also guarded by a valve. The synangium bifurcates into two branches as right aortic trunk and left aortic trunk. Each aortic trunk divides into three arches, the pulmocutaneous, systemic and carotid arches.

3. Working of Heart:

Heart of frog is myogenic (heart beat originates from the heart muscles itself). Rhythmic contraction and relaxation of the heart is called heartbeat. Heart continuously beats during the life span which is under the nervous control to pump blood throughout the body. Contraction phase of ventricle is called systole and relaxation phase is called diastole. Wave of contraction originates from the sinus venosus and spreads over its wall and auricles. The sinus venosus contracts, whose contraction drives the mixed blood from the sinus venosus to the right auricle. The backward flow of the blood from right auricle to the sinus venosus is checked by the sinu-auricular valves. Meanwhile, the left auricle also receives oxygenated blood through pulmonary veins from the lungs. When the two auricles are full of blood, they contract simultaneously. The blood cannot go back into pulmonary veins as the openings of the pulmonary veins are small and oblique which are closed automatically by the contraction of the left auricle. Thus, blood from both auricles is pumped into the single ventricle through auriculoventricular aperture. Now, wave of the contraction is passed over the wall of the ventricle. There are two views regarding how the ventricle pumps blood through the truncus arteriosus:

a. Old view or conventional view

According to this view given by Brucke 1858, the ventricle contains impure blood in the right side received from the right auricle, mixed blood in middle region and pure or oxygenated blood in the left side from the left auricle. Whole Blood can't get mixed thoroughly because of viscosity of blood and presence of columnae carnea on the inner wall of ventricle. When the ventricle contracts, deoxygenated blood from its right side passes into cavum pulmocutaneum and is then carried to the lungs and skin for oxygenation. The spiral valve doesnot allow the blood to pass into the cavum aorticum at this time. Then, opening of cavum pulmocutaneum is closed by spiral valve. Next, mixed blood is pumped into cavum aorticum which passes through

systemic arches. Finally, oxygenated blood from the left side is passed through cavum aorticum into the carotid arches which flow to the head region. Thus, spiral valve in truncus arteriosus play major role in directing blood in different arches.

b. **Modern View**

According to the modern view, both oxygenated and deoxygenated bloods are mixed in the ventricle. When the ventricle contracts and the backward flow of blood into auricles are prevented by the auriculo-ventricular valve, the mixed blood of the ventricle enters the truncus arteriosus. From the truncus arteriosus mixed blood goes to three arches (carotid, systemic and pulmocutaneous) and reaches all the parts of the body.

By this view, It is concluded that there is complete mixing of blood in ventricle, spiral valve is nonfunctional and blood leaving from truncus arteriosus is mixed blood which circulates throughout the body.

B. BLOOD VESSELS

Blood vessels are tubes or channels of variable sizes forming the complex network in the body of frog. Their prime function is to transport blood among the various parts of the body. There is unidirectional flow of blood in blood vessels. Blood vessels are of three types

1. Arteries:

They are muscular, elastic and thick-walled blood vessels. Arteries transport blood from heart to the various parts of the body. They have narrow lumen. There is more pressure of blood in arteries and hence they are without valves. To withstand such a great pressure, they have thick wall. They are deeply seated in the body and transport oxygenated blood but in frog, arteries transport mixed blood. These blood vessels do not collapse easily after death because of their thicker and rigid wall. Arteries divide into smaller branches called arterioles and arterioles divide into capillaries.

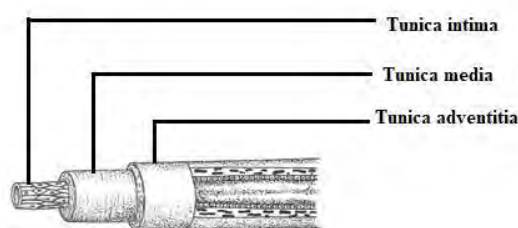


Figure 8.4.17 Artery in frog

Histologically, wall of artery consists of outermost fibrous layer of collagen (tunica adventitia), middle thick muscular layer and innermost layer of squamous epithelial cells (endothelium). Muscular layer is well developed in arteries.

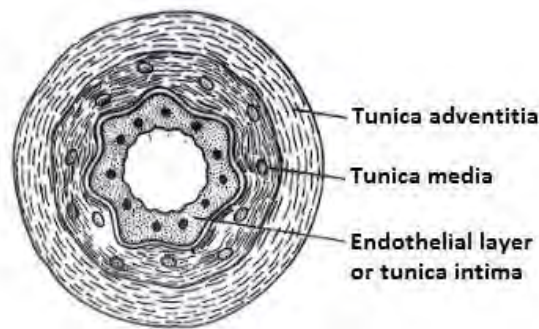
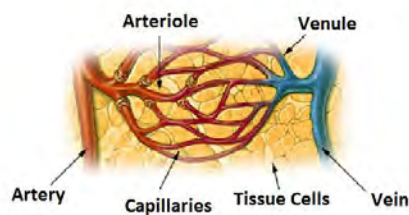


Figure 8.4.18 T.S. of artery

2. Capillaries:

Capillaries are fine thread like network of blood vessels extending all body tissues. Their wall is extremely thin which i.e made up of single layer of squamous epithelial cell called endothelium. There is no muscular and fibrous layer in the capillary wall. Capillaries are found abundantly in muscles and glands. Because of their thin wall exchange of nutrients, gases, hormones, waste occurs in between blood and tissues under pressure. Capillaries form a network around organ or tissue between the arterioles and venules. But in some organs like liver, spleen and red bone marrow, irregular blood spaces called sinusoids replace blood capillaries.



3. Veins:

Veins are thin walled, inelastic blood vessels having wide lumen. They transport blood from different parts of the body to the heart. Comparatively, there is less pressure of blood on the wall of veins so they have valves at frequent intervals. Valves in the veins check reverse flow of blood. Veins are superficially situated in the body. Generally, veins transport deoxygenated blood but in the case of frog, they carry mixed blood. These vessels collapse after cut or death easily because of their feebly developed muscular wall. Veins divides into fine branches called venules.

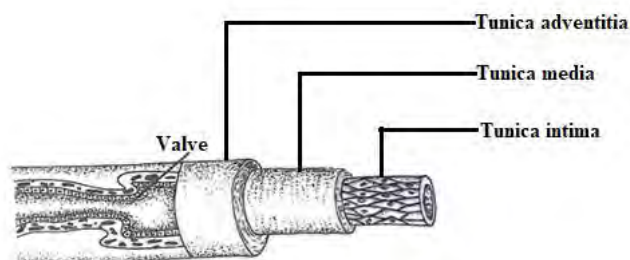


Figure 8.4.19 Vein in frog

Histologically, wall of vein consists of outermost fibrous layer of collagen (tunica adventitia), middle thin muscular layer and innermost layer of squamous epithelial cells (endothelium). Muscular layer is poorly developed in veins.

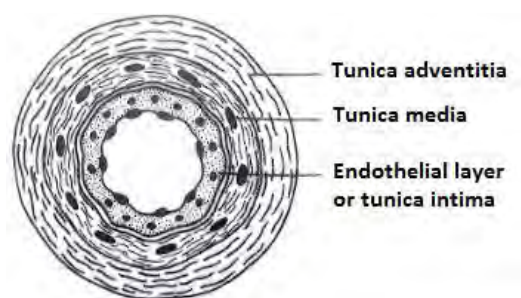


Figure 8.4.20 T.S. of vein

C. BLOOD

Blood is a liquid connective tissue composed of different type of blood cells suspended freely in a clear liquid called plasma. It keeps circulating in closed tubes called blood vessels throughout the body. Generally, Blood pH is 7. Blood consists of mainly 2 parts: Plasma and Blood corpuscles.

1. Plasma

Plasma is non-living, clear, pale yellow, slightly alkaline watery portion comprising about 55% of the blood. Dissolved substances in the plasma are nutrients, mineral salts, urea, hormones, proteins and other soluble substances. Major proteins found in plasma are serum albumin, serum globulin, fibrinogen and Heparin. Serum albumin has role in maintaining osmotic pressure and serum globulin forms enzymes and antibodies. Fibrinogen has role in clotting of blood in wound and injuries and heparin is an anticoagulant which prevents blood clotting in blood vessels.

Functions of plasma:

- i. Plasma transports nutrients, hormones, oxygen and metabolic wastes like urea carbon dioxide to the respective parts of the body.
- ii. Plasma proteins perform various functions such as maintaining blood osmotic pressure; neutralize damaged body protein, toxin and engulf germs.
- iii. Some plasma protein like fibrinogen helps in clotting of blood during cut etc.

2. Blood cells or blood corpuscles

a. Red blood cells or Erythrocytes

Red coloured cells (RBCs) are numerous (about 2.5-4 million per cubic mm of blood), oval, flattened, nucleated, and biconvex in shape. RBCs have respiratory pigment called haemoglobin. Hemoglobin transports oxygen to the tissues in the form of oxy-haemoglobin and also imparts red colour to the blood. They are formed in liver and spleen and destroyed in the same organs. In frog, their life span is about 100 days.



Figure 8.4.21 An erythrocyte

Functions of RBC

- i. RBCs transport oxygen from lungs to tissues (in oxyhaemoglobin form) and carbon dioxide (in carbamino form) from tissues to lungs.
- ii. RBCs also have role in maintaining pH of blood.
- iii. They maintain viscosity of blood.

b. White blood cells or Leucocytes

White blood cells are colourless and without haemoglobin, fewer (5000-7000 per cubic mm), nucleated and amoeboid shaped. They are formed in liver, yellow bone marrow and spleen in frog. Life span is about 20 days. Their number increases during infection. They engulf dead cell and bacteria through phagocytosis and also called phagocytes. Because of their changeable shape, they squeeze through capillary wall and show diapedesis.

Leucocytes are polymorphic i.e. found in different form. On the basis of presence or absence of granules in cytoplasm, they are granulocytes and agranulocytes.

a. Granulocytes:

- i. They are irregular shaped cells and filled with granular cytoplasm with specific staining property.
- ii. Nucleus is variable shaped and strongly lobulated.
- iii. Granulocytes are more numerous (about 70% of total leucocytes) and produced in red bone marrow.

Based on nature of granules present, shape of nucleus and staining properties, they are of 3 types which are Eosinophil, Basophils and neutrophils.



Figure 8.4.22 Granulocytes

Table: Comparison between Eosinophil, Basophil and neutrophil

Eosinophil	Basophil	Neutrophil
1. These cells stain red in acidic staining reagent like eosin. 2. These cells have bilobed nucleus.	1. These cells stain blue in basic stain like methylene blue and haematoxylin. 2. These cells have 'S' shaped nucleus.	1. These cells stain to both acidic or basic stain. They also stain with neutral dyes like wright's stain or leishman's stain. 2. They have multilobed nucleus.

b. Agranulocytes:

- i. These leucocytes are filled with non-granular and clear cytoplasm.
- ii. Nucleus is either round or kidney shaped which is comparatively larger sized.
- iii. They comprise about 30% of total WBCs.
- iv. They are produced in lymphatic nodules.

Agranulocytes are of 2 types:

- Lymphocytes: They are smaller cells with comparatively larger and spherical nucleus that nearly occupies the entire cell. They have small amount of cytoplasm. They produce antibodies.
- Monocytes: They are large cells with kidney shaped nucleus. They have comparatively more cytoplasm. They are phagocytic.



Figure 8.4.23 Agranulocytes

Functions of leucocytes or WBCs

- i. They destroy disease causing germs and have main role in the defensive mechanism of body.
- ii. They act as scavenger as they ingest harmful bacteria and other foreign particles and remove dead tissue cells.
- iii. They produce antibodies against different bacterial toxins.
- iv. Monocytes and neutrophil engulf the bacteria, dead cells and foreign particles. This is called phagocytosis or cell eating.
- v. Lymphocytes and eosinophil produce antitoxin to neutralize bacterial poison or toxin.

c. Platelets or Thrombocytes

They are much smaller, nucleated and spindle shaped cells. They are colorless and produced in bone marrow. Their number is about 2-4 million per cubic mm and life span is of about 7 days.



Figure 8.4.24 Platelets

Functions of Blood

- i. **Transportation:** Blood transport O_2 , CO_2 , glucose, amino acid, hormone, metabolic wastes to the target organs.
- ii. **Regulation:** Blood is the liquid medium transmitting uniform heat throughout body. It also controls level of water and salts in the body of frog.
- iii. **Protection:** WBCs protect the body from pathogenic bacteria viruses and other microbes by engulfing them and neutralizing their toxins. Clotting of blood occurs at the injured sites during excessive bleeding which is essential to save life. This is done by plasma protein and platelets.

EXERCISE

A. Tick the correct alternative.

1. Blood transport urea from liver to the..... for elimination.
 - a. stomach
 - b. lungs
 - c. intestine
 - d. kidney
2. In which protective covering heart is enclosed?
 - a. pericardium
 - b. myocardium
 - c. Pleura
 - d. meninges
3. Which of the following structure is present in the heart of frog but absent in mammals' heart?
 - a. Left auricle
 - b. Right auricle
 - c. sinus venosus
 - d. pulmonary vein
4. How sinus venosus is formed in the heart of frog?
 - a. By the fusion of two precaval
 - b. By the enlargement of postcaval
 - c. By the fusion of truncus arteriosus
 - d. By the fusion of two precaval and one postcaval
5. In frog, Which of the following blood vessel transport blood from the ventricle to various part of the body?
 - a. Pulmonary vein
 - b. pulmonary artery
 - c. truncus arteriosus
 - d. post caval
6. While you consider anatomical arrangement in the heart of frog, which of the following part would be the proximal part of truncus arteriosus, where it connects to heart?
 - a. The point where truncus arteriosus bifurcates
 - b. Middle part of truncus arteriosus
 - c. The junction between truncus arteriosus and right ventricle
 - d. The place where right aortic trunk trifurcates
7. Which of the following opening is without valve in the heart of frog?
 - a. Sinu-atrial opening
 - b. opening of pulmonary veins
 - c. auriculo-ventricular opening
 - d. opening of ventricle to truncus arteriosus
8. How is the structure of artery different from vein reflecting its function in blood vascular system?
 - a. They have larger and wide lumen that can hold more volume of blood
 - b. They have valves to prevent backflow of blood

- c. They have very thin wall for exchange of substances between blood and tissues
 - d. They are thick walled to withstand more pressure of blood
9. RBC of frog is different from mammal's RBC because
- a. It has no haemoglobin
 - b. It has nucleus
 - c. It has no nucleus
 - d. It is white coloured
10. Which of the following is agranulocytes?
- a. Monocytes
 - b. eosinophil
 - c. basophil
 - d. neutrophil

B. Answer the following questions:

1. Describe the structure and working mechanism of heart of frog.
2. What do you mean by blood vessels? Write short note on blood vessels in frog.
3. What are capillaries? Write their function?
4. Draw neat and labelled diagram of internal structure of heart of frog?
5. What is blood? Write short note on amphibian blood.
6. What are the differences between granulocytes and agranulocyte?
7. Observe the figure given below and answer the following questions:

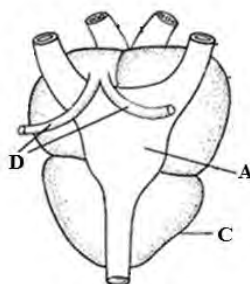


Figure 1

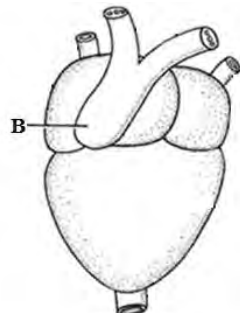


Figure 2

- i. Identify figure 1 and figure 2?
- ii. Label the parts A, B, C, D.
- iii. What is the function of A, B and D.

8.4.5 RESPIRATORY SYSTEM

Organs coordinated for the intake and supply of oxygen to the tissues and throwing out carbon dioxide from the body constitute respiratory system. The entire process of respiration consists of mechanical and chemical processes such as inhaling oxygen and exhaling carbon dioxide, transport of gases and oxidation of food in the tissues to release energy.

Tadpole or larva of frog lives completely in water and breathes through four pairs of external gills. Such respiration is called branchial respiration whereas Adult Frog spends dual or amphibious mode of life and performs respiration by the following ways:

1. **Cutaneous respiration (through moist skin)**
2. **Buccopharyngeal respiration (through buccopharyngeal lining)**
3. **Pulmonary respiration (through lungs)**

1. **Cutaneous respiration:** This type of respiration occurs all the time whether the frog is on land or in water. When the frog is metabolically less active and demand of oxygen is low or at the time of hibernation and aestivation; cutaneous respiration takes place.

Skin of frog is very thin, moist, highly vascularized and an efficient organ for cutaneous respiration. It maintains skin moist by frequently visiting water sources and secreting slippery mucus by mucous gland present in its skin.

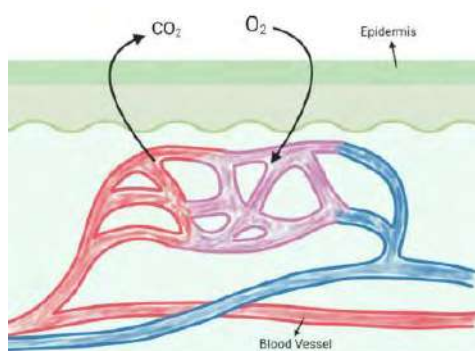


Figure 8.4.24 Cutaneous respiration in frog

During gaseous exchange through skin, oxygen first dissolves in the thin layer of water covering the skin and diffuses through the epidermis into the blood capillaries present in the dermis. Then, oxygen is carried by the blood in the form of oxyhaemoglobin to the tissues and oxy-haemoglobin dissociates into oxygen and haemoglobin near the tissues. Oxygen diffuses into the cell. Oxygen is used for oxidation of glucose in the cell and carbon-dioxide is the waste product produced due to this process which is also carried by blood to the skin surface and then gets diffused out.

2. **Bucco-pharyngeal respiration:**
This type of respiration takes place through the lining (internal layer) of bucco-pharyngeal cavity when the frog is resting on land or partially immersed in water. The inner lining of

bucco-pharyngeal cavity is moist and richly supplied with blood capillaries. Hence, it serves as the respiratory surface for exchange of gases. Bucco-pharyngeal respiration takes place with the help two sets of muscles called sternohyal muscle and petrohyal muscles. Sternohyal muscles are those muscles, connected with sternum and hyoid whereas petrohyal muscles are connected with squamosal and hyoid bone. Contraction of sternohyal muscles lowers the floor of buccal cavity and contraction of petrohyal muscle raises the floor of buccal cavity. Process of **inspiration** and **expiration** in buccal respiration is discussed below.

i. Inspiration

- At first, sternohyal muscle contracts and floor of buccal cavity is lowered.
- Then, volume of buccal cavity increases and air pressure in the buccal cavity decreases.
- Air from outside, rushes into the cavity through nostrils.
- Gullet, glottis and mouth remain closed during this process and no air passes into lungs.
- Fresh air or oxygen diffuses through mucous layer (inner layer) of buccal cavity and passed into blood capillaries

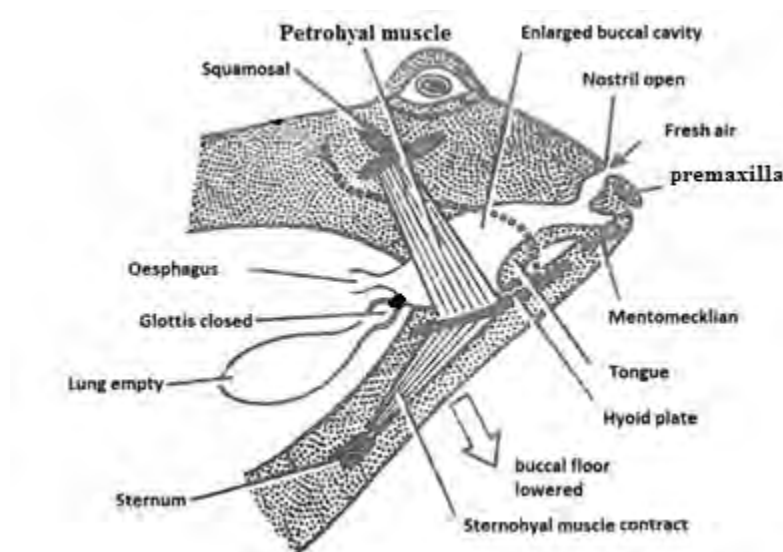


Figure 8.4.25 Inspiration in bucco pharyngeal respiration

- Meanwhile, CO₂ diffuses into the buccopharyngeal cavity from blood capillaries.

ii. Expiration

- Sternohyal muscle relaxes, petrohyal muscle contracts and floor of buccal cavity is raised.
- Consequently, volume of buccal cavity decreases and air pressure increases in the buccal cavity.
- Then air rich in carbondioxide, from buccal cavity escapes out through nostrils.

3. Pulmonary respiration

This type respiration takes place through the lungs on land, in which atmospheric oxygen is inhaled through nostrils. It occurs when the frog is more active and demand of oxygen is very high. Lungs are primary organs for pulmonary respiration. The route through which air enters or exits from the lungs is called respiratory tract or path which consists of nostrils, buccopharyngeal cavity, laryngotracheal chamber, bronchi and lungs.

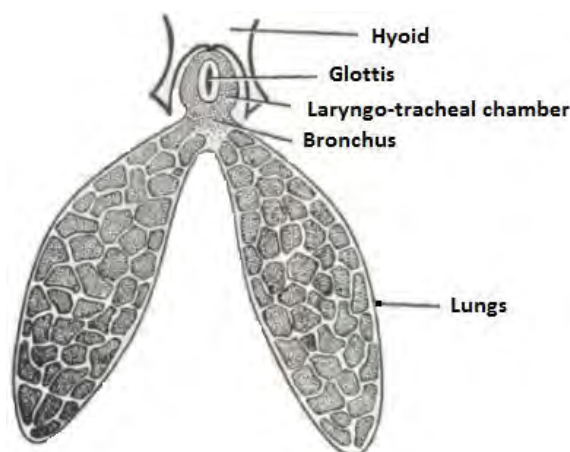


Figure 8.4.26 Pulmonary respiratory organs

a. Nostrils:

External nostrils are the paired openings situated dorsolaterally, a little above the mouth. They open into olfactory chamber of skull and then lead into buccal cavity through a pair of openings called internal nostrils. Each internal nostril is present on the either side of patches of vomerine teeth.

b. Buccopharyngeal cavity:

Internal nostrils open into a wide cavity which serves as a common passage of food and air called buccopharyngeal cavity. Buccopharyngeal cavity posteriorly leads in to laryngotracheal chamber through an opening called glottis.

c. Laryngotracheal chamber

Laryngotracheal chamber is a small thin walled chamber which performs the function of larynx and trachea. Its wall is supported by cartilages that consist of paired crescentic arytenoid cartilages and a single ring like cricoid cartilage. The inner or mucous membrane of laryngotracheal chamber is thrown into a pair of elastic horizontal folds called vocal cords. These vocal cords are stretched and relaxed by muscles connected with the cartilages. Such muscles can change the tension of cord and hence pitch of the sound too. When air from lungs is forcefully passed out between the vocal cords of laryngotracheal chamber, vibration vocal cords results the production of sound. Hence, laryngotracheal chamber is also called voice box. At the time of croaking, vocal sacs amplify the sound in male frog. Laryngotracheal chamber is connected to lungs of either side by a short tubular bronchus.

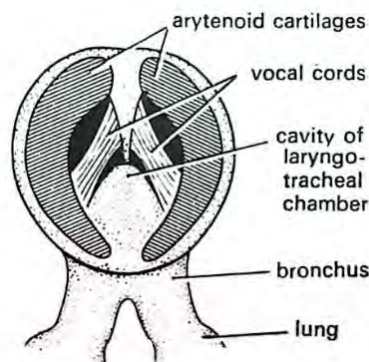


Figure 8.4.27 Laryngotracheal chamber in frog

d. Lungs:

Lungs are paired, pinkish, oval, thin walled and highly elastic sacs like structures situated inside the anterior body cavity on either side of the heart. They are the chief respiratory organs and also help in buoyancy in water. They are supplied with pulmonary arteries and pulmonary veins.

Histologically, the wall of lung consists of three layers: outer peritoneum, middle layer of connective tissue and inner layer of epithelial cells. Peritoneum consists of simple squamous epithelium, connective tissue contains unstriated muscle fibre, blood vessels, nerves etc. and inner layer of epithelial cells. The inner surface of lung is divided into a series of small chambers called alveoli by trabeculae or septa. The inner surface of alveoli is lined by ciliated columnar epithelium having mucus secreting goblet cells. Septa are highly vascularised for gaseous exchange. There is no division of bronchi into bronchioles in lung and there are few alveoli in lungs of frog. Hence, lungs of frog are poorly developed and less efficient.

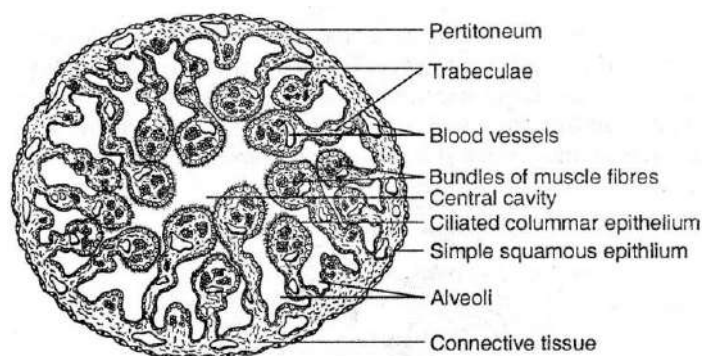


Figure 8.4.28 T.S of lung of frog

Mechanism of pulmonary ventilation or breathing

Pulmonary respiration takes place in between buccal respiration. Two sets of muscles i.e. sternohyal and petrohial present in buccopharyngeal cavity have main role in pulmonary respiration. Sternohyal muscles are connected with the sternum and hyoid bone present in the lower jaw and their contraction lower floor of buccal cavity. Similarly, petrohial muscles are

connected with hyoid and squamosal of skull and their contraction raise the floor of buccal cavity. Process of pulmonary ventilation can be discussed under following points:

1. Inspiration:

- Glottis and mouth are closed but nostrils remain open.
- Sternohyal muscle contracts causing the lowering of floor of buccal cavity.
- Volume of buccal cavity increases and air pressure inside the cavity decreases.
- Air rushes into the buccal cavity through the nostrils from outside.
- Now, mentomeckalian bone of lower jaw raises premaxillae upward to close nostrils.
- Then, Contraction of petrohyal muscle takes place raising the floor of buccal cavity.
- As a result, volume of bucco pharyngeal cavity decreases and air pressure in the cavity increases.
- Glottis open and air rushes to lungs. (mouth and gullet are closed in this time)
- When lungs are filled with air, then glottis is closed and gaseous exchange takes place in lungs for some time and buccal respiration also take place at that time.

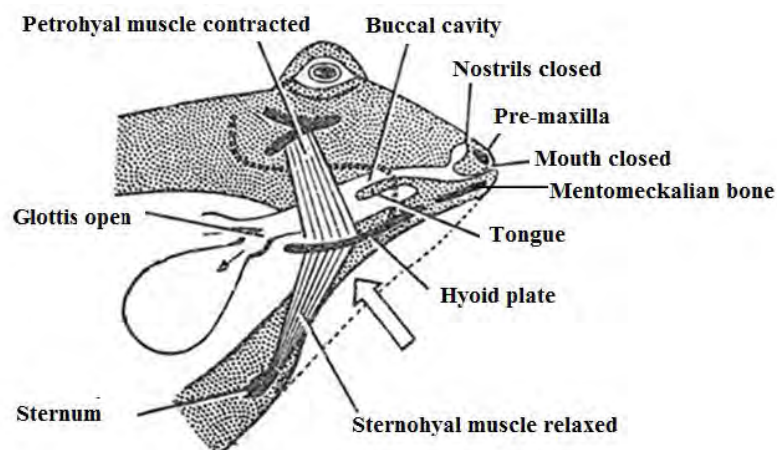


Figure 8.4.29 Inspiration in pulmonary respiration

2. Expiration

- First of all, contraction of lungs takes place, aided by abdominal muscles.
- As a result, lung volume decreases and air pressure in the lung increases.
- External nostrils are closed.
- Sternohyal muscles contract and volume of buccal cavity increases.
- Consequently, air pressure decreases in the buccal cavity and air from lungs moves to buccal cavity by opening glottis.
- Then, contraction of petrohyal muscles takes place.
- Volume of buccal cavity decreases and air pressure increases inside it.
- Glottis is closed and air moves out by opening nostrils.

Physiology of respiration

In frog, entire process of respiration can be discussed under the following headings:

1. **Breathing or external respiration:** It is the process of taking in oxygen and throwing out carbon dioxide. As discussed earlier, this process occurs in frog through moist skin, buccopharyngeal cavity and lungs.
2. **Transport of oxygen:** A very few amounts of oxygen (about 1%- 3%) is dissolved in the blood plasma which is transported to different parts of the body. In RBC, an iron-based protein called haemoglobin is present. When haemoglobin combines with oxygen, an unstable compound called oxyhaemoglobin is formed. Most of the oxygen (about 97%- 99%) is transported by the blood in the form of oxyhaemoglobin to the tissues. One molecule of haemoglobin transports four molecule of oxygen. Formation of oxyhaemoglobin is favoured by decreased CO_2 concentration, low temperature etc. in the blood.
3. **Internal respiration:** Oxyhaemoglobin is unstable compound which dissociates into oxygen and haemoglobin near the tissues because of some factors like more CO_2 concentration, high temperature etc. Oxygen enters the body cell where glucose burns with oxygen to release energy, carbon dioxide and water.
4. **Transport of CO_2 :** CO_2 is released in internal respiration as wastes which diffuse out from the cell to the blood. Then, it is transported to the lungs in the form of carbonic acid, bicarbonates and carbamino compound:
 - i. **In the form of carbonic acid (7%):** Few amounts of carbondioxide is transported in the form of carbonic acid. Water in plasma combines with carbondioxide to form carbonic acid which is transported to the lungs for its expulsion.
 - ii. **In the form of bicarbonates (70%):** Most of the carbondioxide produced is transported in the bicarbonate form. CO_2 diffused to the blood combines with water in RBC to form carbonic acid in the presence of carbonic anhydrase. Carbonic acid ionises into H^+ and HCO_3^- . Then, majority of HCO_3^- shift into the plasma from RBC. To compensate the loss of HCO_3^- , Cl^- from plasma diffuses into RBC. This phenomenon is called chloride shift or Hamburger phenomenon. Now HCO_3^- in plasma combines with Na^+ to form sodium bicarbonate and transported to lungs for the elimination of CO_2 .
 - iii. **In the form of carbamino compound (23%):** When carbondioxide reacts with haemoglobin it forms unstable carbamino compound (HbNHCOOH). It is transported to the lungs and gets dissociated to release carbondioxide for the expulsion.

EXERCISE

A. Tick the correct alternative.

1. Muscle that in respiration in frog is
 - a. sternohyal muscle
 - b. diaphragm
 - c. lingual muscle
 - d. petrohyal muscle and sternohyal muscle
2. Buccopharyngeal cavity communicates with the respiratory tract posteriorly by
 - a. External nares
 - b. glottis
 - c. gullet
 - d. internal nares
3. Which of the following structure is absent in the lung of frog?
 - a. Bronchus
 - b. bronchiole
 - c. lungs
 - d. vocal cord
4. Carbon dioxide is the byproduct of cellular respiration that should be eliminated from the body. Which of the following statement best describes the form of which most of the carbon dioxide is transported from tissues to the lungs via blood?
 - a. In dissolved form with plasma
 - b. Bound to haemoglobin as carbamino haemoglobin
 - c. Transported as bicarbonates
 - d. In RBC as carbonic acid
5. Oxygen diffuses through the respiratory surface and enters blood stream which is then transported to various tissues of the body. In which form majority oxygen is transported by blood?
 - a. Haemoglobin combines with oxygen to form oxyhaemoglobin
 - b. In the form of bicarbonates
 - c. Oxygen dissolves in plasma and transported
 - d. In RBC as carbonic acid
6. Hibernation and aestivation are the remarkable physiological adaptation shown by frogs to survive in extreme environmental condition such as extreme cold and hot. During such period of inactivity, which type of respiration mainly supports frog?
 - a. branchial respiration
 - b. cutaneous respiration
 - c. pulmonary respiration
 - d. buccal respiration
7. In the process of buccal inspiration, air is drawn into the buccal cavity and for this the floor of buccal cavity undergoes some specific movement. Such movement is essential for creating pressure difference which is for inflow of air. What is the action of floor of buccal cavity at this time?
 - a. Floor of buccal cavity raised up to increase buccal volume

- b. Floor of buccal cavity lowered down for increasing buccal volume
 - c. Floor of buccal cavity lowered down for decreasing buccal volume
 - d. Floor of buccal cavity raised up to increase air pressure in buccal cavity
8. Cutaneous respiration allows frogs to exchange gases directly through skin. Such mode of respiration is made possible by certain specialities of frog's skin. Which of the following best explains why cutaneous respiration is feasible in frog?
- a. Skin is scaly which favour diffusion of gases
 - b. Skin is thin moist and vascularized
 - c. Skin secrete toxic substances which help to absorb oxygen
 - d. Skin is dry and thin which facilitate diffusion
9. Chloride shift occurs in CO_2 transport in the form of
- a. Carbonic acid
 - b. bicarbonates
 - c. carbonic acid
 - d. dissolved state

B. Answer the following questions:

1. Briefly discuss buccopharyngeal inspiration and expiration.
2. How respiration in frog is possible through skin? Discuss.
3. Write about the mechanism of pulmonary ventilation in frog?
4. Discuss the various structures of pulmonary respiratory tract.
5. Why are the lungs of frog less efficient organs than the mammals?
6. How sound is produced in frog? Discuss
7. How does the transport of oxygen and carbon dioxide occurs in the body of frog?
8. Write a short note on lungs of frog.

8.4.5 REPRODUCTIVE SYSTEM

The group of organs concerned for producing offspring for the continuation of the generation constitutes reproductive system. Frog is unisexual animal where well marked sexual dimorphism especially in breeding season is found.

Activity: 8.13

Objective: To identify the reproductive organs in frog.

Apparatus required: dissecting tray, forcep, needle, blade, magnifying glass

Procedure:

- i. Lay down a chloroformed or freshly preserved frog in dissecting dish ventro-dorsally i.e. ventral surface facing upwards.
- ii. Fix the frog by pinning through the limbs.
- iii. Dissect open the body cavity and remove alimentary canal.
- iv. Observe kidney which is either with oval shaped testis or with irregular ovary on the either side of vertebral column.
- v. Identify other organs associated with reproduction (take help of your teacher if required)
- vi. Draw labeled diagram of reproductive system and discuss.

Conclusion:

1. MALE REPRODUCTIVE SYSTEM

a) Testes:

Testes are paired, oval, yellowish coloured structures. Each testis is attached on the antero-ventral surface of the kidney with the help of a double fold of peritoneum called mesorchium.

Histologically, each testis contains hundreds of microscopic convoluted tubular units called the semeniferous tubules. The wall of semeniferous tubule is lined by germinal epithelial cells or primordial germ cells which later transform into sperms by the process of spermatogenesis. The space between the semeniferous tubules is filled with the connective tissue, blood capillaries, nerve fibers and interstitial cells. The interstitial cells secrete a male sex hormone called testosterone, which produces the secondary sexual characters in breeding season such as development of vocal sacs, nuptial pads etc. The sperms are arranged in the form of sperm bundles and nourished by nurse cells. A mature sperm is elongated microscopic cell with three distinct parts: head, middle piece and tail. A conical cytoplasmic structure present on top of the head is called acrosome which is used for the penetration of the egg membrane during fertilization as it contains a chemical called sperm lysine. In the middle piece, mitochondria and two centrioles are present. Tail helps in movement of sperm. Some yellowish finger like outgrowths are found attached nearer to the anterior region of each testis which are fat-bodies, used up at the time of hibernation.

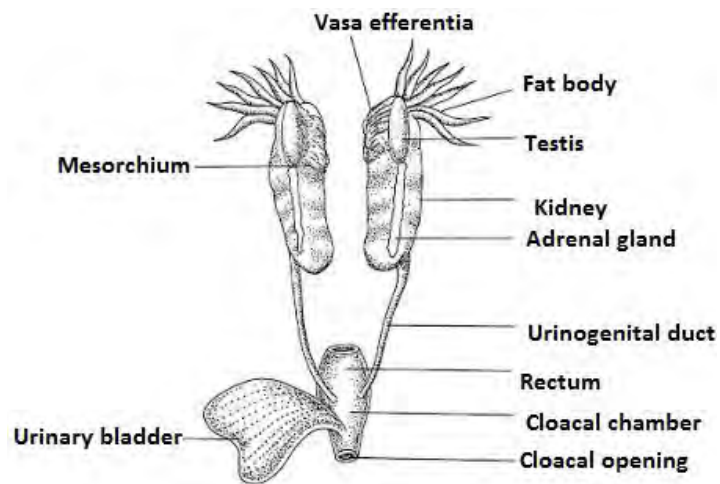


Figure 8.4.30 Male reproductive organs of *Rana tigrina*

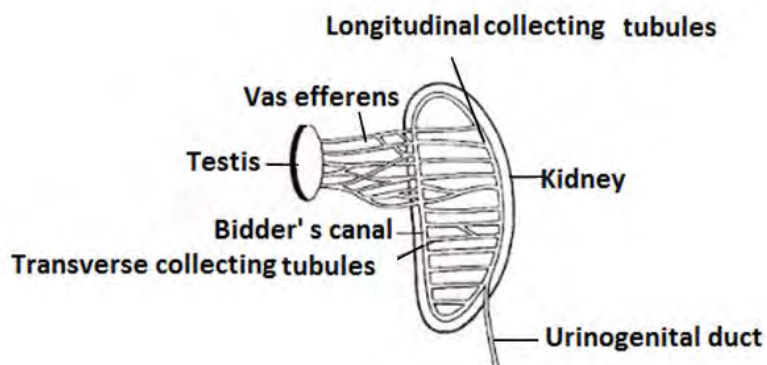


Figure 8.4.31 L.S. of kidney showing vasa efferentia

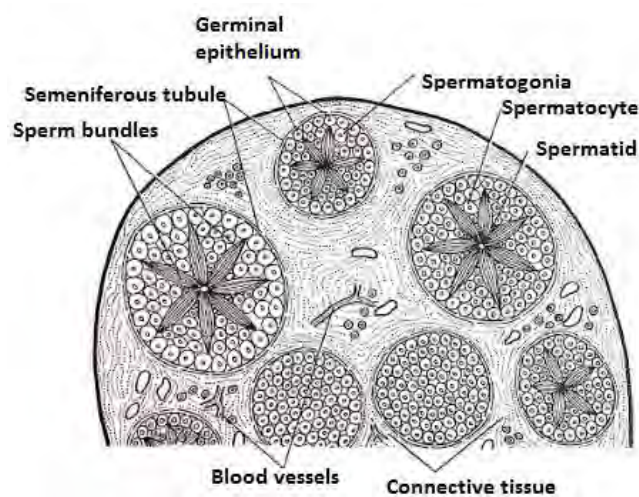


Figure 8.4.32 T.S. of testis of frog

b) Vasa efferentia:

There are 10-12 very fine tubes emerging from the testis to the kidney. The vasa efferentia traverse through the mesorchium and open into Bidder's canal along the inner margin of each kidney. The sperms from the lumen of semeniferous tubules are passed into Bidder's canal via vasa efferentia and then carried to longitudinal collecting tubule through the transverse collecting tubules. Longitudinal tubule leads posteriorly into urinogenital duct.

c) Urinogenital duct:

Each kidney gives rise to a white muscular tube called urinogenital duct or ureter at its outer border which transports both sperms and urine. Each urinogenital duct runs posteriorly and opens into the cloacal chamber. In some frog, it dilates to form a seminal vesicle to store the sperms temporarily. Seminal vesicles are not found in *Rana tigrina*.

d) Cloacal chamber and Cloacal aperture:

It is a common chamber that receives faecal matter, urine and sperms. All these products are discharged out through cloacal aperture. Copulatory organ is absent in frog. After amplexus or pseudo copulation, the male frog sheds sperms on the female's ova.

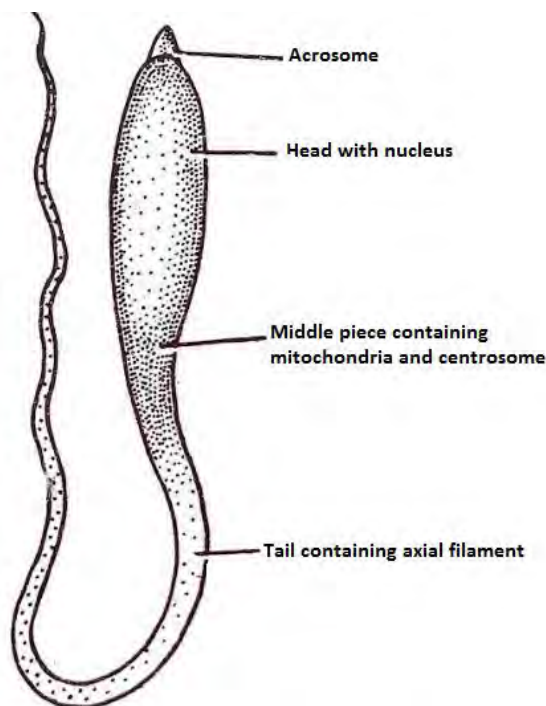


Figure 8.4.33 A sperm of frog

2. FEMALE REPRODUCTIVE SYSTEM**1. Ovaries:**

They are paired, irregular shaped, blackish white, lobulated structures, each attached to the dorsal wall of abdomen, and kidney with the help of thin membrane known as mesovarium. Ovaries become enlarged during breeding season and female's belly become bulging. The ovaries have no internal connections with the kidneys. During the breeding season, the wall of the ovarian follicles ruptures to release the ova into the coelom which is called ovulation.

Histologically, ovary is a thin walled sac that contains many lobules. Each lobule consists of outer layer of theca externa and inner layer of theca interna with connective tissue in between. Connective tissue contains blood vessels, nerves etc. Theca externa is internally lined by germinal epithelial cells at certain places which undergo oogenesis to form ovum. The ovum is surrounded by single layer of follicular cells, which in turn enveloped by the extension of theca interna.

Each unfertilized ovum is blackish white large cell and is surrounded by vitelline or egg membrane. Upper pole of ovum is called animal pole and lower pole is called vegetal pole. Ovum is furthermore surrounded by albumin which protects the egg from desiccation and external infections. Egg of frog is mesolecithal i.e. containing moderate amount of yolk and telolecithal i.e. yolk concentrated towards vegetal pole.

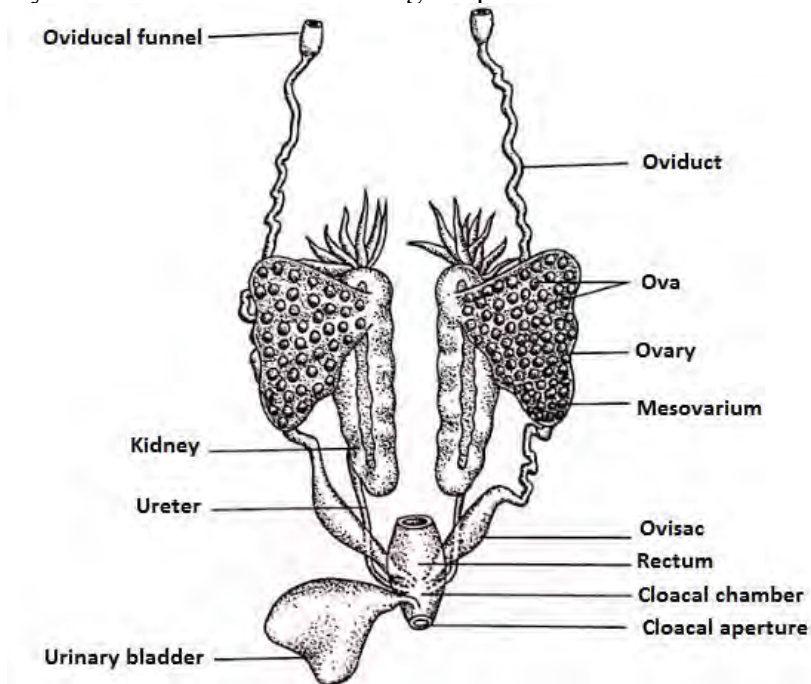


Figure 8.4.34 Female reproductive organs of frog

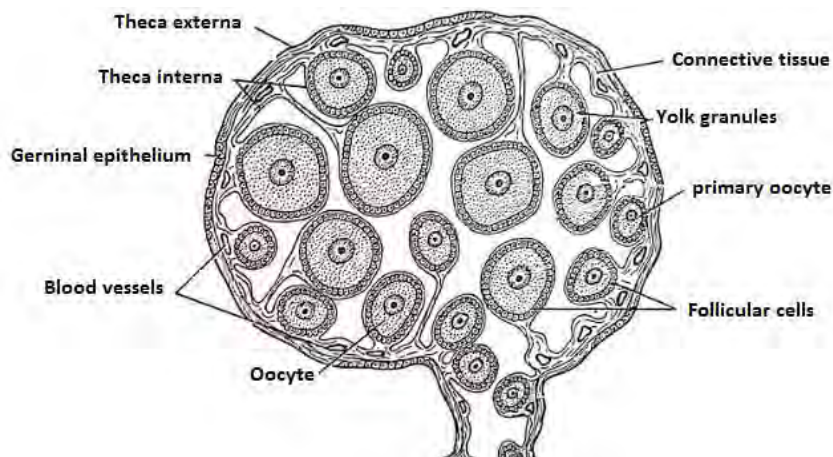


Figure 8.4.35 T.S of Ovary

2. Oviducts:

These are paired, white, long, much convoluted and internally glandular and ciliated tubes lying one on either side of the body cavity. Each oviduct consists of oviducal funnel, tubular part and ovisac (uterus). By the rupture of ovarian follicles, the ova are released into body cavity which is called ovulation and ova reach the oviducal funnels through ostia (mouth of funnel). Then, they move through tubules and stored in the ovisac. Beating of cilia on the inner wall of oviduct facilitates the movement of ova. Ova are coated externally by the albuminous secretion while passing via oviduct. Ova are released at the time of amplexus. A mature female frog can lay 2500 to 3000 ova at a time. Fertilization is external. Development is indirect involving a larval stage called tadpole.

3. Cloacal chamber and cloaca:

Cloacal chamber is the median sac between hind limbs that opens outside by cloacal opening. Ova are discharged to water through cloaca during or after amplex or amplexus.

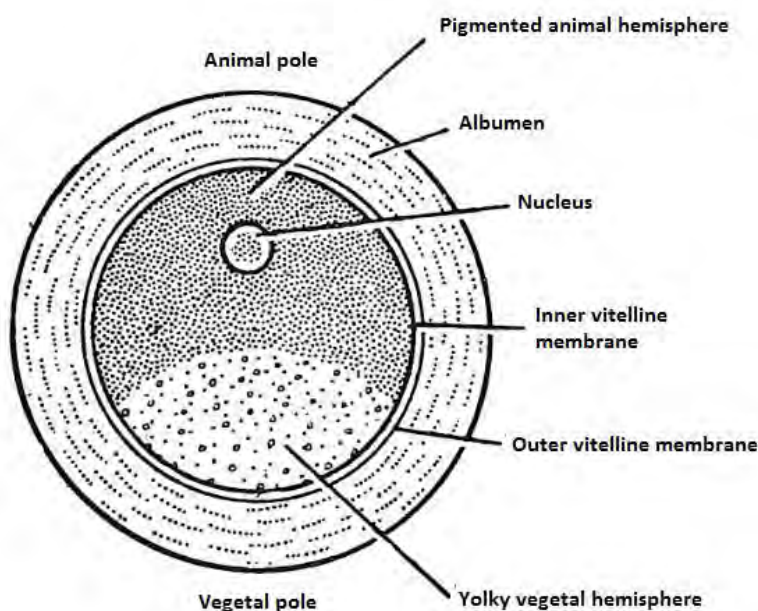


Figure 8.4.36 Unfertilized egg of frog

Amplexus:

Under the influence of testosterone hormone, development of copulatory or nuptial pads, vocal sacs and formation of sperms takes place in the male frog during breeding season. Basal part of first finger or index finger of male is enlarged or swollen to form copulatory pad. With the help of vocal sac, male frog is capable of producing croaking sound which attracts the nearby female frog. Then male frog mount on the back of female and grasp female's abdomen firmly which is called sexual embrace. Then, female frog is stimulated and lays eggs in water in the form of spawn and milt is discharged over it by male. Fertilization occurs which is followed by embryonic development.



(a)



(b)

Figure 8.4.37 (a) Copulating frog (b) Spawn laid by frog in water

EXERCISE

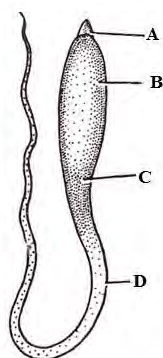
A. Tick the correct alternative.

1. Which of the following structure present in the sperm provide energy for its movement?
 - a. Mitochondria
 - b. centriole
 - c. nucleus
 - d. acrosome
2. Fertilization is the complicated process that begins with the penetration of the egg membrane by the sperm resulting the formation of zygote by the fusion of gametic materials. Which of the following best describes the mechanism through which sperm penetrates the egg membrane during fertilization?
 - a. Sperm make the use of tail to penetrate the egg
 - b. When sperm touch egg membrane, then nucleus of egg attract sperm.
 - c. Acrosome in sperm produce lytic enzyme for dissolving egg membrane
 - d. Head of sperm is pointed for the penetration of egg membrane
3. Bidders canal is present in....
 - a. Kidney of male
 - b. testis
 - c. kidney of female
 - d. ureter
4. The process of formation of ovum is
 - a. Oogenesis
 - b. ovulation
 - c. spermiogenesis
 - d. amplexus
5. The belly of female frog seems bulging during breeding season because
 - a. Their abdomen is full of fertilized ovum
 - b. Ovaries enlarge and abdomen is full of unfertilized ovum
 - c. They eat too much in this season
 - d. They become too fat in this season
6. Egg of frog is mesolecithal because of yolk in their egg.
 - a. little
 - b. maximum
 - c. moderate
 - d. centrally located

7. Outer covering of unfertilized egg in frog just after ovulation is called.....
 - a. Vitelline membrane
 - b. fertilization membrane
 - c. grey crescent
 - d. albumen
8. Telolecithal egg in frog means
 - a. Yolk is present towards vegetal pole
 - b. Yolk is present centrally
 - c. Yolk is found at animal pole
 - d. Yolk is uniformly mixed with cytoplasm
9. In frog, testosterone hormone has crucial role for the development of male secondary sexual characteristics and regulation of various physiological processes. which of the following structure in testis has main role in the production of testosterone?
 - a. Semeniferous tubule
 - b. Sertoli cell
 - c. Leydig cell
 - d. Epididymis

B. Answer the following questions:

1. What is sexual dimorphism? How male frog is distinguished from female frog?
2. Draw neat and labelled diagram of male reproductive system of frog and explain it.
3. Briefly describe the structure of sperm of frog with diagram
4. Draw neat and labelled diagram of T.S of testis.
5. Why ureter in male frog is called urinogenital duct unlike ureter in female frog?
Observe the diagram and answer the following question:

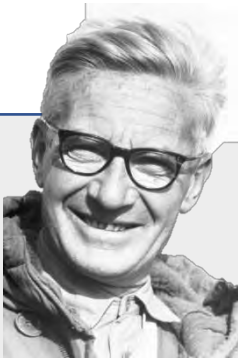


- i. Identify the given structure and label the parts A, B, C and D.
- ii. What is the function of A and D.
- iii. Name the organelle found inside C that helps in cleavage after fertilization.
6. Enlist female reproductive organs of frog? Describe them with well labelled diagram.
7. Briefly describe the structure of unfertilized ovum of frog.

Unit

9

Biota and Environment



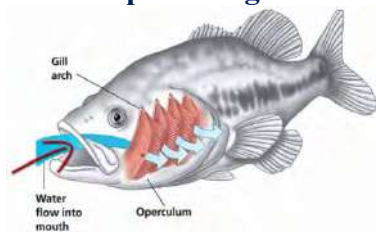
Nikolaas
Tinbergen
(1907-1988)

Nikolaas Tinbergen, a Nobel laureate, pioneered the study of animal behavior. His research on fixed action patterns revealed instinctive behaviors triggered by specific stimuli. Tinbergen's work in animal communication and navigation, notably in bees and birds, revolutionized ethology. His contributions reshaped our understanding of animals' cognitive abilities and adaptive behaviors in their natural environments.

Chapter 9.1

ANIMAL ADAPTATION

Observe the pictures given and discuss the following questions:



Fish



Dolphin



Cheetah



Mole



Sloth



Birds

- VI. What might be the habitat of given animals?
- VII. What morphological variations do you find among them?
- VIII. Do such variations facilitate them to adapt in their environment? How?
- IX. What is the adjustment of animals with their environment called?

9.1.1 GENERAL INTRODUCTION

In the given pictures, animals living in different habitats are shown. Fish lives in water has developed several structures in its body like gills for respiration, fins for swimming in water and streamlined body to pass in water easily. Similarly, Dolphin also lives in water which has modified fore limbs as fin like structures called flippers and its body is fish like in appearance. Cheetah has long and strong limbs, small head and ears thrown back for running swiftly on the ground to catch prey and fight. Mole lives underground, has clawed digits, palms are shovel like and snout pointed for digging holes. Sloth is hanging on a tree branch whose body is modified to cope with tree dwelling habit such as strong limbs with claws, powerful muscles on chest etc. Birds are seen flying in the sky with their wings, streamlined body, feathers etc. So, each organism of nature modifies itself to cope with the change in environment where it lives because environment is the home for various organisms.

The adjustment made by the organism to survive in its habitat according to the environmental needs is called adaptation.

Survival of animals in the particular region is possible due to adaptation. In other words, adaptation is the process of structural, behavioral and physiological changes in animals by which they can survive and reproduce in their habitat. Structural changes means developing body structures by animals such as fins and gills in fishes, flippers in dolphin, wings in bird

strong and elongated limbs in running animals, patagia in bat, webbed feet in duck etc. and behavioural changes are the behaviour shown by animals such as hibernation, migration, communication etc. Similarly, physiological changes involves maintenance of internal physiological processes like temperature regulation, osmoregulation etc.

Animal adaptation can be broadly categorized as aquatic and terrestrial adaptation.

9.1.2 AQUATIC ADAPTATION

Activity 9.1

Objective: To identify the adaptational features of fish

Apparatus required: dissecting tray, forceps, needle

Procedure:

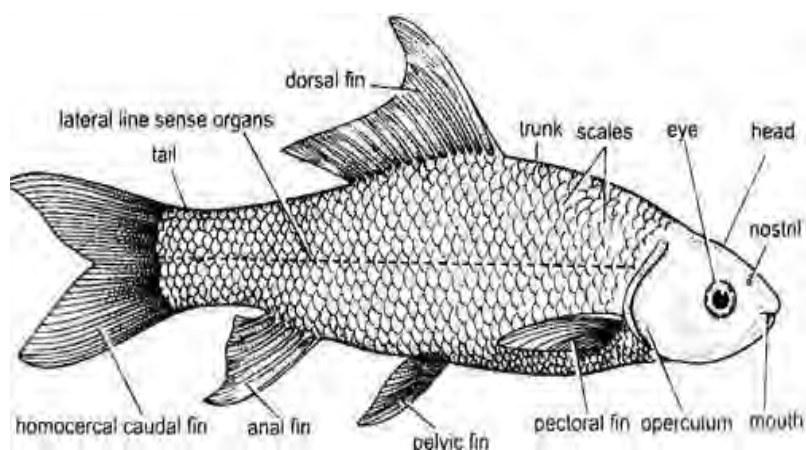
- vii. Take a freshly preserved or chloroformed fish.
- viii. Put it on dissecting tray.
- ix. Observe its structure thoroughly
- x. Note down all the features that help to adapt to the environment.
- xi. Identify more features. (Take help of your teacher)
- xii. Draw its labeled diagram and discuss.

Conclusion

Animals that live in water are called aquatic animals. Aquatic adaptation is the adjustment or acclimatization of animals in water by developing special structures in their body. Aquatic adaptation can further be divided as:

1. PRIMARY AQUATIC ADAPTATION

Those animals and their ancestors which lived primarily in water and have never come to land are called primary aquatic animals and the adaptation shown by them is called primary aquatic adaptation. They are fishes which respire through gills. Following adaptational features are found in primary aquatic animals:



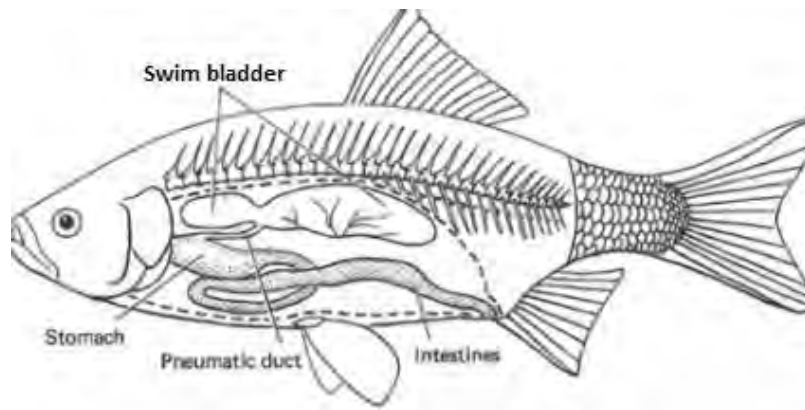


Figure: 9.1.1 Various structures of aquatic adaptation in fish

- i. They have streamlined and laterally compressed body. Such body shape favours swift movement in water by reducing friction.
- ii. Locomotion takes place through fins which are paired (pectoral and pelvic fins) and unpaired (anal, dorsal and caudal fin). Caudal fins also serve as rudder, helps in changing direction while swimming.
- iii. Respiration takes place through gills and gills are protected within gill cover or operculum. In some fishes like shark, gill cover is absent. Some fishes have also developed accessory air breathing organs.
- iv. Body is covered by waterproof protective scales and which are of various types such as placoid scales, cycloid scales, ctenoid scales etc.
- v. They have mucous cells in skin which secrete mucus. Mucus act as lubricants while swimming and also protect body from microbial infection.
- vi. Most bony fishes have swim bladder or gas filled bladder which is a small outgrowth from gut, serve as floating or buoyant organ. This bladder is inflated while ascending towards the surface and deflated while descending towards the bottom in water.
- vii. They have lateral line on either lateral side of the body which consist of large number of sense organs called neuromasts. These sense organs detect water pressure and temperature at different depth.
- viii. Their eye consists of semitransparent, movable nictitating membrane which protects the eyes from dirt and foreign substances in water and provides clear vision.
- ix. Fishes living in marine water and fresh water regulate salt and water in their body. Freshwater fishes have chloride cells and marine fishes have salt secreting cells in gills to excrete excess salt from body.

2. SECONDARY AQUATIC ADAPTATION

Those animals which live in both land and water show secondary aquatic adaptation. They breathe through lungs. Such animals live occasionally on land and most of the time in water for food and shelter. They have developed following adaptational features:

- i. Their body is streamlined or fish like, neck is short or indistinct and head is produced as snout or rostrum which facilitates swimming in water easily.

- ii. Fore limbs are modified as fish fin like structure called paddles or flipper in whales, dugong, sea cow etc. Some animals like duck, frog, tortoises, crocodiles etc. have webbed toes for swimming in water.
- iii. Tail is large, flat and also developed as tail fluke in whale, dolphin, and dugongs for swimming. But in some animals tail is absent or rudimentary.
- iv. Hair, sweat gland and sebaceous glands are absent in whale, dolphin, seals, penguins etc. instead, there is a thick layer of dermal fat called blubber which act as insulator thus retain warmth.
- v. Nostrils are placed on the top of head so that they can breathe by raising only head from water surface. Nostrils are also protected by muscular valve like structure.
- vi. Majority of secondary aquatic animals breathe through lungs. Lung is large, non-lobulated and highly elastic so as to store large volume of oxygen before diving. Amphibians breathe through skin and very few amphibians through external gills.
- vii. Eyes are small, protected by thick sclera and present high on face. Eye ball surface is protected by fatty substance secreted by harderian gland in whales.
- viii. They have small ear opening without pinnae and in some forms like walruses have small pinnae.
- ix. Testes are not embedded in scrotal sac but found inside posterior abdominal cavity. Duct of mammary gland can dilate to reserve milk which is later fed to young ones under water.

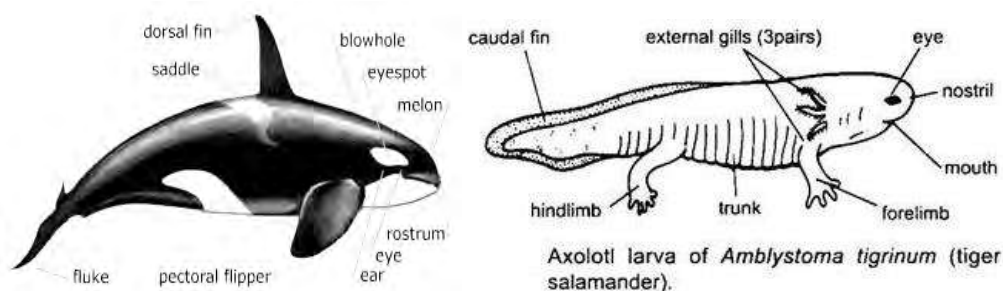


Figure: 9.1.2 Secondary aquatic adaptation



Questions to think?

When a Rahu fish from pond is introduced into ocean water? Does it survive?

9.1.3 TERRESTRIAL ADAPTATION

Animals suited for living on land are called terrestrial animals. They have developed special features in their body to live on land. Terrestrial adaptation can be further classified into three types:

- a. **Cursorial adaptation:** Those animals which are adapted for running on the ground are called cursorial animals and adaptation exhibited by them is called cursorial adaptation. They run on the ground to escape from predator, for getting food and for finding mate.

Example: Cheetah, tiger, lion, horse, cat, ostrich, lizard etc. Adaptational features are listed below:



Figure: 9.1.3 Cursorial Adaptation in some animals

- i. For swift passing in air, Body is modified as spindle shape, head and neck is well extended, ear is thrown backward.
- ii. Their body have powerful or tight musculature.
- iii. They have long limbs with comparatively shorter humerus and femur but longer radio-ulna and tibia-fibula.
- iv. Their limbs are efficient propellers while running where hindlimbs also support heavier body.
- v. These animals have comparatively stronger front part than hinder part.
- vi. They have mainly three types of foot posture or progression on the ground:
 - Digitigrade locomotion: found in tiger, leopard, cat, dog, wolf etc. in which only digits touch on ground at running and digits are with shock absorbing pad on the ventral surface.
 - Unguligrade locomotion: found in cow, goat, horse etc. in which animals move on tips of hoofed toes.
 - Plantigrade locomotion: found in bear, primates etc. where the entire palm or sole of feet touch on ground while running.

- b. **Fossorial adaptation:** Animals which are adapted to live underground by making burrows or holes are called fossorial animals. Such adaptation is known as fossorial adaptation. These animals come out of burrow mostly at the night time in search of food and other activities. Example: moles, burrowing owls, some rodents, badgers etc.



Burrowing owl

Mole

Figure: 9.1.4 Fossorial adaptation

- i. Their body is compact, rigid and spindle shaped.
- ii. Head is anteriorly tapered to form somewhat conical snout that aids in digging.
- iii. Shoulder muscles are powerful and well developed.
- iv. Forelimbs are short, stout, provided with claws and shovel like palms. Example: mole

- v. Tail is either absent and if present, found in reduced form.
- vi. Eye and external ears are poorly developed. Eyes are protected by nictitating membrane. In some forms external ears are totally absent (spiny ant eater).
- vii. Mostly, they undergo hibernation.

c. Arboreal adaptation:

Animals adapted for climbing trees, walls, rocks, ceilings etc. are called arboreal animals. This type of adaptation is also called scansorial adaptation. Such adaptation helps them to procure food and also provide retreat and safety. Some arboreal animals permanently live in trees, swing on tree branches and are frugivorous. Arboreal animals can be broadly categorized as:

- i. **Rock and wall climbers:** They climb on walls of buildings, rocks. Example: wall lizard, gecko etc.
- ii. **Terrestrial-arboreal form:** These animals mostly live in trees and sometime come to the ground. Example: Sloth bear, striped palm squirrel etc.
- iii. **Arboreal form:** They are completely tree dwelling forms. Example: Lemur, Gibbon etc.

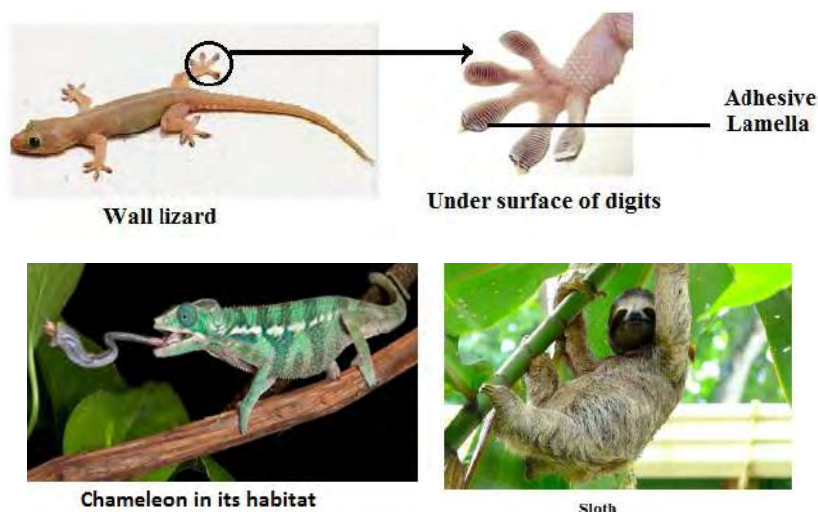


Figure: 9.1.5 Arboreal Adaptation

Following are the arboreal adaptational features:

- i. They have small, slender and stout body which favors running while climbing walls, rocks, trees etc.
- ii. Presence of neck provide mobility for head to see object at the vicinity.
- iii. Their body is covered by dry horny scales which protect the body and also prevents loss of water.
- iv. Tongue is long, protrusible and sticky for capturing prey.
- v. The ribs of arboreal animals are curved which give thorax a sub-circular shape.
- vi. Girdle bones (pectoral girdle and pelvic girdle) are strong enough to support body weight.
- vii. Their digits have sharp long and curved claw. Some animals like gibbon, orangutans have opposable and prehensile toes in hind feet for climbing and grasping tree branches.

- viii. Tail is long and prehensile in majority of the arboreal animals. Flying squirrels have non-prehensile tails provided with spines and scales to prevent from slipped down while climbing.
- ix. Adhesive lamellas are present on the ventral surface of digits in wall lizard which create partial vacuum to cling on the wall and ceilings. Wall lizard and some geckos can easily detach their tail to escape from predator and later re-grow their tail.
- x. Adhesive pads are found either at the tip or under surface of tree frog and some geckos.

d. Volant/ aerial adaptation:

The adaptation which is shown by the animals to fly or glide in air is called flying or volant adaptation. Some animals fly in air for long time whereas some fly for short duration. None of the aerial animals fly indefinitely, and they have to return to the earth for resting and nesting. Volant adaptation is of two types:

1. Active flight: In active flight, animals fly in air for a long time. This is also called true and sustained flight. Example: Majority of birds, bat and insects. Adaptational features in true fliers are:

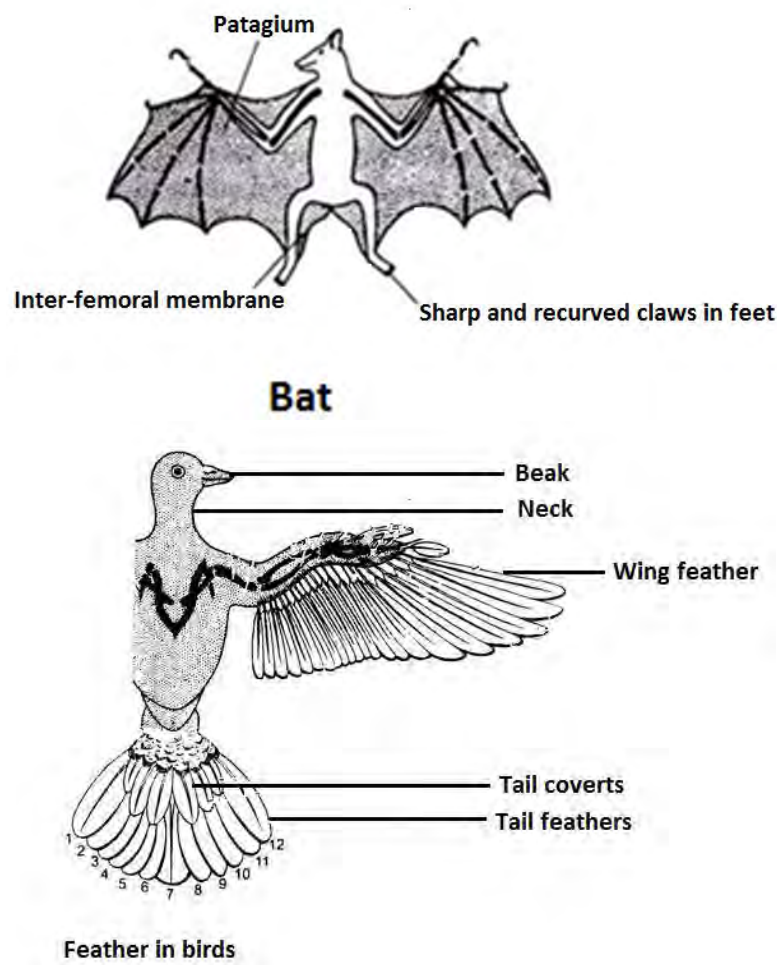


Figure: 9.1.6 Aerial adaptation: active flight

- i. They have boat shaped or streamlined body without any projections from body that resist flying.
- ii. In bat, sustaining organs are called patagia which are paper-thin, elastic extensions of leathery skin from the lateral sides of body, legs and tail.
- iii. In birds, sustaining organs are wings which are modified fore limbs with powerful flight muscles and feathers.
- iv. Body is covered by various types of feather like quills, contour feather, down feather which keep them light, smooth and well protected from adverse environmental condition.
- v. They have light and spongy bones, also called pneumatic bones.
- vi. Lungs are connected with air sacs for providing sufficient oxygen to tissues for the continuous liberation of energy during flight.
- vii. They have keeled sternum which facilitate passing in air and also serve as the site for the attachment of flight muscle (pectoral muscle) of wing.
- viii. Birds have developed special mechanism by their leg muscles and tendons to grip or perch on the tree branches, electrical wires, rod etc while resting. This is called perching.
- ix. Other adaptational features in them are body weight reduced, internal structure are centralized, absence of left ovary, absence of urinary bladder, fused vertebrae etc. also aid in flying.

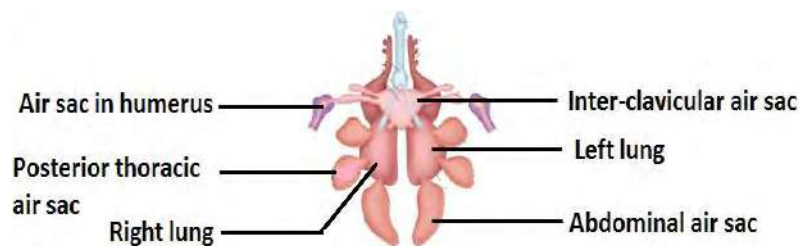


Figure: 9.1.7 Air sac with lungs in birds

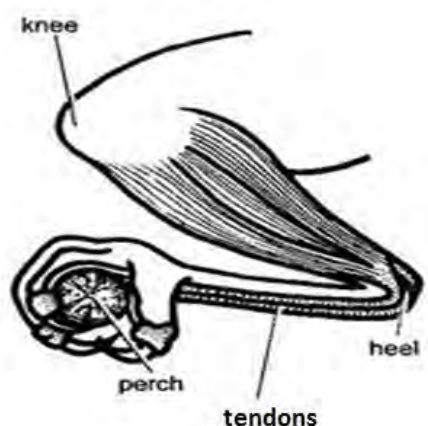


Figure: 9.1.8 Perching in bird

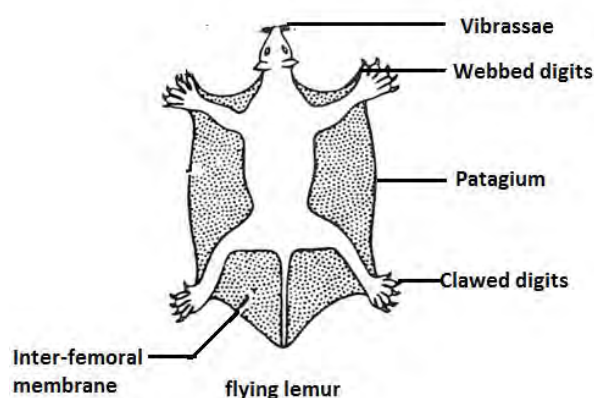
2. Passive flight

In passive flight, animals fly in air for short duration and cover only few meter horizontal distances. Animals leap or jump from certain height i.e. from top of tree,

hills, buildings etc. and later come down to the earth by gravity in the short time. At this moment, they cover some horizontal distance with the help of sustaining organ or patagia. This adaptation is also called Gliding adaptation. Animals which glide in air are flying fish (*Exocoetus*), Flying frog (*Rhacophorus*), *Draco* (flying lizard), flying snake (*chrysopelea*), flying lemur (*Cynocephalus*) etc.

Adaptational features include:

- i. They have developed patagia, a fold of skin stretched on the either lateral side of between trunk and limbs.
- ii. In flying fish, pectoral fins are extended as patagia and their caudal fin is hypobatic (ventral lobe larger for quick take off from water surface).
- iii. Patagia are supported by about 7 pair of elongated ribs (in *Draco*).



Flying snake

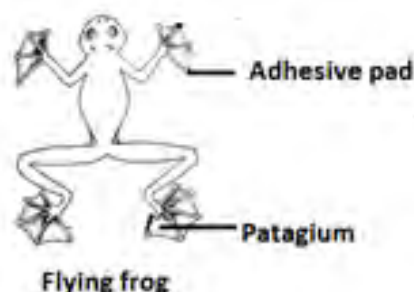
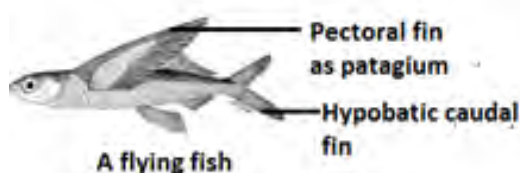


Figure: 9.1.9 Aerial adaptation: passive flight

- iv. In flying snake, ribs are spread, ventral body surface is made flat and concave while gliding.
- v. Some frogs glide in air with the help of their webbed toes. The toes are also provided with adhesive pad for safe landing after the glide is over.

Activity 9.1

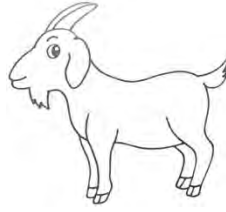
Visit your biology laboratory, observe and identify the adaptational features of different vertebrates present there. Fill in the table below and discuss.

S.N.	Animals	Adaptational features

EXERCISE

A. Tick the correct alternative.

1. Which type of adaptation is shown by fishes?
 - a. primary aquatic
 - b. secondary aquatic
 - c. burrowing
 - d. scansorial
2. Swim bladder is the specialized organ that helps certain aquatic animals to maintain buoyancy in water which is crucial to remain floating in water effortlessly. In which of the following animals' swim bladder is primarily found?
 - a. aquatic mammals such as whale and dolphin
 - b. bony fishes that live in freshwater
 - c. cartilaginous fishes which live in marine water
 - d. aquatic Reptiles like sea turtle, crocodiles, water snake
3. Sensory organs present in the lateral line system in fishes are.....
 - a. neurons
 - b. neuromasts
 - c. chromatophores
 - d. neuroglia
4. Which of the following statement is true for whale?
 - a. whale repires by gills
 - b. whale respies by moist skin
 - c. whale is amphibious
 - d. whale respies by Lungs
5. Cursorial adaptation is the evolutionary modification found in animals, adapted for running efficiently on the ground. Such adaptation helps in high speed locomotion over terrestrial habitat. Which of the following group of animal known for exhibiting cursorial adaptation?
 - a. cheetah, frog pigeon, horse
 - b. lion, whale, fish, bat
 - c. cheetah, tiger, lion horse
 - d. monkey, lion, frog pigeon
6. Which of the following type of locomotion is found in animals of cat family?
 - a. unguligrade
 - b. digitigrade
 - c. plantigrade
 - d. crawling
7. Identify the mode of locomotion is found in the given animal.

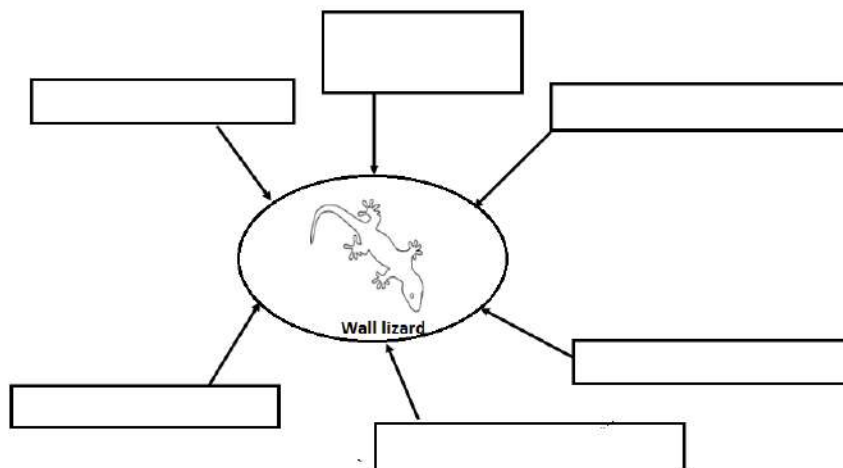


- a. digitigrade
 - b. unguligrade
 - c. plantigrade
 - d. swimming
8. An animal was seen on the land, with compact, spindle shaped body and conical snout. Its forelimbs are short strong with sharp claws with shovel like palms. Based on these characteristics, what would be the adaptation of this animal?
- a. arboreal- living in tree
 - b. aquatic – swimming in water
 - c. volant- flying in air
 - d. fossorial – burrowing
9. Which of the following is not true for Fossorial adaptation?
- a. they live underground
 - b. they have shovel like palm with clawed digits
 - c. they have small, stout body with pointed snout
 - d. they live mostly in trees
10. Those animals which are adapted for climbing called.....
- a. cursorial animal
 - b. scansorial animal
 - c. aquatic animal
 - d. burrowing animal
11. Saumyata saw a lizard climbing the wall of her house. Then she tried to catch it but its tail was suddenly broken off but the lizard continued to climb up. After sharing about this event to her teacher. She learned about the ability of lizard to regenerate its tail. What is this phenomenon called?
- a. metamorphosis
 - b. autotomy
 - c. vasectomy
 - d. moulting
12. Which type of adaptation is shown by Gibbon.....
- a. arboreal
 - b. cursorial
 - c. fossorial
 - d. aquatic
13. Bat possesses unique anatomical features which enable them to sustain flight and navigate through air. Considering the adaptation which of the following organ is primarily responsible for sustaining flight?
- a. pneumatic bones with fur on their body
 - b. modified forelimbs with elongated finger connected by wing membrane

- c. webbed feet that provides propulsion through air
 - d. wings with feather
14. The mechanism of gripping objects like tree branch, wire, rope etc. by their hind limbs without any risk of falling down is.....
- a. flight
 - b. perching
 - c. gliding
 - d. resting
15. In flying fish, which of the following fins are modified as patagia?
- a. anal fin
 - b. pelvic fin
 - c. caudal
 - d. pectoral fin

B. Answer the following questions:

1. What do you mean by secondary aquatic adaptation? Enlist the various adaptational features of secondary aquatic animals with examples.
2. Rahu is the freshwater animal. What type of adaptation and morphological features are found in its body?
3. What are arboreal animals? How are they suited to survive in their habitat?
4. Enlist the adaptational features of animals showing cursorial adaptation.
5. Compare and contrast primary aquatic animals and secondary aquatic animals.
6. Compare and contrast volant animals with cursorial animals.
7. Which type of adaptation is found in bat and birds? How are they are modified for flying in air?
8. What do you mean by gliding adaptation? Write any four examples of animal showing gliding adaptation and also mention their adaptational features.
9. Enlist various adaptational features that help wall lizard to survive in its habitat



Project work:

Prepare a list of animals found in your locality. Find out their adaptational feature and make a poster on different types of adaptations with reference to these animals.

Chapter 9.2

ANIMAL BEHAVIOUR

Let's discuss the following questions:

- i. What are the stimuli?
- ii. Do all plants and animals respond to stimuli? The response of animals to stimuli is more remarkable? Why?
- iii. Do you know that a baby crocodile starts to swim after being hatched? Why?
- iv. Have you heard the loud sound of frogs with inflated sacs in their throat on rainy days? What might be the reason behind it?

9.2.1 GENERAL INTRODUCTION

The activity of all the living beings i.e. from microscopic to higher organism is influenced by environmental factors. Any external environmental factors, such as heat, cold, touch, pain, chemical, light, sound etc. are called stimuli. In unicellular organisms, individual cell itself responds to stimuli. For instance: Euglena moves towards glucose solution. Higher animals have well developed nervous system and hence degree of sensitivity is remarkable in them. However, some plant like Touch Me Not (*Mimosa pudica*) also responds to touch by immediate overlapping of leaves. Similarly, directional growth of plant parts in response to stimuli like sunlight, chemical, earth etc. is called tropism. When mosquito repellent is burnt inside the room, mosquitos fly away. In all of the above cases, reactions shown by the organisms against stimuli are called responses.

Animals behaviour is the outwardly expressed course of action produced in organism in response to stimulus from a given situation. Behaviour helps animal for adaptation in the particular environment. Ethology is the study of animal behaviour. Ethology may also be defined as the study of behaviour of animals in their normal environment including both external and internal processes by which they respond to change in environment. Khorad Lorenz is the father of ethology.

Animal behaviour may be broadly classified as:

1. **Innate or inborn or stereotyped behaviour:**

Behaviours which are genetically controlled and inherent, without patent learning during life time are called innate behaviour. This kind of behaviour is essentially the outcome of inherited properties of nervous system of the organism. Example: Fish, tortoise etc. starts swimming just after emerging from the egg. Young spider spins web without learning from parents, larva of silkworm forms cocoon etc.

Reflexes, taxis, migration, courtship, leadership, dominance, kinesis etc. are the various types of innate behaviour.

2. Acquired or learnt behaviour:

All those behaviours which an animal learns during its life time through experience and practice are known as learnt behaviour. This type of behaviour is not inherited from parents to progeny. Examples: singing, dancing, painting, learning languages etc.

9.2.2 REFLEX ACTION



Questions to think?

What is the reason for watering your mouth when you see or get smell of delicious food?

In higher animals, many responses are involuntary and instantaneous. These responses occur without prior thinking. Example: watering of mouth occur at the sight or smell of delicious food, immediate withdrawal of hand or leg when stepped on sharp objects, blinking of eye when some object is about to fall on eyes, taking immediate support by an individual while S/he is about to fall down from chair, coughing triggered by allergens etc. these all action are reflex action. Thus reflex action is the involuntary or instant and automated response of an animal towards stimuli. Reflex action is of following types:

- Spinal reflexes:** Reflex actions which involve spinal cord and nerves. Example: knee jerking, withdrawing hand from fire etc.
- Cerebral reflexes:** Reflex actions which involve brain and nerves. Example: Eye blinking, sneezing, watering of mouth etc.
- Both cerebral and spinal reflexes:** Reflex actions which involve both brain and spinal cord along with nerves. Example: Hunger, coughing, hiccupping etc.

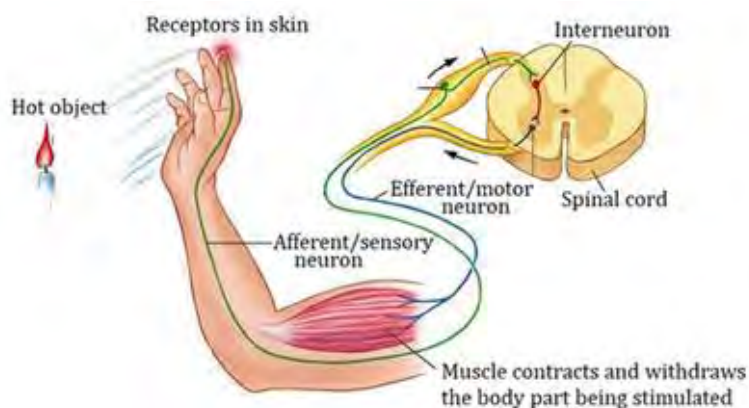


Figure: 9.2.1 Quick and automated response to hot object

In reflex action, nerve impulse or information travels in a specific path or route from receptor to effector which is called **reflex arc**.

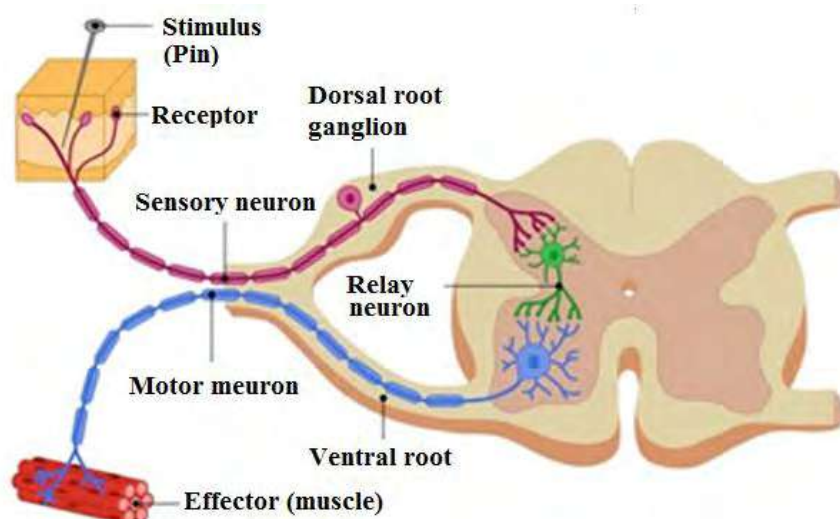


Figure: 9.2.2 Reflex arc

Reflex arc is formed by following components:

- Receptor organs:** They are sensory organs like skin eye ear tongue etc. which receive stimuli. These organs have nerve endings which generate sensory impulses after the perception of specific stimulus.
- Sensory or afferent nerves:** Those nerves which transmit impulses or informations from sensory organ to brain and spinal cord are called sensory nerves. Cell body of afferent nerve lies inside the dorsal root of spinal cord.
- Motor or efferent nerves:** Those nerves which conduct motor impulses from brain and spinal cord to effector organs are called motor nerves. Cell body of efferent nerve lies inside the ventral root of spinal cord.
- Modulator:** It is the central nervous system (brain and spinal cord) which modifies sensory impulses to motor impulses. Inside the spinal cord, grey mater contains interneuron which forms synapse (nerves junction) with both sensory nerve and motor nerves. Interneurons act as the bridge for incoming and outgoing impulses. In some reflexes (monosynaptic reflex), there may not be interneuron where impulses are directly passed from sensory neuron to motor neuron through synapse.
- Effector organs:** Those organs which respond to stimuli or external environmental factors are called effector organ. Effector organs are muscles and glands.

Mechanism of reflex action:

The receptor organs are innervated by sensory nerve endings. Such nerve endings induce sensory impulses or information after detecting stimulus, which pass through sensory neuron and reach spinal cord or brain where information is processed and transformed into motor impulses and then such impulses transmit through motor nerve to reach effector organs. Four sequential steps of reflex action consist of reception, conduction, modulation (interpretation) and effect.

Example: In the case of touching cold object or ice, receptors in finger detect stimulus (ice) resulting the production of impulses. Such impulses are transmitted to spinal cord through sensory nerves. In spinal cord, sensory impulses are modified as motor impulses which are

transmitted through motor neuron to the arm muscles. Now, these muscles contract quickly and hand is pulled away.

Significance of reflex action

- i. Reflex action prevents overloading of brain because spinal cord is also involved in this process.
- ii. Reflex action protects animals from harmful stimuli.



Questions to think?

An earthworm when kept in a brighter place starts crawling towards dark. Why?

9.2.3 TAXES

In general, animals adjust their body posture in normal or balanced position in space. If animals are exposed to some environmental factors or stimuli, they orient their body either towards stimuli or move away from these stimuli. Such a directional movement of organisms in response to external stimulus is called is called a **taxis**. When the organism or cell moves towards the source of stimulation, it is called **positive taxis**. If the organism or cell moves away from the source of stimulation it is called **negative taxis**. Taxis can also be defined as the behavioural response of an organism to external stimuli.

Examples: Bacteria are attracted towards nutrient such as sugar amino acid (attraction or positive response) but repelled by harmful substances and bacterial wastes (repulsion or negative response).

Euglena avoids salt solution (repulsion or negative response) but attracted towards glucose solution (attraction or positive response)

Cock roaches discard lighted area (repulsion or negative response).

TYPES OF TAXES

On the basis of type or nature of stimulus perceived by animals

1. **Phototaxis:** Phototaxis is defined as the movement of animals either towards light or escape away from light. Example: Earthworm, mosquito, cockroach etc. move away from bright light showing negative phototaxis but *Euglena*, moth, housefly etc. move towards lighted area showing positive phototaxis. *Euglena* avoids bright light.



Euglena attracted towards light



moths attracted towards light

Figure: 9.2.3 Phototaxis

2. **Chemotaxis:** Chemotaxis is defined as the movement of organism either towards a chemical stimulus or away from it. Example: *Euglena* moves away from strong acid (negative chemotaxis) but moves towards weak acid solution (positive chemotaxis).



Figure: 9.2.4 Mosquito flying away from mosquito repellent

3. **Thermotaxis:** Directional movement of organism in response to temperature is called thermotaxis. *Paramecium* prefers to live in water of temperature ranging from 24°C - 28°C but avoids below 24°C or above 28°C. *Hydra* prefers to live in cold water but escapes away if water temperature exceeds 25°C.
4. **Thigmotaxis:** It is the response of an organism to physical contact or touch stimulus. *Paramecium* and *Amoeba* move away (negative thigmotaxis) from an object after touching it. Earwigs seek contact with a solid object showing positive thigmotaxis.



Figure: 9.2.5 Earwig showing positive thigmotaxis

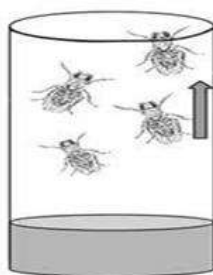


Figure: 9.2.6 Fruit flies showing negative geotaxis

5. **Geotaxis:** It is the response of organism to Earth's gravity. Earthworm always tends to move downward away from earth surface indicating positive geotaxis. *Paramecium* responds by swimming up in water against gravity which is negative geotaxis. Fruit fly also move up if kept in a vertical glass tube. Arboreal animals show negative geotaxis whereas animals living underground show positive geotaxis.
6. **Rheotaxis:** Movement of animals in response to water and air current is called rheotaxis. Some fishes like eel avoid oncoming water currents and turn away where as some fish like zebra fish move towards the current of water. Birds and insects show positive rheotaxis although they can move in any direction.

7. **Galvanotaxis or electrotaxis:** It is the response of organisms to electric current. If Paramecium is kept in weak electric field, it moves towards cathode.

On the basis of orientation of animals

1. **Klinotaxis:** It is the turning movement of animal by successive comparison of stimulus intensities. Some animals lack distinct sense organs but they possess receptor cells at the antero-dorsal side of the body. Such organisms respond by comparing stimulus intensities of both sides by bending their head first in one direction and in another direction. This process continues until both sides are equally stimulated.
Example: Maggots of housefly, *Euglena* etc. move in this way or show wavy movement with light stimulus of different intensities thrown from two sides.
2. **Tropotaxis:** It is the straight orientation of organism in which organism moves either towards or away from stimulus. No lateral or wavy movement of organism as in klinotaxis is found. It is found in bilaterally symmetrical animals having paired sense organ where these organs compare stimulus intensities of both side simultaneously and show straight movement.
Example: Tick and lice show positive phototropotaxis.
3. **Telotaxis:** If two sources of stimuli of equal intensity operated at the same time, animal orients to any one stimulus but not both or intermediate.
Example: In morning time, honey bee moves with light but rest on flower when it finds. But while returning hive, uses source of light. In above case, flower and sunlight are two stimuli operating at the same time.
4. **Menotaxis:** It is the orientation or movement of organism towards a stimulus at certain angle. It is also called 'light compass response'.
Example: Insects like honey bee, ants, beetle (*Geotrapes sylvaticus*) etc make constant angle to the sunlight while returning home. If direction of sunlight is changed apparently using mirror, they also change their path.
5. **Mnemotaxis:** Movement of organism in response to complex stimuli situations is called Mnemotaxis.
Example: Hunting wasp uses a number of stimuli such as landmarks, light direction, trails of chemical left by them etc. while returning their nest. Similarly, many long distant migratory birds while returning their original home ground use a number of stimuli like land mark, coastal line, river, mountain range, celestial bodies etc.

9.2.4 DOMINANCE

It is a type of social behaviour in which an individual dominates other members of the society or group by aggression or threat or by any other means. In the social animals, it is necessary to keep all the members of the society under control. The dominating animal has higher chances of getting food, mate, shelter and other resources. Dominance is determined by various factors like age, sex, experience, morphology and physiological status of an animal. In most cases, older one dominates young one, stronger is dominating over weak one, bigger to smaller one, male to female. There are several ways by which dominant animal sub-ordinates or suppresses other member and some examples are given below:

1. Newly matured song bird dominates older bird by singing beautifully while attracting female for mating.
2. Dog defends its territory by snoring and posing teeth when it encounters other dogs. The dominated dog runs away by lowering tail.
3. Dominant animal occupies middle position in the herd of cattle while finding resources.
4. Many male dogs gather around and move in with dominant female dog during breeding season. This phenomenon is also found in Lemur.
5. When two unfamiliar buffalos encounter suddenly in grassland, each of them start showing their aggressiveness by pawing ground, head-butting, shoving or even charging. Also found among goats, oxen etc.



A wild fox defending its territory



A pride of lions with Dominance hierarchy

Figure: 9.2.7 Examples of dominance

- i. Dominating animal get higher chances of various resources like mate, food, shelter etc.
- ii. Dominance is usually linked with survival and reproductive potential.
- iii. Dominant animal has more opportunities to choose mate leading to higher quality offspring and increment in reproductive success.
- iv. Dominance keeps the individual fit and healthy.

9.2.5 LEADERSHIP

It is also an innate behaviour of animal in which an individual lead and guide other members in a group. A leader occupies the highest rank or hierarchy level irrespective of age and sex. Leadership is an ability of individual animal to lead and provide proper guidance. This type of social behaviour is needed at the time of moving in group, finding resources, migration, defending territories, fighting with enemies and many more. A real leader mostly initiates, stabilizes and integrates the activities o a group members. Leadership can be seen in some animals like ant, deer, sheep, kangaroo etc. A leader gets better priority of food, place, mate etc.



Figure: 9.2.8 Leadership in some animals

Example:

1. In red deer, old female (hind) is the leader who looks after the welfare of other females and young ones. Male deer (Stag) only visits the herd at the time of breeding season for mating. Later the stag moves away.
2. Sometimes, a flock of geese can be seen flying over the sky, in which a bird at the front is leading the flock.
3. In honey bee colony, all the activities of beehive are regulated and co-ordinated by a queen bee with the help of pheromones.
4. In the rhesus monkey, leadership and dominance are found together in which wide range of territory is maintained by a strong and aggressive dominant male as a leader in the troop. A troop consists of less dominant adult males, adult females and infants.

9.2.6 MIGRATORY BEHAVIOUR IN ANIMALS**Let's discuss some questions before starting this topic:**

- i. What do you mean by migration?
- ii. Do all animals migrate?
- iii. What might be the causes of migration in animals?
- iv. Have you ever seen bird migration in the sky?

The term migration is derived from a Latin word 'Migrare' which literally means 'to travel or going from one place to another'. Migration is the regular and periodic passing of animals from one place to another place for various purposes. It is a complex type of inborn behaviour which is shown by insects, birds fishes, some mammals, turtle etc. Animals migrate for various purposes viz. in search of food, to protect from adverse environmental condition, to find mate, shelter and for reproduction.

1. MIGRATION IN FISHES

Migration in fishes can be defined as the to and fro movement from feeding and resting place to nesting and breeding place and vice versa. Not all fishes are migratory in nature and some fishes which don't migrate at all are called resident fishes. Some fishes migrate daily and some fishes migrate at the specific time in the year. The distance of migration ranges from few meters to thousands of kilometer.

Fishes move by different ways during migration. For instance: some fish passively move with water current which is called drifting movement and some migrating fishes swim in all directions called random swimming movement. Another type of movement in fishes in which they swim in the particular direction in response to the certain stimulus is called oriented swimming movement.

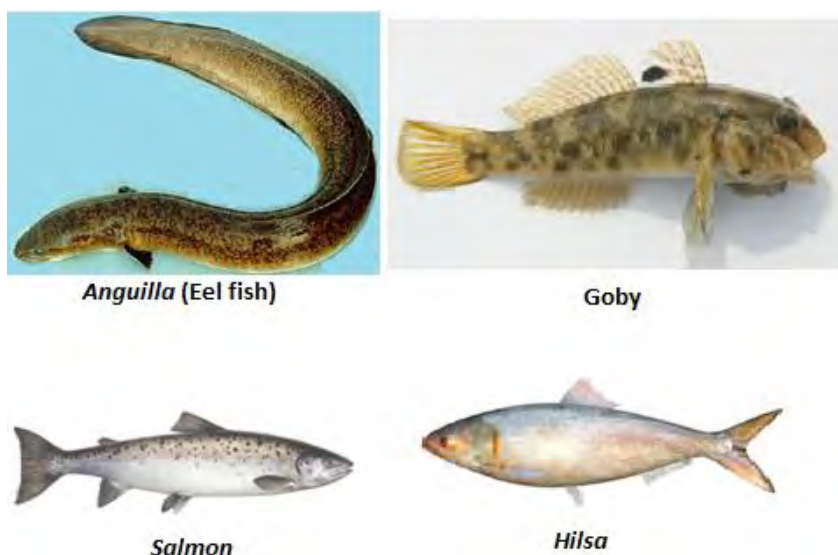


Figure: 9.2.9 some migratory fishes

Factors influencing fish migration

- i. **Physical factors:** Physical factors are light intensity, temperature, water current, turbidity and depth of water etc. These factors influence fish migration. Any change or alterations in any of these physical factors compel fish to migrate for searching their favourable environment. For example those fishes which tend to remain in clear or less turbid water migrate for searching such places as the water of stream, river etc. become more turbid in rainy season.
- ii. **Chemical factors:** These factors consist of salinity of water, smell, pH, taste of water, dissolved oxygen and overall water chemistry that influence in fish migration.
- iii. **Biological factors:** They are gonadal activity of fish, hormones (FSH) secreted by endocrine glands, availability of food, predators etc.

Types of fish migration

Various types of fish migration can be discussed as follow:

1. **Diadromous migration:** Truly migratory fishes like *Salmon*, *Hilsa*, *Anguilla*, *Gobbies* etc. perform this type of migration. In this, Migration occurs from sea water to fresh water and vice versa. It is further divided into following types:
 - i. **Anadromous migration:** Some marine fishes migrate toward freshwater mainly for breeding or reproduction which is called anadromous migration. Example: *Salmon*, Sea lamprey, *Hilsa*, *Shad* etc. Various changes that occur in the body of fish during migration are accumulation of reserve food, maturation of gonad, degeneration of alimentary canal etc. After the breeding process is over, young ones and adult return to their original home ground or feeding places.
 - ii. **Catadromous migration:** Some freshwater fishes which migrate to sea water or marine water for reproduction which is called catadromous migration. Example: Eel (*Anguilla bengalensis*) which is found in river system of Nepal migrate to Bay of Bengal. Various changes that occur in the body of fish during migration are

suspended feeding, maturation of gonad, degeneration of alimentary canal, body colour become silver white from yellow etc.

- iii. **Amphidromous migration:** The type migration which occurs from ocean water to fresh water and freshwater to ocean water for feeding purpose instead of reproduction. Example: gobies fishes.
2. **Potadromous migration:** When fish migration is confined only within freshwater, it is called potadromous migration. Example: carp fishes, trout etc.
3. **Oceanodromous migration:** The migration of fishes which is confined only to marine water or sea water is called oceanodromous migration.
4. **Alimental migration:** Migration of fishes for feeding purpose is called alimental migration. Example: sharks, carps etc.
5. **Shoreward migration:** migration of fishes towards sea shore or bank of river is called shoreward migration. Example: *Anabas*
6. **Vertical migration:** Migration of fishes from bottom or depth of water to the surface and in the reverse direction is called vertical migration. Example: sword fish, meckereel etc.
7. **Latitudinal migration:** Migration of fish from north to south and vice versa. Example: sword fish, hammer headed shark etc.
8. **Climatic migration:** fishes migrate in response to change in season or climate for seeking safe place is called climatic migration.

Advantages of fish migration

1. Migration ensures abundant supply of food, suitable breeding ground and shelter.
2. It also provides suitable condition for the survival of juveniles in the migrated place from enemies.
3. Migration also protects fishes from adverse environmental situations.
4. Some ichthyologists believe that migration is an adaptation towards abundance.

2. MIGRATION IN BIRDS

Migration of various types of birds is a fascinating and spectacular event associated with bird life. Many birds can be seen flying in the sky from one place to another. According to Cahn (1935), “Migration is the periodic passing of animals from one place to another”. Migration in birds can also be defined as the regular and periodic passing of birds from their breeding and nesting ground to feeding and resting ground. Such movement occurs during the particular period of the year and the birds usually follow the same route. Some migratory birds are Siberian crane, golden plover of USA, black and white cuckoos, robins, hawk, crane, geese etc. Those birds which do not migrate and remain in their home ground all the time are called resident birds. Example: Bob white, ruffled sand grouse etc.



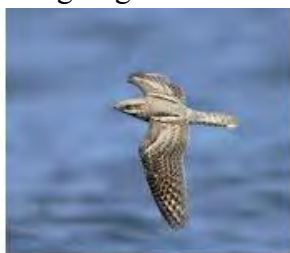
Figure: 9.2.10 Migratory behavior in bird

Stimulus or cause of migration

- i. Though exact cause of bird migration is unknown, some factor which stimulate bird migration are listed in points below:
- ii. Intensity of light stimulates the gonad affecting nervous system bringing migration.
- iii. Scarcity of food, shortening day length, increase in coldness or hotness etc. in certain area causes migration.
- iv. Many birds show restlessness after the deposition of fat in their body followed by migration.

Types of migration in birds

1. **Latitudinal:** It is the type of migration of bird which occurs from northern hemisphere to southern hemisphere and vice versa. Golden plover of USA migrate to south i.e. Argentina; Siberian birds migrate to plains of Himalayas in India and Nepal.
2. **Longitudinal:** Migration of birds from east to west and vice versa is called longitudinal migration. E.g. Starling bird move from East Europe or Asia to the Atlantic coast.
3. **Altitudinal migration:** Migration of birds which takes place from higher altitude to lower altitude and vice versa. Example: wood cock, bush chat, Violet green swallows of U.K, Lophophorus in Nepal.
4. **Vagrant migration:** Some birds from their home migrate in all direction to a long distance for food and protection from enemies called vagrant or irregular migration. Herons after breeding migrate in this way.



Nightjar bird



Golden plover of USA



Heron



Fly catcher bird

Figure: 9.2.11 some migratory birds

5. **Seasonal migration:** Migration of bird related to seasonal changes. E.g. Nightingales, swifts, cuckoos etc. are summer visitors but snow bunting, and redwings are winter visitors.
6. **Daily migration:** Daily movement of bird from their nest in response to light, temperature, food. For E.g. sparrow, crow etc.

Mode of flight during migration

Birds migrating at night are called nocturnal migrants and those at day time are called diurnal migrants. Common nocturnal migrants are thrushes, night hawk, owl, nightjar etc. and diurnal migrants are crow, swallow, robins, pelican, etc.

At the time migration some birds travel in separate companies and some birds in mixed companies. Distance travelled by birds depends on the local climatic condition and species of bird. Himalayan snow partridges descend hardly about one or two mile distance whereas European white stork covers 8000 miles. Smaller bird fly close to earth within about 3000 feet from earth surface and some species of birds even cross Andes and the Himalayas at the altitude of 20000 feet or more. Birds usually travel 5-6 hours a day resting in between for food and water.

Migratory birds usually follow definite lines of flight. Nocturnal migrants proceed with general airflow on a broad front. Birds take reference of configuration of land, coastline, course of Great River, intervening mountains chain, position of celestial bodies, constellation during migration.

Advantages

- i. It helps to protect bird from harsh climatic condition.
- ii. This phenomenon helps bird to find breeding ground.
- iii. It prevents overcrowding of birds in the particular area and helps to exploit food and other resources from new or untouched places.
- iv. It ensures better chance of survival of young ones from predator in the migrated place.

Disadvantages

- i. At the long journey of migration, some birds may be excessively tired and may fall down on sea, river, forest, rocks and die.
- ii. There is a high risk of natural enemies during migration.
- iii. Various natural calamities like heavy rain, snow fall, storms, hurricane etc may be the cause of death for many migratory birds.
- iv. Several parasitic infections may occur at the time of migration.

EXERCISE

A. Tick the correct alternative.

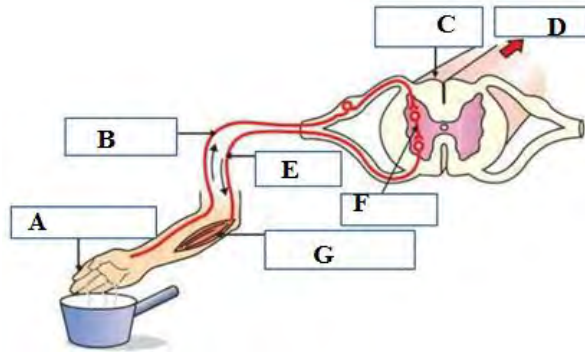
1. A young one of fish starts swimming after emerging from egg. What type of behaviour is this?
 - a. learnt behaviour
 - b. innate behaviour
 - c. Acquired behaviour
 - d. Migratory behaviour
2. The organs which perceive stimulus are called.....
 - a. receptors
 - b. effectors
 - c. Glands
 - d. muscles
3. Which of the following events is not the example of reflex action?
 - a. blinking eye
 - b. Reading
 - c. Coughing
 - d. hiccuping
4. Toad is active at night time, this is the example of
 - a. positive phototaxis
 - b. positive chemotaxis
 - c. negative phototaxis
 - d. positive geotaxis
5. Male cockroach is attracted by the pheromones emitted by female cockroach at the time of mating. This is the example of.....
 - a. phototaxis
 - b. rheotaxis
 - c. Chemotaxis
 - d. Geotaxis
6. Migration of fishes which is only take place in fresh water is called.....
 - a. catadromous
 - b. amphidromous
 - c. oceanodromous
 - d. potadromous
7. During rainy season, there are floods and strong water currents in river and streams. Fishes seek and move to smaller side channel with less current, water bottom or hide under rock. Which type of taxis is this?
 - a. geotaxis
 - b. klinotaxis
 - c. tropotaxis
 - d. rheotaxis
8. Moles live underground. Which type of taxis is this?
 - a. Chemotaxis

- b. phototaxis
 - c. geotaxis
 - d. galvanotaxis
9. Considering the movement of sperm toward the egg during fertilization, evaluate the following statement and select which one is true?
- a. Sperm movement is completely a mechanical process and dependent on motility mechanism of sperm without the influence of female reproductive path
 - b. Sperms are actively transported by the muscular movement of female genital tract
 - c. Sperm movement is influenced by chemicals released by egg and guiding sperm toward it, called chemotaxis.
 - d. Sperm movement toward the egg is due to the result of positive geotaxis
10. Which type of taxis is also called light compass response.....
- a. telotaxis
 - b. mnemotaxis
 - c. menotaxis
 - d. tropotaxis
11. Migration fish which takes place from seawater to fresh water is called.....
- a. anadromous
 - b. catadromous
 - c. potadromous
 - d. oceanodromous
12. Some fishes such as *Anguilla* move from river system of Nepal to sea. Which type of migration is this?
- a. anadromous
 - b. potadromous
 - c. catadromous
 - d. oceanodromous
13. Which of the following birds shows latitudinal migration.....
- a. golden plover of USA
 - b. heron
 - c. flycatcher
 - d. pigeon
14. Which of the following is spinal reflex?
- a. sneezing
 - b. salivation
 - c. knee jerk
 - d. blinking
15. A snail moving on a glass slab when tapped retracts its body within hard shell. But when repeatedly touched it ignores or stops hiding in shell and continues on its way. What type of behaviour is this?
- a. learnt behaviour

- b. innate behaviour
- c. stereotyped behaviour
- d. imprinting

B. Answer the following questions:

1. What is animal behaviour? Describe its types briefly.
2. What is shown in the given diagram? Label the parts A, B, C, D, E, F, G.



3. How do animals show dominance? Describe briefly.
4. Describe the various types of taxes on the basis of nature of stimulus with examples.
5. What is migration in birds? Why do they migrate? What are the different types of bird migration?
6. Fish migration is regulated by several factors. Enlist them and describe.
7. Describe various types of fish migration.
8. What is leadership? Briefly describe leadership in animals.
9. What are the advantages and disadvantages of bird migration?

Chapter 9.3

ENVIRONMENTAL POLLUTION

Let's study a case

According to a news published on 6th September 2023 in the newspaper 'my Republica', About 42000 people die because of the effect of air pollution every year in Nepal and according to WHO, Kathmandu is placed 96th rank among the most polluted cities in the world. The same newspaper which published a news article on 16th April stated that Kathmandu had become the first in the list of most polluted cities in the world in terms of air pollution on Saturday evening. Different kind of non-communicable diseases are emerging because of this situation. According to an environmentalist, from the United Nations Development Commission on clean air, Madhesh Pradesh is also experiencing more pollution because of various industries present there. Polluted air consists of several harmful substances or pollutants such as CO, CO₂ harmful gases and carcinogens. Such substances are circulated throughout the body with blood and affect various organs including lungs. Because of the effect of air pollution, Average life expectancy of Nepalese has been decreased by 4.6 years.

For the past few years, such pollution related news has been publishing from time to time in Nepal. This is only a sample news item.

Discuss the questions given below on the basis of given case:

- What might be the causes of aforementioned condition in Kathmandu?
- What are the current health issues faced by animals and plants including human beings due to such situations?
- What role can be played to control this condition on your behalf?

9.3.1 GENERAL INRODUCTION

The word pollution is derived from a latin word pollutionem which means 'defilement'. Simply, pollution is the introduction of harmful substances to the environment. Such activity results degradation of natural or original quality of various environmental components. The causes of pollution are natural and anthropogenic both. Anthropogenic causes include various type of human intrusion on the nature such as industrial activities, using excessive pesticides and chemical fertilizer in agricultural land, fossil fuel combustion, and unsystematic disposal of municipal and industrial wastes, deforestation and increasing urbanization. Similarly, natural causes are volcanic eruptions, forest fire, dust storms, decay of dead organic matter, pollens etc. Environmental pollution is now being a global burning issue and posing a serious threat to flora and fauna including human beings. Pollution causes different types of health disorders in human such as asthma, bronchitis, poor mental health, anaemia, COPD (chronic obstructive pulmonary disease), blood pressure etc.

Human population is increasing day by day and it obviously demand for more food, transportation, water supply, road, housings, hospital, vehicles electricity and more industrial products. Its consequences are depletion and degradation of natural resources.

To conclude, pollution is any undesirable changes in the physical, chemical and biological characteristics of the environment.

Any substances that make the environment dirty and polluted are called **pollutants**.

TYPES OF POLLUTANTS

On this basis of changing or unchanged nature of pollutants, they are of two types:

- a. **Primary pollutant:** Those pollutants which remain in the same form as they are discharged from the sources to the environment. Example: DDT, fly ash etc.
- b. **Secondary pollutant:** Pollutants which are formed by the chemical combination of primary pollutants. They are more toxic than primary pollutants. Example: smog, peroxy-acetyl nitrate (PAN), ozone etc.

On the basis of degrading or non-degrading nature of pollutants, they are of two types:

- a. **Degradable pollutants:** such pollutants which degrade or decompose in nature quite rapidly by the action of microbes and heat. Example: biological or organic wastes.
- b. **Non degradable pollutants:** such pollutants which do not degrade or decompose in nature are called non-degradable wastes. Example: DDT, BHC, plastic, tin can etc.

9.3.2 AIR POLLUTION

Normal composition of atmospheric air is 78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide, 0.4% water vapour and remaining amount other gases. Various chemicals, smoke, particles, gases etc. are released to the atmosphere by both manmade and natural cause resulting in the alteration of natural quality of atmosphere which is air pollution. Air pollution impacts adversely on the status of natural resources, health of plants, animals including human beings. Any substances polluting or altering the originality of air are called air pollutants.



Figure: 9.3.1 Air Pollution

1. SOURCES

Major sources of air pollution are illustrated below:

a. Natural sources

Dust storms, volcanic gases, emission of natural gases, pollens, spores, methane produced by decaying plants and animal, release of methane trapped in arctic region etc in nature itself cause air pollution. Highest fraction of total pollution about 99.95% is due to natural sources. Only 0.05% of total pollution is due to human activities. However man made population is quite harmful as it is localised in certain area only.

b. Factories

Many factories are set up by human beings to meet the increasing demand of increased population. Various factories of food, paper, cement, bricks, shoes, rubber, clothes etc which emit harmful gases viz. CO_2 , SO_2 , NO , H_2S , CO etc. into the environment.

c. Means of transportation

Automobiles, air craft, railways are run by the consumption of fossil fuel and petroleum products. While burning such fuels, harmful gases like CO_2 , SO_2 , NO etc. are produced and released to the environment.

d. Metallurgical processing

Metallurgical industries have been identified as the contributor to the problem of air pollution since many centuries. During the extraction of metals from ores, smelting and refining processes liberate wastes such as mineral dust, fumes containing fluorides and the wastes also consist of many hazardous metals like lead, nickel, mercury, arsenic, cobalt, selenium etc.

e. Domestic burning of fuel and waste

Various domestic fuels like firewood, kerosene, cooking gases etc. are burnt for household purposes and such activity also releases harmful gases such as CO_2 , CO etc. containing smoke. Similarly burning of plastics, left over straw in fields by farmers, burning of filth in dumped site, forest fire etc. also contributes to air pollution.

f. Nuclear power plant

There may be occasional or accidental release of hazardous radiations like alpha rays, gamma rays from nuclear power plants.

2. EFFECTS OF AIR POLLUTION

Various effects of air pollution can be described under following headings:

a. Effects on the environment

i. Greenhouse effect:

Gases such as SO_2 , NO_2 , CO_2 , methane, chlorofluoro carbon water vapour etc. which trap solar radiation on the earth surface and increase in temperature of earth take place. This phenomenon is called greenhouse effect which is detrimental to the organisms.

ii. Acid rain

Gases like SO_2 , NO_x , CO_2 and other chemicals released from various sources to the atmosphere remain precipitated on the top of buildings, rock, trees and other infrastructures as dry form which later mix and react with rain water to form acid rain. Acid rain water badly affects living beings.

iii. Depletion of ozone layer

Some chemicals such as chlorofluoro carbon, methyl chloroform carbon tetrachloride, methyl bromide etc. if present in atmosphere for a long time cause the depletion of ozone layer in stratosphere. Due to which harmful ultraviolet radiations from the sun enter earth surface causing skin and eye problems, cancer, bleaching of living tissues etc.

iv. Reduction in visibility

Atmosphere becomes unclear due to mixing of smoke, dust particles, fog etc. Due to this objects can't be seen in polluted environment.

v. Reduction in solar radiation

Solar radiation is absorbed or blocked by pollutants in air which may increase the temperature of atmosphere.

b. Effects on plants and animals

Due to the reduction in solar radiation, stomata of green plants do not open which negatively affects the several plant physiological activities like photosynthesis, respiration and transpiration. Acid rain has detrimental effect on the growth of plants because of mineral and nutrient deficiencies in soil. Less crop yielding, stunted growth of plants, leaves turn yellowish, lichens on tree are also the results of acid rain and air pollution. Aquatic ecosystems will also be disturbed by acid rain.

Air pollution brings several health related complications in animals like bronchitis, pneumonia and cardiovascular diseases. Pollutants will also interfere with hormonal secretion in animals leading to reduced gonadal activity, infertility and birth of defective progenies.

c. Effects on human

- i. Smoke, fly ash, dust, soot etc. deteriorate the clothes and other articles used by human and also produce allergic reaction causing bronchial asthma, chronic bronchitis.
- ii. Carbon monoxide combines with haemoglobin to form carboxy-haemoglobin and stops the formation of oxy-haemoglobin which lead to serious health disorders like asphyxia, impairs O₂ transport, headache and blurred vision.
- iii. Hydrogen sulphide causes eye and throat irritation and nausea.
- iv. Nickel and cadmium also cause respiratory disorder whereas metal like lead causes anaemia and nervous disorder.
- v. Oxides of nitrogen in air cause eye allergies, respiratory problems, dilation of arteries, lung oedema etc.
- vi. Various disease are increasing due to air pollution such as dementia, stroke, poor mental health, autism, COPD, lung cancer, asthma. Women may suffer from anaemia, infertility, miscarriage, gestational diabetes, premature menopause mental illness.

3. PREVENTIVE MEASURES

- i. Particulate pollutants in air can be separated and extracted by using some equipment like arresters and scrubbers.

- ii. Pollutants released from industries should be changed into least toxic form by some chemical treatments before releasing to the environments.
- iii. No harmful gases and particulate matters are released by electric vehicles or automobiles. So, their uses should be highly prioritized by the government and public.
- iv. Least consumption of fossil fuels and excessive emphasis on the alternative sources of energy such as solar energy electricity biogas should be given.
- v. Industries should be open far from human settlement, public awareness, strict implementation of law or environmental act prevent air pollution.

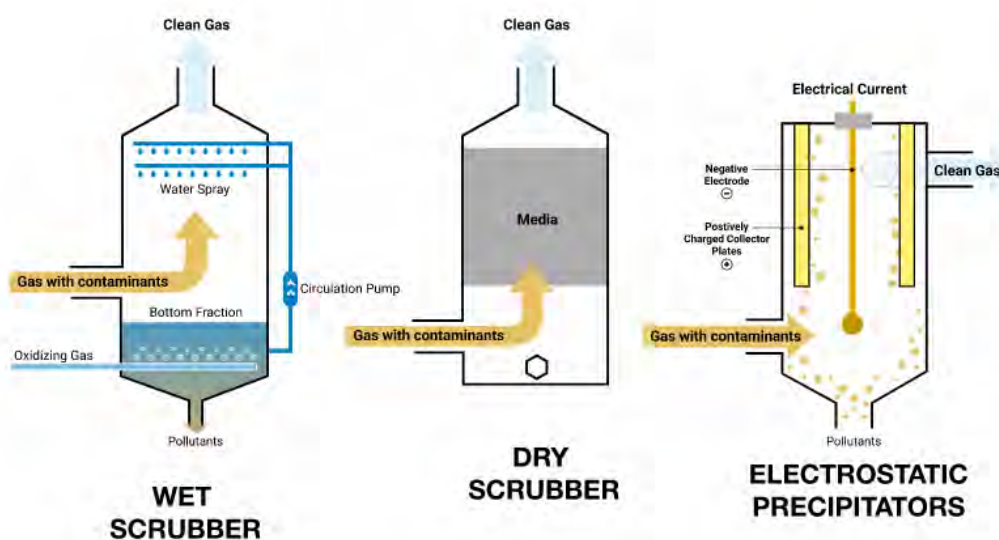


Figure: 9.3.2 Instruments used in purifying air

9.3.3 WATER POLLUTION

Water pollution is change in natural quality of water due to the addition of external substances or contaminants in it. It may also be defined as the degradation of the quality of water due to mixing of inorganic, organic, biological, radiological substance and heat. Such activity makes water unfit and unhealthy for human use and survival of aquatic life. In general, normal water is colourless, odourless, and tasteless but polluted water is turbid and having unpleasant smell and so does its taste.

Any undesirable change in physical, chemical and biotic components of aquatic environment is called water pollution.



Figure: 9.3.3 Water Pollution

1. SOURCES

Sources of water pollution are discussed under following headings:

i. Domestic sewage:

Everything that passes from houses or residential area such as food residue, waste water after washing utensils and clothes by detergents, human excreta, animal wastes, wastes from slaughter house, and wastes from food processing industries are discharged into river, lakes, streams and other water bodies. Contents of domestic sewage are mostly biodegradable. Raw sewage contains inorganic and organic compounds and a number of pathogens causing water borne disease. Inorganic compounds are nitrate, phosphate, sodium, calcium etc.

ii. Industrial effluents

Waste water discharged from all industries is called effluents. Industrial wastes consists of inorganic substances such as lead, mercury, phosphorus, sulphites, sulphides etc. and organic wastes are oils, grease, organic solvents etc. some industries also use microorganisms like viruses and bacteria. These are all discharged to water bodies with water.

iii. Run- off water from agriculture land

Nowadays, there is competition among farmers to use different types of insecticides, pesticides, fungicides and chemical fertilizers in the name of more yields. Such chemicals decompose or degrade in nature very slowly. They are washed by rain water and mixed into river, lakes, ponds etc. altering the water quality.

iv. Accidental oil spill or leakage

Spilling and leakage of oil from tankers, pipelines pollute water sources. Oil is immiscible in water and thus makes a thin layer over water surface preventing aeration of water. Such condition badly affects aquatic life.

v. Nuclear power plant

Nuclear weapon investigation, nuclear power houses, dumping of radioactive waste and nuclear calamities are also the major source of contamination of water bodies. Mining activities of radioactive elements like uranium pollute surface water and ground water.

2. EFFECTS

- Polluted water contains pathogens such as *Escherichia coli*, *Salmonella typhi* causing several waterborne diseases and bring epidemic condition in the community.
- When organic compounds or wastes exceed optimum level in water, decaying of such wastes needs large number of decomposers or microorganisms. These microorganisms need large amount of oxygen for decomposition of these organic wastes, leading to the rise of **BOD** or **biological oxygen demand**. BOD is defined as the amount of oxygen required by micro-organism while oxidizing the entire organic matter present in one litre of water at given temperature. Value of BOD is more in polluted water.
- Waste water discharged from most of the industries may be at higher temperature. Electric power plant, nuclear power station and thermal power plant use water as coolant and these units release hot water to nearby sources like river, sea and lake

raising temperature of these water bodies. It is also called **thermal pollution**. Such activity causes the oxygen depletion in water and threatens aquatic life.

- d. Pesticides and fertilizers after being swept or washed away by rain water mix to nearby water sources and alter the overall chemical composition of water which affects freshwater and marine ecosystem. These substances may incorporate into food chain and get accumulated in organisms of higher trophic level.
- e. Nuclear power plants established in the coastal regions emit radiations and atomic wastes which pollute water and bring several health hazards to marine animals and human beings who consume seafood.
- f. Water bodies become enriched or overloaded by nutrients such as phosphate and nitrates found in domestic sewage, industrial effluents and run off from field. Consequently, growth of more aquatic plants and algal bloom take place in water. This prevents aeration of water and entry of sunlight. Death and decay of these algal blooms need more decomposer and bacteria which demand more oxygen in water and the entire condition is called **Eutrophication**.
- g. Some metals such as Mercury, lead etc. in polluted water bring serious health related issues like cancer, renal disorder, eyes problem, nervous and cardiovascular disorder, skin allergies etc.

3. PREVENTIVE MEASURES

- i. Household degradable organic wastes and sewage can be collected and converted to compost manure.
- ii. Industrial effluents should be treated and made least toxic before discharging into water sources.
- iii. If possible wastes can be recycled or treated before dumped.
- iv. Use of insecticide, pesticide and fertilizer (agrochemicals) should be banned in agriculture field.
- v. Making people aware, afforestation, checking population growth and strict implementation of environment protection act are main ways to prevent water pollution.

9.3.4 SOIL POLLUTION



Figure: 9.3.4 Soil Pollution

Soil is an important abiotic component of environment where all living beings and micro-organisms thrive. Throwing and dumping wastes into the soil from various sources deteriorate the natural quality and originality of soil. Soil pollution is defined as any undesirable changes

in the physical, chemical and biological aspects of soil. Soil pollution alters texture, fertility and water holding capacity of soil.

1. SOURCES

a. Domestic wastes

Wastes produced from houses such as plastics, rubber, unused food materials, dust, waste paper, tin cans, excreta of animals, broken pieces of utensils, glasses, unused agricultural products etc. are dumped into the soil. Such condition diminishes soil fertility. This situation also favours growth of pathogenic micro-organisms and spread to nearby residential areas causing epidemics.

b. Municipal wastes

In urban area, wastes such as plastic, leather, paper, glasses etc. produced from hospital, offices, houses, schools, colleges, and streets etc. which are collected by municipality. Such wastes consist of both degradable and non-degradable waste and they should be separately managed and dumped. If not, organic content in soil and heavy metal content like Cu, Pb, Cr, Ni etc will increase.

c. Wastes from industries

Various types of industries such as paper and pulp industries, food processing industry, soap and detergent factory, pharmaceuticals, mining industries produce various bi-products at the time of manufacture of goods. Bi-product or wastes produced are sulphide, bleaching liquors, pathogens, polyphosphates, drugs, mine wastes, suspended solids, chloride, and heavy metals etc. which are released to external environment causing soil pollution.

d. Biocides and chemical fertilizer

Biocides are the chemicals used to kill insects, pest, mite, fungi and rodents which destroy our cultivated crops and annoy us. They are of various types such as, insecticide, pesticide, rodenticide, fungicides and so on which include DDT, aldrin, lindane, parathion, toxaphane. Farmers also use different types of chemical fertilizers in the field to enhance crop production. Nowadays, maximum and haphazard use of pesticides and chemical fertilizer caused soil pollution.

e. Physical disturbances

Unplanned irrigation schemes, building construction, atomic explosion, and deforestation have resulted soil pollution which lead to soil erosion, expansion of deserts and scanty rainfall.

f. Acid rain

Air pollution causes acid precipitation in the environment which is of two types- dry precipitation and wet precipitation. Many chemicals including acid particles, gases etc. either remain in air or settle down on the soil or any hard surfaces which is called dry precipitation. During rainfall, such acidic gases or particles dissolved in water forming acid and fall back on soil.

g. Radioactive wastes

Nuclear dust and radioactive wastes penetrate the soil and accumulated inside due to Radioactivity.

h. Overgrazing and deforestation

Overgrazing and clearing forest removes vegetations which cover the soil surface. Due to this, soil erosion occurs easily and topsoil layer which is rich in organic matter and nutrient is swept away by wind and water exposing infertile subsoil layer. Similarly, overgrazing and deforestation disturb soil microbial communities, nutrients cycling between soil and plants, and make soil compact decreasing water holding capacity and porosity.

2. EFFECTS OF SOIL POLLUTION

- i. Excessive use of biocides and chemical fertilizers in cropland make soil sterile thereby altering the physicochemical parameters of soil making it unfit for plants and animals. It causes insufficient and contaminated food supply to animals.
- ii. Soil pollution also affects air and water by making them polluted.
- iii. All organisms including human being come in contact with polluted soil containing heavy metals like lead, mercury which bring several genetic disorders, congenital illness and other health related issues such as cancer, eye problems, skin allergies, neurological disorder, urinary problems, gastro-intestinal disorder etc.
- iv. Pollutants like plastic rubber glasses etc. obstruct the nutrient absorption, disturbing plant physiology, growth and finally crop failure.
- v. Polluted soil is unfit for microbial community in the soil and its consequence is loss of all types of biodiversity like vegetation, insects, birds etc. from that area.
- vi. Polluted landscape or soil has no aesthetic and recreational value.

3. CONTROL MEASURES OF SOIL POLLUTION

- i. Instead of dumping all wastes to the particular site, adopt 3R (reduce, reuse and recycle) principle for degradable and non-degradable wastes.
- ii. Animal excreta can be used for the production of biogas for household purpose.
- iii. Using biocides should be banned or minimised.
- iv. Use of biofertilizer and manures should be encouraged instead of applying chemical fertilizer in soil.
- v. Landslide and soil erosion can be prevented by cutting down trees and by promoting afforestation.

Project work:

Divide the students of your class into different group and visit a nearby polluted area with your teacher to prepare reports on air, water and soil pollution.

9.3.5 PESTICIDES

Biocides are the chemicals which are used to kill different types of economically harmful organisms. Biocides include pesticide, insecticide, rodenticide, fungicides, herbicide etc. A Pest is any undesired organism that either destroys or interferes with the production of crops, livestock or forestry and annoys human beings. Pest may be various types of insects, molluscs, rodents, unwanted plants in cultivated crops, annelids, fungi, mites. Pesticides are poisonous chemicals used to kill pests.

They are of various types:

1. **Organochlorines:** They are chlorinated hydrocarbons which include DDT (dichloro diphenyl trichloro ethane), Dieldrin, Lindane, etc. such insecticide are also called hard insecticide as they persist in the environment for long time and hard to degrade. They act by contact, ingestion and by vapour action in some forms.
2. **Organophosphates:** They are organophosphorus compounds which include Parathion, Malathion etc. They are nerve poison, inhibit the enzyme choline esterase, also act by fumigants and contact.
3. **Carbamates:** These chemicals are based on the carbamic acid nucleus. They include Carbaryl, Aldicarb, Methomyl etc. They are also nerve poison, inhibit the enzyme choline esterase in insects.
4. **Plant derivatives:** Certain plants have toxic properties for insects. Some parts of them are used to extract chemicals for killing insects called plant derived insecticides. Which include Pyrethrum (extracted from the flower of *Chrysanthemum*), rotenone (extracted from root of *Derris elliptica*) and nicotine (from leaves of tobacco plant).
5. **Synthetic Pyrethroids:** They are synthetic insecticides that contain pyrethrum and include Permethrin, Cypermethrin, Fenvalerate etc
6. **Oils:** Oils are also sprayed to crops for destroying insects.
7. **Insect growth regulator:** Such insecticide interfere insect growth hormone system and kill their stages of lifecycle. They include Deminon, Penfluron, Benzoylureas etc.

EFFECT OF PESTICIDES

1. Pesticides not only destroy pests but also degrade various component of environment such as air water soil causing **environmental pollution**.
2. Pesticides are generally non-biodegradable and such chemical enter plants body which then transferred through food chain and get accumulated the body of animals of higher trophic level which is called **bio-magnification**.

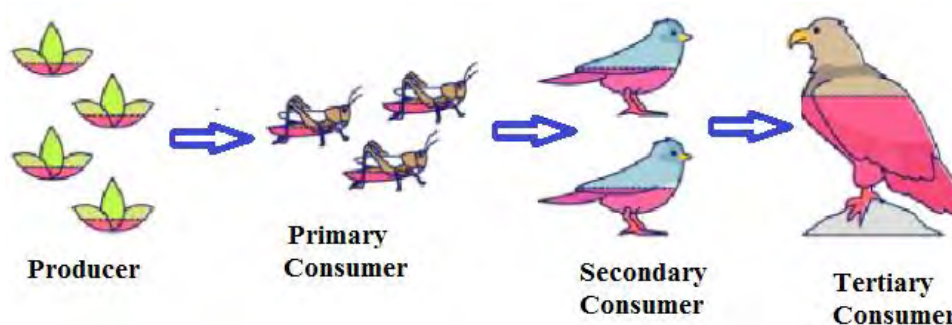


Figure: 9.3.5 Bio-magnification (Pink colour indicates toxin)

3. Some pesticides have wide range of activity killing both targeted organism (pests) and non-targeted organism. Sometimes pollinating insects viz. honey bees, soil fauna viz. earthworm any many other animals like bird, mammals and fish may be badly affected by such poisonous chemicals.

4. Pesticides or chemical residue may remain in fruits, vegetable, leaf surface or any other part of plant leading to contamination such parts are later consumed by humans and animals will suffered by several health related issues in long term.

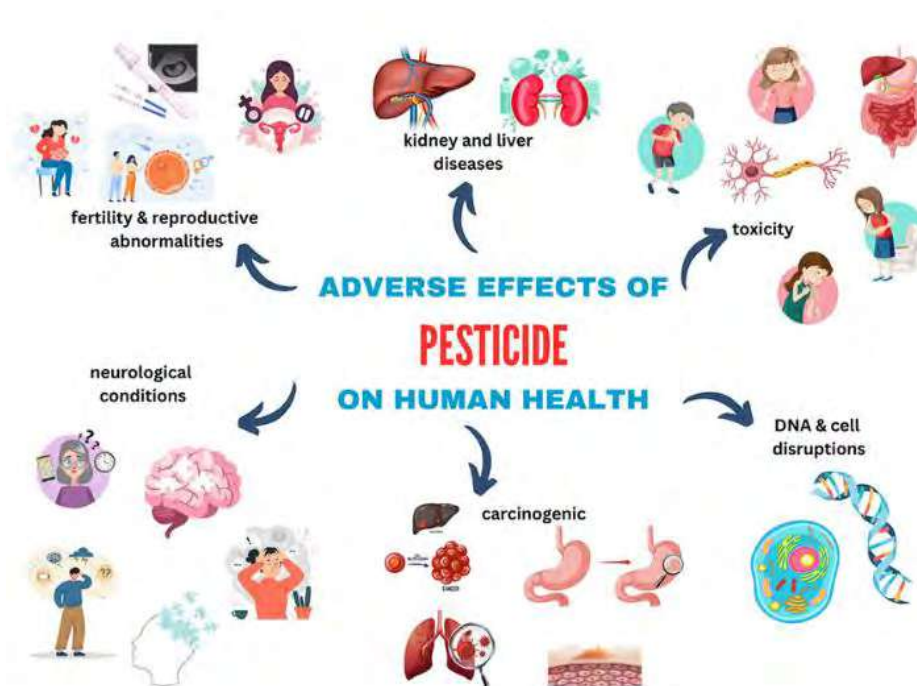


Figure: 9.3.6 Effects of pesticide on human health

5. A variety of wild animals, plants, aquatic organism, microorganism and overall biodiversity (ecological diversity, species diversity and genetic diversity) is harmed by pesticides in long run use.
6. Insect may genetically develop resistance against pesticides due to excessive and prolonged use. Later, such pesticides won't work.
7. Pest develops resistance to pesticides because of repeated use. As a result, farmers must purchase new and often more expensive pesticides as pests become resistant to older and cheaper ones. The continuous introduction of new pesticides can lead to environmental contamination and harm to non-target organisms, including beneficial insects, wildlife, and even human health. Such condition is called pesticide tread mill or 'pesticide trap'.

Alternative approaches for minimizing the use of pesticides

Besides using chemical, there are several other techniques that can be adopted to control pests like crop rotation, biological control (inoculating other organisms in crops which kill or eat pest), use of bio-pesticides (ash, urine of cow, neem extracts etc), mechanical control etc

Nowadays an effective strategy for controlling pest called IPM (integrated pest management) which is also recommended by environment activist. This technique adopts all the method of controlling pests with the least use of chemical pesticides.

EXERCISE

A. Tick the correct alternative.

1. Acid rain is mainly caused by the increased concentration of gases.
 - a. SO_3 and CO
 - b. Ozone
 - c. SO_2 and NO_2
 - d. CO_2 and CO
2. Minamata disease was first detected in.....
 - a. Japan
 - b. India
 - c. USA
 - d. Russia
3. Photochemical smog in metropolitan cities mainly consists of.....
 - a. Carbon dioxide and carbon monoxide
 - b. Sulphur dioxide
 - c. Oxides of nitrogen
 - d. Suspended particulate matter
4. What will happen when there is excessive use of fertilizer in the freshwater resources?
 - a. Animal population decrease
 - b. Plant population decrease
 - c. Eutrophication occur
 - d. Number of fishes decrease
5. Why DDT is considered harmful pesticide for the environment?
 - a. It is easily degradable
 - b. It is non-biodegradable.
 - c. It is organophosphate
 - d. It is insecticide.
6. Which of the following is considered world environment day?
 - a. 12th April
 - b. 9th September
 - c. 3rd January
 - d. 5th June
7. Pollution of water by E.coli is concerned with the discharge of.....
 - a. Heavy metal
 - b. Industrial sewage
 - c. Faeces
 - d. Throwing garbage
8. Which of the following is not a greenhouse gas?
 - a. CO_2
 - b. CO
 - c. CFCs
 - d. CH_4
9. Full form of BOD is.....
 - a. Biotic oxygen demand

- b. Biogenetic oxygen demand
 - c. Biological oxygen demand
 - d. Biochemical oxygen demand
10. Which of the following is most closely associated with the outbreak of typhoid fever and why?
- a. Soil pollution because pathogen in the soil can directly affect individual through skin contact.
 - b. Water pollution because typhoid fever is caused by the bacteria *Salmonella* which are mainly transmitted through contaminated water or food.
 - c. Air pollution because air borne pathogen inhaled, leading to respiratory infection which degrade the immune system of an individual.
 - d. Thermal pollution because salmonella exist in hot water
11. The gas which is produced in paddy field causing global warming is
- a. Chlorine
 - b. Sulphur dioxide gas
 - c. Hydrogen sulphide
 - d. Methane
12. Which of the following indicates SO₂ pollution in the environment?
- a. Lichens
 - b. Pteridophytes
 - c. Moss
 - d. Algae
13. The phenomenon in which certain pollutants accumulates in tissues in the increasing concentration along the food chain is called
- a. Eutrophication
 - b. Biomagnification
 - c. Biological oxygen demand
 - d. Global warming
14. Which of the following is the heavy metal pollutant released in automobile exhaust?
- a. Mercury
 - b. Lead
 - c. Sodium
 - d. CO

B. Answer the following questions:

1. What is pollution? Briefly describe different types of pollutants.
2. What do you mean by air pollution? Write its sources and effects.
3. What is water pollution? What are the sources of water pollution.
4. What is the role of industries and agrochemical in soil pollution?
5. What measures do you suggest to prevent water pollution?
6. What can we control pollution from automobile exhausts? Give suggestions
7. Describe the ways by which soil is degraded.
8. How can we control gaseous pollutants?

9. What are the effects of air pollution on the health of human being and other living organisms?
10. Briefly describe the effect of water pollution.

Project work

1. Visit a nearby agricultural farmland and farmers and inquire about the various types of pesticides used there. Prepare a short report on it and discuss in class.
2. Make 3-4 groups of students with the help of your teacher and visit farmers of nearby farmland to survey on health hazards by the use of pesticides. Make report and discuss in class.
3. Prepare a power point presentation on pesticides of biological origin which are used locally and discuss.

Unit 10

Conservation Biology



Edward
O. Wilson
(1834-1919)

He is a well-known biologist and naturalist who popularized the concept of biophilia, which is the innate human affinity for other living organisms. He is a Professor at Harvard and has published many books and articles on the importance of biodiversity and the threats it faces. He is also a champion of the Half-Earth Project, which aims to conserve half of the planet's land and sea for nature.

Chapter 10.1

CONSERVATION BIOLOGY

Discuss the following questions:

- X. What do you know about biodiversity and why is it important to study?
- XI. Can you say some ecosystems that support biodiversity?
- XII. Do you think there is a moral or ethical responsibility of human to conserve biodiversity?
- XIII. Do biodiversity have positive or negative impact to human lives?
- XIV. Human beings are responsible for the loss of biodiversity. How?

10.1.1 CONCEPT OF BIODIVERSITY

Biodiversity, or biological diversity, encompasses the wide array of life on Earth from tiny microbes to large whales. Out of an estimated 8.7 million eukaryotic species, only 1.4 million have been identified, leaving 86% of land and 91% of marine species undiscovered. These diverse species are adapted to specific environments, ranging from mountain peaks to ocean depths and polar ice caps to rainforests. Biodiversity includes all life forms—plants, animals, fungi, and microorganisms - along with the communities they create and the habitats they inhabit. In essence, biodiversity, a blending word of ‘biology’ and ‘diversity’, encapsulates the rich variety of life and ecosystems found on our planet which also refers to the variety among living organisms in terrestrial, marine, and aquatic ecosystems, comprising diversity within species, between species, and of ecosystems. It holds significance in both human-managed and natural ecosystems, providing essential goods and services that sustain human society.

In other words, biodiversity is the umbrella term which includes the number and frequency of ecosystem, species and genes in a given assemblage or the totality of ‘genes, species and ecosystems’ of a region.

LEVELS OF BIODIVERSITY

There are mainly three levels of biodiversity:

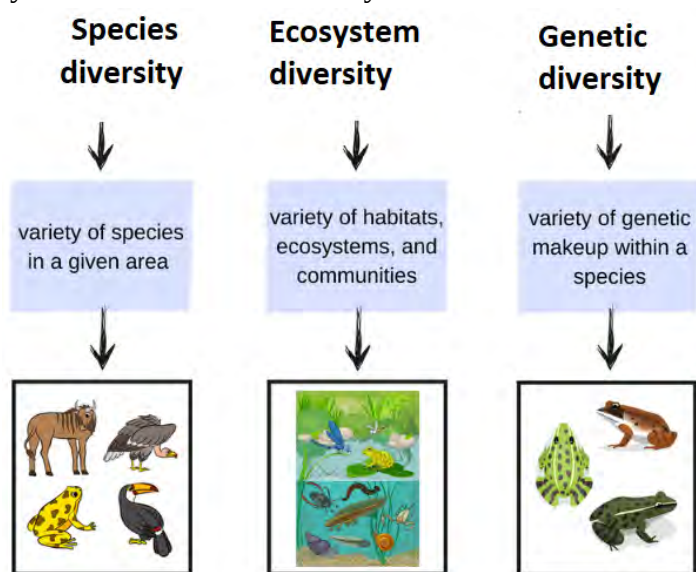


Figure 10.1.1 Different levels of biodiversity

a. Species Diversity: Species diversity is defined as the variety in the number and richness of the species of a region or the count of different species coexisting within a community. The greater the variety of species, the healthier the ecosystem, forming crucial links in the food chain and web.

b. Ecological Diversity (community and ecosystem diversity): It is the most extensive level of biodiversity. It encompasses the number and variety of interactions in ecosystems within a specific area. Earth showcases ecosystem diversity with diverse environments like forests, oceans, deserts, wetlands, and grasslands.

c. Genetic Diversity: All the life forms, spanning from microbes to plants and humans, possess genes carrying distinct traits and characteristics. Genetic diversity is the diversity in the number and types of genes as well as chromosomes present in different species and the variation of genes and alleles in the same species. A larger population for reproduction offers more gene combinations in the offspring.

Importance of biodiversity

Biodiversity is crucial for following purposes:

- i. Preserving the variety of life forms.
- ii. Responsibly utilizing ecosystems, species, and genetic resources.
- iii. Ensuring fair distribution of benefits from genetic resource utilization.
- iv. Providing recreational, cultural, and spiritual nourishment for personal and social wellness.
- v. Maintaining and functioning the ecosystems which offers essential services such as oxygen supply, clean air and water, pollination, pest control, and wastewater treatment.

BIODIVERSITY IN NEPAL

Nepal boasts rich biodiversity, housing valuable flora and fauna. Our country's unique assemblage of diverse flora and fauna is because of varied topography and climatic condition within a short distance. The country features six different biomes, 35 forest types, and 118 ecosystems classified based on their altitude, variations in climate and vegetation. This diversity includes numerous endemic species, making Nepal a heaven for unique and varied life forms.

LOSS OF BIODIVERSITY

The permanent loss of different kinds of plants, animals, and other living things is called extinction of biodiversity. This happens when species disappear from the Earth forever. If these species disappear, it can disrupt the balance of nature and harm ecosystems. The world has faced species extinction at an alarming rate mainly because of human interference. Nepal is also facing a significant decline in biodiversity, contending with various threats. That's why it's important for everyone to work together to protect Nepal's biodiversity and the animals that call it home.

Major causes of decline of biodiversity are:

- i. habitat encroachment
- ii. poaching
- iii. unsustainable resource use
- iv. introduction of alien or invasive species
- v. human-wildlife conflicts
- vi. filling up wetlands
- vii. climate change
- viii. overgrazing
- ix. invasive species
- x. natural disasters
- xi. pollution due to large-scale infrastructure projects.

Table: 10.1.1 Comparative data of species in the world and in Nepal

Group	Known species	
	in Nepal	Relative to the world (%)
Flora (3.2% of the world)		
Angiosperms	6,973	3.2
Gymnosperms	28	5.1
Pteridophytes	534	5.1
Bryophytes	1,150	8.2
Lichens	771	2.3
Fungi	2,025	2.6
Algae	1,001	2.5
Flora Total	11,971	3.2
Fauna (1.1% of the world)		
Mammals	210	5.2
Birds	871	9.5
Reptiles	137	1.9
Amphibians	53	2.5
Fishes	228	1.9
Mollusks	192	-
Moths	3,958	3.6
Butterflies	651	3.7
Spiders	175	0.4
Rotifers	61	-
Crustaceans	59	-
Other Insects	5,052	0.7
Platyhelminthes	168	1.4
Fauna Total	11,861	1.1

Source: Nepal Biodiversity Research and Conservation Centre, Department of National Park and Wildlife Conservation

10.1.2 BIODIVERSITY CONSERVATION

Biodiversity conservation involves safeguarding and scientifically managing diverse life forms to sustain their levels and provide lasting benefits for current and future generations. It protects plant, animal, microbial, and genetic resources crucial for food production, agriculture, and ecosystem functions like soil fertilization, nutrient recycling, pest control, erosion prevention, and crop and tree pollination. Conservation practices aim to manage nature and resources for present and future generations, ensuring the sustained well-being of humanity.

There are two basic strategies of biodiversity conservation:

a. In-Situ Conservation (within natural habitat): This method protects organisms in their natural habitats like national parks and other protected areas. For instance, in Chitwan National Park, we have centers for Elephant Breeding, Gharial Conservation, and Vulture Conservation.

b. Ex-Situ Conservation (outside natural habitat): This type of conservation strategy includes protection of animals outside their natural habitats such as botanical or zoological gardens, cryopreservation, seed gene banks etc.

10.1.3 NATIONAL PARKS IN NEPAL

A National Park is an area dedicated to safeguarding and nurturing wildlife and their natural habitats for scientific, educational, and recreational purposes. In Nepal, these parks aim to conserve the environment, including plants, animals, and scenic landscapes, ensuring their proper management and utilization. National parks hold scientific, aesthetic, and ecological significance, strictly prohibiting activities like wildlife poaching, tree cutting, grazing, and settlement. These protected zones contribute to eco-tourism development and are recognized by the IUCN. Nepal boasts 12 national parks, covering approximately 23.39% of the country's land, totaling about 10,288 sq. km.

National Parks in Nepal are:

1. Banke National Park
2. Bardia National Park
3. Chitwan National Park
4. Khaptad National Park
5. Langtang National Park
6. Makalu Barun National Park
7. Parsa National Park
8. Rara National Park
9. Sagarmatha National Park
10. Shey-Phoksundo National Park
11. Shivapuri Nagarjun National Park
12. Shukla Phanta National Park

Do you know?

Buffer zones are special areas made to better protect specific conservation areas, usually around the edges. In these zones, there might be rules about how resources are used, but people can still do certain activities. There are altogether 13 buffer zones.

1. BANKE NATIONAL PARK

Area : 550 sq. km.

Established : 2010 A.D.

Location : Banke, Bardia, Dang and Salyan

Features:

- i. Banke national park was established for the conservation of wild tigers, an endangered wildlife species.
- ii. It conserves three species of mammals (tiger, striped hyaena, four-horned antelope), four species of birds (giant hornbill, black stork, Bengal florican, and lesser florican) and two species of reptiles (gharial crocodile and python) are protected.
- iii. The river Rapti on the south and River Babai on the north form the lifeline of the Park.

- iv. It is enriched with 8 ecosystems: Sal forest, deciduous riverine forest, savannahs and grasslands, mixed hardwood forest, flood plain community, Bhabar, and foothills of Chure range.
- v. It is home for 124 plants, 34 mammals, more than 300 birds, 24 reptiles, 7 amphibians, and 58 fish species.
- vi. Ninety percent of its natural forest coverage is primarily composed of sal, karma, khair, and sissoo.
- vii. It is mainly concerned with conserving species such as royal Bengal tiger, Asiatic wild elephant and four-horned antelope.

2. BARDIYA NATIONAL PARK

Area : 968 sq. km
Established : 1976 A.D.
Location : Banke, Bardia, Dang and Salyan

Features:

- i. Bardiya national park is the largest national park in the lowland Terai.
- ii. It was a wildlife reserve (1976) that turned into a national park in 1988.
- iii. Its major vegetation and forest types include wooded grassland and the riverine forest.
- iv. Seventy percent of its forest comprises sal trees, a mixture of grassland and riverine forests.
- v. It is a home to endangered animals such as the Royal Bengal tiger, wild elephant, greater one-horned rhinoceros, swamp deer, black buck, gharial, marsh mugger crocodiles, gangetic dolphin, Bengal florican, lesser florican and sarus crane.
- vi. It shelters over 30 varieties of mammals, 230 species of birds and several species of snakes, lizards and fishes.

3. CHITWAN NATIONAL PARK

Area : 952.63 sq. km
Established : 1973 A.D.
Location : Chitwan, Nawalparasi, Parsa and Makwanpur

Features:

- i. Chitwan national park is the oldest national park in Nepal and was designated as a UNESCO World Heritage Site in 1984.
- ii. It has a diverse ecosystem: the Churia hills, Ox-bow lakes, and the flood plains of the Rapti, Reu and Narayani Rivers.
- iii. It is home to over 50 mammal species, more than 525 birds, and 55 amphibians and reptiles.
- iv. It conserves endangered animals including One-horned rhinoceros, Gaur, Royal Bengal tiger, Wild elephant, Four-horned antelope, Pangolin, Golden monitor lizard, Python, etc. Bengal florican. Lesser florican, Giant hornbill, Black stork, White stork, etc.
- v. About 70% of the park is covered by sal forests and grassland constitutes 20% of the park.

4. KHAPTAD NATIONAL PARK

Area : 225 sq. km
Established : 1984 A.D.
Location : Bajhang, Bajura, Doti and Achham

Features:

- i. Khaptad national park is the only mid-mountain national park in Western Nepal.
- ii. Flora of the park can be divided into three basic vegetation zones: lower altitude, subtropical, and temperate.
- iii. It is mainly rich in Montane Sal, Pines, *Alder* species, *Lindera nacusua*, *Cinnamomum tamca*, Spruce, fir, hemlock, oak, *Aesculus indica*, maple, Fir oak, birch, and rhododendron.
- iv. It is home to over 20 species of mammals including barking deer, wild boar, goral, Himalayan black bear, Yellow-throated Marten, Rhesus monkey, Langur, leopard, wild dogs, jackal and musk deer.
- v. It comprises 135 species of flowering plants, about 224 species of medicinal herbs, 266 species of migratory birds, 175 species of breeding birds, including Impeyan, pheasant (Dhanphe) etc.
- vi. The core area of Khaptad is known for its religious value, including the Ashram of Khaptad Swami, Sahashra Linga (3,200 m altitude).

5. LANGTANG NATIONAL PARK

Area	: 1710 sq. km.
Established	: 1976 A.D.
Location	: Nuwakot, Rasuwa, and Sindhupalchok

Features:

- i. Langtang national park is rich in Sal (*Shorea robusta*), Chirpine, Nepalese alder, oak, silver fir, hemlock, and Nepalese larch (*Larix nepalensis*), Rhododendron (*R. arboretum*, *R. barbatum*, *R. campanulatum*, and *R. lepidotum*), *Sorbus microphyla* and twisted *R. campanulatum*.
- ii. It is a habitat for red panda, musk deer, Himalayan tahr, Himalayan black bear, snow leopard, wild dog, ghoral, serow and more than 250 species of birds.
- iii. It is famous for Gosaikunda, a religious place.

6. MAKALU BARUN NATIONAL PARK

Area	: 1,500 sq. km
Established	: 1992 (Conservation Area)
Location	: Sankhuwasabha and Solukhumbu

Features:

- i. Makalu Barun National Park is the only protected area on earth with an elevation gain of 8,000 m.
- ii. It is recognized for its tremendous diversity of plants, animals and people.
- iii. It is famous for 31 varieties of rhododendron, 47 varieties of orchids, 56 rare plants, Snow leopard, red panda, musk deer, wild boar, etc.

7. PARSA NATIONAL PARK

Area	: 627.39 sq. km
Established	: 2017 (Wildlife reserve in 1984)
Location	: Chitwan, Makawanpur, Parsa and Bara

Features:

- i. Parsa national park is dominated by Churiya hills ranging from 750 m to 950 m, running east to west through the park.
- ii. It has a subtropical monsoon climate.
- iii. Its forest is composed of tropical and subtropical types with sal constituting about 90% of the vegetation.
- iv. It comprises riverine forest comprising khair, silk cotton trees, sal, pines, Sabai grass.
- v. It conserves various endangered species such as wild Asian elephant, Royal Bengal tiger, Sloth bear, and Leopard.
- vi. It is home for above 500 species of birds like White breasted kingfisher, Paradise flycatcher, Large racquet-tailed drongo, Golden backed woodpecker, Giant hornbill (Endangered), etc.
- vii. It is famous for reptiles and different kinds of snakes including common Cobra, Common and banded Krait, Python and King cobra and mammals such as Blue bull, Sambar, Chital, Hog deer, Barding deer, Langur, Rhesus macaques, striped hyena, Jungle cat, and Palm civet.

8. RARA NATIONAL PARK

Area	: 106 sq. km
Established	: 1976 A.D.
Location	: Mugu and Jumla

Features:

- i. Rara national park is the smallest protected area in Nepal.
- ii. It is famous for Rara Lake (Mahendra Tal), the biggest lake (10.8 sq. km) and home for snow trout (*Schizothorax oreinus sinuatus*), located at the altitude of 2990 m.
- iii. It is rich in blue pine, rhododendrons, Blue pine, herbs, marshlands, tussock grasslands, fir, oak, juniper, hemlock, spruce and birch species.
- iv. Its altitude ranges from 2800 m to 4039 m (Chuchemara peak).
- v. It is mainly a coniferous forest.
- vi. It is home to about 20 different species of mammals such as Musk deer, Himalayan black bear, Leopard, Jackal, Himalayan tahr, Yellow throated marten, Otter, Wild dog, Common langur, Rhesus macaque and Red panda.
- vii. It conserves 214 species of birds including coots, snow cock, and some species of pheasants, grebes, mallard, common teal, red-crested pochard, gulls and Gallinaceous birds.

9. SAGARMATHA NATIONAL PARK

Area	: 1,148 sq, km
Established	: 1976 A.D.
Location	: Solu-Khumbu

Features:

- i. Sagarmatha national park includes the highest peak in the world: Sagarmatha and some renowned peaks Lhotse, Cho-Oyu, Thamserku, Nuptse, Ama Dablam, Pumori, Kwangde.
- ii. It was enlisted in the World Heritage Sites in 1979.

- iii. It conserves vegetation such as pine and hemlock forests, while fir, juniper, birch, rhododendron, scrub and alpine plant Pine.
- iv. It is a home for over 118 species of bird such as the Impeyan pheasant, snow cock, blood pheasant, red billed cough etc. and mammals such as red panda, snow leopard, musk deer, Himalayan tahr, marten, Himalayan mouse hare (pika).

10. SHEY-PHOKSUNDO NATIONAL PARK

Area : 3,555 sq. km
Established : 1984 A. D.
Location : Dolpa and Mugu

Features:

- i. Shey-phoksundo national park is the largest national park in the country.
- ii. Its altitude ranges from 2,130 m (Ankhe) to 6,883 m (Kanjiroba Himal).
- iii. It comprises Nepal's deepest and second largest lake, Phoksundo Lake.
- iv. It is famous for the Shey Gumpa Monastery established in the 11th century.
- v. It conserves rhododendron, caragana shrubs, and Salix, Juniper, white Himalayan birch, silver fir, blue pine, spruce, hemlock, cedar, poplar, and bamboo.
- vi. About five percent of the park is forest.
- vii. It protects 6 species of reptiles and 29 species of butterfly, including the highest flying butterfly in the world, *Paralasa nepalaica*.
- viii. It is a habitat for over 200 species of birds including yellow-throated marten, Tibetan partridge, wood snip, white-throated tit, wood accentor, and crimson-eared rose-finch.
- viii. It is home for endangered species such as the snow leopard, grey wolf, musk deer, and blue sheep, goral, great Tibetan sheep, Himalayan tahr, leopard, jackal, and Himalayan black bear.

11. SHIVAPURI NAGARJUN NATIONAL PARK

Area : 159 sq. km
Established : 2002 A.D.
Location : Kathmandu Valley

Features:

- i. Shivapuri Nagarjun National Park is located in a transition zone between subtropical and temperate climates.
- ii. It protects a variety of natural forest including pine, oak, rhododendron etc.
- iii. It is a home for 177 species of birds including over 9 threatened species, 102 species of butterflies including some rare and endangered species, and 129 species of mushroom.
- iv. It protects mammalian species such as Himalayan Black bear, leopard, jungle cat, and rhesus monkey.

12. SHUKLA PHANTA NATIONAL PARK

Area : 305 sq. km
Established : 2017 A.D.
Location : Kanchanpur

Features:

- i. Shukla phanta national park was earlier managed as a hunting reserve (1969), and then wildlife reserve (1976).
- ii. It is famous for the highest density in tiger population.
- iii. It is home for 24 species of mammal, 350 species of birds (180 breeding species), 14 species of fish and 10 species of ectoparasites and biting flies.
- iv. It was established primarily to conserve Bahrasinghe.
- v. Its altitude ranges from 174 m to 1386 m.
- vi. It conserves vegetation types including sal forest, sal savanna and supports the largest population of Bengal florican (*Houbaropsis bengalensis*).

10.1.4 WILDLIFE RESERVE OF NEPAL

Wildlife reserves are dedicated areas for conserving and managing animals and their habitats. They focus on protecting rare, endangered, or specific animals by carefully managing their living spaces to increase their numbers. Similar to national parks, activities like poaching, hunting, tree cutting, grazing domestic animals, and constructing houses are strictly forbidden in wildlife reserves. Entry for people and facilities that could impact wildlife negatively, including tourism-related development, is also restricted. Nepal has one Wildlife Reserve, namely Koshi Tappu, covering a total area of 175 sq. km. This reserve serves as a sanctuary for the protection of wildlife.

1. KOSHI TAPPU WILDLIFE RESERVE

Area : 176 sq. km.

Established : 1976

Location : Saptari and Sunsari (Eastern Nepal)

Features:

- i. Koshi Tappu Wildlife Reserve experiences three seasons.
- ii. It is primarily composed of tall grasslands.
- iii. the Predominantly tall khar-pater grassland with khair-sissoo scrub forest and deciduous mixed riverine forest.
- iv. The reserve is a valued habitat for a variety of wildlife, primarily wild buffalo (around 159) and 20 other animal species like Hog deer, Wild boar, Spotted deer, Blue bull, Rock Python, etc.
- v. The Koshi Barrage is a vital resting place for several migratory birds, including 87 winter and trans-Himalayan migratory species.
- vi. Koshi river is home for 80 species of fish, endangered Gharial crocodile and Gangetic dolphin.

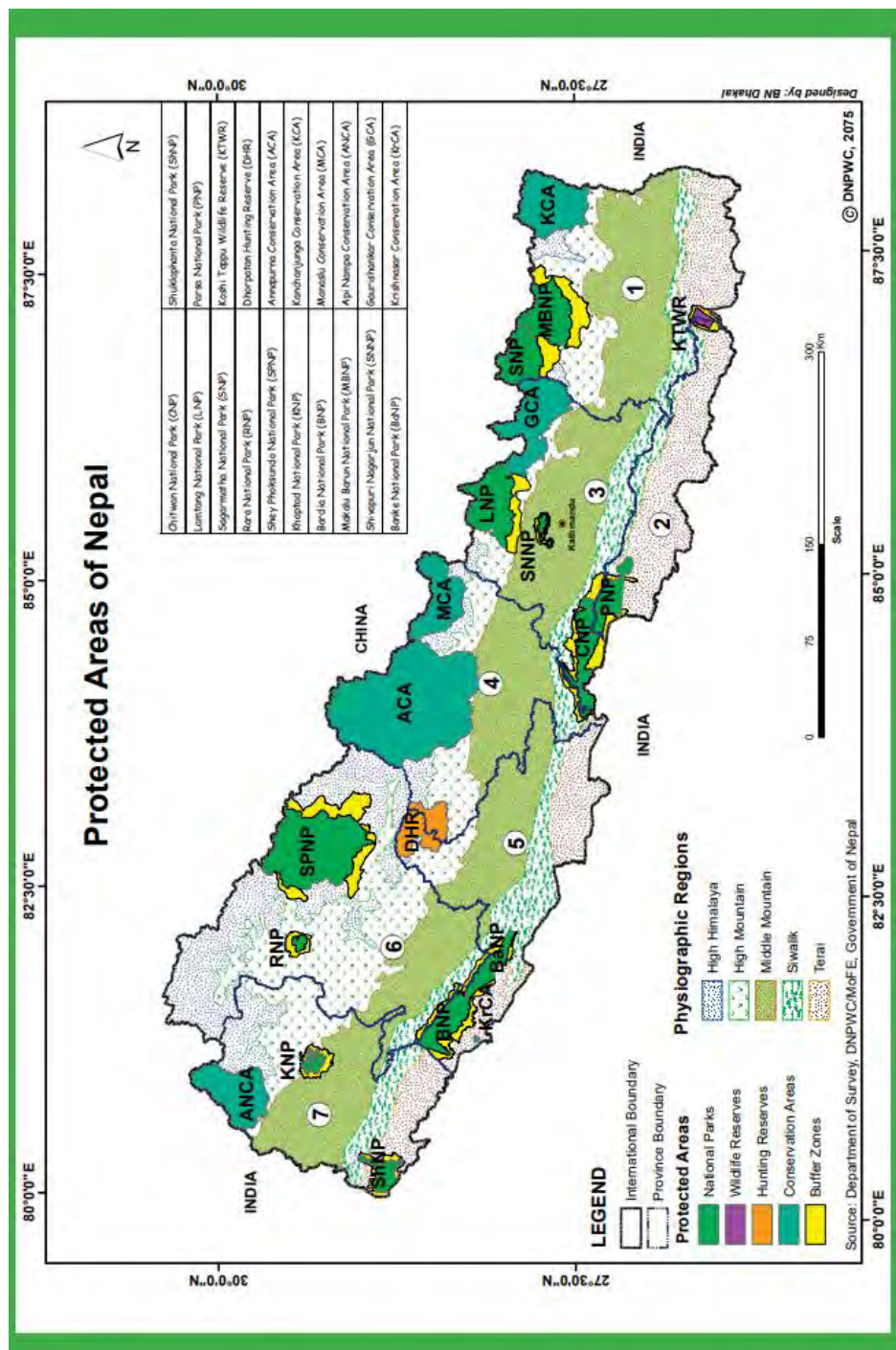


Figure 10.1.2 Protected areas of Nepal

10.1.5 HUNTING RESERVE

An area where, in the past, people were legally permitted to hunt wild animals for food or sport. Currently, Nepal strictly prohibits hunting through conservation laws. However, there is one hunting reserve in Nepal (Dhorpatan Hunting Reserve) where lawful hunting of Himalayan Blue Sheep and Himalayan Thaar is permitted. The Dhorpatan Hunting Reserve caters to the hunting needs of both Nepalese and foreign hunters specifically targeting Himalayan Blue

Sheep and Himalayan Tahr. Dhorpatan Hunting Reserve stands as the sole hunting reserve in Nepal.

DHORPATAN HUNTING RESERVE

Area : 1325 sq. km.
Established : 1983 (gazetted in 1987)
Location : Rukum, Myagdi and Baglung

Features:

- i. Dhorpatan Hunting Reserve is the only hunting reserve in Nepal.
- ii. Its height ranges from 3000 m to over 7000 m.
- iii. Meadows above 4000 m, called patans, are vital for animals like blue sheep and other plant-eating animals.
- iv. The reserve is split into six parts for managing hunting.
- v. Grazing of livestock starts in February and continues till October, with over 80,000 animals entering the reserve yearly.
- vi. Its common plant species include fir, pine, birch, rhododendron, hemlock, oak, juniper and spruce.
- vii. Above 50% of the area of the reserve at altitude is pastureland.
- viii. This area is a top spot for blue sheep, which are highly sought after for hunting.
- ix. It is a home for animals like blue sheep (counted to be 852 in 2007), leopards, gorals, serows, Himalayan tahrs, black bears, deer, wild pigs, monkeys, langurs, and hares; 137 types of birds primarily including pheasants and partridges.
- x. Endangered species in the reserve include musk deer, wolves, red pandas, cheer pheasants, and danphes.
- xi. The authority responsible for issuing hunting licenses is the Department of National Parks and Wildlife Conservation.

10.1.6 CONSERVATION AREAS

The conservation area focuses on preserving the natural environment and ensuring sustainable use of resources through integrated management plans, adhering to the principles of sustainable development. The total area spanned by the conservation area is 11,327 sq. km., encompassing six conservation areas.

1. ANNAPURNA CONSERVATION AREA

Area : about 7,629 sq. km
Established : 1992
Location : Sankhuwasabha and Solukhumbu

Features:

- i. Annapurna conservation area is the first and largest protected area of Nepal.
- ii. It is rich in biodiversity and is home for 1,226 species of flowering plants, 105 mammals, 518 birds, 40 reptiles and 23 amphibians.
- iii. It comprises the Annapurna himalayan range and Kali Gandaki River Valley (the world's deepest valley).

- iv. It comprises the world's largest rhododendron forest (Ghorepani) and the world's highest altitude freshwater lake: Tilicho lake (Manang).

2. API-NAMPA CONSERVATION AREA

Area : 1,903 sq. km

Established : 2010

Location : Darchula

Features:

- i. Api-nampa conservation area is named after the peaks Api and Nampa.
- ii. Its altitude ranges from 539 to 7,132 m.
- iii. It was established to conserve the unique flora, fauna, biodiversity and cultural heritage of the area.
- iv. Its altitude variation offers diverse climatic condition supporting several wildlife including mammals like Himalayan Tahr, Blue sheep, Musk deer, common langur (*Semnopithecus entellus*), jackal (*Canis aureus*), grey wolf (*Canis lupus*) (V), Himalayan black bear (*Selenarctos thibetanus*) (V), Red panda (*Ailurus fulgens*) (V), snow leopard (*Uncia uncia*) (E), Himalayan musk deer (*Moschus chrysogaster*), Serow (*Capricornis sumatraensis*) (I), Himalayan tahr (*Hemitragus jemlahicus*) (K) and goral (*Nemorhaedus goral*).
- v. Some major species of bird it accommodates include Daphne (*Impeyan pheasant*), Munal, Snow Chock, Blood pheasant, Red billed chough, Yellow-billed chough, etc.
- vi. It is also famous for valuable medicinal Panchaunle (*Dactylorhiza hatagirea*), Kutki (*Neopicrorhiza scrophulariiflora*), Yarsagumbu (*Cordyceps sinensis*), Jatamansi (*Nardostachys grandiflora*), Sarpagandha (*Rauvolfia serpentina*), Sugandhawal (*Valeriana jatamansi*), etc.

3. GAURISHANKAR CONSERVATION AREA

Area : 2,179 sq. km

Established : January 2010

Location : Ramechhap, Dolakha and Sindhupalchok

Features:

- i. The Nepal Government gave the National Trust for Nature Conservation (NTNC) the job of managing the Gaurishankar Conservation Area for 20 years.
- ii. It is primarily rich in 16 types of vegetations: *Pinus roxburghii* forest, Schima-Castanopsis forest, *Alnus* forest, *Pinus wallichiana* forest, *Pinus patula* forest, *Rhododendron* forest, *Quercus lanata* forest, Lower temperate oak forest (*Quercus semicarpifolia* forest), Lower temperate mixed broad leaved forest, *Abies* forest, Upper temperate mixed forest (*Birch-rhododendron* forest), Temperate mountain oak forest, East Himalayan Oak forest, Juniperus forest, Shrubland (*Rhododendron anthopogon* bushes) and Moist alpine scrubs.
- iii. Forest and bushes, cultivated land, grasslands and glaciers occupy 44.5%, 8.8%, 8.6%, and 2.77% of the total area, respectively.
- iv. It harbors 565 species of plants, 77 species of mammals, 16 species of fishes, 9 species of amphibians, 22 species of reptiles and 235 species of birds.

4. KANCHANJUNGA CONSERVATION AREA

Area : about 2,035 sq.km.

Established : 1998

Location : Taplejung

Features:

- i. Kanchanjunga Conservation Area is home to broadleaf deciduous trees dominated by quercus, castanopsis, *Rhododendron arboreum* and some members of the laurel family.
- ii. Its altitude ranges from 800 m to 8586 m.
- iii. It shelters snow leopard, leopard, red panda, blue sheep, musk deer, gray wolf, and more.
- iv. In 1997, the Government of Nepal declared Kanchenjunga region as a part of WWF's Living Planet Campaign 2000.

5. KRISHNASAAR (BLACKBUCK) CONSERVATION AREA

Area : 16.95 sq. km

Established : 2009

Location : Bardia

Features:

- i. The major purpose of Krishnasaar Conservation Area is to protect the blackbuck (*Antelope cervicapra*).
- ii. This is the first organized effort to conserve the endangered Blackbuck (*Antelope cervicapra cervicapra*).
- iii. In Khairapur, Nepal, Black Buck numbers fell to 9 (1975), then rose to 177 (1990) due to conservation. But habitat loss caused a decline again. Now, over 200 Black Bucks live in Krishnasaar Conservation Area.

6. MANASLU CONSERVATION AREA

Area : 1663 sq. km

Established : 1998

Location : Gorkha and Manang

Features:

- i. Manaslu Conservation area inhabits 33 species of mammals, 110 species of birds, 11 species of butterflies and 3 species of reptiles.
- ii. There are about 2000 species of plants, 11 types of forests and over 50 species of useful plants.
- iii. Its bioclimatic zones vary from subtropical to Nival with a range of altitude rises from 600 m to 8,163 m (peak of Mt. Manaslu).
- iv. It has different types of medicinal plants
- v. Wildlifes it's famous for include snow leopard, Himalayan musk deer, Himalayan tahr, red panda, etc.

10.1.7 BIODIVERSITY HOTSPOTS

Biodiversity hotspots are areas characterized by both abundant biological diversity, with a rich variety of plants and animals, and significant threats to their survival. Essentially, these

biogeographic regions exhibit high productivity but are constantly at risk of destruction, necessitating protective measures. Forest habitats serve as prime examples of biodiversity hotspots, facing ongoing threats like illegal logging, pollution, and deforestation. The concept of hotspots was introduced by Norman Myers in 1988.

Do You Know?

Norman Myers, the world's leading environmental analysts, introduced the concept of hotspots in 1988, identifying regions with high biodiversity to prioritize conservation efforts due to their ecological significance.



Nepal's Himalayan region has been identified as one of the world's ten most endangered biodiversity hotspots. The leading four biodiversity hotspots include Upper Amazonia/Guyana Shield, the Congo Basin, New Guinea/Melanesian Islands, and the Himalaya - Nepal.

10.1.8 WETLAND

Wetlands, like marshes and swamps, are areas with shallow water or moisture-saturated soil. They include marshes, estuaries, mudflats, ponds, swamps, deltas, shallow seas, bogs, lakes, and floodplains. These lands are fertile for agriculture and teeming with diverse wildlife. They play a crucial role in high-mountain and lowland ecosystems. Wetlands offer various benefits, serving as habitats for fish, wildlife, including endangered species.

In Nepal, there are 242 wetlands occupying 743,500 hectares (about 5% of the country's area) and are considered important productive ecosystems of the world. Some of them are: Phoksundo Wetland, Koshi Tappu Wildlife Reserve, Jagadishpur Reservoir, Gosaikunda Wetland, Gokyo Wetland Series, Ghodaghodi Lake Area, Beeshazar and Associated Lakes, Maipokharai, etc.

Nepal is committed to the conservation of these sites of immense importance and has signed the Ramsar Convention in 1988. Ten wetlands are listed as Ramsar sites recognizing the international importance. They are tabulated below.

Table: 10.1.2 Wetlands of global importance (Ramsar Sites) of Nepal

SN	Name	Districts	Area (Ha)
1.	Koshi Tappu Wildlife Reserve	Sunsari	17,500
2.	Beesh Hazar Tal	Chitwan	3,200
3.	Ghodaghodi Tal	Kailali	2,563
4.	Jagadishpur Reservoir	Kapilvastu	225
5.	Gokyo Lake Complex	Solukhumbu	7,770
6.	Gosainkunda Complex	Rasuwa	1,030
7.	Rara Lake	Mugu	1,583
8.	Shey-Phoksundo	Dolpa	494
9.	Mai Pokhari	Ilam	12
10.	Pokhara Valley Lake Cluster	Kaski	26106
		Total area	60,483

Benefits of Wetlands

Besides recreational and educational benefits, studying wetlands helps us understand their importance in sustaining life and ecosystems. Following are a few benefits of wetland:

- i. Wetlands foster rich and diverse ecosystems, providing habitats for various plant and animal species.
- ii. They act as natural buffers, absorbing and storing excess water during heavy rainfall, helping prevent floods.
- iii. Wetlands filter and purify water by trapping pollutants and sediments, contributing to improved water quality.
- iv. Wetlands offer opportunities for recreational activities such as bird watching, fishing, and eco-tourism.
- v. They play a role in climate regulation by storing carbon and helping to mitigate the impacts of climate change.
- vi. Wetlands are often fertile areas suitable for agriculture, supporting crops and sustaining livelihoods.
- vii. Many threatened and endangered species rely on wetlands for their survival, making them crucial for biodiversity conservation.
- viii. Studying wetlands enhances our understanding of ecosystems, biodiversity, and environmental science.
- ix. Vegetation in wetlands helps stabilize soil, preventing erosion and maintaining the integrity of surrounding landscapes.
- x. Wetlands hold cultural value for many communities, often being sites of historical importance and traditional practices.

10.1.9 RAMSAR SITES

The term "simsar", in Nepali, refers to wetland indicating an area with a continuous water source, including rice fields, waterlogged zones, and ponds. Currently, Nepal has ten Ramsar sites, covering 5.5% of the country, recognized for their international importance under the Ramsar Convention. The Ramsar Convention (intergovernmental environmental treaty),

established in 1971 by UNESCO and named after the city of Ramsar in Iran, aims to protect wetlands globally. It is the first treaty for conserving natural resources, focusing on halting wetland loss and managing remaining ones wisely through international collaboration, policy-making, capacity building, and technology transfer.

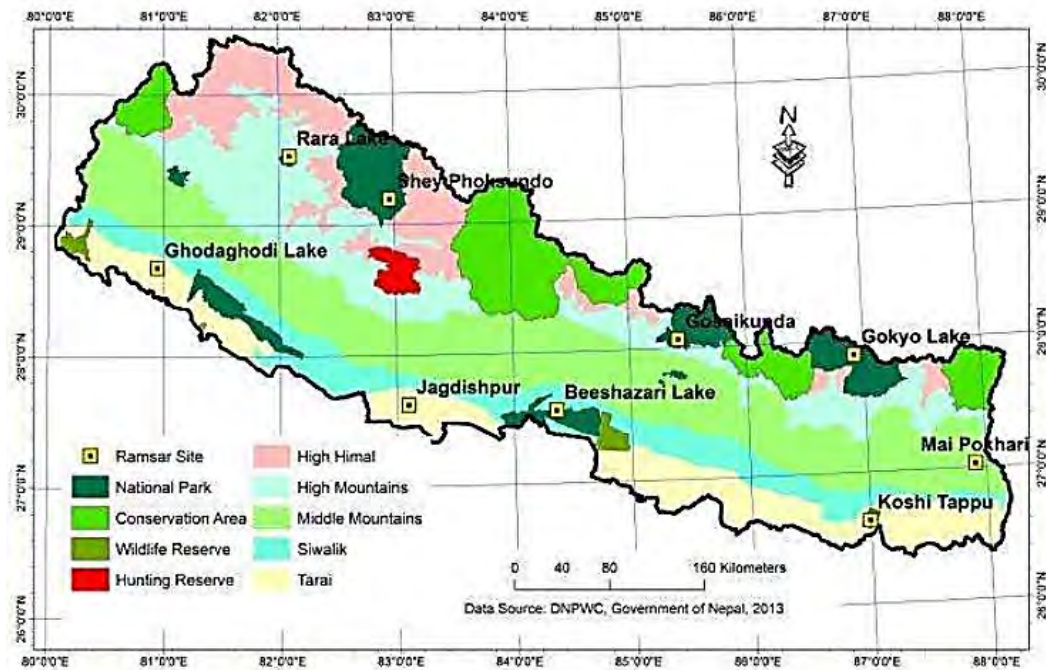


Figure 10.1.3 Ramsar Sites in Nepal

Do You Know?

Wetlands are ecosystems characterized by water saturation, supporting diverse flora and fauna. Ramsar refers to the Ramsar Convention, an international treaty established (1971) that aims to protect and conserve wetlands of international importance.



EXERCISE

A. Tick the correct alternatives:

1. What does biodiversity refer to?
 - a. The variety of life on Earth
 - b. The number of ecosystems
 - c. The size of different species
 - d. The depth of ocean habitats
2. Which level of biodiversity includes interactions within ecosystems?
 - a. Species Diversity
 - b. Ecological Diversity
 - c. Genetic Diversity
 - d. Environmental Diversity
3. What is the total number of flora species in Nepal?
 - a. 11,861
 - b. 11,971
 - c. 12,971
 - d. 10,971
4. How many species of birds are found in Nepal?
 - a. 871
 - b. 951
 - c. 751
 - d. 771
5. Which of the following is NOT a major cause of biodiversity decline?
 - a. Habitat encroachment
 - b. Climate change
 - c. Eco-friendly farming
 - d. Pollution
6. What is the purpose of Ex-Situ Conservation?
 - a. Protecting organisms in their natural habitats
 - b. Safeguarding animals outside their natural habitats
 - c. Conserving biodiversity within national parks
 - d. Managing wildlife for eco-tourism
7. Which national park is primarily concerned with conserving species such as the royal Bengal tiger, Asiatic wild elephant, and four-horned antelope?
 - a. Banke National Park
 - b. Bardiya National Park
 - c. Chitwan National Park
 - d. Sagarmatha National Park
8. Which national park is famous for being the largest in the country and includes Nepal's deepest and second-largest lake, Phoksundo Lake?
 - a. Langtang National Park
 - b. Shey-Phoksundo National Park
 - c. Makalu Barun National Park
 - d. Khaptad National Park

9. How many wildlife reserves does Nepal have?
 - a. 1
 - b. 2
 - c. 3
 - d. 4
10. Which animal is primarily targeted for hunting in the Dhorpatan Hunting Reserve?
 - a. Musk deer
 - b. Blue sheep
 - c. Red panda
 - d. Snow leopard
11. Which conservation area is primarily known for protecting the world's largest rhododendron forest and the highest altitude freshwater lake?
 - a. Annapurna Conservation Area
 - b. Api-Nampa Conservation Area
 - c. Gaurishankar Conservation Area
 - d. Kanchanjunga Conservation Area
12. Which conservation area is focused on conserving the blackbuck (*Antelope cervicapra*)?
 - a. Krishnasaar (Blackbuck) Conservation Area
 - b. Manaslu Conservation Area
 - c. Gaurishankar Conservation Area
 - d. Kanchanjunga Conservation Area
13. Wetlands occupy approximately what percentage of Nepal's area?
 - a. 1%
 - b. 5%
 - c. 10%
 - d. 20%
14. What role do wetlands play in climate regulation?
 - a. Storing excess water during heavy rainfall
 - b. Providing habitats for various plant and animal species
 - c. Filtering and purifying water
 - d. Storing carbon and mitigating the impacts of climate change

B. Answer the following questions:

1. What is biodiversity?
2. What are the four crucial purposes served by biodiversity?
3. Name the three levels of biodiversity.
4. Briefly explain the importance of national parks.
5. Define species diversity.
6. Explain ecological diversity.
7. What is genetic diversity?
8. What are the two basic strategies of biodiversity conservation?
9. Can you name:

- a. the oldest National Park in Nepal
 - b. the largest national park in Nepal
10. Why is biodiversity important? List them.
 11. Name one species protected in Bardiya National Park.
 12. What is unique about Shey-Phoksundo National Park?
 13. Describe the features of Shivapuri Nagarjun National Park.
 14. Why is Shukla Phanta National Park famous, and what does it aim to conserve?
 15. What is the primary purpose of wildlife reserves?
 16. Which reserve in Nepal permits lawful hunting of Himalayan Blue Sheep and Himalayan Thaar?
 17. Describe the features of the Koshi Tappu Wildlife Reserve.
 18. Why is the Dhorpatan Hunting Reserve significant, and name any 4 animals found there?
 19. What is the primary objective of the Gaurishankar Conservation Area?
 20. What is the significance of the Krishnasaar Conservation Area?
 21. Describe the unique features and biodiversity of the Annapurna Conservation Area.
 22. What role do wetlands play in ecosystems?
 23. Define the term "Ramsar sites".
 24. Discuss the significance of wetlands in sustaining life and ecosystems, highlighting their benefits and importance for biodiversity conservation.

Chapter 10.2

WILDLIFE

Discuss the following questions:

- i. How do protected areas contribute to the protection of wildlife?
- ii. What distinguishes Ramsar sites from other wetlands, and why are they essential for the conservation of biodiversity?
- iii. Why is IUCN Red List categories created?
- iv. How can wildlife be economically and ecologically valuable?

10.2.1 WILDLIFE

Wildlife refers to living organisms in their natural habitat, such as wild animals (fauna) and plants (flora), which cannot be easily cultivated or domesticated. Examples include tigers, lions, elephants, and rhododendrons, oaks, etc.

IMPORTANCE OF WILDLIFE

Importance of wildlife is as follows:

- i. Wildlife balances populations and maintains the food chain.
- ii. It contributes to a self-sustaining environment.
- iii. It comprises various plants and animals that have medicinal properties.
- iv. It supports tourism-related economic opportunities.
- v. It serves as a gene bank for breeding programs.
- vi. It preserves organisms with genetic potential.
- vii. It contributes to high-yielding, disease-resistant plants and animals.

CAUSES OF EXTINCTION OF WILDLIFE

Wildlife faces threats, partly from adverse climate conditions, but mainly due to human activities disrupting natural ecosystems. Major causes of extinction include:

- i. habitat destruction,
- ii. poaching,
- iii. environmental pollution,
- iv. international trade,
- v. over-exploitation,
- vi. climate change,
- vii. human-wildlife conflict,
- viii. disease transmission
- ix. natural disasters
- x. invasive species
- xi. deforestation,
- xii. pollution

CONSERVATION AND MANAGEMENT OF WILDLIFE

Conservation involves wisely using the Earth's resources for today and preserving them for the future. Wildlife conservation focuses on safeguarding species at risk of extinction. Protecting global wildlife is a crucial environmental task. The UN Conference on Biodiversity in 1992 revealed that out of around 30 million species, only 1.5 million are known. Natural extinction occurs, but current rates indicate potential loss of a quarter of Earth's species in the next 30 years. Conservation efforts are vital for sustaining biodiversity.



Figure 10.2.1 Some protected (a) birds and (b) mammals of Nepal

CONSERVATION STRATEGY

Scientists from more than 100 countries crafted a thorough Global Conservation Strategy for the responsible utilization of wildlife and resources during the UN Conference on Biodiversity in 1992. This strategy encompasses:

- i. Wildlife habitats require thorough study for protection, examining critical areas like feeding, breeding, nursery, and resting grounds.
- ii. Steps should be taken to safeguard these habitats, including the development of new protected areas tailored to animals' needs.
- iii. Accurate census data on wild animals in specific areas must be maintained, with counts conducted at least once every five years.
- iv. International agreements need establishment to protect the habitats of migratory species covering large areas.
- v. Strict enforcement of laws is necessary to prevent international wildlife trade and pleasure hunting.
- vi. Preservation of wild varieties essential for genetic engineering and biotechnology work should be prioritized.

- vii. National parks and wildlife reserve areas should be established to conserve the natural habitats of wildlife.
- viii. Efforts should be made to educate people about the use and importance of wildlife.

10.2.2 IUCN RED LIST

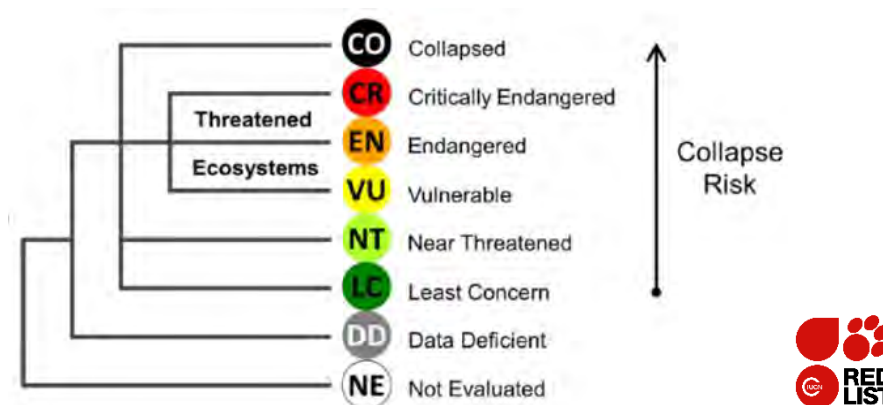


Figure 10.2.2 Categories of IUCN Red list

The IUCN Red List is a comprehensive inventory of the global conservation status and extinction risk of biological species. It was established in 1964 by the International Union for Conservation of Nature (IUCN). The primary purpose of the IUCN Red List is to provide information about the conservation status of species and to draw attention to the magnitude and importance of threatened biodiversity. The IUCN Red List categories are intended to be an easily understood system for classifying species at high risk of global extinction. It divides species into nine categories: Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild and Extinct. The eight categories of wildlife species are: Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern, Data Deficient, and Not Evaluated. The list is updated periodically. **(For latest updates visiting its official site is recommended)**

1. **Extinct:** Species that no longer exist.
2. **Extinct in the Wild:** Species that only exist in captivity or human-managed situations.
3. **Critically Endangered:** Species that are facing an extremely high risk of extinction in the wild.
4. **Endangered:** Species that are facing a very high risk of extinction in the wild.
5. **Vulnerable:** Species that are facing a high risk of extinction in the wild.
6. **Near Threatened:** Species that are close to being classified as Vulnerable.
7. **Least Concern:** Species that are not currently at risk of extinction.
8. **Data Deficient:** Species for which there is insufficient information to make an assessment of their risk of extinction.
9. **Not Evaluated:** Used for species that have not yet been assessed by the IUCN. This category does not indicate that a species is not at risk of extinction, but simply that the species has not yet been studied enough to assign it to a category.

The objective of designing the red list is:

- i. to raise awareness about the level of risk to biodiversity.
- ii. to document and recognize species highly susceptible to extinction.
- iii. to develop strategies for the conservation of endangered species.
- iv. to disseminate information on global agreements, such as the Convention on Biological Diversity and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) with awareness campaigns conducted by the government and concerned agencies.

What is IUCN?

The International Union for the Conservation of Nature and Natural Resources (IUCN), founded in 1948 and headquartered in Morges, Switzerland, is a prominent international institution dedicated to the sustainable use and conservation of biodiversity. Renamed IUCN-The World Conservation Union in 1990, it boasts over 70 member organizations, encompassing both governmental and nongovernmental agencies. With a panel comprising more than 5,000 experts, the IUCN collaborates with influential institutions like the World Bank, Asian Development Bank, UNESCO, and others. Recognized for its unique position, the IUCN serves as a key provider of technical advice on biodiversity issues.



10.2.3 ENDANGERED SPECIES OF NEPAL

The following is the list of endangered species of Nepal:

Table: 10.1.3 List of endangered species of Nepal

S.N.	Common Name	Scientific Name
	Birds (9)	
1	Black Stork	<i>Ciconia nigra</i>
2	White Stork	<i>Ciconia ciconia</i>
3	Sarus Crane	<i>Grus antigone</i>
4	Cheer Pheasant	<i>Catreus wallichii</i>
5	Himalayan Monal	<i>Lophophorus impejanus</i>
6	Crimson-horned Pheasant	<i>Tragopan satyra</i>
7	Bengal Florican	<i>Houbaropsis bengalensis</i>
8	Lesser Florican	<i>Sypheotides indicus</i>
9	Great Hornbill	<i>Buceros bicornis</i>
	Mammals (26)	
1	Red panda	<i>Ailurus fulgens</i>

2	Striped Hyena	<i>Hyaena hyaena</i>
3	Mute ox	<i>Bos mutus</i>
4	Tibetan antelope	<i>Pantholops hodgsoni</i>
5	Argali	<i>Ovis ammon</i>
6	Asian water buffalo	<i>Bubalus arnee</i>
7	Gaur	<i>Bos gaurus</i>
8	Swamp deer	<i>Cervus duvauceli</i>
9	Alpine musk deer	<i>Moschus chrysogaster</i>
10	Pygmy Hog	<i>Sus salvanius</i>
11	Asiatic elephant	<i>Elephas maximus</i>
12	Snow leopard	<i>Panthera uncia</i>
13	Bengal Tiger	<i>Panthera tigris</i>
14	Clouded leopard	<i>Pardofelis nebulosa</i>
15	Bobcat	<i>Felis lynx</i>
16	Leopard Cat	<i>Prionailurus bengalensis</i>
17	Spotted Linsang	<i>Prionodon pardicolor</i>
18	Brown bear	<i>Ursus arctos</i>
19	Gray wolf	<i>Canis lupus</i>
20	Ganges river dolphin	<i>Platanista gangetica</i>
21	Pangolin	<i>Manis pentadactyla/Manis crassicaudata</i>
22	Assam Macaque	<i>Macaca assamensis</i>
23	Black Buck	<i>Antelope cervicapra</i>
24	Four-horned antelope	<i>Tetraceros quadricornis</i>
25	Hispid hare	<i>Caprolagus hispidus</i>
26	One horned Rhinoceros	<i>Rhinoceros unicornis</i>
Reptiles (3)		
1	Asiatic Rock python	<i>Python molurus</i>
2	Gharial	<i>Gavialis gangeticus</i>
3	Calcutta Oval-grain Lizard	<i>Varanus flavescens</i>

Activity: Exploring Endangered Wildlife in Nepal

Objective: Students will research endangered wildlife in Nepal and understand the role of IUCN.

Materials Required:

- Access to the internet for research.
- Paper and pens for notes.
- Projector or whiteboard for presentations

Procedure:

- i. Briefly explain the importance of biodiversity and endangered species.
- ii. Introduce the IUCN and its role in conservation.
- iii. Divide students into small groups.
- iv. Assign each group one endangered animal species in Nepal (e.g., Bengal Tiger, Red Panda, Great Hornbill).
- v. Assist them with some guiding research questions:

- o What is the habitat of this species? - o What are the main threats to its survival? - o What is the current population status according to the IUCN Red List? - o What conservation efforts are in place to protect this species?
- vi. Each group prepares a brief presentation (about 3 minutes) summarizing their findings.
- vii. Groups present their research to the class.
- viii. Encourage questions and discussions after each presentation.
- ix. Summarize the key points about the endangered species and the importance of conservation, highlighting the role of IUCN in protecting endangered species.

EXERCISE

A. Tick the correct alternatives:

1. Which region has been identified as one of the world's ten most endangered biodiversity hotspots?
 - a. Upper Amazonia/Guyana Shield
 - b. Congo Basin
 - c. New Guinea/Melanesian Islands
 - d. Himalaya - Nepal
2. What is the primary objective of the IUCN Red List?
 - a. To raise awareness about climate change
 - b. To provide information about species conservation status
 - c. To promote wildlife tourism
 - d. To regulate international wildlife trade
3. Which of the following is listed as an endangered bird species in Nepal?
 - a. Red Panda
 - b. Bengal Tiger
 - c. Great Hornbill
 - d. Himalayan Monal

B. Answer the following questions:

1. Discuss the significance of biodiversity hotspots and the threats they face, with a focus on Nepal's Himalayan region.
2. Define wildlife conservation.
3. What are the major causes of wildlife extinction?
4. Briefly explain the significance of the IUCN Red List.
5. Discuss the importance of wildlife conservation and the major threats faced by wildlife.
6. Explain the key components of the Global Conservation Strategy outlined during the UN Conference on Biodiversity in 1992.

Project work

- a. Create an engaging poster highlighting urgent conservation needs for specific endangered organisms in Nepal.
- b. Visit a zoological museum or protected areas, and compile your findings in the form of a report on the existing fauna.
- c. Investigate innovative strategies for the preservation of biodiversity, developed by countries around the world.
