Cell - Cell Organelles: Plasma Membrane, Cell Wall, Cytoplasm, Nucleus, Mitochondria. Prokaryotic Cells vs. Eukaryotic Cells. Plant Cell vs. Animal Cell.

Compiled from [NCERT Science Textbooks Class 6-12.]

Cell

Robert Hooke	Discovered and coined the term cell in 1665
Robert Brown	Discovered Cell Nucleus in 1831
Schleiden and Schwann	Presented The cell theory, that all the plants and animals are composed of cells and that the cell is the basic unit of life. Schleiden (1838) and Schwann (1839).

With the discovery of the electron microscope in 1940, it was possible to observe and understand the complex structure of the cell and its various organelles.

Cell Organelles

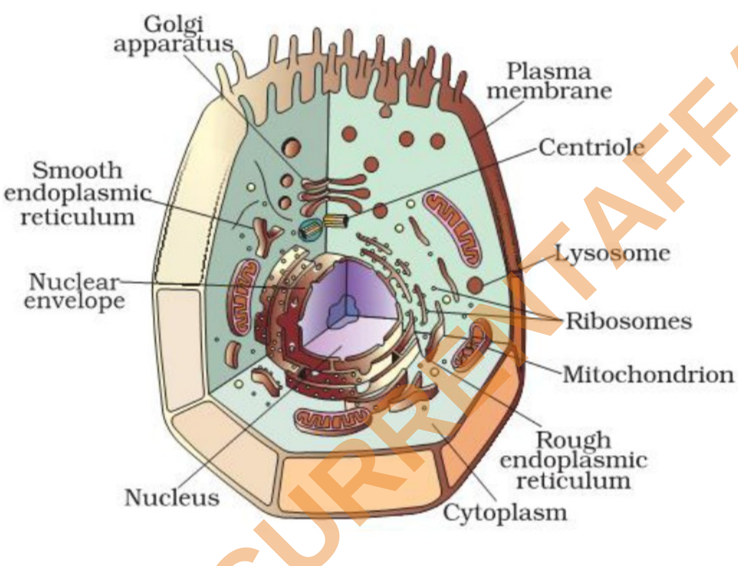


Fig. 5.5: Animal cell

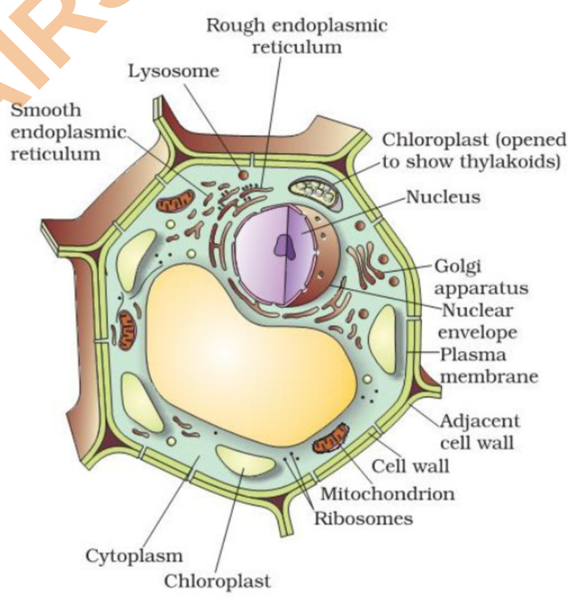


Fig. 5.6: Plant cell

Plasma Membrane or Cell Membrane

0 **Cell membrane** is also called the plasma membrane.

1 It can be observed only through an electron microscope.

2 Plasma membrane is the **outermost** covering of the cell that separates the contents of the cell from its external environment.

Endocytosis

0 The plasma membrane is flexible and is made up of organic molecules called **lipids** and **proteins**.

1 The flexibility of the cell membrane also enables the cell to engulf in food and other material from its external environment. Such processes are known as endocytosis (endo → internal; cyto → of a cell). **Amoeba** acquires its food through such processes.

Diffusion

0 Plasma membrane is a selectively permeable membrane [The plasma membrane is porous and allows the movement of substances or materials both inward and outward].

1 Some substances like carbon dioxide or oxygen can move across the cell membrane by a process called **diffusion** [spontaneous movement of a substance from a region of high concentration (hypertonic solution) to a region where its concentration is low (hypotonic solution)].

2 Thus, diffusion plays an important role in gaseous exchange between the cells as well as the cell and its external environment.

Osmosis

0 Water also obeys the law of diffusion. The movement of water molecules through a selectively permeable membrane is called osmosis.

1 Osmosis is the passage of water from a region of high water concentration through a semi-permeable membrane to a region of low water concentration. Thus, **osmosis is a special case of diffusion** through a selectively permeable membrane.

2 Unicellular freshwater organisms and most plant cells tend to gain water through osmosis. **Absorption of water by plant roots** is also an example of osmosis.

3 Thus, diffusion is important in exchange of gases and water in the life of a cell. In additions to this, the cell also obtains nutrition from its environment.

4 Different molecules move in and out of the cell through a type of transport requiring use of energy in the form of **ATP.**

Reverse Osmosis (RO)

0 Reverse osmosis (RO) is a **water purification technology** that uses a semipermeable membrane to remove larger particles from drinking water.

5888 In reverse osmosis, an **applied pressure** is used to overcome osmotic pressure.

5889 Reverse Osmosis is a phenomenon where pure water flows from a dilute solution [hypotonic] through a semi permeable membrane to a higher concentrated solution [hypertonic].

5890 **Semi permeable** means that the membrane will allow small molecules and ions to pass through it but acts as a barrier to larger molecules or dissolved substances.

Cell Wall

23 Cell wall is ***absent in animals***.

24 Plant cells, in addition to the plasma membrane, have another **rigid** outer covering called the cell wall. The cell wall lies **outside** the plasma membrane.

25 The plant cell wall is mainly composed of **cellulose**. Cellulose is a complex substance and provides **structural strength** to plants.

Plasmolysis

5888 When a living plant cell loses water through osmosis there is shrinkage or contraction of the contents of the cell away from the cell wall. This phenomenon is known as plasmolysis (plasma → fluid; lysis → disintegration, decomposition).

5889 **Only living cells**, and not dead cells, are able to absorb water by osmosis. Cell walls permit the cells of **plants, fungi** and **bacteria** to withstand very dilute [hypotonic] external media without shrinkage.

5890 In such media the cells tend to lose water by osmosis. The cell shrinks, building up pressure against the cell wall. The wall exerts an equal pressure against the shrunken cell.

5891 Cell wall also prevents the bursting of cells when the cells are surrounded by a hypertonic medium (medium of high concentration).

5892 In such media the cells tend to gain water by osmosis. The cell swells, building up pressure against the cell wall. The wall exerts an equal pressure against the swollen cell.

5893 Because of their walls, plant cells can withstand much greater changes in the surrounding medium than animal cells.

Cytoplasm

23 It is the jelly-like substance present between the **cell membrane** and the **nucleus**.

23 The cytoplasm is the **fluid** content inside the plasma membrane.

24 It also contains many specialized **cell organelles [**mitochondria, golgi bodies, ribosomes, etc**].**

25 Each of these organelles performs a specific function for the cell.

26 Cell organelles are enclosed by **membranes**.

27 The significance of membranes can be illustrated with the example of viruses.

28 **Viruses lack any membranes** and hence do not show characteristics of life until they enter a living body and use its cell machinery to multiply.

Nucleus

23 It is an important component of the living cell.

24 It is generally spherical and located in the center of the cell.

25 It can be stained and seen easily with the help of a microscope.

26 Nucleus is separated from the cytoplasm by a **double layered** membrane called the **nuclear membrane**.

27 This membrane is also porous and allows the movement of materials between the cytoplasm and the inside of the nucleus [diffusion].

28 With a microscope of higher magnification, we can see a smaller spherical body in the nucleus. It is called the **nucleolus**.

29 In addition, nucleus contains thread-like structures called **chromosomes**. These carry genes and help in **inheritance** or transfer of characters from the parents to the offspring. **The chromosomes can be seen only when the cell divides**.

30 Gene is a **unit of inheritance** in living organisms. It controls the transfer of a hereditary characteristic from parents to offspring. This means that your parents pass some of their characteristics on to you.

31 Nucleus, in addition to its role in inheritance, acts as **control center** of the activities of the cell.

32 The entire content of a living cell is known as **protoplasm [cytoplasm + nucleus]**. It includes the cytoplasm and the nucleus. Protoplasm is called the **living substance** of the cell.

33 The nucleus of the bacterial cell is not well organized like the cells of multicellular organisms. There is **no nuclear membrane**.

5888 Every cell has a membrane around it to keep its own contents separate from the external environment.

5889 Large and complex cells, including cells from multicellular organisms, need a lot of chemical activities to support their complicated structure and function.

5890 To keep these activities of different kinds separate from each other, these cells use membrane-bound little structures (or 'organelles') within themselves.

Chromosomes

23 The nucleus contains chromosomes, which are visible as rod-shaped structures only when the cell is about to divide.

24 Chromosomes contain **information for inheritance** of features from parents to next generation in the form of **DNA (deoxyribo nucleic acid)** molecules.

25 Chromosomes are composed of **DNA and Protein**.

26 DNA molecules contain the information necessary for constructing and organizing cells. Functional segments of dna are called **genes**.

27 In a cell which is not dividing, this dna is present as part of **chromatin material**. Chromatin material is visible as entangled mass of thread like structures. Whenever the cell is about to divide, the chromatin material gets **organised into chromosomes**.

28 The nucleus plays a central role in **cellular reproduction**, the process by which a single cell divides and forms two new cells.

29 It also plays a crucial part, along with the environment, in determining the way the cell will develop and what form it will exhibit at maturity, by directing the chemical activities of the cell.

Prokaryotic Cells vs. Eukaryotic Cells

5888 Organisms whose cells **lack a nuclear membrane**, are called **prokaryotes** (pro = primitive or primary; karyote ≈karyon = nucleus).

5889 Organisms with cells **having a nuclear membrane** are called eukaryotes.

5890 Prokaryotic cells also **lack most of the other cytoplasmic organelles** present in eukaryotic cells.

5891 Many of the functions of such organelles are also performed by **poorly organised parts of the cytoplasm**.

23 The chlorophyll in photosynthetic prokaryotic bacteria is associated with **membranous vesicles (bag like structures) but not with plastids** as in eukaryotic cells.

Prokaryotes → defined nuclear region, the membrane-bound cell organelles are absent.

Eukaryotic Cells → have nuclear membrane as well as membrane-enclosed organelles.

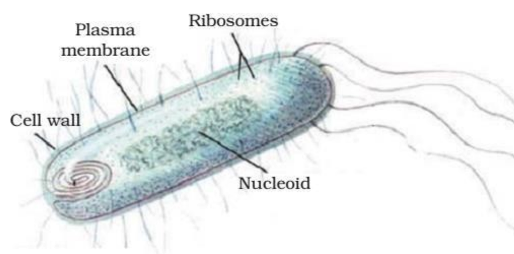


Fig. 5.4: *Prokaryotic cell*

	Prokaryotes	**Eukaryotes**
Organisms	Monera: Eubacteria and Archebacteria	Protists, Fungi, Plants and Animals
Meaning of name	Pro = before Karyon = nucleus	Eu = after Karyon = nucleus
Evolution	3.5 billion years ago (older type of cell)	1.5 billion years ago
Uni-/multicellular	Unicellular (less complex)	Multicellular (more complex)
Cell wall	almost all have cell walls (murein)	fungi and plants (cellulose and chitin): none in animals
Organelles	usually none	many different ones with specialized functions
Metabolism	anaerobic and aerobic: diverse	mostly aerobic
Genetic material	single circular double stranded DNA	complex chromosomes usually in pairs; each with a single double stranded DNA molecule and associated proteins contained in a nucleus
Location of genetic	Nucleoid region	Nucleus

information		
Mode of division	binary fission mostly; budding	mitosis and meiosis using a spindle: followed by cytokinesis

Nucleoid

5888 In some organisms like bacteria, the nuclear region of the cell may be **poorly defined** due to the **absence of a nuclear membrane**. Such an undefined nuclear region containing only **nucleic acids** is called a **nucleoid.**

Vacuoles

23 Empty structure in the cytoplasm is called vacuole. It could be single and big as in an onion cell (plant cell). Cheek cells (animal cells) have smaller vacuoles.

24 Large vacuoles are common in plant cells. Vacuoles in animal cells are much smaller.

25 Vacuoles are **storage sacs** for solid or liquid contents.

26 The central vacuole of some plant cells may occupy 50-90% of the cell volume.

27 In plant cells vacuoles are full of cell sap and provide **turgidity** [swollen and distended or congested] and **rigidity** to the cell.

28 Many substances of importance in the life of the plant cell are stored in vacuoles. These include amino acids, sugars, various organic acids and some proteins.

29 In single-celled organisms like amoeba, the food vacuole contains the food items that the amoeba has consumed.

30 In some unicellular organisms, specialized vacuoles also play important roles in expelling excess water and some wastes from the cell

Endoplasmic Reticulum (ER)

5888 The endoplasmic reticulum (ER) is a large network of membrane-bound tubes and sheets. It looks like long tubules or round or long bags (vesicles).

5889 The ER membrane is similar in structure to the plasma membrane.

5890 There are two types of ER — **rough endoplasmic reticulum (RER)** and **smooth endoplasmic reticulum (SER)**.

Rough Endoplasmic Reticulum RER – Ribosomes

23 RER looks rough under a microscope because it has particles called **ribosomes** attached to its surface.

24 The ribosomes, which are present in all active cells, are the **sites of protein manufacture.**

25 The manufactured proteins are then sent to various places in the cell depending on need, using the ER.

Smooth Endoplasmic Reticulum SER

5888 The SER helps in the manufacture of **fat molecules, or lipids**, important for cell function.

Functions of Endoplasmic Reticulum (ER)

23 Some of these proteins and lipids help in building the cell membrane. This process is known as **membrane biogenesis**.

24 Some other proteins and lipids function as **enzymes and hormones**.

25 Although the ER varies greatly in appearance in different cells, it always forms a network system.

26 Thus, one function of the ER is to serve as **channels for the transport** of materials (especially proteins) between various regions of the cytoplasm or between the cytoplasm and the nucleus.

27 The ER also functions as a cytoplasmic framework providing a **surface** for some of the **biochemical activities** of the cell.

28 **In the liver cells of the group of animals called vertebrates, SER plays a crucial role in detoxifying many poisons and drugs**.

Golgi Apparatus or Golgi Complex

5888 The golgi apparatus consists of a system of membrane-bound vesicles arranged approximately parallel to each other in stacks called **cisterns**.

5889 These membranes often have connections with the membranes of ER and therefore constitute another portion of a complex cellular membrane system.

5890 The material synthesized near the ER is **packaged and dispatched** to various targets inside and outside the cell through the golgi apparatus.

5891 Its functions include the **storage, modification and packaging** of products in vesicles.

23 In some cases, **complex sugars** may be made from simple sugars in the golgi apparatus.

24 The golgi apparatus is also involved in the formation of **lysosomes**.

Lysosomes

5888 Lysosomes are a kind of **waste disposal system** of the cell.

5889 Lysosomes help to keep the cell clean by digesting any foreign material as well as worn-out cell organelles.

5890 Foreign materials entering the cell, such as bacteria or food, as well as old organelles end up in the lysosomes, which break them up into small pieces. Lysosomes are able to do this because they contain **powerful digestive enzymes** capable of breaking down all organic material.

5891 During the disturbance in cellular metabolism, for example, when the cell gets damaged, lysosomes may burst and the enzymes digest their own cell. Therefore, lysosomes are also known as the **'suicide bags'** of a cell.

5892 Structurally, lysosomes are membrane-bound sacs filled with digestive enzymes. These enzymes are made by **RER**.

Mitochondria

0 Mitochondria are known as the **powerhouse** of the cell.

1 The energy required for various chemical activities needed for life is released by mitochondria in the form of **ATP** (Adenosine Triphosphate) molecules.

[If Mitochondria is the Power Plant. ATP is the Electricity].

23 ATP is known as the **energy currency** of the cell.

24 The body uses energy stored in ATP for making new chemical compounds and for mechanical work.

25 Mitochondria have **two membrane** coverings instead of just one.

26 The outer membrane is very porous while the inner membrane is **deeply folded**. These folds create a large surface area for **ATP-generating chemical reactions**.

27 Mitochondria are strange organelles in the sense ***that they have their own DNA*** and ***ribosomes***. Therefore, mitochondria are able to make some of their **own proteins [ribosomes prepare proteins]**.

Plastids

You might have noticed several small colored bodies in the cytoplasm of the cells of Tradescantia leaf. They are scattered in the cytoplasm of the leaf cells. These are called plastids.

They are of **different colours**. Some of them contain **green pigment** called **chlorophyll**. Green coloured plastids are called **chloroplasts**. They provide green colour to the leaves.

Chloroplasts are important for **photosynthesis** in plants.

Chloroplasts also contain various yellow or orange pigments in addition to chlorophyll.

Plastids are present **only in plant cells**. There are two types of plastids – **chromoplasts (coloured plastids)** and **leucoplasts (white or colourless plastids)**.

Leucoplasts are primarily organelles in which materials such as starch, oils and protein granules are stored.

The internal organization of the plastids consists of numerous membrane layers embedded in a material called the stroma.

Plastids are similar to mitochondria in external structure. Like the mitochondria, **plastids also have their own dna and ribosomes**.

Summary

Each cell acquires its structure and ability to function because of the organization of its membrane and organelles in specific ways. The cell thus has a basic structural organization. This helps the cells to perform functions like respiration, obtaining nutrition, and clearing of waste material, or forming new proteins. Thus, the cell is the fundamental structural unit of living organisms. It is also the basic functional unit of life.

Cells are enclosed by a plasma membrane composed of **lipids and proteins**.

The presence of the cell wall enables the cells of plants, fungi and bacteria to exist in hypotonic media without bursting.

The ER functions both as a passage way for intracellular transport and as a manufacturing surface.

The golgi apparatus consists of stacks of membrane-bound vesicles that function in the storage, modification and packaging of substances manufactured in the cell.

Most plant cells have large membranous organelles called plastids, which are of two types – chromoplasts and leucoplasts.

Chromoplasts that contain chlorophyll are called chloroplasts and they perform photosynthesis. Leucoplasts help in the storage of oils, starch and protein granules.

Most mature plant cells have a large central vacuole that helps to maintain the **turgidity** of the cell and stores important substances including wastes.

Prokaryotic cells have **no membrane-bound organelles**, their chromosomes are composed of only nucleic acid, and they have **only very small ribosomes** as organelles.

A white blood cell (**WBC**) in human blood is an example of a single cell which can change its shape.

Bacterial cell also has a cell wall.

In egg white material is albumin which solidifies on boiling. The yellow part is yolk. It is part of the single cell.

Valonia ventricosa, a species of algae with a diameter that ranges typically from 1 to 4 centimetres is among the largest unicellular species.

Plant Cell vs. Animal Cell

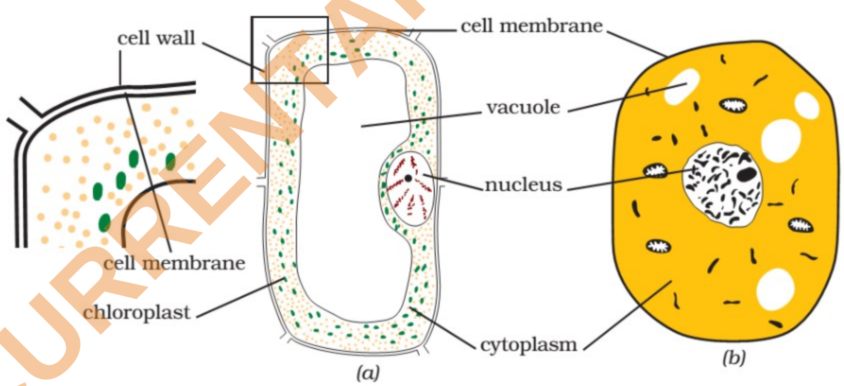


Fig. 8.7 : *(a) Plant cell (b) Animal cell*

Table 8.1 : Comparison of Plant Cell and Animal Cell

	Animal Cell	Plant Cell
Nucleus	Present	Present
Cilia	Present	It is very rare
Shape	Round (irregular shape)	Rectangular (fixed shape)
Chloroplast	Animal cells don't have chloroplasts	Plant cells have chloroplasts because they make their own food

Cytoplasm	Present	Present
Endoplasmic Reticulum (Smooth and Rough)	Present	Present
Ribosomes	Present	Present
Mitochondria	Present	Present
Vacuole	One or more small vacuoles (much smaller than plant cells).	One. large central vacuole taking up 90% of cell volume.

Questions

0 Can you name the two organelles we have studied that contain their own genetic material?
1 What would happen to the life of a cell if there was no golgi apparatus?
2 Where do the lipids and proteins constituting the cell membrane get synthesised?
3 What is osmosis?
4 Why are lysosomes known as suicide bags?
5 Where are proteins synthesized inside the cell?

Q1. Statements

Diffusion and osmosis are similar processes.
In osmosis, the particles flow from hypertonic solution to hypotonic solution.
In Reverse Osmosis, the particles flow from hypotonic solution to hypertonic solution.
Osmosis is used in water purification process.
Reverse osmosis is used by plant cells to avoid bursting due to plasmolysis.

Which of the above are true?

0 All
1 3,4 and 5 only
2 1,2 and 3 only
3 1 and 2 only

Q2. Statements

Protoplasm = Cytoplasm + Nucleus + Plasma Membrane

Osmosis happens in dead cells as well.

Bacteria have cell walls.

Virus are non-living substances.

Animals have no cell walls and vacuoles.

Which of the above are true?

0All

13,4 only

22, 3 and 5 only

31, 3 and 4 only

Answers

Q1→C

Q2→B

Any doubts? Leave a comment..

Biomolecules – Carbohydrates – Monosaccharides: Glucose, Fructose; Disaccharides: Sucrose, Lactose; Oligosaccharides and Polysaccharides: Starch, Cellulose, Glycogen.

Biomolecule

5888 A biomolecule [biological molecule] is any molecule that is present in living organisms — microorganisms, plants and animals.

5889 They are mostly made up of **carbon, oxygen, hydrogen** and **nitrogen**.

5890 **Proteins, carbohydrates, lipids,** and **nucleic acids [DNA** and **RNA]** are Macromolecules or Macro-biomolecules.

Table 9.4 Average Composition of Cells

Component	% of the total cellular mass
Water	70-90
Proteins	10-15
Carbohydrates	3
Lipids	2
Nucleic acids	5-7
Ions	1

23 Other small molecules such as vitamins, primary metabolites, secondary metabolites, etc. are also biomolecules.

24 Most biomolecules are organic compounds.

Metabolism == the chemical processes that occur within a living organism to maintain life.

Metabolite == a substance formed in or necessary for metabolism.

Primary metabolite == Metabolite that is directly involved in normal growth, development, and reproduction. Eg: **ethanol, lactic acid**, and **certain amino acids**.

Secondary metabolite == Metabolites that are not directly involved in the normal growth, development, or reproduction of an organism. Unlike primary metabolites, absence of secondary metabolites does not result in immediate death, but rather in long-term impairment. Eg: ergot alkaloids, antibiotics, etc.

Alkaloid == any of a class of nitrogenous organic compounds of plant origin which have pronounced physiological actions on humans. Eg: **morphine** obtained from **opium poppy**.

Carbohydrates

5888 Carbohydrates are one of the most important biomolecules that forms a major part of the living things.

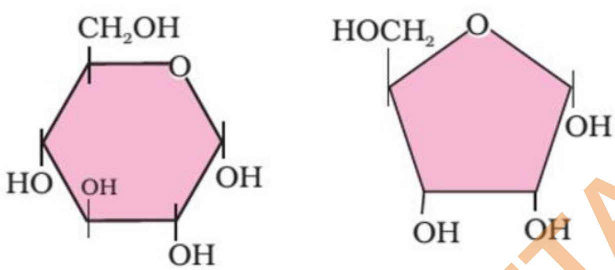
5889 Carbohydrates are primarily produced by **plants** and form a very large group of naturally occurring organic compounds.

5890 Some common examples of carbohydrates are cane **sugar, glucose, starch,** etc.

5891 Most of them have a general formula, **$C_x(H_2O)_y$**, and were considered as **hydrates of carbon** from where the name carbohydrate was derived.

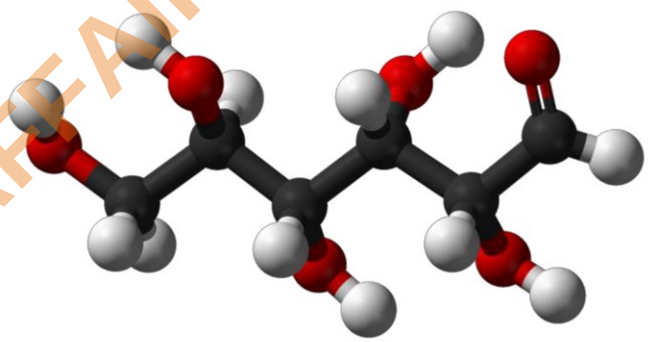
Hydrate == a compound in which water molecules are chemically bound to another compound or an element. Eg: α-d-Glucose hydrate ($C_6H_{14}O_7$).

23 For example, the molecular formula of glucose ($C_6H_{12}O_6$) fits into this general formula, $C_6(H_2O)_6$. But all the compounds which fit into this formula may not be classified as carbohydrates.



$C_6H_{12}O_6$ (Glucose) $C_5H_{10}O_5$ (Ribose)

Sugars (Carbohydrates)



Acetic acid (CH_3COOH) fits into this general formula **$C_x(H_2O)_y$** → $C_2(H_2O)_2$ but is **not a carbohydrate.**

Exception: **Rhamnose**, $C_6H_{12}O_5$ is a **carbohydrate** but does not fit in this definition of **$C_x(H_2O)_y$**.

5888 Chemically, the carbohydrates may be defined as optically active **polyhydroxy [multiple HO groups]** aldehydes or ketones or the compounds which produce such units on hydrolysis.

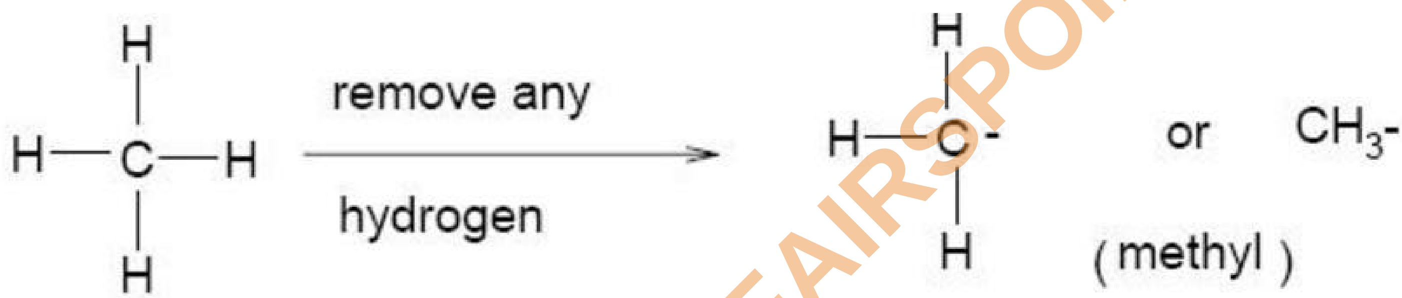
Carbohydrates produce **aldehydes** and **ketones** on **hydrolysis** [the chemical breakdown of a compound due to reaction with water].

Aldehyde == an organic compound containing the group — CHO, formed by the **oxidation of alcohols**. Typical aldehydes include methanal (formaldehyde) and ethanal (acetaldehyde).

Ketone == an organic compound containing a carbonyl group =C=O bonded to two alkyl groups, e.g. acetone].

Alkyl == denoting a hydrocarbon radical derived from an alkane by removal of a hydrogen atom].

Alkane == any of the series of saturated hydrocarbons including methane, ethane, propane, and higher members].



23 Some of the carbohydrates, which are sweet in taste, are also called **sugars**.

24 The most common sugar, used in our homes is named as **sucrose** whereas the sugar present in milk is known as **lactose**.

25 Carbohydrates are also called **saccharides** (Greek: sakcharon means sugar).

26 Carbohydrates are classified on the basis of their behavior on hydrolysis. They have been broadly divided into following three groups.

Monosaccharides

5888 A carbohydrate that cannot be hydrolyzed further to give simpler unit of polyhydroxy aldehyde or ketone is called a monosaccharide.

5889 About 20 monosaccharides are known to occur in nature. Some common examples are **Glucose**, **Fructose**, **Ribose**, **Galactose**, etc.

5890 If a monosaccharide contains an aldehyde group [–CHO], it is known as an **aldose** and if it contains a keto group [=C=O], it is known as a **ketose**.

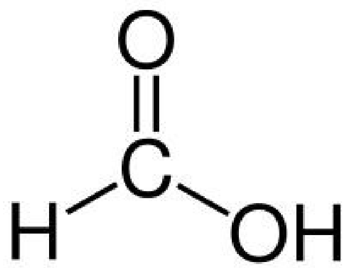
Glucose

23 Glucose occurs freely in nature as well as in the combined form.

5888 It is present in **sweet fruits** and **honey**. **Ripe grapes** also contain glucose in large amounts.

5889 Glucose is an **aldohexose [**An aldohexose is a hexose with an aldehyde group on one end**]** and is also known as **dextrose**. It is the **monomer** of many of the larger carbohydrates, namely **starch, cellulose**.

Aldohexose == An aldohexose is a hexose with an aldehyde group on one end.



Aldehyde group [–CHO]

Hexose == any of the class of simple sugars whose molecules contain six carbon atoms (e.g. glucose)

23 It is probably the most abundant organic compound on earth.

24 Glucose is found to exist in two different crystalline forms which are named as α and β.

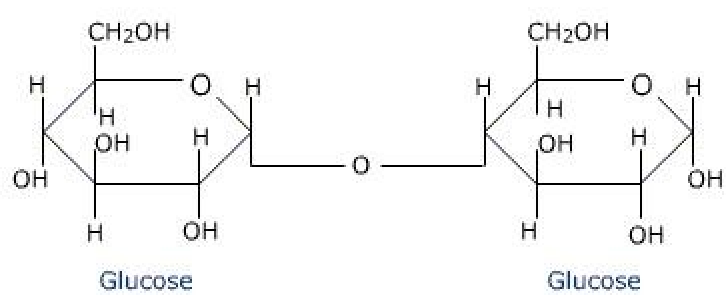
25 Such isomers, i.e., α-form and β-form, are called **anomers**.

Fructose

5888 Fructose is an important **ketohexose**. It is obtained along with glucose by the hydrolysis of disaccharide, **sucrose**.

5889 The two monosaccharides are joined together by an oxide linkage formed by the loss of a water molecule.

5890 Such a linkage between two monosaccharide units through **oxygen atom** is called ***Glycosidic Linkage***.



Ribose

23 The ribose β-D-ribofuranose forms part of the backbone of RNA. It is related to deoxyribose, which is found in DNA.

Galactose

5888 Galactose is a monosaccharide. When combined with glucose (monosaccharide), through a condensation reaction, the result is the disaccharide **lactose**.

5889 The hydrolysis of lactose to glucose and galactose is catalyzed by the enzymes **lactase** and β-**galactosidase**.

Oligosaccharides

23 Carbohydrates that yield **two to ten** monosaccharide units, on hydrolysis, are called oligosaccharides.

24 They are further classified as **disaccharides**, **trisaccharides**, **tetrasaccharides**, etc., depending upon the number of monosaccharides, they provide on hydrolysis.

25 Amongst these the most common are **disaccharides**.

26 The two monosaccharide units obtained on hydrolysis of a disaccharide may be **same or different.**

27 For example, sucrose on hydrolysis gives one molecule each of glucose and fructose whereas maltose gives two molecules of glucose only.

Sucrose == Glucose + Fructose

Maltose == Glucose + Glucose

Lactose == Glucose + Galactose

Sucrose

5888 One of the common disaccharides is sucrose which on hydrolysis gives equimolar mixture of glucose and fructose.

Maltose

23 Another disaccharide, maltose is composed of two α-D-glucose units

Lactose

5888 It is more commonly known as **milk sugar** since this **disaccharide is found in milk**.

It is composed of β-D-galactose and β-D-glucose.

Polysaccharides

23 Carbohydrates which yield a large number of monosaccharide units on hydrolysis are called polysaccharides.

24 Some common examples are **Starch, Cellulose, Glycogen, Gums,** etc.

25 Polysaccharides are **long chains of sugars**. Polysaccharides are ***not sweet*** in taste, hence they are also called **non-sugars**.

26 They are threads (literally a cotton thread) containing different **monosaccharides** as building blocks.

27 For example, **Cellulose** is a polymeric polysaccharide consisting of only one type of monosaccharide i.e., **Glucose**. Cellulose is a homopolymer. **Starch** is a variant of this but present as a store house of energy in plant tissues.

28 Animals have another variant called **Glycogen**.

29 **Inulin** is a polymer of **fructose**.

30 Plant cell walls are made of cellulose. Paper made from plant pulp and cotton fibre is **cellulosic**. There are more **complex polysaccharides** in nature.

31 Exoskeletons of arthropods, for example, have a complex polysaccharide called **chitin.** These complex polysaccharides are mostly homopolymers.

Starch

23 Polysaccharides contain a large number of monosaccharide units joined together by **glycosidic linkages**.

24 These are the **most commonly** encountered carbohydrates in nature.

25 They mainly act as the food storage or structural materials.

26 Starch is the main storage polysaccharide of plants.

27 It is the most **important dietary source** for human beings.

28 High content of starch is found in cereals, roots, tubers and some vegetables.

29 It is a polymer of α-glucose and consists of two components — **Amylose** and **Amylopectin**.

30 **Amylose is water soluble** polysaccharide which constitutes about 15-20% of starch.

31 **Amylopectin is water insoluble** polysaccharide which constitutes about 80- 85% of starch.

Cellulose

5888 Cellulose occurs **exclusively in plants** and it is the most abundant organic substance in plant kingdom.

5889 It is a predominant constituent of **cell wall** of plant cells.

5890 Cellulose is a straight chain polysaccharide **composed only of β-D-glucose units**.

Glycogen

23 The carbohydrates are stored in animal body as ***Glycogen.***

24 It is also known as **animal starch** because its structure is similar to amylopectin and is rather more highly branched.

25 It is present in **liver, muscles** and **brain**.

26 Glycogen is also found in yeast and fungi.

27 When the body needs glucose, enzymes break the glycogen down to glucose.

Importance of Carbohydrates

5888 Carbohydrates are essential for life in both plants and animals.

5889 They form a major portion of our food. Honey has been used for a long time as an instant source of energy in ayurvedic system of medicine.

5890 Carbohydrates are used as storage molecules as **starch in plants** and **glycogen in animals.**

5891 Cell wall of bacteria and plants is made up of cellulose which is a carbohydrate.

5892 We build furniture, etc. from cellulose in the form of wood and clothe ourselves with cellulose in the form of **cotton fibre**.

5893 They provide raw materials for many important industries like textiles, paper, lacquers and breweries.

Summary

5888 Carbohydrates are optically active polyhydroxy aldehydes or ketones or molecules which provide such units on hydrolysis.

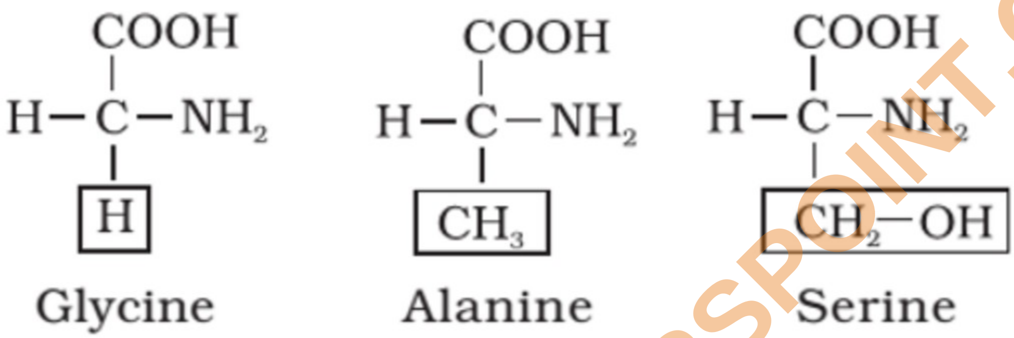
5889 They are broadly classified into three groups — monosaccharides, disaccharides and polysaccharides.

5890 Glucose, the most important source of energy for mammals, is obtained by the digestion of starch.

23 Monosaccharides are held together by glycosidic linkages to form disaccharides or polysaccharides.

Amino Acids

5888 Amino acids are organic compounds containing an **amino group [NH2]** and an **acidic group [COOH]** as substituents on the same carbon i.e., the a-carbon. Hence, they are called a-amino acids. They are **substituted methanes**.



Amino acids

TABLE 9.4 Average Composition of Cells

Component	% of the total cellular mass
Water	70-90
Proteins	10-15
Carbohydrates	3
Lipids	2
Nucleic acids	5-7
Ions	1

23 All proteins are **polymers of α-amino acids**.

24 Amino acids contain **amino (–NH2)** and **carboxyl (–COOH)** functional groups.

25 Depending upon the relative position of amino group with respect to carboxyl group, the amino acids can be classified as α, β, γ, δ and so on.

26 Only **α-amino acids** are obtained on hydrolysis of proteins.

27 All α-amino acids have trivial names, which usually reflect the property of that compound or its source.

28 **Glycine** is so named since it has **sweet taste** (in Greek glykos means sweet) and **tyrosine** was first obtained from cheese (in Greek, tyros means cheese.)

29 Amino acids are classified as acidic, basic or neutral depending upon the relative number of amino and carboxyl groups in their molecule.

5888 Equal number of amino and carboxyl groups makes it neutral;

5889 more number of amino than carboxyl groups makes it basic and

5890 more carboxyl groups as compared to amino groups makes it acidic.

5889 The amino acids, which can be synthesized in the body, are known as **nonessential amino acids**.

5890 On the other hand, those which cannot be synthesized in the body and must be obtained through diet, are known as **essential amino acids.**

5891 Amino acids are usually colorless, crystalline solids. These are **water-soluble**, high melting solids and behave like **salts** rather than simple amines or carboxylic acids.

5892 This behavior is due to the presence of both **acidic (carboxyl group)** and **basic (amino group) groups** in the same molecule.

5893 In aqueous solution, the carboxyl group can lose a proton and amino group can accept a proton, giving rise to a dipolar ion known as **zwitter ion**. This is neutral but contains both positive and negative charges.

5894 In zwitter ionic form, amino acids show **amphoteric** behavior as they react both with acids and bases.

5895 Except **glycine**, all other naturally occurring α-amino acids are **optically active**, since the α-carbon atom is asymmetric.

Optically Active: https://www.youtube.com/watch?v=gBELxxGbzKk

Proteins

23 Proteins are the **most abundant** biomolecules of the living system.

24 Chief sources of proteins are milk, cheese, pulses, peanuts, fish, meat, etc.

25 They occur in every part of the body and form the fundamental basis of structure and functions of life.

26 They are also required for **growth and maintenance** of body.

27 The word protein is derived from Greek word, “proteios” which means primary or of prime importance.

28 Proteins are **polypeptides**.

[**Peptide** == a compound consisting of two or more **amino acids** linked in a chain].

5888 Proteins are linear chains of amino acids linked by **peptide bonds**.

5889 Each protein is a **polymer of amino acids**.

[**Monomer** == a molecule that can be bonded to other identical molecules to form a polymer].

Therefore, amino acids can be essential or non-essential.

[**Non-Essential Amino Acids** == Amino Acids that our body can make].

[**Essential Amino Acids** == We get them through our diet/food].

0 **Collagen** is the most abundant protein in animal world.

1 **Ribulose bisphosphate Carboxylase-Oxygenase (RuBisCO)** is the most abundant protein in the whole of the biosphere.

Structure of Proteins

0 You have already read that proteins are the polymers of α-amino acids and they are connected to each other by **peptide bond** or **peptide linkage**.

1 Chemically, peptide linkage is an amide [an organic compound containing the group -C(O)NH2] formed between –COOH group and $–NH_2$ group.

2 The reaction between two molecules of similar or different amino acids, proceeds through the combination of the **amino group of one molecule** with the **carboxyl group of the other**.

3 This results in the elimination of a water molecule and formation of a **peptide bond –CO–NH–**. The product of the reaction is called a **dipeptide** because it is made up of **two amino acids**.

4 If a third amino acid combines to a dipeptide, the product is called a **tripeptide**.

5 **A tripeptide contains three amino acids linked by two peptide linkages**.

6 Similarly when four, five or six amino acids are linked, the respective products are known as tetrapeptide, pentapeptide or hexapeptide, respectively.

7 When the number of such amino acids is more than ten, then the products are called **polypeptides**.

8 A polypeptide with more than hundred amino acid residues, having molecular mass higher than 10,000u is called a **protein**.

9 However, the distinction between a polypeptide and a protein is not very sharp.

0 Polypeptides with fewer amino acids are likely to be called proteins if they ordinarily have a well-defined conformation of a protein such as **insulin** which contains **51 amino acids**.

1 Proteins can be classified into two types on the basis of their molecular shape: **Fibrous Proteins** and **Globular proteins**.

Fibrous proteins

0 When the polypeptide chains run parallel and are held together by **hydrogen** and **disulphide** bonds, then fibre– like structure is formed.

1 Such proteins are generally **insoluble in water**. Some common examples are **keratin** (present in hair, wool, silk) and **myosin** (present in muscles), etc.

Globular proteins

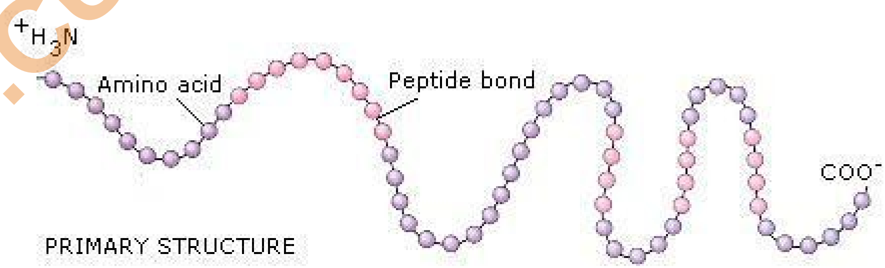
0 This structure results when the chains of polypeptides coil around to give a **spherical shape**.

1 These are usually **soluble in water**. **Insulin** and **albumin**s are the common examples of globular proteins.

Primary structure of proteins

0 Proteins may have one or more polypeptide chains. Each polypeptide in a protein has amino acids linked with each other in a specific sequence and it is this sequence of amino acids that is said to be the primary structure of that protein.

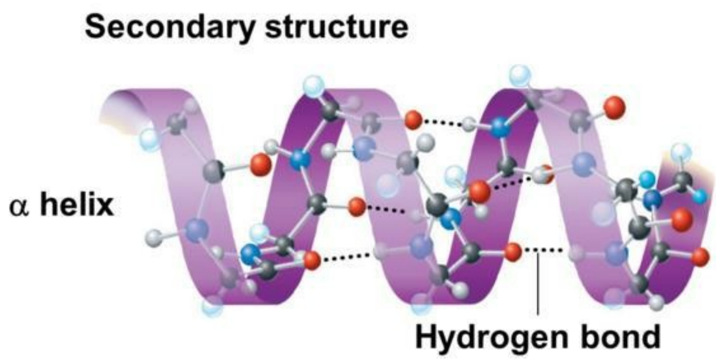
1 Any change in this primary structure i.e., the sequence of amino acids creates a different protein.



Secondary structure of proteins

The secondary structure of protein refers to the shape in which a long polypeptide chain can exist.

Protein found in a biological system with a unique three-dimensional structure and biological activity is called a **native protein**.



When a protein in its native form, is subjected to physical change like change in temperature or chemical change like change in pH, the hydrogen bonds are disturbed. Due to this, globules unfold and helix get uncoiled and **protein loses its biological activity**. This is called **denaturation of protein**.

During denaturation 2° and 3° structures are destroyed but 1° structure remains intact. The **coagulation of egg white** on boiling is a common example of denaturation. Another example is **curdling of milk** which is caused due to the formation of lactic acid by the bacteria present in milk.

Role of Proteins

Some transport nutrients across cell membrane,
some fight infectious organisms,
some are hormones,
some are enzymes, etc.

TABLE 9.5 Some Proteins and their Functions

Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception (smell, taste, hormone, etc.)
GLUT-4	Enables glucose transport into cells

Enzymes

Life is possible due to the coordination of various chemical reactions in living organisms. An example is the digestion of food, absorption of appropriate molecules and ultimately production of energy. This process involves a sequence of reactions and all these reactions occur in the body under very mild conditions. This occurs with the help of certain **biocatalysts** called **enzymes**.

Catalyst == a substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change.

Almost all the enzymes are **globular proteins**.

Enzymes are very specific for a particular reaction and for a particular substrate.

They are generally named after the compound or class of compounds upon which they work. For example, the enzyme that catalyses hydrolysis of maltose into glucose is named as **maltase**.

Sometimes enzymes are also named after the reaction, where they are used. For example, the enzymes which catalyse the oxidation of one substrate with simultaneous reduction of another substrate are named as **oxidoreductase** enzymes. The ending of the name of an enzyme is **-ase**.

Almost all enzymes are proteins.

There are some **nucleic acids** that behave like enzymes. These are called **ribozymes**.

An enzyme like any protein has a primary structure, i.e., amino acid sequence of the protein.

Enzyme catalysts differ from inorganic catalysts in many ways. Inorganic catalysts work efficiently at high temperatures and high pressures, while enzymes get damaged at high temperatures (say above 40°C).

However, enzymes isolated from organisms who normally live under extremely high temperatures (e.g., hot vents and sulphur springs), are stable and retain their catalytic power even at high temperatures (up to 80°-90°C). Thermal stability is thus an important quality of such enzymes isolated from thermophilic organisms.

Thermophile == a bacterium or other microorganism that grows best at high temperatures (above 45°C).

Factors Affecting Enzyme Activity

The activity of an enzyme can be affected by a change in the conditions which can alter the structure of the protein. These include temperature, pH, change in substrate concentration or binding of specific chemicals that regulate its activity.

Temperature and pH

Enzymes generally function in a narrow range of temperature and pH.

Each enzyme shows its highest activity at a particular temperature and pH called the **optimum temperature and optimum pH**.

Activity declines both below and above the optimum value.

Low temperature preserves the enzyme in a **temporarily inactive state** whereas high temperature **destroys enzymatic activity** because proteins are **denatured by heat**.

Concentration of Substrate

With the increase in substrate concentration, the velocity of the enzymatic reaction rises at first. The reaction ultimately reaches a maximum velocity (Vmax) which is not exceeded by any further rise in concentration of the substrate. This is because the enzyme molecules are fewer than the substrate molecules and after saturation of these molecules, there are no free enzyme molecules to bind with the additional substrate molecules.

The activity of an enzyme is also sensitive to the presence of specific chemicals that bind to the enzyme. When the binding of the chemical shuts off enzyme activity, the process is called **inhibition** and the chemical is called an **inhibitor**.

When the inhibitor closely resembles the substrate in its molecular structure and inhibits the activity of the enzyme, it is known as **competitive inhibitor**.

Summary

Proteins are the polymers of about twenty different α-amino acids which are linked by **peptide bonds**.

Ten amino acids are called essential amino acids because they cannot be synthesised by our body, hence must be provided through diet.

Proteins perform various structural and dynamic functions in the organisms.

Proteins which contain only α-amino acids are called **simple proteins**.

The secondary or tertiary structure of proteins get disturbed on change of pH or temperature and they are not able to perform their functions. This is called **denaturation of proteins**.

Enzymes are biocatalysts which speed up the reactions in biosystems. They are very specific and selective in their action and chemically all enzymes are proteins.

Primary and Secondary Metabolites, Vitamins, Deficiency Diseases, Micronutrients – Vitamins and Minerals, Food Sources of Vitamins and Minerals.

Primary and Secondary Metabolites

In animal tissues, one notices the presence of all categories of compounds shown in Figure 9.1. These are called primary metabolites.

However, when one analyses plant, fungal and microbial cells, one would see thousands of compounds other than these called primary metabolites, e.g. alkaloids, flavonoids, rubber, essential oils, antibiotics, colored pigments, scents, gums, spices. These are called secondary metabolites.

TABLE 9.1 A Comparison of Elements Present in Non-living and Living Matter*

Element	% Weight of Earth's crust	Human body
Hydrogen (H)	0.14	0.5
Carbon (C)	0.03	18.5
Oxygen (O)	46.6	65.0
Nitrogen (N)	very little	3.3
Sulphur (S)	0.03	0.3
Sodium (Na)	2.8	0.2
Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (Si)	27.7	negligible

TABLE 9.2 A List of Representative Inorganic Constituents of Living Tissues

Component	Formula
Sodium	Na^+
Potassium	K^+
Calcium	Ca^{++}
Magnesium	Mg^{++}
Water	H_2O
Compounds	$NaCl$, $CaCO_3$, PO_4^{3-}, SO_4^{2-}

TABLE 9.3 Some Secondary Metabolites

Pigments	Carotenoids, Anthocyanins, etc.
Alkaloids	Morphine, Codeine, etc.
Terpenoides	Monoterpenes, Diterpenes etc.
Essential oils	Lemon grass oil, etc.
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Drugs	Vinblastin, curcumin, etc.
Polymeric substances	Rubber, gums, cellulose

TABLE 9.4 Average Composition of Cells

Component	% of the total cellular mass
Water	70-90
Proteins	10-15
Carbohydrates	3
Lipids	2
Nucleic acids	5-7
Ions	1

Vitamins

Vitamins are organic compounds that are required in small amounts in our diet but their deficiency causes specific diseases.

Most of the vitamins cannot be synthesized in our body but plants can synthesize almost all of them, so they are considered as **essential food factors**.

However, the **bacteria of the gut** can produce some of the vitamins required by us.

All the vitamins are generally available in our diet. Different vitamins belong to various chemical classes and it is difficult to define them on the basis of structure.

They are generally regarded as **organic compounds** required in the diet in **small amounts** to perform **specific biological functions** for normal maintenance of optimum growth and health of the organism.

Vitamins are designated by alphabets A, B, C, D, etc. Some of them are further named as sub-groups e.g. B1, B2, B6, B12, etc.

Vitamin A keeps our skin and eyes healthy.

Vitamin C helps body to fight against many diseases. Vitamin C gets easily destroyed by heat during cooking.

Vitamin D helps our body to use calcium for bones and teeth.

Excess of vitamins is also harmful and vitamin pills should not be taken without the advice of doctor.

The term "Vitamine" was coined from the word vital + amine since the earlier identified compounds had amino groups.

Later work showed that most of them did not contain amino groups, so the letter 'e' was dropped and the term vitamin is used these days.

Vitamins are classified into two groups depending upon their **solubility** in water or fat.

Fat soluble vitamins

Vitamins which are soluble in fat and oils but insoluble in water are kept in this group. These are vitamins **A, D, E and K**. They are stored in **liver** and **adipose (fat storing) tissues**.

Water soluble vitamins

B group vitamins and vitamin **C** are soluble in water so they are grouped together.

Water soluble vitamins **must be supplied regularly** in diet because they are readily **excreted in urine and cannot be stored** (except vitamin B12) in our body.

Deficiency Diseases

A person may be getting enough food to eat, but sometimes the food may not contain a particular nutrient. If this continues over a long period of time, the person may suffer from its deficiency.

Deficiency of one or more nutrients can cause diseases or disorders in our body. Diseases that occur due to lack of nutrients over a long period are called deficiency diseases.

Vitamin/ Mineral	Deficiency disease/disorder	Symptoms
Vitamin A	Loss of vision	Poor vision, loss of vision in darkness (night), sometimes complete loss of vision
Vitamin B1	Beriberi	Weak muscles and very little energy to work
Vitamin C	Scurvy	Bleeding gums, wounds take longer time to heal
Vitamin D	Rickets	Bones become soft and bent
Calcium	Bone and tooth decay	Weak bones, tooth decay
Iodine	Goiter	Glands in the neck appear swollen, mental disability in children
Iron	Anaemia	Weakness

a) Vitamin A--------- Night blindness

b) Vitamin B1--------- Beriberi

c) Vitamin B2-------- Ariboflavinosis

d) Vitamin B3 -------- Pellagra

e) Vitamin B5 -------- Paresthesia

f) Vitamin B6 -------- Anemia

g) Vitamin B7 ------ Dermatitis, enteritis

h) Vitamin B9 & Vitamin B12 ----- Megaloblastic anemia

Vitamin C ------ Scurvy, Swelling of Gums

Vitamin D ------ Rickets & Osteomalacia

Vitamin E ------ Less Fertility

Vitamin K ------ Non-Clotting of Blood.

Micronutrients – Vitamins and Minerals

https://www.dsm.com/content/dam/dsm/cworld/en_US/documents/what-are-micronutrients.pdf

Micronutrients, as opposed to macronutrients (protein, carbohydrates and fat), are comprised of **vitamins and minerals** which are required in small quantities to ensure normal metabolism, growth and physical well-being.

Vitamins

These are essential organic nutrients, most of which are not made in the body, or only in insufficient amounts, and are mainly obtained through food.

When their intake is inadequate, vitamin deficiency disorders are the consequence.

Although vitamins are only present and required in minute quantities, compared to the macronutrients, they are as vital to health and need to be considered when determining nutrition security.

Each of the 13 vitamins known today have specific functions in the body: **vitamin A, provitamin A (Beta-carotene), vitamin B1, vitamin B2, vitamin B6, vitamin B12, biotin, vitamin C, vitamin D, vitamin E, folic acid, vitamin K, niacin and pantothenic acid.**

Minerals

These are inorganic nutrients that also play a key role in ensuring health and well- being.

They include the trace elements **copper, iodine, iron, manganese, selenium and zinc** together with the macro elements **calcium, magnesium, potassium and sodium**.

Five Important Micronutrients

As with vitamins, minerals they are found in small quantities within the body and they are obtained from a wide variety of foods.

No single food contains all of the vitamins and minerals we need and, therefore, a balanced and varied diet is necessary for an adequate intake.

Of course, we already know a huge amount about how these work, and the importance they have in normal human growth and development.

Based on this, an Expert Panel of nutritionist, NGOs and development agencies indentified five micronutrients such as those below in their priority group:

Vitamin A

This vital micronutrient is found in a range of different foods including carrots, spinach, broccoli, milk, egg, liver and fish.

It plays an essential role in **vision** (lack of Vitamin A is a common cause of blindness), reproduction and growth, and the functioning of a healthy immune system (it plays a key role in the development of white blood cells).

Worldwide about 5 million children under the age of five are affected by **xerophthalmia**, a serious eye disorder caused by vitamin A deficiency.

These children are at **risk of becoming blind** and are more likely to die of common childhood diseases.

Folate (folic acid)

This is a generic term for a **group of B vitamins** including **folic acid** and naturally occurring **folates.**

Folic acid is a synthetic folate compound used in vitamin supplements and fortified food because of its increased stability.

Folates are found in egg, dairy products, asparagus, orange juice, dark green leafy vegetables, beans and brown bread.

They play a key role in the **metabolism of amino acids** and the **production of proteins**, the **synthesis of nucleic acid** (the molecules that carry genetic information in the cells), and the **formation of blood cells**.

Iodine

Seaweed and fish are rich sources but in many countries the addition of iodine (known as iodization) to salt is an important source.

Iodine is one of the most important elements required by the **developing foetus** due to its effect on **brain development**.

Iodine also serves a number of other important functions especially in the **production of hormones.**

Goitre is a visible sign of severe iodine deficiency.

Iron

Iron has a number of key functions within the body. It acts as a **carrier for oxygen** from the lungs to the body's tissues – it does so in the form of **hemoglobin** – and it also integral to the working of various tissues through the role that it plays in enzymatic reactions.

Iron deficiency ultimately leads to **iron deficiency anemia**, the most common cause of anemia, a condition in which the blood lacks healthy red bloods cells required to carry oxygen, and which results in morbidity and death.

Iron deficiency is the most widespread health problem in the world, impairing normal mental development in 40-60% of infants in the developing world.

Iron-rich foods include lentils, red meat, poultry, fish, lentils, leaf vegetables and chick-peas.

Zinc

Found in a range of foodstuffs including liver, eggs, nuts, cereals and seafood.

The absence of zinc is associated with a number of conditions including, **short stature, anemia, impaired healing of wounds, poor gonadal function, and impaired cognitive and motor function.**

It can also lead to appetite disorders, as well as contributing to the increased severity and incidence of **diarrhea and pneumonia**.

The most important effect of zinc deficiency is its impact on children's resistance to infectious diseases including the **risk of infection**, the recurrence of infections and the severity of infection. This is well document in the case of diarrhoea. Zinc nutrition is therefore an important determinant of mortality in children.

Food Sources of Vitamins and Minerals

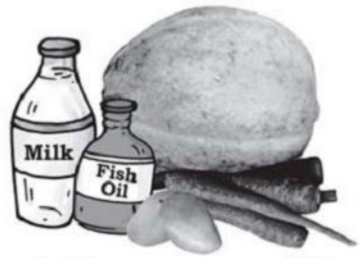


Fig. 2.6 *Some sources of Vitamin A*

Fig. 2.7 *Some sources of Vitamin B*

Fig. 2.8 *Some sources of Vitamin C*

Fig. 2.9 *Some sources of Vitamin D*

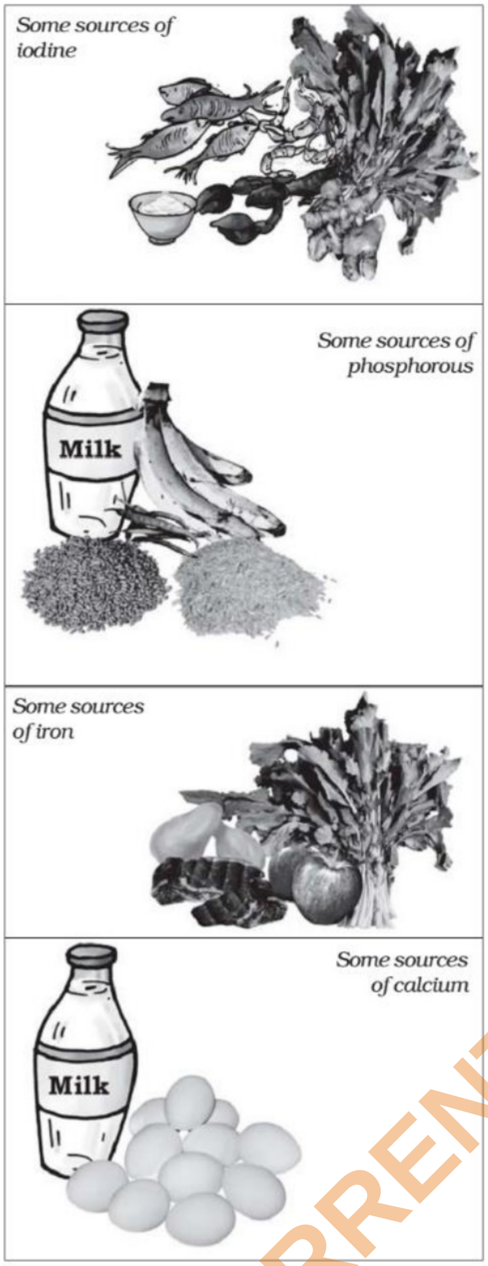


Fig. 2.10 Sources of some minerals

Dietry Fibers

Dietary fibres are also known as roughage. Roughage is mainly provided by plant products in our foods.

Whole grains and pulses, potatoes, fresh fruits and vegetables are main sources of roughage.

Roughage does not provide any nutrient to our body, but is an essential component of our food and adds to its bulk. This helps our body get rid of undigested food.

Questions

Q1. Besides proteins and carbohydrates, other elements of nutritional value found in milk, include [1996]

Calcium, potassium and iron

Calcium and potassium

Potassium and iron

Calcium and iron

http://www.thedoctorwillseeyounow.com/content/kids/art3933.html

Q2. What is average fat content of Buffalo Milk?

7.2%

4.5%

9.0%

10.0%

Buffalo Milk → 7.2%

Cow Milk → 4.4%

Buffalo's milk contain all nutrients in higher proportion than the cow's milk.

Q3. Prelims GS 2014: Consider the following pairs:

Vitamin Deficiency	*Disease*
1. Vitamin C	*Scurvy*
2. Vitamin D	*Rickets*
3. Vitamin E	*Night blindness*

Which of the pairs given above is/ are correctly matched?

1 and 2 only

3 only

1, 2 and 3

None

DNA and RNA | Deoxyribonucleic Acid | Ribonucleic Acid – Chromosomes, Nucleotide and Nucleoside, Nucleic acids, DNA and RNA, Recombinant DNA.

Nucleus

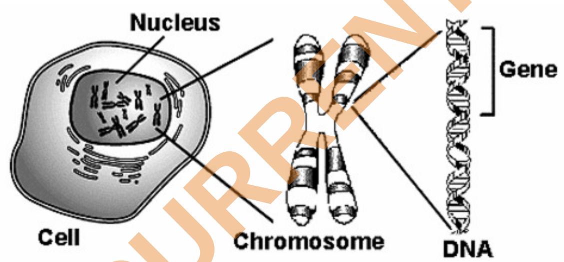
Nucleus contains thread-like structures called **chromosomes** [long continuous molecule of DNA]. These carry **genes** and help in **inheritance** or transfer of characters from the parents to the offspring. The chromosomes can be seen **only** when the cell divides.

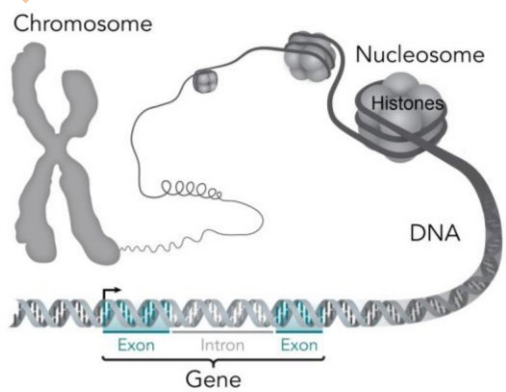
Gene is a **unit of inheritance** in living organisms. It controls the transfer of a hereditary characteristic from parents to offspring.

Chromosomes

In a cell which is not dividing, dna is present as part of **chromatin material**. Chromatin material is visible as entangled mass of thread like structures.

The **nucleosome** is the fundamental subunit of chromatin. Each nucleosome is composed of a little less than two turns of DNA wrapped around a set of eight proteins called **histones**.





Whenever the cell is about to divide, the chromatin material gets **organized into chromosomes**.

Chromosomes are visible as rod-shaped structures **only** when the cell is about to divide.

Chromosomes are composed of **DNA** and **Protein**. Chromosomes contain **information for inheritance** of features from parents to next generation in the form of **DNA** (deoxyribo nucleic acid) molecules.

DNA molecules contain the information necessary for constructing and organizing cells. Functional segments of dna are called **genes**.

Nucleotide and Nucleoside

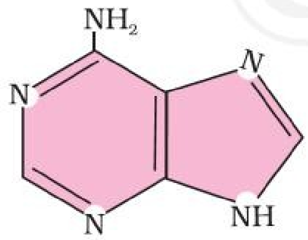
- Living organisms have a number of carbon compounds in which **heterocyclic rings** can be found.
- When heterocyclic rings are attached to a **sugar**, they are called **nucleosides**.
- If a **phosphate group** is also found esterified to the sugar they are called **nucleotides**.
- Nucleic acids like **DNA** and **RNA** consist of **nucleotides** only.

Heterocyclic Rings == A heterocyclic compound or ring structure is a cyclic compound that has atoms of at least two different elements as members of its ring(s).

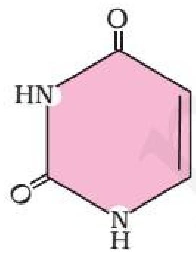
Ester == An organic compound made by replacing the hydrogen of an acid by an alkyl or other organic group.

Nucleic Acids

- Nucleic acid is a macromolecule that is found in the **acid insoluble** fraction of any living tissue.
- Together with polysaccharides and polypeptides these comprise the true macromolecular fraction of any living tissue or cell.
- For nucleic acids, the building block is a **nucleotide,** i.e. nucleic acids are polymers of nucleotides.
- Since nucleic acids are long chain polymers of nucleotides, they are also called **polynucleotides**.
- The nucleotides are joined to one another in a chain by **covalent bonds** between the sugar of one nucleotide and the phosphate of the next, resulting in an alternating **sugar-phosphate backbone**.
- A nucleotide has three chemically distinct components. One is a **heterocyclic compound**, the second is a **monosaccharide** and the third a **phosphoric acid** or **phosphate**.
- The sugar found in polynucleotides is either **ribose (a monosaccharide pentose)** or **deoxyribose**.
- The heterocyclic compounds in nucleic acids are the nitrogenous bases named **Adenine, Guanine, Uracil, Cytosine,** and **Thymine**.

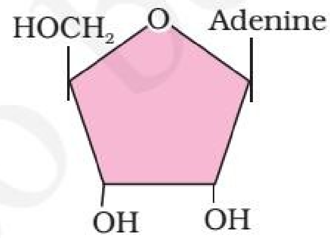


Adenine (Purine)

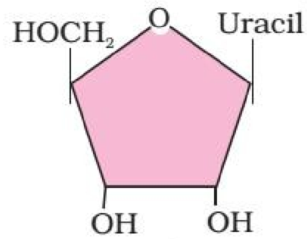


Uracil (Pyrimidine)

Nitrogen bases

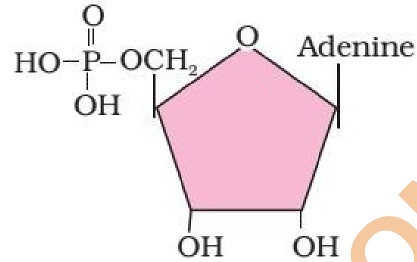


Adenosine



Uridine

Nucleosides



Adenylic acid

Nucleotide

DNA and RNA

Every generation of each and every species resembles its ancestors in many ways. How are these characteristics transmitted from one generation to the next?

It has been observed that **nucleus** of a living cell is responsible for this transmission of inherent characters, also called **heredity**.

The particles in nucleus of the cell, responsible for heredity, are called **chromosomes** which are made up of **proteins** and another type of biomolecules called **nucleic acids**.

Nucleic acids are responsible for the transfer of characters from parents to off springs. There are two types of nucleic acids — DNA and RNA.

A nucleic acid containing deoxyribose is called deoxyribonucleic acid **(DNA)** while that which contains ribose is called ribonucleic acid **(RNA)**.

Both DNA and RNA contain **Adenine, Guanine and Cytosine**. The fourth base is **Thymine in DNA** and **Uracil in RNA**.

The structure of DNA is a double strand [helix] whereas RNA is a single strand molecule.

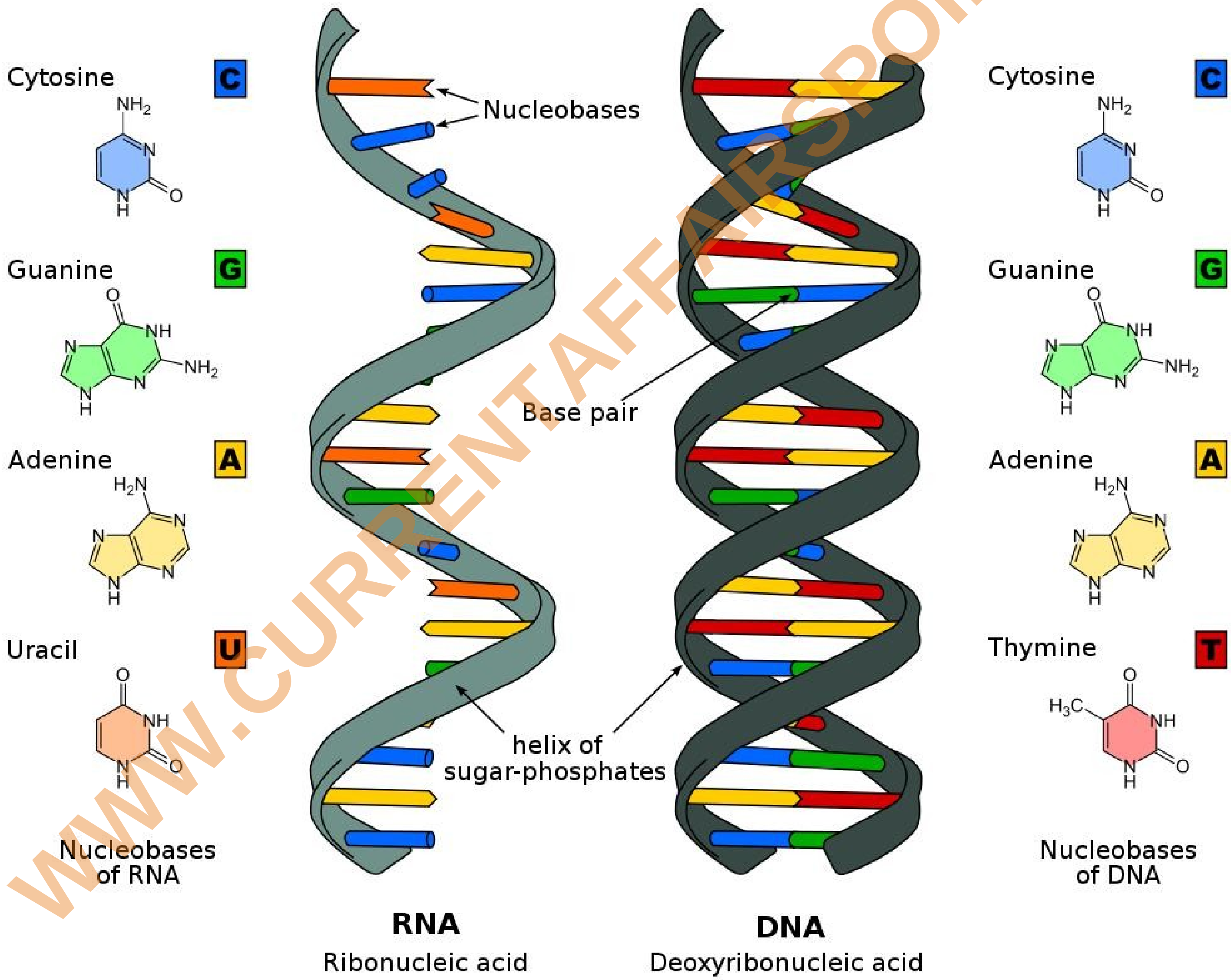
Hydrogen bonds bind the nitrogenous bases of the two separate polynucleotide strands to make double-stranded DNA.

The DNA backbone is resistant to cleavage, and both strands of the double-stranded structure store the **same** biological information. Biological information is **replicated** as the two strands are separated.

Within cells, DNA is organized into long structures called **chromosomes**. During cell division these chromosomes are duplicated in the process of **DNA replication**, providing each cell its own complete set of chromosomes.

Eukaryotic organisms (animals, plants, fungi, and protists) store most of their DNA inside the cell nucleus and some of their DNA in organelles, such as **mitochondria** or **chloroplasts**.

In contrast, prokaryotes (bacteria and archaea) store their DNA only in the **cytoplasm**.



DNA is the **chemical basis of heredity** and have the coded message for proteins to be synthesized in the cell.

There are three types of RNA — mRNA, rRNA and tRNA which actually carry out the **protein synthesis** in the cell based on the coded message for proteins provided by DNA.

Ribonucleic acid (RNA) is implicated in various biological roles in coding, decoding, regulation, and expression of genes.

Cellular organisms use messenger RNA (mRNA) to convey genetic information that directs synthesis of specific proteins.

Many viruses encode their genetic information using an RNA genome. Example: HIV virus used this technique to proliferate within human body.

Biological Functions of Nucleic Acids – DNA and RNA

DNA is the chemical basis of heredity and may be regarded as the **reserve of genetic information**.

DNA is exclusively responsible for maintaining the identity of different species of organisms over millions of years.

A DNA molecule is capable of **self-duplication** during cell division and identical DNA strands are transferred to daughter cells.

Another important function of nucleic acids is the protein synthesis in the cell. Actually, the proteins are synthesized by various **RNA** molecules in the cell but the message for the synthesis of a particular protein is present in **DNA**.

DNA Fingerprinting

It is known that every individual has unique fingerprints. These occur at the tips of the fingers and have been used for identification for a long time but these can be altered by surgery.

A sequence of bases on DNA is also **unique** for a person and information regarding this is called DNA fingerprinting. It is same for every cell and cannot be altered by any known treatment.

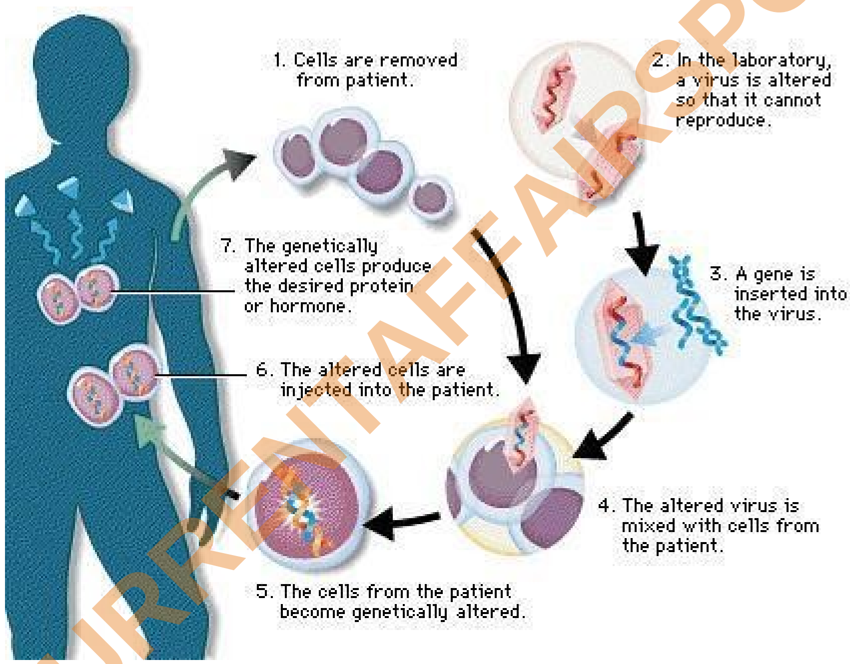
DNA fingerprinting is now used (i) in forensic laboratories for identification of criminals. (ii) to determine paternity of an individual. (iii) to identify the dead bodies in any accident by comparing the DNA's of parents or children. (iv) to identify racial groups to rewrite biological evolution.

Recombinant DNA

Recombinant DNA (rDNA) molecules are DNA molecules formed by laboratory methods of genetic recombination (such as molecular cloning) to bring together genetic material from **multiple** sources, creating sequences that would not otherwise be found in the genome.

Recombinant DNA is possible because DNA molecules from all organisms share the **same** chemical structure. They **differ** only in the **nucleotide sequence** within that identical overall structure.

In most cases, organisms containing recombinant DNA have apparently normal phenotypes. That is, their appearance, behavior and metabolism are usually unchanged.



Applications of recombinant DNA technology

Recombinant DNA is widely used in biotechnology, medicine and research.

Recombinant DNA is used to identify, map and sequence genes, and to determine their function.

Recombinant DNA is used to produce

Recombinant human insulin,

Recombinant human growth hormone,

Recombinant blood clotting factor VIII,

Recombinant hepatitis B vaccine,

Insect-resistant crops etc.

Fats - Lipid, Fatty Acid, Saturated fat, Unsaturated fat. Healthy Fats – Omega-3 and Omega-6, Monounsaturated and Polyunsaturated. Unhealthy Fats – Saturated Fat and Trans Fat.

Fat

Fat is one of the three main macronutrients: fat, carbohydrate, and protein.

Fat is a major source of energy and helps your body absorb vitamins.

Fat has the most calories compared to any other nutrient. Controlling fat intake is one of the most important steps in losing or maintaining weight and preventing or delaying type 2 diabetes.

Fats, also known as **triglycerides**, are esters of three **fatty acid chains** and the **alcohol glycerol**.

Fats are solids at room temperature. Oil refers to a fat with unsaturated fatty acid chains that is liquid at room temperature.

Fats, like other lipids, are generally **insoluble in water**.

Lipid

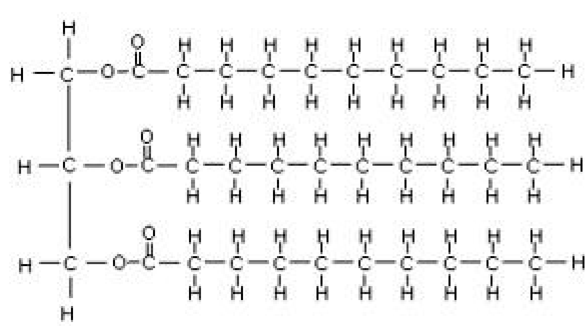
A lipid is chemically defined as a substance that is **insoluble in water** and soluble in alcohol and chloroform.

Lipids are an important component of living cells. Together with carbohydrates and proteins, lipids are the main constituents of plant and animal cells.

Cholesterol and **triglycerides** are lipids. Lipid is not necessarily a triglyceride.

Glycerol is a simple sugar alcohol compound. A triglyceride is an ester derived from glycerol and three fatty acids (tri + glyceride)

Triglycerides are the main constituent of body fat in humans and animals, as well as vegetable fat.



Triglycéride

Fatty Acid

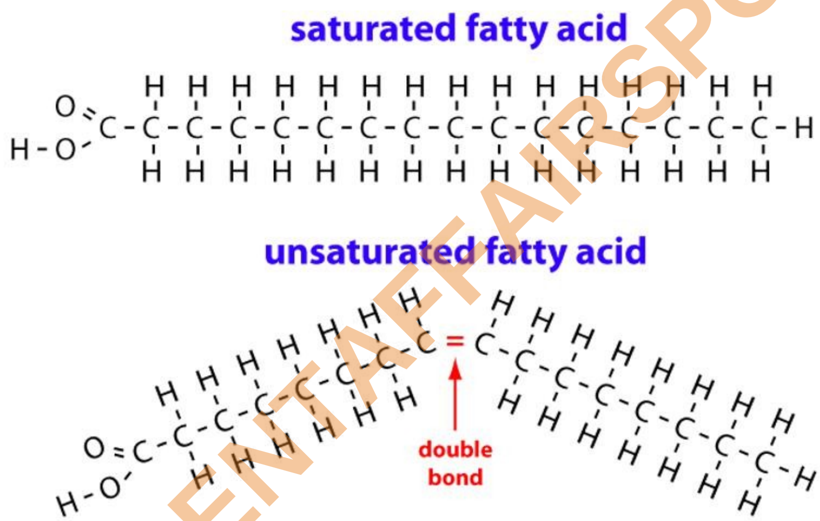
A fatty acid is a carboxylic acid with a long aliphatic chain [organic compounds in which carbon atoms form open chains], which is either saturated or unsaturated.

Some fatty acids are called essential because they cannot be synthesized in the body from simpler constituents.

There are two essential fatty acids (EFAs) in human nutrition: **alpha-linolenic acid (an omega-3 fatty acid)** and **linoleic acid (an omega-6 fatty acid).**

Fats and other lipids are broken down in the body by enzymes called **LIPASES** produced in the **pancreas.**

Fats are made of long chains of carbon (C) atoms. Some carbon atoms are linked by single bonds (-C-C-) and others are linked by double bonds (-C=C-).



Saturated fat

A saturated fat is a fat in which the fatty acids all have **single bonds**.

A saturated fat has the maximum number of hydrogens bonded to the carbons, and therefore is 'saturated' with hydrogen atoms.

Most animal fats are saturated whereas the **fats of plants and fish are generally unsaturated**.

Many experts recommend a **diet low in saturated fat**.

Saturated fats are popular with manufacturers of processed foods because they are **less vulnerable to rancidity** and are, in general, **more solid at room temperature** than unsaturated fats.

Unsaturated fat

An unsaturated fat is a fat or fatty acid in which there is at least one **double bond** within the fatty acid chain.

Where double bonds are formed, hydrogen atoms are eliminated.

In cellular metabolism, unsaturated fat molecules contain somewhat less energy (i.e., fewer calories) than an equivalent amount of saturated fat.

The greater the degree of unsaturation in a fatty acid (i.e., the more double bonds in the fatty acid) the more vulnerable it is to **rancidity** [lipid oxidation][rusting of fats].

Antioxidants can protect unsaturated fat from lipid oxidation.

Healthy Fats – Omega-3 and Omega-6, Monounsaturated and Polyunsaturated

The main types of "healthy" fats are **monounsaturated**, **polyunsaturated, alpha-linolenic acid (an omega-3 fatty acid)** and **linoleic acid (an omega-6 fatty acid)**.

The fat is termed "monounsaturated" if there is one double bond, and "polyunsaturated" if there are two or more double bonds.

Omega-3 and Omega-6 fatty acids are heart healthy fats and can help in lowering high triglyceride values in blood. They are found in fish, soybean products, Walnuts etc.

Both of these fatty acids are needed for growth and repair, but can also be used to make other fatty acids.

The omega-3 and omega-6 are fatty acids are both polyunsaturated. The difference is in where the first of the double bonds occurs.

Both omega-3 (ω-3) and omega-6 (ω-6) fatty acids are important components of cell membranes.

There is increasing support for omega-3 fatty acids in protecting against fatal heart disease and it is known that they have **anti-inflammatory effects**.

There is also growing interest in the role of omega-3 fatty acids in the prevention of diabetes and certain types of cancer.

Monounsaturated and polyunsaturated fat are considered "heart healthy" and can help with improving cholesterol when used in place of unhealthy fats.

Some sources of these fats include almonds, cashews, pecans, peanuts, pine nuts, pumpkin, sesame seeds, sunflower seeds, Olive oil and olives, vegetable oils (such as sunflower, safflower, corn, soybean, and cottonseed).

Unhealthy Fats – Saturated Fat and Trans Fat

The main types of "unhealthy" fats are **saturated** and **trans-fat**.

Saturated fats are primarily found in foods that come from animals, such as meat and dairy.

Saturated fats are unhealthy because they increase LDL ("bad" cholesterol) levels in your body and increase your risk for heart disease.

Many saturated fats are "solid" fats that you can see, such as the fat in meat. Other sources of saturated fats include high-fat cheeses, high-fat cuts of meat, butter, Ice cream, palm and coconut oils, etc..

Trans fats, or trans-unsaturated fatty acids, trans fatty acids, are a type of unsaturated fats that are uncommon in nature.

Trans fat is simply **liquid oils turned into solid fats** during food processing. There is also a small amount of trans fat that occurs naturally in some meat and dairy products, but those found in processed foods tend to be the most harmful to your health.

Trans fats are worse than saturated fats. They increase LDL ("bad" cholesterol) and decreasing HDL ("healthy" cholesterol).

Trans fatty acids are used as preservative in packaged food items. Foods containing trans-fat are usually labeled as "**partially hydrogenated**".

Partially hydrogenated oil is less likely to spoil, so foods made with it have a longer shelf life.

Trans fats are easy to use, inexpensive to produce and last a long time. Trans fats give foods a desirable taste and texture.

Q1. Statements:

Trans fats are considered beneficial for the human body

Double bond chemistry of the fat molecules in Trans fats causes a Plaque formation

Omega-3 fatty acids are considered healthier than the saturated fatty acids

Codes:

1 & 3

2 & 3

1 & 2

d) 1, 2, 3

Ans. B

Adipose tissue

In animals, adipose, or fatty tissue with adipose cells is the body's means of storing fat derived from the diet and from liver metabolism.

Under stress conditions, adipose cells degrade their stored fat to supply fatty acids and also glycerol.

These metabolic activities are regulated by several hormones (e.g., insulin, glucagon and epinephrine).

Metabolic Basis for Living

Metabolic pathways can lead to a more complex structure from a simpler structure (for example, **acetic acid becomes cholesterol**) or lead to a simpler structure from a complex structure (for example, **glucose becomes lactic acid in our skeletal muscle**).

The former cases are called **biosynthetic pathways** or **anabolic pathways**. The latter constitute degradation and hence are called **catabolic pathways**.

Anabolic pathways, as expected, **consume energy**. Assembly of a protein from amino acids requires energy input.

On the other hand, catabolic pathways lead to the release of energy. For example, when glucose is degraded to lactic acid in our skeletal muscle, energy is liberated.

This metabolic pathway from glucose to lactic acid which occurs in 10 metabolic steps is called **glycolysis**.

Living organisms have learnt to trap this energy liberated during degradation and store it in the form of chemical bonds.

As and when needed, this bond energy is utilized for biosynthetic, osmotic and mechanical work that we perform.

The most important form of energy currency in living systems is the bond energy in a chemical called **adenosine triphosphate (ATP)**.

Cell Cycle, Cell Division, Phases of Cell Cycle: Interphase, Mitosis: Prophase, Prometaphase, Metaphase, Anaphase, Telophase. Cytokinesis. Significance of Mitosis.

Cell Cycle and Cell Division

During the division of a cell, **DNA replication** and cell growth takes place.

DNA: DNA and RNA | Recombinant DNA

All these processes, i.e., cell division, DNA replication, and cell growth have to take place in a coordinated way to ensure correct division and formation of **progeny (offspring)** cells containing intact **genomes** (the complete set of genetic material of an organism).

The sequence of events by which a cell duplicates its genome, synthesizes the other constituents of the cell and eventually divides into two daughter cells is termed **cell cycle.**

Although cell growth (in terms of cytoplasmic increase) is a continuous process, DNA synthesis occurs only during one specific stage in the cell cycle.

The replicated chromosomes (DNA) are then distributed to **daughter nuclei** by a complex series of events during **cell division**. These events are themselves under **genetic control [DNA]**.

Cell Cycle – Phases of Cell Cycle

A typical eukaryotic cell divides **once in approximately every 24 hours**.

Eukaryotic vs Prokaryotic Cells: Eukaryotic vs. Prokaryotic Cells | Plant Cell vs. Animal Cell

However, this duration of cell cycle can vary from organism to organism and also from cell type to cell type.

Yeast for example, can progress through the cell cycle in only about 90 minutes.

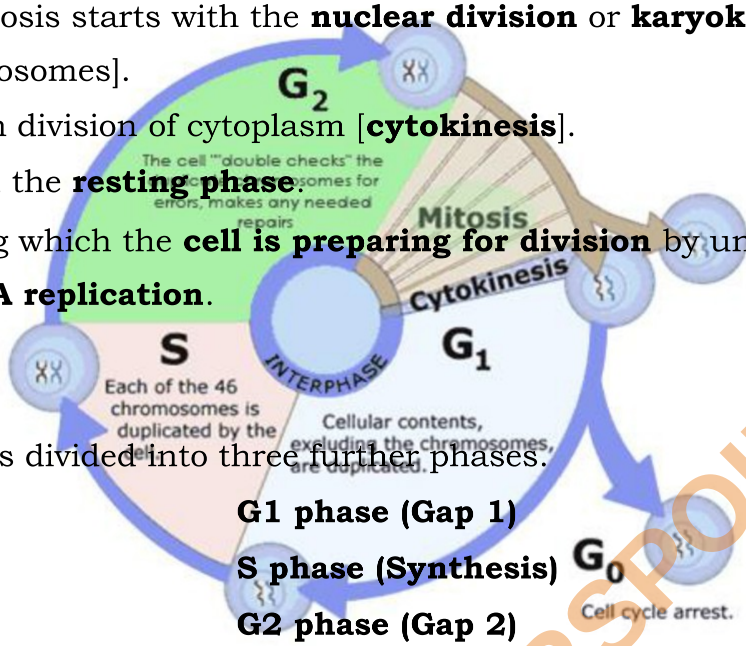
Basic Phases of Cell Cycle – Interphase and M Phase or Mitosis

Interphase == Phase between two successive M phases.

M Phase [Mitosis phase] == **Actual cell division or Mitosis**.

In the 24 hour average duration of cell cycle of a human cell, cell division proper lasts for only about an **hour**. The **interphase** lasts more than **95%** of the duration of cell cycle.

The M Phase or Mitosis starts with the **nuclear division** or **karyokinesis** [separation of daughter chromosomes].



It usually ends with division of cytoplasm [**cytokinesis**].

Interphase is called the **resting phase**.

It is the time during which the **cell is preparing for division** by undergoing both **cell growth** and **DNA replication**.

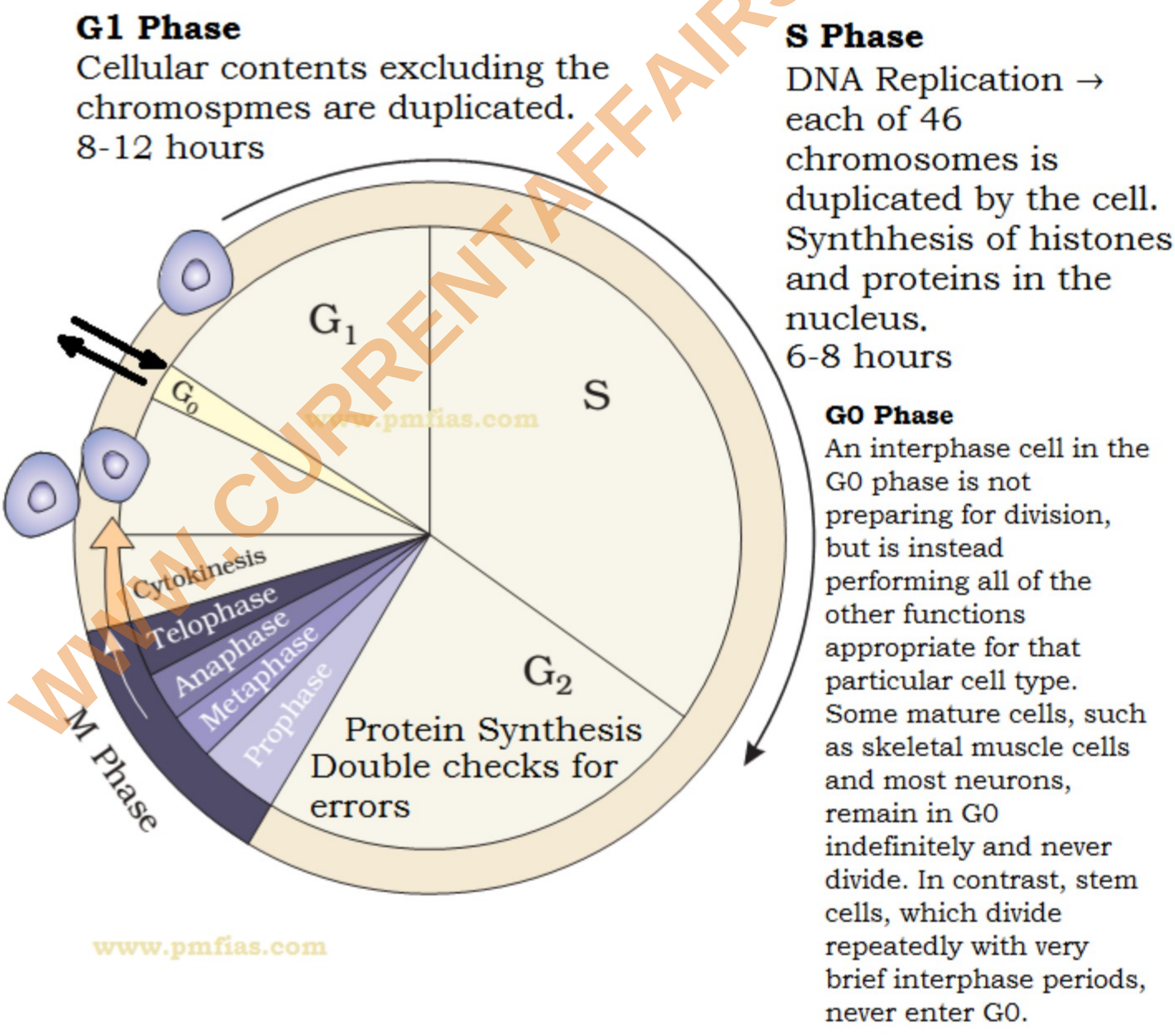
Interphase

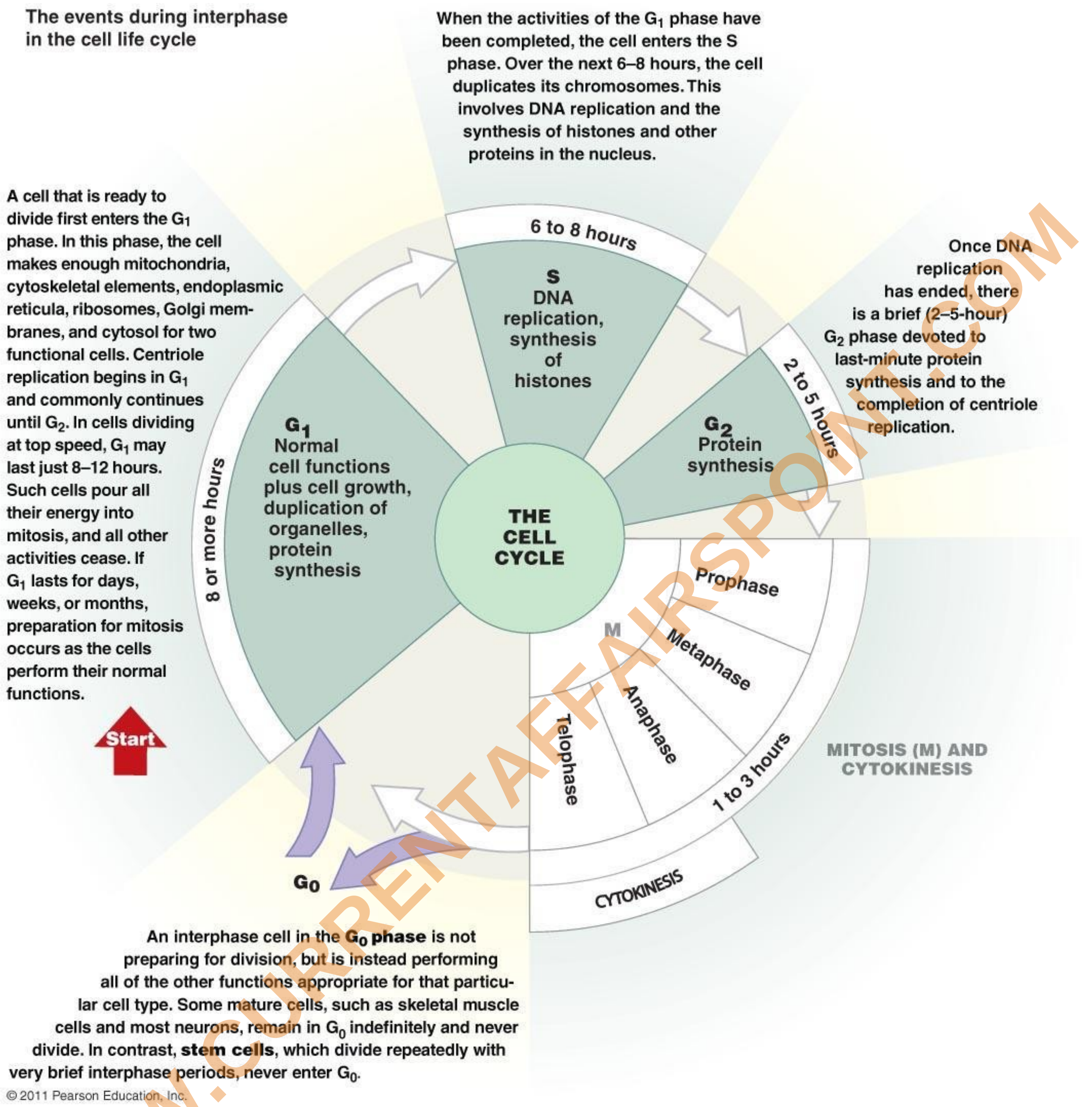
The interphase is divided into three further phases.

G1 phase (Gap 1)

S phase (Synthesis)

G2 phase (Gap 2)





G1 phase

G1 phase == interval between mitosis and beginning of DNA replication [initiation of DNA replication].

During G1 phase the cell is metabolically active and **continuously grows** but **does not replicate its DNA.**

S or synthesis phase

S or synthesis phase == **DNA synthesis or replication takes place**.

During this time the amount of **DNA per cell doubles**.

If the initial amount of DNA is denoted as 2C then it increases to 4C.

However, there is **no increase in the chromosome number**; if the cell had **diploid or 2n** number of chromosomes at G1, even after s phase the number of chromosomes remains the same, i.e., 2n.

In animal cells, during the S phase, DNA replication begins in the **nucleus**, and the **centriole** duplicates in the cytoplasm.

G2 phase

During the G2 phase, **proteins** are synthesized in preparation for **mitosis** while cell growth continues.

In the S and G2 phases the new DNA molecules formed are not distinct but intertwined.

Onion root tip cell has 16 chromosomes in each cell. Can you tell how many chromosomes will the cell have at G1 phase, after S phase, and after M phase?

Also, what will be the DNA content of the cells at G1, after S and at G2, if the content after M phase is 2C?

Quiescent stage (G0)

Some cells in the adult animals **do not appear to exhibit division** (e.g., **heart cells**) and many other cells divide only occasionally, as needed to replace cells that have been lost because of injury or cell death.

These cells that do not divide further exit G1 phase to enter an inactive stage called quiescent stage (G0) of the cell cycle.

Cells in this stage remain **metabolically active** but **no longer proliferate** unless called on to do so depending on the requirement of the organism.

Mitosis Phase or M Phase

This is the most dramatic period of the cell cycle, involving a major **reorganization** of virtually all components of the cell.

Since the number of **chromosomes in the parent and progeny cells is the same**, it is also called as **equational division**.

Though for convenience mitosis has been divided into four stages of nuclear division, it is very essential to understand that cell division is a progressive process and very clear-cut lines cannot be drawn between various stages.

Mitosis is the process in which a **eukaryotic cell nucleus** splits in **two**, followed by division of the **parent cell into two daughter cells**.

The word “mitosis” means “threads,” and it refers to the **threadlike appearance of chromosomes** as the cell prepares to divide.

Early microscopists were the first to observe these structures, and they also noted the appearance of a specialized network of **microtubules** during mitosis.

These tubules, collectively known as the **spindle fibres**, extend from structures called **centrosomes** — with one centrosome located at each of the opposite ends, or poles, of a cell.

As mitosis progresses, the microtubules [spindle fibres] attach to the chromosomes, which have **already duplicated their DNA** and aligned across the center of the cell.

The spindle tubules then shorten and move toward the poles of the cell. As they move, they pull the one copy of each chromosome with them to opposite poles of the cell.

This process ensures that each daughter cell will contain **one exact copy of the parent cell DNA.**

Mitosis consists of five morphologically distinct phases:

prophase,

prometaphase,

metaphase,

anaphase, and

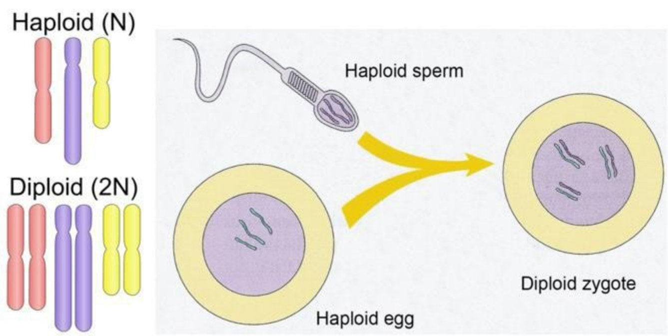
telophase.

Each phase involves characteristic steps in the process of chromosome alignment and separation.

Once mitosis is complete, the entire cell divides in two by way of the process called **cytokinesis.**

In animals, mitotic cell division is only seen in the diploid somatic cells.

But plants can show mitotic divisions in both haploid and diploid cells.



[**Diploid** == containing two complete sets of chromosomes, one from each parent].

[**Haploid** == only one set of chromosomes from one of the parent].

[**Somatic** == the parts of an organism **other than the reproductive cells**].

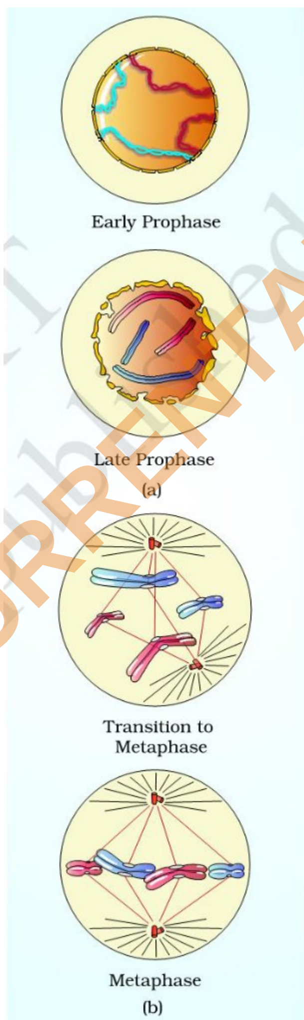


Figure 10.2 a and b : A diagrammatic view of stages in mitosis

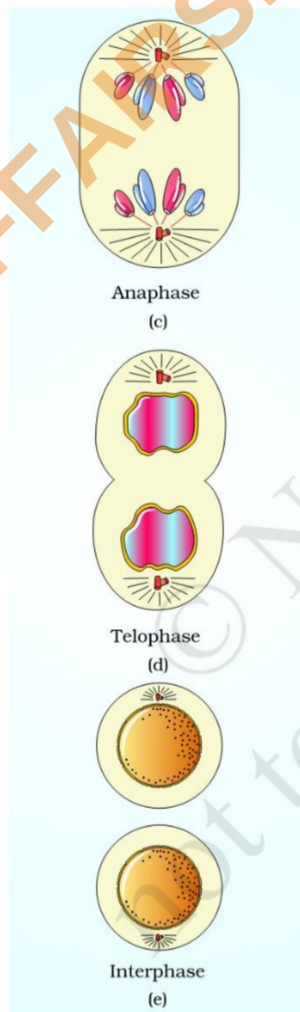


Figure 10.2 c to e : A diagrammatic view of stages in Mitosis

Prophase

Prophase is the first stage in mitosis, occurring after the conclusion of the G2 portion of interphase [see cyclic image above].

During prophase, the parent cell chromosomes — which were duplicated during S phase — **condense** and become thousands of times more **compact** than they were during interphase.

The chromosomal material becomes untangled during the process of chromatin condensation.

Because each duplicated chromosome consists of two identical sister chromatids joined at a point called the **centromere**, these structures now appear as X-shaped bodies when viewed under a microscope.

The mitotic **spindle** also begins to develop during prophase.

As the cell's two centrosomes move toward opposite poles, microtubules [spindle fibres] gradually assemble between them, forming the network that will later pull the duplicated chromosomes apart.

Centriole == each of a pair of minute cylindrical structures near the nucleus in eukaryotic cells, involved in the development of spindle fibres in cell division.

The centriole, which had undergone duplication during S phase of interphase, now begins to move towards opposite poles of the cell.

The completion of prophase can thus be marked by the following characteristic events:

Chromosomal material condenses to form compact mitotic chromosomes.

Chromosomes are seen to be composed of two chromatids attached together at the centromere (the point on a chromosome by which it is attached to a spindle fibre during cell division.).

Initiation of the assembly of mitotic spindle, the microtubules, the proteinaceous components of the cell cytoplasm help in the process.

Cells at the end of prophase, when viewed under the microscope, do not show golgi complexes, endoplasmic reticulum, nucleolus and the nuclear envelope.

Prometaphase

When prophase is complete, the cell enters prometaphase — the second stage of mitosis.

During prometaphase, the nuclear membrane breaks down into numerous small vesicles [a small fluid-filled sac]. As a result, the spindle microtubules now have direct access to the genetic material of the cell.

Each microtubule is highly dynamic, growing outward from the **centrosome** and collapsing backward as it tries to locate a chromosome.

Eventually, the microtubules find their targets and connect to each chromosome at its **kinetochore**, a complex of proteins positioned at the **centromere**.

A tug-of-war then ensues as the chromosomes move back and forth toward the two poles.

Metaphase

As prometaphase ends and metaphase begins, the chromosomes **align** along the cell equator.

Every chromosome has at least two microtubules extending from its **kinetochore** — with at least one microtubule connected to each pole.

At this point, the tension within the cell becomes balanced, and the chromosomes no longer move back and forth.

The complete disintegration of the nuclear envelope marks the start of the second phase of mitosis, hence the chromosomes are spread through the cytoplasm of the cell.

By this stage, condensation of chromosomes is completed and they can be observed **clearly** under the microscope. This then, is the stage at which morphology of chromosomes is most easily studied.

At this stage, metaphase chromosome is made up of two sister chromatids, which are held together by the **centromere**. Small disc-shaped structures at the surface of the centromeres are called **kinetochores**.

These structures serve as the sites of attachment of spindle fibres (formed by the spindle fibres) to the chromosomes that are moved into position at the center of the cell.

Hence, the metaphase is characterized by all the chromosomes coming to lie at the equator with one chromatid of each chromosome connected by its kinetochore to spindle fibres from one pole and its sister chromatid connected by its kinetochore to spindle fibres from the opposite pole.

The plane of alignment of the chromosomes at metaphase is referred to as the metaphase plate.

The key features of metaphase are:

Spindle fibres attach to kinetochores of chromosomes.

Chromosomes are moved to spindle equator and get aligned along metaphase plate through spindle fibres to both poles.

Anaphase

Metaphase leads to anaphase, during which each chromosome's sister chromatids separate and move to opposite poles of the cell.

Upon separation, every chromatid becomes an **independent** chromosome.

At the onset of anaphase, each chromosome arranged at the metaphase plate is **split** simultaneously and the **two daughter chromatids**, now referred to as chromosomes of the future daughter nuclei, begin their migration towards the two opposite poles.

As each chromosome moves away from the equatorial plate, the centromere of each chromosome is towards the pole.

Thus, anaphase stage is characterized by the following key events:

Centromeres split and chromatids separate.

Chromatids move to opposite poles.

Telophase

During telophase, the chromosomes arrive at the cell poles, the mitotic spindle disassembles, and the vesicles that contain fragments of the original nuclear membrane assemble around the two sets of chromosomes.

Climax results in the formation of a **new nuclear membrane** around each group of chromosomes.

At the beginning of the final stage of mitosis, i.e., telophase, the chromosomes that have reached their respective poles **decondense** and lose their individuality.

The individual chromosomes can no longer be seen and chromatin material tends to collect in a mass in the two poles.

This is the stage which shows the following key events:

Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.

Nuclear envelope assembles around the chromosome clusters.

Nucleolus, golgi complex and ER reform.

Cell Organelles: Cell Organelles

Cytokinesis – Actual Cell Division

Cytokinesis is the physical process that finally splits the parent cell into two identical daughter cells.

Mitosis is the process of **nuclear division**, which occurs just prior to cell division, or cytokinesis.

Mitosis accomplishes not only the segregation of duplicated chromosomes into daughter nuclei (karyokinesis), but the cell itself is divided into two daughter cells by a separate process called **cytokinesis** at the end of which cell division is complete.

In an animal cell, this is achieved by the appearance of a furrow in the plasma membrane. The furrow gradually deepens and ultimately joins in the center dividing the cell cytoplasm into two.

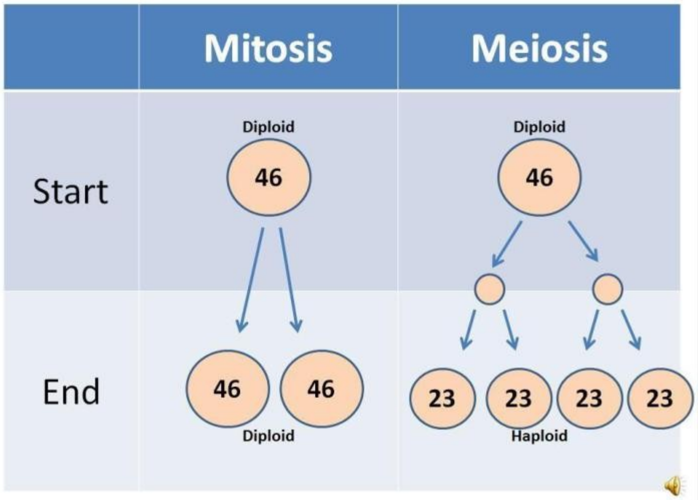
Plant cells however, are enclosed by a relatively inextensible cell wall, therefore they undergo cytokinesis by a different mechanism.

In plant cells, wall formation starts in the center of the cell and grows outward to meet the existing lateral walls.

The formation of the new cell wall begins with the formation of a simple precursor, called the cell-plate.

At the time of cytoplasmic division, organelles like mitochondria and plastids get distributed between the two daughter cells.

In some organisms karyokinesis is not followed by cytokinesis as a result of which **multinucleate** condition arises leading to the formation of **syncytium** (e.g., liquid endosperm in coconut).


Mitosis
Meiosis
Start
Diploid
46
Diploid
46
End
46
46
Diploid
23
23
23
23
Haploid

Interphase
The nucleolus and the nuclear envelope are distinct and the chromosomes are in the form of threadlike chromatin.

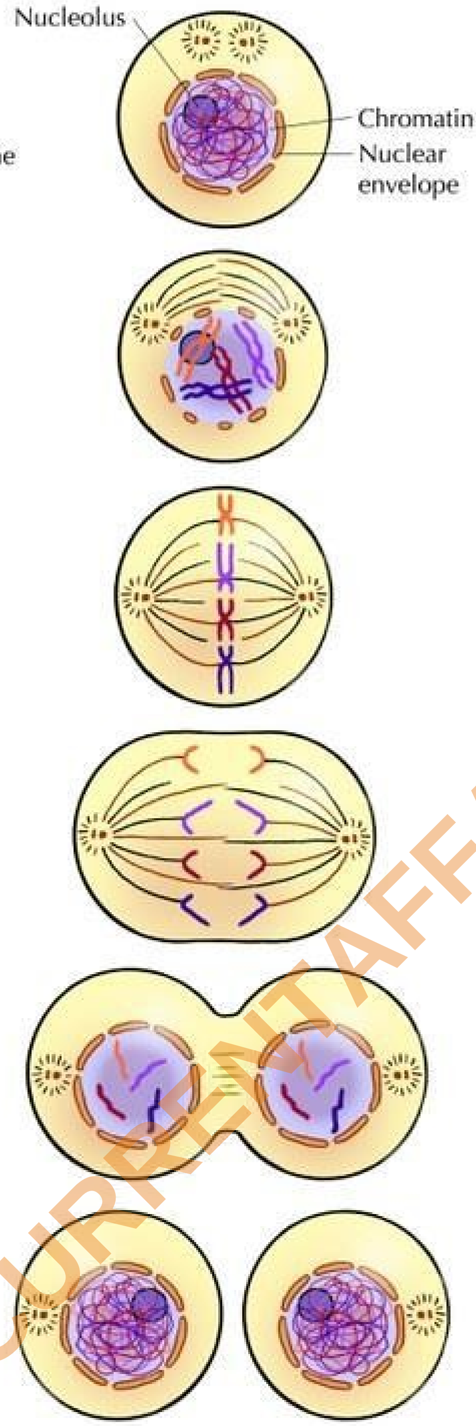
Prophase
The chromosomes appear condensed, and the nuclear envelope in not apparent.

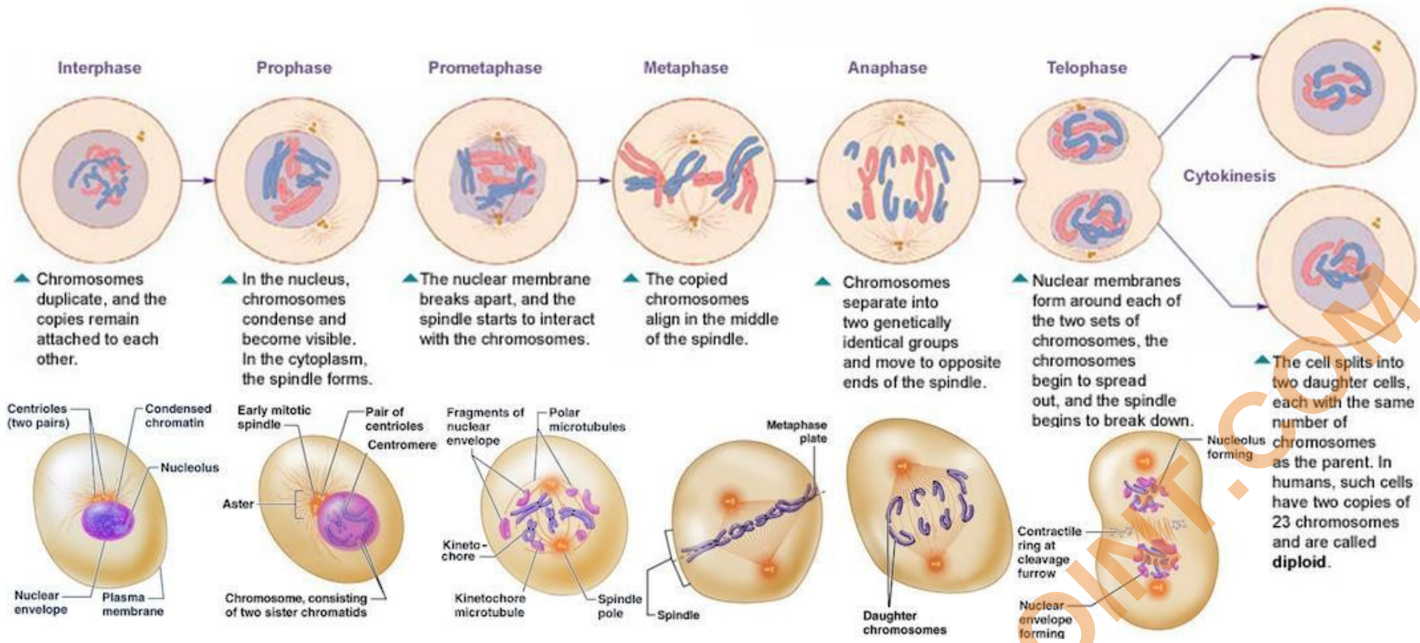
Metaphase
Thick, coiled chromosomes, each with two chromatids, are lined up on the metaphase plate.

Anaphase
The chromatids of each chromosome have separated and are moving toward the poles.

Telophase
The chromosomes are at the poles, and are becoming more diffuse. The nuclear envelope is reforming. The cytoplasm may be dividing.

Cytokinesis (part of telophase)
Division into two daughter cells is completed.





Significance of Mitosis

Mitosis or the **equational division** is usually restricted to the diploid cells only. However, in some lower plants and in some social insects haploid cells also divide by mitosis.

Mitosis usually results in the production of diploid daughter cells with identical genetic complement.

The growth of multicellular organisms is due to mitosis. Cell growth results in disturbing the ratio between the nucleus and the cytoplasm. It therefore becomes essential for the cell to divide to restore the nucleo-cytoplasmic ratio.

A very significant contribution of mitosis is **cell repair**. The cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are being constantly replaced.

Mitotic divisions in the meristematic tissues - the apical and the lateral cambium, result in a continuous growth of plants throughout their life.

More Knowledge

[Cell Organelles | Plant Cell vs. Animal Cell](#)
[Carbohydrates | Monosaccharides | Polysaccharides](#)

[Proteins | Amino Acids | Enzymes](#)

[Vitamins and Minerals – Deficiency Diseases](#)

Fats | Healthy Fats and Unhealthy Fats

Animal Tissues – Epithelium, Connective Tissues

Human Digestive System | Digestive Glands

Respiratory System – NCERT General Science

Endocrine Glands and Hormones

Human Neural System | Human Brain

Muscular and Skeletal System

Nucleic acids – DNA and RNA | Recombinant DNA

Meiosis – Meiotic Cell Division – Production of Gametes – Meiosis I and Meiosis II, Significance of Meiosis. Mitosis – Meiosis Comparison.

Meiosis

Meiosis is a specialized kind of cell division that **reduces the chromosome number by half** and results in the production of **haploid daughter cells**.

The production of offspring by sexual reproduction includes the **fusion** of two **gametes** [sperm and ovum], each with a complete **haploid set** of chromosomes.

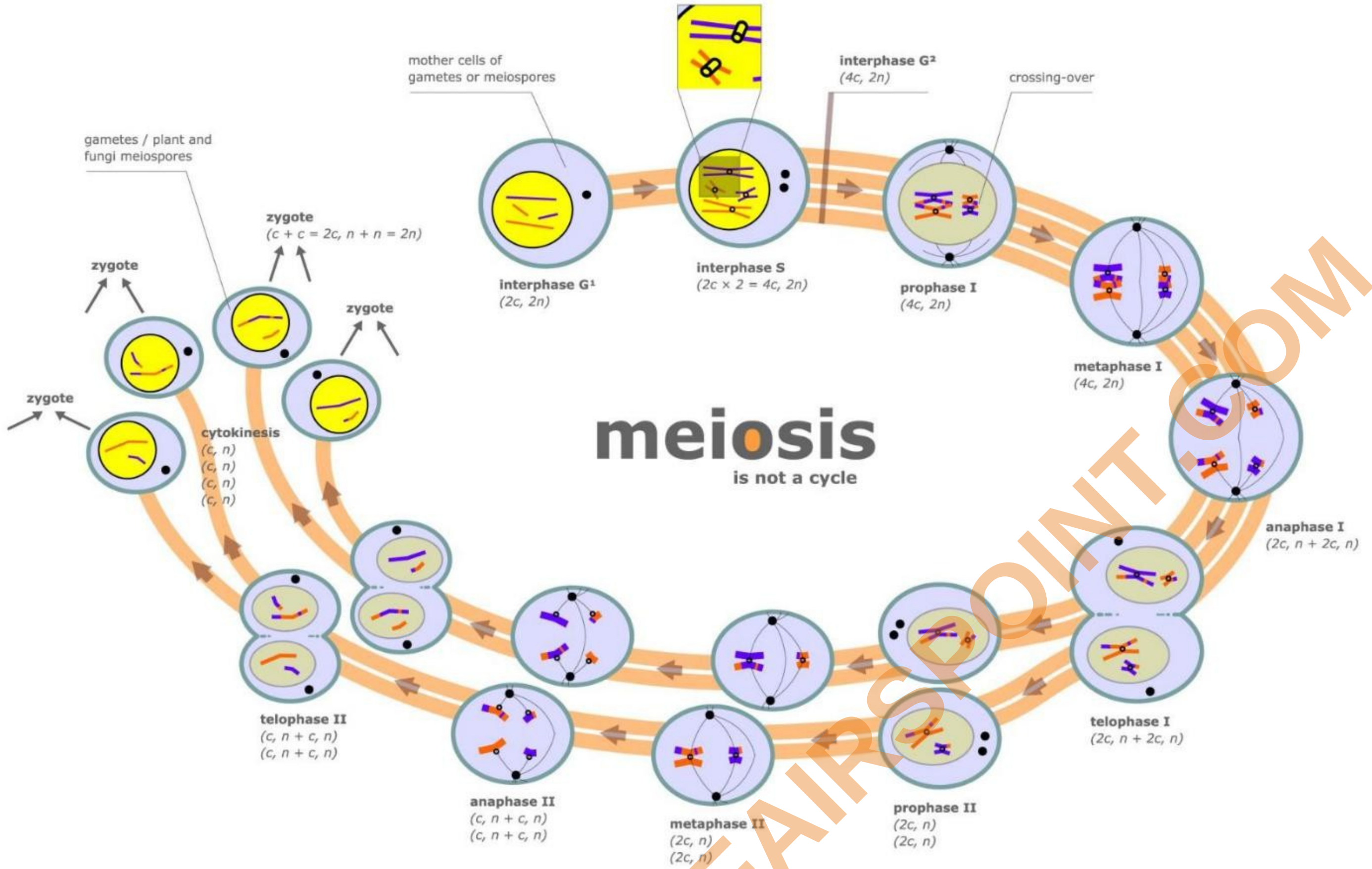
These haploid gametes come into existence due to meiosis [meiosis type of cell division]. The gametes are formed from specialized **diploid cells**.

[**Diploid** == containing two complete sets of chromosomes, one from each parent].

[**Haploid** == only one set of chromosomes from one of the parent].

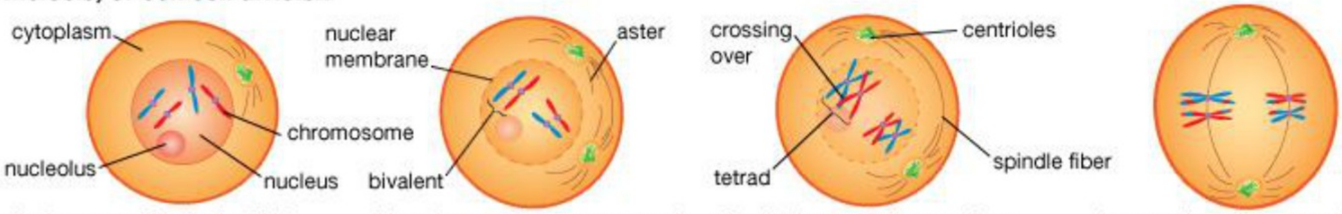
Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas **fertilization** restores the diploid phase.

Meiotic events can be grouped under the following phases



mother cells of gametes or meiospores
interphase G¹
(2c, 2n)
interphase S
(2c × 2 = 4c, 2n)
interphase G²
(4c, 2n)
crossing-over
prophase I
(4c, 2n)
metaphase I
(4c, 2n)
anaphase I
(2c, n + 2c, n)
telophase I
(2c, n + 2c, n)
prophase II
(2c, n)
(2c, n)
metaphase II
(2c, n)
(2c, n)
anaphase II
(c, n + c, n)
(c, n + c, n)
telophase II
(c, n + c, n)
(c, n + c, n)
cytokinesis
(c, n)
(c, n)
(c, n)
(c, n)
gametes / plant and fungi meiospores
zygote
zygote
(c + c = 2c, n + n = 2n)
zygote
zygote
meiosis
is not a cycle

Meiosis, or sex cell division

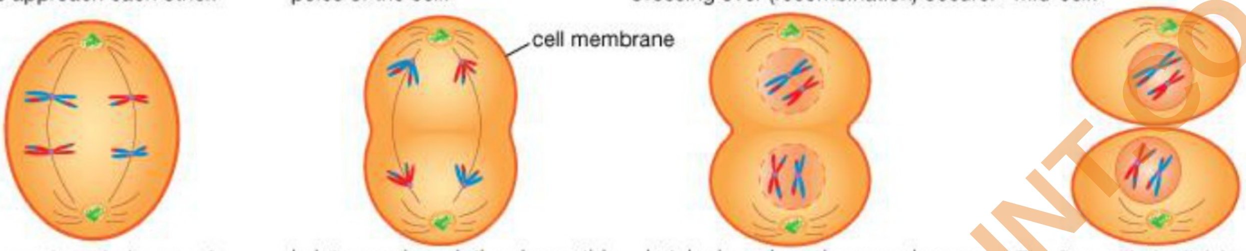


At the onset of meiosis, DNA strands thicken into chromosomes. Homologous, or like, chromosomes begin to approach each other.

Homologous chromosomes pair to form bivalents. The centrioles divide and move to opposite poles of the cell.

The bivalents duplicate to form tetrads, or four-chromatid groups. The nuclear membrane disintegrates. Crossing over (recombination) occurs.

In metaphase I, the tetrads, attached to spindle fibers at their centromeres, line up at mid-cell.

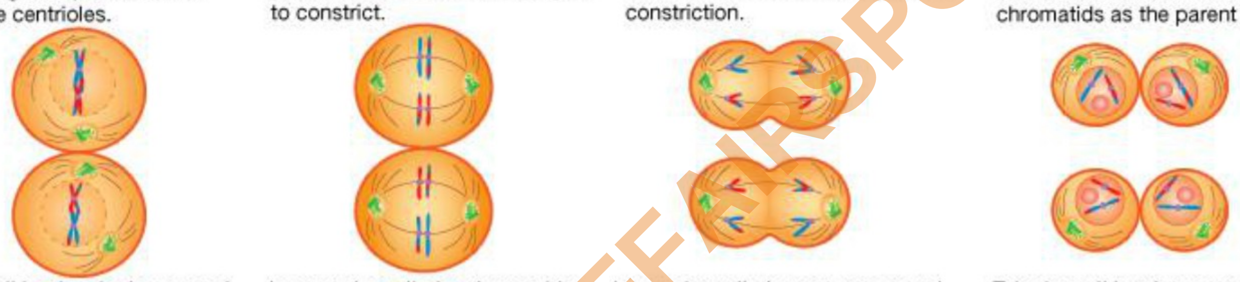


In early anaphase I, the tetrads separate, and the paired chromatids move along the spindle to their respective centrioles.

In late anaphase I, the chromatids have almost reached the spindle poles. The cell membrane begins to constrict.

In telophase I, nuclear membranes enclose the separated chromatids. The cell membrane completes its constriction.

The first meiotic division ends. There are now two cells, each with the same number of chromatids as the parent cell.

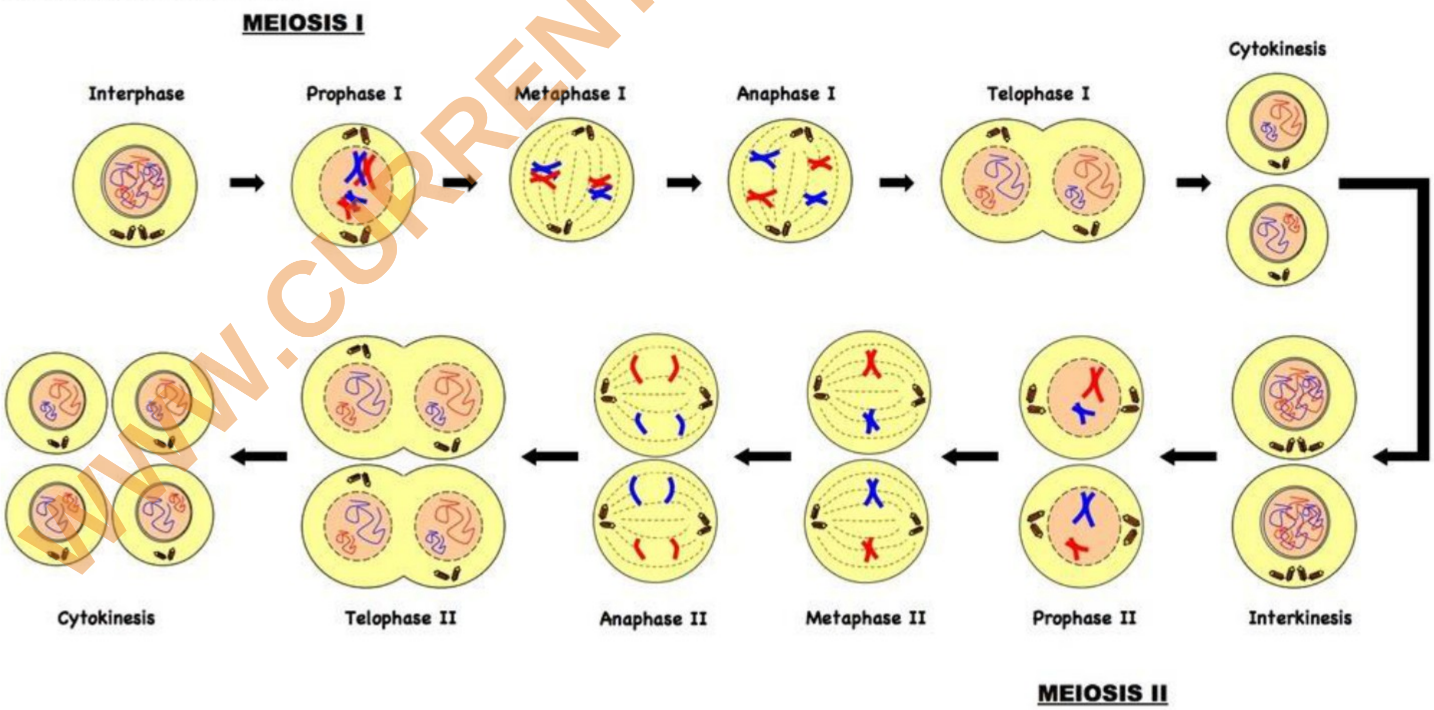


Prophase II begins. In the second meiotic division, homologous chromatids do not duplicate but merely separate.

In metaphase II, the chromatids line up at mid-cell. The centrioles and asters are at the poles. A spindle has formed.

In anaphase II, the now-separated chromatids approach their respective poles. The cell membrane begins to constrict.

Telophase II has been completed. There are now four cells, each with half the number of chromosomes of the parent cell.



Meiosis I

Prophase I

Prophase of the first meiotic division is typically longer and more complex when compared to prophase of mitosis.

It has been further subdivided into the following five phases based on chromosomal behavior, i.e., Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

Leptotene

During leptotene stage the chromosomes become gradually visible under the light microscope.

The **compaction** of chromosomes continues throughout leptotene.

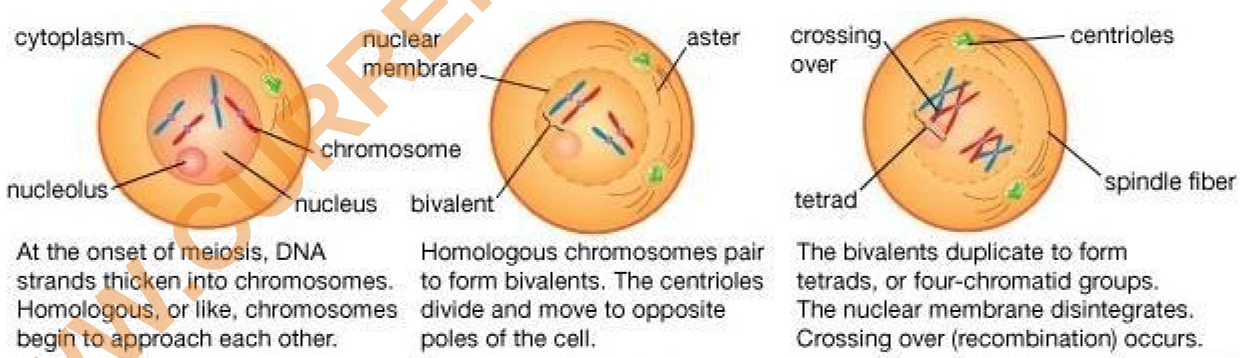
Zygotene

During this stage chromosomes start pairing together and this process of association is called **synapsis**.

Such paired chromosomes are called **homologous chromosomes**.

Chromosome synapsis is accompanied by the formation of complex structure called **synaptonemal complex**.

The complex formed by a pair of synapsed homologous chromosomes is called a **bivalent or a tetrad**. However, these are more clearly visible at the next stage.



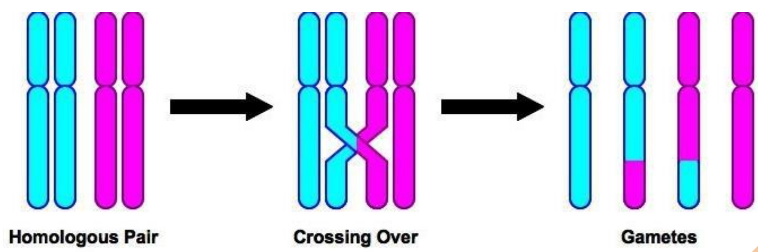
The first two stages of prophase I are relatively short-lived compared to the next stage, that is pachytene.

Pachytene

During this stage bivalent chromosomes now clearly appears as **tetrads**.

This stage is characterized by the appearance of **recombination nodules**, the sites at which **crossing over** occurs between **non-sister** chromatids of the homologous chromosomes.

Crossing over is the exchange of genetic material between two homologous chromosomes.



Pic Credits: http://www.ib.bioninja.com.au/_Media/chiasma_med.jpeg

Crossing over is an enzyme-mediated process and the enzyme involved is called **recombinase**.

Crossing over leads to recombination [exchange] of genetic material on the two chromosomes.

Recombination between homologous chromosomes is completed by the end of pachytene, leaving the chromosomes linked at the sites of crossing over.

Diplotene

The beginning of diplotene is recognized by the dissolution of the synaptonemal complex and the tendency of the recombined homologous chromosomes of the bivalents to separate from each other except at the sites of crossovers.

These X-shaped structures, are called **chiasmata**.

Diakinesis

This is marked by terminalisation of chiasmata.

During this phase the chromosomes are fully condensed and the **meiotic spindle** is assembled to prepare the homologous chromosomes for separation.

By the end of diakinesis, the nucleolus disappears and the nuclear envelope also breaks down.

Diakinesis represents transition to metaphase.

Metaphase I

The bivalent chromosomes align on the equatorial plate. The microtubules from the opposite poles of the spindle attach to the pair of homologous chromosomes.

Anaphase I

The homologous chromosomes separate, while sister chromatids remain associated at their centromeres.

Telophase I

The nuclear membrane and nucleolus reappear, cytokinesis follows and this is called as **diad of cells**.

Interkinesis

The stage between the two meiotic divisions is called **interkinesis** and is generally short lived.

Interkinesis is followed by prophase II, a much simpler prophase than prophase I.

Meiosis II

Prophase II

Meiosis II is initiated immediately after cytokinesis, usually before the chromosomes have fully elongated.

In contrast to meiosis I, meiosis II resembles a **normal mitosis**.

The nuclear membrane disappears by the end of prophase II. The chromosomes again become compact.

Metaphase II

At this stage the chromosomes align at the equator and the microtubules from opposite poles of the spindle get attached to the **kinetochores** of sister chromatids.

Anaphase II

It begins with the simultaneous splitting of the **centromere** of each chromosome (which was holding the sister chromatids together), allowing them to move toward opposite poles of the cell.

Telophase II

Meiosis ends with telophase II, in which the two groups of chromosomes once again get enclosed by a nuclear envelope; cytokinesis follows resulting in the formation of **tetrad of cells** i.e., **four haploid daughter cells**.

Significance of Meiosis

Meiosis is the mechanism by which conservation of specific chromosome number of each species is achieved across generations in sexually reproducing organisms, even though the process, per se, paradoxically, results in **reduction of chromosome number by half.**

It also increases the genetic variability in the population of organisms from one generation to the next. **Variations** are very important for the process of evolution.

Mitosis – Meiosis Comparison

Cell cycle is divided into two phases called (i) **Interphase** – a period of preparation for cell division, and (ii) **Mitosis** (M phase) – the actual period of cell division.

Interphase is further subdivided into G1, S and G2.

G1 phase is the period when the cell grows and carries out normal metabolism. Most of the **organelle duplication** also occurs during this phase.

S phase marks the phase of **DNA replication** and chromosome duplication.

G2 phase is the period of **cytoplasmic growth**.

Mitosis is also divided into four stages namely prophase, metaphase, anaphase and telophase.

Prophase == Chromosomes condense [chromatids to chromosomes], centrioles move to the opposite poles, nuclear envelope and the nucleolus disappear and the spindle fibres start appearing.

Metaphase == alignment of chromosomes at the equatorial plate.

Anaphase == centromeres divide, chromatids start moving towards the two opposite poles.

Telophase == chromosomal elongation starts, nucleolus and the nuclear membrane reappear.

Cytokinesis == cytoplasmic division.

Mitosis thus, is the **equational division** in which the chromosome number of the parent is conserved in the daughter cell.

In contrast to mitosis, meiosis occurs in the **diploid cells**, which are destined to form **gametes**.

It is called the **reduction division** since it **reduces the chromosome number by half** while making the gametes.

In sexual reproduction when the two gametes fuse the chromosome number is **restored** to the value in the parent.

Meiosis is divided into two phases – **meiosis I** and **meiosis II**.

In the first meiotic division the **homologous chromosomes pair to form bivalents, and undergo crossing over.**

Meiosis I has a long prophase.

Prophase I == leptotene, zygotene, pachytene, diplotene and diakinesis.

Metaphase I == bivalents arrange on the equatorial plate.

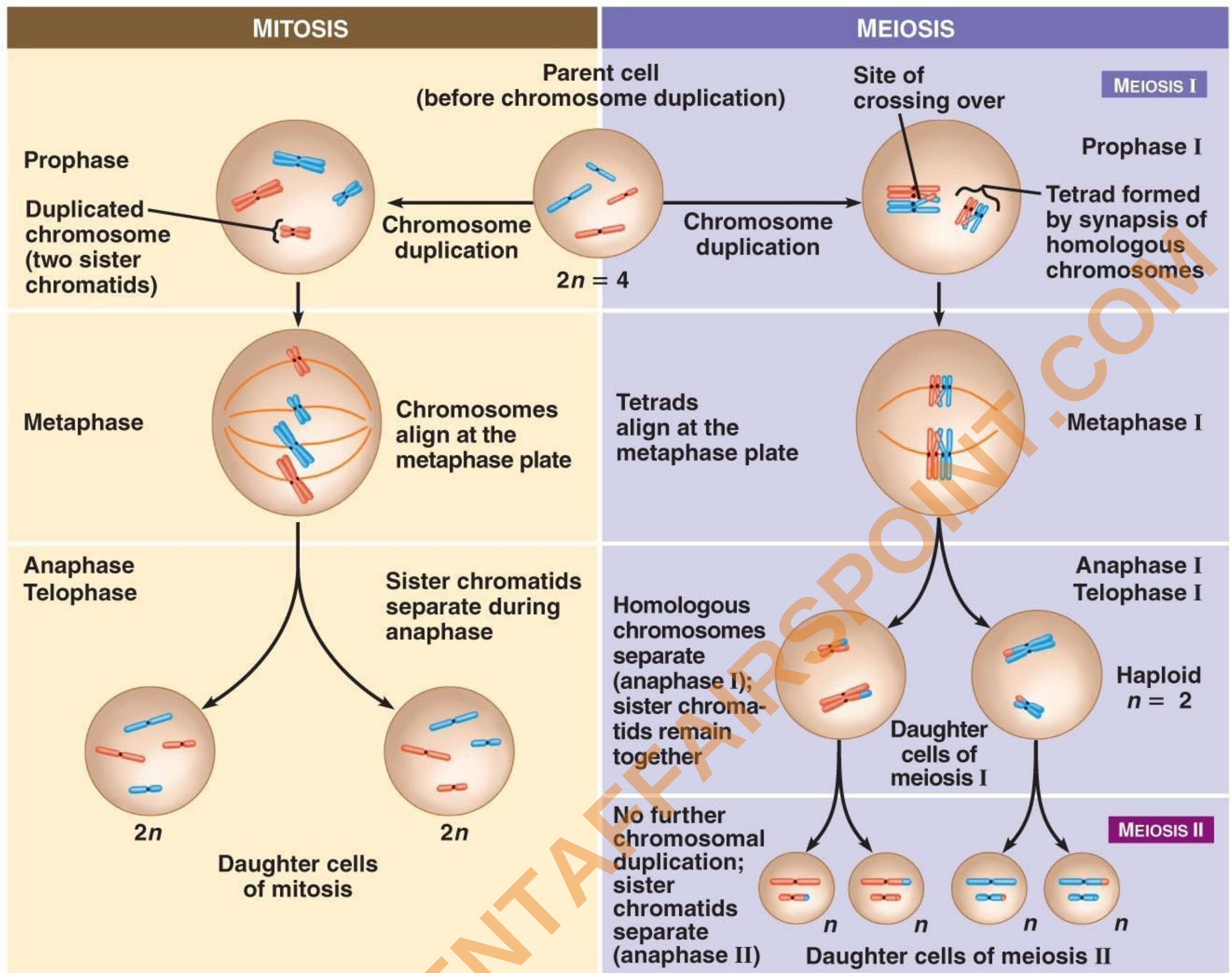
Anaphase I == homologous chromosomes move to the opposite poles with both their chromatids. Each pole receives half the chromosome number of the parent cell.

Telophase I == nuclear membrane and nucleolus reappear.

Meiosis II is similar to mitosis.

During anaphase II the sister chromatids separate.

Thus at the end of meiosis **four haploid cells** are formed.



	Mitosis	**Meiosis**
Number of divisions	One	Two – Meiosis I and Meiosis II.
DNA Replication	Occurs during interphase	Occurs during interphase
Role	Asexual cellular reproduction and cell repair. Produces only somatic cells.	Asexual cellular reproduction that produces gametes.
Type of cells that divide	In animals, mitotic cell division is only seen in the diploid somatic cells. But plants can show mitotic divisions in both haploid and	Meiotic cell division is seen only in diploid cells.

	diploid cells.	
Cell Cycle	Both cell division and cell cycle.	It is only cell division and not cell cycle.
Daughter cells produced	Two diploid daughter cells (2n) that are genetically identical to the parent cell.	Four haploid daughter cells (n) containing half the number of chromosome as the parent cell.

Mendel’s Laws of Inheritance – Law of Dominance, Law of Segregation. Incomplete Dominance, Co-dominance, Inheritance of Two Genes, Law of Independent Assortment.

Source|Credits|Picture Credits: NCERT Science Textbooks Class 6-12.

Mendel’s Experiments on Inheritance

Inheritance is the process by which characters are passed on from parent to progeny; it is the basis of heredity. **Variation** is the degree by which progeny differ from their parents.

It was only during the mid-nineteenth century that a major headway was made in the understanding of inheritance.

Gregor Mendel, conducted hybridisation experiments on garden peas for seven years (1856-1863) and proposed the laws of inheritance in living organisms.

Mendel conducted such artificial pollination/cross pollination experiments using several true-breeding pea lines.

[**Truebreeding line** == A truebreeding line is one that, having undergone continuous **self-pollination**, shows the stable trait inheritance and expression for several generations].

Mendel investigated characters in the garden pea plant that were manifested as two opposing traits, e.g., tall or dwarf plants, yellow or green seeds etc.

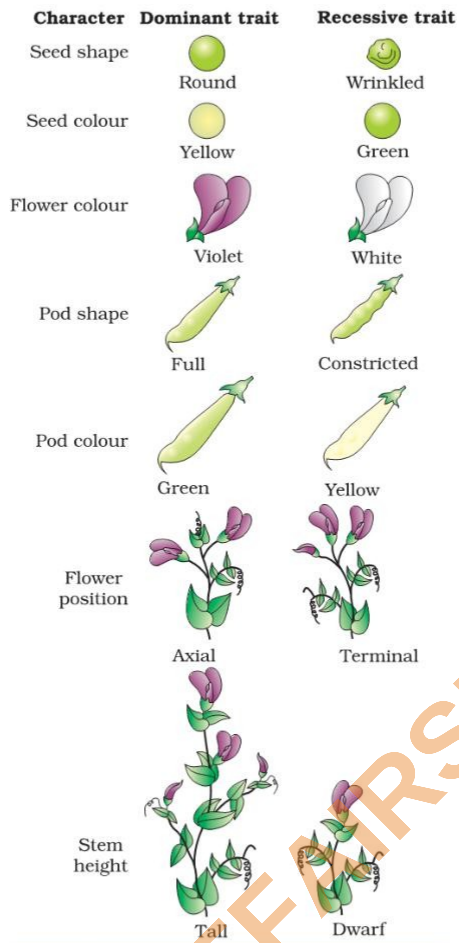


Figure 5.1 Seven pairs of contrasting traits in pea plant studied by Mendel

Let us take the example of one such hybridisation experiment carried out by Mendel where he crossed tall and dwarf pea plants to study the **inheritance of one gene**.

He collected the seeds produced as a result of this cross and grew them to generate plants of the first hybrid generation. This generation is also called the **Filial1 progeny** or the F1.

Mendel observed that all the F 1 progeny plants were tall, like one of its parents; none were dwarf.

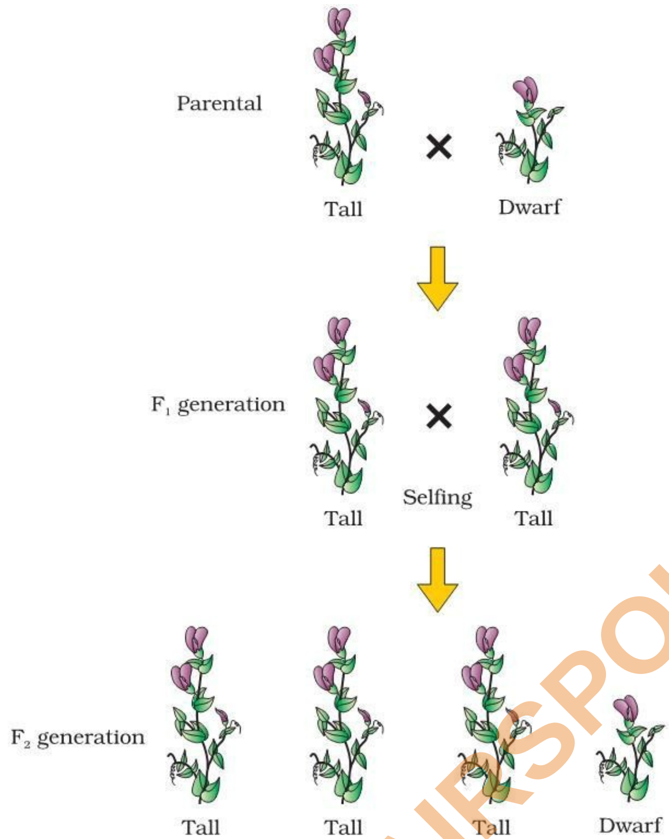


Figure 5.3 Diagrammatic representation of monohybrid cross

He made similar observations for the other pairs of traits – he found that the F 1 always resembled either one of the parents, and that the trait of the other parent was not seen in them.

Mendel then self-pollinated the tall F1 plants and to his surprise found that in the Filial generation some of the offspring were 'dwarf'; the character that was not seen in the F generation was now expressed.

The proportion of plants that were dwarf were 1/4th of the F 2 plants while 3/4th of the F2 plants were tall.

The tall and dwarf traits were identical to their parental type and did not show any blending, that is all the offspring were either tall or dwarf, none were of in between height.

Similar results were obtained with the other traits that he studied: only one of the parental traits was expressed in the F1 generation while at the F 2 stage both the traits were expressed in the proportion **3:1**. The contrasting traits did not show any blending at either F1 or F2 stage.

Factors – Genes

Based on these observations, Mendel proposed that something was being stably passed down, unchanged, from parent to offspring through the gametes, over successive generations. He called these things as **'factors'**.

Now we call the 'factors' as **genes**. Genes, therefore, are the **units of inheritance**. They contain the information that is required to express a particular trait in an organism.

Pair of Alleles - Homozygous and Heterozygous

Genes which code for a pair of contrasting traits are known as **alleles**, i.e., they are slightly different forms of the same gene.

If we use alphabetical symbols for each gene, then the capital letter is used for the trait expressed at the F 1 stage and the small alphabet for the other trait.

For example, in case of the character of height, T is used for the Tall trait and t for the 'dwarf', and T and t are **alleles** of each other. Hence, in plants the **pair of alleles** for height would be TT, Tt or tt.

Genotype and Phenotype == TT and tt are called the **genotype** of the plant while the descriptive terms tall and dwarf are the **phenotype**.

Mendel proposed that in a true breeding, tall or dwarf pea variety the allelic pair of genes for height are identical or **homozygous**, TT and tt, respectively. On the other hand, the allelic pair Tt is **heterozygous**.

From the observation that the recessive parental trait is expressed without any blending in the F2 generation, we can infer that, when the tall and dwarf plant produce gametes, by the process of **meiosis**, the alleles of the parental pair separate or segregate from each other and **only one allele is transmitted to a gamete**.

This segregation of alleles is a random process and so there is a 50 per cent chance of a gamete containing either allele, as has been verified by the results of the crossings. In this way the gametes of the tall TT plants have the allele T and the gametes of the dwarf tt plants have the allele t.

During fertilisation the two alleles, T from one parent say, through the pollen, and t from the other parent, then through the egg, are united to produce zygotes that have one T allele and one t allele. In other words the hybrids have Tt. Since these hybrids contain alleles which express contrasting traits, the plants are **heterozygous**.

Dominant and Recessive Factor

What twould be the phenotype of a plant that had a genotype Tt? As Mendel found the phenotype of the F1heterozygote Tt to be exactly like the TT parent in appearance, he proposed that in a pair of dissimilar factors, one dominates the other (as in the F1) and hence is called the **dominant factor** while the other factor is **recessive**.

In this case T (for tallness) is dominant over t (for dwarfness), that is recessive. He observed identical behaviour for all the other characters/trait-pairs that he studied.

It is convenient (and logical) to use the capital and lower case of an alphabetical symbol to remember this concept of dominance and recessiveness.

Alleles can be similar as in the case of **homozygotes** TT and tt or can be dissimilar as in the case of the **heterozygote** Tt.

Since the Tt plant is heterozygous for genes controlling one character (height), it is a **monohybrid** and the cross between TT and tt is a **monohybrid cross**.

Punnett Square

The production of gametes by the parents, the formation of the zygotes, the F1 and F2 plants can be understood from a diagram called **Punnett Square** as shown in Figure below.

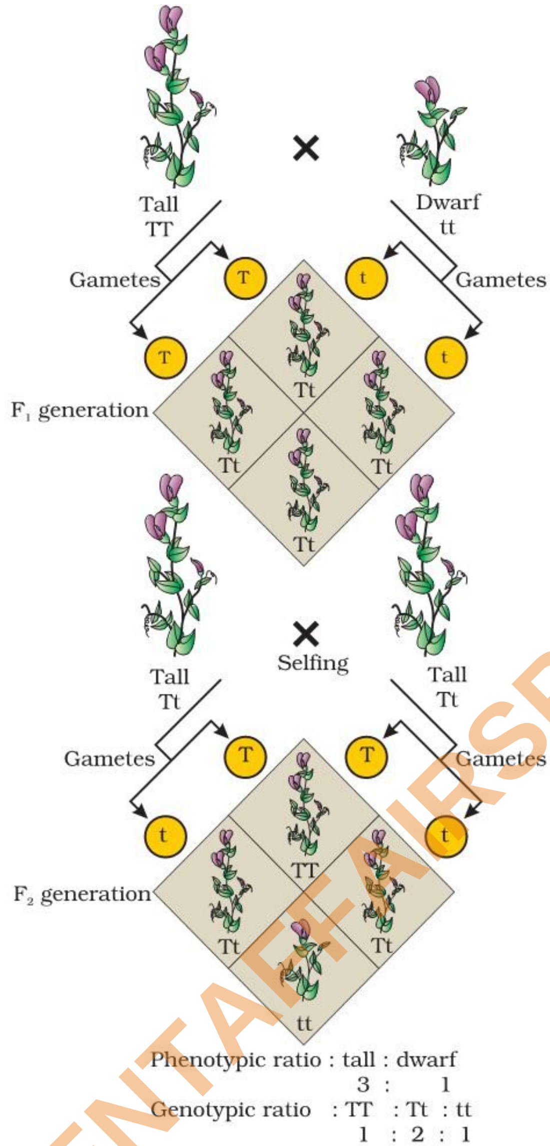


Figure 5.4 A Punnett square used to understand a typical monohybrid cross conducted by Mendel between true-breeding tall plants and true-breeding dwarf plants

The Punnett Square above shows the parental tall TT (male) and dwarf tt (female) plants, the gametes produced by them and, the F1 Tt progeny. The F1 plants of genotype Tt are self-pollinated.

The F1 plant of the genotype Tt when self-pollinated, produces gametes of the genotype T and t in equal proportion.

When fertilisation takes place, the pollen grains of genotype T have a 50 per cent chance to pollinate eggs of the genotype T, as well as of genotype t.

Also pollen grains of genotype t have a 50 per cent chance of pollinating eggs of genotype T, as well as of genotype t. As a result of random fertilisation, the resultant zygotes can be of the genotypes TT, Tt or tt.

From the Punnett square it is easily seen that 1/4th of the random fertilisations lead to TT, 1/2 lead to Tt and 1/4th to tt.

Though the F1 have a genotype of Tt, but the phenotypic character seen is 'tall'.

At F2, 3/4th of the plants are tall, where some of them are TT while others are Tt.

Test Cross

Externally it is not possible to distinguish between the plants with the genotypes TT and Tt. Hence, within the genopytic pair Tt only one character 'T' tall is expressed. Hence the character T or 'tall' is said to dominate over the other allele t or 'dwarf' character.

It is thus due to this dominance of one character over the other that all the F 1 are tall (though the genotype is Tt) and in the F2 3/4th of the plants are tall (though genotypically 1/2 are Tt and only 1/4th are TT).

This leads to a phenotypic ratio of 3/4th tall : (1/4 TT + 1/2 Tt) and 1/4th tt, i.e., a 3:1 ratio, but a genotypic ratio of 1:2:1.

The genotypic ratios can be calculated by simply looking at the phenotype of a dominant trait but it is not possible to know the **genotypic composition**.

That is, for example, whether a tall plant from F1 or F 2 has TT or Tt composition, cannot be predicted.

Therefore, to determine the genotype of a tall plant at F2, Mendel crossed the tall plant from F2 with a dwarf plant. This he called a **test cross**.

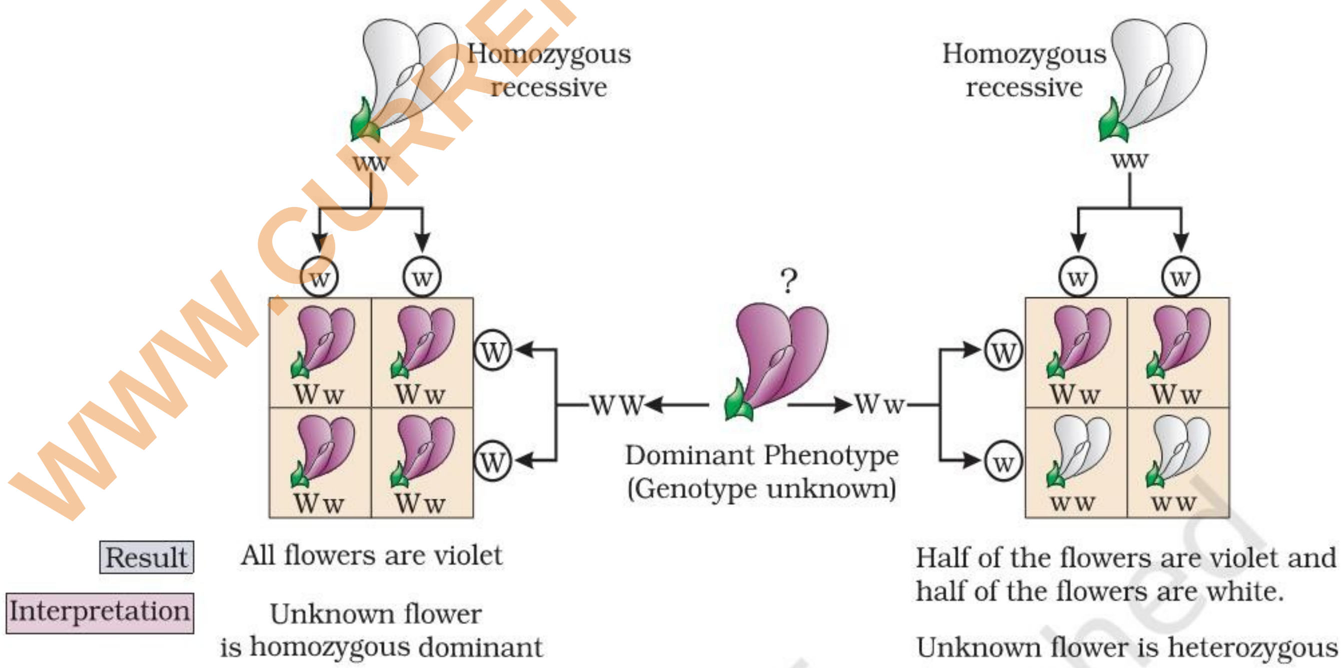


Figure 5.5 Diagrammatic representation of a test cross

In a typical test cross an organism (pea plants here) showing a dominant phenotype (and whose genotype is to be determined) is crossed with the recessive parent.

The progenies of such a cross can easily be analysed to predict the genotype of the test organism.

Figure shows the results of typical test cross where violet colour flower (W) is dominant over white colour flower (w).

Mendel's Laws of Inheritance

Based on his observations on monohybrid crosses Mendel proposed two general rules to consolidate his understanding of inheritance in monohybrid crosses.

Today these rules are called the **Principles or Laws of Inheritance**: the **First Law or Law of Dominance** and the **Second Law or Law of Segregation**.

First Law or Law of Dominance

Characters are controlled by discrete units called **factors**.

Factors occur in **pairs**. [pair of alleles]

In a dissimilar pair of factors one member of the pair dominates (**dominant**) the other (**recessive**).

The law of dominance is used to explain the expression of only one of the parental characters in a monohybrid cross [Mendel's Experiments on Inheritance] in the F1 and the expression of both in the F 2. It also explains the proportion of 3:1 obtained at the F2.

Second Law or Law of Segregation

This law is based on the fact that the alleles **do not show any blending** and that both the characters are recovered as such in the F 2 generation though one of these is not seen at the F1 stage.

Though the parents contain two alleles during gamete formation, the factors or alleles of a pair segregate from each other such that a gamete receives **only one of the two factors [either dominant or recessive]**.

Of course, a homozygous parent produces all gametes that are similar while a heterozygous one produces two kinds of gametes each having one allele with equal proportion.

Incomplete Dominance

When experiments on peas were repeated using other traits in other plants, it was found that sometimes the F 1 had a phenotype that did not resemble either of the two parents and was in between the two.

The inheritance of flower colour in the dog flower (snapdragon or Antirrhinum sp.) is a good example to understand incomplete dominance.

In a cross between true-breeding red-flowered (RR) and truebreeding white-flowered plants (rr), the F1 (Rr) was pink. When the F1 was self-pollinated the F 2 resulted in the following ratio 1 (RR) Red : 2 (Rr) Pink: 1 (rr) White.

Here the genotype ratios were exactly as we would expect in any mendelian monohybrid cross, but the phenotype ratios had changed from the 3:1 dominant : recessive ratio.

What happened was that R was not completely dominant over r and this made it possible to distinguish Rr as pink from RR (red) and rr (white).

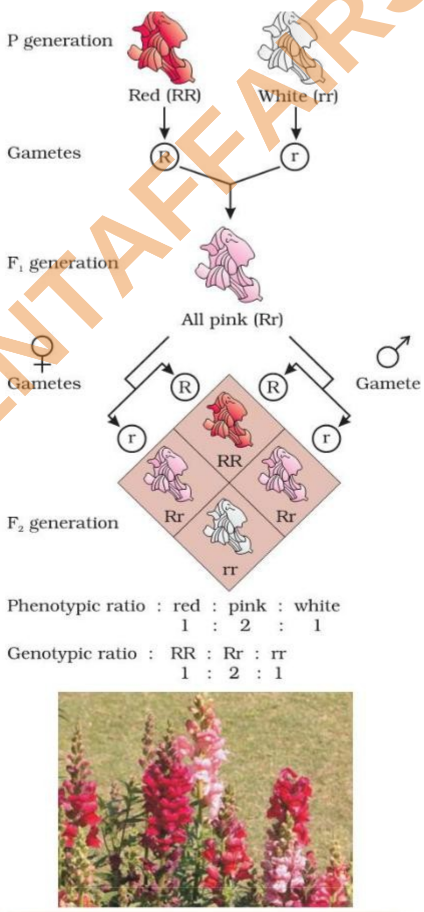


Figure 5.6 Results of monohybrid cross in the plant Snapdragon, where one allele is incompletely dominant over the other allele

Co-dominance

Till now we were discussing crosses where the F1 resembled either of the two parents (dominance) or was in-between (incomplete dominance). But, in the case of co-dominance the F 1 generation **resembles both parents**.

A good example is different types of red blood cells that determine ABO blood grouping in human beings.

ABO blood groups are controlled by the **gene I**. The plasma membrane of the red blood cells has **sugar polymers** that protrude from its surface and the kind of sugar is controlled by the gene. The gene (I) has three alleles **IA, IB and i**.

The alleles **IA and IB produce a slightly different form of the sugar** while allele **i does not produce any sugar**.

Because humans are diploid organisms, each person possesses any two of the three I gene alleles.

IA and IB are completely dominant over i, in other words when IA and i are present only IA expresses (because i does not produce any sugar), and when IB and i are present IB expresses.

But when IA and IB are present together they both express their own types of sugars: this is because of **co-dominance**. Hence red blood cells have both A and B types of sugars.

Since there are three different alleles, there are six different combinations of these three alleles that are possible, and therefore, a total of six different genotypes of the human ABO blood types. How many phenotypes are possible?

Table 5.2: Table Showing the Genetic Basis of Blood Groups in Human Population

Allele from Parent 1	Allele from Parent 2	Genotype of offspring	Blood types of offspring
I^A	I^A	$I^A I^A$	A
I^A	I^B	$I^A I^B$	AB
I^A	i	$I^A i$	A
I^B	I^A	$I^A I^B$	AB
I^B	I^B	$I^B I^B$	B
I^B	i	$I^B i$	B
i	i	$i\,i$	O

Here there are 6 Genotypes and 4 Phenotypes [A, B, AB and O].

Inheritance of Two Genes

Mendel also worked with and crossed pea plants that differed in two characters, as is seen in the cross between a pea plant that has seeds with yellow colour and round shape and one that had seeds of green colour and wrinkled shape.

Yellow colour was dominant over green and round shape dominant over wrinkled.

Let us use the genotypic symbols Y for dominant yellow seed colour and y for recessive green seed colour, R for round shaped seeds and r for wrinkled seed shape.

The genotype of the parents can then be written as RRYY and rryy. The cross between the two plants can be written down as in Figure showing the genotypes of the parent plants.

The gametes RY and ry unite on fertilisation to produce the F1 hybrid RrYy.

When Mendel self hybridised the F1 plants he found that 3/4th of F2 plants had yellow seeds and 1/4th had green.

The yellow and green colour segregated in a 3:1 ratio. Round and wrinkled seed shape also segregated in a 3:1 ratio; just like in a monohybrid cross.

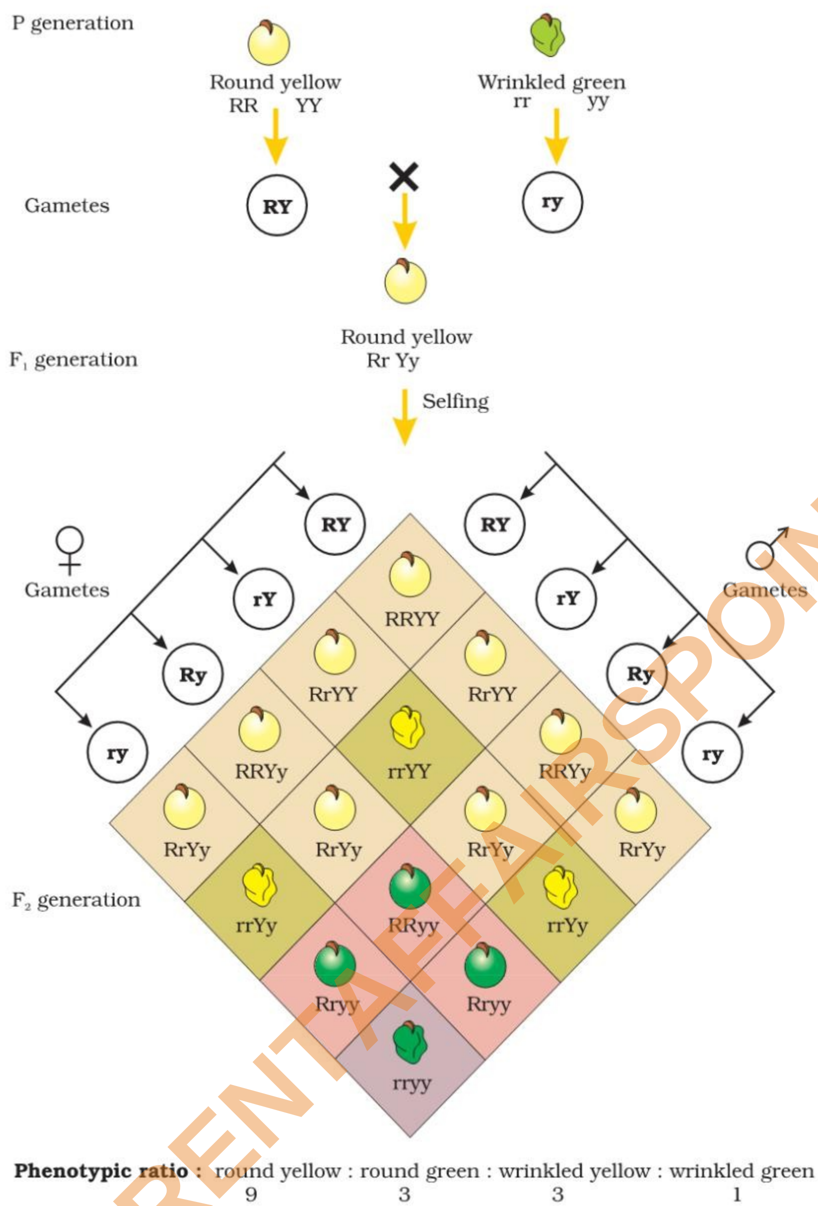


Figure 5.7 Results of a dihybrid cross where the two parents differed in two pairs of contrasting traits: seed colour and seed shape

Law of Independent Assortment

In the dihybrid cross, the phenotypes round, yellow; wrinkled, yellow; round, green and wrinkled, green appeared in the ratio **9:3:3:1.**

Such a ratio was observed for several pairs of characters that Mendel studied. The ratio of 9:3:3:1 can be derived as a combination series of 3 yellow: 1 green, with 3 round : 1 wrinkled. This derivation can be written as follows: (3 Round : 1 Wrinkled) (3 Yellow : 1 Green) = 9 Round, Yellow : 3 Wrinkled, Yellow: 3 Round, Green : 1 Wrinkled, Green.

Based upon such observations on dihybrid crosses (crosses between plants differing in two traits) Mendel proposed a **second set of generalisations** that we call **Mendel's Law of Independent Assortment**.

The law states that **'when two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent of the other pair of characters'**.

You can verify the law using The Punnett square above [Inheritance of Two Genes – dihybrid cross].

Summary

Genetics is a branch of biology which deals with principles of inheritance and its practices.

Progeny resembling the parents in morphological and physiological features has attracted the attention of many biologists.

Mendel was the first to study this phenomenon systematically. While studying the pattern of inheritance in pea plants of contrasting characters, Mendel proposed the principles of inheritance, which are today referred to as 'Mendel's Laws of Inheritance'.

He proposed that the 'factors' (later named as genes) regulating the characters are found in pairs known as alleles.

He observed that the expression of the characters in the offspring follow a definite pattern in different–first generations (F1), second (F2) and so on. Some characters are dominant over others.

The dominant characters are expressed when factors are in heterozygous condition (Law of Dominance). The recessive characters are only expressed in homozygous conditions.

The characters never blend in heterozygous condition.

A recessive character that was not expressed in heterozygous condition may be expressed again when it becomes homozygous. Hence, characters segregate while formation of gametes (Law of Segregation).

Not all characters show true dominance. Some characters show incomplete, and some show co-dominance.

When Mendel studied the inheritance of two characters together, it was found that the factors independently assort and combine in all permutations and combinations (Law of Independent Assortment).

Different combinations of gametes are theoretically represented in a square tabular form known as 'Punnett Square'.

The factors (now known as gene) on chromosomes regulating the characters are called the genotype and the physical expression of the characters is called phenotype.

Chromosomal Theory of Inheritance - Linkage and Recombination - Human Genome Project - Applications and Benefits of Human Genome Project.

Chromosomal Theory of Inheritance

Due to advancements in microscopy during 1900s, scientists were able to observe cell division. This led to the discovery of structures in the nucleus that appeared to double and divide just before each cell division. These were called **chromosomes** (colored bodies, as they were visualised by staining).

By 1902, the chromosome movement during meiosis had been worked out. The behavior of chromosomes was parallel to the behavior of genes and used biologists used chromosome movement to explain Mendel's laws.

[Mitosis (equational division) and meiosis (reduction division) were explained in previous posts].

The important things to remember are that chromosomes as well as genes occur in pairs. The two alleles of a gene pair are located on homologous sites on homologous chromosomes.

During Anaphase of meiosis I, the two chromosome pairs can align at the metaphase plate independently of each other.

To understand this, compare the chromosomes of four different colour in the left and right columns. In the left column (Possibility I) orange and green is segregating together. But in the right hand column (Possibility II) the orange chromosome is segregating with the red chromosomes.

Sutton and Boveri argued that the pairing and separation of a pair of chromosomes would lead to the segregation of a pair of factors they carried. Sutton united the knowledge of **chromosomal segregation** with **Mendelian principles** and called it the **chromosomal theory of inheritance**.

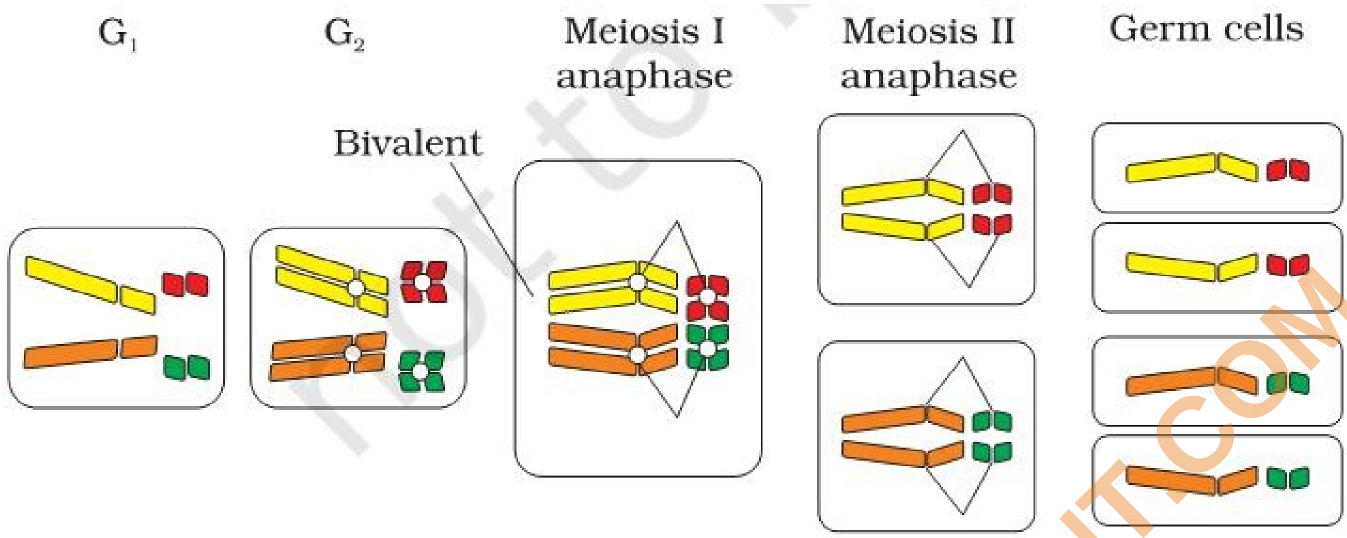


Figure 5.8 Meiosis and germ cell formation in a cell with four chromosomes. Can you see how chromosomes segregate when germ cells are formed?

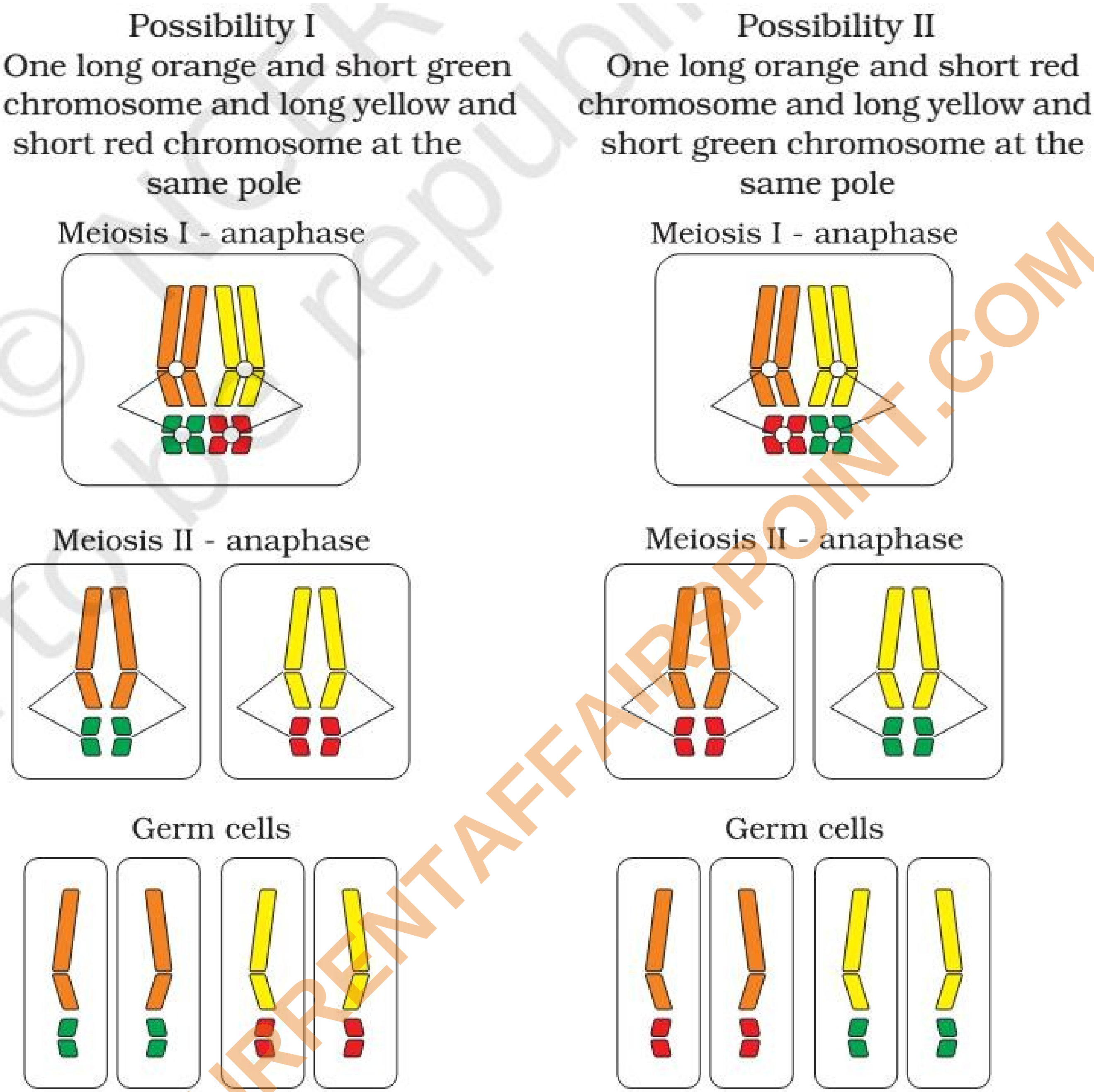


Figure 5.9 Independent assortment of chromosomes

Following this synthesis of ideas, experimental verification of the chromosomal theory of inheritance by Thomas Hunt Morgan and his colleagues, led to discovering the **basis for the variation that sexual reproduction produced**.

Morgan worked with the tiny fruit flies, Drosophila melanogaster, which were found very suitable for such studies.

Linkage and Recombination

Morgan carried out several dihybrid crosses in Drosophila to study genes that were sex-linked. The crosses were similar to the dihybrid crosses carried out by Mendel in peas.

For example Morgan hybridised yellow-bodied, white-eyed females to brown-bodied, red-eyed males and intercrossed their F 1 progeny. He observed that the two genes **did not segregate independently** of each other and the F 2 ratio deviated very significantly from the 9:3:3:1 ratio (expected when the two genes are independent).

Morgan and his group knew that the genes were located on the X chromosome and saw quickly that when the two genes in a dihybrid cross were situated on the same chromosome, the proportion of parental gene combinations were much higher than the non-parental type.

Morgan attributed this due to the **physical association or linkage of the two genes and coined the term linkage to describe this physical association of genes on a chromosome and the term recombination to describe the generation of non-parental gene combinations**.

Alfred Sturtevant used the frequency of recombination between gene pairs on the same chromosome as a measure of the distance between genes and 'mapped' their position on the chromosome.

Today genetic maps are extensively used as a starting point in the sequencing of whole genomes as was done in the case of the Human Genome Sequencing Project.

Human Genome Project

Human Genome Project is a publicly funded international collaborative scientific research project aimed at determining the **sequence of chemical base pairs** which make up human DNA, and of identifying and **mapping all of the genes** of the human genome.

[A base pair (bp) is a unit consisting of two **nucleobases** bound to each other by **hydrogen bonds**. They form the building blocks of the DNA double helix, and contribute to the folded structure of both DNA and RNA.]

Human Genome Project was formally launched in 1990, and finally declared complete in 2003.

The "genome" of any given individual is unique; mapping "the human genome" involves sequencing multiple variations of each gene.

All our genes together are known as our 'genome.' The HGP has revealed that there are probably about **20,500 human genes**.

Applications and Benefits of Human Genome Project

Can help us

understand diseases including: genotyping of specific viruses to direct appropriate treatment,

in identification of mutations linked to different forms of cancer,

understand the design of medication and more accurate prediction of their effects,

in advancement of forensic applied sciences, biofuels and other energy applications, agriculture, animal husbandry, etc..

understand evolution much more accurately.

Another proposed benefit is the commercial development of genomics research related to DNA based products, a multibillion-dollar industry.

Summary

After knowing that the genes are located on the chromosomes, a good correlation was drawn between Mendel's laws: segregation and assortment of chromosomes during meiosis. The Mendel's laws were extended in the form of 'Chromosomal Theory of Inheritance'.

Later, it was found that Mendel's law of independent assortment does not hold true for the genes that were located on the same chromosomes. These genes were called as 'linked genes'.

Closely located genes assorted together, and distantly located genes, due to recombination, assorted independently. Linkage maps, therefore, corresponded to arrangement of genes on a chromosome.

Many genes were linked to sexes also, and called as sex-linked genes. The two sexes (male and female) were found to have a set of chromosomes which were common, and another set which was different.

The chromosomes which were different in two sexes were named as sex chromosomes. The remaining set was named as autosomes. In humans, a normal female has 22 pairs of autosomes and a pair of sex chromosomes (XX).

Human Genome Project is a collaborative scientific research project aimed at identifying and **mapping all of the genes** of the human genome.

Human genome project is helpful in wide ranging biotechnology applications.

Sex Determination, Genetic Disorders - Pedigree Analysis, Mutation, Mendelian Disorders: Haemophilia, Sickle-cell anaemia, Phenylketonuria. Chromosomal disorders: Down's Syndrome, Klinefelter's Syndrome, Turner's Syndrome.

Sex Determination

Henking (1891) could trace a specific nuclear structure all through spermatogenesis in a few insects, and it was also observed by him that 50 per cent of the sperm received this structure after spermatogenesis, whereas the other 50 per cent sperm did not receive it.

Henking gave a name to this structure as the X body but he could not explain its significance.

Further investigations by other scientists led to the conclusion that the 'X body' of Henking was in fact a chromosome and that is why it was given the name X-chromosome.

It was also observed that in a large number of insects the mechanism of sex determination is of the XO type, i.e., all eggs bear an additional X-chromosome besides the other chromosomes (autosomes). On the other hand, some of the sperms bear the X-chromosome whereas some do not.

Eggs fertilized by sperm having an X-chromosome become females and, those fertilized by sperms that do not have an X-chromosome become males.

Due to the involvement of the X-chromosome in the determination of sex, it was designated to be the **sex chromosome**, and the rest of the chromosomes were named as **autosomes**.

Grasshopper is an example of XO type of sex determination in which the males have only one X-chromosome besides the autosomes, whereas females have a pair of X-chromosomes.

These observations led to the investigation of a number of species to understand the mechanism of sex determination.

In a number of other insects and mammals including man, XY type of sex determination is seen where both male and female have same number of chromosomes.

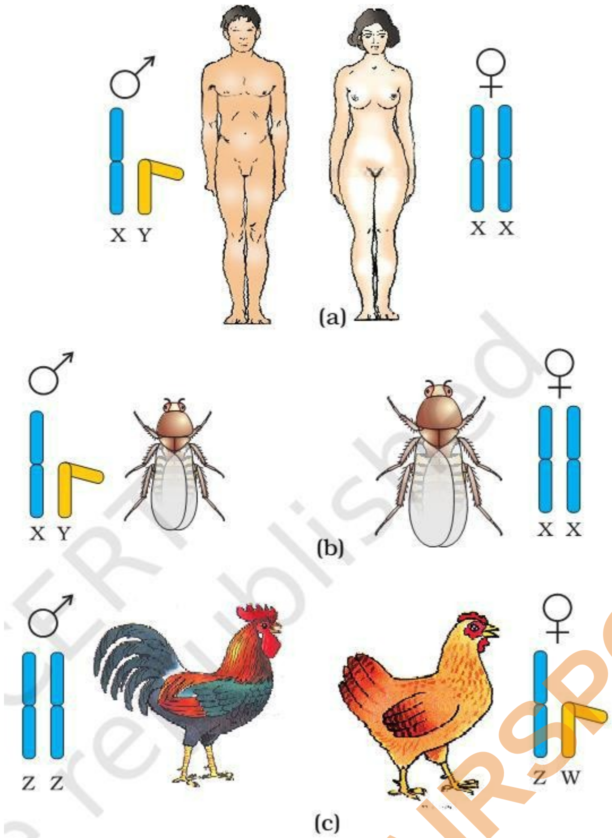


Figure 5.12 Determination of sex by chromosomal differences: (a,b) Both in humans and in *Drosophila*, the female has a pair of XX chromosomes (homogametic) and the male XY (heterogametic) composition; (c) In many birds, female has a pair of dissimilar chromosomes ZW and male two similar ZZ chromosomes

Among the males an X-chromosome is present but its counterpart is distinctly smaller and called the Y-chromosome. Females, however, have a pair of X-chromosomes.

Both males and females bear same number of **autosomes**. Hence, the males have autosomes plus XY, while female have autosomes plus XX.

[one pair of sex chromosome (XX or XY) + 22 pairs of autosomes == total 23 pairs of chromosomes in a human cell nucleus]

In human beings and in Drosophila the males have one X and one Y chromosome, whereas females have a pair of X-chromosomes besides autosomes.

In the above description you have studied about two types of sex determining mechanisms, i.e., XO type and XY type. But in both cases males produce two different types of gametes, (a) either with or without X-chromosome or (b) some gametes with X-chromosome and some with Y-chromosome. Such types of sex determination mechanism is designated to be the example of **male heterogamety**.

In some other organisms, e.g., birds, a different mechanism of sex determination is observed. In this case the total number of chromosome is same in both males and females. But two different types of gametes in terms of the sex chromosomes, are produced by females, i.e., **female heterogamety**.

In order to have a distinction with the mechanism of sex determination described earlier, the two different sex chromosomes of a female bird has been designated to be the Z and W chromosomes. In these organisms the females have one Z and one W chromosome, whereas males have a pair of Z-chromosomes besides the autosomes.

Sex Determination in Humans

It has already been mentioned that the sex determining mechanism in case of humans is XY type. Out of 23 pairs of chromosomes present, 22 pairs are exactly same in both males and females; these are the **autosomes**.

A pair of X-chromosomes are present in the female, whereas the presence of an X and Y chromosome are determinant of the male characteristic.

During spermatogenesis among males, two types of gametes are produced. 50 per cent of the total sperm produced carry the X-chromosome and the rest 50 per cent has Y-chromosome besides the autosomes.

Females, however, produce only one type of ovum with an X-chromosome. There is an equal probability of fertilization of the ovum with the sperm carrying either X or Y chromosome.

In case the ovum fertilizes with a sperm carrying X-chromosome the zygote develops into a female (XX) and the fertilization of ovum with Y-chromosome carrying sperm results into a male offspring.

Thus, it is evident that it is the genetic makeup of the sperm that determines the sex of the child. It is also evident that in each pregnancy there is always 50 per cent probability of either a male or a female child.

It is unfortunate that in our society women are blamed for giving birth to female children and have been ostracized and ill-treated because of this false notion.

Genetic Disorders

Pedigree Analysis

The idea that disorders are inherited has been prevailing in the human society since long. This was based on the heritability of certain characteristic features in families.

After the rediscovery of Mendel's work the practice of analyzing inheritance pattern of traits in human beings began.

Since it is evident that **control crosses** that can be performed in pea plant or some other organisms, are **not possible** in case of human beings, study of the family history about inheritance of a particular trait provides an alternative.

Such an analysis of traits in a several of generations of a family is called the **pedigree analysis**.

In the pedigree analysis the inheritance of a particular trait is represented in the family tree over generations.

In human genetics, pedigree study provides a strong tool, which is utilized to trace the inheritance of a specific trait, abnormality or disease.

Each and every feature in any organism is controlled by one or the other gene located on the DNA present in the chromosome. DNA is the carrier of genetic information. It is hence transmitted from one generation to the other without any change or alteration.

However, changes or alteration do take place occasionally. Such an alteration or change in the genetic material is referred to as **mutation**.

A number of disorders in human beings have been found to be associated with the inheritance of changed or altered genes or chromosomes.

Mutation

Mutation is a phenomenon which results in **alteration of DNA sequences** and consequently results in changes in the genotype and the phenotype of an organism.

In addition to **recombination, mutation** is another phenomenon that leads to variation in DNA.

DNA helix runs continuously from one end to the other in each chromatid, in a highly supercoiled form. Therefore **loss (deletions)** or **gain (insertion/duplication)** of a segment of DNA, result in alteration in chromosomes.

Since genes are known to be located on chromosomes, alteration in chromosomes results in **abnormalities or aberrations**. Chromosomal aberrations are commonly observed in **cancer cells**.

In addition to the above, mutation also arise due to change in a single base pair of DNA. This is known as **point mutation**. A classic example of such a mutation is **sickle cell anemia**.

Deletions and insertions of base pairs of DNA, causes **frame-shift mutations**.

There are many chemical and physical factors that induce mutations. These are referred to as **mutagens**. **UV radiations** can cause mutations in organisms – it is a mutagen.

Mendelian Disorders

Broadly, genetic disorders may be grouped into two categories – **Mendelian disorders** and **Chromosomal disorders**.

Mendelian disorders are mainly determined by **alteration or mutation in the single gene**. These disorders are transmitted to the offspring on the same lines as we have studied in the principle of inheritance.

The pattern of inheritance of such Mendelian disorders can be traced in a family by the **pedigree analysis**.

Most common and prevalent Mendelian disorders are **Haemophilia, Cystic fibrosis, Sickle-cell anaemia, Colour blindness, Phenylketonuria, Thalassemia, etc.**

It is important to mention here that such Mendelian disorders may be **dominant or recessive**.

By pedigree analysis one can easily understand whether the trait in question is dominant or recessive.

Similarly, the trait may also be linked to the sex chromosome as in case of **haemophilia**.

It is evident that this X-linked recessive trait shows transmission from carrier female to male progeny.

Haemophilia

This sex linked recessive disease, which shows its transmission from unaffected carrier female to some of the male progeny has been widely studied.

In this disease, a single protein that is a part of the cascade of proteins involved in the **clotting of blood** is affected. Due to this, in an affected individual a simple cut will result in **non-stop bleeding**.

The **heterozygous female (carrier)** for haemophilia may transmit the disease to sons.

The possibility of a female becoming a haemophilic is extremely rare because mother of such a female has to be at least carrier and the father should be haemophilic (unviable in the later stage of life).

The family pedigree of Queen Victoria shows a number of haemophilic descendents as she was a carrier of the disease.

Sickle-Cell Anaemia

This is an **autosome linked recessive trait** that can be transmitted from parents to the offspring when both the partners are carrier for the gene (or heterozygous). The disease is controlled by a single pair of allele, HbA and HbS.

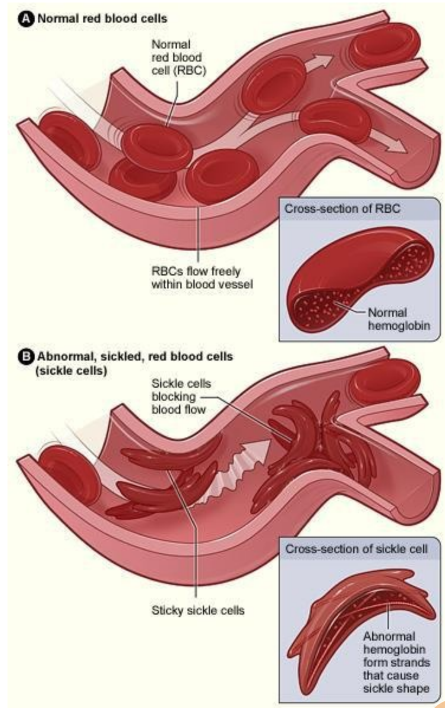
Out of the three possible genotypes **only homozygous individuals** for HbS (HbSHbS) show the diseased phenotype.

Heterozygous (HbAHbS) individuals appear apparently unaffected but they are carrier of the disease as there is 50 per cent probability of transmission of the mutant gene to the progeny, thus exhibiting sickle-cell trait.

The defect is caused by the substitution of **Glutamic acid (Glu)** by **Valine (Val)** at the sixth position of the beta globin chain of the **haemoglobin molecule**.

The substitution of amino acid in the globin protein results due to the single base substitution at the sixth codon of the beta globin gene from GAG to GUG.

The mutant haemoglobin molecule undergoes polymerization under **low oxygen tension** causing the change in the shape of the **RBC** from **biconcave disc** to elongated sickle like structure.



Phenylketonuria

This inborn error of metabolism is also inherited as the **autosomal recessive trait**.

The affected individual lacks an enzyme that converts the **amino acid phenylalanine** into **tyrosine**.

As a result of this **phenylalanine** is accumulated and converted into **phenylpyruvic acid** and other derivatives.

Accumulation of these in brain results in **mental retardation**. These are also excreted through urine because of its poor absorption by kidney.

Chromosomal Disorders

The chromosomal disorders on the other hand are caused due to absence or excess or abnormal arrangement of one or more sex chromosomes.

Failure of segregation of chromatids during cell division cycle results in the gain or loss of a chromosome(s), called **aneuploidy**.

For example, Down's syndrome results in the gain of extra copy of chromosome 21.

Similarly, Turner's syndrome results due to loss of an X chromosome in human females.

Failure of cytokinesis after telophase stage of cell division results in an increase in a whole set of chromosomes in an organism and, this phenomenon is known as **polyploidy**. This condition is often seen in **plants**.

The total number of chromosomes in a normal human cell is 46 (23 pairs). Out of these 22 pairs are autosomes and one pair of chromosomes are sex chromosome.

Sometimes, though rarely, either an additional copy of a chromosome may be included in an individual or an individual may lack one of any one pair of chromosomes. These situations are known as **trisomy** or **monosomy** of a chromosome, respectively.

Such a situation leads to very serious consequences in the individual. **Down's syndrome, Turner's syndrome, Klinefelter's syndrome** are common examples of chromosomal disorders.

Down's Syndrome

The cause of this genetic disorder is the presence of an **additional copy** of the chromosome number 21 **(trisomy of 21)**. This disorder was first described by Langdon Down (1866).

The affected individual is **short statured** with small round head, furrowed tongue and partially open mouth. Palm is broad with characteristic palm crease. Physical, psychomotor and mental development is retarded.

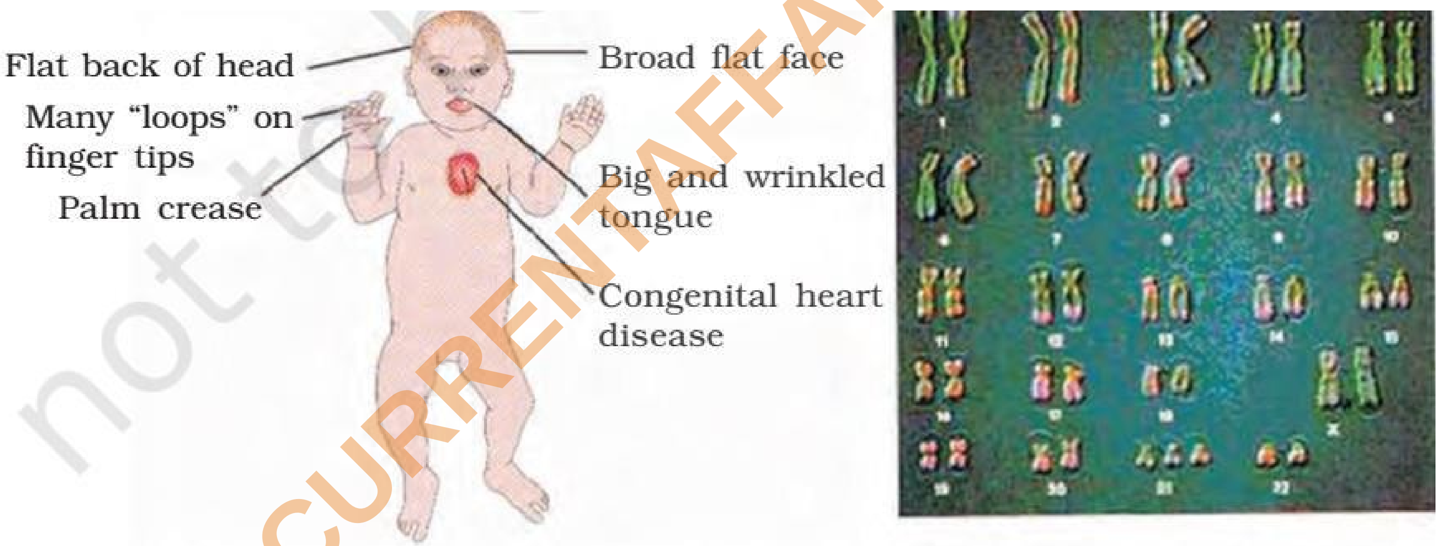


Figure 5.16 *A representative figure showing an individual inflicted with Down's syndrome and the corresponding chromosomes of the individual*

Klinefelter's Syndrome

This genetic disorder is also caused due to the presence of an additional copy of X-chromosome resulting into a karyotype of 47, XXY.

Such an individual has overall masculine development, however, the feminine development (development of breast, i.e., Gynaecomastia) is also expressed. Such individuals are **sterile**.

Turner's Syndrome

Such a disorder is caused due to the **absence** of one of the X chromosomes, i.e., 45 with X0. Such **females** are **sterile** as ovaries are rudimentary besides other features including lack of other secondary sexual characters.

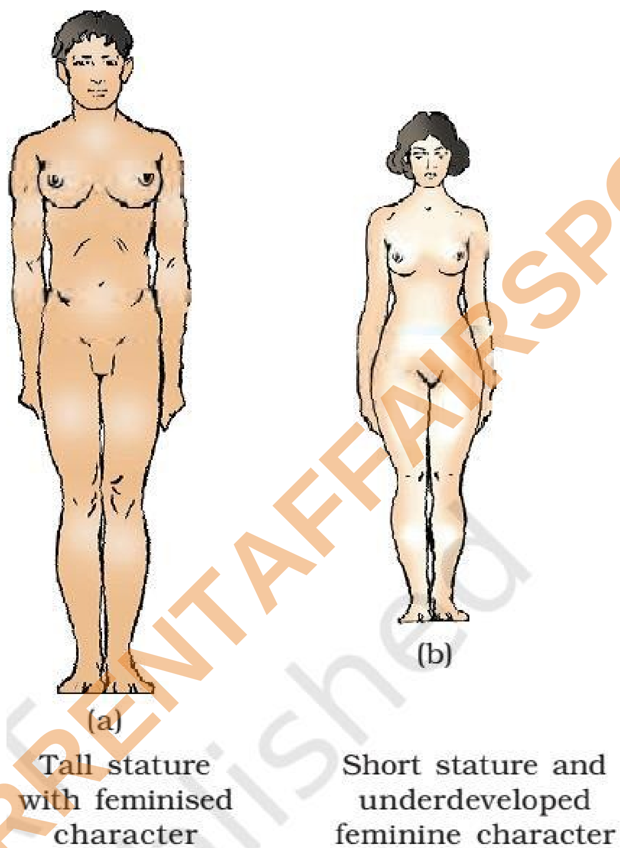


Figure 5.17 Diagrammatic representation of genetic disorders due to sex chromosome composition in humans : (a) Klinefelter Syndrome; (b) Turner's Syndrome

Summary

After knowing that the genes are located on the chromosomes, a good correlation was drawn between Mendel's laws: segregation and assortment of chromosomes during meiosis. The Mendel's laws were extended in the form of 'Chromosomal Theory of Inheritance'.

Later, it was found that Mendel's law of independent assortment does not hold true for the genes that were located on the same chromosomes. These genes were called as 'linked genes'.

Closely located genes assorted together, and distantly located genes, due to recombination, assorted independently. Linkage maps, therefore, corresponded to arrangement of genes on a chromosome.

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The chromosomes which were different in two sexes were named as sex chromosomes. The remaining set was named as autosomes. In humans, a normal female has 22 pairs of autosomes and a pair of sex chromosomes (XX).

A male has 22 pairs of autosomes and a pair of sex chromosome as XY. In chicken, sex chromosomes in male are ZZ, and in females are ZW.

Mutation is defined as change in the genetic material. A point mutation is a change of a single base pair in DNA.

Sickle-cell anemia is caused due to change of one base in the gene coding for beta-chain of hemoglobin.

Inheritable mutations can be studied by generating a pedigree of a family.

Some mutations involve changes in whole set of chromosomes (polyploidy) or change in a subset of chromosome number (aneuploidy). This helped in understanding the mutational basis of genetic disorders.

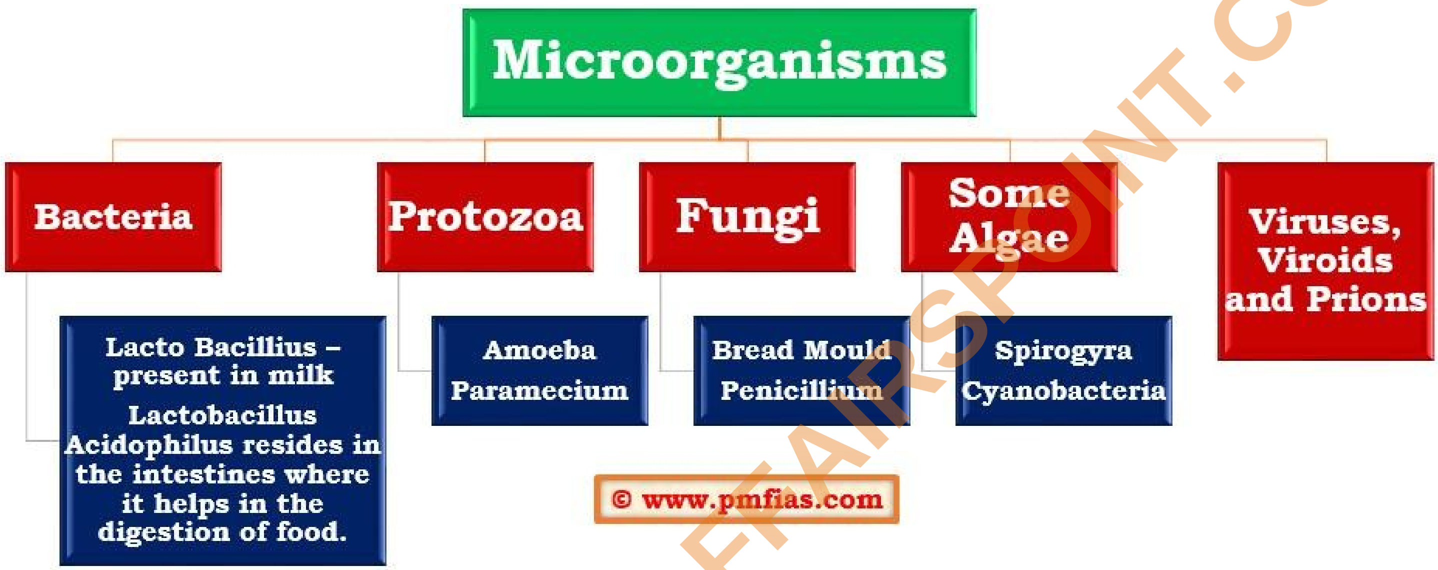
Down's syndrome is due to trisomy of chromosome 21, where there is an extra copy of chromosome 21 and consequently the total number of chromosome becomes 47.

In Turner's syndrome, one X chromosome is missing and the sex chromosome is as XO, and in Klinefelter's syndrome, the condition is XXY. These can be easily studied by analysis of Karyotypes.

Microbes or Microorganisms – Diseases Caused by Microorganisms – Diseases Caused By Bacteria, Viruses, Protozoans and Fungi.

Microbes or Microorganisms

Microorganisms [microbes] include **bacteria, fungi, protozoa, some algae, viruses, viroids** and also **prions** that are proteinacious infectious agents. Viruses reproduce only inside the cells of the host organism, which may be a bacterium, plant or animal.

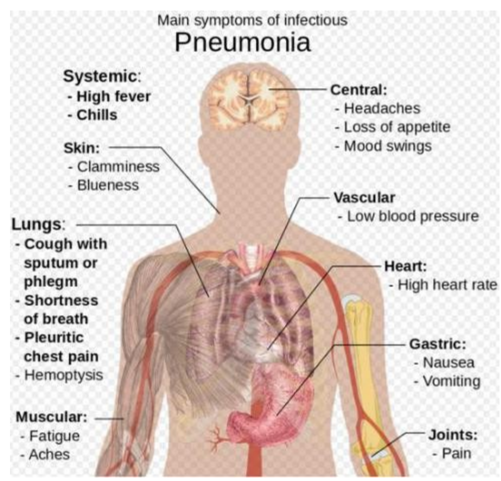


Microorganisms may be **single-celled** like bacteria, some algae and protozoa, or **multicellular**, such as algae and fungi. They can survive under all types of environment, ranging from ice cold climate to hot springs and deserts to marshy lands.

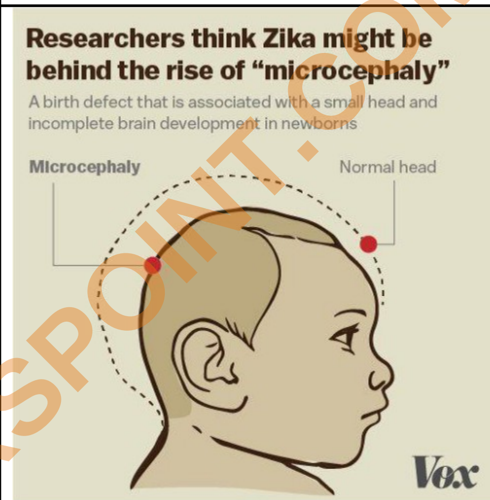
Microorganisms like amoeba can live alone, while fungi and bacteria may live in colonies.

Diseases Caused by Microorganisms

Disease	Causative Agent	Mode Of Transmission	Type Of Organism Affected	Details
Diseases Caused By Bacteria				
Acne vulgaris (or simply acne or pimples)	Propionibacterium acnes	Direct contact/close contact	Humans/ Adolescents	skin disease that occurs when hair follicles become clogged with dead skin cells and oil from the skin. Causes == Genetics + Excessive growth of the bacteria Propionibacterium acnes.
Anthrax	Bacillus anthraces	Contact with infected meat	Most animals including humans	Causes skin infections and Gastrointestinal (GI) infection that are fatal. French scientist Louis Pasteur developed the

				first effective vaccine in 1881.
Cholera	Vibrio cholerae	Water/food	Humans	Effects small intestine. The classic symptom is large amounts of watery diarrhea that lasts a few days. Vomiting and muscle cramps may also occur. Diarrhea can be so severe that it leads within hours to severe dehydration and electrolyte imbalance.
Citrus Canker	Xanthomonas axonopodis	Air	Citrus fruit plants	Infection causes lesions on the leaves, stems, and fruit of citrus trees.
Diptheria 	Corynebacterium diphtheriae	Air/direct contact	Humans	Symptoms: sore throat and fever. The neck may swell in part due to large lymph nodes. Complications may include myocarditis, inflammation of nerves, kidney problems, and bleeding problems due to low blood platelets. Myocarditis may result in an abnormal heart rate and inflammation of the nerves may result in paralysis.
Pneumonia *[caused by bacteria or viruses]*	Streptococcus pneumoniae and Haemophilus influenzae	Air borne droplets of sneeze	Humans	Pneumonia is an inflammatory condition of the lung affecting primarily the microscopic air sacs known as alveoli. 
Peptic ulcers	Helicobacter pylori		Humans	Ulcers in the lining of stomach and starting part of small intestine
Plague	Yersinia pestis	Air/ direct contact	Humans	Unhygienic conditions is the main cause. [You know why Surat is one of the cleanest cities in India?] The symptoms of plague depend on the concentrated areas of infection in each person: bubonic plague in lymph nodes, septicemic plague in blood vessels, pneumonic plague in lungs.
Tuberculosis	Mycobacterium	Air	Humans	Tuberculosis generally affects the lungs, but

	tuberculosis			can also affect other parts of the body. Most infections do not have symptoms, known as latent tuberculosis. About 10% of latent infections eventually progresses to active disease which, if left untreated, kills about half of those infected. The classic symptoms of active TB are a chronic cough with blood-tinged sputum, fever, night sweats, and weight loss.
Typhoid	Salmonella typhi	Water	Humans	Often there is a gradual onset of a high fever over several days. Weakness, abdominal pain, constipation, and headaches also commonly occur.
Diseases Caused By Viruses				
AIDS	Human Immunodeficiency Virus (HIV)	Blood exchange	Humans and primates	Severely weakens immunity and makes way for a number of other pathogens.
Chicken Pox	varicella zoster virus (VZV)	Air/contact	Humans	Chickenpox, also known as varicella, is a highly contagious disease. The disease results in a characteristic skin rash that forms small, itchy blisters. Less severe than small pox. Almost eradicated after the invention of vaccination.
Small Pox	Variola major and Variola minor	Air/contact/water	Humans	One of the highly dreaded diseases that is highly contagious. Almost eradicated after the invention of vaccination.
Chikungunya	Chikungunya viru s	Aedes mosquitoes, such as A. aegypti and A. albopictus		Causes severe joint pains. Animal reservoirs of the virus include monkeys, birds, cattle, and rodents. This is in contrast to dengue, for which primates are the only hosts
Cold, influenza (flu) and most coughs	Rhino viruses	Air borne droplets of sneeze	Humans	Summer are hostile for the virus. Most common during winter months.
Dengue fever	Flavivirus	Female Aedes mosquito	Humans	high fever, headache, vomiting, muscle and joint pains, and a characteristic skin rash. In a small proportion of cases, the disease develops into the life-threatening dengue hemorrhagic fever, resulting in bleeding, **low levels of blood platelets** and blood plasma leakage, or into dengue shock syndrome, where dangerously low blood pressure occurs.
Ebola	Ebola virus	Animal to man	Humans and Some Animals	Ebola infection shows a sudden onset of the disease resulting initially in flu-like symptoms: fever, chills and malaise. As the disease progresses, it results in multi-system involvements indicated by the person experiencing lethargy, nausea, vomiting, diarrhoea and headache.
Foot and Mouth Disease	Picornavirus[genu s Aphthovirus]	Close-contact animal-to-animal spread	Animals	Serious problem to animal farming in India.
Hepatitis B	hepatitis B virus	Blood Exchange,	Humans	Affects the **liver**. Acute as well as chronic.

	(HBV)	STD [**Sexually transmitted disease**]		
Measles	measles virus	Air	Humans	Complications occur in about 30% and may include diarrhea, **blindness, inflammation of the brain, and pneumonia** among others.
Polio or Poliomyelitis	Poliovirus	Water/faecal-mouth	Humans	Weak muscles leading to deformations.
Zika	Zika virus	Aedes mosquitoes, such as A. aegypti and A. albopictus	Humans	
Diseases Caused By Protozoans				
Amoebiasis (amoebic dysentery)	Entamoeba histolytica	Contaminated Water/food	Humans	Symptoms may include abdominal pain, mild diarrhoea, bloody diarrhea or severe colitis with tissue death and perforation. This last complication may cause peritonitis. People affected may develop anemia due to loss of blood.
Dysentery	Leishmania			
Kala-Azar or Visceral leishmaniasis	Leishmania genus	Sandflies	Humans	This disease is the second-largest parasitic killer in the world (after malaria). The parasite migrates to the internal organs such as the liver, spleen (hence "visceral"), and bone marrow, and, if left untreated, will almost always result in the death of the host. Signs and symptoms include fever, weight loss, fatigue, anemia, and substantial swelling of the liver and spleen.
Malaria	Different species of Plasmodium (P. vivax, P. malaria and P. falciparum)	Female Anopheles mosquito	Humans	Malaria causes symptoms that typically include fever, fatigue, vomiting, and headaches. In severe cases it can cause yellow skin, seizures, coma, or death.
Sleeping Sickness	Trypanosoma	Infected tsetse fly	Humans	Initially, in the first stage of the disease, there are fevers, headaches, itchiness, and joint pains. This begins one to three weeks after the bite. Weeks to months later the second stage begins with confusion, poor coordination, numbness and trouble sleeping.

Yellow Vein Mosaic of Okra [Ladies finger]	Bhendi yellow vein mosaic virus	Insect	Okra plant	Okra are dwarfed, malformed.
Diseases Caused By Fungi				
Ringworms	Fungi belonging to the genera Micr Trichophyton and Epidermophyton	Skin-skin contact	Humans	The fungi that cause parasitic infection, collectively dermatophytes, feed on keratin, the material found in the outer layer of skin, hair, and nails.
Rust of wheat	Puccinia rust fungus	Air/seeds	Wheat and other crops	Wheat leaf rust is a fungal disease that affects wheat, barley and rye stems, leaves and grains. In temperate zones it is destructive on winter wheat because the pathogen. overwinters. Infections can lead up to 20% yield loss exacerbated by dying leaves which fertilize the fungus.

Useful Microbes – Microbes In Human Welfare: Microbes in the production of Antibiotics, Vaccines, Curd, Fermented beverages, Biogas, Biofertilisers etc.

Useful Microorganisms – Microorganisms In Human Welfare

Microorganisms include bacteria, fungi, protozoa, some algae, viruses, viroids and also prions. Microorganisms may be single-celled like bacteria, some algae and protozoa, or multicellular, such as algae and fungi.

Some microorganisms are harmful [pathogens] as they cause various diseases in humans. A list of common diseases caused by microorganisms are given in the previous post [Diseases Caused by Microorganisms].

Some other microorganisms are beneficial and contribute to human welfare. This post is about such useful microorganisms [useful microbes].

Antibiotics and Vaccination

Whenever you fall ill the doctor may give you some antibiotic tablets, capsules or injections such as of penicillin. The source of these medicines is microorganisms.

These medicines kill or stop the growth of the disease-causing microorganisms. Such medicines are called **ANTIBIOTICS**.

These days a number of antibiotics are being produced from **bacteria** and **fungi**. **Streptomycin, tetracycline** and **erythromycin** are some of the commonly known antibiotics which are made from fungi and bacteria.

In 1929, **Alexander Fleming** was working on a culture of disease-causing bacteria [**Staphylococci**]. Suddenly he found the spores of a little green mould [**Penicillium notatum**] in one of his culture plates. He observed that the presence of mould prevented the growth of bacteria. In fact, it also killed many of these bacteria. From this the mould **penicillin** was prepared.

Antibiotics have greatly improved our capacity to treat deadly diseases such as plague, whooping cough, diphtheria and leprosy, which used to kill millions all over the globe. Today, we cannot imagine a world without antibiotics.

Antibiotics taken unnecessarily **may kill the beneficial bacteria** in the body.

Antibiotics, however, are not effective against cold and flu as these are caused by **viruses**.

When a disease-carrying microbe enters our body, the body produces **antibodies** to fight the invader. The body also remembers how to fight the microbe if it enters again. So, if dead or weakened microbes are introduced in a healthy body, the body fights and kills them by producing suitable antibodies. The antibodies remain in the body and we are protected from the disease-causing microbes. This is how a vaccine works.

Several diseases, including **cholera, tuberculosis, smallpox** and **hepatitis** can be prevented by vaccination. **Edward Jenner** discovered the vaccine for smallpox in 1798.

Chemicals, Enzymes and other Bioactive Molecules

Microbes are also used for commercial and industrial production of certain chemicals like **organic acids, alcohols** and **enzymes**. Examples of acid producers are

Aspergillus niger (a fungus) of citric acid

Acetobacter aceti (a bacterium) of acetic acid

Clostridium butylicum (a bacterium) of butyric acid

Lactobacillus (a bacterium) of **lactic acid**.

Yeast (Saccharomyces cerevisiae) is used for commercial production of **ethanol**.

Lipases are used in detergent formulations and are helpful in **removing oily stains** from the laundry.

You must have noticed that bottled fruit juices bought from the market are clearer as compared to those made at home. This is because the bottled juices are clarified by the use of **pectinases** and **proteases**.

Streptokinase produced by the bacterium Streptococcus and modified by genetic engineering is used as a **'clot buster'** for removing clots from the blood vessels of patients who have undergone myocardial infraction leading to heart attack.

Another bioactive molecule, **cyclosporin A**, that is used as an immunosuppressive agent in organ-transplant patients, is produced by the fungus **Tnchoderma polysporum**.

Statins produced by the yeast **Monascus purpureus** have been commercialized as blood-cholesterol lowering agents. It acts by competitively inhibiting the enzyme responsible for synthesis of cholesterol.

Milk to Curd

Micro-organisms such as **Lactobacillus** and others commonly called **lactic acid bacteria (LAB)** grow in milk and convert it to curd.

During growth, the LAB produce acids that coagulate and partially digest the milk proteins.

A small amount of curd added to the fresh milk as **inoculum or starter** contain millions of LAB, which at suitable temperatures multiply, thus converting milk to curd, which also improves its nutritional quality by increasing **VITAMIN B12 [helps in the synthesis of DNA and RBC (red blood cells). Vitamin B12 deficiency causes Anemia, severe damage to nervous system etc.]**.

In our stomach too, the LAB play very beneficial role in checking disease-causing microbes.

Microbes and Fermentation

Sugar is converted into alcohol by yeast. This process of conversion of sugar into alcohol is known as **fermentation**. **Louis Pasteur** discovered fermentation in 1857.

The dough, which is used for making foods such as dosa and idli is **fermented by bacteria**. The puffed-up appearance of dough is due to the production of **CO_2 gas** which is released by the microbes.

Similarly the dough, which is used for making bread, is fermented using **baker's yeast** (**Saccharomyces cerevisiae**).

A number of traditional drinks and foods are also made by fermentation by the microbes. 'Toddy', a traditional drink of some parts of southern India is made by fermenting sap from palms.

Microbes are also used to ferment fish, soyabean and bamboo- shoots to make foods.

Cheese, is one of the oldest food items in which microbes were used. The large holes in 'Swiss cheese' are due to production of a large amount of CO_2 by a bacterium named **Propionibacterium sharmanii**.

Fermented Beverages

Microbes especially yeasts have been used from time immemorial for the production of beverages like wine, beer, whisky, brandy or rum.

For this purpose the same yeast **Saccharomyces cerevisiae** used for bread-making and commonly called **brewer's yeast**, is used for fermenting malted cereals and fruit juices, to produce **ethanol**.

Depending on the type of the raw material used for fermentation and the type of processing (with or without distillation) different types of alcoholic drinks are obtained.

Wine and **beer** are produced without distillation whereas **whisky, brandy** and **rum** are produced by distillation of the fermented broth.

Microbes in sewage treatment

Sewage contains large amounts of organic matter and microbes. Many of which are pathogenic.

Treatment of waste water is done by the primary sludge, and the supernatant forms the effluent. The effluent from the primary settling tank is taken for secondary treatment.

The primary effluent is passed into large aeration tanks where it is constantly agitated mechanically and air is pumped into it. This allows vigorous growth of useful **aerobic microbes** into flocs (masses of bacteria associated with fungal filaments to form mesh like structures).

While growing, these microbes consume the major part of the organic matter in the effluent. This significantly reduces the **BOD (biochemical oxygen demand)** of the effluent.

BOD refers to the amount of the oxygen that would be consumed if all the organic matter in one liter of water were oxidized by bacteria.

The sewage water is treated till the BOD is reduced. **BOD is a measure of the organic matter present in the water**. The greater the BOD of waste water, more is its polluting potential.

Once the BOD of sewage or waste water is reduced significantly, the effluent is then passed into a settling tank where the bacterial 'flocs' are allowed to sediment. This sediment is called **activated sludge**.

A small part of the activated sludge is pumped back into the aeration tank to serve as the inoculum or starter.

The remaining major part of the sludge is pumped into large tanks called **anaerobic sludge digesters**. Here, other kinds of bacteria, which grow anaerobically, digest the bacteria and the fungi in the sludge.

During this digestion, bacteria produce a mixture of gases such as **methane, hydrogen sulphide** and **carbon dioxide**. These gases form **biogas** and can be used as source of energy as it is inflammable.

The effluent from the secondary treatment plant is generally released into natural water bodies like rivers and streams.

Microbes in production of biogas

Biogas is a mixture of gases (containing predominantly **methane**) produced by the microbial activity and which may be used as fuel.

Certain bacteria, which grow **anaerobically** on **cellulosic** material, produce large amount of **methane** [greenhouse gas] along with **CO_2** and **H_2**. These bacteria are collectively called **methanogens**, and one such common bacterium is **Methanobacterium**. These bacteria are commonly found in the anaerobic sludge during sewage treatment.

These bacteria are also present in the **rumen** (a part of stomach) of cattle. A lot of cellulosic material present in the food of cattle is also present in the rumen. In rumen, these bacteria help in the breakdown of cellulose and play an important role in the nutrition of cattle. Thus, the excreta (dung) of cattle, commonly called gobar, is rich in these bacteria. Dung can be used for generation of biogas, commonly called **gobar gas**. [Humans cannot digest cellulose. Hence their faecal waste cannot produce methane].

Microbes as biocontrol agents

Biocontrol refers to the use of biological methods for controlling plant diseases and pests. Biological agents are a better alternative to weedicides and pesticides.

Biological control of pests and diseases

In agriculture, there is a method of controlling pests that relies on natural predation rather than introduced chemicals.

A key belief of the organic farmer is that biodiversity furthers health. The more variety a landscape has, the more sustainable it is. The organic farmer, therefore, works to create a system where the insects that are sometimes called pests are not eradicated, but instead are kept at manageable levels by a complex system of checks and balances within a living and vibrant ecosystem.

Contrary to the 'conventional' farming practices which often use chemical methods to kill both useful and harmful life forms indiscriminately, this is a holistic approach that seeks to develop an understanding of the webs of interaction between the myriad of organisms that constitute the field fauna and flora.

The organic farmer holds the view that the eradication of the creatures that are often described as pests is not only possible, but also undesirable, for without them the beneficial predatory and parasitic insects which depend upon them as food or hosts would not be able to survive. Thus, the use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides.

An important part of the biological farming approach is to become familiar with the various life forms that inhabit the field, predators as well as pests, and also their life cycles, patterns of feeding and the habitats that they prefer. This will help develop appropriate means of biocontrol.

The very familiar beetle with red and black markings - the **Ladybird**, and **Dragonflies** are useful to get rid of aphids and mosquitoes, respectively.

An example of microbial biocontrol agents that can be Introduced in order to control butterfly caterpillars is the bacteria **Bacillus thuringiensis** (often written as Bt).

These are available in sachets as dried spores which are mixed with water and sprayed onto vulnerable plants such as brassicas and fruit trees, where these are eaten by the insect larvae. In the gut of the larvae, the toxin is released and the larvae get killed. The bacterial disease will kill the caterpillars, but leave other insects unharmed.

Because of the development of methods of genetic engineering in the last decade or so, the scientists have introduced **B. thuringiensis** toxin genes into plants. Such plants are resistant to attack by insect pests. **Bt-cotton** is one such example, which is being cultivated in some states of our country.

A biological control being developed for use in the treatment of plant disease is the fungus Trichoderma. **Trichoderma** species are free-living fungi that are very common in the root ecosystems. They are effective biocontrol agents of several plant pathogens.

Baculoviruses are pathogens that attack insects and other arthropods. They have been shown to have no negative impacts on plants, mammals, birds, fish or even on non-target insects.

Microbes as biofertilisers

Biofertilisers are organisms that enrich the nutrient quality of the soil. The main sources of biofertilisers are **bacteria, fungi** and **cyanobacteria**.

You may be knowing about the nodules on the roots of leguminous plants formed by the symbiotic association of **Rhizobium**. These bacteria fix atmospheric nitrogen into organic forms, which is used by the plant as nutrient.

Other bacteria can fix atmospheric nitrogen while free-living in the soil (examples **Azospirillum** and **Azotobacter**), thus enriching the nitrogen content of the soil.

Fungi are also known to form symbiotic associations with plants (**mycorrhiza**). Many members of the genus Glomus form mycorrhiza. The fungal symbiont in these associations absorbs **phosphorus** from soil and passes it to the plant.

Plants having such associations show other benefits also, such as resistance to root-borne pathogens, tolerance to salinity and drought, and an overall increase in plant growth and development.

Cyanobacteria are autotrophic microbes widely distributed in aquatic and terrestrial environments many of which can **fix atmospheric nitrogen**, e.g. Anabaena, Nostoc, Oscillatona, etc.

In paddy fields, cyanobacteria serve as an important biofertiliser. Blue green algae also add organic matter to the soil and increase its fertility.

Preservatives

Salts and edible oils are the common chemicals generally used to check the growth of microorganisms. Therefore they are called **preservatives**. We add salt or acid preservatives to pickles to prevent the attack of microbes. **Sodium benzoate** and **sodium metabisulphite** are common preservatives. These are also used in the jams and squashes to check their spoilage.

Common salt has been used to preserve meat and fish for ages. Meat and fish are covered with dry salt to check the growth of bacteria. Salting is also used to preserve amla, raw mangoes, tamarind, etc.

Jams, jellies and squashes are preserved by sugar. Sugar reduces the moisture content which inhibits the growth of bacteria which spoil food.

Use of oil and vinegar prevents spoilage of pickles because bacteria cannot live in such an environment. Vegetables, fruits, fish and meat are often preserved by this method.

Pasteurized milk can be consumed without boiling as it is free from harmful microbes. The milk is heated to about 70$_0$ C for 15 to 30 seconds and then suddenly chilled and stored. By doing so, it prevents the growth of microbes. This process was discovered by **Louis Pasteur**. It is called **pasteurization**.

Summary

Microbes are a very important component of life on earth. Not all microbes are pathogenic. Many microbes are very useful to human beings.

We use microbes and microbially derived products almost every day.

Bacteria called lactic acid bacteria (LAB) grow in milk to convert it into curd.

The dough, which is used to make bread, is fermented by yeast called Saccharomyces cerevisiae.

Certain dishes such as idli and dosa, are made from dough fermented by microbes.

Bacteria and fungi are used to impart particular texture, taste and flavor to cheese.

Microbes are used to produce industrial products like lactic acid, acetic acid and alcohol, which are used in a variety of processes in the industry.

Antibiotics like penicillins produced by useful microbes are used to kill disease-causing harmful microbes.

Antibiotics have played a major role in controlling infectious diseases like diphtheria, whooping cough and pneumonia.

For more than a hundred years, microbes are being used to treat sewage (waste water) by the process of activated sludge formation and this helps in recycling of water in nature.

Methanogens produce methane (biogas) while degrading plant waste.

Biogas produced by microbes is used as a source of energy in rural areas.

Microbes can also be used to kill harmful pests, a process called as biocontrol.

The biocontrol measures help us to avoid heavy use of toxic pesticides for controlling pests.

Source: [NCERT Science Textbooks Class 6-12]

Animal Tissues - Epithelial Tissue: Simple Epithelium and Compound Epithelium, Connective Tissue, Muscular Tissue and Nervous Tissue.

Animal Tissues

Blood and muscles are both examples of tissues found in our body. On the basis of the functions they perform we can think of different types of animal tissues, such as **epithelial tissue, connective tissue, muscular tissue** and **nervous tissue**.

Blood is a type of connective tissue, and muscle forms muscular tissue.

Epithelial Tissue

The **covering or protective tissues** in the animal body are epithelial tissues.

Epithelium covers most organs and cavities within the body.

It also forms a barrier to keep different body systems separate.

The **skin**, the **lining of the mouth**, the **lining of blood vessels**, **lung alveoli** and **kidney tubules** are all made of epithelial tissue.

Epithelial tissue cells are tightly packed and form a continuous sheet.

They have only a small amount of cementing material between them and **almost no intercellular spaces.**

Obviously, anything entering or leaving the body must cross at least one layer of epithelium.

As a result cells of various epithelia play an important role in regulating the **exchange of materials** between the body and the external environment and also between different parts of the body.

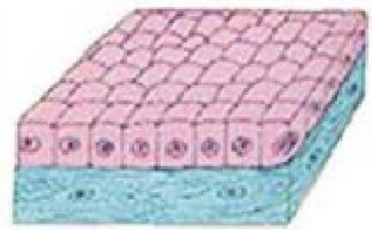
Regardless of the type, all epithelium is usually separated from the underlying tissue by an extracellular fibrous basement membrane.

There are two types of epithelial tissues namely **simple epithelium** and **compound epithelium.**

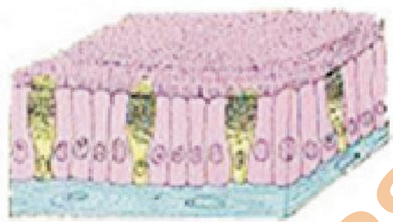
Simple Epithelium

Simple epithelium is composed of a **single layer of cells** and functions as a lining for body **cavities, ducts, and tubes**.

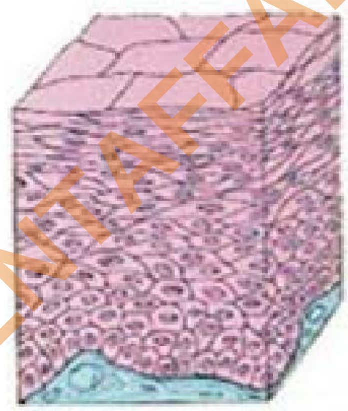
(a) Squamous



(b) Cuboidal



(c) Columnar (Ciliated)



(d) Stratified squamous

Fig. 6.9: *Different types of epithelial tissues*

Squamous Epithelium

The squamous epithelium is made of a **single thin layer** of flattened cells with irregular boundaries.

They are found in the walls of blood vessels and air sacs of lungs and are involved in functions like forming a **diffusion boundary**.

Different epithelia show differing structures that correlate with their unique functions. For example, in cells lining blood vessels or lung alveoli, where transportation of substances occurs through a **selectively Permeable** surface, there is a simple flat kind of epithelium. This is called the simple Squamous epithelium.

Simple squamous epithelial cells are **extremely thin and flat** and form a delicate lining.

The oesophagus and the lining of the mouth are also covered with squamous epithelium.

Stratified Squamous Epithelium

The skin, which protects the body, is made of squamous epithelium.

Skin epithelial cells are arranged in **many layers** to prevent wear and tear.

Since they are arranged in a pattern of layers, the epithelium is called stratified squamous epithelium.

Ciliated Columnar Epithelium

The columnar epithelium is composed of a single layer of **tall** and slender cells. Their nuclei are located at the base.

Where **absorption and secretion** occur, as in the inner lining of the intestine, tall epithelial cells are present.

In the respiratory tract, the columnar epithelial tissue also has cilia, which are hair-like projections on the outer surfaces of epithelial cells. These cilia can **move**, and their movement pushes the mucus forward to clear it. This type of epithelium is thus ciliated columnar epithelium.

They are mainly present in the inner surface of hollow organs like bronchioles and fallopian tubes.

Cuboidal Epithelium

The cuboidal epithelium is composed of a single layer of cube-like cells. This is commonly found in **ducts of glands** and tubular parts of nephrons in kidneys and its main functions are **secretion and absorption**.

Cuboidal epithelium (with cube-shaped cells) forms the lining of kidney tubules and ducts of salivary glands, where it provides **mechanical support**.

Glandular Epithelium

Epithelial cells often acquire additional specialization as **gland cells**, which can secrete substances at the epithelial surface.

Sometimes a portion of the epithelial tissue folds inward, and a multicellular gland is formed. This is glandular epithelium.

Some of the **columnar or cuboidal cells** get specialized for secretion and are called glandular epithelium. They are mainly of two types: unicellular, consisting of isolated glandular cells (**goblet cells** of the alimentary canal), and multicellular, consisting of cluster of cells (**salivary gland**).

On the basis of the mode of pouring of their secretions, glands are divided into two categories namely **EXOCRINE** and **ENDOCRINE** glands.

Exocrine glands secrete mucus, saliva, earwax, oil, milk, digestive enzymes and other cell products. These products are released through ducts or tubes.

In contrast, **endocrine glands do not have ducts**. Their products called **hormones** are secreted directly into the **fluid** bathing the gland.

Compound Epithelium

The compound epithelium consists of two or more cell layers and has **protective function** as it does in our skin.

Compound epithelium is made of more than one layer (**multi-layered**) of cells and thus has a **limited role in secretion and absorption**. Their main function is to provide **protection** against chemical and mechanical stresses.

They cover the dry surface of the skin, the moist surface of buccal cavity, pharynx, inner lining of ducts of salivary glands and of pancreatic ducts.

All cells in epithelium are held together with little intercellular material. In nearly all animal tissues, specialized junctions provide both structural and functional links between its individual cells.

Three types of cell junctions are found in the epithelium and other tissues. These are called as **tight, adhering and gap junctions**.

Tight junctions help to stop substances from leaking across a tissue. Adhering junctions perform cementing to keep neighboring cells together. Gap junctions facilitate the cells to communicate with each other by connecting the cytoplasm of adjoining cells, for rapid transfer of ions, small molecules and sometimes big molecules.

Connective Tissue

Connective tissues are most abundant and widely distributed in the body of complex animals. They are named connective tissues because of their special function of linking and supporting other tissues/organs of the body.

They range from soft connective tissues to specialized types, which include **cartilage, bone, adipose, and blood.**

In all connective tissues except blood, the cells secrete fibres of structural proteins called **collagen or elastin**.

The fibres provide **strength, elasticity and flexibility** to the tissue. These cells also secrete modified polysaccharides, which accumulate between cells and fibres and act as matrix (ground substance).

Connective tissues are classified into three types: (i) Loose connective tissue, (ii) Dense connective tissue and (iii) Specialized connective tissue.

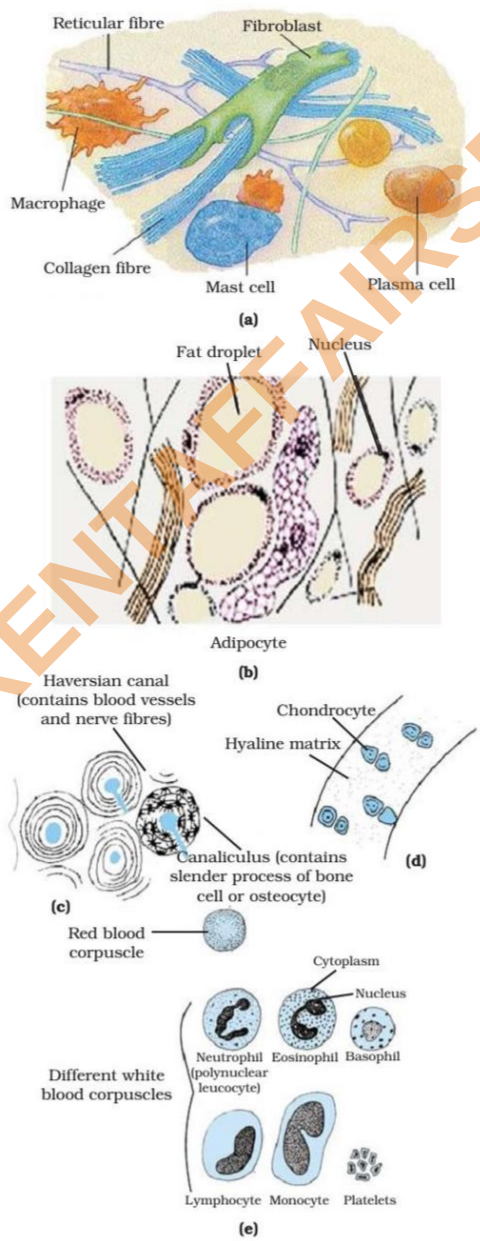


Fig. 6.10: *Types of connective tissues: (a) areolar tissue, (b) adipose tissue, (c) compact bone, (d) hyaline cartilage, (e) types of blood cells*

Loose Connective Tissue

Loose connective tissue has cells and fibres loosely arranged in a semi-fluid ground substance, for example, areolar tissue present beneath the skin.

Often it serves as a **support framework for epithelium**. It contains **fibroblasts** (cells that produce and secrete fibres), **macrophages** [a large phagocytic cell found in stationary form in the tissues or as a mobile white blood cell, especially at sites of infection] and **mast cells** [a cell found in connective tissue and releasing histamine and other substances during inflammatory and allergic reactions].

Adipose tissue is a type of loose connective tissue located mainly beneath the skin. The cells of this tissue are specialized to **store fats**. The excess of nutrients which are not used immediately are converted into fats and are stored in this tissue.

Dense Connective Tissue

Fibres and fibroblasts are compactly packed in the dense connective tissues. Orientation of fibres show a regular or irregular pattern and are called dense regular and dense irregular tissues.

In the dense regular connective tissues, the collagen fibres are present in rows between many parallel bundles of fibres. **Tendons**, which attach skeletal muscles to bones and **ligaments** which attach one bone to another are examples of this tissue.

Dense irregular connective tissue has fibroblasts and many fibres (mostly collagen) that are oriented differently. This tissue is present in the skin.

Specialized Connective Tissue – Cartilage, Bones, Blood, Areolar

Cartilage, bones and **blood** are various types of specialized connective tissues.

The intercellular material of cartilage is solid and pliable and resists compression. Cells of this tissue (**chondrocytes**) are enclosed in small cavities within the matrix secreted by them.

Most of the cartilages in vertebrate embryos are replaced by bones in adults. Cartilage is present in the tip of nose, outer ear joints, trachea, larynx, between adjacent bones of the vertebral column, limbs and hands in adults.

Bone cells are embedded in a hard matrix that is composed of **calcium and phosphorus compounds.**

Bones have a hard and non-pliable ground substance rich in **calcium salts** and **collagen fibres** which give bone its strength. It is the main tissue that provides structural frame to the body. Bones support and protect softer tissues and organs.

The bone cells (**osteocytes**) are present in the spaces called lacunae. The **bone marrow** in some bones is the site of production of blood cells.

Two bones can be connected to each other by another type of connective tissue called the **ligament**. This tissue is very elastic. It has considerable strength. Ligaments contain very little matrix. **Tendons** connect bones to muscles and are another type of connective tissue. Tendons are fibrous tissue with great strength but limited flexibility.

Blood is a fluid connective tissue containing **plasma, red blood cells (RBC), white blood cells (WBC) and platelets**. It is the main circulating fluid that helps in the transport of various substances.

Areolar connective tissue is found between the skin and muscles, around blood vessels and nerves and in the bone marrow.

It fills the space inside the organs, supports internal organs and helps in repair of tissues.

Muscular Tissue

Each muscle is made of many long, cylindrical fibres arranged in parallel arrays. These fibres are composed of numerous fine fibrils, called **myofibrils**.

Muscle fibres contract (shorten) in response to stimulation, then relax (lengthen) and return to their uncontracted state in a coordinated fashion. Muscles contain special proteins called **contractile proteins**, which contract and relax to cause movement.

Muscles are of three types, **skeletal, smooth,** and **cardiac**.

Skeletal Muscle Tissue – Voluntary Muscles

We can move some muscles by conscious will. Such muscles are called voluntary muscles.

These muscles are also called skeletal muscles as they are mostly attached to bones and help in body movement.

Under the microscope, these muscles show alternate light and dark bands or striations. As a result, they are also called striated muscles. The cells of this tissue are long, cylindrical, unbranched and **multinucleate** (having many nuclei).

Skeletal muscle tissue is closely attached to skeletal bones. In a typical muscle such as the biceps, striated (striped) skeletal muscle fibres are bundled together in a parallel fashion. A sheath of tough connective tissue encloses several bundles of such muscle fibres.

Smooth Muscle Tissue – Involuntary Muscles

The movement of food in the alimentary canal or the contraction and relaxation of blood vessels are involuntary movements. We cannot really start them or stop them simply by wanting to do so! Smooth muscles or involuntary muscles control such movements.

They are also found in the iris of the eye, in ureters and in the bronchi of the lungs.

The cells are long with pointed ends (spindle-shaped) and uninucleate (having a single nucleus). They are also called unstriated muscles.

The smooth muscle fibres taper at both ends (fusiform, spindle-shaped) and do not show striations. Cell junctions hold them together and they are bundled together in a connective tissue sheath. The wall of internal organs such as the blood vessels, stomach and intestine contains this type of muscle tissue.

Cardiac Muscle Tissue – Involuntary Muscles

The muscles of the heart show rhythmic contraction and relaxation throughout life. These involuntary muscles are called cardiac muscles. Heart muscle cells are cylindrical, branched and uninucleate.

Cardiac muscle tissue is a contractile tissue present only in the **heart**. Cell junctions fuse the plasma membranes of cardiac muscle cells and make them stick together. Communication junctions (intercalated discs) at some fusion points allow the cells to contract as a unit, i.e., when one cell receives a signal to contract, its neighbors are also stimulated to contract.

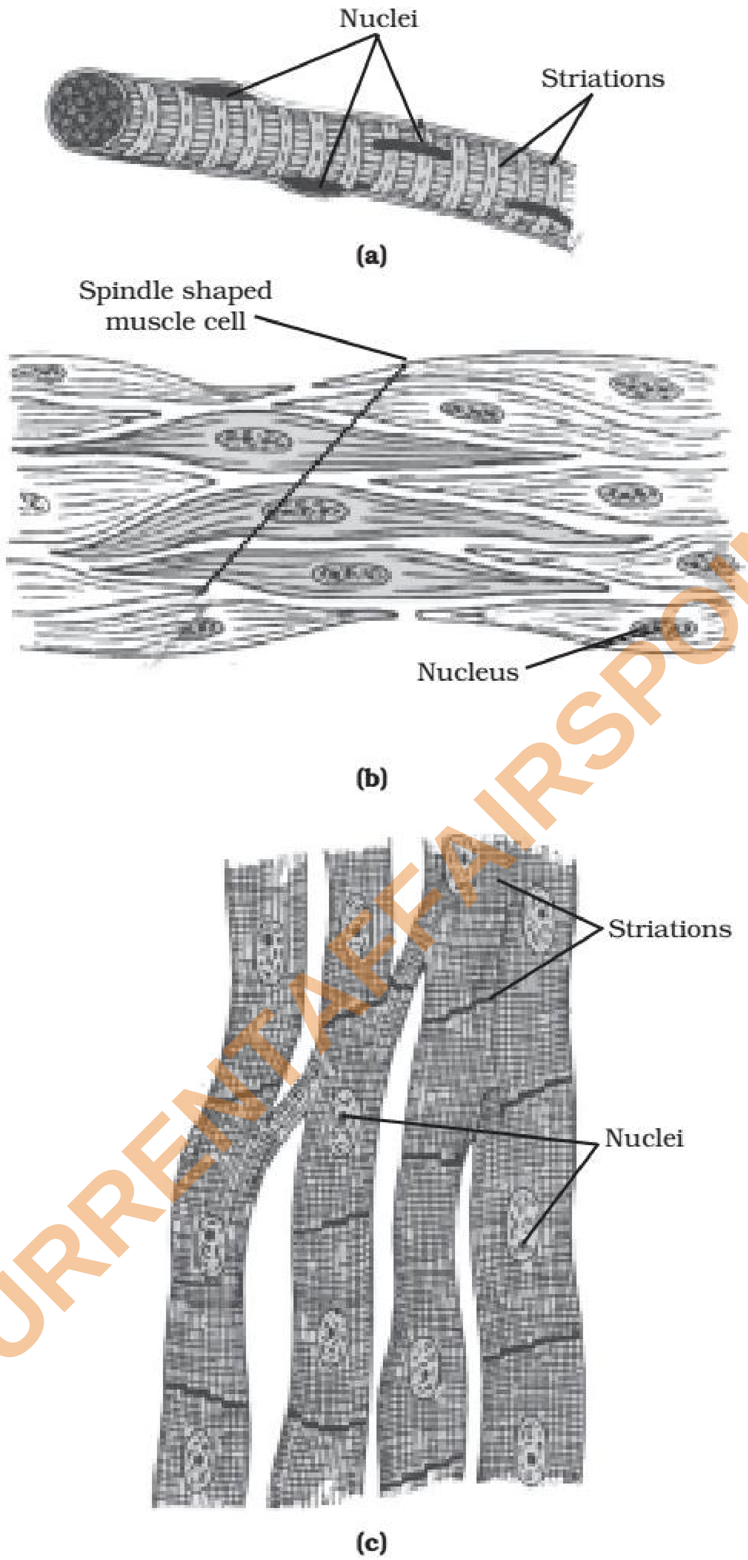


Fig. 6.11: *Types of muscles fibres: (a) striated muscle, (b) smooth muscle, (c) cardiac muscle*

Nervous Tissue

Neural tissue exerts the greatest control over the body's responsiveness to changing conditions.

Neurons, the unit of neural system are excitable cells. The neuroglial cell which constitute the rest of the neural system protect and support neurons.

Neuroglia make up more than one-half the volume of neural tissue in our body.

When a neuron is suitably stimulated, an electrical disturbance is generated which swiftly travels along its **plasma membrane**.

Arrival of the disturbance at the neuron's endings, or output zone, triggers events that may cause stimulation or inhibition of adjacent neurons and other cells.

All cells possess the ability to respond to stimuli. However, cells of the nervous tissue are highly specialized for being stimulated and then transmitting the stimulus very rapidly from one place to another within the body.

The **brain, spinal cord and nerves** are all composed of the nervous tissue. The cells of this tissue are called **nerve cells or neurons**.

A neuron consists of a cell body with a nucleus and cytoplasm, from which long thin hair-like parts arise. Usually each neuron has a single long part, called the **axon**, and many short, branched parts called **dendrites**.

An individual nerve cell may be up to a metre long. Many nerve fibres bound together by connective tissue make up a nerve.

Nerve impulses allow us to move our muscles when we want to. The functional Combination of nerve and muscle tissue is fundamental to most animals. This combination enables animals to move rapidly in response to stimuli.

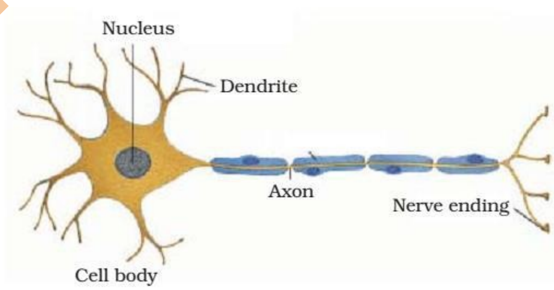


Fig. 6.12: *Neuron-unit of nervous tissue*

Origin of Life on Earth - Evolution of Life on Earth - Adaptive Radiation - Biological Evolution - Origin and Evolution of Man – Timeline of Evolution.

Origin Of Life on Earth

The universe is very old - almost **13 billion years old**. Huge clusters of galaxies comprise the universe.

The Big Bang theory attempts to explain to us the origin of universe. It talks of a singular huge explosion unimaginable in physical terms.

The universe expanded and hence, the temperature came down. Hydrogen and Helium formed sometime later.

The gases condensed under gravitation and formed the galaxies of the present day universe.

In the solar system of the milky way galaxy, earth was supposed to have been formed about **4.5 billion** years back.

There was no atmosphere on early earth. Methane, carbondioxide and ammonia released from molten mass covered the surface.

The **UV rays** from the sun brokeup **water** into **Hydrogen** and **Oxygen** and the lighter H2 escaped. **Oxygen** combined with **ammonia** and **methane** to form water, CO2 and others.

The ozone layer was formed. As earth cooled, the water vapor fell as rain, to fill all the depressions and form oceans.

Life appeared 500 million years after the formation of earth, i.e., almost four billion years back. Some scientists believe that the life came from outerspace.

The first non-cellular forms of life could have originated 3 billion years back. They would have been giant molecules (RNA, Protein, Polysaccharides, etc.). These capsules reproduced their molecules perhaps.

The first cellular form of life did not possibly originate till about 2000 million years ago. These were probably single-cells. All life forms were in water environment only.

The version of a biogenesis, i.e., the first form of life arose slowly through evolutionary forces from non-living molecules is accepted by majority.

However, once formed, how the first cellular forms of life could have evolved into the complex biodiversity of today is the fascinating story that will be discussed below.

Evolution of Life on Earth

Evolutionary Biology is the study of history of life forms on earth.

Homology indicates common ancestry. In the context of biology, homology is the existence of shared ancestry between a pair of structures, or genes, in different species.

A common example of homologous structures in evolutionary biology are the wings of bats and the arms of primates.

Homology is based on **divergent evolution** whereas **Analogy** refers to a situation exactly opposite [**convergent evolution**].

Wings of butterfly and of birds look alike. They are not anatomically similar structures though they perform similar functions.

Hence, analogous structures are a result of convergent evolution - different structures evolving for the same function and hence having similarity.

Other examples of analogy are the eye of the octopus and of mammals or the flippers of Penguins and Dolphins.

One can say that it is the similar habitat that has resulted in selection of similar adaptive features in different groups of organisms but toward the same function: Sweet **potato (root modification)** and **potato (stem modification)** is another example for analogy.

Q1. Which one of the following is a modified stem? [1996]

Carrot

Sweet potato

Coconut

Potato

Carrot → Modified root

Coconut → Modified seed

Adaptive Radiation

During his journey, Charles Darwin went to Galapagos Islands. There he observed an amazing diversity of creatures.

Of particular interest, small black birds later called Darwin's Finches amazed him.

He realized that there were many varieties of finches in the same island. All the varieties, he conjectured, evolved on the island itself.

From the original seed-eating features, many other forms with altered beaks arose, enabling them to become insectivorous and vegetarian finches. This process of evolution of different species in a given geographical area starting from a point and literally **radiating to other areas of geography (habitats)** is called adaptive radiation.

Biological evolution

The essence of Darwinian theory about evolution is **natural selection**. The rate of appearance of new forms is linked to the life cycle or the life span.

Microbes that divide fast have the ability to multiply and become millions of individuals within hours.

A colony of bacteria (say A) growing on a given medium has built- in variation in terms of ability to utilise a feed component.

A change in the medium composition would bring out only that part of the population (say B) that can survive under the new conditions.

In due course of time this variant population outgrows the others and appears as new species. This would happen within days.

For the same thing to happen in a fish or fowl would take million of years as life spans of these animals are in years.

Hence, there must be a **genetic basis for getting selected and to evolve**.

Another way of saying the same thing is that some organisms are better adapted to survive in an otherwise hostile environment. Adaptive ability is inherited. It has a **genetic basis**. **Fitness** is the end result of the ability to adapt and get selected by nature.

A Brief Account of Evolution

About 2000 million years ago (mya) the first cellular forms of life appeared on earth.

The mechanism of how non-cellular aggregates of giant **macromolecules** could evolve into cells with membranous envelop is not known.

Some of these cells had the ability to release O2. The reaction could have been similar to the light reaction in photosynthesis where water is split with the help of solar energy captured and channelized by appropriate light harvesting pigments.

Slowly **single-celled organisms** became **multi-cellular** life forms. By the time of 500 mya, **invertebrates** were formed and active. **Jawless fish** probably evolved around 350 mya. **Sea weeds** and few **plants** existed probably around 320 mya.

We are told that the first organisms that invaded land were **plants**. They were widespread on land when animals invaded land.

Fish with stout and strong fins could move on land and go back to water. This was about 350 mya. These animals called lobefins evolved into the first **amphibians** that lived on both land and water. These were ancestors of modern day **frogs** and **salamanders**.

The amphibians evolved into **reptiles**. They lay **thick-shelled eggs** which do not dry up in sun unlike those of amphibians. Again we only see their modern day descendents, the turtles, tortoises and crocodiles.

In the next 200 million years or so, reptiles of different shapes and sizes dominated on earth. Giant **ferns (pteridophytes)** were present along with reptiles but they all fell to form coal deposits slowly.

Some of these land reptiles went back into water to evolve into fish like reptiles probably 200 mya (e.g. Ichthyosaurs).

The land reptiles were, of course, the dinosaurs. The biggest of them, i.e., **Tyrannosaurus** rex was about 20 feet in height and had huge fearsome dagger like teeth.

About 65 mya, the dinosaurs suddenly disappeared from the earth. We do not know the true reason. Some say climatic changes killed them. Some say most of them evolved into birds. The truth may live in between. Small sized reptiles of that era still exist today.

The first **mammals** were like shrews. Their fossils are small sized. Mammals were **viviparous** and protected their unborn young inside the mother's body.

Mammals were more intelligent in sensing and avoiding danger at least. When reptiles came down mammals took over this earth. T

here were in South America mammals resembling horse, hippopotamus, bear, rabbit, etc. Due to **continental drift**, when South America joined North America, these animals were overridden by North American fauna. Due to the same continental drift pouched mammals of Australia survived because of **lack of competition** from any other mammal.

Q2. With reference to the evolution of living organisms, which one of the following sequences is correct? [2009]

Octopus-Dolphin-Shark

Pangolin-Tortoise-Hawk

Salamander-Python-Kangaroo

Frog-Crab-Prawn

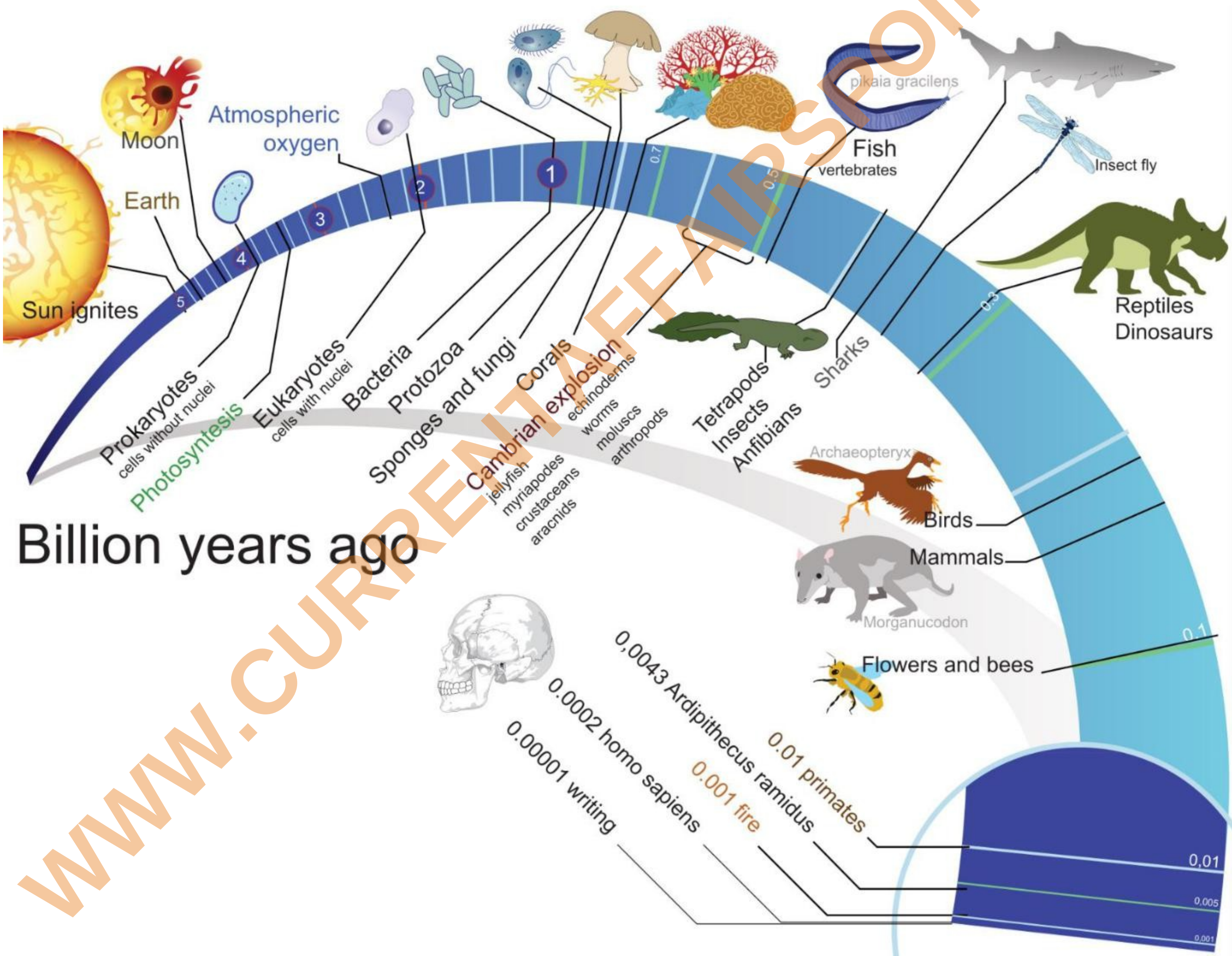
Answer: Evolution == Single cellular → Multicellular → Fishes → Amphibians → Reptiles → Birds → Mammals.

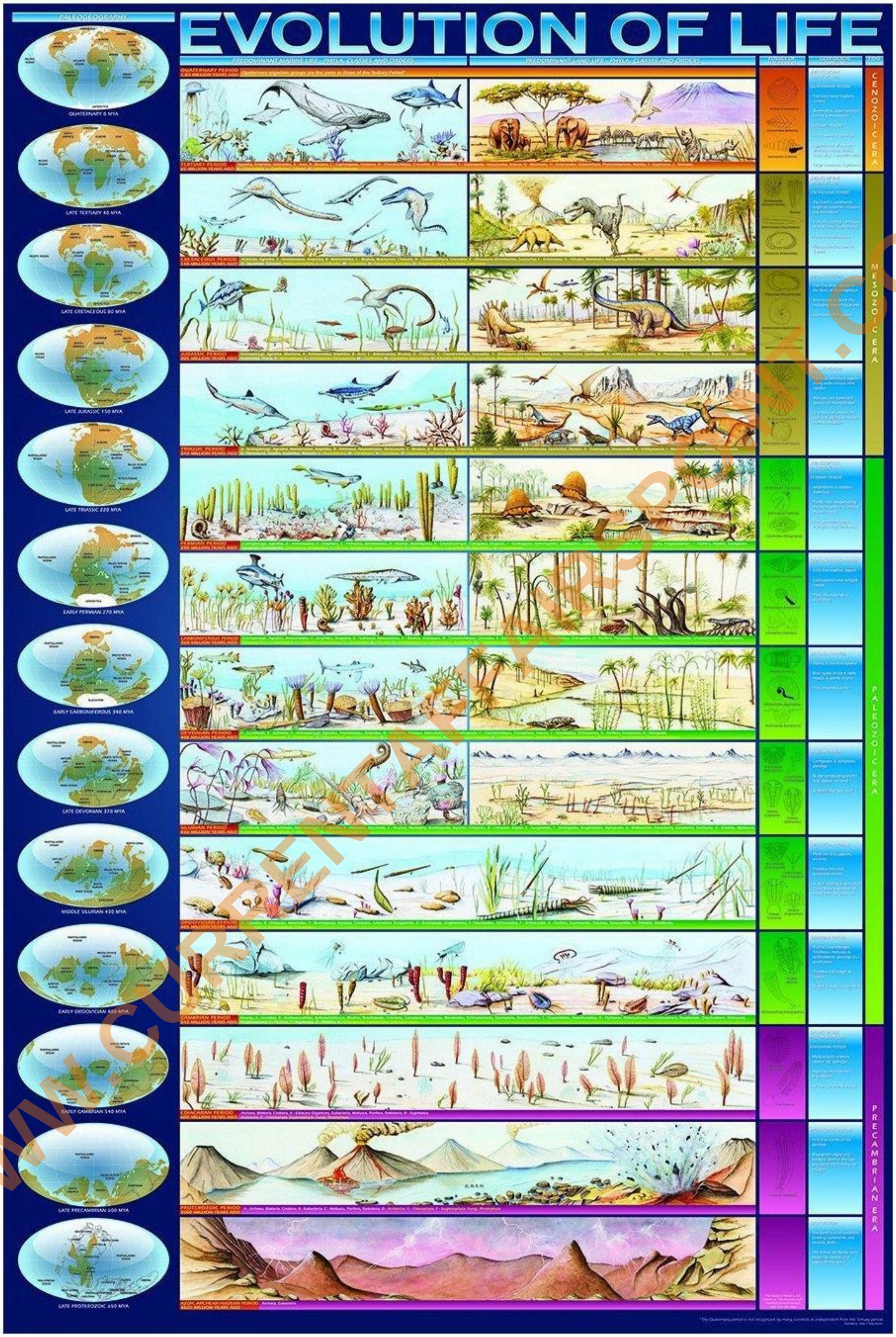
Octopus (Mollusc) – Dolphins and Whales (Mammals) – Shark (Fish)

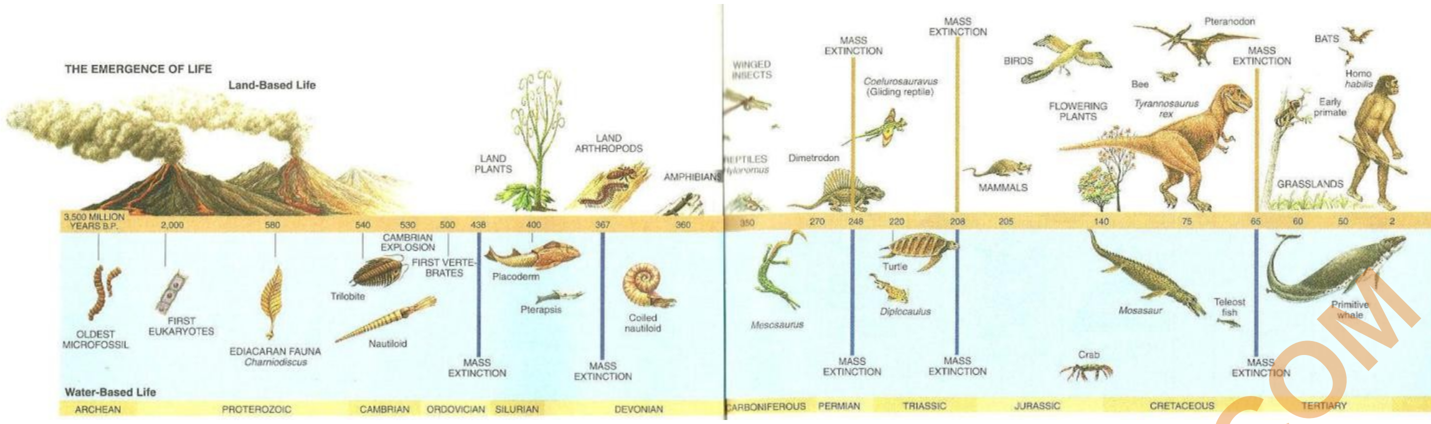
Pangolin (Mammal – always in news as it is an endangered one – its meat is consumed in some South-East Asian countries) – Tortoise (Reptile) – Hawk (Bird)

Salamander (Amphibian) – Python (Reptile) – Kangaroo (Mammal)

Frog (Amphibian) – Crab (Crustaceans) – Prawn (Crustaceans)




EVOLUTION OF LIFE
PALEOGEOGRAPHY
QUATERNARY 0 MYA
LATE TERTIARY 40 MYA
LATE CRETACEOUS 80 MYA
LATE JURASSIC 150 MYA
LATE TRIASSIC 220 MYA
EARLY PERMIAN 270 MYA
EARLY CARBONIFEROUS 340 MYA
LATE DEVONIAN 370 MYA
MIDDLE SILURIAN 430 MYA
EARLY ORDOVICIAN 480 MYA
EARLY CAMBRIAN 540 MYA
LATE PRECAMBRIAN 600 MYA
LATE PROTEROZOIC 650 MYA
CENOZOIC ERA
MESOZOIC ERA
PALEOZOIC ERA
PRECAMBRIAN ERA



THE EMERGENCE OF LIFE
Land-Based Life
LAND PLANTS
LAND ARTHROPODS
AMPHIBIANS
WINGED INSECTS
REPTILES
MASS EXTINCTION
Coelurosauravus (Gliding reptile)
Dimetrodon
MASS EXTINCTION
BIRDS
MAMMALS
FLOWERING PLANTS
Pteranodon
Bee
Tyrannosaurus rex
MASS EXTINCTION
BATS
Homo habilis
Early primate
GRASSLANDS
3,500 MILLION YEARS B.P.
2,000
580
540
530
500
438
400
367
360
350
270
248
220
208
205
140
75
65
60
50
2
OLDEST MICROFOSSIL
FIRST EUKARYOTES
EDIACARAN FAUNA Charniodiscus
CAMBRIAN EXPLOSION
Trilobite
FIRST VERTE-BRATES
Nautiloid
MASS EXTINCTION
Placoderm
Pterapsis
MASS EXTINCTION
Coiled nautiloid
Mesosaurus
MASS EXTINCTION
Turtle
Diplocaulus
MASS EXTINCTION
Crab
Mosasaur
Teleost fish
MASS EXTINCTION
Primitive whale
Water-Based Life
ARCHEAN
PROTEROZOIC
CAMBRIAN
ORDOVICIAN
SILURIAN
DEVONIAN
CARBONIFEROUS
PERMIAN
TRIASSIC
JURASSIC
CRETACEOUS
TERTIARY

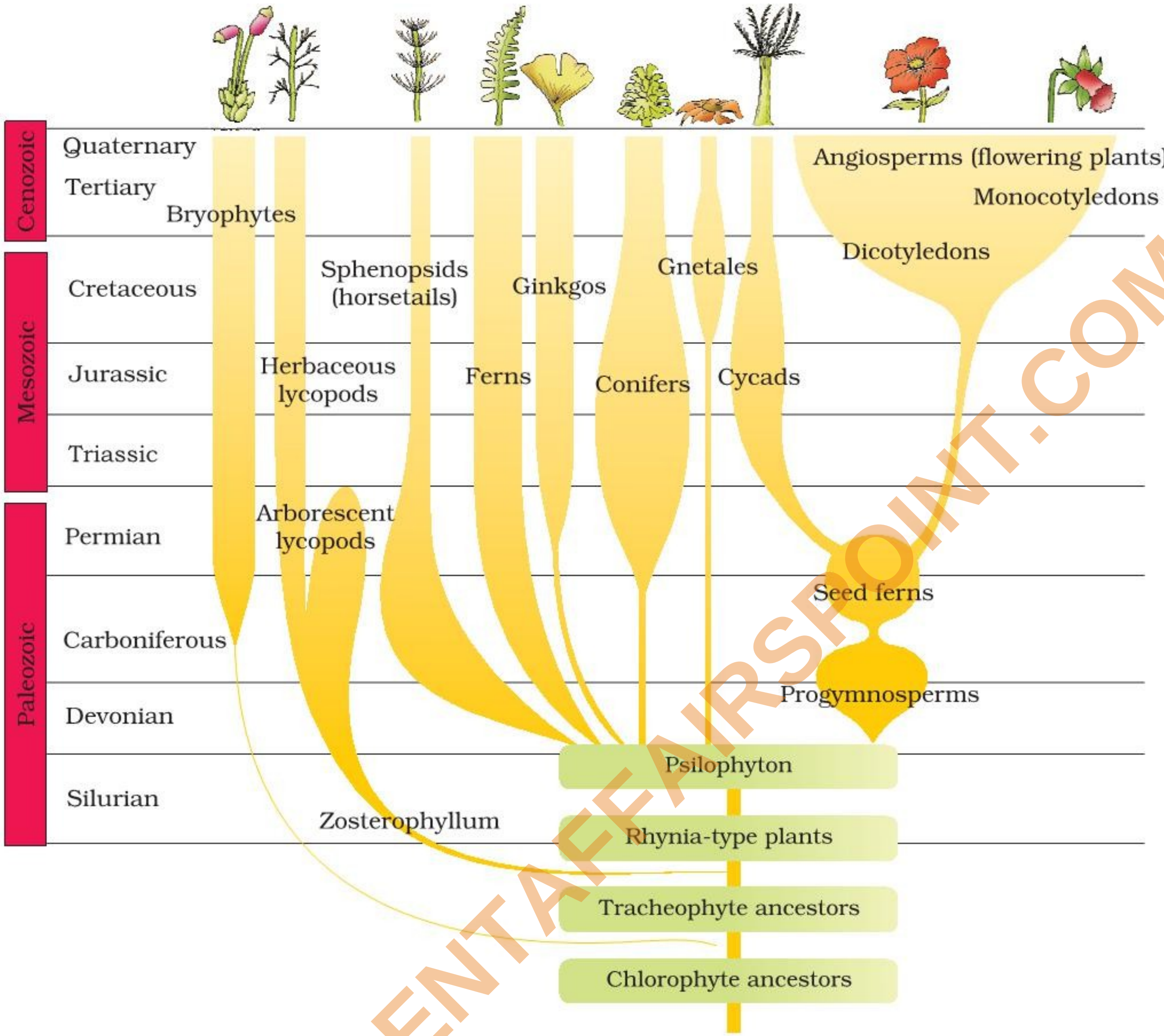


Figure 7.9 A sketch of the evolution of plant forms through geological periods

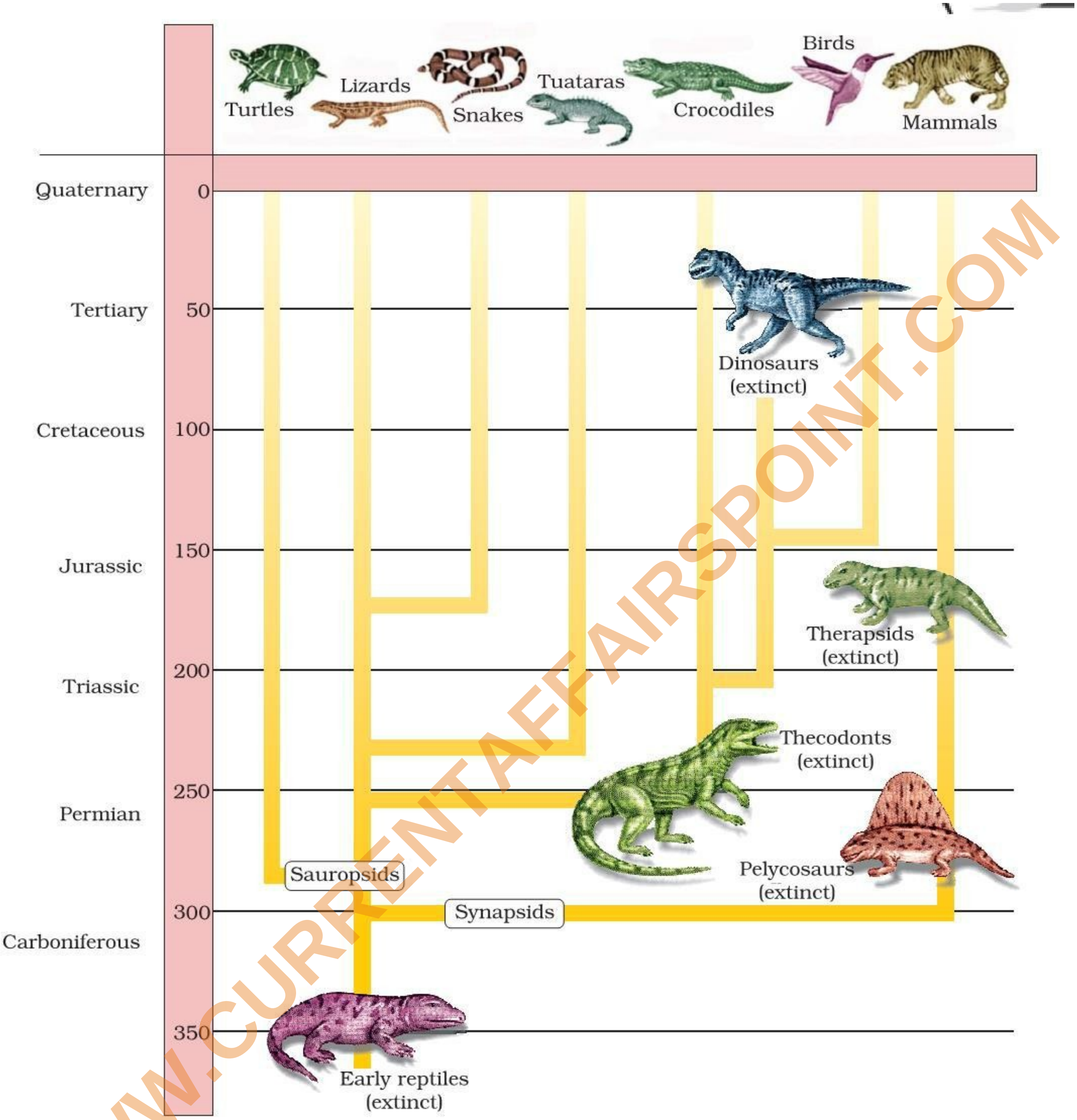


Figure 7.10 Representative evolutionary history of vertebrates through geological period

Origin and Evolution of Man

About 15 mya, primates called **Dryopithecus** and **Ramapithecus** were existing. They were hairy and walked like gorillas and chimpanzees. Ramapithecus was more man-like while Dryopithecus was more ape-like.

Few fossils of man-like bones have been discovered in Ethiopia and Tanzania. These revealed hominid features leading to the belief that about 3-4 mya, man-like primates walked in eastern Africa. They were probably not taller than 4 feet but walked up right.

Two mya, Australopithecines probably lived in East African grasslands. Evidence shows they hunted with stone weapons but essentially ate fruit.

Some of the bones among the bones discovered were different. This creature was called the first human-like being the hominid and was called **Homo habilis**. The brain capacities were between 650-800cc. They probably did not eat meat.

Fossils discovered in Java in 1891 revealed the next stage, i.e., **Homo erectus** about 1.5 mya. Homo erectus had a large brain around 900cc. Homo erectus probably ate meat.

The **Neanderthal man** with a brain size of 1400cc lived in near east and central Asia between 1,00,000-40,000 years back. They used hides to protect their body and buried their dead.

Homo sapiens arose in Africa and moved across continents and developed into distinct races. During ice age between 75,000-10,000 years ago modern Homo sapiens arose.

Pre-historic cave art developed about 18,000 years ago. Agriculture came around 10,000 years back and human settlements started. The rest of what happened is part of human history of growth and decline of civilisations.

Biological Classification: Monera, Protista, Fungi, Plantae, Animalia and, Viruses, Viroids and Lichens. Biodiversity, Classification of Biodiversity, Taxonomic Categories.

Biodiversity

Classification of life forms will be closely related to their **evolution**. **Charles Darwin** first described this idea of evolution in 1859 in his book, **The Origin of Species**.

The number of species that are known and described range between 1.7-1.8 million. Rough estimates state that there are about ten million species on the planet. This refers to **biodiversity** or the number and types of organisms present on earth.

The **warm and humid tropical regions** of the earth, between the tropic of cancer and the tropic of capricorn, are rich in diversity of plant and animal life. This is called the region of **megadiversity**.

Of the biodiversity of the planet, more than half is concentrated in a few countries within tropics.

In alphabetical order, the 17 megadiverse countries are:

Australia
Brazil
China
Colombia
Democratic Republic of the Congo
Ecuador
India
Indonesia
Madagascar
Malaysia
Mexico
Papua New Guinea
Peru
Philippines
South Africa
United States
Venezuela

http://secure.environment.gov.au/biodiversity/hotspots/images/megadiverse-countries.gif

Classification of Biodiversity

There is a need to standardize the naming of living organisms such that a particular organism is known by the same name all over the world. This process is called **nomenclature**.

Obviously, nomenclature or naming is only possible when the organism is described correctly and we know to what organism the name is attached to. This is **identification**.

For plants, scientific names are based on agreed principles and criteria, which are provided in International Code for Botanical Nomenclature (ICBN).

Animal taxonomists have evolved International Code of Zoological Nomenclature (ICZN). The scientific names ensure that each organism has only one name.

Biologists follow universally accepted principles to provide scientific names to known organisms. Each name has two components - the **Generic name** and the **specific epithet**.

This system of providing a name with two components is called **Binomial nomenclature**. This naming system given by **Carolus Linnaeus** is being practised by biologists all over the world.

The scientific name of mango is written as ***Mangifera indica***. In this name Mangifera represents the genus while indica, is a particular **species**, or a specific epithet. Other universal rules of nomenclature are as follows:

- Biological names are generally in Latin and written in **italics**. They are Latinised or derived from Latin irrespective of their origin.
- The first word in a biological name represents the genus while the second component denotes the specific epithet.
- Both the words in a biological name, when handwritten, are separately underlined, or printed in italics to indicate their **Latin origin**.

The first word denoting the genus starts with a capital letter while the specific epithet starts with a small letter. it can be illustrated with the example of *Mangifera indica*.

Name of the author appears after the specific epithet, i.e., at the end of the biological name and is written in an abbreviated form, e.g., *Mangifera indica Linn*. It indicates that this species was first described by Linnaeus.

Since it is nearly impossible to study all the living organisms, it is necessary to devise some means to make this possible. This process is **classification**.

Classification is the process by which anything is grouped into convenient categories based on some easily observable characters.

The scientific term for these categories is **taxa**. Here you must recognise that taxa can indicate categories at very different levels. 'Plants' - also form a taxa. 'Wheat' is also a taxa. Similarly, 'animals', 'mammals', 'dogs' are all taxa - but you know that a dog is a mammal and mammals are animals. Therefore, 'animals', 'mammals' and 'dogs' represent taxa at different levels.

Hence, based on characteristics, all living organisms can be classified into different taxa. This process of classification is **taxonomy**.

External and internal structure, along with the structure of cell, process and ecological information of organisms are essential and form the basis of modern taxonomic studies.

Hence, **characterisation, identification, classification** and **nomenclature** are the processes that are basic to taxonomy.

Human beings were, since long, not only interested in knowing more about different kinds of organisms and their diversities, but also the relationships among them. This branch of study was referred to as **systematics**.

The word systematics is derived from the Latin word 'systema' which means systematic arrangement of organisms. Linnaeus used **Systema Naturae** as the title of his publication.

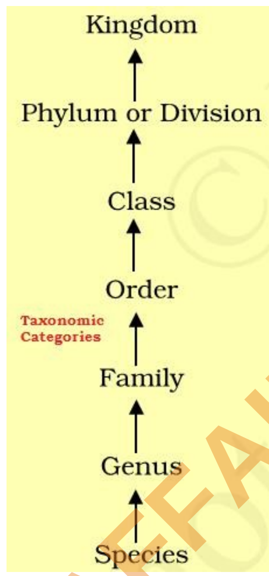
The scope of systematics was later enlarged to include identification, nomenclature and classification.

Systematics takes into account **evolutionary relationships** between organisms.

Taxonomic Categories

Classification is not a single step process but involves hierarchy of steps in which each step represents a rank or category.

Since the category is a part of overall taxonomic arrangement, it is called the taxonomic category and all categories together constitute the taxonomic hierarchy.



Species

Taxonomic studies consider a group of individual organisms with **fundamental similarities** as a species.

Let us consider *Mangifera indica*, *Solanum tuberosum* (potato) and *Panthera leo* (lion). All the three names, indica, tuberosum and leo, represent the specific epithets, while the first words Mangifera, Solanum and Panthera are genera and represents another higher level of taxon or category.

Each genus may have one or more than one specific epithets representing different organisms, but having morphological similarities. For example, Panthera has another specific epithet called tigris (*Panthera tigris*) and Solanum includes species like nigrum and melongena.

Human beings belong to the species sapiens which is grouped in the genus Homo. The scientific name thus, for human being, is written as *Homo sapiens*.

Genus

Genus comprises a group of related species which has more characters in common in comparison to species of other genera.

We can say that genera are aggregates of closely related species. For example, potato and brinjal are two different species but both belong to the genus Solanum.

Lion (*Panthera leo*), leopard (*P. pardus*) and tiger (*P. tigris*) with several common features, are all species of the genus Panthera. This genus differs from another genus Felis which includes cats.

Family

The next category, Family, has a group of related genera with still less number of similarities as compared to genus and species.

Families are characterised on the basis of both vegetative and reproductive features of plant species.

Among animals for example, genus Panthera, comprising lion, tiger, leopard is put along with genus, Felis (cats) in the family

Felidae. Similarly, if you observe the features of a cat and a dog, you will find some similarities and some differences as well. They are separated into two different families - Felidae and Canidae, respectively.

Order

You have seen earlier that categories like species, genus and families are based on a number of similar characters. Generally, order and other higher taxonomic categories are identified based on the aggregates of characters.

Class

This category includes related orders.

Phylum

Classes comprising animals like fishes, amphibians, reptiles, birds along with mammals constitute the next higher category called Phylum.

Kingdom

All animals belonging to various phyla are assigned to the highest category called Kingdom Animalia in the classification system of animals.

The Kingdom Plantae, on the other hand, is distinct, and comprises all plants from various divisions. Henceforth, we will refer to these two groups as animal and plant kingdoms.

Taxonomical Aids

Herbarium

Herbarium is a store **house of collected plant specimens** that are dried, pressed and preserved on sheets. Further, these sheets are arranged according to a universally accepted system of classification.

The herbarium sheets also carry a label providing information about date and place of collection, English, local and botanical names, family, collector's name, etc.

Herbaria also serve as quick referral systems in taxonomical studies.

Botanical Gardens

These specialized gardens have **collections of living plants** for reference.

The famous botanical gardens are at Kew (England), Indian Botanical Garden, Howrah (India) and at **National Botanical Research Institute, Lucknow (India)**.

Museum

Museums have collections of preserved plant and animal specimens for study and reference. Specimens are preserved in the containers or jars in preservative solutions.

Zoological Parks

These are the places where wild animals are kept in protected environments under human care and which enable us to learn about their food habits and behavior.

Key

Key is used for identification of plants and animals based on the similarities and dissimilarities.

The keys are based on the contrasting characters generally in a pair called couplet.

Flora, manuals, monographs and catalogues are some other means of recording descriptions.

Biological Classification

In Linnaeus' time a Two Kingdom system of classification with **Plantae** and **Animalia** kingdoms was developed.

This system did not distinguish between the **eukaryotes and prokaryotes**, **unicellular and multicellular organisms** and **photosynthetic (green algae)** and **non-photosynthetic (fungi)** organisms.

Classification of organisms into plants and animals was easily done and was easy to understand, but, a large number of organisms did not fall into either category. Hence the two kingdom classification used for a long time was found inadequate.

Biologists, such as Ernst Haeckel (1894), Robert Whittaker (1959) and Carl Woese (1977) have tried to classify all living organisms into broad categories, called kingdoms.

The classification Whittaker proposed has five kingdoms and is widely used:

Monera,

Protista,

Fungi,

Plantae and

Animalia.

TABLE 2.1 Characteristics of the Five Kingdoms

Characters	Five Kingdoms				
	Monera	Protista	Fungi	Plantae	Animalia
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellulosic (Polysaccharide + amino acid)	Present in some	Present (without cellulose)	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multiceullar/ loose tissue	Tissue/ organ	Tissue/organ/ organ system
Mode of nutrition	Autotrophic (chemosyn-thetic and photosynthetic) and Hetero-trophic (sapro-phytic/para-sitic)	Autotrophic (Photosyn-thetic) and Hetero-trophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosyn-thetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

More details about each kingdom in the next posts

The main criteria for classification used by him include cell structure, thallus organisation, mode of nutrition, reproduction etc.

It brought together the **prokaryotic bacteria** and the **blue green algae** with other groups which were **eukaryotic**.

It also grouped together the unicellular organisms and the multicellular ones.

The classification did not differentiate between the heterotrophic group - fungi, and the autotrophic green plants, though they also showed a characteristic difference in their walls composition - the fungi had **chitin** in their walls while the green plants had a **cellulosic** cell wall.

When such characteristics were considered, the fungi were placed in a separate kingdom - Kingdom Fungi.

All **prokaryotic organisms** were grouped together under **Kingdom Monera** and the **unicellular eukaryotic organisms** were placed in **Kingdom Protista**.

Kingdom Protista has brought together Chlamydomonas, Chlorella (earlier placed in Algae within Plants and both having cell walls) with Paramoecium and Amoeba (which were earlier placed in the animal kingdom which lack cell wall).

At present the biological classification includes:

0 Kingdom Monera

1 Kingdom Protista

2 Kingdom Fungi

3 Kingdom Plantae

4 Kingdom Animalia

5 Viruses, Viroids and Lichens

Further classification is done by naming the sub-groups at various levels as given in the following scheme: KPC OF GS

Kingdom,

Phylum (For Animals) / Division (For Plants),

Class,

Order,

Family,

Genus,

Species.

Biological Classification – Kingdom Monera, Kingdom Protista, Kingdom Fungi, Kingdom Plantae, Kingdom Animalia, Viruses, Viroids and Lichens.

Biological Classification of Plants and Animals

Biological classification of plants and animals was first proposed by **Aristotle** on the basis of simple morphological characters.

Linnaeus later classified all living organisms into two kingdoms - Plantae and Animalia.

Whittaker proposed an elaborate five kingdom classification - **Monera, Protista, Fungi, Plantae** and **Animalia**.

The main criteria of the five kingdom classification were cell structure, body organisation, mode of nutrition and reproduction, and phylogenetic relationships [evolutionary development and diversification of a species].

At present, the biological classification includes:

- **Kingdom Monera**
- **Kingdom Protista**
- **Kingdom Fungi**
- **Kingdom Plantae**
- **Kingdom Animalia**
- **Viruses, Viroids and Lichens**

In the five kingdom classification, **bacteria** are included in Kingdom Monera.

Kingdom Protista includes all single-celled eukaryotes such as Chrysophytes, Dinoflagellates, Euglenoids, Slime-moulds and Protozoans.

Members of Kingdom Fungi show a great diversity in structures and habitat. Most fungi are saprophytic in their mode of nutrition.

The plantae includes all eukaryotic chlorophyll-containing organisms. Algae, bryophytes, pteridophytes, gymnosperms and angiosperms are included in this group.

The heterotrophic eukaryotic, multicellular organisms lacking a cell wall are included in the Kingdom Animalia.

Some acellular organisms like viruses and viroids as well as the lichens are not included in the five kingdom system of classification.

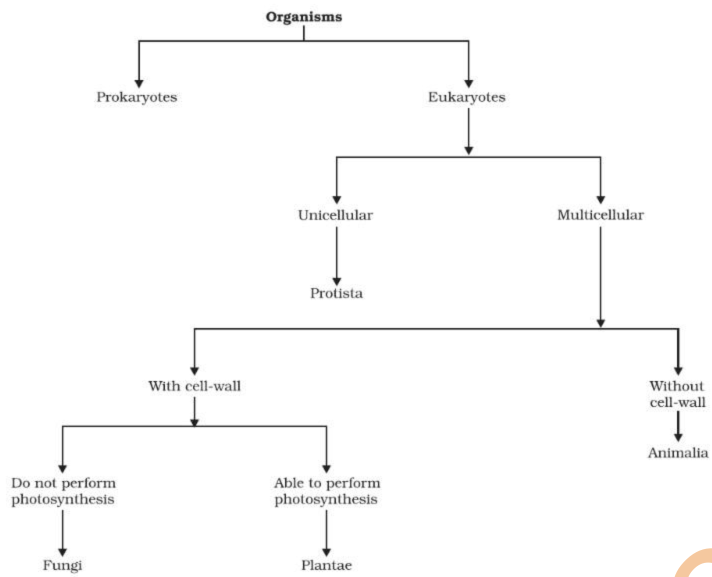


Fig. 7.4: *The Five Kingdom classification*

Monera

The organisms in this group are

prokaryotes == do not have a defined nucleus or organelles {Prokaryotic Cells vs. Eukaryotic Cells}.

0 **unicellular** == do any of them show multi-cellular body designs.

This group includes all **bacteria.** Some well-known bacteria include **blue-green algae** or **cyanobacteria** [have cell walls], and **mycoplasma** [doesn't possess a Cell Wall].

They are the most abundant micro-organisms and live in extreme habitats.

Some of them have **cell walls [bacteria]** while some do not [**mycoplasma**].

The mode of nutrition of organisms in this group can be either by synthesizing their own food (**autotrophic**) or getting it from the environment (**heterotrophic**). Many of them live in or on other organisms as **parasites**.

Bacteria are grouped under four categories based on their shape

the spherical Coccus

the rod-shaped Bacillus

the comma-shaped Vibrium

the spiral Spirillum

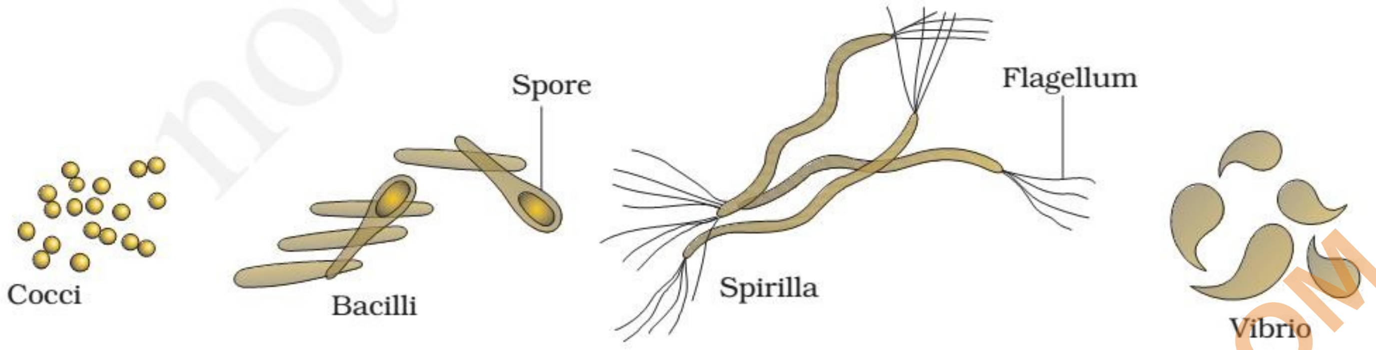


Figure 2.1 Bacteria of different shapes

Some of the bacteria are **autotrophic**, i.e., they synthesise their own food. They may be **photosynthetic autotrophic or chemosynthetic autotrophic** (metabolic synthesis of organic compounds by living organisms using energy derived from reactions involving inorganic chemicals).

Archaebacteria

These bacteria are special since they live in some of the **most harsh** habitats such as
- extreme salty areas (**halophiles**),
- hot springs (**thermoacidophiles**) and
- marshy areas (**methanogens**) {Microbes In Human Welfare | Useful Microbes}.

Archaebacteria differ from other bacteria in having a **different cell wall structure** and this feature is responsible for their survival in extreme conditions.

Methanogens are present in the gut of several ruminant animals such as cows and buffaloes and they are responsible for the production of **methane (biogas)** from the dung of these animals.

Eubacteria

There are thousands of different **eubacteria or 'true bacteria'**.

They are characterized by the presence of a **rigid cell wall**, and if motile, a **flagellum**.

Photosynthetic bacteria

The **cyanobacteria** (also referred to as **blue-green algae**) have chlorophyll a similar to green plants and are photosynthetic autotrophs.

The cyanobacteria are unicellular, colonial, filamentous, freshwater/marine or terrestrial **algae**. The colonies are generally surrounded by gelatinous sheath.

They often form blooms [algal blooms] in polluted water bodies.

Some of these organisms can fix atmospheric nitrogen in specialized cells called **heterocysts**, e.g., **Nostoc** and **Anabaena**.

Chemosynthetic bacteria

Chemosynthetic autotrophic bacteria oxidise various inorganic substances such as nitrates, nitrites and ammonia and use the released energy for their ATP production.

They play a great role in **recycling nutrients** like nitrogen, phosphorous, iron and sulphur.

Heterotrophic bacteria

Heterotrophic bacteria are the most abundant in nature. The majority are important **decomposers**.

Many of them have a significant impact on human affairs. They are helpful in making **curd from milk, production of antibiotics, fixing nitrogen in legume** roots, etc {Microbes In Human Welfare | Useful Microbes}.

Some are pathogens causing damage to human beings, crops, farm animals and pets.

Cholera, typhoid, tetanus, citrus canker are well known diseases caused by different bacteria {Diseases Caused by Microorganisms, Diseases | Acute, Chronic, Communicable Diseases}.

Reproduction

Bacteria reproduce mainly by **fission**.

Sometimes, under unfavorable conditions, they produce **spores**.

They also reproduce by a sort of **sexual reproduction** by adopting a primitive type of DNA transfer from one bacterium to the other.

Mycoplasma

The Mycoplasma are organisms that completely **lack a cell wall**.

They are the smallest living cells known and can **survive without oxygen**.

Many mycoplasma are pathogenic in animals and plants.

Protista

All **single-celled eukaryotes** are placed under Protista [Prokaryotic Cells vs. Eukaryotic Cells].

Boundaries of this kingdom are not well defined. This kingdom forms a link with the others dealing with plants, animals and fungi.

In this group we include **Chrysophytes, Dinoflagellates, Euglenoids, Slime moulds and Protozoans**. Examples are unicellular **algae, diatoms** and **protozoans**.

Their mode of nutrition can be **autotrophic or heterotrophic**.

Members of Protista are **primarily aquatic**. Some have flagella or cilia that helps in movement.

Protists reproduce **asexually** and **sexually** by a process involving cell fusion and zygote formation.

Chrysophytes

This group includes **diatoms** and **golden algae (desmids)**.

Most of them are **photosynthetic**. **Diatoms** are the chief 'producers' in the oceans.

They are found in fresh water as well as in marine environments. They are microscopic and float passively in water currents (**plankton**).

In diatoms the cell walls form two thin overlapping shells. The walls are embedded with silica and thus the walls are indestructible. Thus, diatoms have left behind large amount of cell wall deposits in their habitat; this accumulation over billions of years is referred to as **'diatomaceous earth'**. Being gritty this soil is used in polishing, filtration of oils and syrups.

Dinoflagellates

These organisms are mostly **marine** and **photosynthetic**.

They appear yellow, green, brown, blue or red depending on the main pigments present in their cells.

The cell wall has stiff cellulose plates on the outer surface.

Most of them have **two flagella**; one lies longitudinally and the other transversely in a furrow between the wall plates.

Very often, **red dinoflagellates** (Example: Gonyaulax) undergo such rapid multiplication that they make the **sea appear red (red tides)**.

Toxins released by such large numbers may even kill other marine animals such as fishes.

Euglenoids

Majority of them are **fresh water organisms** found in stagnant water.

Instead of a cell wall, they have a protein rich layer called **pellicle** which makes their body flexible.

They have two flagella, a short and a long one.

Though they are **photosynthetic** in the presence of sunlight, when deprived of sunlight they behave like **heterotrophs** by predating on other smaller organisms.

Interestingly, the pigments of euglenoids are identical to those present in higher plants. Example: Euglena.

Slime Moulds

Slime moulds are **saprophytic protists**.

The body moves along decaying twigs and leaves engulfing organic material.

Under suitable conditions, they form an aggregation called **plasmodium** which may grow and spread over several feet.

During unfavorable conditions, the plasmodium differentiates and forms fruiting bodies bearing spores at their tips. The spores possess **true walls**. They are extremely resistant and survive for many years, even under adverse conditions. The spores are dispersed by air currents.

Protozoans

All protozoans are heterotrophs and live as **predators or parasites**. They are believed to be **primitive relatives of animals**. There are four major groups of protozoans.

Amoeboid protozoans

These organisms live in fresh water, sea water or moist soil.

They move and capture their prey by putting out **pseudopodia (false feet)** as in **Amoeba**.

Marine forms have silica shells on their surface. Some of them such as **Entamoeba** are parasites.

Flagellated protozoans

The members of this group are either free-living or parasitic. They have **flagella**.

The parasitic forms cause diseases such as **sleeping sickness**. Example: **Trypanosoma**.

Ciliated protozoans

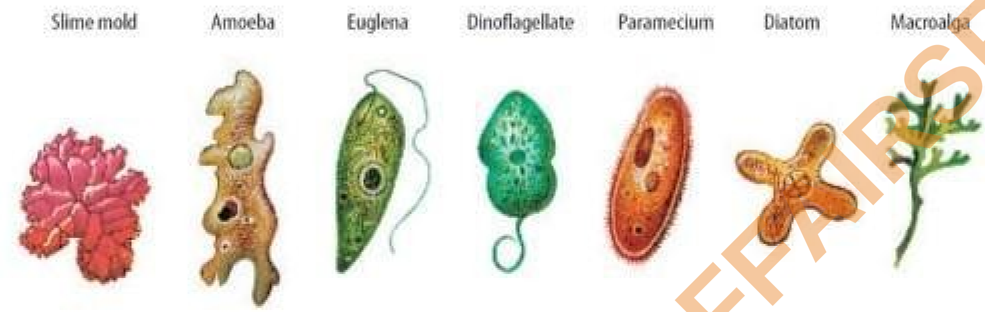
These are aquatic, actively moving organisms because of the presence of thousands of **cilia**.

They have a cavity (gullet) that opens to the outside of the cell surface. The coordinated movement of rows of cilia causes the water laden with food to be steered into the gullet. Example: **Paramoecium**.

Sporozoans

This includes diverse organisms that have an infectious spore-like stage in their life cycle.

The most notorious is **Plasmodium (malarial parasite)** which causes malaria, a disease which has a staggering effect on human population {Diseases Caused by Microorganisms}.



Fungi

These are **heterotrophic eukaryotic organisms**.

Most fungi are heterotrophic and absorb soluble organic matter from dead substrates and hence are called **saprophytes**.

Those that depend on living plants and animals are called **parasites**.

Some fungal species live in permanent mutually dependent relationships with **bluegreen algae (or cyanobacteria)**. Such relationships are called **symbiotic**. These symbiobic life forms are called **lichens**. They can also live as **symbionts** in association with roots of higher plants as **mycorrhiza**.

Fungi + Bluegreen algae (Cyanobacteria) == Lichens. (Prelims 2014)

Q1. Lichens, which are capable of initiating ecological succession even on a bare rock, are actually a symbiotic association of

algae and bacteria

algae and fungi

bacteria and fungi

fungi and mosses

Reproduction in fungi can take place by vegetative means - **fragmentation, fission** and **budding**.

Asexual reproduction is by **spores** called conidia or sporangiospores or zoospores, and sexual reproduction is by oospores, ascospores and basidiospores.

The various spores are produced in distinct structures called **fruiting bodies**. The sexual cycle involves the following three steps:

1) Fusion of protoplasms between two motile or non-motile gametes called **plasmogamy**.

2) Fusion of two nuclei called **karyogamy**.

3) Meiosis in zygote resulting in haploid spores {Meiosis | Mitosis – Meiosis Comparison}.

When a fungus reproduces sexually, two haploid hyphae of compatible mating types come together and fuse. In some fungi the fusion of two haploid cells immediately results in diploid cells (2n).

However, in other fungi (ascomycetes and basidiomycetes), an intervening dikaryotic stage (n + n, i.e., **two nuclei per cell**) occurs; such a condition is called a dikaryon and the phase is called **dikaryophase** of fungus. Later, the parental nuclei fuse and the cells become diploid. The fungi form fruiting bodies in which reduction division occurs, leading to formation of haploid spores.

Many of fungi have the capacity to become multicellular organisms at certain stages in their lives.

They have cell-walls made of a tough complex sugar called **chitin**.

Fungi are cosmopolitan and occur in air, water, soil and on animals and plants.

They prefer to grow in warm and humid places. With the exception of yeasts which are unicellular, fungi are **filamentous**.

Their bodies consist 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 - these are called coenocytic hyphae.

Others have septae or cross walls in their hyphae. The cell walls of fungi are composed of **chitin** and **polysaccharides** {Carbohydrates | Monosaccharides | Polysaccharides}.

When your bread develops a mould or your orange rots it is because of fungi.

The common **mushroom** you eat and toadstools are also fungi.

White spots seen on mustard leaves are due to a parasitic fungus.

Some unicellular fungi, e.g., **yeast** are used to make bread and beer.

Other fungi cause diseases in plants and animals; **wheat rust-causing Puccinia** is an important example.

Some are the source of antibiotics, e.g., **Penicillium**.

Phycomycetes

Asexual reproduction takes place by zoospores (motile) or by aplanospores (non-motile).

These spores are endogenously produced in sporangium.

A zygospore is formed by fusion of two gametes.

These gametes are similar in morphology (isogamous) or dissimilar (anisogamous or oogamous).

Some common examples are Mucor, **Rhizopus** (the bread mould mentioned earlier) and **Albugo** (the parasitic fungi on mustard).

Ascomycetes

Commonly known as sac-fungi, the as comycetes are mostly multicellular, e.g., **Penicillium**, or rarely unicellular, e.g., **yeast (Saccharomyces)**.

Basidiomycetes

Commonly known forms of basidiomycetes are **mushrooms, bracket fungi or puffballs**.

They grow in soil, on logs and tree stumps and in living plant bodies as parasites, e.g., rusts and smuts.

The asexual spores are generally not found, but vegetative reproduction by **fragmentation** is common.

The **sex organs are absent**, but plasmogamy is brought about by fusion of two vegetative or somatic cells of different strains or genotypes. The resultant structure is dikaryotic.

Deuteromycetes

Commonly known as **imperfect fungi** because only the asexual or vegetative phases of these fungi are known.

Plantae

These are **multicellular eukaryotes** with **cell walls** mainly made of **cellulose** {Plant Cell vs. Animal Cell}.

They are **autotrophs** and use chlorophyll for photosynthesis.

A few members are partially heterotrophic such as the **insectivorous plants** or **parasites**. **Bladderwort** and **Venus fly trap** are examples of insectivorous plants and **Cuscuta** is a parasite.

Plantae includes **algae, bryophytes, pteridophytes, gymnosperms** and **angiosperms**.

Life cycle of plants has two distinct phases - the **diploid sporophytic** and the **haploid gametophytic** - that alternate with each other.

The lengths of the haploid and diploid phases, and whether these phases are free-living or dependent on others, vary among different groups in plants. This phenomenon is called **alternation of generation**.

Animalia

These include all organisms which are **multicellular eukaryotes without cell walls**. They are **heterotrophs**.

They directly or indirectly depend on plants for food. They digest their food in an internal cavity and store food reserves as **glycogen or fat** { Carbohydrates **,** Fats - Healthy Fats and Unhealthy Fats}.

Their mode of nutrition is holozoic - by ingestion of food.

They follow a definite growth pattern and grow into adults that have a definite shape and size.

Higher forms show elaborate sensory and neuromotor mechanism. Most of them are capable of locomotion.

The sexual reproduction is by copulation of male and female followed by embryological development.

Viruses, Viroids and Lichens

In the five kingdom classification of Whittaker {Biological Classification} there is no mention of some **acellular** organisms like **viruses** and **viroids,** and **lichens**. These are briefly introduced here.

Viruses did not find a place in classification since they are not truly 'living', if we understand living as those organisms that have a cell structure.

The viruses are non-cellular organisms that are characterized by having an inert crystalline structure outside the living cell.

Viruses are **obligate parasites**. Once they infect a cell they take over the machinery of the host cell to replicate themselves, killing the host.

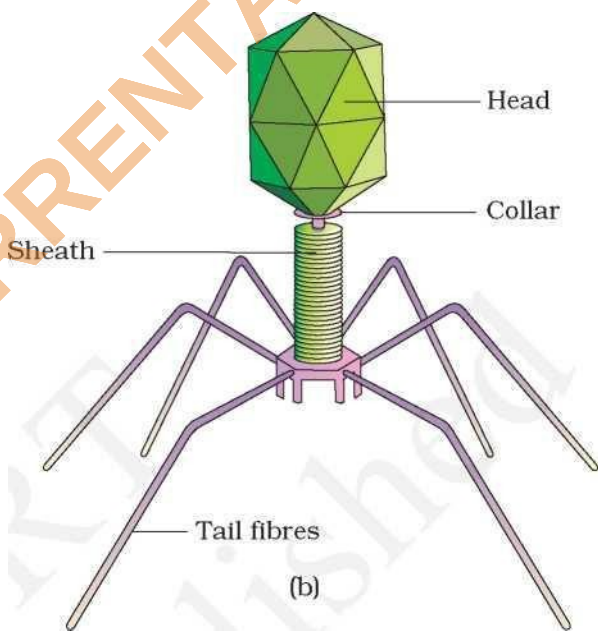
The name virus that means venom or poisonous fluid was given by Pasteur.

In addition to proteins, viruses also **contain** genetic material, that could be either **RNA or DNA**. No virus contains both RNA and DNA.

In general, viruses that infect plants have single stranded RNA and viruses that infect animals have either single or double stranded RNA or double stranded DNA.

Bacterial viruses or **bacteriophages** (viruses that infect the bacteria) are usually double stranded DNA viruses

The protein coat called **capsid** made of small subunits called capsomeres, protects the nucleic acid. These capsomeres are arranged in helical or polyhedral geometric forms.



Viruses cause diseases like mumps, small pox, herpes and influenza. AIDS in humans is also caused by a virus.

In plants, the symptoms can be mosaic formation, leaf rolling and curling, yellowing and vein clearing, dwarfing and stunted growth.

Viroids

Viroids are infectious agents that are smaller than viruses. A viroid was found to be a **free RNA**; it **lacked the protein coat** that is found in viruses, hence the name viroid. The RNA of the viroid was of low molecular weight. Viroids caused potato spindle tuber disease.

Lichens

Lichens are **symbiotic** associations i.e. mutually useful associations, between **algae and fungi**.

The algal component is known as phycobiont and fungal component as mycobiont, which are autotrophic and heterotrophic, respectively.

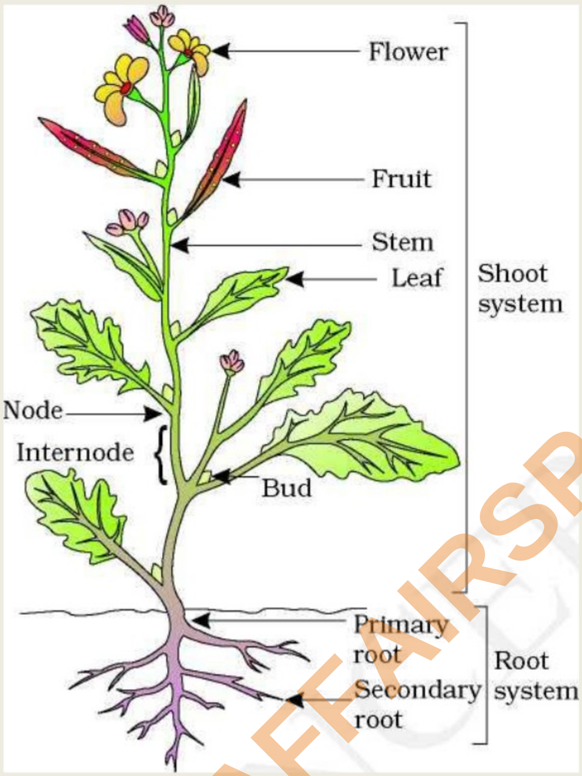
Algae prepare food for fungi and fungi provide shelter and absorb mineral nutrients and water for its partner.

So close is their association that if one saw a lichen in nature one would never imagine that they had two different organisms within them.

Lichens are very good **pollution indicators** - they do not grow in polluted areas.

Plant Parts – Root, Stem, Leaf, Transpiration, Respiration in Plants, Flower, Androecium, Gynoecium, Fruit, Transport Of Water And Minerals In Plants.

Plant Parts and Their Functions – Structural Organization in Plants



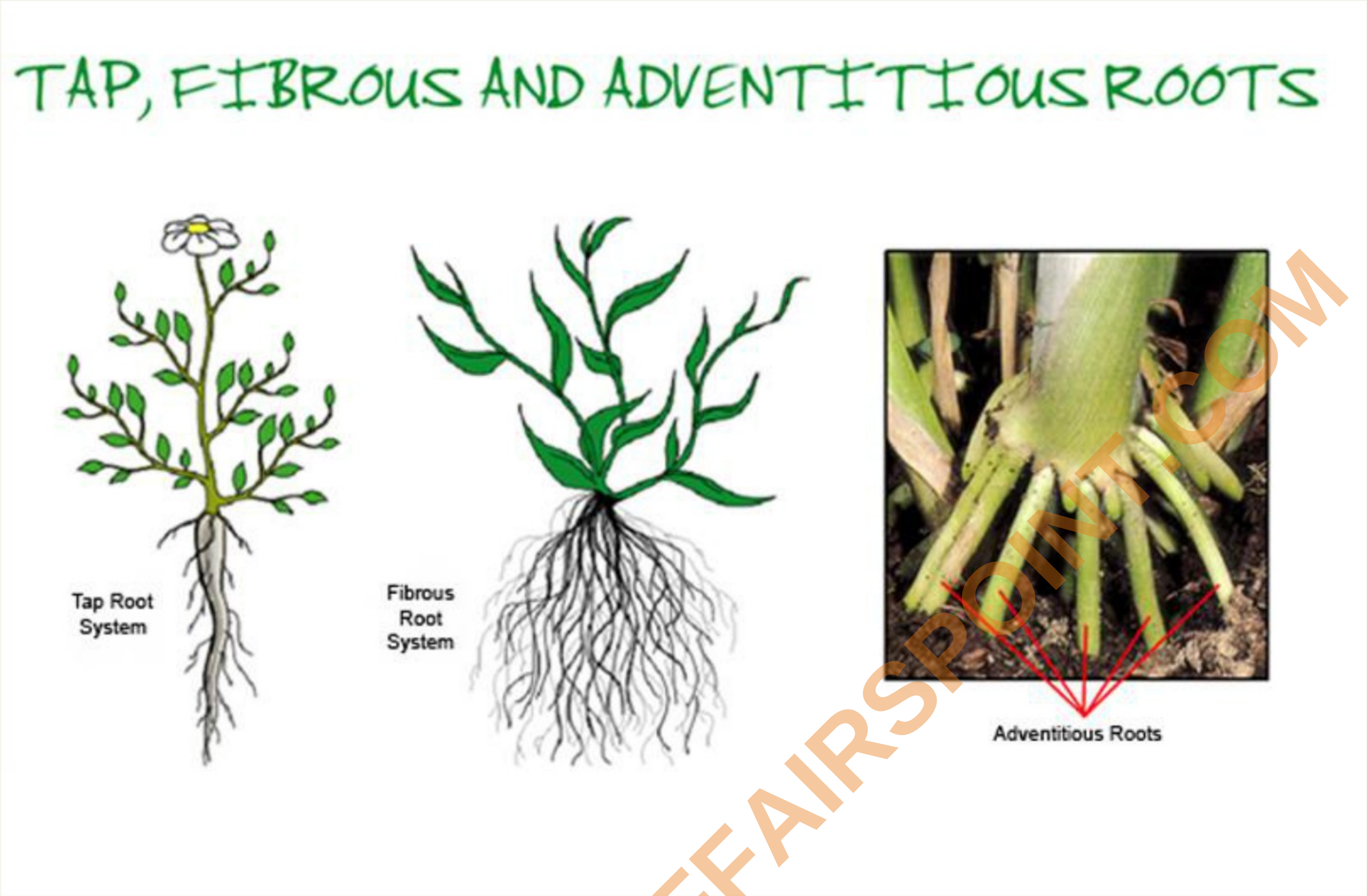
The Root

The main functions of the root system are absorption of water and minerals from the soil, providing a proper anchorage to the plant parts, **storing reserve food material** and **synthesis of plant growth regulators**.

In majority of the dicotyledonous plants, the direct elongation of the **radicle** leads to the formation of primary root which grows inside the soil. It bears lateral roots of several orders that are referred to as secondary, tertiary, etc. roots. The primary roots and its branches constitute the **tap root system**, as seen in the mustard plant.

In monocotyledonous plants, the primary root is short lived and is replaced by a large number of roots. These roots originate from the base of the stem and constitute the **fibrous root system**, as seen in the wheat plant.

In some plants, like grass, Monstera and the banyan tree, roots arise from parts of the plant other than the radicle and are called **adventitious roots**.



http://www.biosci.ohio-state.edu/~plantbio/osu_pcmb/pcmb_lab_resources/images/pcmb101/stms_rts_lvs/root_types.jpg

The root is covered at the apex by a thimble-like structure called the **root cap**. It protects the tender apex of the root as it makes its way through the soil.

Tap roots of carrot, turnip and adventitious roots of sweet potato, get swollen and store food.

Hanging structures that support a banyan tree are called **prop roots**. Similarly, the stems of **maize** and **sugarcane** have supporting roots coming out of the lower nodes of the stem. These are called **stilt roots**.

In some plants such as Rhizophora growing in swampy areas, many roots come out of the ground and grow vertically upwards. Such roots, called **pneumatophores**, help to get oxygen for respiration.

The Stem

The region of the stem where leaves are born are called **nodes** while internodes are the portions between two nodes.

Some stems perform the function of storage of food, support, protection and of vegetative propagation.

Underground stems of **potato, ginger, turmeric, zaminkand, colocasia** are modified to store food in them.

Stem tendrils which develop from **axillary buds**, are slender and spirally coiled and help plants to climb such as in gourds (cucumber, pumpkins, watermelon) and grapevines.

Axillary buds of stems may also get modified into woody, straight and pointed **thorns**. Thorns are found in many plants such as Citrus, Bougainvillea. They protect plants from browsing animals.

Some plants of arid regions modify their stems into flattened (Opuntia), or fleshy cylindrical (Euphorbia) structures. They contain chlorophyll and carry out photosynthesis.

Underground stems of some plants such as grass and strawberry, etc., spread to new niches and when older parts die new plants are formed.

The Leaf

Leaves originate from **shoot apical meristems**. Leaf develops at the node and bears a bud in its axil. The axillary bud later develops into a **branch**.

A typical leaf consists of three main parts: **leaf base, petiole** and **lamina**.

The petiole help hold the blade to light. Long thin flexible petioles allow leaf blades to flutter in wind, thereby cooling the leaf and bringing fresh air to leaf surface.

The lamina or the leaf blade is the green expanded part of the leaf with veins and veinlets. There is, usually, a middle prominent vein, which is known as the midrib. Veins provide rigidity to the leaf blade and act as channels of transport for water, minerals and food materials.

Leaf Venation

The arrangement of veins and the veinlets in the lamina of leaf is termed as venation.

When the veinlets form a network, the venation is termed as **reticulate**. When the veins run parallel to each other within a lamina, the venation is termed as parallel.

Leaves of **dicotyledonous** plants generally possess reticulate venation, while parallel venation is the characteristic of most **monocotyledons**.

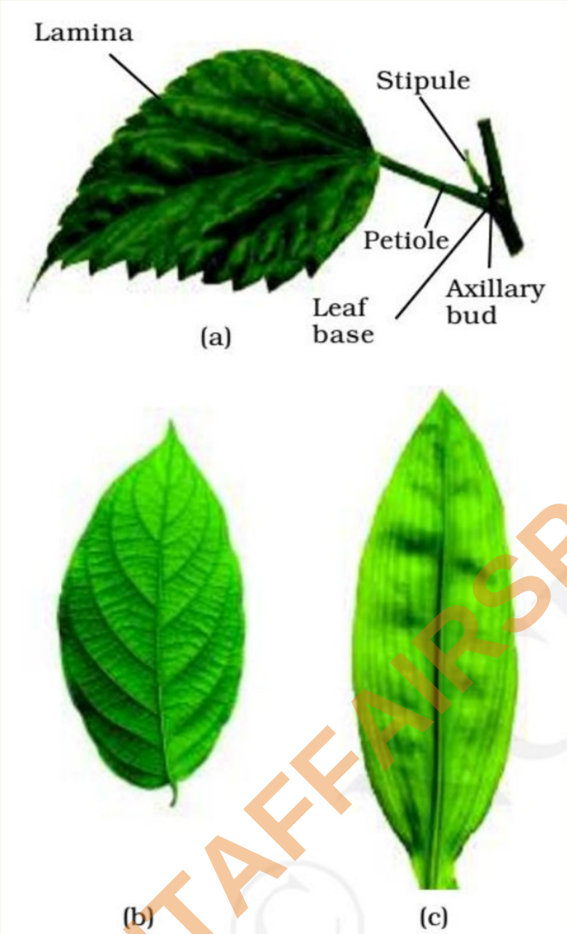


Figure 5.7 Structure of a leaf :
(a) Parts of a leaf
(b) Reticulate venation
(c) Parallel venation

Modifications of Leaves

Leaves are often modified to perform functions other than photosynthesis. They are converted into **tendrils** for climbing as in peas or into **spines** [thorns] for defense as in cacti. The fleshy leaves of onion and garlic store food.

Leaves of certain insectivorous plants such as pitcher plant, **venus-fly trap** are also modified leaves.

Root Modification	Stem Modification	Leaf Modification
Carrot and **Sweet Potato**.	**Potato, Ginger, Turmeric, Zaminkand** and **Colocasia**.	**Onion and Garlic.**

Transpiration

Plants absorb mineral nutrients and water from the soil. Not all the water absorbed is utilised by the plant. The water evaporates through the stomata present on the surface of the leaves by the process of transpiration.

The evaporation of water from leaves generates a **suction pull** (the same that you produce when you suck water through a straw) which can pull water to great heights in the tall trees. Transpiration also **cools** the plant.

Water absorption through roots can be increased by keeping the plants

in the shade

in dim light

under the fan

covered with a polythene bag

When we place a plant under the fan the speed of air flow is very high. Transpiration will take place in presence of high air flow through the stomata. Rate of transpiration increases during windy condition.

Increase in the rate of transpiration increases the water absorption also because when transpiration occurs, it will create a transpiration pull and more water absorption will take place.

Do Plants Also Respire?

In plants each part can independently take in oxygen from the air and give out carbon dioxide. Even roots can respire. Can you guess what would happen if a potted plant is overwatered?

Plants carry out **photosynthesis only during the day** and **respiration both during the day time as well as night**.

Did you know? For us oxygen is essential, but for those organisms which do not use it, oxygen is toxic. In fact, our white blood cells use oxygen to kill invading bacteria. Even for humans, it may be dangerous to breathe pure oxygen for long.

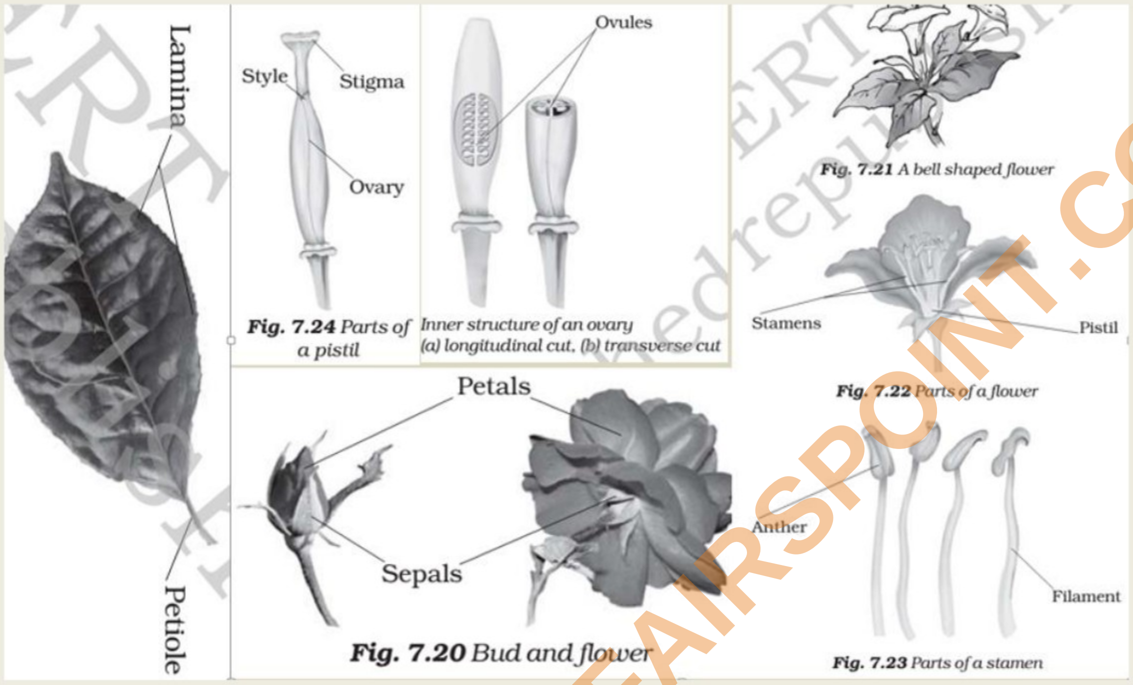
The Flower

The flower is the reproductive unit in the **angiosperms**. It is meant for sexual reproduction. Androecium and gynoecium are reproductive organs.

When a flower has both androecium and gynoecium, it is **bisexual**. A flower having either only **stamens or only carpels** is **unisexual**.

Aestivation: The mode of arrangement of sepals or petals in floral bud with respect to the other members of the same whorl is known as aestivation.

Parts of a flower



Androecium

Androecium is composed of **stamens**. Each stamen which represents the male reproductive organ consists of a stalk or a filament and an anther. Each anther is usually bilobed and each lobe has two chambers, the pollen-sacs. The pollen grains are produced in pollen-sacs. A sterile stamen is called **staminode**.

Gynoecium

Gynoecium is the female reproductive part of the flower and is made up of one or more carpels. A carpel consists of three parts namely stigma, style and ovary.

After fertilization, the ovules develop into seeds and the ovary matures into a fruit.

Placentation: The arrangement of ovules within the ovary is known as placentation.

The Fruit

The fruit is a characteristic feature of the flowering plants.

It is a **mature or ripened ovary**, developed after fertilisation.

If a fruit is formed without fertilisation of the ovary, it is called a **parthenocarpic fruit**.

The Seed: The **ovules** after fertilisation, develop into **seeds**.

Transport Of Water And Minerals In Plants

Plants absorb water and minerals by the roots. The roots have root hair. The root hair increase the surface area of the root for the absorption of water and mineral nutrients dissolved in water. The root hair is in contact with the water present between the soil particles.

Can you guess how water moves from the root to the leaves? What kind of transport system is present in plants?

Plants have pipe-like vessels to transport water and nutrients from the soil. The vessels are made of special cells, forming the vascular tissue.

The vascular tissue for the transport of water and nutrients in the plant is called the **xylem**. The xylem forms a continuous network of channels that connects roots to the leaves through the stem and branches and thus transports water to the entire plant leaves synthesise food.

The food has to be transported to all parts of the plant. This is done by the vascular tissue called the **phloem**. Thus, xylem and phloem transport substances in plants.

Summary

Flowering plants exhibit enormous variation in shape, size, structure, mode of nutrition, life span, habit and habitat. They have well developed root and shoot systems.

Root system is either tap root or fibrous. Generally, dicotyledonous plants have tap roots while monocotyledonous plants have fibrous roots.

The roots in some plants get modified for storage of food, mechanical support and respiration. The shoot system is differentiated into stem, leaves, flowers and fruits.

The morphological features of stems like the presence of nodes and internodes, multicellular hair and positively phototropic nature help to differentiate the stems from roots. Stems also get modified to perform diverse functions such as storage of food, vegetative propagation and protection under different conditions.

Leaf is a lateral outgrowth of stem developed exogeneously at the node. These are green in colour to perform the function of photosynthesis. Leaves exhibit marked variations in their shape, size, margin, apex and extent of incisions of leaf blade (lamina). Like other parts of plants, the leaves also get modified into other structures such as tendrils, spines for climbing and protection respectively.

The flower is a modified shoot, meant for sexual reproduction. The flowers are arranged in different types of inflorescences. They exhibit enormous variation in structure, symmetry, position of ovary in relation to other parts, arrangement of petals, sepals, ovules etc.

After fertilisation, the ovary is converted into fruits and ovules into seeds. Seeds either may be monocotyledonous or dicotyledonous. They vary in shape, size and period of viability. The floral characteristics form the basis of classification and identification of flowering plants. This can be illustrated through semi-technical descriptions of families. Hence, a flowering plant is described in a definite sequence by using scientific terms. The floral features are represented in the summarised form as floral diagrams and floral formula.

Water comes out of leaves in the form of vapour by a process called transpiration. Plants release a lot of water into the air through this process.

Plantae - Plant Kingdom, Algae – Thallophytes: Green Algae, Brown Algae, Red Algae, Uses of algae, Bryophytes, Pteridophytes, Cryptogamae.

Plantae

Classification among plants depends on

- whether the plant body has well differentiated, distinct components,
- whether the differentiated plant body has special tissues for the transport of water and other substances within it,
- ability to bear seeds, and
- whether the seeds are enclosed within fruits.

Phylogenetic classification [evolutionary relationships], **cytotaxonomy** [cytological information like chromosome number, structure, behavior] and **chemotaxonomy** [chemical constituents of the plant], are used by taxonomists for classifying plants.

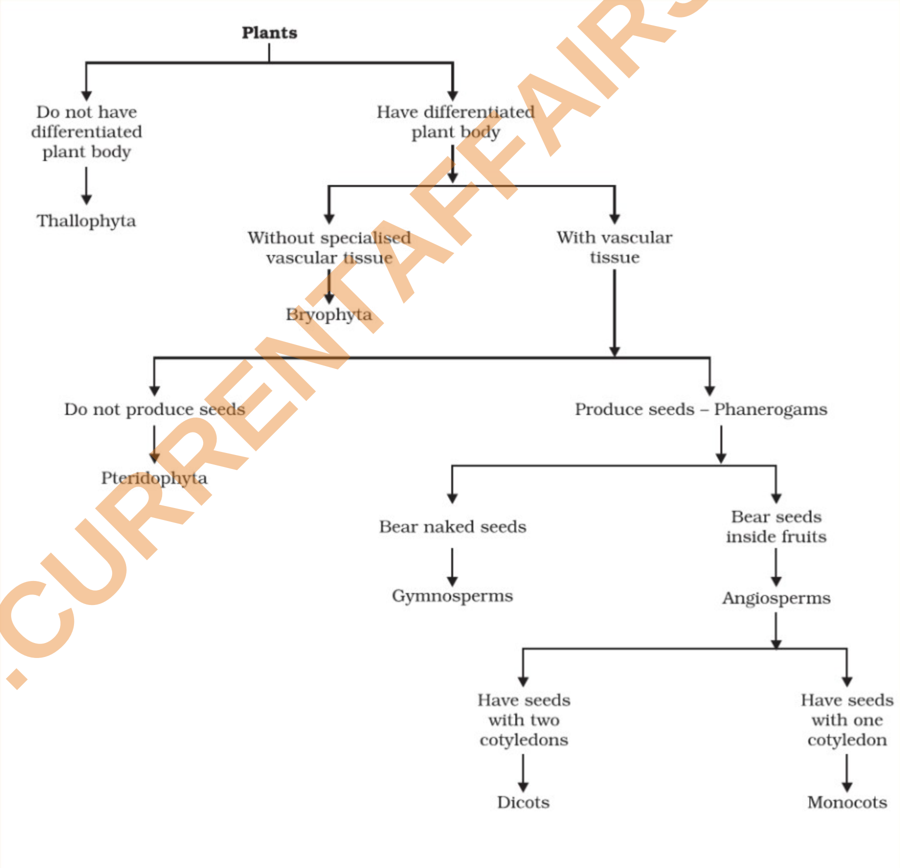


Fig. 7.11: *Classification of plants*

Plant Kingdom

Plants are **multicellular eukaryotes** with **cell walls** mainly made of **cellulose** {Plant Cell vs. Animal Cell}.

They are **autotrophs** and use chlorophyll for photosynthesis. A few members are partially heterotrophic such as the **insectivorous plants** or **parasites**. **Bladderwort** and **Venus fly trap** are examples of insectivorous plants and **Cuscuta** is a parasite.

Plantae includes *algae, bryophytes, pteridophytes, gymnosperms and angiosperms*.

Fungi, and members of the **Monera** and **Protista** having **cell walls** have now been excluded from Plantae. So, the cyanobacteria that are also referred to as blue green algae are **not 'algae'** any more.

Algae – Thallophytes

Plants that do not have well-differentiated body design fall in this group. They are commonly called **algae**.

Algae are **chlorophyll-bearing, simple, thalloid, autotrophic** and largely aquatic (both fresh water and marine) organisms.

[**Thallus** == a plant body not differentiated into stem, leaves, and roots and without a vascular system, typical of algae, fungi, lichens, and some liverworts].

They occur in a variety of other habitats: moist stones, soils and wood. Some of them also occur in association with **fungi (lichen)** and animals (e.g., on **sloth bear**).

The form and size of algae is highly variable. The size ranges from the microscopic unicellular forms like **Chlamydomonas**, to colonial forms like **Volvox** and to the filamentous forms like **Ulothrix** and **Spirogyra**. A few of the marine forms such as **kelps**, form massive plant bodies.

The algae reproduce by **vegetative, asexual and sexual methods**. Vegetative reproduction is by **fragmentation**. Each fragment develops into a thallus.

Asexual reproduction is by the production of different types of **spores**, the most common being the **zoospores [**capable of swimming by means of a flagellum**]**. They are **flagellated (motile)** and on germination gives rise to new plants.

Sexual reproduction takes place through fusion of two gametes. These gametes can be flagellated and similar in size (as in Chlamydomonas) or non-flagellated (non-motile) but similar in size (as in Spirogyra). Such reproduction is called **isogamous [**Fusion of two gametes similar in size**]**.

Fusion of two gametes dissimilar in size, as in some species of Chlamydomonas is termed as **anisogamous**.

Fusion between one large, non-motile (static) female gamete and a smaller, motile male gamete is termed **oogamous**, e.g., Volvox, Fucus. [Compare this with human sperm and ovum]

Chlorophyceae – Green Algae

The members of chlorophyceae are commonly called **green algae**.

The plant body may be unicellular, colonial or filamentous.

They are usually grass green due to the dominance of pigments **chlorophyll a and b**. The pigments are localised in definite chloroplasts.

Most of the members have one or more storage bodies called **pyrenoids** located in the chloroplasts. Pyrenoids contain protein besides starch. Some algae may store food in the form of oil droplets.

Green algae usually have a rigid cell wall made of an inner layer of **cellulose** and an outer layer of **pectose**.

Vegetative reproduction usually takes place by fragmentation or by formation of different types of spores.

Asexual reproduction is by flagellated zoospores produced in zoosporangia.

The sexual reproduction shows considerable variation in the type and formation of sex cells and it may be isogamous, anisogamous or oogamous.

Some commonly found green algae are: **Chlamydomonas, Volvox, Ulothrix, Spirogyra** and **Chara**.

Phaeophyceae – Brown Algae

The members of phaeophyceae or **brown algae** are found primarily in **marine habitats**.

They show great variation in size and form. They range from simple branched, filamentous forms (Ectocarpus) to profusely branched forms as represented by kelps, which may reach a height of 100 metres.

They possess **chlorophyll a, c, carotenoids** and **xanthophylls**. They vary in colour from olive green to various shades of brown depending upon the amount of the **xanthophyll pigment, fucoxanthin** present in them.

The vegetative cells have a cellulosic wall usually covered on the outside by a gelatinous coating of **algin**. The protoplast contains, in addition to plastids, a centrally located vacuole and nucleus.

Vegetative reproduction takes place by fragmentation.

Asexual reproduction in most brown algae is by biflagellate zoospores that are pear-shaped and have two unequal laterally attached flagella.

Sexual reproduction maybe isogamous, anisogamous or oogamous.

Union of gametes may take place in water or within the oogonium (oogamous species).

The gametes are pyriform (pear-shaped) and bear two laterally attached flagella.

The common forms are **Ectocarpus, Dictyota, Laminaria, Sargassum** and **Fucus**.

Rhodophyceae – Red Algae

The members of rhodophyceae are commonly called **red algae** because of the predominance of the red pigment, **r-phycoerythrin** in their body.

Majority of the red algae are marine with greater concentrations found in the warmer areas.

They occur in both well-lighted regions close to the surface of water and also at great depths in oceans where relatively little light penetrates.

The red thalli of most of the red algae are multicellular. Some of them have complex body organisation.

The food is stored as floridean starch which is very similar to amylopectin and glycogen in structure.

The red algae usually reproduce vegetatively by fragmentation.

They reproduce asexually by non-motile spores and sexually by non-motile gametes.

Sexual reproduction is oogamous.

The common members are: **Polysiphonia, Porphyra, Gracilaria** and **Gelidium**.

TABLE 3.1 Divisions of Algae and their Main Characteristics

Classes	Common Name	Major Pigments	Stored Food	Cell Wall	Flagellar Number and Position of Insertions	Habitat
Chlorophyceae	Green algae	Chlorophyll *a, b*	Starch	Cellulose	2-8, equal, apical	Fresh water, brackish water, salt water
Phaeophyceae	Brown algae	Chlorophyll *a, c,* fucoxanthin	Mannitol, laminarin	Cellulose and algin	2, unequal, lateral	Fresh water (rare) brackish water, salt water
Rhodophyceae	Red algae	Chlorophyll *a, d,* phycoerythrin	Floridean starch	Cellulose, pectin and poly sulphate esters	Absent	Fresh water (some), brackish water, salt water (most)

Uses of algae

Algae are useful to man in a variety of ways. At least a half of the total **carbon dioxide fixation** on earth is carried out by algae through photosynthesis.

Being photosynthetic they increase the level of dissolved oxygen in their immediate environment.

They are of paramount importance as **primary producers** of energy-rich compounds which form the basis of the food cycles of all aquatic animals.

Many species of **Porphyra, Laminaria** and **Sargassum** are among the 70 species of marine algae used as food.

Certain marine brown and red algae produce large amounts of **hydrocolloids** (water holding substances), e.g., **algin (brown algae)** and **carrageen (red algae)** which are used commercially.

Agar, one of the commercial products obtained from Gelidium and Gracilaria are used to grow microbes and in preparations of **ice-creams** and jellies.

Chlorella a unicellular alga, rich in **proteins** is used as food supplement even by space travellers.

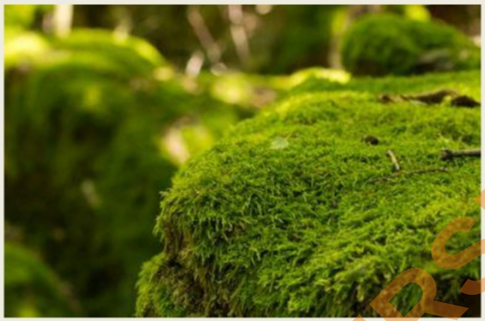
The algae are divided into three main classes: **Chlorophyceae, Phaeophyceae** and **Rhodophyceae**.

Bryophytes

Bryophytes are called **amphibians** of the plant kingdom because these plants can live in soil but are dependent on water for sexual reproduction.

The plant body is commonly differentiated to form stem and leaf-like structures. However, there is **no specialized tissue for the conduction of water** and other substances from one part of the plant body to another.

Bryophytes include the various **mosses (funaria), marchantia** and **liverworts** that are found commonly growing in damp, humid and shaded localities. They play an important role in **plant succession** on bare rocks/soil.



The plant body of bryophytes is more differentiated than that of algae. It is thallus-like and erect, and attached to the substratum by unicellular or multicellular **rhizoids [root like structures]**.

They **lack true roots, stem or leaves**. They may possess root-like, leaf-like or stem-like structures.

The main plant body of the bryophyte is **haploid**. It produces gametes, hence is called a **gametophyte**.

The sex organs in bryophytes are multicellular. The male sex organ is called **antheridium**. They produce biflagellate antherozoids. The female sex organ called **archegonium** is flask-shaped and produces a single egg.

The antherozoids are released into water where they come in contact with archegonium. An antherozoid fuses with the egg to produce the zygote.

Zygotes do not undergo reduction division [Meiosis] immediately. They produce a multicellular body called a sporophyte. The sporophyte is not free-living but attached to the photosynthetic gametophyte and derives nourishment from it.

Some cells of the sporophyte undergo reduction division (meiosis) to produce haploid spores. These spores germinate to produce gametophyte.

Bryophytes in general are of little economic importance but some mosses provide food for herbaceous mammals, birds and other animals.

Species of **Sphagnum**, a moss, provide peat that have long been used as fuel, and as packing material for trans-shipment of living material because of their capacity to hold water.

Mosses along with **lichens** are the first organisms to colonise rocks and hence, are of great ecological importance. They **decompose rocks** making the substrate suitable for the growth of higher plants.

Since mosses form dense mats on the soil, they reduce the impact of falling rain and **prevent soil erosion**. The bryophytes are divided into liverworts and mosses.

Pteridophytes

In this group, the plant body is **differentiated** into roots, stem and leaves and **has specialized tissue** for the conduction of water and other substances from one part of the plant body to another. Some examples are **marsilea, ferns** and **horse-tails**.

Pteridophytes are used for medicinal purposes and as **soil-binders**. They are also frequently grown as **ornamentals**.

Evolutionarily, they are the first terrestrial plants to possess vascular tissues - **xylem** and **phloem**.

The pteridophytes are found in cool, damp, shady places though some may flourish well in sandy-soil conditions.

You may recall that in bryophytes the dominant phase in the life cycle is the gametophytic plant body. However, in pteridophytes, the main plant body is a **sporophyte** which is differentiated into **true root, stem and leaves**.

These organs possess well-differentiated vascular tissues. The leaves in pteridophyta are **small (microphylls)** as in Selaginella or **large (macrophylls)** as in ferns.

The spores germinate to give rise to inconspicuous, small but multicellular, free-living, mostly photosynthetic thalloid gametophytes called prothallus.

These gametophytes require cool, damp, shady places to grow. Because of this specific restricted requirement and the need for water for fertilisation, **the spread of living pteridophytes is limited** and restricted to narrow geographical regions.

Cryptogamae

The **thallophytes**, the **bryophytes** and the **pteridophytes** have **naked embryos** that are called **spores**.

The reproductive organs of plants in all these three groups are very inconspicuous, and they are therefore called '**cryptogamae**', or 'those with **hidden reproductive organs**'.

Kingdom Plantae – Phanerogams – Plants with Seeds: Gymnosperms, Angiosperms: Monocots and Dicots or Dicotyledon and Monocotyledon.

Phanerogams – Plants with Seeds

Plants with well differentiated reproductive tissues that ultimately make seeds are called **phanerogams**.

Seeds are the result of the reproductive process. They consist of the embryo along with stored food, which serves for the initial growth of the embryo during germination.

This group is further classified, based on whether the seeds are **naked or enclosed** in fruits, giving us two groups: **gymnosperms** and **angiosperms**.

Gymnosperms

This term is made from two greek words: gymno– means naked and sperma– means seed.

The plants of this group bear **naked seeds [**ovules are not enclosed by any ovary wall**]** and are usually **perennial, evergreen** and **woody**. The seeds that develop post-fertilisation are naked too. Examples are **pines**, such as deodar.

Gymnosperms include medium-sized trees or tall trees and shrubs. One of the gymnosperms, the **giant redwood tree Seguoia** is one of the tallest tree species.

The roots are generally **tap roots** {Plant Parts and Their Functions}**. Roots in some genera have fungal association in the form of mycorrhiza (Pinus), while in some others (Cgcas**) small specialised roots called coralloid roots are associated with N2-fixing cyanobacteria.

The leaves in gymnosperms are well-adapted to withstand **extremes** of temperature, humidity and wind.

In conifers, the needle-like leaves reduce the surface area. Their **thick cuticle** and **sunken stomata** also help to reduce water loss.

The gymnosperms are **heterosporous**; they produce haploid microspores and megaspores.

The two kinds of spores are produced within sporangia that are borne on sporophylls which are arranged spirally along an axis to form lax or compact **strobili or cones**.

The strobili bearing microsporophylls and microsporangia are called **microsporangiate** or **male strobili**.

The microspores develop into a male gametophytic generation which is highly reduced and is confined to only a limited number of cells. This reduced gametophyte is called a pollen grain. The development of pollen grains take place within the **microsporangia**.

The cones bearing megasporophylls with ovules or **megasporangia** are called **macrosporangiate** or **female strobili**.

The male or female cones or strobili may be borne on the same tree (**Pinus**). However, in **cycas** male cones and megasporophylls are borne on different trees.

Unlike bryophytes and pteridophytes {Bryophytes – Pteridophytes }, in gymnosperms the male and the female gametophytes do not have an independent free-living existence. They remain within the sporangia retained on the sporophytes.

The pollen grain is released from the microsporangium. They are carried in air currents and come in contact with the opening of the ovules borne on megasporophylls.

The pollen tube carrying the male gametes grows towards archegonia in the ovules and discharge their contents near the mouth of the archegonia.

Following fertilisation, zygote develops into an embryo and the ovules into seeds. These seeds are **not covered**.

Gymnosperms: (a) Cycas (b) Pinus (c) Ginkgo

Angiosperms

This word is made from two greek words: angio– means covered and sperma– means seed.

Unlike the gymnosperms where the ovules are naked, in the **angiosperms or flowering plants**, the pollen grains and ovules are developed in specialised structures called **flowers**.

The seeds develop inside an organ which is modified to become a **fruit**. These are also called **flowering plants**.

The male sex organ in a flower is the **stamen**. Each stamen consists of a slender filament with an anther at the tip. The anthers, following Meiosis, produce **pollen grains**.

The female sex organ in a flower is the **pistil** or the **carpel**. Pistil consists of an ovary enclosing one to many ovules. Within ovules are present highly reduced female gametophytes termed embryo-sacs. The embryo-sac formation is preceded by meiosis. Hence, each of the cells of an embryo-sac is **haploid**.

Each embryo-sac has a three-celled egg apparatus - one egg cell and two synergids, three antipodal cells and two polar nuclei. The polar nuclei eventually fuse to produce a diploid secondary nucleus.

Pollen grain, after dispersal from the anthers, are carried by wind or various other agencies to the stigma of a pistil. This is termed as **pollination**.

The pollen grains germinate on the stigma and the resulting pollen tubes grow through the tissues of stigma and style and reach the ovule.

The pollen tubes enter the embryo-sac where two male gametes are discharged. One of the male gametes fuses with the egg cell to form a **zygote (syngamy)**.

The other male gamete fuses with the diploid secondary nucleus to produce the **triploid primary endosperm nucleus (PEN).**

Because of the involvement of two fusions, this event is termed as **double fertilisation**, an event **unique to angiosperms**.

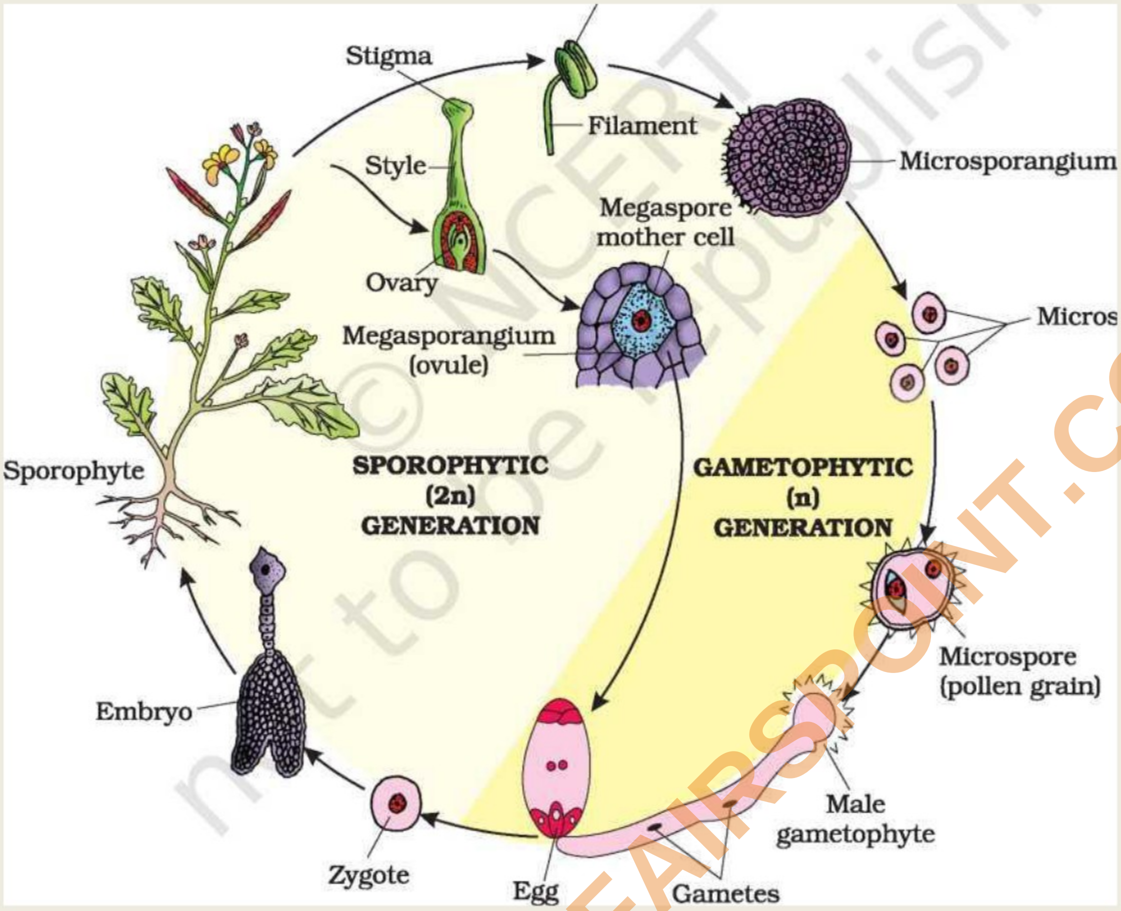


Figure: Life cycle of an angiosperm

The zygote develops into an embryo (with one or two cotyledons) and the PEN develops into endosperm which provides nourishment to the developing embryo.

The synergids and antipodals degenerate after fertilisation. During these events the ovules develop into seeds and the ovaries develop into fruit.

Plant embryos in seeds have structures called **cotyledons**. Cotyledons are called '**seed leaves**' because in many instances they emerge and become green when the seed germinates. Thus, cotyledons represent a bit of pre-designed plant in the seed.

Monocots and Dicots

The angiosperms are divided into two groups on the basis of the number of cotyledons present in the seed.

Plants with seeds having a single cotyledon are called **monocotyledonous** or **monocots**. Plants with seeds having two cotyledons are called **dicots.**

Figure: Angiosperms : (a) A dicotyledon (b) A monocotyledon

Kingdom Plantae - Summary

Plant kingdom includes algae, bryophytes, pteridophytes, gymnosperms and angiosperms.

Algae [thallophytes] are chlorophyll-bearing simple, thalloid, autotrophic and largely aquatic organisms.

Depending on the type of pigment possesed and the type of stored food, algae are classfied into three classes, namely *Chlorophyceae, Phaeophyceae and Rhodophyceae*.

Algae usually reproduce vegetatively by fragmentation, asexually by formation of different types of spores and sexually by formation of gametes which may show isogamy, anisogamy or oogamy.

Bryophytes are plants which can live in soil but are dependent on water for sexual reproduction. Their plant body is more differentiated than that of algae. It is thallus-like and prostrate or erect and attached to the substratum by rhizoids. They possess root-like, leaf-like and stem-like structures.

The bryophytes are divided into liverworts and mosses. The plant body of liverworts is thalloid and dorsiventral whereas mosses have upright, slender axes bearing spirally arranged leaves.

The main plant body of a bryophyte is gamete-producing and is called a gametophyte. It bears the male sex organs called antheridia and female sex organs called archegonia.

The male and female gametes produced fuse to form zygote which produces a multicellular body called a sporophyte. It produces haploid spores. The spores germinate to form gametophytes.

In pteridophytes the main plant is a sporophyte which is differentiated into true root, stem and leaves. These organs possess well-differentiated vascular tissues. The sporophytes bear sporangia which produce spores.

The spores germinate to form gametophytes which require cool, damp places to grow. The gametophytes bear male and female sex organs called antheridia and archegonia, respectively. Water is required for transfer of male gametes to archegonium where zygote is formed after fertilisation. The zygote produces a sporophyte.

The gymnosperms are the plants in which ovules are not enclosed by any ovary wall. After fertilisation the seeds remain exposed and therefore these plants are called naked-seeded plants.

The gymnosperms produce microspores and megaspores which are produced in microsporangia and megasporangia borne on the sporophylls. The sporophylls - microsporophylls and megasporophylls - are arranged spirally on axis to form male and female cones, respectively. The pollen grain germinates and pollen tube releases the male gamete into the ovule, where it fuses with the egg cell in archegonia. Following fertilisation, the zygote develops into embryo and the ovules into seeds.

In angiosperms, the male sex organs (stamen) and female sex organs (pistil) are borne in a flower. Each stamen consists of a filament and an anther. The anther produces pollen grains (male gametophyte) after meiosis. The pistil consists of an ovary enclosing one to many ovules. Within the ovule is the female gametophyte or embryo sac which contains the egg cell.

The pollen tube enters the embryo-sac where two male gametes are discharged. One male gamete fuses with egg cell (syngamy) and other fuses with diploid secondary nucleus (triple fusion). This phenomenon of two fusions is called double fertilisation and is unique to angiosperms. The angiosperms are divided into two classes - the dicotyledons and the monocotyledons.

During the life cycle of any sexually reproducing plant, there is alternation of generations between gamete producing haploid gametophyte and spore producing diploid sporophyte. However, different plant groups as well as individuals may show different patterns of life cycles - haplontic, diplontic or intermediate.

Match the following (column I with column II)	
Column I	**Column II**
Chlamydomonas	Moss
Cycas	Pteridophyte
Selaginella	Algae
Sphagnum	Gymnosperm

Plant Tissue - Meristematic Tissue, Permanent Tissue - Simple Permanent Tissue: Parenchyma, Chlorenchyma. Complex Permanent Tissue: Xylem, Phloem.

Plant Tissues

Plants are stationary or fixed – they don't move. Most of the tissues they have are supportive, which provides them with structural strength.

Most of the plant tissues are dead, since dead cells can provide mechanical strength as easily as live ones, and need less maintenance.

Animals on the other hand move around in search of food, mates and shelter. They consume more energy as compared to plants. Most of the tissues they contain are living.

Another difference between animals and plants is in the pattern of growth. The growth in plants is limited to certain regions, while this is not so in animals.

There are some tissues in plants that divide throughout their life. These tissues are localised in certain regions.

Based on the dividing capacity of the tissues, various plant tissues can be classified as **growing or meristematic tissue** and **permanent tissue**.

Cell growth in animals is more uniform. So, there is no such demarcation of dividing and non-dividing regions in animals.

The structural organisation of organs and organ systems is far more specialised and localised in complex animals than even in very complex plants. This fundamental difference reflects the different modes of life pursued by these two major groups of organisms, particularly in their different feeding methods.

Also, they are differently adapted for a sedentary existence on one hand (plants) and active locomotion on the other (animals), contributing to this difference in organ system design.

Meristematic Tissue

The growth of plants occurs only in certain specific regions. This is because the **dividing tissue**, also known as meristematic tissue, is located only at these points.

Depending on the region where they are present, meristematic tissues are classified as **apical, lateral** and **intercalary**.

New cells produced by meristem are initially like those of meristem itself, but as they grow and mature, their characteristics slowly change and they become differentiated as components of other tissues.

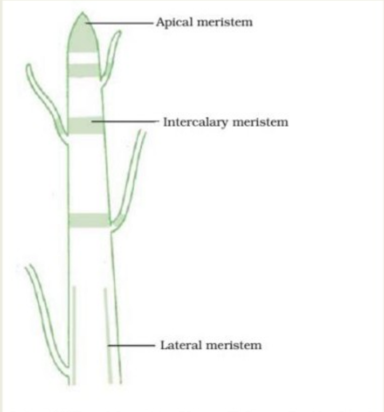


Fig. 6.2: *Location of meristematic tissue in plant body*

Apical meristem is present at the growing tips of stems and roots and increases the length of the stem and the root.

The girth of the stem or root increases due to **lateral meristem (cambium)**.

Intercalary meristem is the meristem at the base of the leaves or internodes (on either side of the node) on twigs.

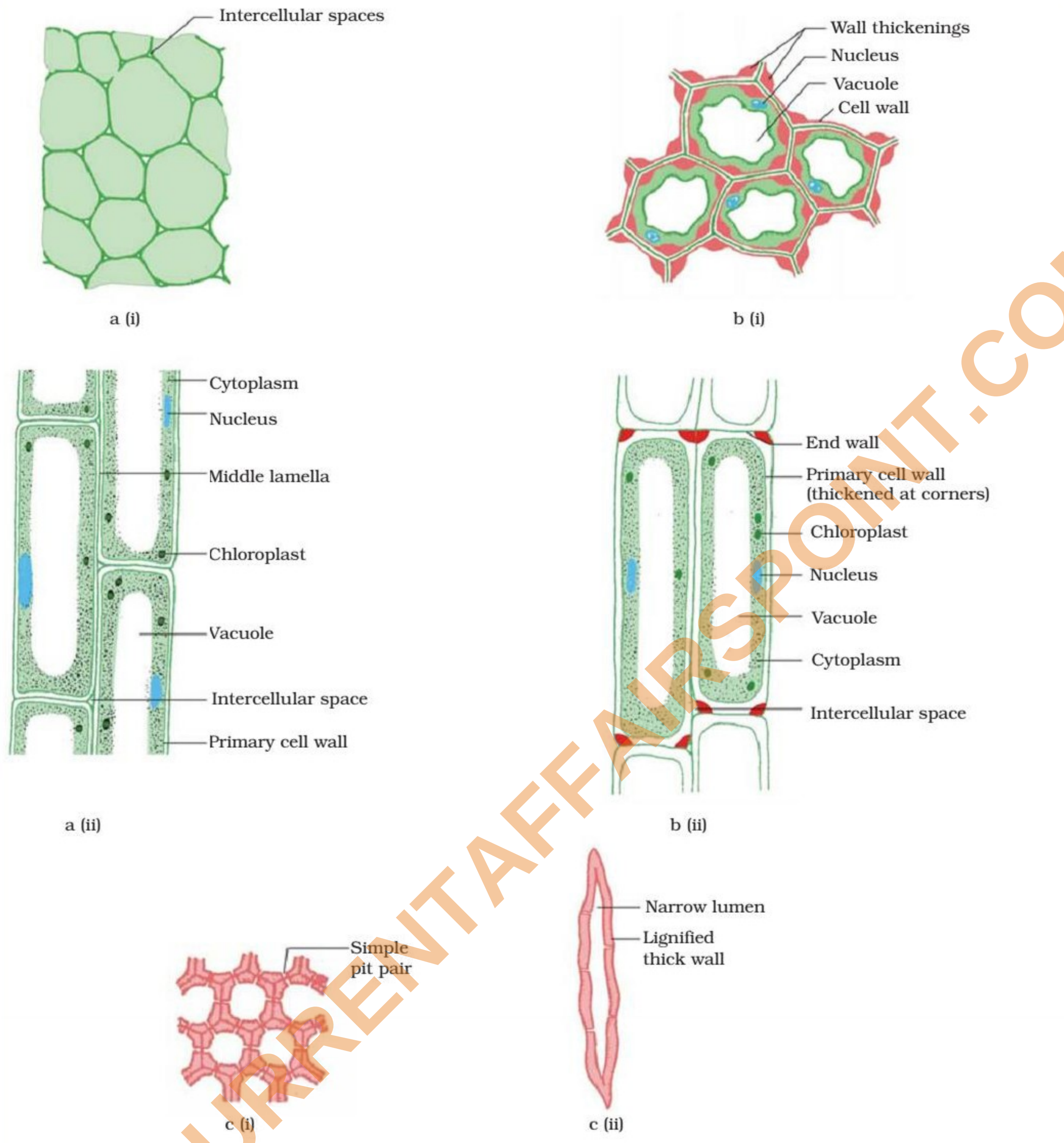
As the cells of this tissue are very active, they have **dense cytoplasm, thin cellulose walls** and **prominent nuclei**. They **lack vacuoles**.

Permanent Tissue

What happens to the cells formed by meristematic tissue? They take up a specific role and lose the ability to divide. As a result, they form a permanent tissue.

This process of taking up a permanent shape, size, and a function is called **differentiation**. Cells of meristematic tissue differentiate to form different types of permanent tissue.

Simple Permanent Tissue



. 6.4: Various types of simple tissues: (a) Parenchyma (i) transverse section, (ii) longitudinal section; (b) Collenchyma (i) transverse section, (ii) longitudinal section; (c) Sclerenchyma (i) transverse section, (ii) longitudinal section.

Parenchyma

A few layers of cells form the basic **packing tissue**. This tissue is parenchyma, a type of permanent tissue. It consists of relatively **unspecialised cells with thin cell walls**.

They are **live cells**. They are usually loosely packed, so that large spaces between cells (intercellular spaces) are found in this tissue.

Chlorenchyma

This tissue provides support to plants and also **stores food**. In some situations, it contains chlorophyll and performs photosynthesis, and then it is called chlorenchyma.

Aerenchyma

In aquatic plants, large air cavities are present in parenchyma to give **buoyancy** to the plants to help them float. Such a parenchyma type is called aerenchyma. The parenchyma of stems and roots also stores nutrients and water.

Collenchyma

The flexibility in plants is due to another permanent tissue, collenchyma. It allows easy bending in various parts of a plant (leaf, stem) without breaking. It also provides mechanical support to plants. We can find this tissue in leaf stalks below the epidermis. The cells of this tissue are living, elongated and irregularly thickened at the corners. There is **very little intercellular space**.

Sclerenchyma

Yet another type of permanent tissue is sclerenchyma. It is the tissue which makes the plant **hard and stiff**. We have seen the husk of a coconut. It is made of sclerenchymatous tissue. The cells of this tissue are **dead**. They are long and narrow as the walls are thickened due to **lignin** (a chemical substance which acts as cement and hardens them). Often these walls are so thick that there is **no internal space** inside the cell. This tissue is present in stems, around vascular bundles, in the veins of leaves and in the hard covering of seeds and nuts. It provides strength to the plant parts.

Epidermis

What you observe is the outermost layer of cells, called epidermis. The epidermis is usually made of a single layer of cells.

In some plants living in very dry habitats, the Epidermis may be thicker since protection against water loss is critical.

The entire surface of a plant has this outer covering of epidermis. It protects all the parts of the plant.

Epidermal cells on the aerial parts of the plant often secrete a waxy, water-resistant layer on their outer surface. This aids in protection against loss of water, mechanical injury and invasion by parasitic fungi.

Since it has a **protective role** to play, cells of epidermal tissue form a continuous layer **without intercellular spaces**.

Most epidermal cells are relatively flat. Often their outer and side walls are thicker than the inner wall.

Small pores in the epidermis of the leaf are called **stomata**. Stomata are enclosed by two kidney-shaped cells called **guard cells**. They are necessary for exchanging gases with the atmosphere.

Transpiration (loss of water in the form of water vapour) also takes place through stomata

Epidermal cells of the roots, whose function is water absorption, commonly bear long hair-like parts that greatly increase the total absorptive surface area.

In some plants like desert plants, epidermis has a thick waxy coating of **cutin** (chemical substance with waterproof quality) on its outer surface.

As plants grow older, the outer protective tissue undergoes certain changes. A strip of secondary meristem replaces the epidermis of the stem. Cells on the outside are cut off from this layer. This forms the several-layer thick cork or the bark of the tree. Cells of cork are dead and compactly arranged without intercellular spaces. They also have a chemical called suberin in their walls that makes them impervious to gases and water

Complex Permanent Tissue

The different types of tissues we have discussed until now are all made of **one type of cells**, which look like each other. Such tissues are called simple permanent tissue. Yet another type of permanent tissue is complex tissue.

Complex tissues are made of **more than one type of cells**. All these cells coordinate to perform a common function.

Xylem and **phloem** are examples of such complex tissues. They are both conducting tissues and constitute a vascular bundle.

Vascular or conductive tissue is a distinctive feature of the complex plants, one that has made possible their survival in the terrestrial environment.

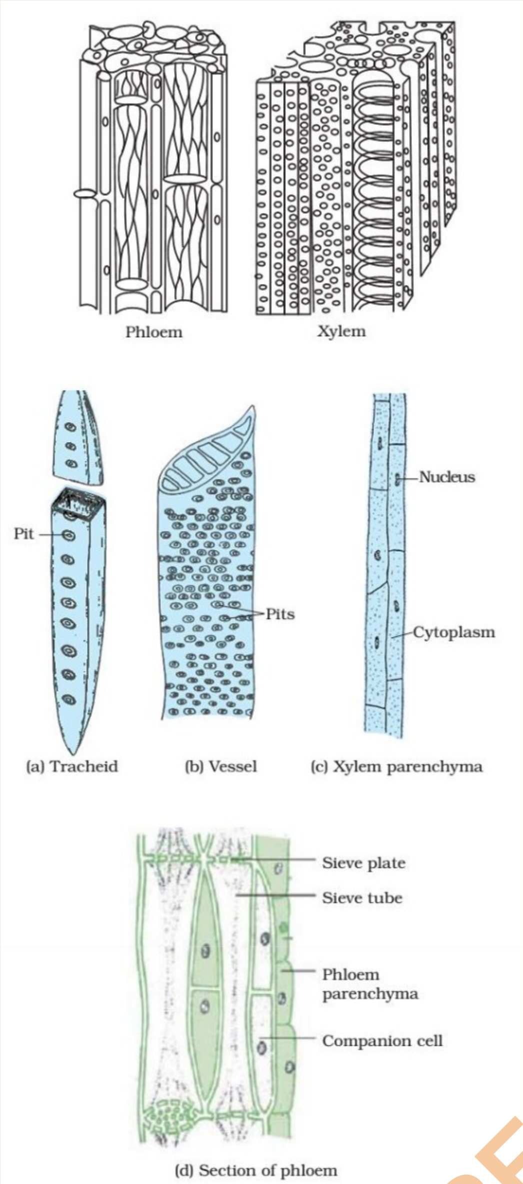


Fig. 6.7: *Types of complex tissue*

Xylem

Xylem consists of **tracheids, vessels, xylem parenchyma** and **xylem fibres**. The cells have thick walls, and many of them are dead cells.

Tracheids and vessels are tubular structures. This allows them to transport water and minerals vertically.

The parenchyma **stores food** and helps in the **sideways conduction of water**. Fibres are mainly supportive in function.

Phloem

Phloem is made up of four types of elements: **sieve tubes, companion cells, phloem fibres** and the **phloem parenchyma**. Sieve tubes are tubular cells with perforated walls.

Phloem is unlike xylem in that materials can move in **both directions** in it. Phloem transports **food** from leaves to other Parts of the plant. Except for phloem fibres, phloem cells are living cells.

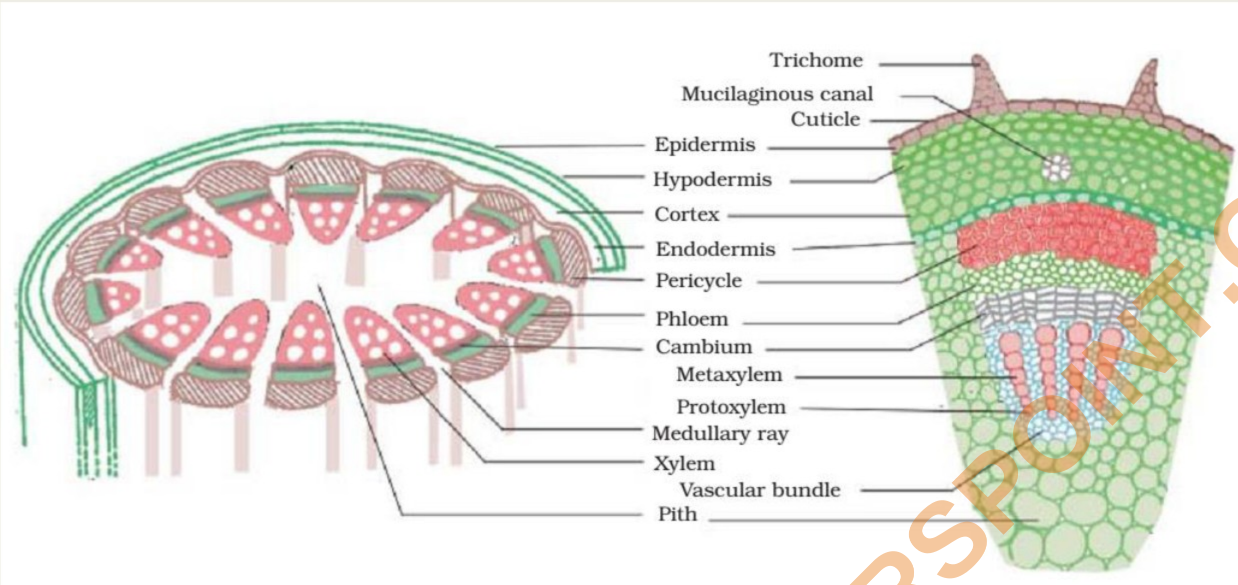


Fig. 6.3: *Section of a stem*

Nutrition in Plants - Photosynthesis, Saprotrophs, Symbiosis, Parasites, Macronutrients - Micronutrients in Plants, Nitrogen Cycle, Nitrogen Fixation.

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Nutrition in Plants

Nutrition is the mode of taking food by an organism and its utilization by the body.

The mode of nutrition in which organisms make food themselves from simple substances is called **autotrophic (auto = self; trophos = nourishment)** nutrition. Therefore, plants are called autotrophs.

Animals and most other organisms take in readymade food prepared by the plants. They are called **heterotrophs (heteros = other)**.

Insectivorous plants have both autotrophic and heterotrophic mode of nutrition.

Photosynthesis – Food Making Process In Plants

Carbon dioxide from air is taken in through the tiny pores present on the surface of the leaves. These pores are surrounded by **'guard cells'**. Such pores are called **stomata**.

Water and minerals are transported to the leaves by the vessels which run like pipes throughout the root, the stem, the branches and the leaves. They form a continuous path or passage for the nutrients to reach the leaf.

The leaves have a green pigment called **chlorophyll**. It helps leaves to capture the energy of the sunlight. This energy is used to synthesise (prepare) food from **carbon dioxide** and **water**. Since the synthesis of food occurs in the presence of sunlight, it is called **photosynthesis (Photo: light; synthesis: to combine)**.

So we find that chlorophyll, sunlight, carbon dioxide and water are necessary to carry out the process of photosynthesis. Thus, sun is the ultimate source of energy for all living organisms.

Besides leaves, photosynthesis also takes place in other green parts of the plant — in **green stems** and **green branches**.

The desert plants have scale or spine-like leaves to **reduce loss of water** by transpiration. These plants have green stems which carry out photosynthesis.

During photosynthesis, chlorophyll containing cells of leaves, in the presence of sunlight, use carbon dioxide and water to synthesise **carbohydrates**. The carbohydrates ultimately get converted into **starch**.

The leaves other than green also have chlorophyll. The large amount of red, brown and other pigments mask the green colour. Photosynthesis takes place in these leaves also.

Chlorophyll Pigments

Within the leaves, the **mesophyll cells** have a large number of chloroplasts that are responsible for CO2 fixation.

A chromatographic separation of the leaf pigments shows that the colour that we see in leaves is not due to a single pigment but due to four pigments: **Chlorophyll a** (bright or **blue green** in the chromatogram), **chlorophyll b** (**yellow green**), **xanthophylls** (**yellow**) and **carotenoids** (**yellow to yellow-orange**).

Light Reactions and Dark Reactions

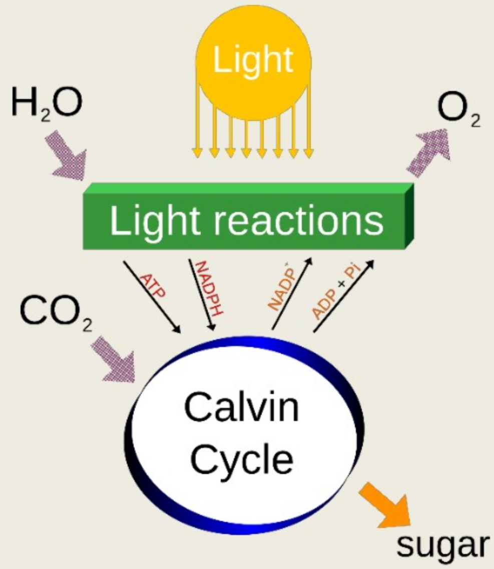
Within the chloroplast there is the membranous system consisting of grana, the stroma lamellae, and the fluid stroma. There is a clear division of labour within the chloroplast.

The membrane system is responsible for **trapping the light energy** and also for the **synthesis of ATP and NADPH**. [**light reactions**]

In the light reaction the light energy is absorbed by the pigments present in the antenna, and funnelled to special chlorophyll a molecules called reaction centre chlorophylls.

In stroma, enzymatic reactions incorporate CO2 [chemosynthetic pathway- carbon fixing reactions] into the plant leading to the **synthesis of sugar**, which in turn forms **starch**. [**dark reactions**]

The former set of reactions, since they are directly light driven are called **light reactions**. The latter are not directly light driven but are dependent on the products of light reactions (ATP and NADPH). Hence, to distinguish the latter they are called, by convention, as **dark reactions**. However, this should not be construed to mean that they occur in darkness or that they are not lightdependent.



Factors Affecting Photosynthesis

Law of Limiting Factors: If a chemical process is affected by more than one factor, then its rate will be determined by the factor which is **nearest to its minimal value**: it is the factor which directly affects the process if its quantity is changed.

For example, despite the presence of a green leaf and optimal light and CO2 conditions, the plant may not photosynthesise if the temperature is very low. This leaf, if given the optimal temperature, will start photosynthesising.

Carbon dioxide Concentration

The concentration of CO 2 is very low in the atmosphere (between 0.03 and 0.04 per cent). Increase in concentration upto 0.05 per cent can cause an increase in CO 2 fixation rates; beyond this the levels can become damaging over longer periods.

Temperature

The dark reactions being enzymatic are **temperature controlled**. Though the light reactions are also temperature sensitive they are affected to a much lesser extent.

The temperature optimum for photosynthesis of different plants also depends on the habitat that they are adapted to. Tropical plants have a higher temperature optimum than the plants adapted to temperate climates.

Water

Water stress causes the **stomata to close** hence reducing the CO 2 availability.

Besides, water stress also makes leaves wilt, thus, reducing the surface area ofthe leaves and their metabolic activity as well.

Light

There is a linear relationship between incident light and CO2 fixation rates at low light intensities.

At higher light intensities, gradually the rate does not show further increase as other factors become limiting.

Saprotrophs – Fungi

Fungi have a different mode of nutrition. They secrete digestive juices on the dead and decaying matter and convert it into a solution. Then they absorb the nutrients from it.

This mode of nutrition in which organisms take in nutrients in solution form from dead and decaying matter is called saprotrophic nutrition.

Plants which use saprotrophic mode of nutrition are called saprotrophs. *Mushrooms* are best example.

Symbiosis

Some organisms live together and share shelter and nutrients. This is called symbiotic relationship. For example, certain fungi live in the roots of trees. The tree provides nutrients to the fungus and, in return, receives help from it to take up water and nutrients from the soil.

Plants absorb mineral nutrients from the soil. So, their amounts in the soil keep on declining. Fertilisers and manures contain plant nutrients such as nitrogen, potassium, phosphorous, etc.

Usually crops require a lot of nitrogen to make proteins. After the harvest, the soil becomes deficient in nitrogen.

Though nitrogen gas is available in plenty in the air, plants cannot use it in the manner they can use carbon dioxide. They need nitrogen in a soluble form.

The bacterium called **Rhizobium** can take atmospheric nitrogen and converts it into a soluble form. But Rhizobium cannot make its own food. So it lives in the roots of gram, peas, moon beans and other legumes and provides them with nitrogen (symbiosis).

Most of the pulses (dals) are obtained from **leguminous plants**. In return, the plants provide food and shelter to the bacteria. They have a symbiotic relationship.

Parasites

A parasite is an organism which lives in or on another organism and benefits by deriving nutrients at the other's expense.

Plants like **cuscuta** are parasites. They take food from the host plant.

Amarbelis an example of: (i) autotroph (ii) parasite (iii) saprotroph (iv) host

Mineral Nutrition

The basic needs of all living organisms are essentially the same. They require macromolecules, such as carbohydrates, proteins and fats, and water and minerals for their growth and development.

Only a few elements have been found to be absolutely essential for plant growth and metabolism. These elements are further divided into two broad categories based on their quantitative requirements.

Macronutrients and Micronutrients in Plants

Macronutrients are generally present in plant tissues in large amounts. The macronutrients include

Carbon

Hydrogen

Oxygen

Nitrogen

Phosphorous

Sulphur

Potassium

Calcium and

Magnesium.

Micronutrients or trace elements, are needed in very small amounts. These include

Iron

Manganese

Copper

Molybdenum

Zinc

Boron

Chlorine and

Nickel.

In addition to the 17 essential elements named above, there are some beneficial elements such as

Sodium

Silicon

Cobalt and

Selenium. They are required by higher plants.

Nitrogen

Nitrogen is required by all parts of a plant, particularly the **meristematic tissues** and the metabolically active cells.

Nitrogen is one of the major constituents of proteins, nucleic acids, vitamins and hormones.

Phosphorus

Phosphorus is a constituent of **cell membranes**, certain proteins, all nucleic acids and nucleotides, and is required for all phosphorylation reactions.

Potassium

In plants, this is required in more abundant quantities in the **meristematic tissues, buds, leaves and root tips**.

Potassium helps to maintain an **anion-cation balance** in cells and is involved in protein synthesis, opening and closing of stomata, activation of enzymes and in the maintenance of the turgidity of cells.

Calcium

Calcium is required by meristematic and differentiating tissues. During cell division it is used in the **synthesis of cell wall**, particularly as calcium pectate in the middle lamella.

It accumulates in older leaves. It is involved in the normal functioning of the cell membranes. It activates certain enzymes and plays an important role in regulating metabolic activities.

Magnesium

It activates the enzymes of respiration, photosynthesis and are involved in the **synthesis of DNA and RNA**.

Nitrogen Cycle

Apart from carbon, hydrogen and oxygen, nitrogen is the most prevalent element in living organisms.

Nitrogen is a constituent of amino acids, proteins, hormones, chlorophylls and many of the vitamins.

Plants compete with microbes for the limited nitrogen that is available in soil. Thus, nitrogen is a **limiting nutrient** for both natural and agricultural eco-systems.

Nitrogen exists as two nitrogen atoms joined by a very strong **triple covalent bond** ($N \equiv N$). The process of conversion of **nitrogen (N2) to ammonia** is termed as nitrogen-fixation.

In nature, **lightning** and **ultraviolet radiation** provide enough energy to convert nitrogen to nitrogen oxides (NO, NO2, N2O).

Industrial combustions, forest fires, automobile exhausts and power-generating stations are also sources of atmospheric nitrogen oxides.

Decomposition of organic nitrogen of dead plants and animals into ammonia is called **ammonification**.

Some of this ammonia volatilises and re-enters the atmosphere but most of it is converted into **nitrate** by soil bacteria.

Ammonia is first oxidised to **nitrite** by the bacteria **Nitrosomonas** and/or **Nitrococcus**.

The nitrite is further oxidised to **nitrate** with the help of the bacterium **Nitrobacter**. These steps are called **nitrification**. These nitrifying bacteria are **chemoautotrophs**.

The nitrate thus formed is absorbed by plants and is transported to the leaves. In leaves, it is reduced to form ammonia that finally forms the amine group of **amino acids**.

Nitrate present in the soil is also reduced to nitrogen by the process of **denitrification**. Denitrification is carried by bacteria **Pseudomonas** and **Thiobacillus**.

The enzyme, **nitrogenase** which is capable of nitrogen reduction is present exclusively in **prokaryotes**. Such microbes are called **N2-fixers**.

The nitrogen-fixing microbes could be free-living or symbiotic. Examples of free-living nitrogen-fixing aerobic microbes are **Azotobacter** and **Beijemickia** while **Rhodospirillum** is anaerobic and Bacillus free-living.

In addition, a number of **cyanobacteria** such as **Anabaena** and **Nostoc** are also free-living nitrogen-fixers.

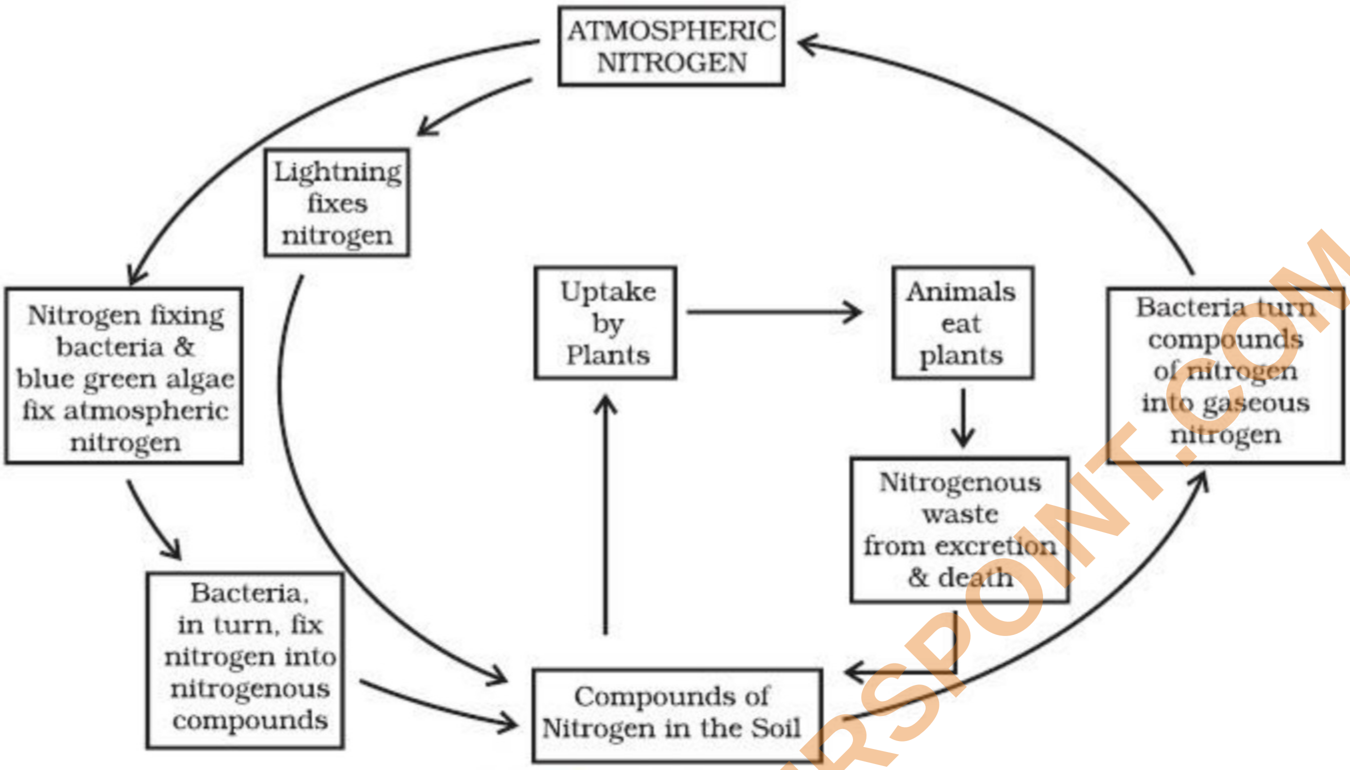


***Fig. 2.10** : Nitrogen cycle*

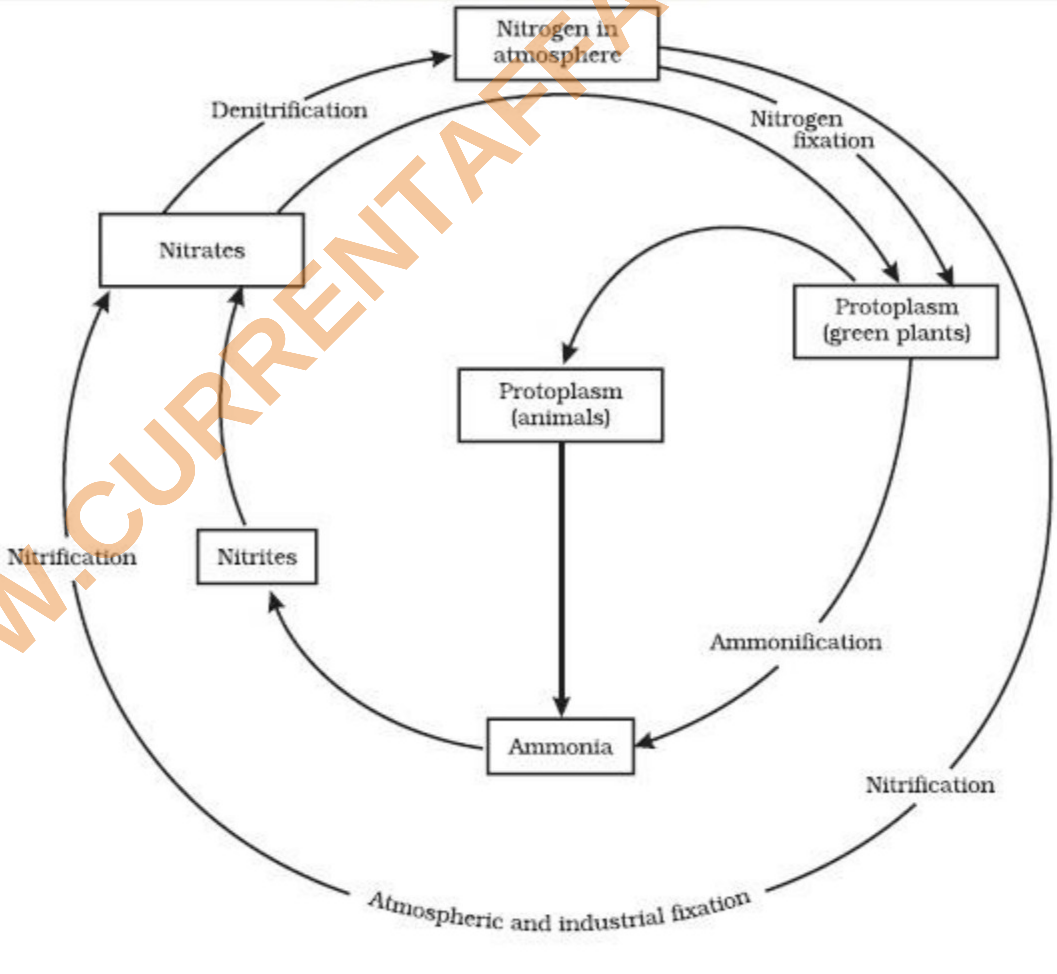


***Fig.14.6:** Nitrogen-cycle in nature*

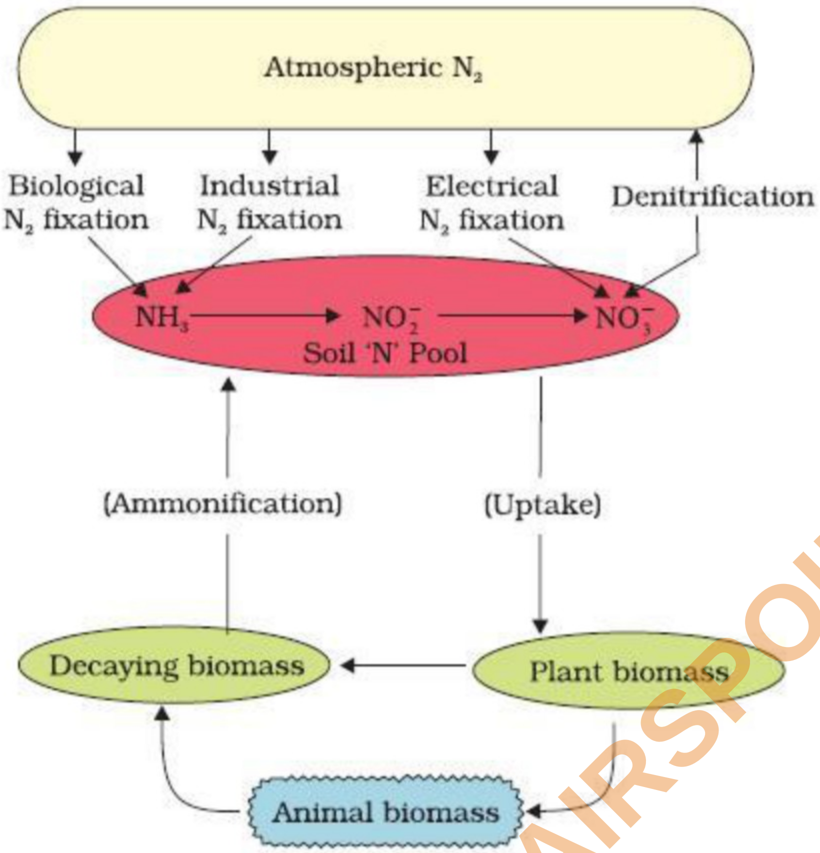


Figure 12.3 The nitrogen cycle showing relationship between the three main nitrogen pools – atmospheric soil, and biomass

Symbiotic Biological Nitrogen Fixation

Several types of symbiotic biological nitrogen fixing associations are known. The most prominent among them is the legume-bacteria relationship.

Species of rod-shaped **Rhizobium** has such relationship with the roots of several legumes such as **alfalfa, sweet clover, sweet pea, lentils, garden pea, broad bean, clover beans**, etc.

The most common association on roots is as **nodules**. These nodules are small outgrowths on the roots. The microbe, Frankia, also produces nitrogen-fixing nodules on the roots of nonleguminous plants (e.g., Alnus).

Both **Rhizobium** and **Frankia**. are free- living in soil, but as symbionts, can fix atmospheric nitrogen.

Summary

Plants obtain their inorganic nutrients from air, water and soil.

Plants absorb a wide variety of mineral elements.

Not all the mineral elements that they absorb are required by plants.

Out of the more than 105 elements discovered so far, less than 21 are essential and beneficial for normal plant growth and development.

The elements required in large quantities are called macronutrients while those required in less quantities or in trace are termed as micronutrients.

These elements are either essential constituents of proteins, carbohydrates, fats, nucleic acid etc., and/or take part in various metabolic processes.

Deficiency of each of these essential elements may lead to symptoms called deficiency symptoms.

Chlorosis, necrosis, stunted growth, impaired cell division, etc., are some prominent deficiency symptoms.

Plants absorb minerals through roots by either passive or active processes. They are carried to all parts of the organism through xylem along with water transport.

Nitrogen is very essential for the sustenance of life. Plants cannot use atmospheric nitrogen directly. But some of the plants in association with N2-fixing bacteria, especially roots of legumes, can fix this atmospheric nitrogen into biologically usable forms. Nitrogen fixation requires a strong reducing agent and energy in the form of ATP.

N2-fixation is accomplished with the help of nitrogenfixing microbes, mainly Rhizobium. The enzyme **nitrogenase** which plays an important role in biological N2 fixation is very **sensitive to oxygen**. Most of the processes take place in **anaerobic** environment.

The energy, ATP, required is provided by the respiration of the host cells. Ammonia produced following N2 fixation is incorporated into amino acids as the amino group.

Sexual and Asexual Reproduction in Plants – Asexual Reproduction: Vegetative Propagation, Budding, Spores – Sexual Reproduction: Unisexual, Bisexual.

Modes Of Reproduction in Plants

There are several ways by which plants produce their offspring. These are categorised into two types: (i) **asexual**, and (ii) **sexual** reproduction.

In asexual reproduction plants can give rise to new plants **without seeds**, whereas in sexual reproduction, new plants are obtained from seeds.

Asexual Reproduction in Plants

Asexual reproduction occurs through:

Vegetative Propagation,

Budding,

Fragmentation and

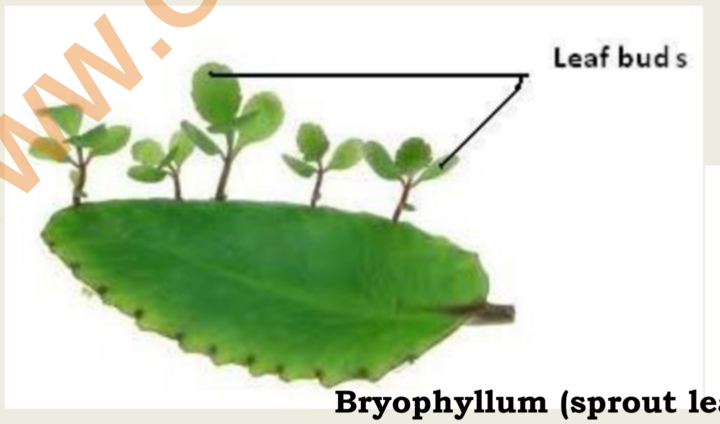
Spore formation.

Vegetative Propagation

Most plants have roots, stems and leaves. These are called the **vegetative parts** of a plant.

Vegetative Propagation is a type of asexual reproduction in which new plants are produced from roots, stems, leaves and buds. Since reproduction is through the vegetative parts of the plant, it is known as **vegetative propagation**.

Bryophyllum (sprout leaf plant) has buds in the margins of leaves. If a leaf of this plant falls on a moist soil, each bud can give rise to a new plant.



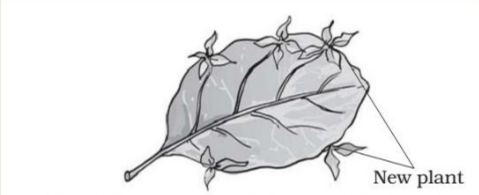


Fig. 12.4 Leaf of bryophyllum with buds in the margin

Bryophyllum (sprout leaf plant)

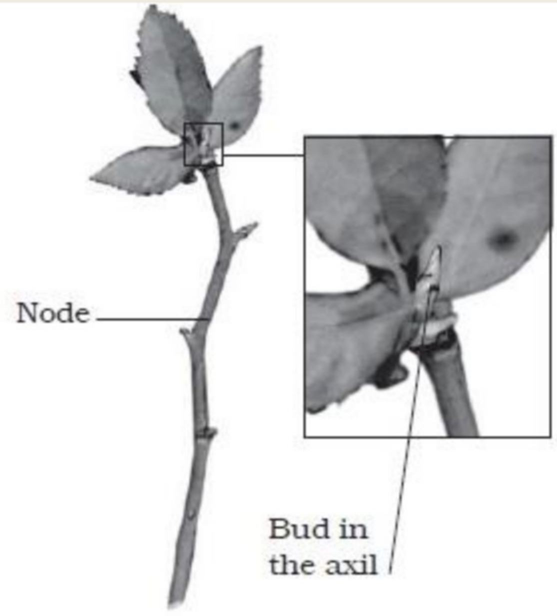


Fig. 12.1 Stem-cutting of rose

The roots of some plants can also give rise to new plants. **Sweet potato** and **dahlia** are examples.

Plants such as cacti produce new plants when their parts get detached from the main plant body. Each detached part can grow into a new plant.

Plants produced by vegetative propagation take less time to grow and bear flowers and fruits earlier than those produced from seeds.

The new plants are exact copies of the parent plant, as they are produced from a **single parent**.

Budding

Yeast is a single-celled organism. The small bulb-like projection coming out from the yeast cell is called a bud.

The bud gradually grows and gets detached from the parent cell and forms a new yeast cell.

The new yeast cell grows, matures and produces more yeast cells. If this process continues, a large number of yeast cells are produced in a short time.

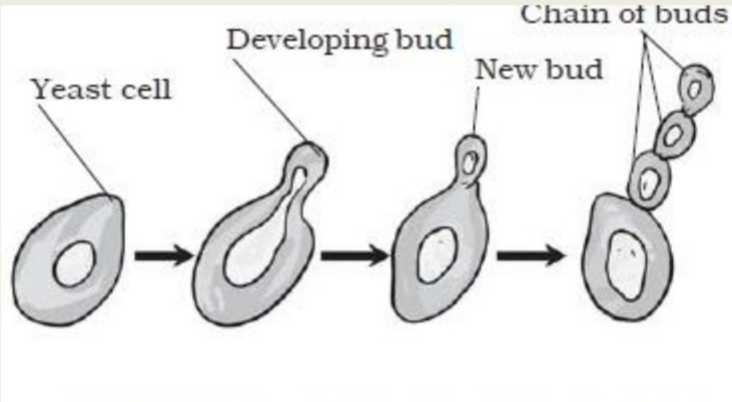
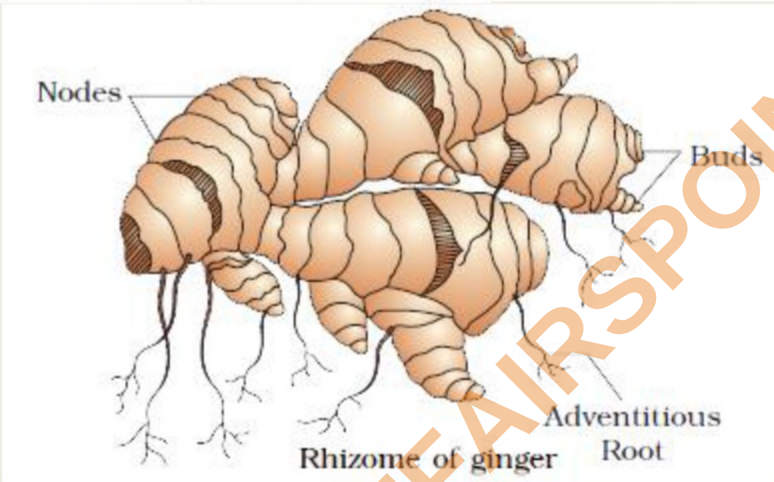


Fig. 12.5 Reproduction in yeast by budding

Fig. 12.2 Potato plant sprouting from an 'eye'



Fragmentation

When water and nutrients are available algae grow and multiply rapidly by fragmentation.

An alga breaks up into two or more fragments. These fragments or pieces grow into new individuals. This process continues and they cover a large area in a short period of time.

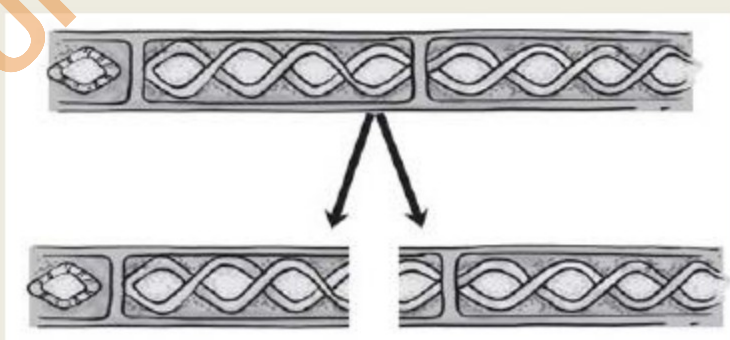


Fig. 12.6 Fragmentation in spirogyra (an alga)

Spore formation

Fungi on a bread piece grow from spores which are present in the air. When spores are released they keep floating in the air.

The spores are asexual reproductive bodies. As they are very light, they can cover long distances.

Each spore is covered by a hard protective coat to withstand unfavorable conditions such as high temperature and low humidity. So they can survive for a long time.

Under favourable conditions, a spore germinates and develops into a new individual.

Plants such as **moss** and **ferns** also reproduce by means of spores.

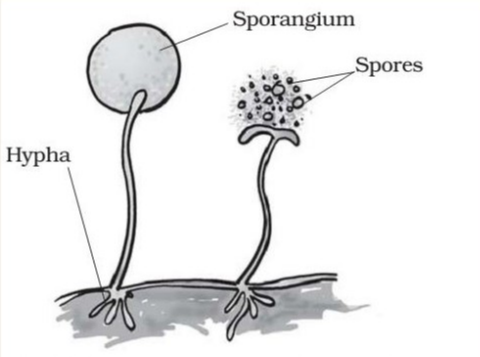


Fig. 12.7 Reproduction through spore formation in fungus

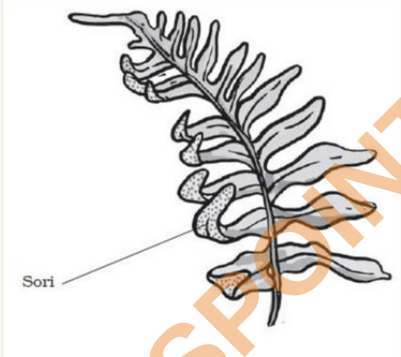
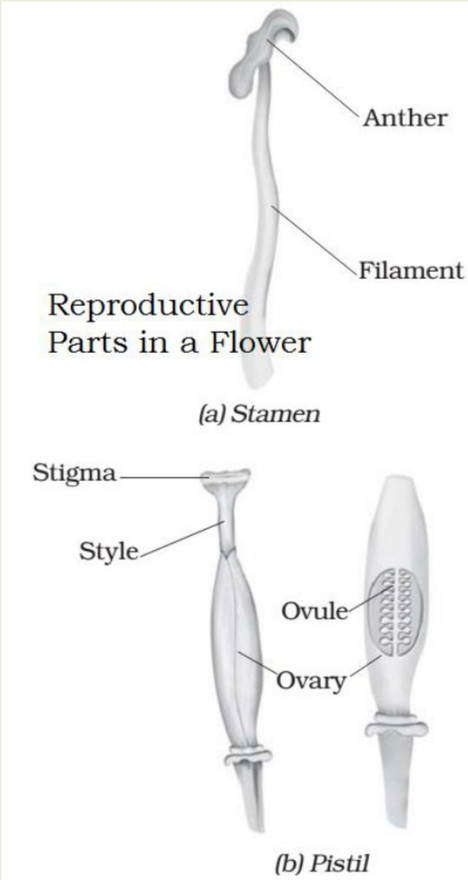


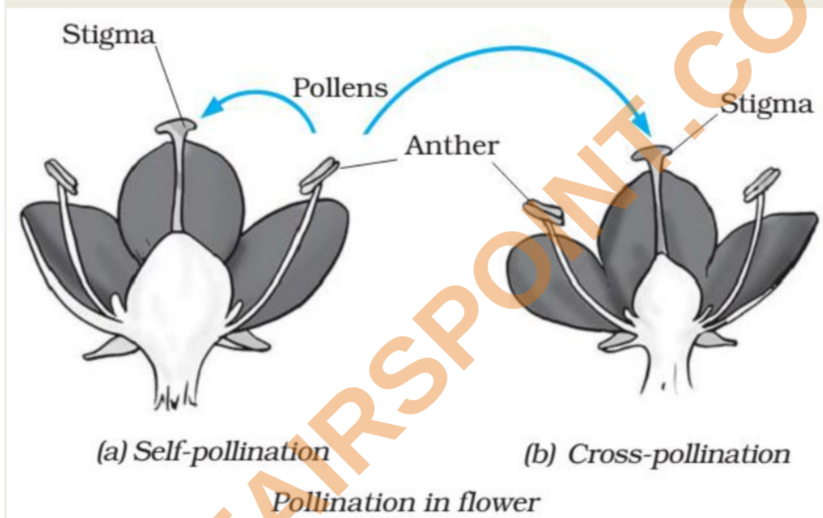
Fig. 12.8 Reproduction through spore formation in fern

Sexual Reproduction in Plants – Unisexual and Bisexual

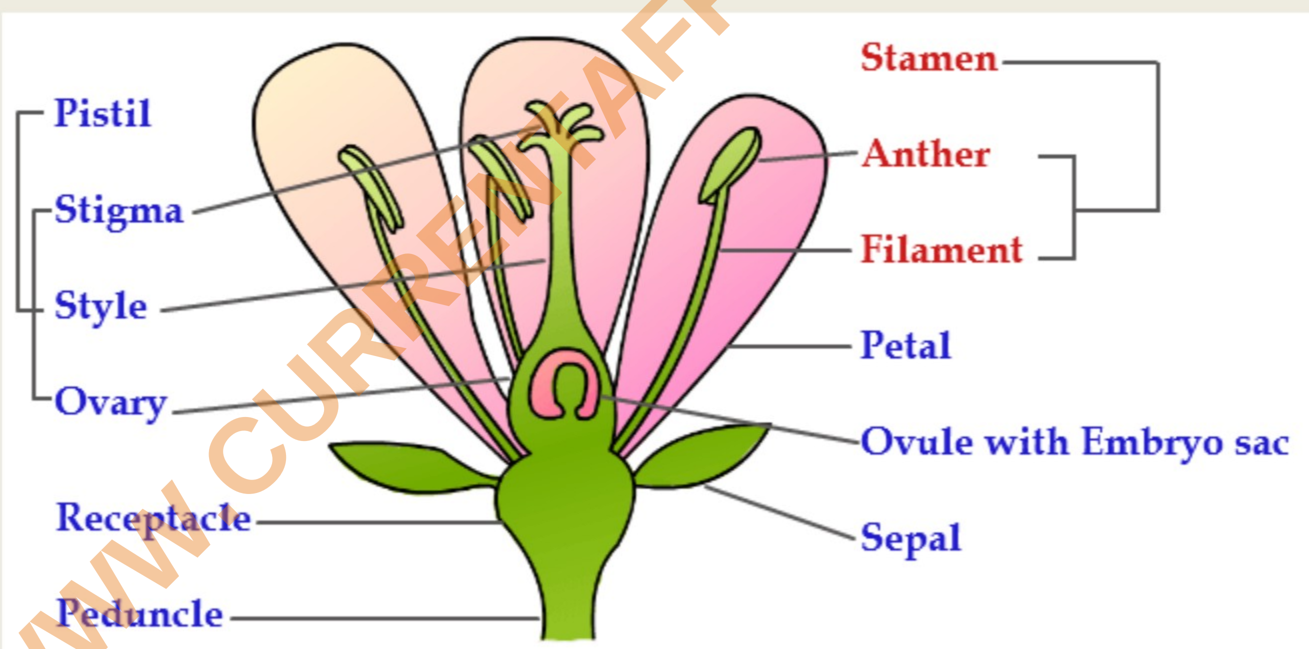
The flowers are the **reproductive parts** of a plant. The **stamens** are the male reproductive part and the **pistil** is the female reproductive part.



Reproductive Parts in a Flower



Pollination in flower



The flowers which contain either only the pistil or only the stamens are called **unisexual flowers**. The flowers which contain both stamens and pistil are called **bisexual flowers**.

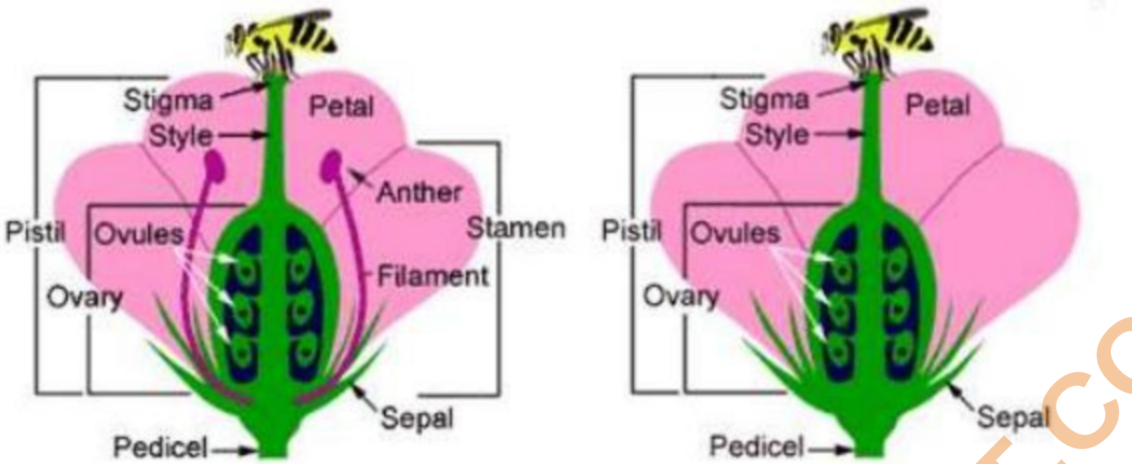


Figure 20. Complete flower structure

Imperfect (pistillate) flower structure

BISEXUAL FLOWER

UNISEXUAL FLOWER

Corn, papaya and **cucumber** produce unisexual flowers, whereas **mustard, rose** and **petunia** have bisexual flowers.

Both the male and the female unisexual flowers may be present in the same plant or in different plants.

Anther contains pollen grains which produce **male gametes**. A pistil consists of stigma, style and ovary. The **ovary** contains one or more **ovules**. The female gamete or the egg is formed in an ovule. In sexual reproduction a male and a female gamete fuse to form a **zygote**.

Pollination

Generally pollen grains have a tough protective coat which prevents them from drying up. Since pollen grains are light, they can be carried by wind or water. Insects visit flowers and carry away pollen on their bodies.

Some of the pollen lands on the stigma of a flower of the same kind. The transfer of pollen from the anther to the stigma of a flower is called **pollination**.

If the pollen lands on the stigma of the same flower it is called **self-pollination**. When the pollen of a flower lands on the stigma of another flower of the same plant, or that of a different plant of the same kind, it is called **cross-pollination**.

Fertilisation

The cell which results after fusion of the gametes is called a **zygote**. The process of fusion of male and female gametes (to form a zygote) is called **fertilization**. The zygote develops into an **embryo**.

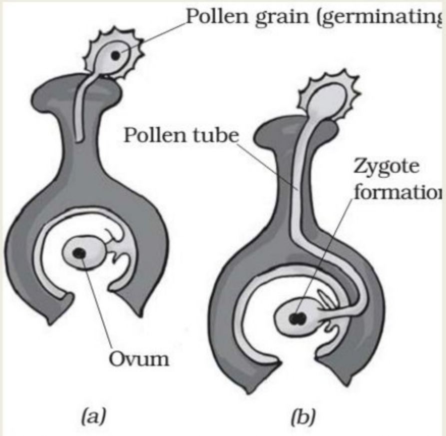


Fig. 12.11 Fertilisation (Zygote formation)

Fruits and seed formation

After fertilization, the **ovary grows into a fruit** and other parts of the flower fall off. The fruit is the **ripened ovary**.

The **seeds develop from the ovules**. The seed contains an embryo enclosed in a protective seed coat. Some fruits are fleshy and juicy such as mango, apple and orange. Some fruits are hard like almonds and walnuts.

Seed dispersal

Some seeds are dispersed by animals, especially spiny seeds with hooks which get attached to the bodies of animals and are carried to distant places. Examples are Xanthium and Urena.

Some seeds are dispersed when the fruits burst with sudden jerks. The seeds are scattered far from the parent plant. This happens in the case of Castor and Balsam.

Match the Following

Column I	Column II
1. Bud 2. Eyes 3. Fragmentation	a) Maple b) Spirogyra c) Yeast

4. Wings 5. Spores	d) Bread mould e) Potato f) Rose

Asexual reproduction vs Sexual reproduction

Asexual reproduction	**Sexual reproduction**
Only one parent plant is involved.	Both male and female parents are involved.
b) Occurs in unisexual plants.	b) Occurs in bisexual plants.
c) Occurs in lower plants.	c) Occurs in higher plants.
Reproductive organs are not present.	Fully developed reproductive parts are present
In most of the methods the original parent disappears.	Original parents remain alive after process of reproduction.
Process like gamete formation or fertilization is not seen.	Fertilization of gametes give rises to zygote.
Characteristics of only one parent is inherited.	Characteristics of both parents are inherited.
No need of seeds.	Seeds are used to get new plants from a flower.

Self-Pollination	**Cross-Pollination**
Pollen grains are transferred to the stigma of the same flower.	Pollen grains are carried to stigma of another flower.

Occurs in bisexual plants having anther and stigma maturing at same time. It takes place in plants like wheat, peas etc.	Occurs in bisexual flowers having anther and stigma maturing at different times. It takes place in plants like lady-finger, tomato, brinjal etc.

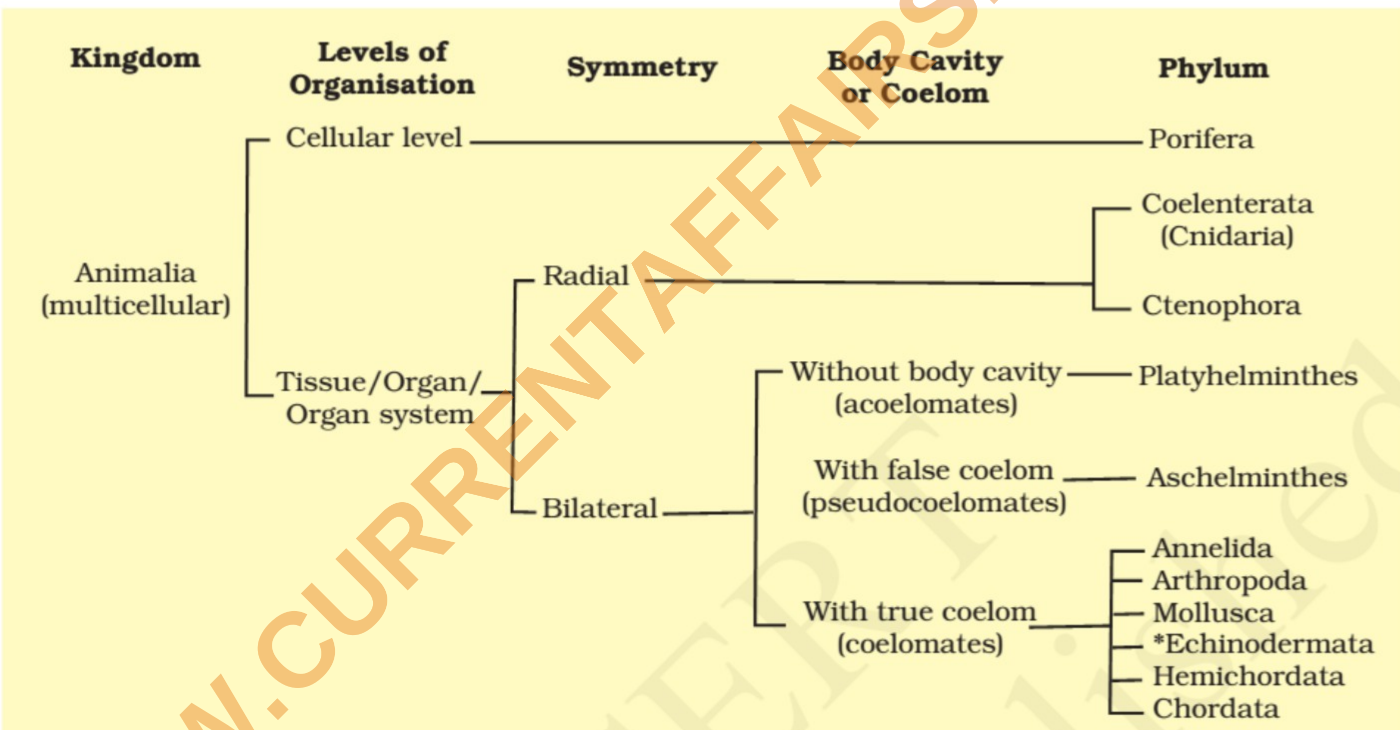
Classification of Animal Kingdom - Porifera, Coelenterata, Platyhelminthes, Aschelminthes, Annelida, Arthropoda, Mollusca, Echinodermata, Chordata.

Basis for Animal Kingdom Classification

Classification of Animal Kingdom is based on various fundamental features like -

Levels of Organisation,
Symmetry,
Diploblastic and Triploblastic Organisation,
Coelom development,
Segmentation of the body and
Presense or absence of Notochord.

The broad classification of Animalia based on common fundamental features:



*Echinodermata exhibits radial or bilateral symmetry depending on the stage.

Figure 4.4 Broad classification of Kingdom Animalia based on common fundamental features

Levels of Organisation

Though all members of Animalia are multicellular, all of them do not exhibit the same pattern of organisation of cells.

For example, in sponges, the cells are arranged as loose cell aggregates, i.e., they exhibit **cellular level of organisation**. Some division of labour (activities) occur among the cells.

In coelenterates, the arrangement of cells is more complex. Here the cells performing the same function are arranged into tissues, hence is called **tissue level of organisation**.

A still higher level of organisation, i.e., organ level [**organ level of organisation**] is exhibited by members of Platyhelminthes and other higher phyla where tissues are grouped together to form organs, each specialised for a particular function.

In animals like Annelids, Arthropods, Molluscs, Echinoderms and Chordates, organs have associated to form functional systems, each system concerned with a specific physiological function. This pattern is called **organ system level of organisation**.

Organ systems in different groups of animals exhibit various patterns of complexities.

For example, the digestive system in **Platyhelminthes (incomplete digestive system)** has only a single opening to the outside of the body that serves as both mouth and anus, and is hence called incomplete. A **complete digestive system** has two openings, mouth and anus.

Similarly, the circulatory system may be of two types: **open type** in which the blood is pumped out of the heart and the cells and tissues are directly bathed in it and **closed type** in which the blood is circulated through a series of vessels of varying diameters (arteries, veins and capillaries).

Symmetry

Animals can be categorised on the basis of their symmetry.

Sponges are mostly asymmetrical, i.e., any plane that passes through the centre does not divide them into equal halves.

When any plane passing through the central axis of the body divides the organism into two identical halves, it is called **radial symmetry**. Coelenterates, Ctenophores and Echinoderms have this kind of body plan.

Animals like Annelids, Arthropods, etc., where the body can be divided into identical left and right halves in only one plane, exhibit **bilateral symmetry**.

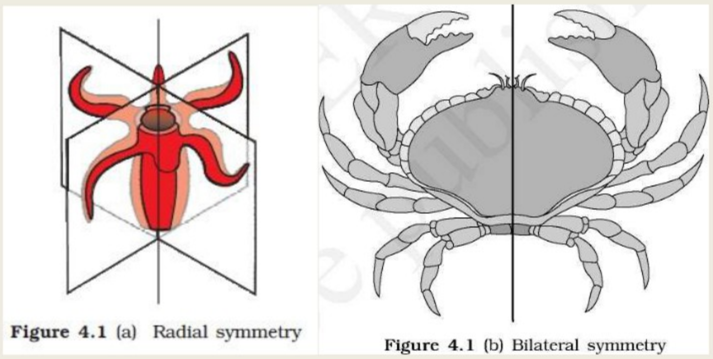
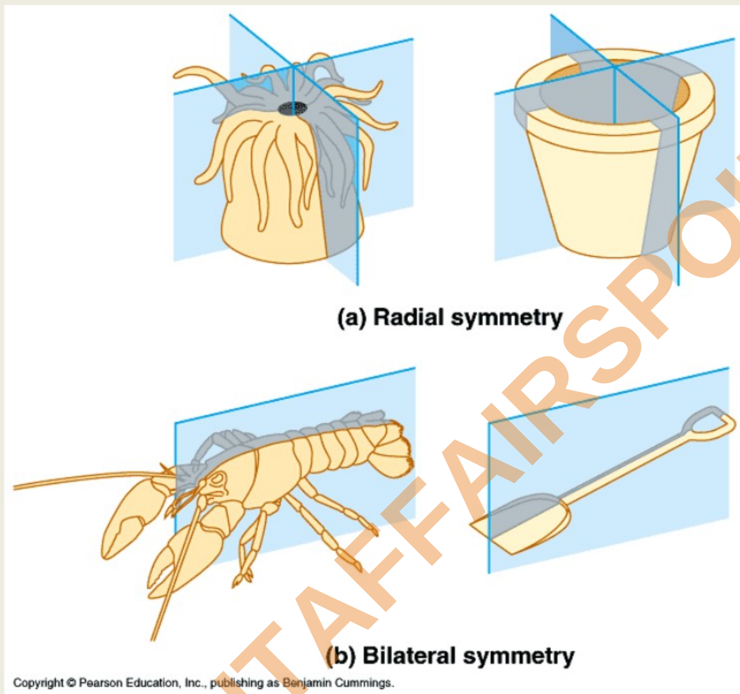


Figure 4.1 (a) Radial symmetry

Figure 4.1 (b) Bilateral symmetry



Diploblastic and Triploblastic Organisation

Animals in which the cells are arranged in two embryonic layers, an **external ectoderm** and an **internal endoderm**, are called **diploblastic animals**, e.g., Coelenterates. An undifferentiated layer, **mesoglea**, is present in between the ectoderm and the endoderm.

Those animals in which the developing embryo has a third germinal layer, **mesoderm**, in between the ectoderm and endoderm, are called **triploblastic animals** (platyhelminthes to chordates).

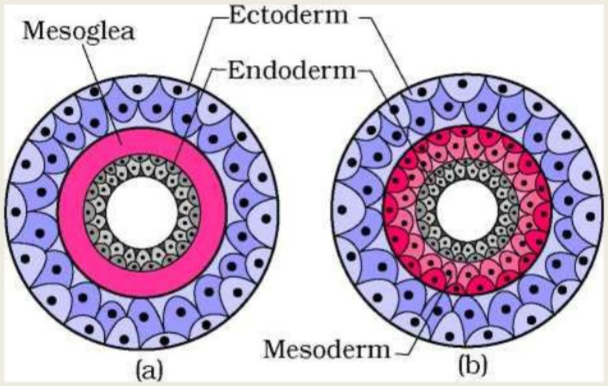


Figure: Showing germinal layers : (a) Diploblastic (b) Triploblastic

Coelom

Presence or absence of a cavity between the body wall and the gut wall is very important in classification.

The body cavity, which is lined by **mesoderm** is called **coelom**.

Animals possessing coelom are called **coelomates**, e.g., Annelids, Molluscs, Arthropods, Echinoderms, Hemichordates & Chordates.

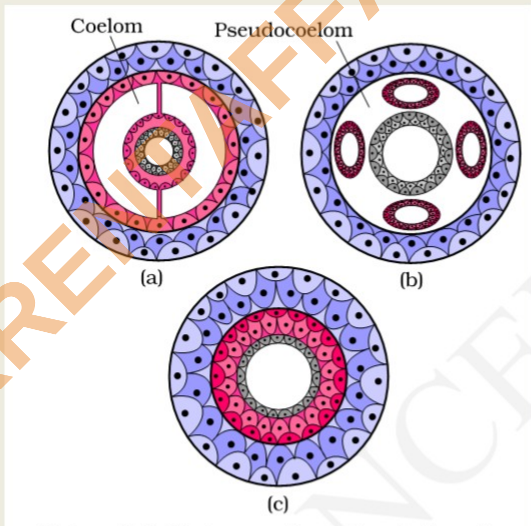


Figure 4.3 Diagrammatic sectional view of : (a) Coelomate (b) Pseudocoelomate (c) Acoelomate

In some animals, the body cavity is not lined by mesoderm, instead, the mesoderm is present as scattered pouches in between the ectoderm and endoderm. Such a body cavity is called **pseudocoelom** and the animals possessing them are called pseudocoelomates, e.g., Aschelminthes.

The animals in which the body cavity is absent are called **acoelomates**, e.g., Platyhelminthes.

Segmentation

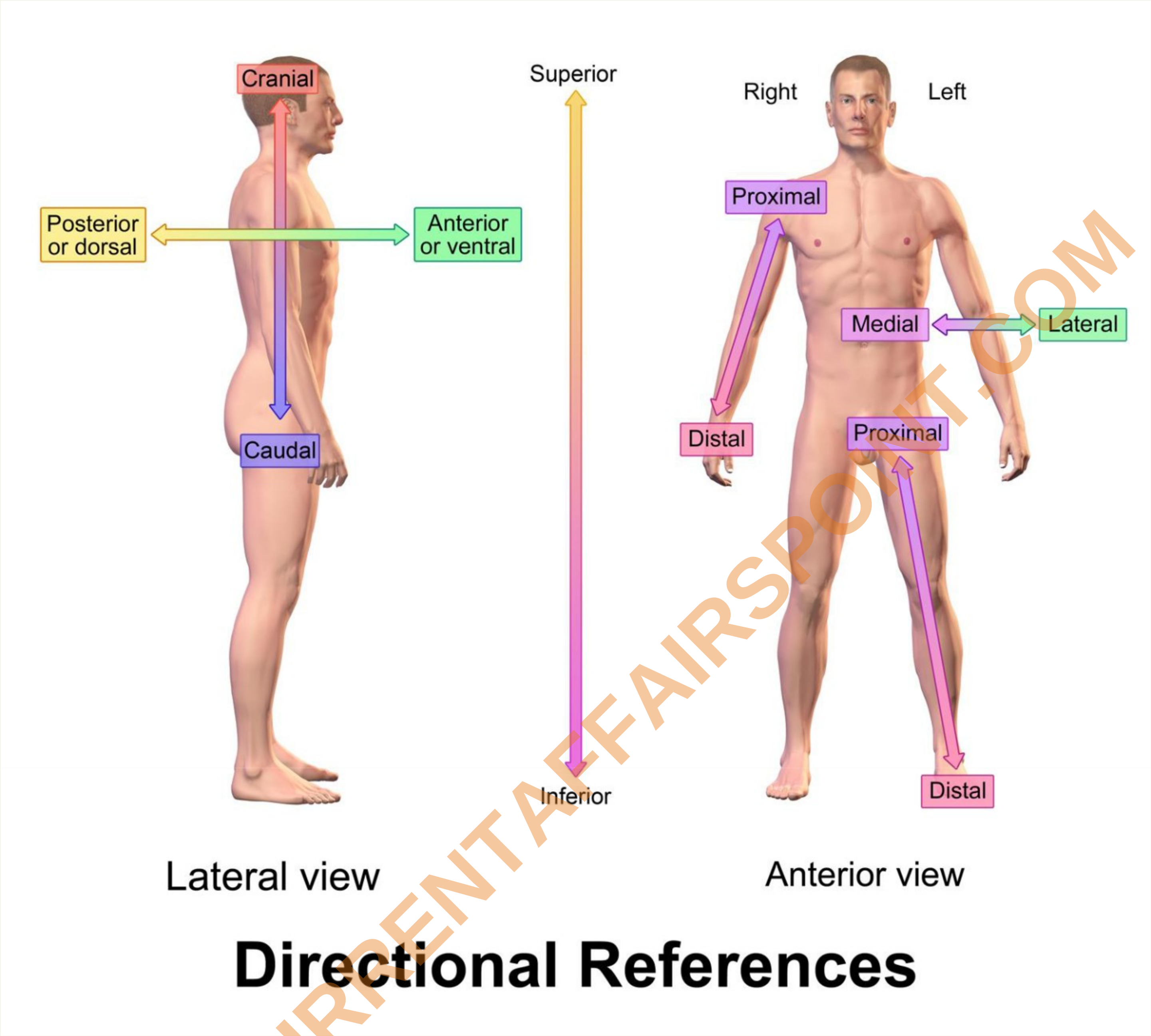
In some animals, the body is externally and internally divided into segments with a serial repetition of at least some organs.

For example, in earthworm, the body shows this pattern called **metameric segmentation** and the phenomenon is known as **metamerism**.

Notochord

Notochord is a mesodermally [the middle layer of cells or tissues of an embryo, or the parts derived from this (e.g. cartilage, muscles, and bone)] derived rod-like structure formed on the dorsal side [posterior] during embryonic development in some animals.

Animals with notochord are called **chordates** and those animals which do not form this structure are called non-chordates, e.g., Porifera to Echinoderms.



https://upload.wikimedia.org/wikipedia/commons/e/e7/Blausen_0019_AnatomicalDirectionalReferences.png

Classification of Animal Kingdom

Animal Kingdom is classified into:

Phylum - Porifera

Phylum - Coelenterata (Cnidaria)

Phylum - Ctenophora

Phylum - Platyhelminthes

Phylum - Aschelminthes (Nemotoda) Annelida

Phylum - Arthropoda

Phylum - Mollusca

Phylum - Echinodermata

Phylum - Hemichordata

Phylum - Chordata

Phylum - Porifera

Phylum – Porifera includes organisms with holes.

They are primitive multicellular animals and have **cellular level of organisation**.

They are non-motile animals attached to some solid support.

The body design involves very **minimal differentiation** and division into tissues.

They are commonly called **sponges**.

They are generally marine and mostly **asymmetrical animals**.

Sponges have a water transport or **canal system**.

Water enters through minute **pores (ostia)** in the body wall into a central cavity, **spongocoel**, from where it goes out through the **osculum**.

This pathway of water transport is helpful in food gathering, respiratory exchange and removal of waste.

The body is supported by a skeleton made up of **spicules or spongin fibres**.

Sexes are not separate (**hermaphrodite**), i.e., eggs and sperms are produced by the same individual.

Sponges reproduce **asexually** by fragmentation and **sexually** by formation of gametes.

Fertilisation is **internal** and development is **indirect** having a larval stage which is morphologically distinct from the adult.

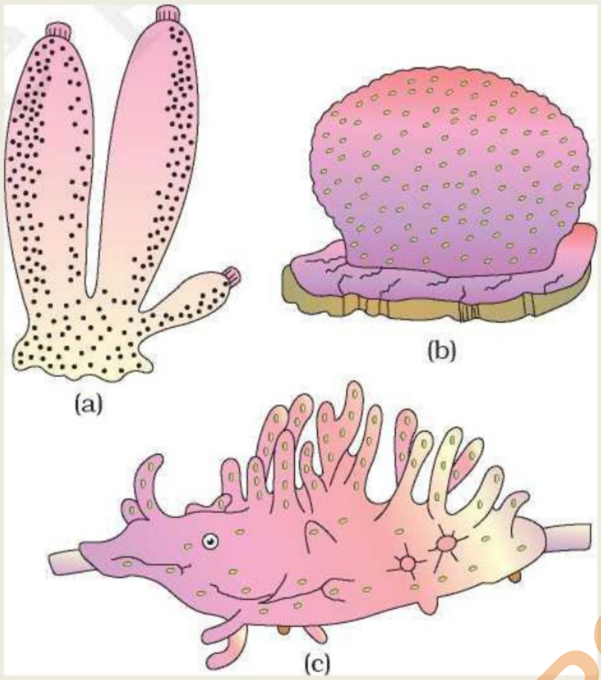


Figure: Examples of Porifera : (a) Sycon (b) Euspongia (c) Spongilla

Examples: Sycon (Scypha), **Spongilla (Fresh water sponge)** and **Euspongia (Bath sponge)**.

Phylum - Coelenterata (Cnidaria)

The name cnidaria is derived from the **cnidoblasts or cnidocytes** (which contain the **stinging capsules or nematocytes**) present on the tentacles and the body.

Cnidoblasts are used for anchorage, defense and for the capture of prey.

Coelenterata (Cnidaria) are aquatic, mostly marine **sessile** or **free-swimming radially symmetrical** animals.

They exhibit tissue level of organization [have more body design differentiation than sponges].

They have a central gastro-vascular cavity with a single opening.

They are **diploblastic**.

Some of these species live in **colonies (corals)**.

Some have a solitary [living alone] like–span (**hydra**).

Some of the cnidarians, e.g., corals have a skeleton composed of calcium carbonate.

Cnidarians exhibit two basic body forms called **polyp** and **medusa**. The former is a sessile and cylindrical form like Hydra, Adamsia (Sea anemone), etc. whereas, the latter is umbrella-shaped and free-swimming like Aurelia or jelly fish.

Those cnidarians which exist in both forms exhibit alternation of generation (Metagenesis), i.e., polyps produce medusae asexually and medusae form the polyps sexually (e.g., Obelia).

Jellyfish and **sea anemones** are common examples.

Digestion is extracellular and intracellular.

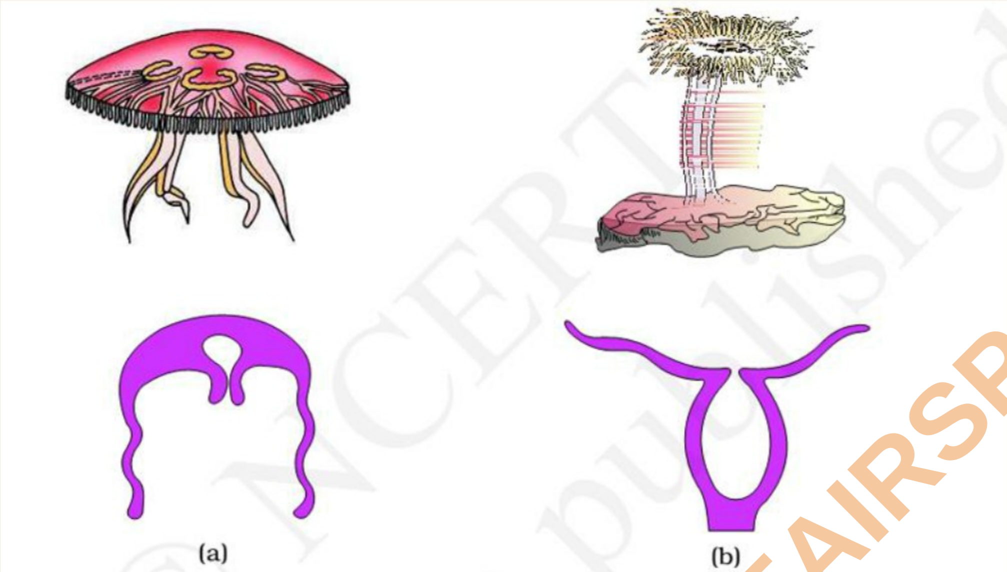


Figure 4.6 Examples of Coelenterata indicating outline of their body form : (a) *Aurelia* (Medusa) (b) *Adamsia* (Polyp)

Figure 4.7 Diagrammatic view of Cnidoblast

Examples: Aurelia (jelly fish), Physalia (Portuguese man-of-war), Adamsia (Sea anemone), Pennatula (Sea-pen), Gorgonia (Sea-fan) and Meandrina (Brain coral).

Phylum - Ctenophora

Ctenophora are commonly known as **sea walnuts or comb jellies**.

They exclusively marine, **radially symmetrical, diploblastic** animals.

They exhinit tissue level of organisation.

The body bears eight external rows of ciliated comb plates, which help in locomotion.

Figure 4.8 Example of Ctenophora (*Pleurobrachia*)

Digestion is both extracellular and intracellular.

Bioluminescence (the property of a living organism to emit light) is well-marked in ctenophores.

Sexes are not separate and reproduction takes place only by sexual means.

Fertilisation is **external** [fertilization occurs outside the body] with **indirect development** [zygote → larvae → animal].

Examples: **Pleurobrachia** and **Ctenoplana**.

Phylum - Platyhelminthes

Platyhelminthes are more complexly designed than the earlier groups.

They are **bilaterally symmetrical**.

They are **triploblastic**. This allows outside and inside body linings as well as some organs to be made. There is thus some degree of tissue formation [**organ level of organisation**].

The body is flattened dorsiventrally, meaning from top to bottom, which is why these animals are called **flatworms**.

They may be freeliving or **parasitic**. Hooks and suckers are present in the parasitic forms.

Some examples are freeliving animals like **planarians**, or parasitic animals like **liverflukes.**

Parisites are mostly **endoparasites** found in animals including human beings. Some of them absorb nutrients from the host directly through their body surface.

Acoelomate: There is no true internal body cavity or coelom, in which well developed organs can be accommodated.

Specialised cells called **flame cells** help in osmoregulation and excretion.

Sexes are not separate.

Fertilisation is **internal** and development is **indirect**.

Some members like Planaria possess high regeneration capacity.

Phylum – Aschelminthes (Nemotoda)

Body in aschelminthes (Nemotoda) is **cylindrical** [bilaterally symmetrical] rather than flattened.

They exhibit organ-system level of body organization [there are tissues, but no real organs].

They are **triploblastic**. A sort of body cavity or a **pseudocoelom**, is present.

They are freeliving, aquatic, terrestrial or parasitic in plants and animals.

These are very familiar as **parasitic worms** causing diseases, such as the worms causing **elephantiasis (filarial worms)** or the worms in the intestines (**roundworm or pinworms**).

The body is circular in cross-section, hence, the name **roundworms**.

Alimentary canal is complete.

An excretory tube removes body wastes from the body cavity through the excretory pore.

Sexes are separate (**dioecious**), i.e., males and females are distinct.

Often females are longer than males.

Fertilisation is internal and development may be direct (the young ones resemble the adult) or indirect.

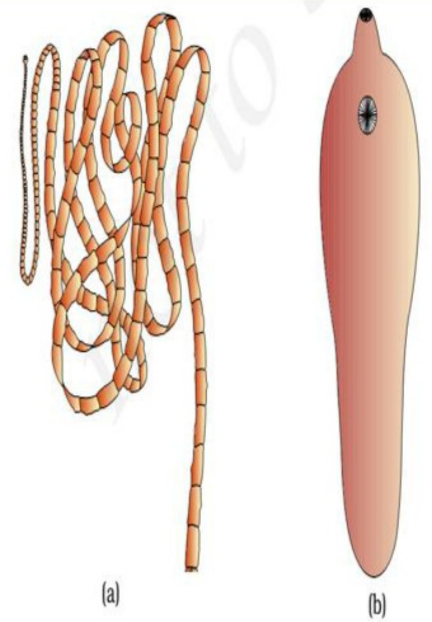


Figure 4.9 Examples of Platyhelminthes : (a) Tape worm (b) Liver fluke

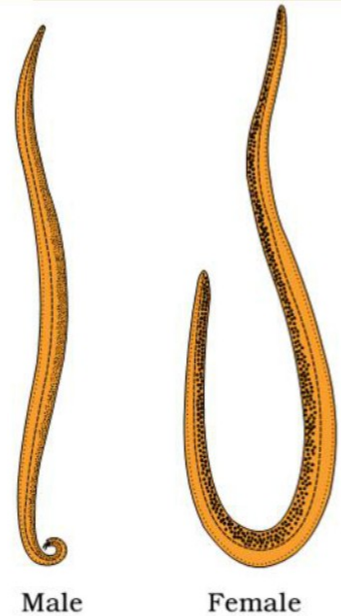


Figure 4.10 Aschelminthes – Roundworm

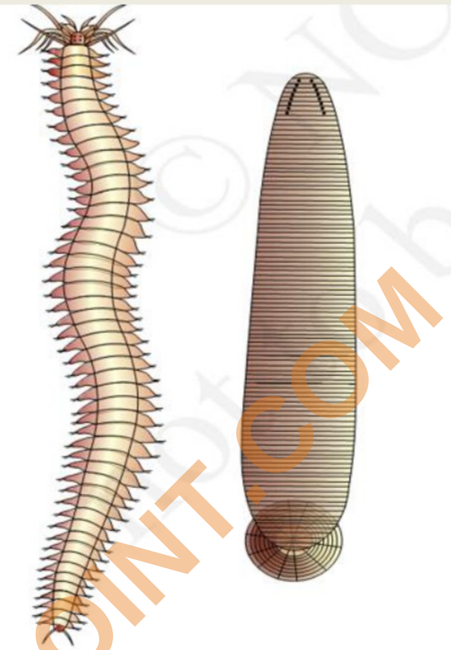


Figure 4.11 Examples of Annelida : (a) *Nereis* (b) *Hirudinaria*

Phylum - Annelida

Annelida are aquatic [marine and fresh water] or terrestrial; free-living, and sometimes parasitic.

Their body surface is distinctly marked out into segments or metameres **[metamerically segmented]** and, hence, the phylum name Annelida (Latin, annulus: little ring).

They exhibit **organ-system level** of body organization.

They are **coelomate** [true body cavity]. This allows true organs to be packaged in the body structure.

They are **bilateral symmetric** and **triploblastic**.

They possess longitudinal and circular muscles which help in locomotion.

Aquatic annelids like Nereis possess lateral appendages, **parapodia**, which help in swimming.

A closed circulatory system is present.

Nephridia (sing. nephridium) help in osmoregulation and excretion.

Neural system consists of paired **ganglia** (sing. ganglion) connected by lateral nerves to a double ventral nerve cord.

Nereis, an aquatic form, is dioecious [Sexes are separate], but **earthworms** and **leeches** are monoecious [having both the male and female reproductive organs in the same individual].

Reproduction is sexual.

Phylum - Arthropoda

Arthropoda is probably the **largest** group of animals. Over two-thirds of all named species on earth are arthropods.

They have **jointed legs** (the word 'arthropod' means 'jointed legs').

Some familiar examples are **prawns, butterflies, houseflies, spiders, scorpions and crabs** and some insects.

They exhibit **organ-system** level of organisation.

They are bilaterally symmetrical, triploblastic, segmented and **coelomate** animals. The coelomic cavity is blood-filled.

The body of arthropods is covered by **chitinous** exoskeleton. The body consists of head, thorax and abdomen.

There is an **open circulatory system**, and so the blood does not flow in well defined blood vessels.

Respiratory organs are gills, book gills, book lungs or tracheal system.

Sensory organs like antennae, eyes (compound and simple), **statocysts** or balance organs are present.

Excretion takes place through **malpighian tubules**.

They are mostly dioecious.

Fertilisation is usually internal.

They are mostly oviparous.

Development may be direct or indirect.

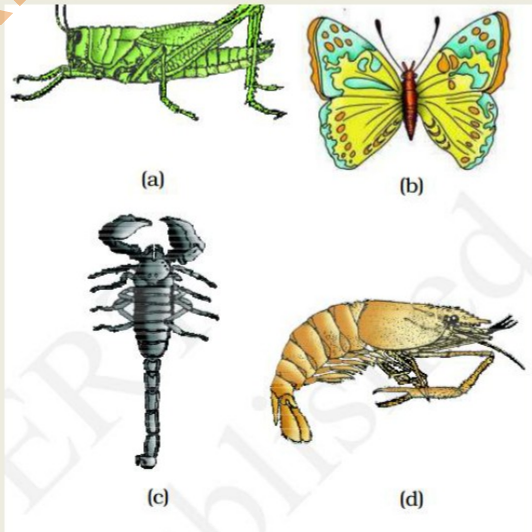


Figure 4.12 Examples of Arthropoda : (a) Locust (b) Butterfly (c) Scorpion (d) Prawn

Phylum - Mollusca

Mollusca are the second largest animal phylum. They are terrestrial or aquatic.

They exhibit **organ-system level of organization**.

They are **bilaterally symmetrical, triploblastic, coelomate animals**. There is little segmentation.

They have an open circulatory system and **kidney-like** organs for excretion. The anterior head region has sensory tentacles.

The mouth contains a file-like rasping organ for feeding, called **radula**.

They are usually dioecious and oviparous with indirect development.

Body is covered by a calcareous shell and is unsegmented with a distinct head, muscular foot and visceral hump. A soft and spongy layer of skin forms a mantle over the visceral hump.

Examples are **octopus**, **snails** and **mussels**.

Figure 4.13 Examples of Mollusca : (a) *Pila* (b) *Octopus*

Phylum - Echinodermata

These animals have an endoskeleton of calcareous ossicles [calcium carbonate structures] and, hence, the name Echinodermata (**spiny skinned organisms**).

They are exclusively free-living **marine animals** with **organ-system level** of organisation.

They are **triploblastic** with a **coelomic** cavity [coelomate animals]. The adult echinoderms are **radially symmetrical** but larvae are **bilaterally symmetrical**.

Water-driven tube system [water vascular system] are used for locomotion, capture and transport of food and respiration.

They are triploblastic and coelomate animals.

Digestive system is complete. An excretory system is absent.

Sexes are separate. Reproduction is sexual. Fertilisation is usually external.

Development is indirect with free-swimming larva.

Examples: Star fish, Sea urchin, Sea lily, Sea cucumber, Brittle star

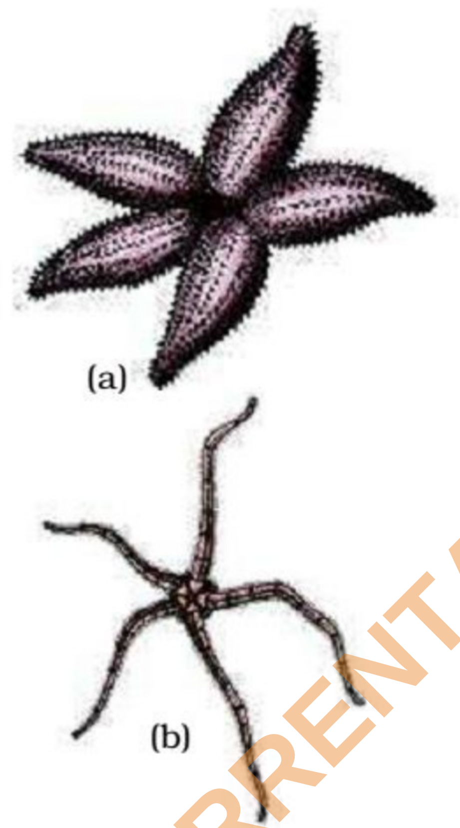


Figure 4.14 Examples of Echinodermata : (a) *Asterias* (b) *Ophiura*

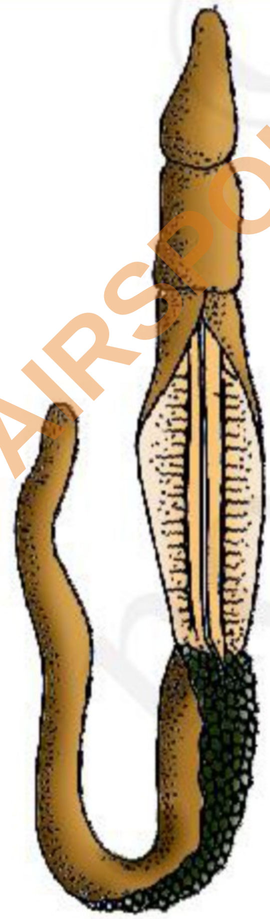


Figure 4.15 *Balanoglossus*

Phylum - Hemichordata

Hemichordata was earlier considered as a sub-phylum under phylum Chordata. But now it is placed as a separate phylum under **non-chordata**.

This phylum consists of a small group of **worm-like marine animals** with **organ-system level** of organisation.

They are cylindrical [bilaterally symmetrical], triploblastic, coelomate animals.

The body is Circulatory system is of open type.

Respiration takes place through gills.

Excretory organ is present.

Sexes are separate. Fertilisation is external. Development is indirect.

Examples: Balanoglossus and Saccoglossus.

Phylum - Chordata

Animals belonging to phylum Chordata are fundamentally characterised by the presence of a notochord, a dorsal hollow nerve cord and paired pharyngeal gill slits.

They are **bilaterally symmetrical, triploblastic, coelomate** with **organ-system level** of organisation.

They possess a post anal tail and a closed circulatory system.

Phylum Chordata is divided into three subphyla: Urochordata or Tunicata, Cephalochordata and Vertebrata.

Subphyla Urochordata and Cephalochordata are often referred to as protochordates and are exclusively **marine**.

In Urochordata, notochord is present only in **larval tail**, while in Cephalochordata, it extends from head to tail region and is persistent throughout their life.

Examples: Urochordata - Ascidia, Salpa, Doliolum; Cephalochordata - Amphioxus or Lancelet.

All chordates possess the following features:

have a notochord

have a dorsal nerve cord

are triploblastic

have paired gill pouches

are coelomate.

Figure 4.17 *Ascidia*

Table 4.1 Comparison of Chordates and Non-chordates

S.No.	Chordates	Non-chordates
1.	Notochord present.	Notochord absent.
2.	Central nervous system is dorsal, hollow and single.	Central nervous system is ventral, solid and double.
3.	Pharynx perforated by gill slits.	Gill slits are absent.
4.	Heart is ventral.	Heart is dorsal (if present).
5.	A post-anal part (tail) is present.	Post-anal tail is absent.

Vertebrata

These animals have a true vertebral column and internal skeleton, allowing a completely different distribution of muscle attachment points to be used for movement.

The members of subphylum Vertebrata possess notochord during the embryonic period.

The notochord is replaced by a cartilaginous or bony vertebral column in the adult.

Thus all vertebrates are chordates but all chordates are not vertebrates.

Besides the basic chordate characters, vertebrates have a ventral muscular heart with two, three or four chambers, kidneys for excretion and osmoregulation and paired appendages which may be fins or limbs.

Vertibrates are **bilaterally symmetrical, triploblastic, coelomic** and **segmented**, with complex differentiation of body tissues and organs.

S.No.	Chordates	Non-chordates
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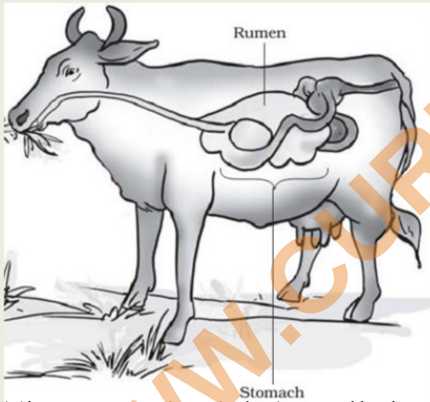
Nutrition in Animals

The breakdown of complex components of food into simpler substances is called digestion.

Amazing fact: Starfish feeds on animals covered by hard shells of calcium carbonate. After opening the shell, the starfish pops out its stomach through its mouth to eat the soft animal inside the shell. The stomach then goes back into the body and the food is slowly digested. (one of serious threats to coral reefs)

Digestion In Grass-Eating Animals

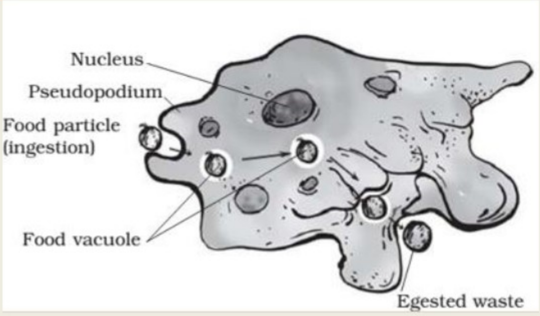


Have you observed cows, buffaloes and other grass-eating animals chewing continuously even when they are not eating grass? Actually, they quickly swallow the grass and store it in a separate part of the stomach called rumen here the food gets partially digested and is called cud. But later the cud returns to the mouth in small lumps and the animal chews it. This process is called rumination and these animals are called ruminants.

The grass is rich in cellulose, a type of carbohydrate. Many animals, including humans, cannot digest cellulose.

Ruminants have a large sac-like structure between the small intestine and large intestine (Fig. 2.9). The cellulose of the food is digested here by the action of certain bacteria) which are not present in humans.

Feeding And Digestion In Amoeba



Amoeba is a microscopic single-celled organism found in pond water. Amoeba has a cell membrane, a rounded, dense nucleus and many small bubble-like vacuoles (Fig. 2.10) in its cytoplasm.

Amoeba constantly changes its shape and position. It pushes out one, or more finger-like projections, called pseudopodia or false feet for movement and capture of food.

Amoeba feeds on some microscopic organisms. When it senses food, it pushes out pseudopodia around the food particle and engulfs it. The food becomes trapped in a food vacuole. Digestive juices are secreted into the food vacuole. They act on the food and break it down into simpler substances.

The undigested residue of the food is expelled outside by the vacuole.

Respiration in Organisms

The air we breathe in is transported to all parts of the body and ultimately to each cell. In the cells, oxygen in the air helps in the breakdown of food. The process of breakdown of food in the cell with the release of energy is called cellular respiration. Cellular respiration takes place in the cells of all organisms.

In the cell, the food (glucose) is broken down into carbon dioxide and water using oxygen. When breakdown of glucose occurs with the use of oxygen it is called aerobic respiration. Food can also be broken down, without using oxygen. This is called anaerobic respiration. Breakdown of food releases energy.

Glucose (With the use of oxygen) ➔ carbon dioxide + water + energy

You should know that there are some organisms such as yeast that can survive in the absence of air. They are called anaerobes. They get energy through anaerobic respiration. In the absence of oxygen, glucose breaks down into alcohol and carbon dioxide, as given below:

Glucose (Without the use of oxygen) ➔ alcohol + carbon dioxide + energy.

Yeasts are single-celled organisms. They respire anaerobically and during this process yield alcohol. They are, therefore, used to make wine and beer (fermentation).

Our muscle cells can also respire anaerobically, but only for a short time, when there is a temporary deficiency of oxygen. During heavy exercise, fast running, cycling, walking for many hours or heavy weight lifting, the demand for energy is high. But the supply of oxygen to produce the energy is limited. Then anaerobic respiration takes places in the muscle cells to fulfill the demand of energy

(In muscle) Glucose (in the absence of oxygen) $\rightarrow$ LACTIC ACID + energy.

Have you ever wondered why you get muscle cramps after heavy exercise? The cramps occur when muscle cells respire anaerobically. The partial breakdown of glucose produces lactic acid. The accumulation of lactic acid causes muscle cramps. We get relief from cramps after a hot water bath or a massage. Can you guess why it is so? Hot water bath or massage improves circulation of blood. As a result, the supply of oxygen to the muscle cells increases.

The increase in the supply of oxygen results in the complete breakdown of lactic acid into carbon dioxide and water.

Breathing

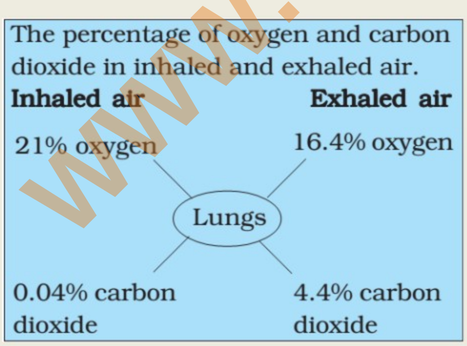
Breathing means taking in air rich in oxygen and giving out air rich in carbon dioxide with the help of respiratory organs. The taking in of air rich in oxygen into the body is called inhalation and giving out of air rich in carbon dioxide is known as exhalation.

On an average, an adult human being at rest breathes in and out 15–18 times in a minute. During heavy exercise, the breathing rate can increase upto 25 times per minute. While we exercise, not only do we breathe fast, we also take deep breaths and thus inhale more oxygen.

Lungs are present in the chest cavity. This cavity is surrounded by ribs on the sides. A large, muscular sheet called diaphragm forms the floor of the chest cavity.

Breathing involves the movement of the diaphragm and the rib cage.

The percentage of oxygen and carbon dioxide in inhaled and exhaled air:



Breathing in other animals

Cockroach: A cockroach has small openings on the sides of its body. Other insects also have similar openings. These openings are called spiracles. Insects have a network of air tubes called tracheae for gas exchange

Oxygen rich air rushes through spiracles into the tracheal tubes, diffuses into the body tissue, and reaches every cell of the body. Similarly, carbon dioxide from the cells goes into the tracheal tubes and moves out through spiracles. These air tubes or tracheae are found only in insects and not in any other group of animals.

In fish Gills are well supplied with blood vessels for exchange of gases.

Phylum - Chordata - Division In Vertebrata: Cyclostomata, Pisces, Chondrichthyes, Osteichthyes, Amphibia, Amphibia, Reptilia, Aves, Mammalia.

Source | Credits | Picture Credits: NCERT General Science

Phylum - Chordata

Animals belonging to phylum Chordata are fundamentally characterised by the presence of a **notochord**, a **dorsal hollow nerve cord** and **paired pharyngeal [**relating to the pharynx**] gill slits**.

They are **bilaterally symmetrical, triploblastic, coelomate** with **organ-system level** of organisation.

Phylum Chordata is divided into three subphyla: **Urochordata** or Tunicata, **Cephalochordata** and **Vertebrata**.

Subphyla Urochordata and Cephalochordata are often referred to as protochordates and are exclusively **marine**.

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Comparison of Chordates and Non-chordates

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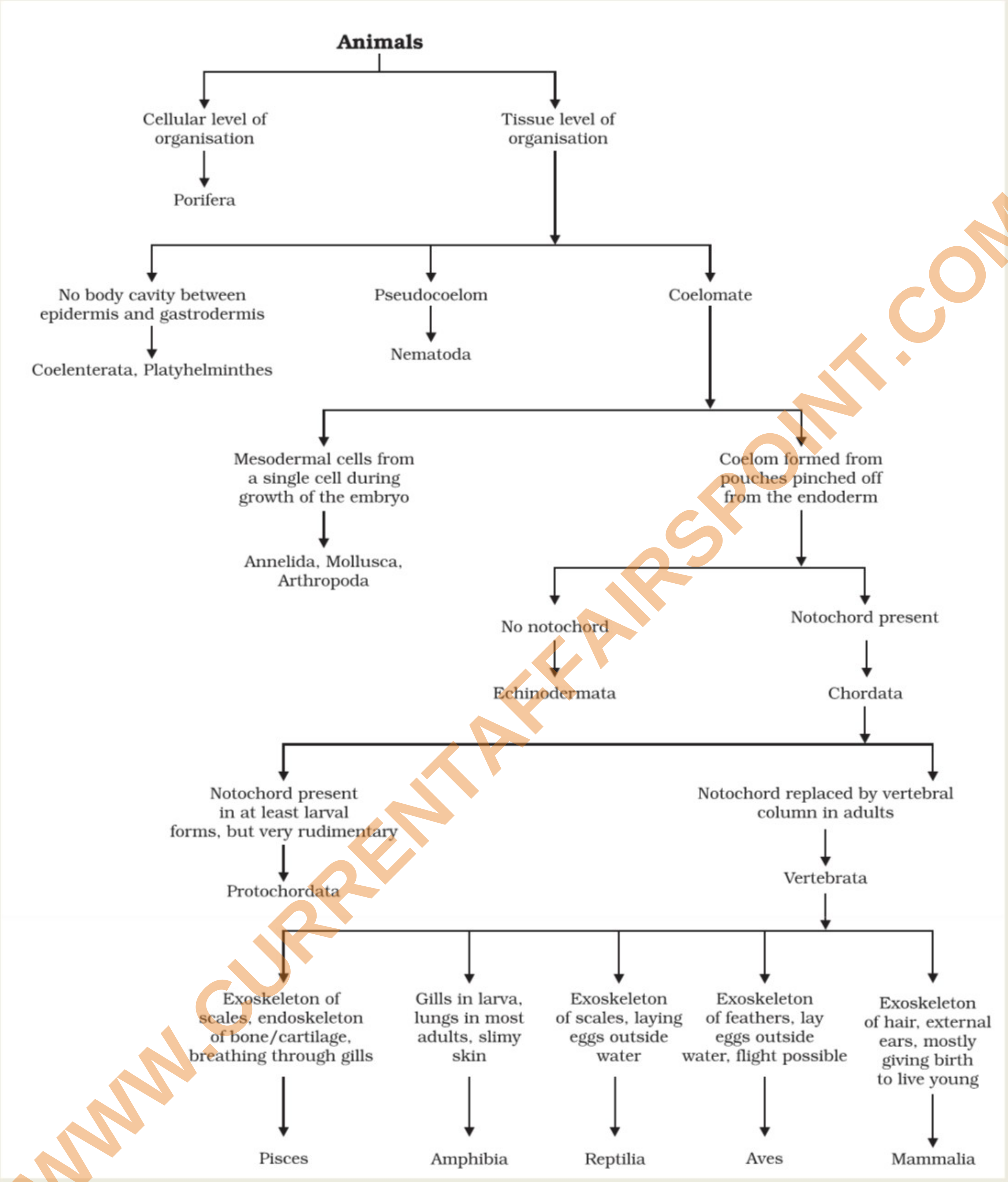
The members of subphylum Vertebrata possess **notochord** during the **embryonic period**.

The notochord is replaced by a **cartilaginous or bony vertebral column** in the adult.

Thus all vertebrates are chordates but all chordates are not vertebrates.

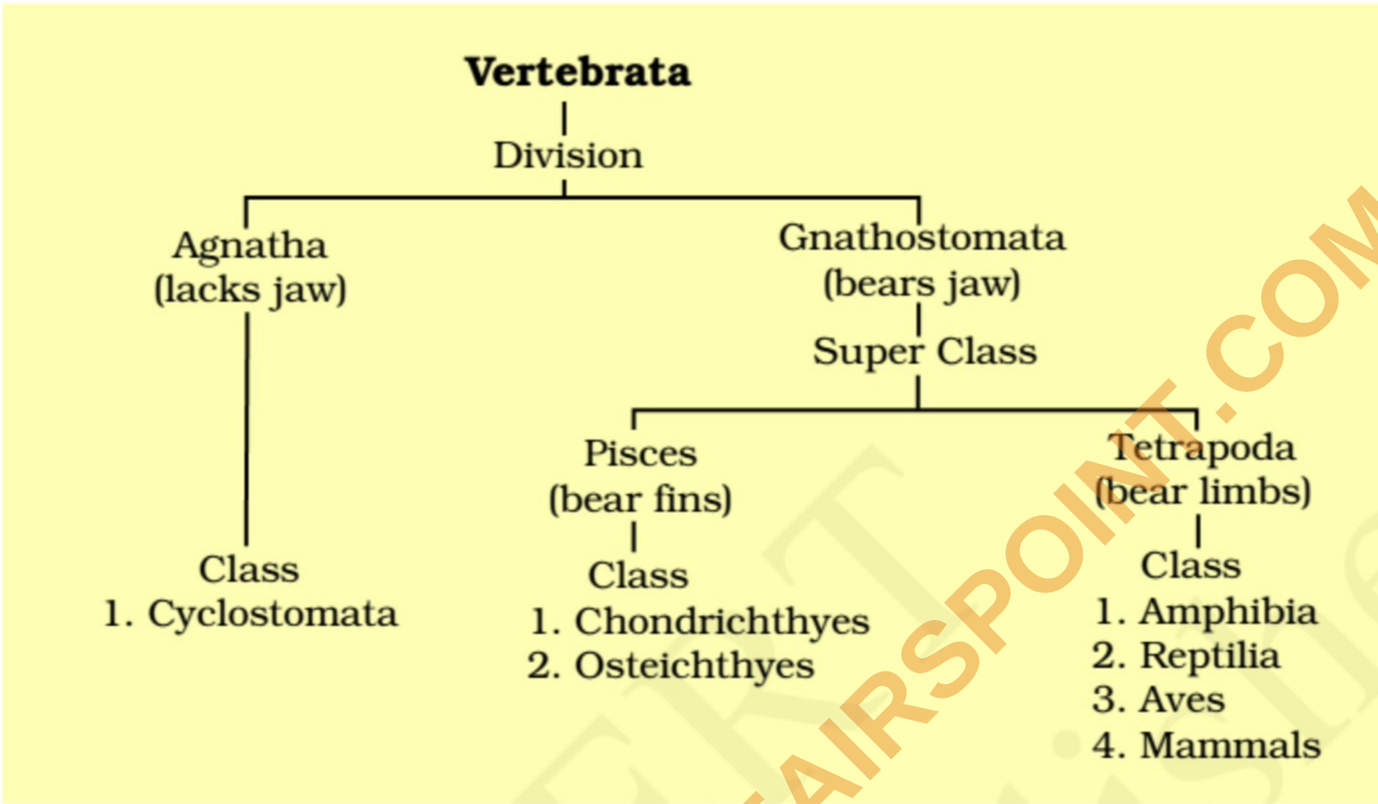
Besides the basic chordate characters, vertebrates have a ventral muscular heart with two, three or four chambers, kidneys for excretion and osmoregulation and paired appendages which may be fins or limbs.

Vertibrates are **bilaterally symmetrical, triploblastic, coelomic** and **segmented**, with complex differentiation of body tissues and organs.



Division In Vertebrata

The subphylum Vertebrata is further divided as follows:



Basic Concepts

Viviparous and Oviparous Animals

We have learnt that some animals give birth to young ones while some animals lay eggs which later develop into young ones.

The animals which give birth to young ones are called **viviparous animals**.

Those animals which lay eggs are called **oviparous animals**.

In some animals, the young ones may look very different from the adults. Recall the life cycle of the silkworm (egg → larva or caterpillar → pupa → adult) (egg → tadpole (larva) → adult). The transformation of the larva into an adult through drastic changes is called **metamorphosis.**

Warm Blooded vs. Cold Blooded Animals

Warm Blooded or Endotherms or Homoiothermous animals	Cold Blooded or Ectotherms or Poikilothermous Animals
All mammals and birds with few exceptions are warm blooded. [Bats, Echidnas, Mole Rats etc. cannot regulate their body temperature]	All reptiles, insects, arachnids, amphibians and fish are cold blooded.

They maintain a constant internal body temperature irrespective of external environment. [Can regulate their body temperature by generating their own heat when they are in a cooler environment, and by cooling themselves when they are in a hotter environment]	Their body temperature changes according to the external environment. [If a cold blooded animal is taken to the equator its body temperature increases and if taken to the poles its body temperature decreases]
They can survive in a wide of environments as they are able to regulate their body temperature.	They cannot survive in a wide of environments. [Tropical animals cannot survive in the polar region and vice versa]
They require a lot of food for their survival. Most of the food consumed is utilized to maintain a constant body temperature.	Most of the food consumed is converted into body mass. So they need less food compared to warm blooded animals.
They are active in both warm and cold environments.	They are active in warm environments and are very sluggish in cold environments.
To stay cool, warm-blooded animals usually sweat. Animals like elephants use their ears to cool their body [large, thin ears which loose heat quickly]. Some warm-blooded animals, especially birds, migrate from colder to warmer regions in the winter. Mammals have hair, fur and birds have feathers to help keep them warm. Warm-blooded animals can also shiver to generate more heat when they get too cold.	Cold-blooded animals often like to bask in the sun to warm up and increase their metabolism. Some cold-blooded animals, such as bees or dragonflies, shiver to stay warm when in a cold environment.
Constant body temperature provide a nice warm environment for viruses, bacteria and parasites to live in.	Constantly changing body temperatures make life more difficult for the parasites.

Hibernation

Hibernation is a state of inactivity and metabolic depression in few endotherms [warm blooded animals – bear, rodents] and ectotherms [many reptiles like snakes, turtles and amphibians like frogs]. Snakes, lizards, toads, frogs, salamanders and most turtles will mostly hibernate during harsh winters.

Hibernating animals usually retreat to a den, a burrow, or a hollow log for protection and shelter.

During "true hibernation," the animal's body temperature drops, and its rate of breathing slows down. These hibernating animals are very difficult to awaken.

Some warm-blooded animals such as bears, rodents etc. hibernate during extreme weather seasons and unfavorable conditions.

During hibernation these animals live off of stored body fat and can drop their body temperatures significantly.

Most animals will eat large amounts of food before hibernating.

Class - Cyclostomata

All living members of the class Cyclostomata are **ectoparasites** [ives on the outside of its host] on some fishes.

They have an elongated body bearing 6-15 pairs of gill slits for respiration.

Cyclostomes have a sucking and circular mouth **without jaws**.

Their body is devoid of scales and paired fins.

Cranium and vertebral column are **cartilaginous**.

Circulation is of closed type.

Cyclostomes are marine but migrate for spawning [release or deposit eggs] to fresh water.

After spawning, within a few days, they die. Their larvae, after **metamorphosis** **[**transformation from an immature form to an adult form in two or more distinct stages. Example: Larvae → Tadpole → Frog**]**, return to the ocean.

Examples: Petromyzon (Lamprey) and Myxine (Hagfish).

Figure 4.18 A jawless vertebrate - *Petromyzon*

Class - Pisces

These are fish. Their skin is covered with **scales**/plates. They lay eggs [oviporous].

They obtain oxygen dissolved in water by using gills.

The body is streamlined, and a muscular tail is used for movement.

They are **cold-blooded** and their hearts have only **two chambers**, unlike the four that humans have.

Some fish skeletons are made entirely of cartilage [Chondrichthyes], such as sharks, and some with a skeleton made of both bone and cartilage [Osteichthyes].

Chondrichthyes

They are marine animals with streamlined body and have **cartilaginous endoskeleton**. Mouth is located **ventrally**.

Notochord is persistent throughout life.

Gill slits are separate and without operculum (gill cover).

The skin is tough, containing minute placoid scales.

Teeth are modified placoid scales which are backwardly directed.

Their **jaws** are very powerful.

These animals are **predaceous** [shark].

Due to the **absence of air bladder**, they have to **swim constantly** to avoid sinking.

Heart is two-chambered (one auricle and one ventricle).

Some of them have electric organs (e.g., Torpedo) and some possess poison sting (e.g., Trygon).

They are **cold-blooded (poikilothermous)** animals, i.e., they lack the capacity to regulate their body temperature.

Sexes are separate. In males pelvic fins bear claspers.

They have internal fertilisation and many of them are **viviparous** [give birth to young ones].

Examples: Scoliodon (Dog fish), Pristis (Saw fish), Carchaiodon (Great white shark), Trygon (Sting ray).

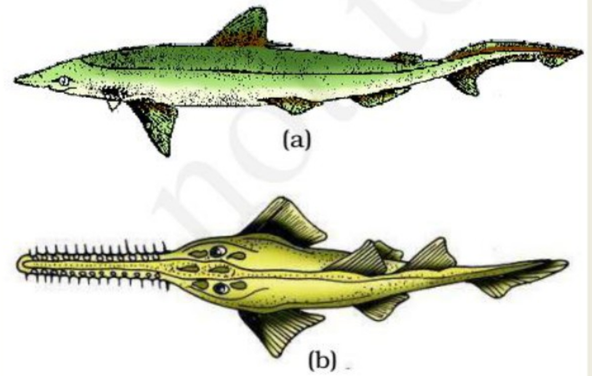


Figure 4.19 Example of Cartilaginous fishes : (a) *Scoliodon* (b) *Pristis*

Osteichthyes

It includes both marine and fresh water fishes with **bony endoskeleton**.

Their body is streamlined. Mouth is mostly **terminal**.

They have four pairs of gills which are covered by an operculum on each side.

Skin is covered with cycloid/ctenoid scales.

Air bladder is present which regulates buoyancy.

Heart is **two- chambered** (one auricle and one ventricle).

They are **cold-blooded** animals.

Sexes are separate.

Fertilisation is usually external.

They are mostly **oviparous** and development is direct.

Examples: Flying fish, Sea horse, Fighting fish, Angel fish etc.

Figure 4.20 Examples of Bony fishes : (a) *Hippocampus* (b) *Catla*

Class - Amphibia

As the name indicates (Gr., Amphi : dual, bios, life), amphibians can live in aquatic as well as terrestrial habitats.

The amphibian skin is moist without scales [mucus glands in the skin]. The eyes have eyelids. A tympanum represents the ear.

Alimentary canal, urinary and reproductive tracts open into a common chamber called **cloaca** which opens to the exterior.

They have a **three-chambered heart** (two auricles and one ventricle). These are **cold-blooded** animals.

Respiration is through **gills, lungs** and through **skin.**

Respiration is by gills, lungs and through skin.

Sexes are separate. Fertilisation is external.

They are oviparous and development is indirect.

Examples: Toad, Frog), Tree frog, Salamander, Limbless amphibia.

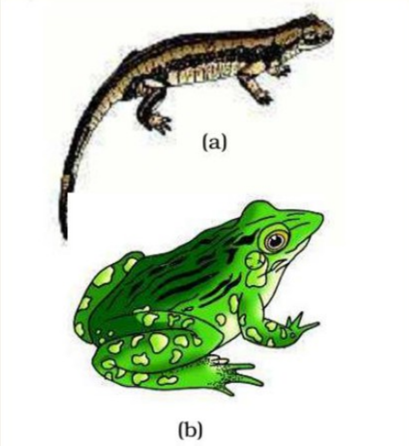


Figure 4.21 Examples of Amphibia :
(a) *Salamandra*
(b) *Rana*

Class - Reptilia

The class name refers to their **creeping or crawling** mode of locomotion (Latin, repere or reptum, to creep or crawl).

They are mostly terrestrial animals and their body is covered by dry and cornified skin, epidermal scales or **scutes**. Snakes and lizards shed their scales as skin cast.

They do not have external ear openings. Tympanum represents ear. Limbs, when present, are two pairs.

Heart is usually **three-chambered**, but **four-chambered in crocodiles**.

Reptiles are **poikilotherms [cold-blooded animals]**.

They lay eggs with tough coverings and do not need to lay their eggs in water, unlike amphibians.

Sexes are separate.

Fertilisation is internal.

They are oviparous and development is direct.

Examples: Turtle), Tortoise, Chameleon (Tree lizard), Garden lizard, Crocodile, Alligator, Wall lizard, Poisonous snakes - Naja (Cobra), Bangarus (Krait), Vipera (Viper).

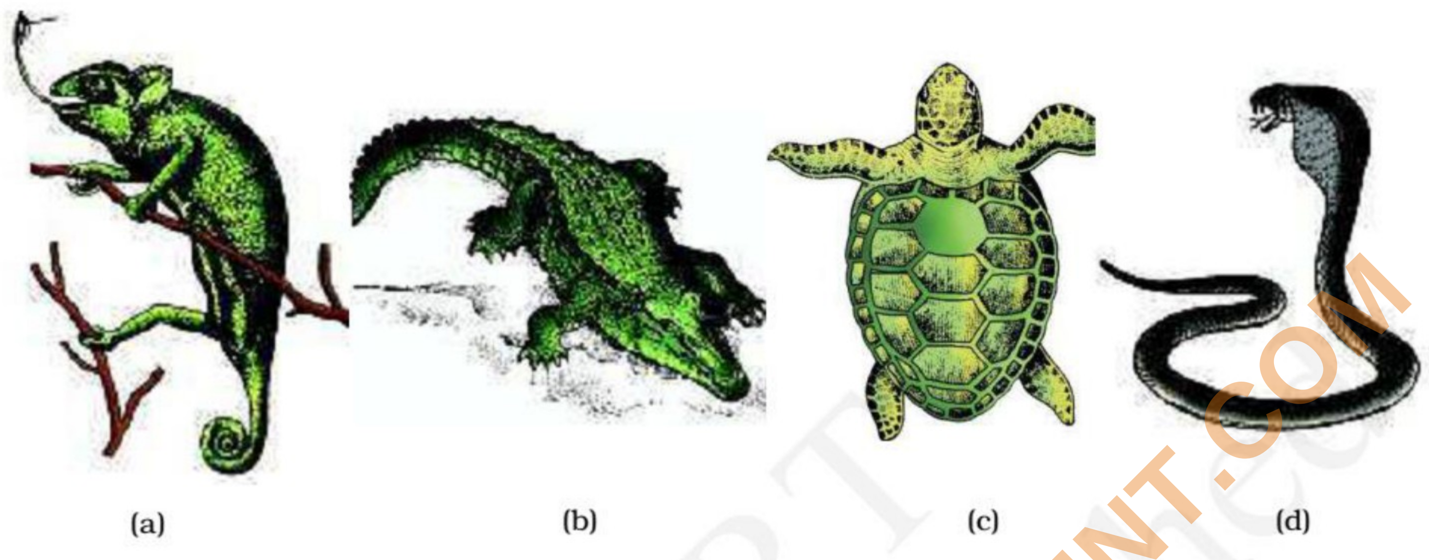


Figure 4.22 Reptiles: (a) *Chameleon* (b) *Crocodilus* (c) *Chelone* (d) *Naja*

Class - Aves

They have a **four-chambered heart**. They breathe through lungs. All birds fall in this category.

The characteristic features of Aves (birds) are the presence of feathers and most of them can fly except flightless birds (e.g., Ostrich). The forelimbs are modified into wings.

The hind limbs generally have scales and are modified for walking, swimming or clasping the tree branches.

Skin is dry without glands except the oil gland at the base of the tail.

Endoskeleton is fully ossified (bony) and the long bones are hollow with air cavities (**pneumatic**).

The digestive tract of birds has additional chambers, the **crop** and **gizzard**.

They are **warm-blooded (homoiothermous)** animals, i.e., they are able to maintain a constant body temperature.

Respiration is by lungs. Air sacs connected to lungs supplement respiration.

Sexes are separate. Fertilisation is internal. They are oviparous and development is direct.

Examples : Crow, Pigeon, Ostrich), Neophron (Vulture) etc..

Class - Mammalia

Mammals are **warm-blooded** animals with **four-chambered hearts**.

Most mammals familiar to us produce **live young ones**. However, a few of them, like the **Platypus** and the **Echidna** lay eggs, and some, like kangaroos give birth to very poorly developed young ones.

They are found in a variety of habitats - polar ice caps, deserts, mountains, forests, grasslands and dark caves. Some of them have adapted to fly or live in water.

The most unique mammalian characteristic is the presence of milk producing glands **(mammary glands)** by which the young ones are nourished.

They have two pairs of limbs, adapted for walking, running, climbing, burrowing, swimming or flying.

The skin of mammals is unique in possessing hair. External **ears or pinnae** are present. Different types of teeth are present in the jaw.

Heart is **four-chambered**. They are **homoiothermous** [warm-blooded]. Respiration is by lungs.

Sexes are separate and fertilisation is internal.

They are viviparous with few exceptions and development is direct.

Examples: Oviparous – Platypus; Viviparous – Kangaroo, Flying fox), Delphinus (Common dolphin), Balaenoptera (Blue whale), etc.

Animal Classification Summary

Porifera includes multicellular animals which exhibit cellular level of organisation and have characteristic flagellated choanocytes.

The coelenterates have tentacles and bear cnidoblasts. They are mostly aquatic, sessile or free-floating. The ctenophores are marine animals with comb plates.

The platyhelminths have flat body and exhibit bilateral symmetry. The parasitic forms show distinct suckers and hooks.

Aschelminthes are pseudocoelomates and include parasitic as well as non-parasitic round worms.

Annelids are metamerically segmented animals with a true coelom.

The arthropods are the most abundant group of animals characterised by the presence of jointed appendages.

The molluscs have a soft body surrounded by an external calcareous shell. The body is covered with external skeleton made of chitin.

The echinoderms possess a spiny skin. Their most distinctive feature is the presence of water vascular system.

The hemichordates are a small group of worm-like marine animals. They have a cylindrical body with proboscis, collar and trunk.

Phylum Chordata includes animals which possess a notochord either throughout or during early embryonic life. Other common features observed in the chordates are the dorsal, hollow nerve cord and paired pharyngeal gill slits.

Some of the vertebrates do not possess jaws (Agnatha) whereas most of them possess jaws (Gnathostomata). Agnatha is represented by the class, Cyclostomata. They are the most primitive chordates and are ectoparasites on fishes. Gnathostomata has two super classes, Pisces and Tetrapoda.

Classes Chondrichthyes and Osteichthyes bear fins for locomotion and are grouped under Pisces. The Chondrichthyes are fishes with cartilaginous endoskeleton and are marine.

Classes, Amphibia, Reptilia, Aves and Mammalia have two pairs of limbs and are thus grouped under Tetrapoda. The amphibians have adapted to live both on land and water.

Reptiles are characterised by the presence of dry and cornified skin. Limbs are absent in snakes. Fishes, amphibians and reptiles are poikilothermous (coldblooded).

Aves are warm-blooded animals with feathers on their bodies and forelimbs modified into wings for flying. Hind limbs are adapted for walking, swimming, perching or clasping.

The unique features of mammals are the presence of mammary glands and hairs on the skin. They commonly exhibit viviparity.

Match the following	
1. Operculum	a) Ctenophora
2. Parapodia	b) Mollusca
3. Scales	c) Porifera
4. Comb plates	d) Reptilia
5. Radula	e) Annelida
6. Hairs	f) Cyclostomata and Chondrichthyes
7. Choanocytes	g) Mammalia
8. Gill slits	h) Osteichthyes

Salient Features of Different Phyla in the Animal Kingdom

Phylum	**Level of Organi-sation**	**Symmetry**	**Coelom**	**Segmention**	**Digestive System**	**Circu-latory System**	**Respi-ratory System**	**Distinctive Features**
Porifera	Cellular	Various	Absent	Absent	Absent	Absent	Absent	Body with pores and canals in walls.
Coelenterata (Cnidaria)	Tissue	Radial	Absent	Absent	Incomplete	Absent	Absent	Cnidoblasts present.
Ctenophora	Tissue	Radial	Absent	Absent	Incomplete	Absent	Absent	Comb plates for locomotion.
Platyhelm-inthes	Organ & Organ - system	Bilateral	Absent	Absent	Incomplete	Absent	Absent	Flat body, suckers.
Aschelmin-thes	Organ - system	Bilateral	Pseudo-coelomate	Absent	Complete	Absent	Absent	Often wormshaped, elongated.
Annelida	Organ - system	Bilateral	Coelomate	Present	Complete	Present	Absent	Body segmentation like rings.
Arthropoda	Organ - system	Bilateral	Coelomate	Present	Complete	Present	Present	Exoskeleton of cuticle, jointed ap-pendages.
Mollusca	Organ - system	Bilateral	Coelomate	Absent	Complete	Present	Present	External skeleton of shell usually present.
Echino-dermata	Organ-system	Radial	Coelomate	Absent	Complete	Present	Present	Water vascular system, radial symmetry.
Hemi-chordata	Organ-system	Bilateral	Coelomate	Absent	Complete	Present	Present	Worm-like with proboscis, collar and trunk.
Chordata	Organ-system	Bilateral	Coelomate	Present	Complete	Present	Present	Notochord, dorsal hollow nerve cord, gill slits with limbs or fins.

TABLE 4.2 Salient Features of Different Phyla in the Animal Kingdom

Phylum	Level of Organisation	Symmetry	Coelom	Segmentation	Digestive System	Circulatory System	Respiratory System	Distinctive Features
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Chordata	Organ-system	Bilateral	Coelomate	Present	Complete	Present	Present	Notochord, dorsal hollow nerve cord, gill slits with limbs or fins.

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Biotechnology, Genetic Engineering, Cloning, Recombinant DNA, Cloning Vectors, Competent Host, Biotechnology And Its Applications in Medicine & Agriculture.

Biotechnology

Biotechnology deals with techniques of using live organisms or enzymes from organisms to produce products and processes useful to humans.

Making curd, bread or wine, which are all microbe-mediated processes, could also be thought as a form of biotechnology.

However, it is used in a restricted sense today, to refer to such of those processes which use **genetically modified organisms** to achieve the same on a larger scale.

Modern biotechnology using genetically modified organisms was made possible only when man learnt to alter the chemistry of DNA and construct recombinant DNA. This key process is called **recombinant DNA technology** or **genetic engineering**.

This process involves the use of **restriction endonucleases, DNA ligase, appropriate plasmid or viral vectors** to isolate and ferry the foreign DNA into host organisms, expression of the foreign gene, purification of the gene product, i.e., the functional protein and finally making a suitable formulation for marketing. Large scale production involves use of bioreactors.

Genetic Engineering

Genetic engineering involves the techniques to alter the chemistry of genetic material (DNA and RNA) and thus **change the phenotype** of the host organism.

Asexual reproduction preserves the genetic information, while sexual reproduction permits variation.

Traditional hybridisation procedures used in plant and animal breeding, very often lead to inclusion and multiplication of undesirable genes along with the desired genes.

The techniques of genetic engineering which include **creation of recombinant DNA,** use of **gene cloning** and **gene transfer**, overcome this limitation and allows us to isolate and introduce only one or a set of desirable genes without introducing undesirable genes into the target organism.

There are three basic steps in genetically modifying an organism — 1. identification of DNA with desirable genes;

introduction of the identified DNA into the host;

maintenance of introduced DNA in the host and transfer of the DNA to its progeny.

Cloning

DNA which is somehow transferred into an alien organism would not be able to multiply itself in the progeny cells of the organism.

But, when it gets integrated into the genome of the recipient, it may multiply and be inherited along with the host DNA. This is because the alien piece of DNA has become part of a chromosome, which has the ability to replicate.

In a chromosome there is a specific DNA sequence called the **origin of replication**, which is responsible for initiating replication.

Therefore, for the multiplication of any alien piece of DNA in an organism it needs to be a part of a chromosome(s) which has a specific sequence known as 'origin of replication'.

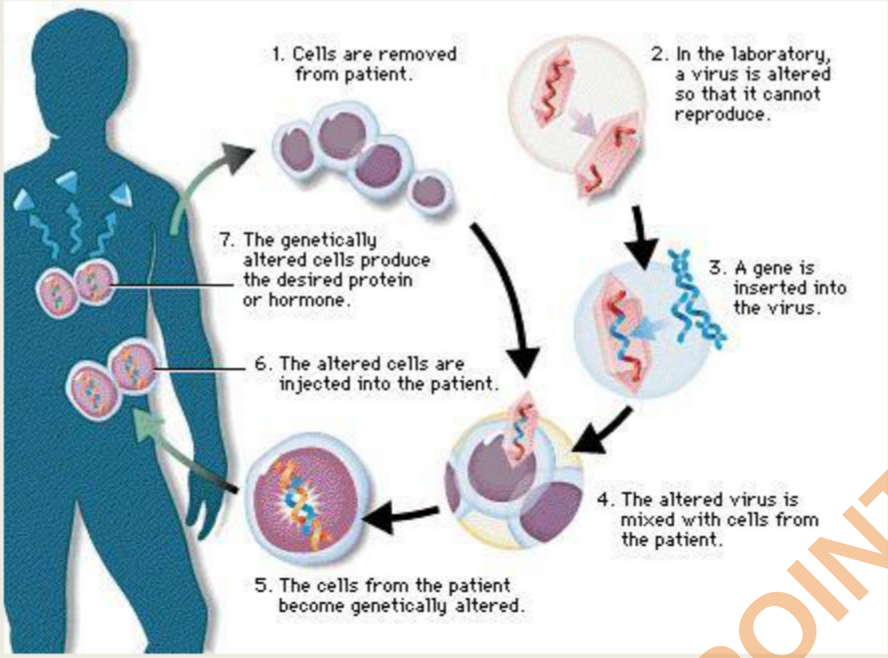
Thus, an alien DNA is linked with the origin of replication, so that, this alien piece of DNA can replicate and multiply itself in the host organism. This can also be called as **cloning or making multiple identical copies of any template DNA**.

Recombinant DNA (rDNA)

Recombinant DNA (rDNA) molecules are DNA molecules formed by laboratory methods of genetic recombination (such as molecular cloning) to bring together genetic material from **multiple** sources, creating sequences that would not otherwise be found in the genome.

Recombinant DNA is possible because DNA molecules from all organisms share the **same** chemical structure. They **differ** only in the **nucleotide sequence** within that identical overall structure.

In most cases, organisms containing recombinant DNA have apparently normal phenotypes. That is, their appearance, behavior and metabolism are usually unchanged.



The cutting of DNA at specific locations became possible with the discovery of the so-called **‘molecular scissors’- restriction enzymes**.

Restriction enzymes belong to a larger class of enzymes called **nucleases**. These are of two kinds; exonucleases and endonucleases.

Exonucleases remove nucleotides from the ends of the DNA whereas, endonucleases make cuts at specific positions within the DNA.

The cut piece of DNA was then linked with the plasmid DNA. These plasmid DNA act as vectors to transfer the piece of DNA attached to it.

You probably know that mosquito acts as an insect vector to transfer the malarial parasite Into human body.

In the same way, a plasmid can be used as vector to deliver an alien piece of DNA into the host organism.

The linking of antibiotic resistance gene with the plasmid vector became possible with the enzyme **DNA ligase**, which acts on cut DNA molecules and joins their ends. This makes a new combination of circular autonomously replicating DNA created in vitro and is known as **recombinant DNA**.

When this DNA is transferred into Escherichia coli, a bacterium closely related to Salmonella, it could replicate using the new host’s DNA polymerase enzyme and make multiple copies. The ability to multiply copies of antibiotic resistance gene in E. coli was called cloning of antibiotic resistance gene in E. coli.

Applications of Recombinant DNA Technology

Recombinant DNA is widely used in biotechnology, medicine and research.

Recombinant DNA is used to identify, map and sequence genes, and to determine their function.

Recombinant DNA is used to produce

Recombinant human insulin,

Recombinant human growth hormone,

Recombinant blood clotting factor VIII,

Recombinant hepatitis B vaccine,

Insect-resistant crops etc.

Cloning Vectors

You may be surprised to know that we have learnt the lesson of transferring genes into plants and animals from bacteria and viruses which have known this for ages - how to deliver genes to transform eukaryotic cells and force them to do what the bacteria or viruses want.

For example, Agrobacterioum tumifaciens, a pathogen of several dicot plants is able to deliver a piece of DNA known as 'T-DNA' to transform normal plant cells into a tumor and direct these tumor cells to produce the chemicals required by the pathogen.

Similarly, retroviruses in animals have the ability to transform normal cells into cancerous cells.

A better understanding of the art of delivering genes by pathogens in their eukaryotic hosts has generated knowledge to transform these tools of pathogens into useful vectors for delivering genes of interest to humans.

The tumor inducing (Ti) plasmid of AgrobcLCterium tumifaciens has now been modified into a cloning vector which is no more pathogenic to the plants but is still able to use the mechanisms to deliver genes of our interest into a variety of plants.

Similarly, retroviruses have also been disarmed and are now used to deliver desirable genes into animal cells.

So, once a gene or a DNA fragment has been ligated into a suitable vector it is transferred into a bacterial, plant or animal host (where it multiplies).

Plasmids and bacteriophages [vectors] have the ability to replicate within bacterial cells independent of the control of chromosomal DNA.

Competent Host – Methods to Induce Alien DNA into Host Cells

Since DNA is a **hydrophilic molecule**, **it cannot pass through cell membranes**. In order to force bacteria to take up the plasmid, the bacterial cells must first be made 'competent' to take up DNA. Recombinant DNA can then be forced into such cells by incubating the cells with recombinant DNA on ice, followed by placing them briefly at 42$_0$C (heat shock), and then putting them back on ice. This enables the bacteria to take up the recombinant DNA. This is not the only way to introduce alien DNA into host cells.

In a method known as micro-injection, recombinant DNA is directly injected into the nucleus of an animal cell.

In another method, suitable for plants, cells are bombarded with high velocity micro-particles of gold or tungsten coated with DNA in a method known as **biolistics or gene gun**.

And the last method uses 'disarmed pathogen' vectors, which when allowed to infect the cell, transfer the recombinant DNA into the host.

Biotechnology And Its Applications

Biotechnology essentially deals with industrial scale production of biopharmaceuticals and biologicals using genetically modified microbes, fungi, plants and animals.

The applications of biotechnology include therapeutics, diagnostics, genetically modified crops for agriculture, processed food, bioremediation, waste treatment, and energy production.

Cloning

Cloning is the production of an exact copy of a cell, any other living part, or a complete organism.

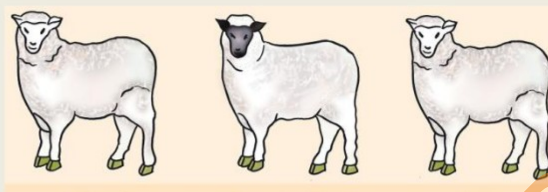
Cloning of an animal was successfully performed for the first time by Ian Wilmut and his colleagues at the Roslin Institute in Edinburgh, Scotland.

They cloned successfully a sheep named Dolly. Dolly was born in 1996 and was the first mammal to be cloned.

During the process of cloning Dolly, a cell was collected from the mammary gland of a female Finn Dorsett sheep. Simultaneously, an egg was obtained from a Scottish blackface ewe. The nucleus was removed from the egg. Then, the nucleus of the mammary gland cell from the Finn Dorsett sheep was inserted into the egg of the

Scottish blackface ewe whose nucleus had been removed. The egg thus produced was implanted into the Scottish blackface ewe. Development of this egg followed normally and finally Dolly was born. Though Dolly was given birth by the Scottish blackface ewe, it was found to be absolutely identical to the Finn Dorsett sheep from which the nucleus was taken. Since the nucleus from the egg of the Scottish blackface ewe was removed, Dolly did not show any character of the Scottish blackface ewe.

Dolly was a healthy clone of the Finn Dorsett sheep and produced several offspring of her own through normal sexual means.



(a) Finn Dorsett sheep (b) Scottish blackface ewe (c) Dolly

Since Dolly, several attempts have been made to produce cloned mammals. However, many die before birth or die soon after birth. The cloned animals are many-a-time found to be born with severe abnormalities.

Biotechnological applications in agriculture

Let us take a look at the three options that can be thought for increasing food production

agro-chemical based agriculture;

organic agriculture; and

genetically engineered crop-based agriculture.

Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called Genetically Modified Organisms (GMO). GM plants have been useful in many ways. Genetic modification has:

made crops more tolerant to abiotic stresses (cold, drought, salt, heat).

reduced reliance on chemical pesticides (pest-resistant crops).

helped to reduce post harvest losses.

increased efficiency of mineral usage by plants (this prevents early exhaustion of fertility of soil).

enhanced nutritional value of food, e.g., Vitamin 'A' enriched rice.

In addition to these uses, GM has been used to create tailor-made plants to supply alternative resources to industries, in the form of starches, fuels and pharmaceuticals.

Bt toxin is produced by a bacterium called **Bacillus thuringiensis** (Bt for short).

Some strains of Bacillus thuringiensis produce proteins that kill certain insects such as tobacco budworm, armyworm, beetles and dipterans flies, mosquitoes.

Why does this toxin not kill the Bacillus? Actually, the Bt toxin protein exist as inactive protoxins but once an insect ingest the inactive toxin, it is converted into an active form of toxin due to the alkaline pH of the gut which solubilise the crystals.

Bt toxin gene has been cloned from the bacteria and been expressed in plants to provide resistance to insects without the need for insecticides; in effect created a bio-pesticide.

Examples are Bt cotton, Bt corn, rice, tomato, potato and soyabean etc.

Biotechnological applications in medicine

The recombinant DNA technological processes have made immense impact in the area of healthcare by enabling **mass production of safe and more effective therapeutic drugs**.

Further, the recombinant therapeutics **do not induce unwanted immunological responses** as is common in case of similar products isolated from non-human sources.

At present, about 30 recombinant therapeutics have been approved for human-use the world over. In India, 12 of these are presently being marketed.

Genetically Engineered Insulin

Management of adult-onset diabetes is possible by taking insulin at regular time intervals. What would a diabetic patient do if enough human-insulin was not available?

If you discuss this, you would soon realise that one would have to isolate and use insulin from other animals. Would the insulin isolated from other animals be just as effective as that secreted by the human body itself and would it not elicit an immune response in the human body?

Now, imagine if bacterium were available that could make human insulin. Suddenly the whole process becomes so simple. You can easily grow a large quantity of the bacteria and make as much insulin as you need.

Think about whether insulin can be orally administered to diabetic people or not. Why?

Insulin used for diabetes was earlier extracted from pancreas of slaughtered cattle and pigs.

Insulin from an animal source, though caused some patients to develop allergy or other types of reactions to the foreign protein.

Insulin consists of two short polypeptide chains: chain A and chain B, that are linked together by **disulphide** bridges.

In mammals, including humans, insulin is synthesised as a **pro-hormone** (like a pro-enzyme, the pro-hormone also needs to be processed before it becomes a fully mature and functional hormone) which contains an extra stretch called the C peptide. This C peptide is not present in the mature insulin and is removed during maturation into insulin.The main challenge for production of insulin using rDNA techniques was getting insulin assembled into a mature form.

In 1983, Eli Lilly an American company prepared two DNA sequences corresponding to A and B, chains of human insulin and introduced them in plasmids of E. coli to produce insulin chains. Chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.

Gene Therapy

If a person is born with a hereditary disease, can a corrective therapy be taken for such a disease? Gene therapy is an attempt to do this.

Gene therapy is a collection of methods that allows correction of a gene defect that has been diagnosed in a child/embryo.

Here genes are inserted into a person's cells and tissues to treat a disease. Correction of a genetic defect involves delivery of a normal gene into the individual or embryo to take over the function of and compensate for the non-functional gene.

The first clinical gene therapy was given in 1990 to a 4-year old girl with **adenosine deaminase (ADA)** deficiency. This enzyme is crucial for the immune system to function.

The disorder is caused due to the deletion of the gene for adenosine deaminase.

In some children ADA deficiency can be cured by bone marrow transplantation; in others it can be treated by enzyme replacement therapy, in which functional ADA is given to the patient by injection.

But the problem with both of these approaches that they are not completely curative.

As a first step towards gene therapy, lymphocytes from the blood of the patient are grown in a culture outside the body. A functional ADA cDNA (using a retroviral vector) is then introduced into these lymphocytes, which are subsequently returned to the patient.

However, as these cells are not immortal, the patient requires periodic infusion of such genetically engineered lymphocytes.

However, if the gene isolate from marrow cells producing ADA is introduced into cells at early embryonic stages, it could be a permanent cure.

Molecular Diagnosis

You know that for effective treatment of a disease, early diagnosis and understanding its pathophysiology is very important.

Using conventional methods of diagnosis (serum and urine analysis, etc.) early detection is not possible.

Recombinant DNA technology, **Polymerase Chain Reaction (PCR)** and **Enzyme Linked Immuno-sorbent Assay (ELISA)** are some of the techniques that serve the purpose of early diagnosis.

Presence of a pathogen (bacteria, viruses, etc.) is normally suspected only when the pathogen has produced a disease symptom. By this time the concentration of pathogen is already very high in the body.

However, very low concentration of a bacteria or virus (at a time when the symptoms of the disease are not yet visible) can be detected by amplification of their nucleic acid by PCR.

PCR is now routinely used to **detect HIV** in suspected AIDS patients. It is being used to detect mutations in genes in suspected **cancer** patients too. It is a powerful techqnique to identify many other genetic disorders.

ELISA is based on the principle of **antigen-antibody interaction**. Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins, etc.) or by detecting the antibodies synthesised against the pathogen.

Transgenic animals

Animals that have had their DNA manipulated to possess and express an extra (foreign) gene are known as transgenic animals.

Transgenic rats, rabbits, pigs, sheep, cows and fish have been produced, although over 95 per cent of all existing transgenic animals are mice.

Why are these animals being produced? How can man benefit from such modifications? Let us try and explore some of the common reasons.

Normal physiology and development: Transgenic animals can be specifically designed to allow the study of how genes are regulated, and how they affect the normal functions of the body and its development, e.g., study of complex factors involved in growth such as insulin-like growth factor. By introducing genes from other species that alter the formation of this factor and studying the biological effects that result, information is obtained about the biological role of the factor in the body.

Study of disease: Many transgenic animals are designed to increase our understanding of how genes contribute to the development of disease. These are specially made to serve as models for human diseases so that investigation of new treatments for diseases is made possible. Today transgenic models exist for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.

Biological products: Medicines required to treat certain human diseases can contain biological products, but such products are often expensive to make. Transgenic animals that produce useful biological products can be created by the introduction of the portion of DNA (or genes) which codes for a particular product such as human protein. Similar attempts are being made for treatment of phenylketonuria (PKU) and cystic fibrosis. In 1997, the first transgenic cow, Rosie, produced human protein-enriched milk (2.4 grams per litre). The milk contained the human alpha-lactalbumin and was nutritionally a more balanced product for human babies than natural cow-milk.

Vaccine safety: Transgenic mice are being developed for use in testing the safety of vaccines before they are used on humans. Transgenic mice are being used to test the safety of the polio vaccine. If successful and found to be reliable, they could replace the use of monkeys to test the safety of batches of the vaccine.

Chemical safety testing: This is known as toxicity/safety testing. The procedure is the same as that used for testing toxicity of drugs. Transgenic animals are made that carry genes which make them more sensitive to toxic substances than non-transgenic animals. They are then exposed to the toxic substances and the effects studied. Toxicity testing in such animals will allow us to obtain results in less time.

Biotechnology: Ethical Issues

The manipulation of living organisms by the human race cannot go on any further, without regulation. Some ethical standards are required to evaluate the morality of all human activities that might help or harm living organisms.

Going beyond the morality of such issues, the biological significance of such things is also important. Genetic modification of organisms can have unpredicatable results when such organisms are introduced into the ecosystem.

Therefore, the Indian Government has set up organisations such as **GEAC (Genetic Engineering Approval Committee)**, which will make decisions regarding the validity of GM research and the safety of introducing GM-organisms for public services.

The modification/usage of living organisms for public services (as food and medicine sources, for example) has also created problems with patents granted for the same.

There is growing public anger that certain companies are being granted patents for products and technologies that make use of the genetic materials, plants and other biological resources that have long been identified, developed and used by farmers and indigenous people of a specific region/country.

Rice is an important food grain, the presence of which goes back thousands of years in Asia's agricultural history. There are an estimated 200,000 varieties of rice in India alone. The diversity of rice in India is one of the richest in the world.

Basmati rice is distinct for its unique aroma and flavour and 27 documented varieties of Basmati are grown in India. There is reference to Basmati in ancient texts, folklore and poetry, as it has been grown for centuries.

In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati, in the US and abroad. This 'new' variety of Basmati had actually been derived from Indian farmer's varieties.

Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty. The patent extends to functional equivalents, implying that other people selling Basmati rice could be restricted by the patent.

Several attempts have also been made to patent uses, products and processes based on Indian traditional herbal medicines, e.g., turmeric neem. If we are not vigilant and we do not immediately counter these patent applications, other countries/individuals may encash on our rich legacy and we may not be able to do anything about it.

Biopiracy is the term used to refer to the use of bio-resources by multinational companies and other organisations without proper authorisation from the countries and people concerned without compensatory payment.

Most of the industrialised nations are rich financially but poor in biodiversity and traditional knowledge. In contrast the developing and the underdeveloped world is rich in biodiversity and traditional knowledge related to bio-resources.

Traditional knowledge related to bio-resources can be exploited to develop modern applications and can also be used to save time, effort and expenditure during their commercialisation.

There has been growing realisation of the injustice, inadequate compensation and benefit sharing between developed and developing countries. Therefore, some nations are developing laws to prevent such unauthorised exploitation of their bio-resources and traditional knowledge.

The Indian Parliament has recently cleared the second amendment of the Indian Patents Bill, that takes such issues into consideration, including patent terms emergency provisions and research and development initiative.

Summary

Biotechnology has given to humans several useful products by using microbes, plant, animals and their metabolic machinery.

Recombinant DNA technology has made it possible to engineer microbes, plants and animals such that they have novel capabilities.

Genetically Modified Organisms have been created by using methods other than natural methods to transfer one or more genes from one organism to another, generally using techniques such as recombinant DNA technology.

GM plants have been useful in increasing crop yields, reduce post-harvest losses and make crops more tolerant of stresses.

There are several GM crop plants with improved nutritional value of foods and reduced the reliance on chemical pesticides (pest-resistant crops).

Recombinant DNA technological processes have made immense impact in the area of healthcare by enabling mass production of safe and more effective therapeutics.

Since the recombinant therapeutics are identical to human proteins, they do not induce unwanted immunological responses and are free from risk of infection as was observed in case of similar products isolated from non-human sources. Human insulin is made in bacteria yet its structure is absolutely identical to that of the natural molecule.

Transgenic animals are also used to understand how genes contribute to the development of a disease by serving as models for human diseases, such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.

Gene therapy is the insertion of genes into an individual's cells and tissues to treat diseases especially hereditary diseases. It does so by replacing a defective mutant allele with a functional one or gene targeting which involves gene amplification.

Viruses that attack their hosts and introduce their genetic material into the host cell as part of their replication cycle are used as vectors to transfer healthy genes or more recently portions of genes.

Human Digestive System - Digestive Glands, Enzyme Action in Stomach, Enzyme Action in Small Intestine, Absorption of Digested Products, Disorders of Digestive System.

Human Digestive System

Biomacromolecules (carbohydrates, proteins etc.) in food cannot be utilized by our body in their original form.

They have to be broken down and converted into simple substances (glucose, amino acids etc.) in the digestive system.

During the digestion process, Biomacromolecules like

carbohydrates get broken into simple sugars such as glucose,

fats into fatty acids and glycerol,

proteins into amino acids.

This process of conversion of complex food substances to simple absorbable forms is called **digestion**.

Alimentary Canal

The food passes through a continuous canal called **alimentary canal**. The canal can be divided into various compartments: (1) the buccal cavity, (2) foodpipe or oesophagus, (3) stomach, (4) small intestine, (5) large intestine ending in the rectum and (6) the anus.

The activities of the gastro-intestinal tract [**alimentary canal**] are under neural and hormonal control for proper coordination of different parts.

The sight, smell and/or the presence of food in the oral cavity can stimulate the secretion of saliva.

Gastric and intestinal secretions are also, similarly, stimulated by neural signals.

The muscular activities of different parts of the alimentary canal can also be moderated by neural mechanisms.

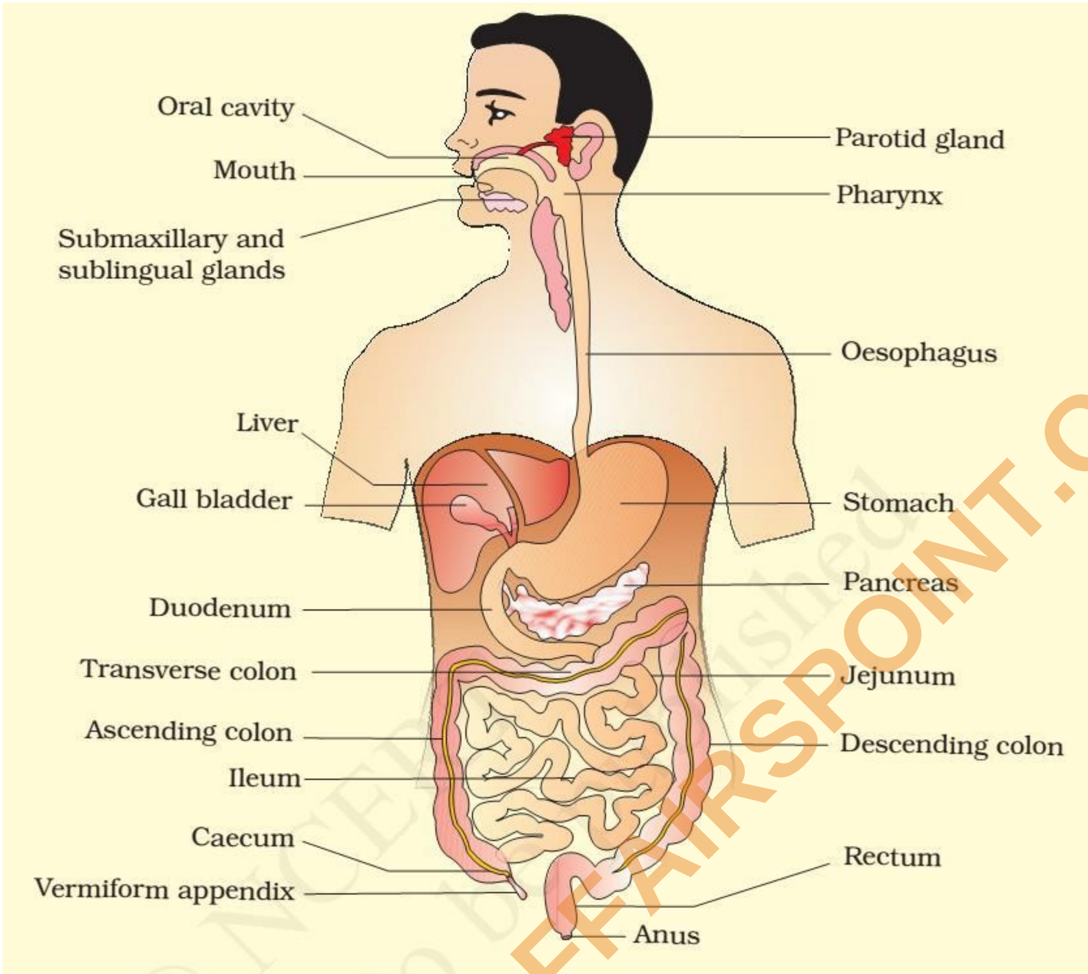


Figure 16.1 The human digestive system

Buccal Cavity or Oral Cavity – Teeth, Tongue, Saliva

The process of taking food into the body is called **ingestion**. Ingestion happens through mouth. The mouth leads to the buccal cavity or oral cavity.

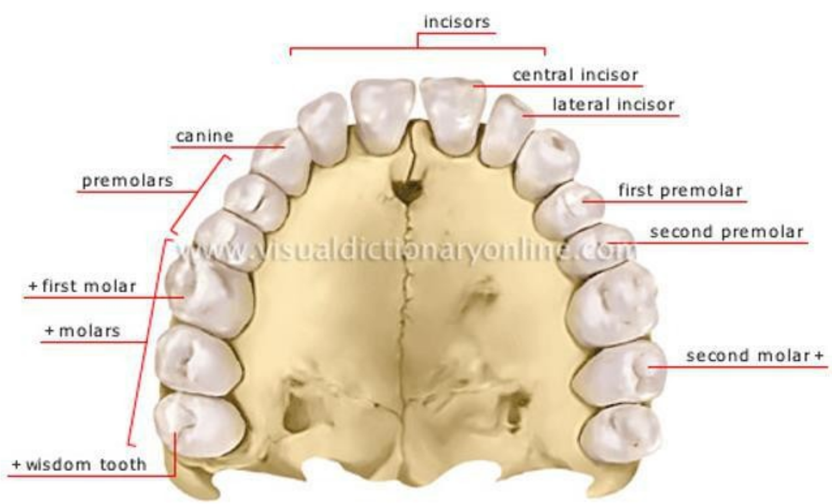
The oral cavity has a number of teeth and a muscular tongue. Each tooth is embedded in a socket of jaw bone.

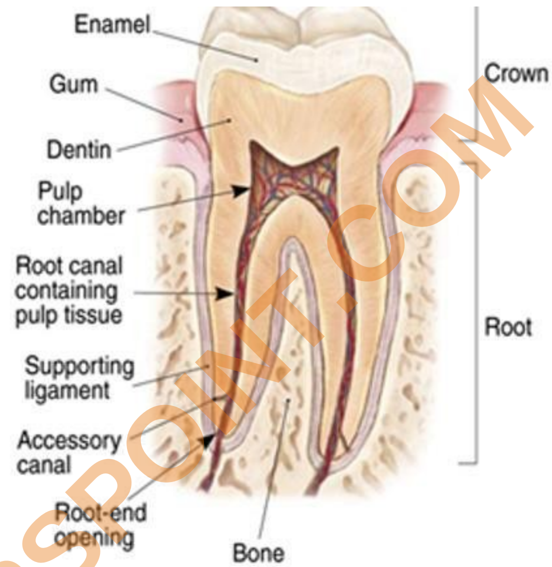
Majority of mammals including human being forms two sets of teeth during their life, a set of **temporary milk or deciduous teeth [milk teeth]** replaced by a set of **permanent or adult teeth [permanent teeth]**.

An adult human has 32 permanent teeth which are of four different types, namely, **incisors (I), canine (C), premolars (PM) & molars (M)**.

Arrangement of teeth in each half of the upper and lower jaw in the order I, C, PM, M is represented by a dental formula which in human is 2123/2123 [2-I,1-C,2-PM,3-M]

The hard chewing surface of the teeth, made up of **enamel** (Enamel is the hardest substance in the human body and contains the **highest percentage of minerals**), helps in the mastication (chewing) of food.





Our mouth has the **salivary glands** which secrete saliva. The saliva breaks down the **starch into sugars**.

The saliva secreted into the oral cavity contains **electrolytes (Na+, K+, Cl", HCOs)** and enzymes, **SALIVARY AMYLASE** and **LYSOZYME**.

The chemical process of digestion is initiated in the oral cavity by the hydrolytic action of the carbohydrate splitting enzyme, the **salivary amylase**.

About 30 per cent of starch is **hydrolysed** here by this enzyme (optimum pH 6.8) into a disaccharide - **maltose**.

$$\text{Polysaccharides (starch)} \xrightarrow{\text{Amylase}} \text{Disaccharides}$$

$$\text{Starch} \xrightarrow[\text{pH 6.8}]{\text{Salivary Amylase}} \text{Maltose}$$

$$\text{Maltose} \xrightarrow{\text{Maltase}} \text{Glucose + Glucose}$$

$$\text{Lactose} \xrightarrow{\text{Lactase}} \text{Glucose + Galactose}$$

$$\text{Sucrose} \xrightarrow{\text{Sucrase}} \text{Glucose + Fructose}$$

Lysozyme present in saliva acts as an **antibacterial** agent that prevents infections.

The tongue is a fleshy muscular organ attached at the back to the floor of the buccal cavity. It mixes saliva with the food during chewing and helps in swallowing food.

The tongue is attached to the floor of the oral cavity by the **frenulum** (a fold of skin beneath the tongue).

The upper surface of the tongue has small projections called **papillae**, some of which bear taste buds.

Foodpipe/Oesophagus

The oral cavity leads into a short **pharynx** which serves as a common passage for food and air. The esophagus and the trachea (wind pipe) open into the pharynx.

A cartilaginous flap called **epiglottis** prevents the entry of food into the glottis during swallowing. [Glottis == opening of the wind pipe].

The swallowed food passes into the foodpipe or oesophagus. The oesophagus is a thin, long tube which extends posteriorly [further back in position] passing through the neck, **thorax** [the part of the body of a mammal between the neck and the abdomen] and diaphragm [separates the thorax from the abdomen in mammals] and leads to a 'J' shaped bag like structure called stomach.

Mucus in saliva helps in lubricating and adhering the masticated food particles into a bolus. The bolus is then conveyed into the pharynx and then into the oesophagus by swallowing or **deglutition**.

The bolus further passes down through the oesophagus by successive waves of muscular contractions called **peristalsis**. The **gastro-oesophageal sphincter** controls the passage of food into the stomach.

Stomach

The inner lining of the stomach secretes **mucous, hydrochloric acid** and **digestive juices**.

The mucous protects the lining of the stomach.

*The acid kills many **bacteria** that enter along with the food and makes the medium in the stomach **acidic**.*

*The digestive juices break down the **proteins** into simpler substances.*

A **muscular sphincter (gastro-oesophageal)** [a ring of muscle surrounding and serving to guard or close an opening] regulates the opening of oesophagus into the stomach.

The stomach, located in the upper left portion of the abdominal cavity, has three major parts – a cardiac portion into which the oesophagus opens, a **fundic region** and a **pyloric portion** which opens into the first part of small intestine.

Small intestine

Small intestine is distinguishable into three regions, a **'C' shaped duodenum**, a **long coiled middle portion jejunum** and a **highly coiled ileum**.

The opening of the stomach into the duodenum is guarded by the **pyloric sphincter**. Ileum opens into the large intestine.

The small intestine is highly coiled and is about **7.5 meters long**. It receives secretions from the liver and the pancreas. Besides, its wall also secretes juices.

The digested food passes into the blood vessels in the wall of the intestine. This process is called **absorption**.

The inner walls of the small intestine have thousands of finger-like outgrowths. These are called **villi (singular villus)**. The villi **increase the surface area for absorption** of the digested food.

Villi are supplied with a network of capillaries and a **large lymph** (a colourless fluid containing white blood cells) vessel called the **lacteal**.

The absorbed substances are transported via the blood vessels to different organs of the body where they are used to build complex substances such as the proteins required by the body. This is called **assimilation**.

In the cells, **glucose** breaks down with the help of **oxygen** into **carbon dioxide** and **water**, and **energy** is released.

The food that remains undigested and unabsorbed then enters into the large intestine.

Large intestine

The large intestine is wider and shorter than small intestine. It is about 1.5 metre in length. Its function is to absorb water and some salts from the undigested food material.

The remaining waste passes into the rectum and remains there as semi-solid faeces. The faecal matter is removed through the anus from time-to-time. This is called **egestion**.

Ingestion → Digestion → Absorption → Assimilation → Egestion

It consists of **caecum**, **colon** and **rectum**. Caecum is a small blind sac which hosts some **symbiotic micro-organisms**.

A narrow finger -like tubular projection, the vermiform **appendix** which is a vestigial organ [small remnant of something that was once more noticeable], arises from the caecum.

Appendix was helpful in digesting **roughage** (fibrous indigestible material in vegetable foodstuffs which aids the passage of food and waste products through the gut). Thousands of years ago, when man used to eat roots, leaves, etc., it was essential. But now it has lost its significance.

The caecum opens into the colon. The colon is divided into three parts - an ascending, a transverse and a descending part. The descending part opens into the rectum which opens out through the anus.

No significant digestive activity occurs in the large intestine. The functions of large intestine are: absorption of some water, minerals and certain drugs; secretion of mucus which helps in adhering the waste (undigested) particles together and lubricating it for an easy passage.

The undigested, unabsorbed substances called faeces enters into the caecum of the large intestine through **ileo-caecal** valve, which prevents the back flow of the faecal matter. It is temporarily stored in the rectum till defaecation.

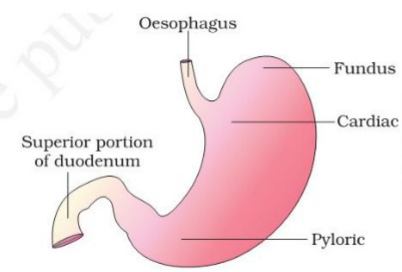


Figure 16.3 Anatomical regions of human stomach

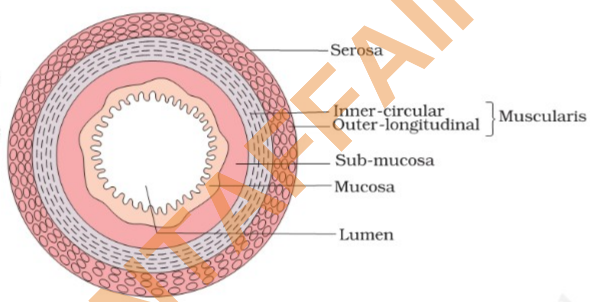


Figure 16.4 Diagrammatic representation of transverse section of gut

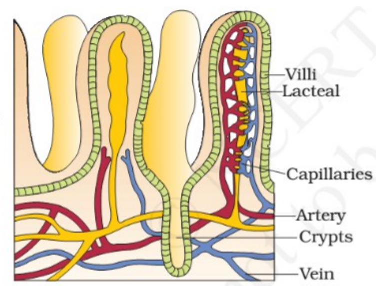


Figure 16.5 A section of small intestinal mucosa showing villi

Layers of Alimentary Canal

The wall of alimentary canal from oesophagus to rectum possesses four layers namely **serosa, muscularis, sub-mucosa** and **mucosa**.

Serosa is the outermost layer and is made up of a thin **mesothelium (epithelium of visceral organs)** with some connective tissues.

Muscularis is formed by **smooth muscles**.

The submucosal layer is formed of **loose connective tissues** containing nerves, blood and lymph vessels. In duodenum, glands are also present in sub-mucosa.

The innermost layer lining the lumen of the alimentary canal is the mucosa. This layer forms irregular folds (**rugae**) in the stomach and small finger-like foldings called **villi** in the small intestine. **Mucosal epithelium** has **goblet cells** which secrete mucus that help in **lubrication**. Mucosa also forms glands in the stomach (**gastric glands**).

Digestive Glands

The digestive glands associated with the alimentary canal include the **salivary glands**, the **liver** and the **pancreas**.

Salivary glands

Saliva is mainly produced by three pairs of salivary glands, the parotids (cheek), the sub-maxillary (lower jaw) and the sub-linguals (below the tongue).

These glands situated just outside the buccal cavity secrete salivary juice into the buccal cavity.

The saliva breaks down the **starch into sugars**.

Liver

The liver is a reddish brown gland situated in the upper part of the abdomen on the right side.

It is the **largest gland** in the body.

It secretes **bile juice** that is stored in a sac called the **gall bladder**.

The bile plays an important role in the **digestion of fats**.

It has two lobes. The hepatic lobules are the structural and functional units of liver containing **hepatic cells**.

The bile secreted by the hepatic cells passes through the hepatic ducts and is stored and concentrated in a thin muscular sac called the **gall bladder.**

The duct of **gall bladder (cystic duct)** along with the **hepatic duct from the liver**, forms the common **bile duct**.

The bile duct and the pancreatic duct open together into the duodenum as the common **hepato-pancreatic duct** which is guarded by a sphincter called the **sphincter of Oddi**.

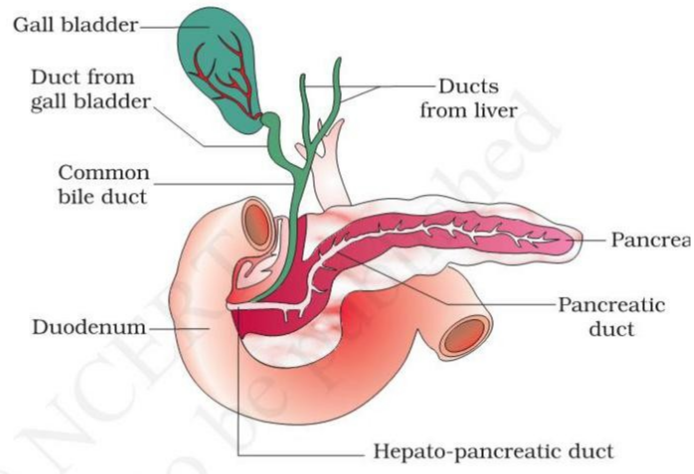


Figure 16.6 The duct systems of liver, gall bladder and pancreas

Pancreas

The pancreas is a large cream coloured gland located just below the stomach.

The pancreatic juice acts on **carbohydrates and proteins** and changes them into simpler forms.

The partly digested food now reaches the lower part of the small intestine where the intestinal juice [succus entericus] completes the digestion of all components of the food.

The pancreas is a compound (both **exocrine and endocrine**) elongated organ situated between the limbs of the 'U' shaped duodenum.

The exocrine portion secretes an **alkaline pancreatic juice** containing enzymes and the endocrine portion secretes **hormones, insulin and glucagon**.

Digestion – Enzyme Action in Stomach

The stomach stores the food for 4-5 hours. The food mixes thoroughly with the acidic gastric juice of the stomach by the churning movements of its muscular wall and is called the **chyme**.

The *proenzyme [inactive precursor of an enzyme]* pepsinogen, on exposure to hydrochloric acid gets converted into the active enzyme **PEPSIN**, the *proteolytic (breakdown of proteins or peptides into amino acids)* enzyme of the stomach.

Pepsin converts **proteins into proteoses and peptones** (peptides).

The mucus and **bicarbonates** present in the gastric juice play an important role in **lubrication** and **protection** of the mucosal epithelium from excoriation by the highly concentrated hydrochloric acid. HCl provides the **acidic** pH (pH 1.8) **optimal for pepsins.**

Rennin is a proteolytic enzyme found in gastric juice of infants which helps in the **digestion of milk proteins**.

Digestion – Enzyme Action in Small Intestine

The pancreatic juice contains inactive enzymes - trypsinogen, chymotrypsinogen, procarboxypeptidases, amylases, lipases and nucleases.

Trypsinogen is activated by an enzyme, **enterokinase**, secreted by the intestinal mucosa into active **TRYPSIN**, which in turn **activates the other enzymes** in the pancreatic juice.

$$\left.\begin{array}{l}\text{Proteins}\\\text{Peptones}\\\text{Proteoses}\end{array}\right\}\xrightarrow[\text{Carboxypeptidase}]{\text{Trypsin/Chymotrypsin}}\text{Dipeptides}$$

$$\text{Nucleic acids}\xrightarrow{\text{Nucleases}}\text{Nucleotides}\longrightarrow\text{Nucleosides}$$

$$\text{Nucleotides}\xrightarrow{\text{Nucleotidases}}\text{Nucleosides}\xrightarrow{\text{Nucleosidases}}\text{Sugars + Bases}$$

$$\text{Dipeptides}\xrightarrow{\text{Dipeptidases}}\text{Amino acids}$$

The bile released into the duodenum contains bile pigments (bilirubin and biliverdin), bile salts, cholesterol and phospholipids but no enzymes.

Bile helps in **emulsification of fats**, i.e., breaking down of the fats into very small micelles. Bile also activates **LIPASES**. Small amounts of **lipases** are secreted by gastric glands.

$$\text{Fats}\xrightarrow{\text{Lipases}}\text{Diglycerides}\longrightarrow\text{Monoglycerides}$$

$$\text{Di and Monoglycerides}\xrightarrow{\text{Lipases}}\text{Fatty acids + Glycerol}$$

The intestinal mucosal epithelium has **goblet cells** which secrete mucus. The secretions of the mucosa along with the secretions of the goblet cells constitute the intestinal juice.

This juice contains a variety of enzymes like **disaccharidases (e.g., maltase), dipeptidases, lipases, nucleosidases**, etc. Hormonal control of the secretion of digestive juices is carried out by local hormones produced by the gastric and intestinal mucosa.

The mucus along with the bicarbonates from the pancreas protects the intestinal mucosa from **acid** as well as provide an **alkaline medium (pH 7.8)** for enzymatic activities.

The breakdown of biomacromolecules mentioned above occurs in the **duodenum** region of the small intestine.

The simple substances thus formed are absorbed in the jejunum and ileum regions of the small intestine.

The undigested and unabsorbed substances are passed on to the large intestine.

Absorption of Digested Products

Absorption is the process by which the end products of digestion pass through the intestinal mucosa into the **blood or lymph**.

Small amounts of monosaccharides like glucose, amino acids and some electrolytes like chloride ions are generally absorbed by simple **diffusion**. The passage of these substances into the blood depends upon the concentration gradients.

However, sometimes substances like glucose and amino acids are absorbed with the help of carrier proteins. This mechanism is called the **facilitated transport**.

Transport of water depends upon the **osmotic gradient.** Active transport occurs against the concentration gradient and hence requires energy. Various nutrients like amino acids, monosaccharides like glucose, electrolytes like Na+ are absorbed into the blood by this mechanism.

Fatty acids and glycerol being **insoluble**, cannot be absorbed into the blood. They are first incorporated into small droplets called **micelles** which move into the intestinal mucosa. They are re-formed into very **small protein coated fat globules** called the **chylomicrons** which are transported into the lymph vessels (lacteals) in the villi. These lymph vessels ultimately release the absorbed substances into the blood stream.

Absorption of substances takes place in different parts of the alimentary canal, like mouth, stomach, small intestine and large intestine. However, maximum absorption occurs in the small intestine.

Summary of Absorption in Different Parts of Digestive System

Mouth	Stomach	Small Intestine	Large Intestine
Certain drugs coming in contact with the mucosa of mouth and lower side of the tongue are absorbed into the blood capillaries lining them.	Absorption of water, simple sugars, and alcohol etc. takes place.	Principal organ for absorption of nutrients. The digestion is completed here and the final products of digestion such as glucose, fructose, fatty acids, glycerol and amino acids are absorbed through the mucosa into the blood stream and lymph.	Absorption of water, some minerals and drugs takes place.

The absorbed substances finally reach the tissues which utilise them for their activities. This process is called **assimilation**.

The digestive wastes, solidified into coherent faeces in the rectum initiate a neural reflex causing an urge or desire for its removal. The egestion of faeces to the outside through the anal opening (defaecation) is a voluntary process and is carried out by a mass peristaltic movement.

Disorders of Digestive System

The inflammation of the intestinal tract is the most common ailment due to **bacterial or viral infections.**

The infections are also caused by the parasites of the intestine like **tapeworm, roundworm, threadworm, hookworm, pin worm**, etc.

Jaundice: The liver is affected, skin and eyes turn yellow due to the deposit of bile pigments.

Vomiting: It is the ejection of stomach contents through the mouth. This reflex action is controlled by the vomit centre in the **medulla**. A feeling of nausea precedes vomiting.

Diarrhoea: The abnormal frequency of bowel movement and increased liquidity of the faecal discharge is known as diarrhoea. It reduces the absorption of food.

Constipation: In constipation, the faeces are retained within the rectum as the bowel movements occur irregularly.

Indigestion: In this condition, the food is not properly digested leading to a feeling of fullness. The causes of indigestion are inadequate enzyme secretion, anxiety, food poisoning, over eating, and spicy food.

Human Respiratory System - General Science NCERT - Respiration Breathing and Exchange of Gases, Mechanism of Breathing, Mechanism of Breathing.

Respiration – Breathing and Exchange of Gases

Oxygen (O2) is utilized by the organisms to indirectly break down nutrient molecules like glucose and to derive energy for performing various activities. Carbon dioxide (CO2) which is harmful is also released during the above **catabolic reactions**. It is, therefore, evident that O2 has to be continuously provided to the cells and CO2 produced by the cells have to be released out. This process of exchange of O2 from the atmosphere with CO2 produced by the cells is called breathing, commonly known as respiration.

Metabolic Pathways

Metabolic pathways that lead to a more complex structure from a simpler structure are called **biosynthetic pathways** or **anabolic pathways**. Example: **acetic acid becomes cholesterol.**

Metabolic pathways that lead to a simpler structure from a complex structure are called **catabolic pathways**. Example: **glucose becomes lactic acid in our skeletal muscle**.

Anabolic pathways **consume energy**. Assembly of a protein from amino acids requires energy input.

On the other hand, catabolic pathways lead to the release of energy. For example, when glucose is degraded to lactic acid in our skeletal muscle, energy is liberated. This metabolic pathway from glucose to lactic acid which occurs in 10 metabolic steps is called **glycolysis**.

Living organisms have learnt to trap this energy liberated during degradation and store it in the form of chemical bonds.

As and when needed, this **bond energy** is utilized for biosynthetic, osmotic and mechanical work that we perform.

The most important form of energy currency in living systems is the bond energy in a chemical called **adenosine triphosphate (ATP)**.

Mechanisms of breathing vary among different groups of animals depending mainly on their habitats and levels of organization.

Lower invertebrates like sponges, coelenterates, flatworms, etc., exchange O2 with CO2 by **simple diffusion** over their entire body surface.

Earthworms use their moist **cuticle** and insects have a network of tubes (**tracheal tubes**) to transport atmospheric air within the body.

Special vascularized structures called **gills** are used by most of the aquatic arthropods and molluscs whereas vascularised bags called lungs are used by the terrestrial forms for the exchange of gases.

Among vertebrates, fishes use gills whereas reptiles, birds and mammals respire through lungs. Amphibians like frogs can respire through their moist **skin** also. Mammals usually have a well-developed respiratory system.

Human Respiratory System

We have a pair of external nostrils opening out above the upper lips. It leads to a nasal chamber through the nasal passage. The nasal chamber opens into the **pharynx**, a portion of which is the **common passage** for food and air.

The pharynx opens through the larynx region into the trachea. **Larynx** is a cartilaginous box which helps in sound production and hence called the **sound box**.

During swallowing glottis can be covered by a thin elastic cartilaginous flap called **epiglottis** to prevent the entry of food into the larynx.

Trachea is a straight tube which divides into a right and left primary **bronchi**. Each bronchi undergoes repeated divisions to form the secondary and tertiary bronchi and **bronchioles** ending up in very thin terminal bronchioles. The tracheae, primary, secondary and tertiary bronchi are supported by **incomplete cartilaginous rings**.

Each terminal bronchiole gives rise to a number of very thin, irregular-walled and vascularised bag-like structures called **alveoli**. The branching network of bronchi, bronchioles and alveoli comprise the lungs.

We have two lungs which are covered by a double layered **pleura**, with pleural fluid between them. It **reduces friction** on the lung-surface. The outer pleural membrane is in close contact with the thoracic lining whereas the inner pleural membrane is in contact with the lung surface.

The part starting with the external nostrils up to the terminal bronchioles constitute the conducting part whereas the alveoli and their ducts form the respiratory or exchange part of the respiratory system.

The conducting part transports the atmospheric air to the alveoli, **clears it from foreign particles, humidifies** and also brings the **air to body temperature**. Exchange part is the site of **actual diffusion** of O2 and CO2 between blood and atmospheric air.

The lungs are situated in the thoracic chamber which is anatomically an air-tight chamber. The thoracic chamber is formed dorsally by the **vertebral column**, ventrally by the **sternum** [breastbone], laterally by the ribs and on the lower side by the dome-shaped **diaphragm**.

The anatomical setup of lungs in thorax is such that *any change in the volume of the thoracic cavity will be reflected in the lung (pulmonary) cavity*. Such an arrangement is essential for breathing, as we cannot directly alter the pulmonary volume.

Respiration involves the following steps:

Breathing or pulmonary ventilation by which atmospheric air is drawn in and CO2 rich alveolar air is released out.

Diffusion of gases (O2 and CO2) across alveolar membrane.

Transport of gases by the blood.

Diffusion of O2 and CO2 between blood and tissues.

Utilisation of O2 by the cells for catabolic reactions and resultant release of CO2.

Mechanism of Breathing

Breathing involves two stages: **inspiration** during which atmospheric air is drawn in and **expiration** by which the alveolar air is released out.

The movement of air into and out of the lungs is carried out by creating a pressure gradient between the lungs and the atmosphere.

Inspiration can occur if the pressure within the lungs (intra-pulmonary pressure) is less than the atmospheric pressure, i.e., there is a negative pressure in the lungs with respect to atmospheric pressure. Similarly, expiration takes place when the intra-pulmonary pressure is higher than the atmospheric pressure.

The **diaphragm** and a specialized set of muscles – external and internal **intercostals** between the ribs, help in generation of such gradients.

Inspiration is initiated by the **contraction** of diaphragm which increases the volume of thoracic chamber in the antero-posterior axis. The **contraction** of external inter-costal muscles lifts up the ribs and the sternum causing an increase in the volume of the thoracic chamber in the dorso-ventral axis. The overall **increase in the thoracic volume** causes a **similar increase in pulmonary volume**.

An increase in pulmonary volume decreases the intra-pulmonary pressure to less than the atmospheric pressure which forces the air from outside to move into the lungs, i.e., inspiration.

Relaxation of the diaphragm and the inter-costal muscles returns the diaphragm and sternum to their normal positions and reduce the thoracic volume and thereby the pulmonary volume. This leads to an increase in intra-pulmonary pressure to slightly above the atmospheric pressure causing the expulsion of air from the lungs, i.e., expiration. We have the ability to increase the strength of inspiration and expiration with the help of additional muscles in the abdomen.

On an average, a healthy human breathes **12-16 times/minute**. The volume of air involved in breathing movements can be estimated by using a **spirometer** which helps in clinical assessment of pulmonary functions.

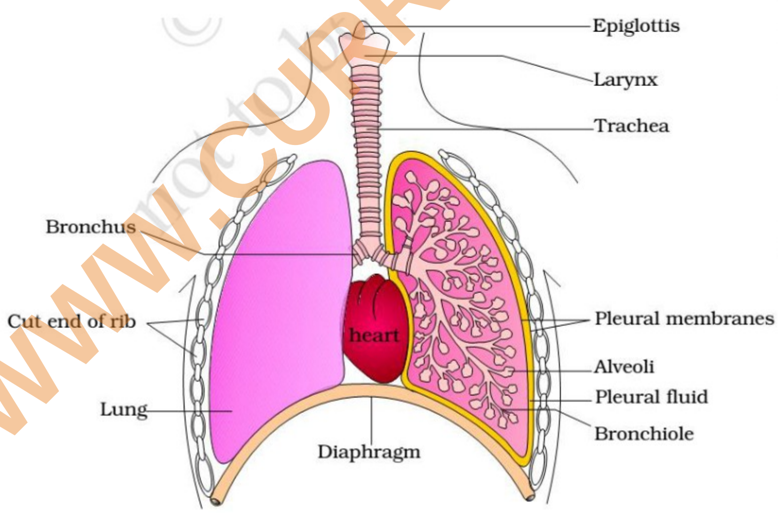


Figure 17.1 Diagrammatic view of human respiratory system (Sectional view of the left lung is also shown)

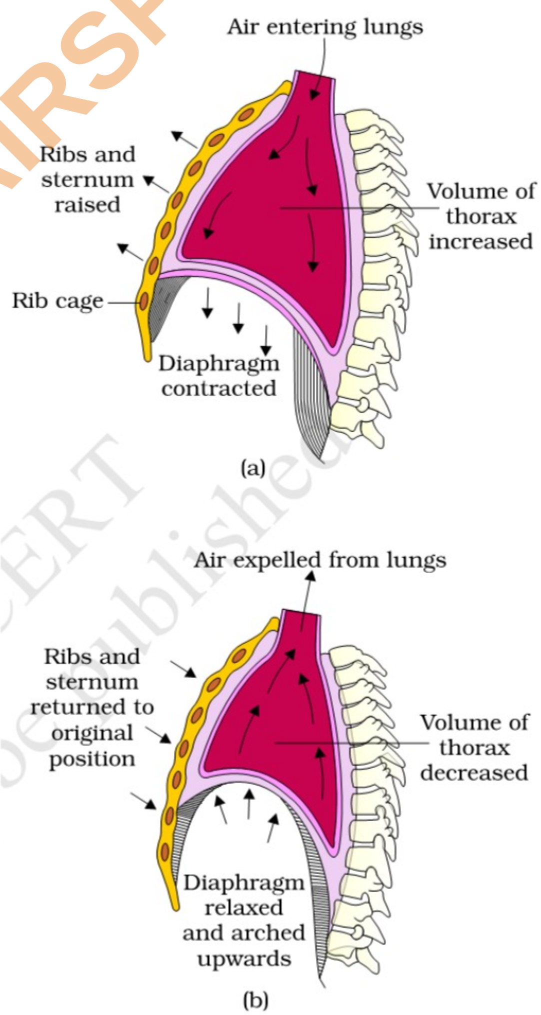


Figure 17.2 Mechanism of breathing showing : (a) inspiration (b) expiration

Exchange of Gases

Alveoli are the primary sites of exchange of gases. Exchange of gases also occur between **blood and tissues**. O2 and CO2 are exchanged in these sites by simple **diffusion** mainly based on pressure/concentration gradient.

Partial pressure of gasses, **Solubility** of the gases as well as the **thickness** of the membranes involved in diffusion are some important factors that can affect the rate of diffusion.

Pressure contributed by an individual gas in a mixture of gases is called partial pressure.

TABLE 17.1 Partial Pressures (in mm Hg) of Oxygen and Carbon dioxide at Different Parts Involved in Diffusion in Comparison to those in Atmosphere

Respiratory Gas	Atmospheric Air	Alveoli	Blood (Deoxygenated)	Blood (Oxygenated)	Tissues
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

Transport of Gases

Blood is the medium of transport for O2 and CO2.

About **97 per cent** of O2 is transported by **RBCs** in the blood. The remaining 3 per cent of O2 is carried in a **dissolved state** through the plasma.

Nearly 20-25 per cent of CO2 is transported by **RBCs** whereas 70 per cent of it is carried as **bicarbonate**. About 7 per cent of CO2 is carried in a **dissolved state** through plasma.

Transport of Oxygen

Haemoglobin is a red coloured **iron** containing pigment present in the RBCs. O2 can bind with haemoglobin in a reversible manner to form **oxyhaemoglobin**.

Each haemoglobin molecule can carry a maximum of **four** molecules of O2. Binding of oxygen with haemoglobin is primarily related to **partial pressure** of O2.

Partial pressure of CO2, hydrogen ion concentration and temperature are the other factors which can interfere with this binding.

Transport of Carbon dioxide

CO_2 is carried by haemoglobin as **carbamino-haemoglobin** (about 20-25 per cent). This binding is related to the partial pressure of CO_2. Partial pressure of O_2 is a major factor which could affect this binding. RBCs contain a very high concentration of the enzyme, **carbonic anhydrase** and minute quantities of the same is present in the plasma too. Nearly 70 per cent of carbon dioxide is transported as bicarbonate (HCO_3) with the help of the enzyme carbonic anhydrase.

At the tissue site where partial pressure of CO_2 is high due to catabolism [the breakdown of complex molecules in living organisms to form simpler ones, together with the release of energy], CO_2 diffuses into blood (RBCs and plasma) and forms HCO_3 and H^{+-}.

At the alveolar site where pCO_2 is low, the reaction proceeds in the opposite direction leading to the formation of CO_2 and H_2O.

Thus, CO_2 trapped as bicarbonate at the tissue level and transported to the alveoli is released out as CO_2. Every 100 ml of deoxygenated blood delivers approximately 4 ml of CO_2 to the alveoli.

Regulation of Respiration

Human beings have a significant ability to maintain and moderate the respiratory rhythm to suit the demands of the body tissues. This is done by the neural system.

A specialised centre present in the **medulla region** of the brain called **respiratory rhythm centre** is primarily responsible for this regulation.

Another centre present in the **pons** region of the brain called **pneumotaxic centre** can moderate the functions of the respiratory rhythm centre. Neural signal from this centre can reduce the duration of inspiration and thereby alter the respiratory rate.

A chemosensitive area is situated adjacent to the rhythm centre which is highly sensitive to CO_2 and hydrogen ions. Increase in these substances can activate this centre, which in turn can signal the rhythm centre to make necessary adjustments in the respiratory process by which these substances can be eliminated.

Disorders of Respiratory System

Asthma: Asthma is a difficulty in breathing causing wheezing due to **inflammation of bronchi** and bronchioles.

Emphysema: Emphysema is a chronic disorder in which alveolar walls are damaged due to which respiratory surface is decreased. One of the major causes of this is **cigarette smoking**.

Occupational Respiratory Disorders: In certain industries, especially those involving grinding or stone-breaking, so much dust is produced that the defense mechanism of the body cannot fully cope with the situation. Long exposure can give rise to inflammation leading to **fibrosis** (proliferation of fibrous tissues) and thus causing serious lung damage. Workers in such industries should wear protective masks.

Human Excretory System – Kidneys, Urine Formation, Tubules: Proximal Convoluted Tubule (PCT), Henle's Loop, Distal Convoluted Tubule (DCT), Collecting Duct.

Excretory System

When our cells perform their functions, certain waste products are released in to the blood stream. These are **toxic** and hence need to be removed from the body.

The process of removal of wastes produced in the cells of the living organisms is called excretion. The parts involved in excretion forms the excretory system.

Waste removal is done by the blood capillaries in the kidneys.

When the blood reaches the two kidneys, it contains both useful and harmful substances. The useful substances are absorbed back into the blood. The wastes are removed as urine.

From the kidneys, the urine goes into the **urinary bladder** through tube-like **ureters**. It is stored in the bladder and is passed out through the urinary opening at the end of a muscular tube called **urethra**. The **kidneys, ureters, bladder and urethra** form the excretory system.

An adult human being normally passes about **1–1.8 L** of urine in 24 hours, and the urine consists of **95% water, 2.5 % urea and 2.5% other waste products**.

Excretory Products and their Elimination

Animals accumulate **ammonia, urea, uric acid, carbon dioxide, water and ions like Na^+, K^+, Cl^-, phosphate, sulphate,** etc., either by metabolic activities or by other means like excess ingestion. These substances have to be removed totally or partially.

Ammonia, urea and **uric acid** are the major forms of **nitrogenous wastes** excreted by the animals.

The way in which waste chemicals are removed from the body of the animal depends on the availability of water.

Ammonia is the most toxic form and requires large amount of water for its elimination, whereas **uric acid, being the least toxic**, can be removed with a minimum loss of water.

Aquatic animals like fishes, excrete cell waste in **gaseous form (ammonia)** which directly dissolves in water.

Some land animals like birds, lizards, snakes excrete a semi-solid, white coloured compound (**uric acid**).

The major excretory product in humans is **urea** which is excreted through urine.

Sometimes a person's kidneys may stop working due to infection or injury. As a result of kidney failure, waste products start accumulating in the blood. Such persons cannot survive unless their blood is filtered periodically through an artificial kidney. This process is called **dialysis**.

The process of excreting ammonia is **Ammonotelism.** Many bony fishes, aquatic amphibians and aquatic insects are **ammonotelic** in nature.

Ammonia, as it is readily soluble, is generally excreted by **diffusion** across body surfaces or through gill surfaces (in fish) as ammonium ions. **Kidneys do not play any significant role in its removal.**

Terrestrial adaptation necessitated the production of lesser toxic nitrogenous wastes like **urea** and **uric acid** for conservation of water.

Mammals, many terrestrial amphibians and marine fishes mainly excrete urea and are called **ureotelic animals**. Ammonia produced by metabolism is converted into urea in the **liver** of these animals and released into the blood which is filtered and excreted out by the kidneys.

Some amount of urea may be retained in the kidney matrix of some of these animals to maintain a desired **osmolarity [**the concentration of a solution expressed as the total number of solute particles per litre**]**.

Reptiles, birds, land snails and insects excrete nitrogenous wastes as **uric acid** in the form of pellet or paste with a minimum loss of water and are called **uricotelic animals**.

A survey of animal kingdom presents a variety of excretory structures. In most of the invertebrates, these structures are simple tubular forms whereas vertebrates have complex tubular organs called kidneys. Some of these structures are mentioned here.

Protonephridia or flame cells are the excretory structures in Platyhelminthes (Flatworms, e.g., Planaria), rotifers, some annelids and the cephalochordate.

Protonephridia are primarily concerned with ionic and fluid volume regulation, i.e., osmoregulation. **Nephridia** are the tubular excretory structures of earthworms and other annelids. Nephridia help to remove nitrogenous wastes and maintain a fluid and ionic balance.

Malpighian tubules are the excretory structures of most of the insects including cockroaches. Malpighian tubules help in the removal of nitrogenous wastes and osmoregulation.

Antennal glands or **green glands** perform the excretory function in crustaceans like prawns.

Human Excretory System

In humans, the excretory system consists of a pair of kidneys, one pair of ureters, a urinary bladder and a urethra.

Kidneys

Kidneys are reddish brown, bean shaped structures situated between the levels of last thoracic and third lumbar vertebra close to the dorsal inner wall of the abdominal cavity.

Each kidney of an adult human measures 10-12 cm in length, 5-7 cm in width, 2-3 cm in thickness with an average weight of 120-170 g.

Towards the center of the inner concave surface of the kidney is a notch called **hilum** through which ureter, blood vessels and nerves enter.

Inner to the hilum is a broad funnel shaped space called the **renal pelvis** with projections called **calyces**.

Inside the kidney, there are two zones, an **outer cortex** and an **inner medulla**. The medulla is divided into a few conical masses (medullary pyramids) projecting into the calyces (singularity: calyx).

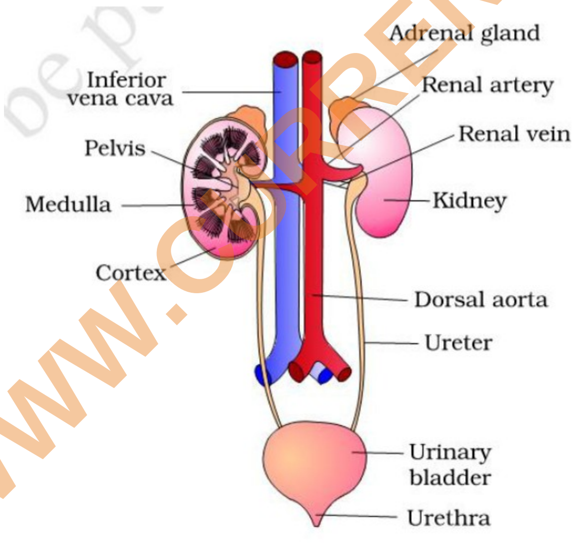


Figure 19.1 Human Urinary system

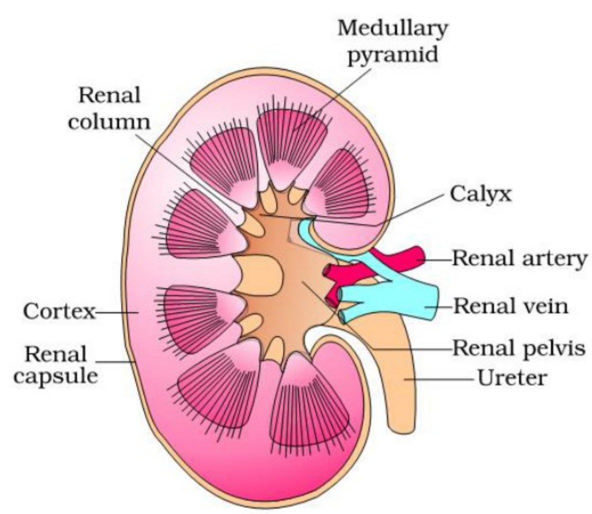


Figure 19.2 Longitudinal section (Diagrammatic) of Kidney

Each kidney has nearly one million complex tubular structures called **nephrons**, which are the functional units.

Each nephron has two parts - the **glomerulus** and the **renal tubule**.

Glomerulus is a tuft of capillaries formed by the **afferent arteriole** - a fine branch of **renal artery**. Blood from the glomerulus is carried away by an **efferent arteriole**.

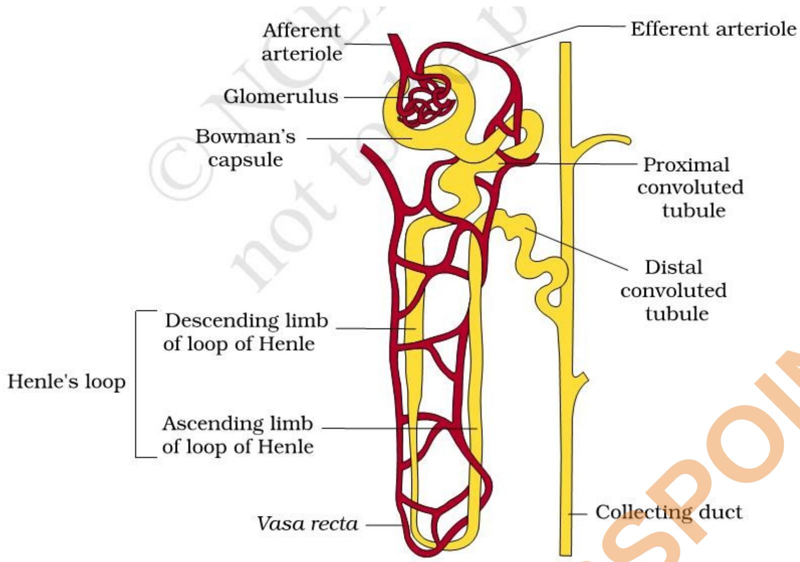


Figure 19.3 A diagrammatic representation of a nephron showing blood vessels, duct and tubule

The renal tubule begins with a double walled cup-like structure called **Bowman's capsule**, which encloses the glomerulus.

Glomerulus along with Bowman's capsule, is called the **malpighian body** or **renal corpuscle**.

The tubule continues further to form a highly coiled network - **proximal convoluted tubule (PCT)**.

A hairpin shaped Henle's loop is the next part of the tubule which has a descending and an ascending limb.

The ascending limb continues as another highly coiled tubular region called distal convoluted tubule (DCT).

The DCTs of many nephrons open into a straight tube called collecting duct, many of which converge and open into the renal pelvis through medullary pyramids in the calyces.

The Malpighian corpuscle, PCT and DCT of the nephron are situated in the cortical region of the kidney whereas the loop of Henle dips into the medulla.

In majority of nephrons, the loop of Henle is too short and extends only very little into the medulla. Such nephrons are called **cortical nephrons**.

In some of the nephrons, the loop of Henle is very long and runs deep into the medulla. These nephrons are called **juxta medullary nephrons**.

The efferent arteriole emerging from the glomerulus forms a fine capillary network around the renal tubule called the **peritubular capillaries**.

A minute vessel of this network runs parallel to the Henle's loop forming a 'U' shaped vasa recta. Vasa recta is absent or highly reduced in cortical nephrons.

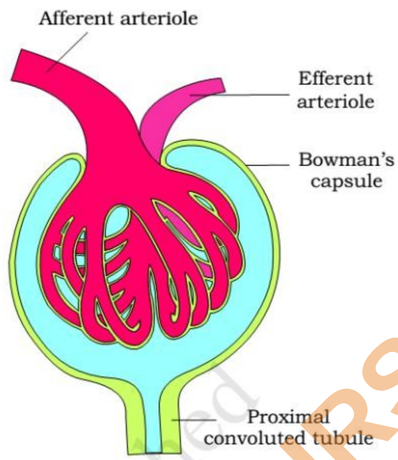


Figure 19.4 Malpighian body (renal corpuscle)

Urine Formation

Urine formation involves three main processes namely, **glomerular filtration, reabsorption** and **secretion**, that takes place in different parts of the nephron.

The first step in urine formation is the filtration of blood, which is carried out by the glomerulus and is called **glomerular filtration**.

On an average, **1100-1200 ml** of blood is filtered by the kidneys per minute.

The glomerular capillary blood pressure causes filtration of blood through 3 layers, i.e., the **endothelium of glomerular blood vessels**, the **epithelium of Bowman's capsule** and a **basement membrane** between these two layers.

The epithelial cells of Bowman's capsule called **podocytes** are arranged in an intricate manner so as to leave some minute spaces called filtration slits or slit pores. Blood is filtered so finely through these membranes, that almost all the constituents of the plasma **except the proteins** pass onto the lumen of the Bowman's capsule. Therefore, it is considered as a process of **ultra-filtration**.

The amount of the filtrate formed by the kidneys per minute is called **glomerular filtration rate (GFR)**. GFR in a healthy individual is approximately 125 ml/minute, i.e., **180 liters per day**!

The kidneys have built-in mechanisms for the regulation of glomerular filtration rate. One such efficient mechanism is carried out by **juxta glomerular apparatus (JGA)**.

A comparison of the volume of the filtrate formed per day (180 liters per day) with that of the urine released (1.5 litres), suggest that nearly 99 per cent of the filtrate has to be reabsorbed by the renal tubules. This process is called **reabsorption**.

The **tubular epithelial cells** in different segments of nephron perform this either by active or passive mechanisms. For example, substances like glucose, amino acids, Na+, etc., in the filtrate are reabsorbed actively whereas the nitrogenous wastes are absorbed by passive transport. Reabsorption of water also occurs passively in the initial segments of the nephron.

During urine formation, the tubular cells secrete substances like H+, K+ and ammonia into the filtrate. **Tubular secretion** is also an important step in urine formation as it helps in the maintenance of **ionic and acid base balance** of body fluids.

Function of the Tubules

Proximal Convoluted Tubule (PCT)

PCT is lined by **simple cuboidal epithelium** which increases the surface area for reabsorption. Nearly all of the essential nutrients, and 70-80 per cent of electrolytes and water are reabsorbed by this segment.

PCT also helps to maintain the **pH and ionic balance** of the body fluids by selective secretion of hydrogen ions, ammonia and potassium ions into the filtrate and by absorption of HCO3- from it.

Henle's Loop

Reabsorption is minimum in its ascending limb. However, this region plays a significant role in the maintenance of **high osmolarity** of medullary interstitial fluid.

The descending limb of loop of Henle is permeable to water but almost impermeable to electrolytes. This concentrates the filtrate as it moves down.

The ascending limb is impermeable to water but allows transport of electrolytes actively or passively. Therefore, as the concentrated filtrate pass upward, it gets diluted due to the passage of electrolytes to the medullary fluid.

Distal Convoluted Tubule (DCT)

Conditional reabsorption of Na+ and water takes place in this segment. DCT is also capable of reabsorption of HCO3- and selective secretion of hydrogen and potassium ions and NH3 to maintain the **pH and sodium-potassium balance** in blood.

Collecting Duct

This long duct extends from the cortex of the kidney to the inner parts of the medulla.

Large amounts of water could be reabsorbed from this region to produce a concentrated urine.

This segment allows passage of small amounts of urea into the medullary interstitium to keep up the osmolarity.

It also plays a role in the maintenance of pH and ionic balance of blood by the selective secretion of H+ and K+ ions.

Mechanism of Concentration of the Filtrate

Mammals have the ability to produce a concentrated urine. The **Henle's loop** and **vasa recta** play a significant role in this.

The flow of filtrate in the two limbs of Henle's loop is in opposite directions and thus forms a counter current.

The flow of blood through the two limbs of vasa recta is also in a counter current pattern.

The proximity between the Henle's loop and vasa recta, as well as the counter current in them help in maintaining an increasing osmolarity towards the inner medullary interstitium. This gradient is mainly caused by **NaCl** and **urea**.

NaCl is transported by the ascending limb of Henle's loop which is exchanged with the descending limb of vasa recta. NaCl is returned to the interstitium by the ascending portion of vasa recta.

Similarly, small amounts of urea enter the thin segment of the ascending limb of Henle's loop which is transported back to the interstitium by the collecting tubule.

The above described transport of substances facilitated by the special arrangement of Henle's loop and vasa recta is called the **counter current mechanism**. This mechanism helps to maintain a concentration gradient in the medullary interstitium.

Presence of such interstitial gradient helps in an easy passage of water from the collecting tubule thereby concentrating the filtrate (urine). Human kidneys can produce urine nearly four times concentrated than the initial filtrate formed.

Regulation of Kidney Function

The functioning of the kidneys is efficiently monitored and regulated by hormonal feedback mechanisms involving the **hypothalamus, JGA** and to a certain extent, the **heart**.

Osmoreceptors in the body are activated by changes in blood volume, body fluid volume and ionic concentration. An excessive loss of fluid from the body can activate these receptors which stimulate the hypothalamus to release **antidiuretic hormone (ADH)** or **vasopressin** from the **neurohypophysis**.

ADH facilitates **water reabsorption** from latter parts of the tubule, thereby preventing **diuresis [increased or excessive production of urine]**.

An increase in body fluid volume can switch off the osmoreceptors and suppress the ADH release to complete the feedback.

ADH can also affect the kidney function by its constrictory effects on blood vessels. This causes an increase in **blood pressure**. An increase in blood pressure can increase the glomerular blood flow and thereby the GFR.

The JGA plays a complex regulatory role. A fall in glomerular blood flow/glomerular blood pressure/GFR can activate the JG cells to release **renin** which converts **angiotensinogen** in blood to angiotensin I and further to angiotensin II.

Angiotensin II, being a powerful vasoconstrictor, increases the **glomerular blood pressure** and thereby GFR.

Angiotensin II also activates the adrenal cortex to release **Aldosterone**. Aldosterone causes reabsorption of Na+ and water from the distal parts of the tubule. This also leads to an increase in blood pressure and GFR. This complex mechanism is generally known as the **Renin-Angiotensin mechanism**.

An increase in blood flow to the atria of the heart can cause the release of **Atrial Natriuretic Factor (ANF)**. ANF can cause vasodilation (dilation of blood vessels) and thereby decrease the blood pressure. ANF mechanism, therefore, acts as a check on the renin-angiotensin mechanism.

Micturition

Urine formed by the nephrons is ultimately carried to the urinary bladder where it is stored till a voluntary signal is given by the central nervous system (CNS). This signal is initiated by the stretching of the urinary bladder as it gets filled with urine. In response, the stretch receptors on the walls of the bladder send signals to the CNS. The CNS passes on motor messages to initiate the contraction of smooth muscles of the bladder and simultaneous relaxation of the **urethral sphincter** causing the release of urine. The process of release of urine is called **micturition** and the neural mechanisms causing it is called the **micturition reflex**.

An adult human excretes, on an average, **1 to 1.5 litres** of urine per day. The urine formed is a light yellow coloured watery fluid which is **slightly acidic** (pH-6.0) and has a characterestic odour.

On an average, 25-30 gm of urea is excreted out per day. Various conditions can affect the characteristics of urine.

Analysis of urine helps in clinical diagnosis of many metabolic discorders as well as malfunctioning of the kidney. For example, presence of **glucose (Glycosuria)** and **ketone bodies (Ketonuria)** in urine are indicative of **diabetes mellitus**.

Role of other Organs in Excretion

Other than the **kidneys, lungs, liver** and **skin** also help in the elimination of excretory wastes.

Our lungs remove large amounts of CO_2 (approximately 200mL/ minute) and also significant quantities of water every day.

Liver, the largest gland in our body, secretes bile-containing substances like **bilirubin, biliverdin, cholesterol, degraded steroid hormones, vitamins and drugs**. Most of these substances ultimately pass out alongwith digestive wastes.

The sweat and sebaceous glands in the skin can eliminate certain substances through their secretions. Sweat produced by the sweat glands is a watery fluid containing **NaCl**, small amounts of **urea, lactic acid**, etc.

Though the primary function of sweat is to facilitate a cooling effect on the body surface, it also helps in the removal of some of the wastes mentioned above.

Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum. This secretion provides a protective oily covering for the skin. Small amounts of nitrogenous wastes could be eliminated through saliva too.

Disorders of the Excretory System

Malfunctioning of kidneys can lead to accumulation of urea in blood, a condition called **uremia**, which is highly harmful and may lead to kidney failure. In such patients, urea can be removed by a process called **hemodialysis**.

Blood drained from a convenient artery is pumped into a dialyzing unit after adding an anticoagulant like **heparin**. The unit contains a coiled cellophane tube surrounded by a fluid (dialyzing fluid) having the **same composition** as that of plasma except the nitrogenous wastes.

The porous cellophane membrane of the tube allows the passage of molecules based on concentration gradient. As nitrogenous wastes are absent in the dialyzing fluid, these substances freely move out, thereby clearing the blood.

The cleared blood is pumped back to the body through a vein after adding anti-heparin to it. This method is a boon for thousands of uremic patients all over the world.

Kidney transplantation is the ultimate method in the correction of acute renal failures (kidney failure). A functioning kidney is used in transplantation from a donor, preferably a close relative, to minimise its chances of rejection by the immune system of the host. Modern clinical procedures have increased the success rate of such a complicated technique.

Renal calculi: Stone or insoluble mass of crystallised salts (**oxalates**, etc.) formed within the kidney.

Glomerulonephritis: Inflammation of glomeruli of kidney.

Summary

Many nitrogen containing substances, ions, CO2, water, etc., that accumulate in the body have to be eliminated.

Nature of nitrogenous wastes formed and their excretion vary among animals, mainly depending on the habitat (availability of water).

Ammonia, urea and **uric acid** are the major nitrogenous wastes excreted.

Protonephridia, nephridia, malpighian tubules, green glands and the **kidneys** are the common excretory organs in animals. They not only eliminate nitrogenous wastes but also help in the maintenance of **ionic and acid-base balance** of body fluids.

In humans, the excretory system consists of one pair of **kidneys, a pair of ureters, a urinary bladder** and **a urethra**.

Each kidney has over a million tubular structures called **nephrons**. Nephron is the functional unit of kidney and has two portions - **glomerulus** and **renal tubule**.

Glomerulus is a tuft of capillaries formed from afferent arterioles, fine branches of renal artery.

The renal tubule starts with a double walled **Bowman's capsule** and is further differentiated into a **proximal convoluted tubule (PCT), Henle's loop (HL)** and **distal convoluted tubule (DCT)**.

The DCTs of many nephrons join to a common collecting duct many of which ultimately open into the renal pelvis through the medullary pyramids. The Bowman's capsule encloses the glomerulus to form **Malpighian or renal corpuscle**.

Urine formation involves three main processes, i.e., **filtration, reabsorption** and **secretion**.

Filtration is a non-selective process performed by the glomerulus using the glomerular capillary blood pressure. About 1200 ml of blood is filtered by the glomerulus per minute to form 125 ml of filtrate in the Bowman's capsule per minute (GFR).

JGA, a specialised portion of the nephrons, plays a significant role in the regulation of GFR.

Nearly 99 per cent reabsorption of the filtrate takes place through different parts of the nephrons.

PCT is the major site of reabsorption and selective secretion. HL [Henle's Loop] primarily helps to maintain **osmolar gradient** within the kidney interstitium.

DCT and collecting duct allow extensive **reabsorption** of water and certain electrolytes, which help in osmoregulation: H^+, K^+ and NH_3 could be secreted into the filtrate by the tubules to maintain the **ionic balance** and **pH** of body fluids.

A counter current mechanism operates between the two limbs of the loop of Henle and those of vasa recta (capillary parallel to Henle's loop). The filtrate gets concentrated as it moves down the descending limb but is diluted by the ascending limb. Electrolytes and urea are retained in the interstitium by this arrangement.

DCT and collecting duct concentrate the filtrate about four times, an excellent mechanism of conservation of water.

Urine is stored in the urinary bladder till a voluntary signal from CNS carries out its release through urethra, i.e., micturition. Skin, lungs and liver also assist in excretion.

Sexual Reproduction - Human Reproductive System, Male and Female Reproductive System, Gametogenesis, Menstrual Cycle, Fertilisation.

Reproduction In Animals

There are two modes by which animals reproduce. These are:

Sexual reproduction, and

Asexual reproduction.

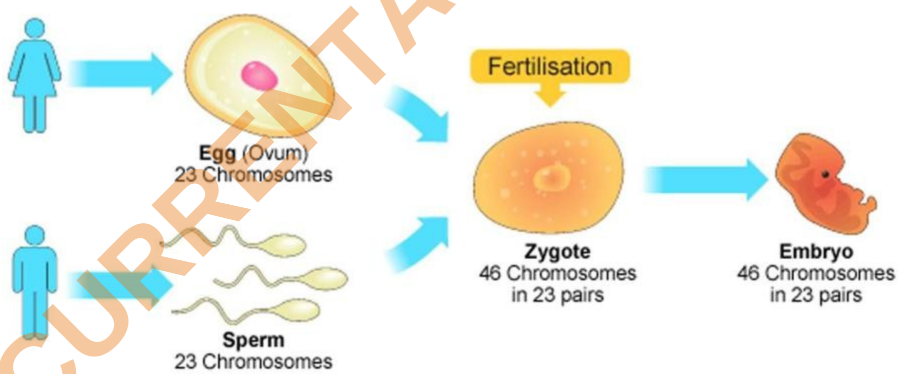
There are many organisms which do not reproduce (mules, sterile worker bees, infertile human couples, etc.).

Sexual Reproduction

The reproductive parts in animals produce **gametes** that fuse to form a **zygote**. It is the zygote which develops into a new individual. This type of reproduction beginning from the fusion of male and female gametes is called **sexual reproduction**.

The male reproductive organs include a pair of **testes (singular, testis)**, **two sperm ducts** and a **penis**. The testes produce the male gametes called **sperms**.

The female reproductive organs are a **pair of ovaries, oviducts (fallopian tubes)** and the **uterus**. **Ovary** produces female gametes called **ova (eggs)**.



In human beings, a single matured egg is released into the oviduct by one of the ovaries every month. **Uterus** is the part where development of the baby takes place. Like the sperm, an egg is also a single cell.

The first step in the process of reproduction is the fusion of a sperm and an ovum. When sperms come in contact with an egg, one of the sperms may fuse with the egg. Such fusion of the egg and the sperm is called **fertilization**.

Internal and External Fertilization

During fertilization, the nuclei of the sperm and the egg fuse to form a single nucleus. This results in the formation of a fertilized egg or zygote.

Fertilization which takes place inside the female body is called **internal fertilization**. Internal fertilization occurs in many animals including humans, cows, dogs and hens.

During spring or rainy season, frogs and toads move to ponds and slow flowing streams. When the male and female come together in water, the female lays hundreds of eggs.

Unlike hen's egg, frog's egg is not covered by a shell and it is comparatively very delicate. A layer of jelly holds the eggs together and provides protection to the eggs.

As the eggs are laid, the male deposits sperms over them. Each sperm swims randomly in water with the help of its long tail. The sperms come in contact with the eggs. This results in fertilization.

This type of fertilization in which the fusion of a male and a female gamete takes place outside the body of the female is called **external fertilization**. It is very common in **aquatic animals** such as fish, starfish, etc.

Asexual Reproduction

In each hydra, there may be one or more bulges. These bulges are the developing new individuals and they are called **buds**. In hydra, the new individuals develop as outgrowths from a single parent. This type of reproduction in which only a single parent is involved is called **asexual reproduction**. Since new individuals develop from the buds in hydra, this type of asexual reproduction is called **budding**.

Another method of asexual reproduction is observed in the microscopic organism, amoeba. Reproduction in which an animal reproduces by dividing into two individuals is called **binary fission**. Apart from budding and binary fission, there are other methods by which a single parent reproduces the young ones.

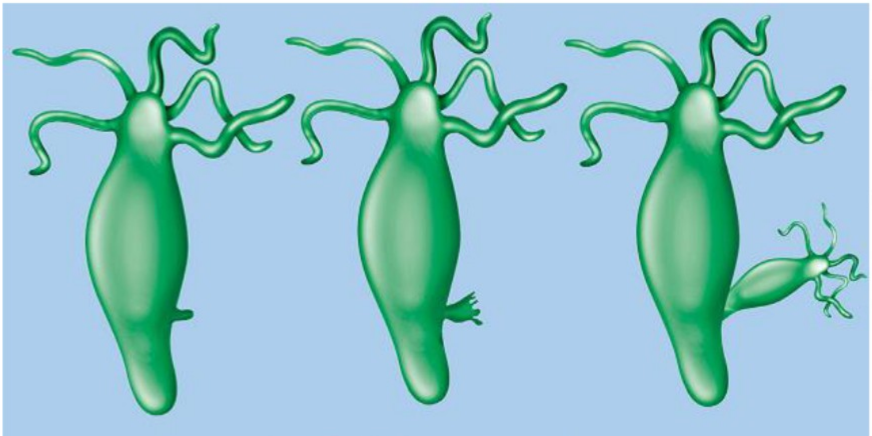


Fig. 9.11 : Budding in Hydra

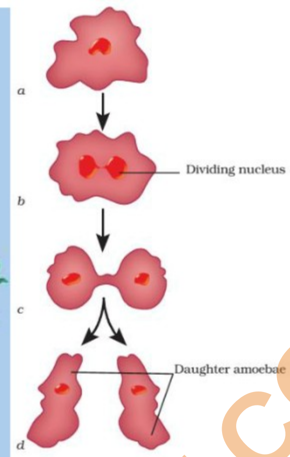


Fig. 9.12 : Binary fission in Amoeba

Human Reproductive System

The reproductive events in humans include

formation of gametes (**gametogenesis**), i.e., **sperms** in males and **ovum** in females,

transfer of sperms into the female genital tract (**insemination**),

fusion of male and female gametes (**fertilisation**) leading to formation of **zygote**.

formation and development of **blastocyst** and its attachment to the uterine wall (**implantation**),

embryonic development (**gestation**) and

delivery of the baby (**parturition**).

Male Reproductive System

The male reproductive system is located in the pelvis region. It includes a pair of **testes** along with **accessory ducts, glands** and the external **genitalia**.

The testes are situated outside the abdominal cavity within a pouch called **scrotum**. The scrotum helps in **maintaining the low temperature** of the testes (2–2.5$_0$C lower than the normal internal body temperature) necessary for spermatogenesis.

Each testis has about 250 testicular lobules. Each lobule contains one to three highly coiled **seminiferous tubules** in which **sperms are produced**.

Each seminiferous tubule is lined on its inside by two types of cells called **male germ cells (spermatogonia)** and **Sertoli cells**.

The male germ cells undergo **meiotic divisions** finally leading to sperm formation, while Sertoli cells provide **nutrition** to the germ cells.

The regions outside the seminiferous tubules called interstitial spaces, contain small blood vessels and interstitial cells or **Leydig cells**. Leydig cells synthesise and secrete testicular hormones called **androgens** [a male sex hormone, such as **testosterone**. Androgens stimulates or controls the development and maintenance of male characteristics].

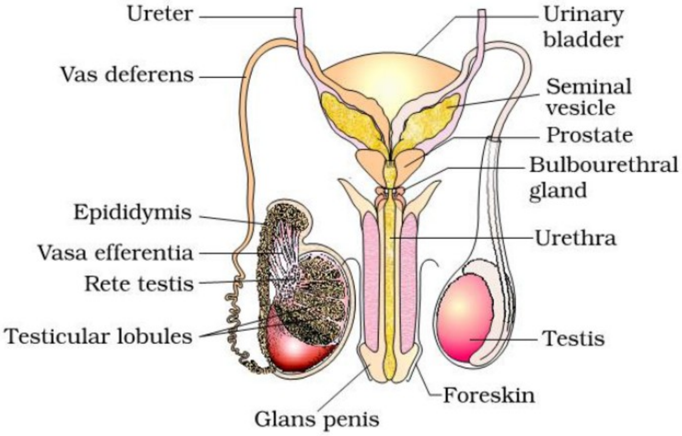


Figure 3.1(b) Diagrammatic view of male reproductive system (part of testis is open to show inner details)

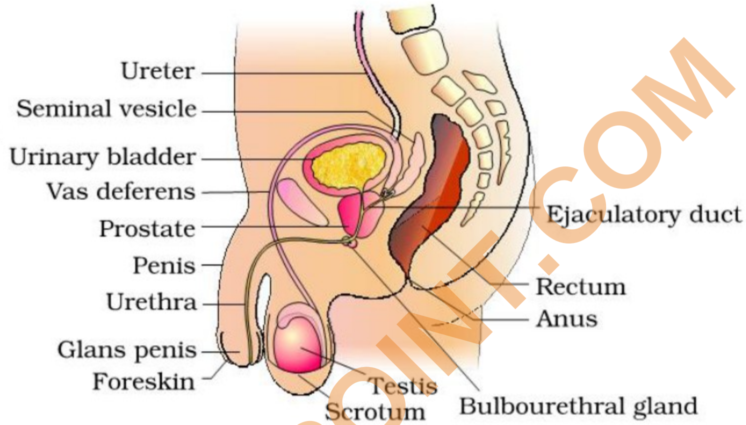


Figure 3.1(a) Diagrammatic sectional view of male pelvis showing reproductive system

The male sex accessory ducts include **rete testis, vasa efferentia, epididymis** and **vas deferens**.

The seminiferous tubules of the testis open into the vasa efferentia through rete testis.

The vasa efferentia leave the testis and open into epididymis. The epididymis leads to vas deferens that ascends to the abdomen and loops over the urinary bladder. It receives a duct from **seminal vesicle** [gland that secrete many of the components of semen] and opens into urethra as the ejaculatory duct. These ducts **store and transport** the sperms from the testis to the outside through urethra.

The urethra originates from the urinary bladder and extends through the penis to its external opening called urethral meatus.

The penis is the male external genitalia. It is made up of special tissue that helps in erection of the penis to facilitate insemination. The enlarged end of penis called the glans penis is covered by a loose fold of skin called foreskin.

The male accessory glands include paired seminal vesicles, a prostate [releasing a fluid component of semen] and paired bulbourethral glands.

Secretions of these glands constitute the **seminal plasma** which is **rich in fructose, calcium and certain enzymes**.

The secretions of bulbourethral glands also helps in the **lubrication** of the penis.

Female Reproductive System

The female reproductive system consists of a pair of **ovaries** along with a pair of **oviducts, uterus, cervix, vagina** and the external **genitalia** located in pelvic region.

These parts of the system along with a pair of the mammary glands are integrated structurally and functionally to support the processes of ovulation, fertilisation, pregnancy, birth and child care.

Ovaries are the primary female sex organs [testis in males] that produce the female gamete (**ovum**) [sperm in males] and several **steroid hormones** (ovarian hormones).

The ovaries are located one on each side of the lower abdomen. Each ovary is connected to the pelvic wall and uterus by ligaments.

Each ovary is covered by a thin epithelium which encloses the ovarian stroma. The stroma is divided into two zones – a peripheral cortex and an inner medulla.

The **oviducts (fallopian tubes), uterus** and **vagina** constitute the female accessory ducts.

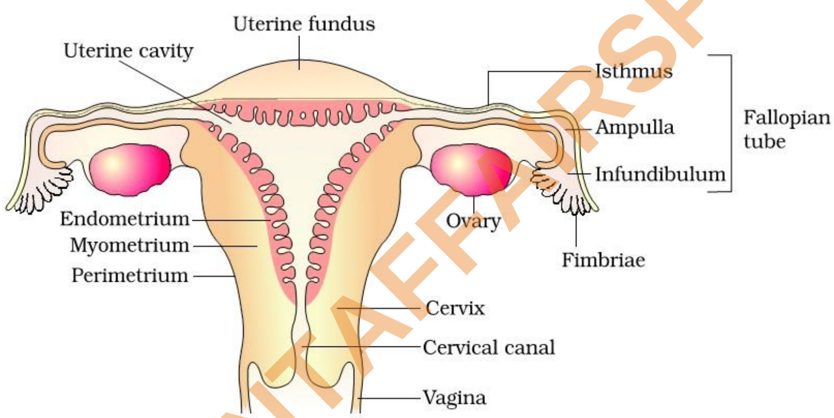


Figure 3.3 (b) Diagrammatic sectional view of the female reproductive system

Each fallopian tube extends from the periphery of each ovary to the uterus, the part closer to the ovary is the funnel-shaped infundibulum.

The edges of the infundibulum possess finger-like projections called fimbriae, which help in **collection of the ovum after ovulation**. The infundibulum leads to a wider part of the oviduct called ampulla.

The last part of the oviduct, isthmus has a narrow lumen and it joins the uterus. The uterus is single and it is also called womb. The shape of the uterus is like an inverted pear.

It is supported by ligaments attached to the pelvic wall. The uterus opens into vagina through a narrow cervix. The cavity of the cervix is called cervical canal which along with vagina forms the birth canal.

The wall of the uterus has three layers of tissue. The external thin membranous perimetrium, middle thick layer of smooth muscle, myometrium and inner glandular layer called endometrium that lines the uterine cavity.

The **endometrium** undergoes cyclical changes during **menstrual cycle** while the **myometrium** exhibits strong contraction during **delivery** of the baby.

The female external genitalia include mons pubis, labia majora, labia minora, hymen and clitoris.

Mons pubis is a cushion of fatty tissue covered by skin and pubic hair. The labia majora are fleshy folds of tissue, which extend down from the mons pubis and surround the vaginal opening.

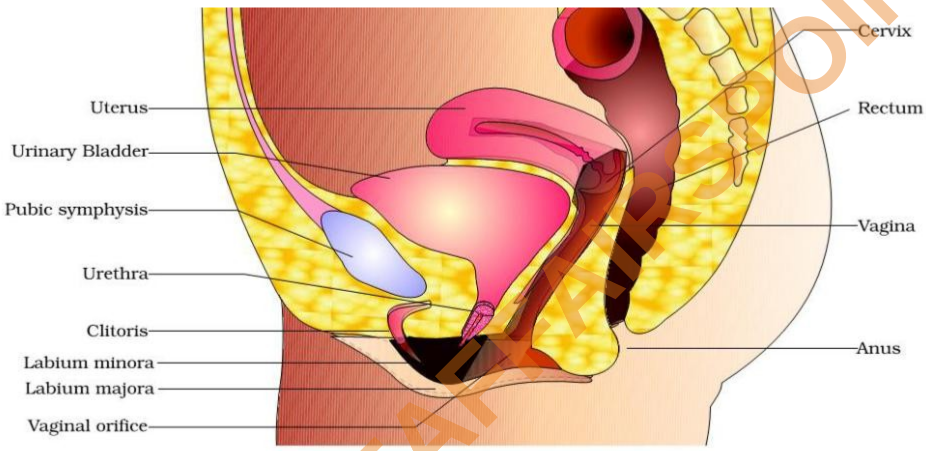


Figure 3.3 (a) Diagrammatic sectional view of female pelvis showing reproductive system

Thelabia minora are paired folds of tissue under the labia majora. The opening of the vagina is often covered partially by a membrane called hymen.

The clitoris is a tiny finger-like structure which lies at the upper junction of the two labia minora above the urethral opening.

The hymen is often torn during the first **coitus (intercourse)**. However, it can also be broken by a sudden fall or jolt, insertion of a vaginal tampon, active participation in some sports like horseback riding, cycling, etc.

In some women the hymen persists even after coitus. In fact, the presence or absence of hymen is **not a reliable indicator of virginity** or sexual experience.

A functional mammary gland is characteristic of all female mammals. The mammary glands are paired structures (breasts) that contain **glandular tissue** and variable amount of fat.

The glandular tissue of each breast is divided into 15-20 mammary lobes containing clusters of cells called **alveoli**. The cells of alveoli **secrete milk**, which is stored in the cavities (lumens) of alveoli. The alveoli open into mammary tubules.

The tubules of each lobe join to form a mammary duct. Several mammary ducts join to form a wider mammary ampulla which is connected to lactiferous duct through which milk is sucked out.

Gametogenesis

The primary sex organs – the **testis in the males** and the **ovaries in the females** produce gametes, i.e, **sperms** and **ovum**, respectively, by the process called **gametogenesis**.

In testis, the immature **male germ cells (spermatogonia)** produce sperms by spermatogenesis that begins at puberty.

The spermatogonia (sing. spermatogonium) present on the inside wall of seminiferous tubules multiply by **mitotic division** and increase in numbers. Each spermatogonium is **diploid** and contains 46 chromosomes.

Some of the spermatogonia called primary spermatocytes periodically undergo **meiosis**.

A primary spermatocyte completes the first meiotic division (reduction division) leading to formation of two equal, **haploid cells** called secondary spermatocytes, which have only 23 chromosomes each.

The secondary spermatocytes undergo the **second meiotic division** to produce four equal, haploid spermatids.

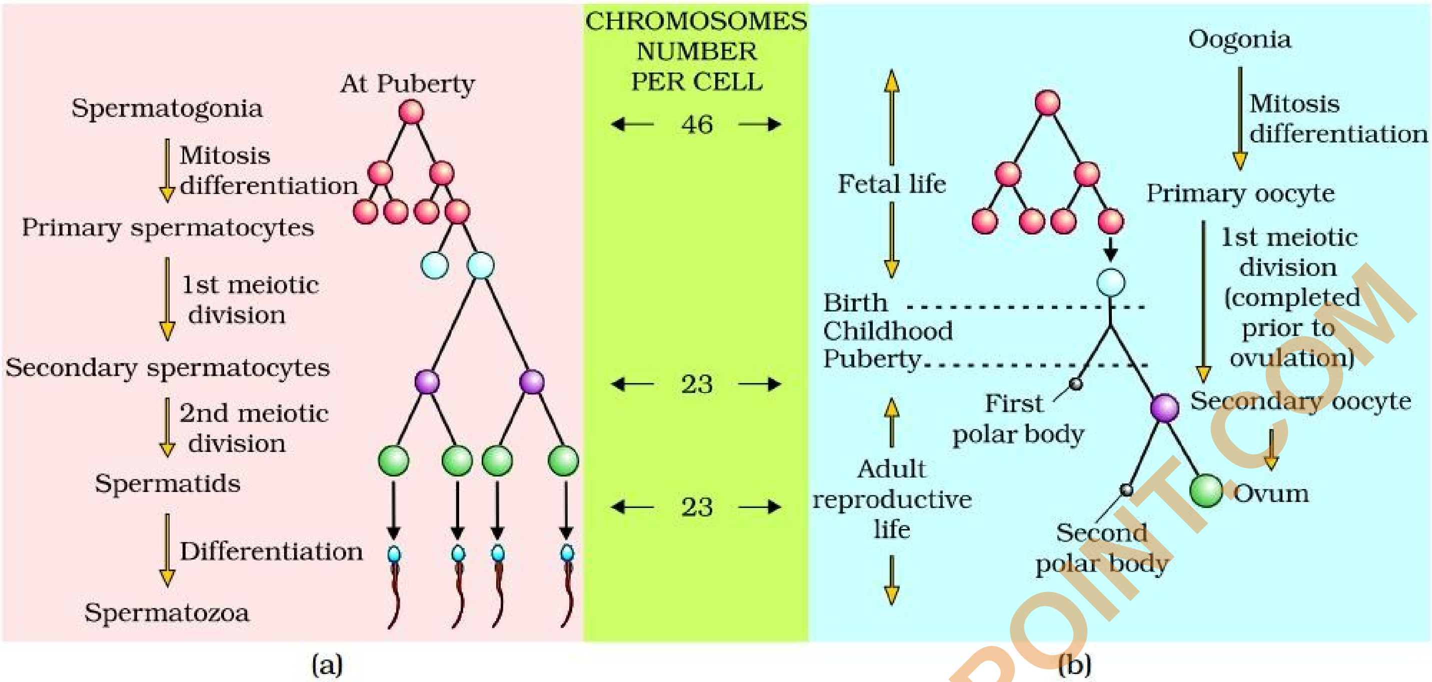


Figure 3.8 Schematic representation of (a) Spermatogenesis; (b) Oogenesis

What would be the number of chromosome in the spermatids? 23 chromosomes.

The spermatids are transformed into spermatozoa (sperms) by the process called spermiogenesis. After spermiogenesis, sperm heads become embedded in the Sertoli cells, and are finally released from the seminiferous tubules by the process called spermiation.

Spermatogenesis starts at the age of puberty due to significant increase in the secretion of **gonadotropin releasing hormone (GnRH)**. This, if you recall, is a **hypothalamic hormone**.

The increased levels of GnRH then acts at the **anterior pituitary gland** and stimulates secretion of two **gonadotropins** – **luteinising hormone (LH)** and **follicle stimulating hormone (FSH)**.

LH acts at the **Leydig cells** and stimulates **synthesis and secretion of androgens**. Androgens, in turn, stimulate the process of spermatogenesis.

FSH acts on the **Sertoli cells** and stimulates secretion of some factors which help in the process of spermiogenesis.

Sperm is a microscopic structure composed of a head, neck, a middle piece and a tail. A plasma membrane envelops the whole body of sperm.

The sperm head contains an elongated haploid nucleus, the anterior portion of which is covered by a cap-like structure, acrosome. The acrosome is filled with enzymes that help fertilization of the ovum.

The middle piece possesses numerous **mitochondria**, which produce energy for the movement of tail that facilitate sperm motility essential for fertilization.

The human male ejaculates about 200 to 300 million sperms during a coitus of which, for normal fertility, at least 60 per cent sperms must have normal shape and size and at least 40 per cent of them must show vigorous motility.

Sperms released from the seminiferous tubules, are transported by the accessory ducts.

Secretions of epididymis, vas deferens, seminal vesicle and prostate are essential for **maturation and motility of sperms**.

The seminal plasma along with the sperms constitute the **semen**. The functions of male sex accessory ducts and glands are maintained by the **testicular hormones (androgens)**.

The process of formation of a mature female gamete is called **oogenesis** which is markedly different from spermatogenesis.

Oogenesis is initiated during the **embryonic development** stage when a couple of million gamete mother cells (oogonia) are formed within each fetal ovary; **no more oogonia are formed and added after birth**.

These cells start division and enter into prophase-I of the meiotic division and get temporarily arrested at that stage, called **primary oocytes**.

Each primary oocyte then gets surrounded by a layer of **granulosa cells** and is called the **primary follicle**.

A large number of these follicles degenerate during the phase from **birth to puberty**. Therefore, at puberty only 60,000-80,000 primary follicles are left in each ovary.

The primary follicles get surrounded by more layers of granulosa cells and a new theca and are called secondary follicles. The secondary follicle soon transforms into a tertiary follicle which is characterised by a fluid filled cavity called antrum.

At this stage the primary oocyte within the **tertiary follicle** grows in size and completes its first **meiotic division**. It is an unequal division resulting in the formation of a large **haploid secondary oocyte** and a tiny first polar body.

The secondary oocyte retains bulk of the nutrient rich cytoplasm of the primary oocyte.

The tertiary follicle further changes into the mature follicle or **Graafian follicle**. The secondary oocyte forms a new membrane called zona pellucida surrounding it.

The Graafian follicle now ruptures to release the secondary oocyte (**ovum**) from the ovary by the process called **ovulation**.

Menstrual Cycle

The reproductive cycle in the female primates (e.g. monkeys, apes and human beings) is called menstrual cycle. The first menstruation begins at puberty and is called **menarche**.

In human females, menstruation is repeated at an average interval of about 28/29 days, and the cycle of events starting from one menstruation till the next one is called the **menstrual cycle**.

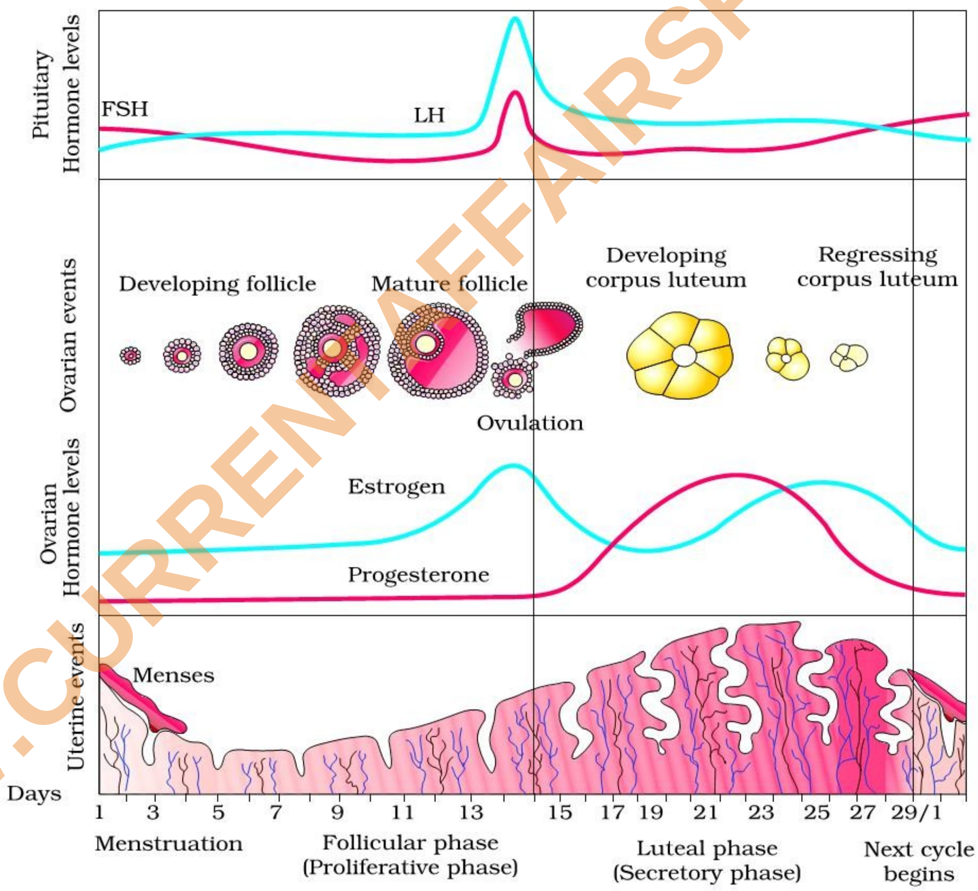


Figure 3.9 Diagrammatic presentation of various events during a menstrual cycle

One ovum is released (ovulation) during the **middle** of each menstrual cycle. The cycle starts with the menstrual phase, when menstrual flow occurs and it lasts for 3-5 days.

The menstrual flow results due to breakdown of endometrial lining of the uterus and its blood vessels which forms liquid that comes out through vagina. Menstruation only occurs if the released ovum is **not fertilized**.

Lack of menstruation may be **indicative of pregnancy**. However, it may also be caused due to some other underlying causes like stress, poor health etc.

The menstrual phase is followed by the follicular phase. During this phase, the primary follicles in the ovary grow to become a fully mature Graafian follicle and simultaneously the endometrium of uterus regenerates through proliferation.

These changes in the ovary and the uterus are induced by changes in the levels of pituitary and ovarian hormones.

The secretion of gonadotropins (LH and FSH) increases gradually during the follicular phase, and stimulates follicular development as well as secretion of **estrogens** by the growing follicles.

Both LH and FSH attain a peak level in the middle of cycle (about 14 th day). Rapid secretion of LH leading to its maximum level during the mid-cycle called LH surge induces rupture of Graafian follicle and thereby the **release of ovum** (ovulation).

The ovulation (ovulatory phase) is followed by the luteal phase during which the remaining parts of the Graafian follicle transform as the corpus luteum.

The corpus luteum secretes large amounts of **progesterone** which is essential for maintenance of the endometrium. Such an endometrium is necessary for implantation of the fertilised ovum and other events of pregnancy.

During pregnancy all events of the menstrual cycle stop and there is no menstruation. In the absence of fertilisation, the corpus luteum degenerates. This causes disintegration of the endometrium leading to menstruation, marking a new cycle.

In human beings, menstrual cycles ceases around 50 years of age; that is termed as **menopause**.

Cyclic menstruation is an indicator of normal reproductive phase and extends between menarche and menopause.

Fertilisation And Implantation

During copulation (coitus) semen is released by the penis into the vagina (insemination). The motile sperms swim rapidly, pass through the cervix, enter into the uterus and finally reach the ampullary region of the **fallopian tube**.

The ovum released by the ovary is also transported to the ampullary region where fertilisation takes place.

Fertilisation can only occur if the ovum and sperms are transported simultaneously to the **ampullary region**. This is the reason why not all copulations lead to fertilisation and pregnancy.

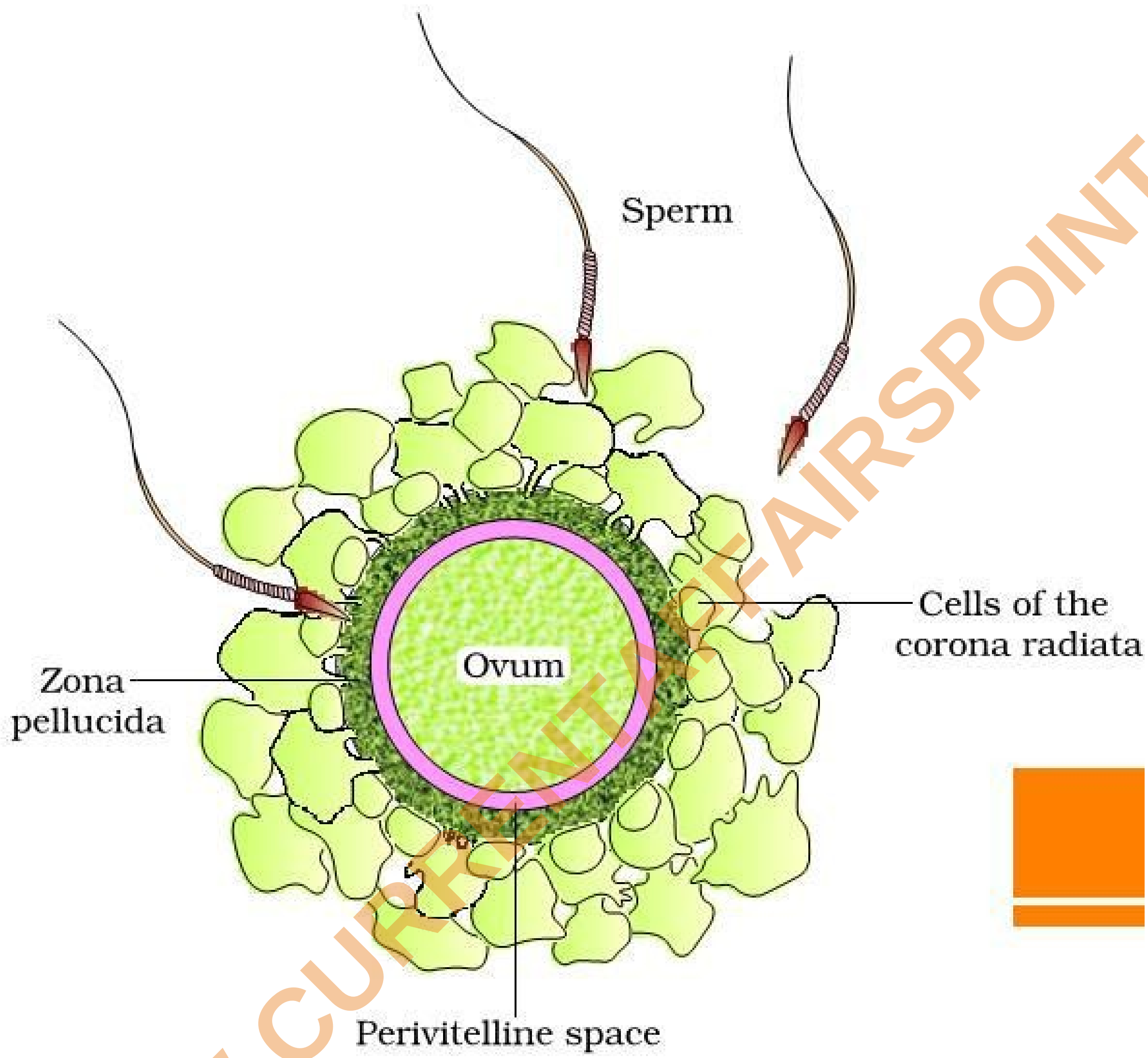
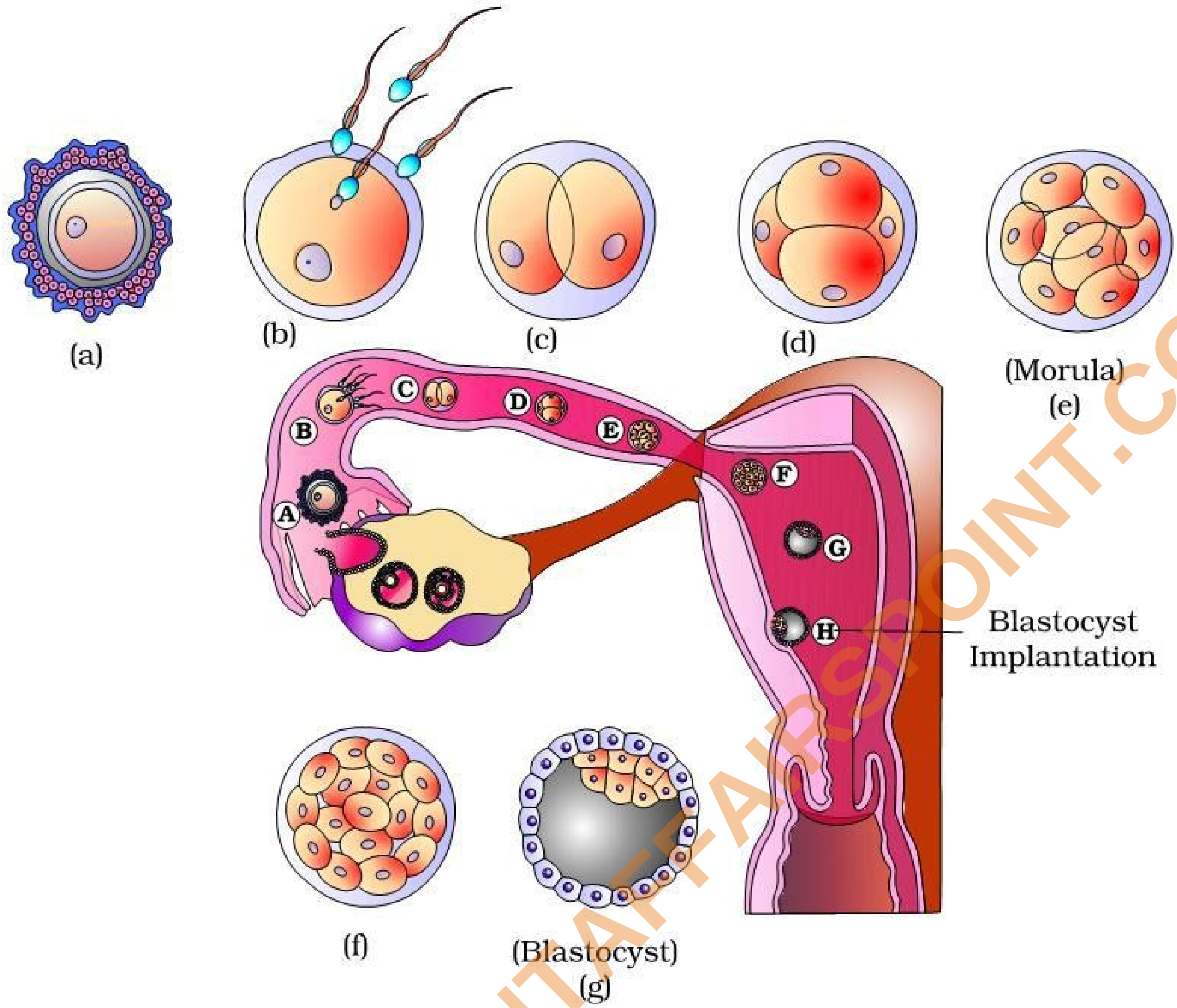


Figure 3.10 Ovum surrounded by few sperms

The process of fusion of a sperm with an ovum is called fertilisation. During fertilisation, a sperm comes in contact with the **zona pellucida** layer of the ovum and induces changes in the membrane that block the entry of additional sperms. Thus, it ensures that **only one sperm** can fertilise an ovum.

The secretions of the acrosome help the sperm enter into the cytoplasm of the ovum through the zona pellucida and the plasma.



1 Transport of ovum, fertilisation and passage of growing embryo through fallopian tube

Ovum surrounded by few sperm blastomeres is called a **morula**. The morula continues to divide and transforms into blastocyst as it moves further into the uterus.

The blastomeres in the blastocyst are arranged into an outer layer called **trophoblast** and an inner group of cells attached to trophoblast called the inner cell mass. The trophoblast layer then gets attached to the **endometrium** and the inner cell mass gets differentiated as the **embryo**.

After attachment, the uterine cells divide rapidly and covers the blastocyst. As a result, the blastocyst becomes embedded in the endometrium of the uterus. This is called **implantation** and it leads to pregnancy.

In Vitro Fertilization

Have you heard of test tube babies? In some women **oviducts are blocked**. These women are unable to bear babies because sperms cannot reach the egg for fertilization. In such cases, doctors collect freshly released egg and sperms and keep them together for a few hours for IVF or **In Vitro Fertilization** (**fertilization outside the body**).

In case fertilization occurs, the zygote is allowed to develop for about a week and then it is placed in the mother's uterus. Complete development takes place in the uterus and the baby is born like any other baby.

Babies born through this technique are **called test-tube babies**. This term is actually misleading because babies cannot grow in test tubes.

Pregnancy And Embryonic Development

After implantation, finger-like projections appear on the trophoblast called chorionic villi which are surrounded by the uterine tissue and maternal blood.

The **chorionic villi** and **uterine tissue** become interdigitated with each other and jointly form a structural and functional unit between developing embryo (foetus) and maternal body called **placenta**.

The placenta facilitate the supply of oxygen and nutrients to the embryo and also removal of carbon dioxide and excretory/waste materials produced by the embryo.

The placenta is connected to the embryo through an **umbilical cord** which helps in the transport of substances to and from the embryo.

Placenta also acts as an **endocrine tissue** and produces several hormones like human chorionic gonadotropin (hCG), human placental lactogen (hPL), estrogens, progestogens, etc.

In the later phase of pregnancy, a hormone called relaxin is also secreted by the ovary. Let us remember that hCG, hPL and relaxin are **produced in women only during pregnancy**.

In addition, during pregnancy the levels of other hormones like estrogens, progestogens, cortisol, prolactin, thyroxine, etc., are increased several folds in the maternal blood.

Increased production of these hormones is essential for supporting the fetal growth, metabolic changes in the mother and maintenance of pregnancy.

Immediately after implantation, the inner cell mass (embryo) differentiates into an outer layer calledectoderm and an inner layer called endoderm. A mesoderm soon appears between the ectoderm and the endoderm [**triploblastic**]. These three layers give rise to all tissues (organs) in adults.

It needs to be mentioned here that the inner cell mass contains certain cells called **stem cells** which have the potency to give rise to all the tissues and organs.

The human pregnancy lasts 9 months. In human beings, after one month of pregnancy, the embryo's heart is formed. The first sign of growing foetus may be noticed by listening to the heart sound carefully through the stethoscope.

By the end of the second month of pregnancy, the foetus develops limbs and digits. By the end of 12 weeks (first trimester), most of the major organ systems are formed, for example, the limbs and external genital organs are well developed.

The first movements of the foetus and appearance of hair on the head are usually observed during the fifth month. By the end of about 24 weeks (end of second trimester), the body is covered with fine hair, eye-lids separate, and eyelashes are formed. By the end of nine months of pregnancy, the foetus is fully developed and is ready for delivery.

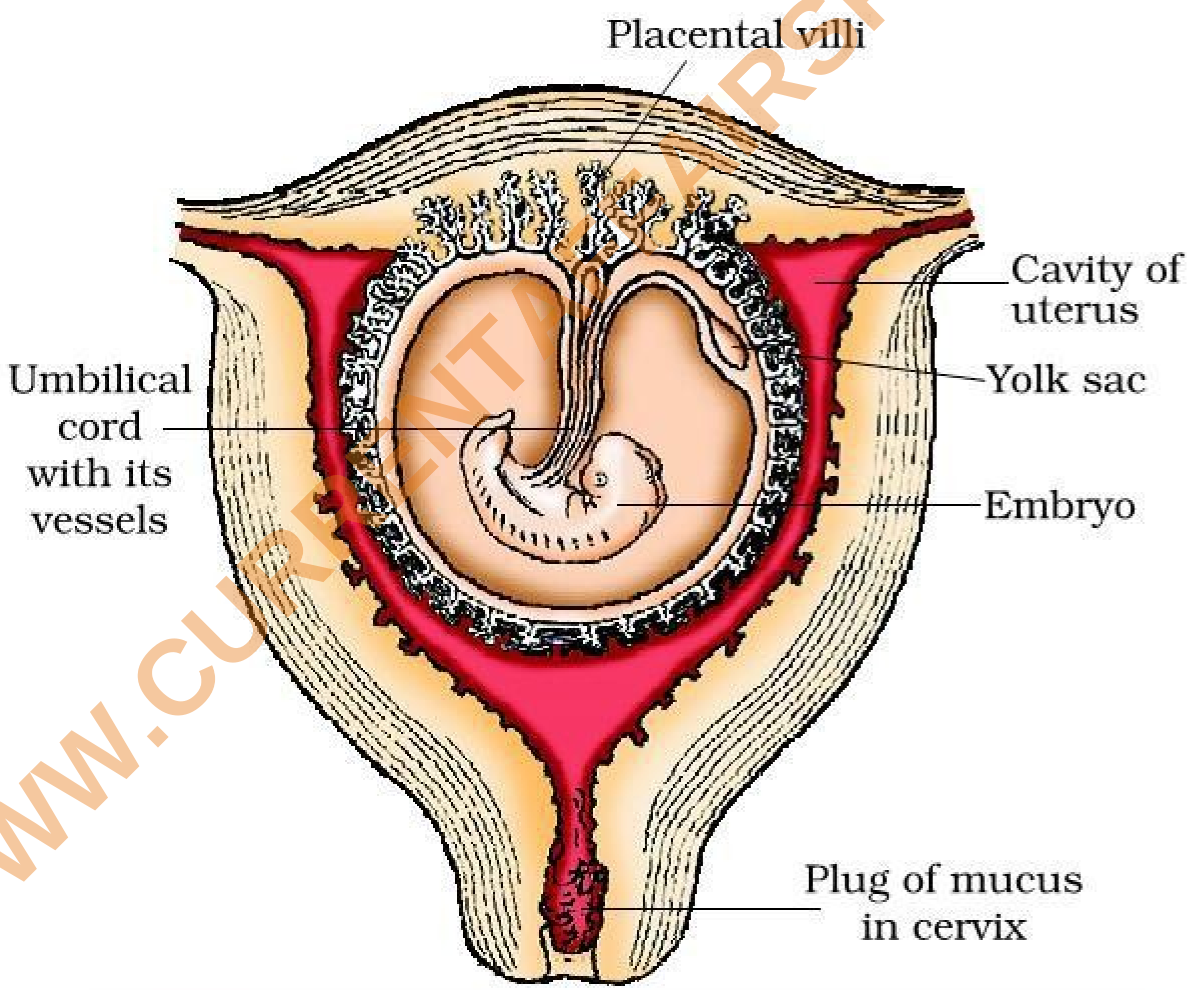


Figure 3.12 The human foetus within the uterus

Parturition And Lactation

The average duration of human pregnancy is about 9 months which is called the gestation period. Vigorous contraction of the uterus at the end of pregnancy causes expulsion/delivery of the foetus. This process of delivery of the foetus (childbirth) is called **parturition**.

Parturition is induced by a complex neuroendocrine mechanism. The signals for parturition originate from the fully developed foetus and the placenta which induce mild uterine contractions called foetal ejection reflex. This triggers release of **oxytocin** from the maternal **pituitary**.

Oxytocin acts on the uterine muscle and causes stronger uterine contractions, which in turn stimulates further secretion of oxytocin. The stimulatory reflex between the uterine contraction and oxytocin secretion continues resulting in stronger and stronger contractions. This leads to expulsion of the baby out of the uterus through the birth canal – parturition.

Soon after the infant is delivered, the placenta is also expelled out of the uterus. The mammary glands of the female undergo differentiation during pregnancy and starts producing milk towards the end of pregnancy by the process called **lactation**. This helps the mother in feeding the newborn.

The milk produced during the initial few days of lactation is called **colostrum** which contains several **antibodies** absolutely essential to develop resistance for the new-born babies.

Breast-feeding during the initial period of infant growth is recommended by doctors for bringing up a healthy baby.

Summary

Humans are sexually reproducing and viviparous.

The male reproductive system is composed of a pair of testes, the male sex accessory ducts and the accessory glands and external genitalia.

Each testis has about 250 compartments called **testicular lobules**, and each lobule contains one to three highly coiled **seminiferous tubules**.

Each seminiferous tubule is lined inside by spermatogonia and Sertoli cells.

The spermatogonia undergo meiotic divisions leading to **sperm formation**, while Sertoli cells provide nutrition to the dividing germ cells.

The **Leydig cells** outside the seminiferous tubules, synthesise and secrete testicular hormones called **androgens**.

The male external genitalia is called penis.

The female reproductive system consists of a pair of ovaries, a pair of oviducts, a uterus, a vagina, external genitalia, and a pair of mammary glands.

The ovaries produce the female gamete (ovum) and some **steroid hormones** (ovarian hormones).

Ovarian follicles in different stages of development are embedded in the stroma.

The oviducts, uterus and vagina are female accessory ducts.

The uterus has three layers namely perimetrium, myometrium and endometrium.

The female external genitalia includes mons pubis, labia majora, labia minora, hymen and clitoris.

The mammary glands are one of the female secondary sexual characteristics.

Spermatogenesis results in the formation of sperms that are transported by the male sex accessory ducts.

A normal human sperm is composed of a head, neck, a middle piece and tail.

The process of formation of mature female gametes is called oogenesis.

The reproductive cycle of female primates is called menstrual cycle.

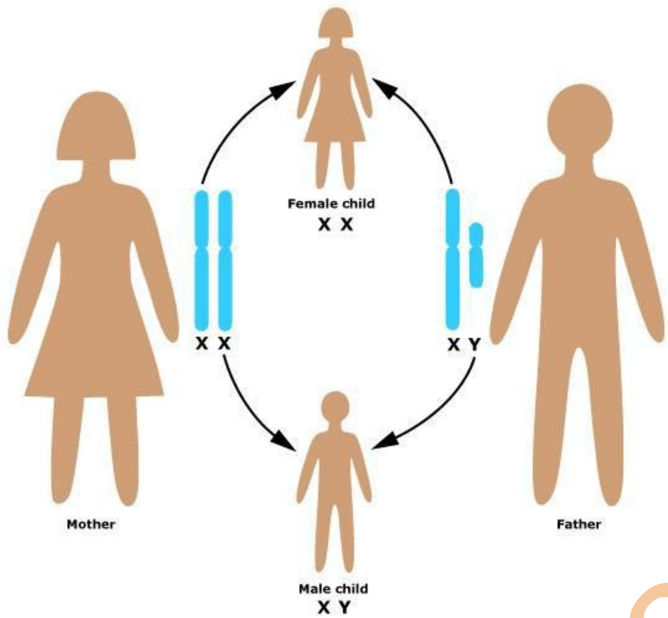
Menstrual cycle starts only after attaining sexual maturation (puberty).

During ovulation only one ovum is released per menstrual cycle.

The cyclical changes in the ovary and the uterus during menstrual cycle are induced by changes in the levels of **pituitary** and **ovarian hormones**.

After coitus, sperms are transported to the junction of the isthmus and ampulla, where the sperm fertilizes the ovum leading to formation of a diploid zygote.

The presence of X or Y chromosome in the sperm determines the sex of the embryo.



The zygote undergoes repeated **mitotic division** to form a blastocyst, which is implanted in the uterus resulting in pregnancy.

After nine months of pregnancy, the fully developed foetus is ready for delivery.

The process of childbirth is called parturition which is induced by a complex neuroendocrine mechanism involving cortisol, estrogens and **oxytocin**.

Mammary glands differentiate during pregnancy and secrete milk after child-birth.

The new-born baby is fed milk by the mother (lactation) during the initial few months of growth.

Reproduction in Humans

The human body undergoes several changes during adolescence. These changes mark the onset of puberty. During puberty the secretion of sweat glands and **sebaceous glands (oil glands)** increases.

The changes which occur at adolescence are controlled by **hormones**. Hormones are chemical substances. These are secretions from **endocrine glands**, or endocrine system.

The male hormone or **TESTOSTERONE** begins to be released by the testes at the onset of puberty. This causes changes in boys like the growth of facial hair.

Once puberty is reached in girls, ovaries begin to produce the female hormone or **ESTROGEN** which makes the breasts develop. Milk secreting glands or mammary glands develop inside the breasts.

The production of these hormones is under the control of another hormone secreted from an **endocrine gland** called **pituitary gland**.

Further, the sex hormones are under the control of hormones from the pituitary gland. The pituitary secretes many hormones, one of which makes ova mature in the ovaries and sperms form in the testes.

Endocrine == glands which secrete hormones or other products directly into the blood or lymph

Exocrine == glands which secrete their products through ducts opening on to an epithelial surface.

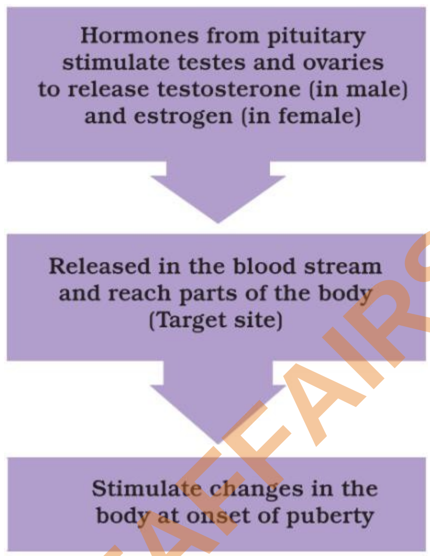


Fig. 10.3 : The onset of puberty is controlled by hormones

Endocrine glands release hormones into the bloodstream to reach a particular body part called **target site**. The target site responds to the hormone. There are many **endocrine glands or ductless glands** in the body.

Reproductive Phase of Life in Humans

Adolescents become capable of reproduction when their testes and ovaries begin to produce gametes.

The capacity for maturation and production of gametes lasts for a much longer time in males than in females.

In females, the reproductive phase of life begins at puberty (10 to 12 years of age) and generally lasts till the age of approximately 45 to 50 years.

The ova begin to mature with the onset of puberty. One ovum matures and is released by one of the ovaries once in about 28 to 30 days.

During this period, the wall of the uterus becomes thick so as to receive the egg, in case it is fertilized and begins to develop. This results in pregnancy.

If fertilization does not occur, the released egg, and the thickened lining of the uterus along with its blood vessels are shed off. This causes bleeding in women which is called **menstruation**.

Menstruation occurs once in about 28 to 30 days. The first menstrual flow begins at puberty and is termed **menarche**.

At 45 to 50 years of age, the menstrual cycle stops. Stoppage of menstruation is termed **menopause**. Initially, menstrual cycle may be irregular. It take some time to become regular.

Menstrual cycle is controlled by **hormones**. The cycle includes the maturation of the egg, its release, thickening of uterine wall and its breakdown if pregnancy does not occur.

In case the egg is fertilized it begins to divide and then gets embedded in the uterus for further development.

Inside the fertilized egg or zygote is the instruction for determining the sex of the baby. This instruction is present in the thread-like structures, called **chromosomes** in the fertilized egg.

All human beings have 23 pairs of chromosomes in the nuclei of their cells. Two chromosomes out of these are the sex chromosomes, named X and Y.

A female has two X chromosomes, while a male has one X and one Y chromosome. The gametes (egg and sperm) have only one set of chromosomes. The unfertilized egg always has one X chromosome. Sperms are of two kinds. One kind has an X chromosome, and the other kind has a Y chromosome.

Reproductive Health and Birth Control Methods

India was amongst the first countries in the world to initiate action plans and programmes at a national level to attain total reproductive health as a social goal. These programmes called '**family planning**' were initiated in 1951.

Statutory ban on **amniocentesis** (a foetal sex determination test based on the chromosomal pattern in the amniotic fluid surrounding the developing embryo) for sex-determination to legally check increasing female feticides.

'Saheli'-a new oral contraceptive for the females was developed by scientists at Central Drug Research Institute (CDRI) in Lucknow, India.

A wide range of contraceptive methods are presently available which could be broadly grouped into the following categories, namely Natural/Traditional, Barrier, IUDs, Oral contraceptives, Injectables, Implants and Surgical methods.

Natural Methods

Natural methods work on the principle of avoiding chances of ovum and sperms meeting. Periodic abstinence is one such method in which the couples avoid or abstain from coitus [sexual intercourse] from day 10 to 17 of the menstrual cycle when ovulation could be expected. As chances of fertilization are very high during this period, it is called the fertile period.

Withdrawal or coitus interruptus is another method in which the male partner withdraws his penis from the vagina just before ejaculation so as to avoid insemination.

Lactational amenorrhea (absence of menstruation) method is based on the fact that ovulation and therefore the cycle do not occur during the period of intense lactation following parturition [childbirth]. Therefore, as long as the mother breast-feeds the child fully, chances of conception are almost nil. However, this method has been reported to be effective only up to a maximum period of six months following parturition. As no medicines or devices are used in these methods, side effects are almost nil. Chances of failure, though, of this method are also high.

Barrier Methods

In barrier methods, ovum and sperms are prevented from physically meeting with the help of barriers. Such methods are available for both males and females. **Condoms** are barriers made of thin rubber/latex sheath that are used to cover the penis in the male or vagina and cervix in the female, just before coitus so that the ejaculated semen would not enter into the female reproductive tract. This can prevent conception.

Diaphragms, cervical caps and vaults are also barriers made of rubber that are Inserted Into the female reproductive tract to cover the cervix during coitus. They prevent conception by blocking the entry of sperms through the cervix. They are reusable. Spermicidal creams, jellies and foams are usually used along with these barriers to increase their contraceptive efficiency.

Intra Uterine Devices (IUDs)

Another effective and popular method is the use of **Intra Uterine Devices (IUDs).** These devices are inserted by doctors or expert nurses in the uterus through vagina. These Intra Uterine Devices are presently available as **Copper T (CuT),** non-medicated IUDs (e.g., Lippes loop), copper releasing IUDs (CuT, Cu7, Multiload 375) and the hormone releasing IUDs (Progestasert, LNG-20).

IUDs Increase **phagocytosis of sperms** within the uterus and the Cu ions released **suppress sperm motility** and the fertilising capacity of sperms. The hormone releasing IUDs, in addition, make the uterus unsuitable for implantation and the cervix **hostile** to the sperms. IUDs are ideal contraceptives for the females who want to delay pregnancy and/or space children. It is one of most widely accepted methods of contraception in India.

Pills

Oral administration of small doses of either **progestogens** or **progestogen-estrogen** combinations is another contraceptive method used by the females. They are used in the form of tablets and hence are popularly called the pills. Pills have to be taken daily for a period of 21 days starting preferably within the first five days of menstrual cycle. After a gap of 7 days (during which menstruation occurs) it has to be repeated in the same pattern till the female desires to prevent conception. They **inhibit ovulation** and implantation as well as alter the quality of cervical mucus to **prevent/retard entry of sperms**. Pills are very effective with lesser side effects and are well accepted by the females.

Progestogens alone or in combination with estrogen can also be used by females as injections or implants under the skin. Their mode of action is similar to that of pills and their effective periods are much longer. Administration of progestogens or progestogen-estrogen combinations or IUDs within 72 hours of coitus have been found to be very effective as **emergency contraceptives** as they could be used to avoid possible pregnancy due to rape or casual unprotected intercourse.

Surgical Methods

Surgical methods, also called sterilization, are generally advised for the male/female partner as a terminal method to prevent any more pregnancies. Surgical intervention blocks gamete transport and thereby prevent conception.

Sterilisation procedure in the male is called **'vasectomy'** and that in the female, **'tubectomy'**.

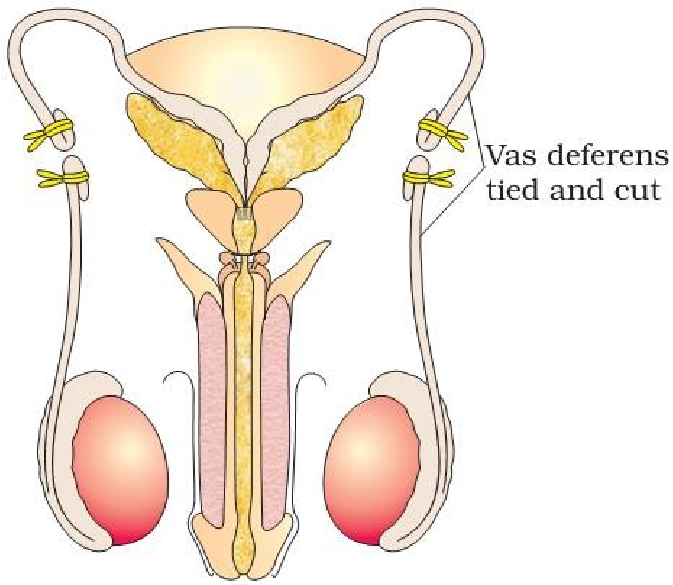


Figure 4.4a Vasectomy

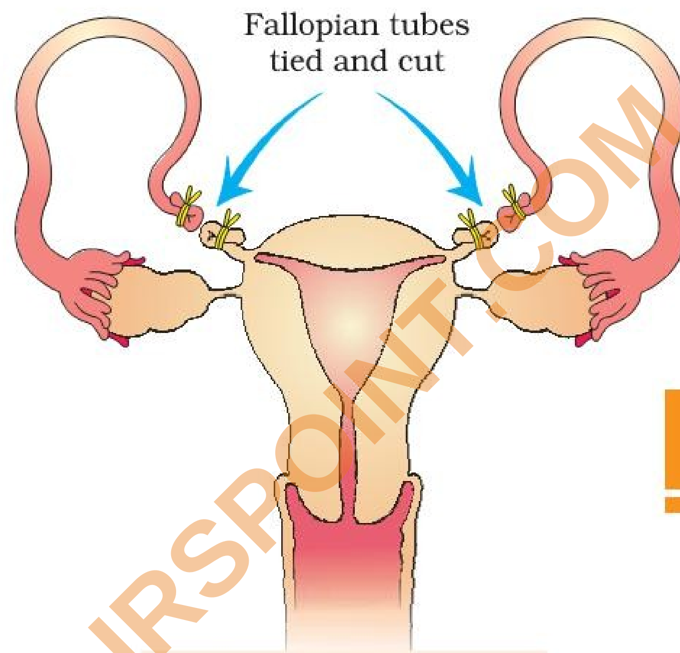


Figure 4.4 (b) Tubectomy

In vasectomy, a small part of the vas deferens is removed or tied up through a small incision on the scrotum whereas in tubectomy, a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through vagina. These techniques are highly effective but their reversibility is very poor.

No doubt, the widespread use of these methods have a significant role in checking uncontrolled growth of population. However, their **possible ill-effects** like nausea, abdominal pain, breakthrough bleeding, irregular menstrual bleeding or even breast cancer, though not very significant, should not be totally ignored.

Sexually Transmitted Diseases (STDs)

Diseases or infections which are transmitted through sexual intercourse are collectively called sexually transmitted diseases (STD) or venereal diseases (VD) or reproductive tract infections (RTI).

Gonorrhoea, syphilis, genital herpes, chlamydiasis, genital warts, trichomoniasis, hepatitis-B and of course, the most discussed infection in the recent years, HIV leading to AIDS are some of the common STDs.

Some of these infections like hepatitis-B and HIV can also be transmitted by sharing of injection needles, surgical instruments, etc., with infected persons, transfusion of blood, or from an infected mother to the foetus too. Except for hepatitis-B, genital herpes and HIV infections, other diseases are completely curable if detected early and treated properly. Early symptoms of most of these are minor and include itching, fluid discharge, slight pain, swellings, etc., in the genital region. Infected females may often be asymptomatic and hence, may remain undetected for long. Absence or less significant symptoms in the early stages of infection and the social stigma attached to the STDs, deter the infected persons from going for timely detection and proper treatment. This could lead to complications later, which include pelvic inflammatory diseases (PID), abortions, still births, ectopic pregnancies, infertility or even cancer of the reproductive tract. STDs are a major threat to a healthy society. Therefore, prevention or early detection and cure of these diseases are given prime consideration under the reproductive health-care programmes. Though all persons are vulnerable to these infections, their incidences are reported to be very high among persons in the age group of 15-24 years - the age group to which you also belong. Don't panic. Prevention is in your hands. You could be free of these infections if you follow the simple principles given below:

Avoid sex with unknown partners/multiple partners.

Always use condoms during coitus.

In case of doubt, go to a qualified doctor for early detection and get complete treatment if diagnosed with disease.

In vitro fertilisation (IVF-fertilisation outside the body in almost similar conditions as that in the body) followed by embryo transfer (ET) is one of such methods. In this method, popularly known as test tube baby programme, ova from the wife/donor (female) and sperms from the husband/donor (male) are collected and are induced to form zygote under simulated conditions in the laboratory. The zygote or early embryos (with upto 8 blastomeres) could then be transferred into the fallopian tube (ZIFT-zygote intra fallopian transfer) and embryos with more than 8 blastomeres, into the uterus (IUT - intra uterine transfer), to complete its further development. Embryos formed by in-vivo fertilisation (fusion of gametes within the female) also could be used for such transfer to assist those females who cannot conceive.

Transfer of an ovum collected from a donor into the fallopian tube (GIFT - gamete intra fallopian transfer) of another female who cannot produce one, but can provide suitable environment for fertilisation and further development is another method attempted. Intra cytoplasmic sperm injection (ICSI) is another specialised procedure to form an embryo in the laboratory in which a sperm is directly injected into the ovum. Infertility cases either due to inability of the male partner to inseminate the female or due to very low sperm counts in the ejaculates, could be corrected by artificial insemination (AI) technique. In this technique, the semen collected either from the husband or a healthy donor is artificially introduced either into the vagina or into the uterus (IUI - intra-uterine insemination) of the female.

Though options are many, all these techniques require extremely high precision handling by specialized professionals and expensive instrumentation. Therefore, these facilities are presently available only in very few centers in the country. Obviously their benefits is affordable to only a limited number of people. Emotional, religious and social factors are also deterrents in the adoption of these methods. Since the ultimate aim of all these procedures is to have children, in India we have so many orphaned and destitute children, who would probably not survive till maturity, unless taken care of. Our laws permit legal adoption and it is as yet, one of the best methods for couples looking for parenthood.

SUMMARY

Diseases or infections transmitted through sexual intercourse are called Sexually Transmitted Diseases (STDs). Pelvic Inflammatory Diseases (PIDs), still birth, infertility are some of the complications of them. Early detection facilitate better cure of these diseases. Avoiding sexual intercourse with unknown/multiple partners, use of condoms during coitus are some of the simple precautions to avoid contracting STDs.

Inability to conceive or produce children even after 2 years of unprotected sexual cohabitation is called infertility. Various methods are now available to help such couples. In Vitro fertilisation followed by transfer of embryo into the female genital tract is one such method and is commonly known as the 'Test Tube Baby' Programme.

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Types of Movements. Muscular System – Muscle Types: Skeletal Muscles, Visceral Muscles, Cardiac Muscles. Skeletal System: Major Joints.

Types of Movements

Voluntary movements are called locomotion. Walking, running, climbing, flying, swimming are all some forms of locomotory movements.

Cells of the human body exhibit three main types of movements, namely, **amoeboid, ciliary** and **muscular**.

Some specialized cells in our body like **macrophages** and **leucocytes** in blood exhibit amoeboid movement. It is effected by **pseudopodia** formed by the streaming of protoplasm (as in Amoeba).

Ciliary movement occurs in most of our internal tubular organs which are lined by **ciliated epithelium**.

The coordinated movements of cilia in the **trachea** help us in removing dust particles and some of the foreign substances inhaled along with the atmospheric air.

Passage of **ova** through the female reproductive tract is also facilitated by the ciliary movement.

Movement of our limbs, jaws, tongue, etc. require muscular movement. The contractile property of muscles are effectively used for locomotion and other movements by human beings and majority of multicellular organisms. Locomotion requires a perfect coordinated activity of muscular, skeletal and neural systems.

Muscular System – Muscle Types

Muscle is a specialized tissue of mesodermal origin. [**Mesodermal** == the middle layer of cells or tissues of an embryo, or the parts derived from this (e.g. cartilage, muscles, and bone)]

About 40-50 per cent of the body weight of a human adult is contributed by muscles.

They have special properties like excitability, contractility, extensibility and elasticity.

Muscles have been classified using different criteria, namely location, appearance and nature of regulation of their activities. Based on their location, three types of muscles are identified : (i) Skeletal (ii) Visceral [the internal organs in the main cavities of the body] and (iii) Cardiac.

Skeletal Muscles

Skeletal muscles are closely associated with the skeletal components of the body. They have a striped appearance under the microscope and hence are called **striated muscles**.

As their activities are under the voluntary control of the nervous system, they are known as **voluntary muscles** too. They are primarily involved in locomotory actions and changes of body postures.

Each organized skeletal muscle in our body is made of a number of **muscle bundles or fascicles** held together by a common connective tissue layer called **fascia**.

Each muscle bundle contains a number of muscle fibres. Each muscle fibre is lined by the plasma membrane called **sarcolemma** enclosing the sarcoplasm.

The endoplasmic reticulum, i.e., sarcoplasmic reticulum of the muscle fibres is the store house of **calcium ions**.

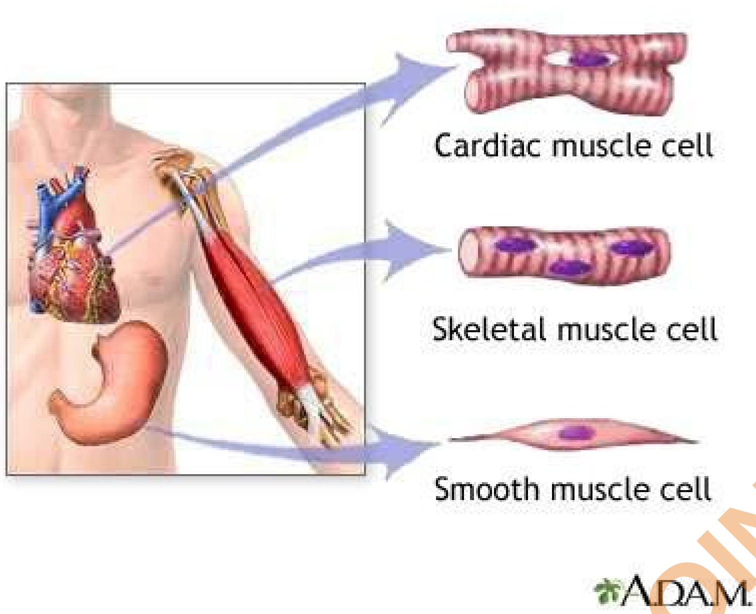
A characteristic feature of the muscle fibre is the presence of a large number of parallelly arranged filaments in the sarcoplasm called **myofilaments or myofibrils**.

Each myofibril has alternate dark and light bands on it. The striated appearance is due to the distribution pattern of two important proteins - **Actin** and **Myosin**.

Actin and myosin are polymerized proteins with contractility. A motor neuron carries signal to the muscle fibre which generates an action potential in it. This causes the release of Ca++ from sarcoplasmic reticulum.

Ca++ activates actin which binds to the myosin head to form a cross bridge. These cross bridges pull the actin filaments causing them to slide over the myosin filaments and thereby causing contraction. Ca++ are then returned to sarcoplasmic reticulum which inactivate the actin. Cross bridges are broken and the muscles relax.

Muscles are classified as Red and White fibres based primarily on the amount of **red coloured myoglobin** pigment in them.



Visceral Muscles

Visceral muscles are located in the inner walls of hollow visceral organs of the body like the alimentary canal, reproductive tract, etc.

They do not exhibit any striation and are smooth in appearance. Hence, they are called **smooth muscles (nonstriated muscle).**

Their activities are not under the voluntary control of the nervous system and are therefore known as **involuntary muscles**.

They assist, for example, in the transportation of food through the digestive tract and gametes through the genital tract.

Cardiac Muscles

As the name suggests, Cardiac muscles are the muscles of heart. Many cardiac muscle cells assemble in a branching pattern to form a cardiac muscle.

Based on appearance, cardiac muscles are **striated**. They are **involuntary** in nature as the nervous system does not control their activities directly.

Skeletal System

Skeletal system consists of a framework of bones and a few cartilages. Bone and cartilage are specialized connective tissues.

The former has a very hard matrix due to **calcium salts** in it and the latter has slightly pliable matrix due to **chondroitin salts**.

In human beings, this system is made up of **206 bones** and a few cartilages. It is grouped into two principal divisions - the axial and the appendicular skeleton.

Axial skeleton comprises 80 bones distributed along the main axis of the body. The skull, vertebral column, sternum and ribs constitute axial skeleton.

Joints

Joints are essential for all types of movements involving the bony parts of the body. Locomotory movements are no exception to this.

Joints are points of contact between bones, or between bones and cartilages.

Joints have been classified into three major structural forms, namely, fibrous, cartilaginous and synovial.

Fibrous joints do not allow any movement. This type of joint is shown by the flat skull bones which fuse end-to-end with the help of dense fibrous connective tissues in the form of sutures, to form the cranium.

In **cartilaginous joints**, the bones involved are joined together with the help of cartilages. The joint between the adjacent vertebrae in the vertebral column is of this pattern and it permits **limited movements**.

Synovial joints are characterized by the presence of a fluid filled synovial cavity between the articulating surfaces of the two bones. Such an arrangement allows **considerable movement**. These joints help in locomotion and many other movements.

Ball and socket joint, hinge joint (knee joint), pivot joint, gliding joint and saddle joint are some examples.

Major Joints

Ball and socket joints

Pivotal Joint: The joint where our neck joins the head is a pivotal joint.

Hinge joints

Fixed joints

There are some bones in our head that are joined together at some joints. The bones cannot move at these joints. Such joints are called **fixed joints**.

When you open your mouth wide, you can move your lower jaw away from your head, isn't it? Try to move your upper jaw, now. Are you able to move it? There is a joint between the upper jaw and the rest of the head which is a fixed joint.

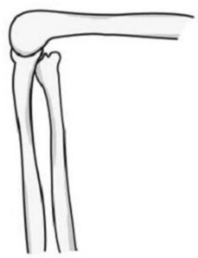


Fig. 8.5 *Hinge joints of the knee*

Fig. 8.3 *A ball and socket joint*

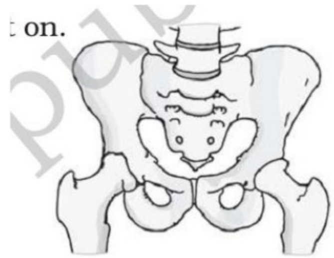


Fig. 8.12 *Pelvic bones.*

Which of the following pairs are correctly matched

1. Knee	Hinge joint
2. Neck joining the head	Ball and socket joint
3. Pelvic bones	Fixed joint
4. Elbow	Pivotal joint

Codes:

All

1 only

1, 3 only

1, 4 only

Disorders of Muscular and Skeletal System

Arthritis: Inflammation of joints.

Osteoporosis: Age-related disorder characterized by decreased bone mass and increased chances of fractures. Decreased levels of **estrogen** is a common cause.

Gout: Inflammation of joints due to accumulation of **uric acid** crystals.

Neural Control and Coordination

As you know, the functions of the organs/organ systems in our body must be coordinated to maintain homeostasis [the maintenance of a stable equilibrium].

Coordination is the process through which two or more organs interact and complement the functions of one another.

The neural system provides an organized network of point-to-point connections for a quick coordination.

The **endocrine system** provides chemical integration through hormones.

Human Neural System

The human neural system is divided into two parts :

- **the central neural system (CNS)**
- **the peripheral neural system (PNS)**

The CNS includes the **brain** and the **spinal cord** and is the site of information processing and control.

The PNS comprises of all the **nerves** of the body associated with the CNS (brain and spinal cord).

Peripheral Neural System (PNS)

The nerve fibres of the PNS are of two types:

- **afferent fibres → tissues/organs to brain**.
- **efferent fibres → brain to tissues/organs**.

The afferent nerve fibres transmit impulses from tissues/organs to the CNS and the efferent fibres transmit regulatory impulses from the CNS to the concerned peripheral tissues/organs.

The PNS is divided into two divisions called **somatic neural system** and **autonomic neural system**.

The somatic neural system relays impulses from the CNS to skeletal muscles while the autonomic neural system transmits impulses from the CNS to the involuntary organs and smooth muscles of the body.

- **Somatic Neural System → Brain to Voluntary muscles**.
- **Autonomic Neural System → Brain to Involuntary muscles**.

The autonomic neural system is further classified into **sympathetic neural system** and **parasympathetic neural system**.

Central Neural System (CNS)

The brain is the central information processing organ of our body, and acts as the '**command and control system**'.

It controls the voluntary movements, balance of the body, functioning of vital involuntary organs (e.g., lungs, heart, kidneys, etc.), thermoregulation, hunger and thirst, circadian (24-hour) rhythms of our body, activities of several endocrine glands and human behavior.

It is also the site for processing of vision, hearing, speech, memory, intelligence, emotions and thoughts.

The human brain is well protected by the skull. Inside the skull, the brain is covered by **cranial meninges** consisting of an outer layer called **dura mater**, a very thin middle layer called **arachnoid** and an inner layer (which is in contact with the brain tissue) called **pia mater**.

Human Brain

The brain can be divided into three major parts: **(i) forebrain, (ii) midbrain, and (iii) hindbrain.**

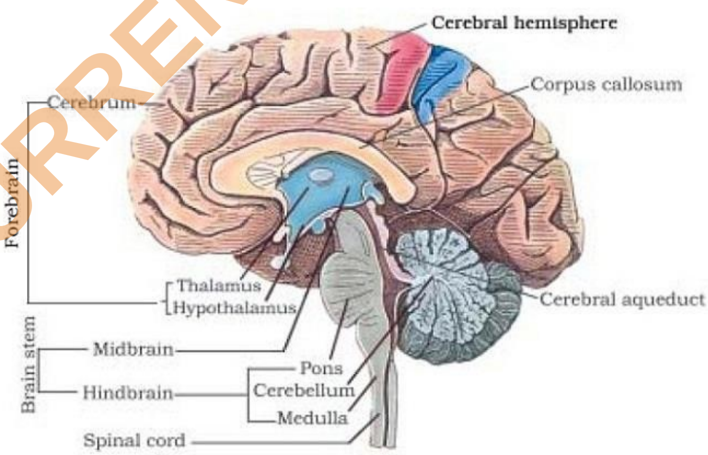


Figure 4. Diagram showing sagital section of the human brain

Forebrain

The forebrain consists of **cerebrum, thalamus** and **hypothalamus**.

Cerebrum forms the major part of the human brain. A deep cleft divides the cerebrum longitudinally into two halves, which are termed as the left and right cerebral hemispheres.

The hemispheres are connected by a tract of nerve fibres called **corpus callosum**.

The layer of cells which covers the cerebral hemisphere is called **cerebral cortex**. The cerebral cortex is referred to as the **grey matter** due to its greyish appearance. The neuron cell bodies are concentrated here giving the colour.

The cerebral cortex contains **motor areas, sensory areas** and large regions that are neither clearly sensory nor motor in function. These regions called as the association areas are responsible for complex functions like **intersensory associations, memory and communication**.

Fibres of the tracts are covered with the **myelin sheath**, which constitute the inner part of cerebral hemisphere. They give an opaque white appearance to the layer and, hence, is called the **white matter**.

The cerebrum wraps around a structure called thalamus, which is a major coordinating centre for **sensory and motor signaling**.

Another very important part of the brain called hypothalamus lies at the base of the thalamus. The hypothalamus contains a number of centres which **control body temperature, urge for eating and drinking**. It also contains several groups of neurosecretory cells, which secrete hormones called **hypothalamic hormones**.

The inner parts of cerebral hemispheres and a group of associated deep structures like amygdala, hippocampus, etc., form a complex structure called the **limbic lobe or limbic system**. Along with the hypothalamus, it is involved in the **regulation of sexual behaviour, expression of emotional reactions** (e.g., excitement, pleasure, rage and fear), and motivation.

Midbrain

The midbrain is located between the thalamus/hypothalamus of the forebrain and pons of the hindbrain. A canal called the **cerebral aqueduct** passess through the midbrain.

The dorsal portion of the midbrain consists mainly of four round swellings (lobes) called **corpora quadrigemina**. Midbrain and hindbrain form the brain stem.

Hindbrain

The hindbrain comprises **pons, cerebellum and medulla** (also called the medulla oblongata).

Pons consists of fibre tracts that interconnect different regions of the brain.

Cerebellum has very convoluted surface in order to provide the additional space for many more neurons.

The medulla of the brain is connected to the spinal cord. The medulla contains centres which control **respiration, cardiovascular reflexes and gastric secretions**.

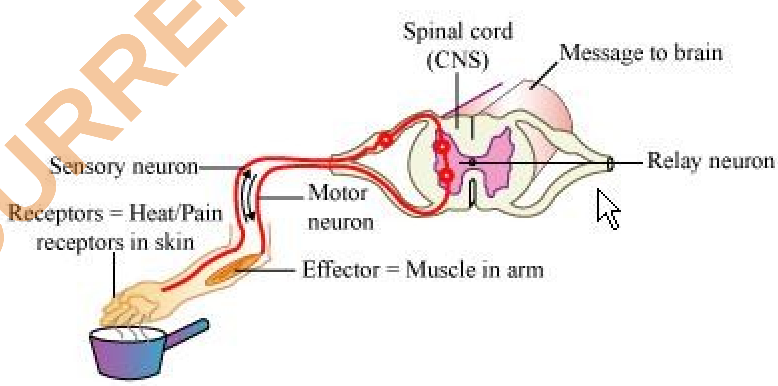
Reflex Action and Reflex Arc

You must have experienced a sudden withdrawal of a body part which comes in contact with objects that are extremely hot, cold pointed or animals that are scary or poisonous.

The entire process of response to a peripheral nervous stimulation, that occurs involuntarily, i.e., without conscious effort or thought and requires the involvement of a part of the central nervous system is called a **reflex action**.

The reflex pathway comprises at least **one afferent neuron (receptor)** and **one efferent (effector or excitor)** neuron appropriately arranged in a series.

The afferent neuron receives signal from a sensory organ and transmits the impulse via a dorsal nerve root into the CNS (at the level of spinal cord). The efferent nueuron then carries signals from CNS to the effector. The stimulus and response thus forms a reflex arc as shown below in the knee jerk reflex.



Eye

Our paired eyes are located in sockets of the skull called orbits.

The adult human eye ball is nearly a spherical structure. The wall of the eye ball is composed of three layers.

The external layer is composed of a dense connective tissue and is called the **sclera**. The anterior portion of this layer is called the **cornea**. The middle layer, **choroid**, contains many blood vessels and looks bluish in colour.

The choroid layer is thin over the posterior two-thirds of the eye ball, but it becomes thick in the anterior part to form the ciliary body.

The ciliary body itself continues forward to form a pigmented and opaque structure called the **iris** which is the visible coloured portion of the eye.

The eye ball contains a transparent crystalline lens which is held in place by ligaments attached to the ciliary body. In front of the lens, the aperture surrounded by the iris is called the **pupil**. The diameter of the pupil is regulated by the muscle fibres of iris.

The inner layer is the **retina** and it contains three layers of neural cells - from inside to outside - **ganglion cells, bipolar cells** and **photoreceptor cells**.

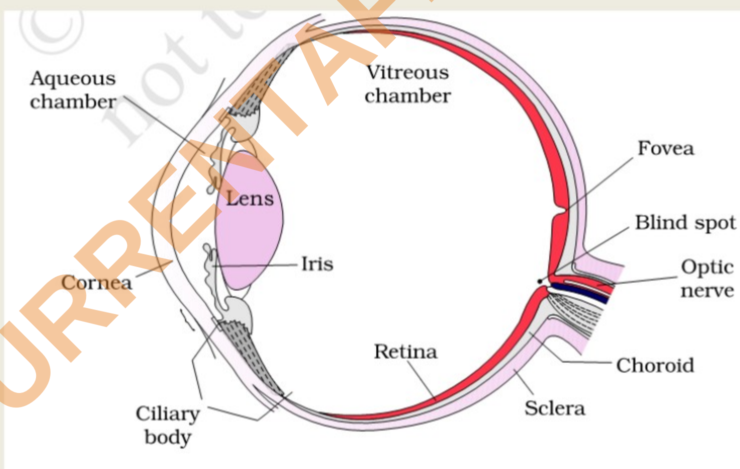


Figure 21.6 Diagram showing parts of an eye

There are two types of photoreceptor cells, namely, **rods** and **cones**. These cells contain the light-sensitive proteins called the **photopigments**.

The daylight **(photopic) vision** and colour vision are functions of cones and the twilight **(scotopic) vision** is the function of the rods.

The rods contain a purplish-red protein called the **rhodopsin** or visual purple, which contains a derivative of **Vitamin A**.

In the human eye, there are three types of cones which possess their own characteristic photopigments that respond to red, green and blue lights. The sensations of different colours are produced by various combinations of these cones and their photopigments. When these cones are stimulated equally, a sensation of white light is produced.

The optic nerves leave the eye and the retinal blood vessels enter it at a point medial to and slightly above the posterior pole of the eye ball. Photoreceptor cells are not present in that region and hence it is called the **blind spot**.

At the posterior pole of the eye lateral to the blind spot, there is a yellowish pigmented spot called **macula lutea** with a central pit called the **fovea**. The fovea is a thinned-out portion of the retina where only the **cones are densely packed**. It is the point where the **visual acuity (resolution)** is the greatest.

The space between the cornea and the lens is called the **aqueous chamber** and contains a thin watery fluid called **aqueous humor**. The space between the lens and the retina is called the **vitreous chamber** and is filled with a transparent gel called **vitreous humor**.

The Ear

The ears perform two sensory functions, hearing and maintenance of body balance.

Anatomically, the ear can be divided into three major sections called the outer ear, the middle ear and the inner ear.

The outer ear consists of the **pinna** and **external auditory meatus** (canal).

The pinna collects the vibrations in the air which produce sound. The external auditory meatus leads inwards and extends up to the **tympanic membrane (the ear drum)**.

There are very fine hairs and wax-secreting glands in the skin of the pinna and the meatus.

The tympanic membrane is composed of connective tissues covered with skin outside and with mucus membrane inside.

The middle ear contains three ossicles called malleus, incus and stapes which are attached to one another in a chainlike fashion.

The malleus is attached to the tympanic membrane and the stapes is attached to the oval window of the cochlea.

The **ear ossicles** increase the efficiency of transmission of sound waves to the inner ear.

An Eustachian tube connects the middle ear cavity with the pharynx. The Eustachian tube helps in **equalising the pressures** on either sides of the ear drum.

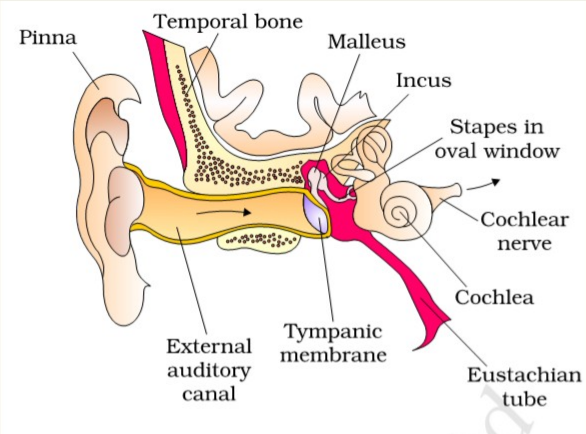


Figure 21.7 Diagrammatic view of ear

The fluid-filled inner ear called labyrinth consists of two parts, the bony and the membranous labyrinths. The bony labyrinth is a series of channels. Inside these channels lies the membranous labyrinth, which is surrounded by a fluid called perilymph. The membranous labyrinth is filled with a fluid called endolymph. The coiled portion of the labyrinth is called cochlea.

The membranes constituting cochlea, the reissner's and basilar, divide the surounding perilymph filled bony labyrinth into an upper scala vestibuli and a lower scala tympani.

The space within cochlea called scala media is filled with endolymph. At the base of the cochlea, the scala vestibuli ends at the oval window, while the scala tympani terminates at the round window which opens to the middle ear.

The organ of corti is a structure located on the basilar membrane which contains hair cells that act as auditory receptors. The hair cells are present in rows on the internal side of the organ of corti. The basal end of the hair cell is in close contact with the afferent nerve fibres. A large number of processes called stereo cilia are projected from the apical part of each hair cell. Above the rows of the hair cells is a thin elastic membrane called tectorial membrane.

The inner ear also contains a complex system called vestibular apparatus, located above the cochlea. The vestibular apparatus is composed of three semi-circular canals and the otolith (macula is the sensory part of saccule and utricle). Each semi-circular canal lies in a different plane at right angles to each other. The membranous canals are suspended in the perilymph of the bony canals. The base of canals is swollen and is called ampulla, which contains a projecting ridge called crista ampullaris which has hair cells. The saccule and utricle contain a projecting ridge called macula. The crista and macula are the specific receptors of the vestibular apparatus responsible for maintenance of balance of the body and posture.

Neurons

The neural system coordinates and integrates functions as well as metabolic and homeostatic activities of all the organs.

Neurons, the functional units of neural system are excitable cells due to a differential concentration gradient of ions across the membrane. The electrical potential difference across the resting neural membrane is called the 'resting potential'.

The nerve impulse is conducted along the axon membrane in the form of a wave of depolarisation and repolarisation.

A synapse is formed by the membranes of a pre-synaptic neuron and a post-synaptic neuron which may or may not be separated by a gap called synaptic cleft. Chemicals involved in the transmission of impulses at chemical synapses are called neurotransmitters.

Human neural system consists of two parts : (i) central neural system (CNS) and (ii) the peripheral neural system. The CNS consists of the brain and spiral cord. The brain can be divided into three major parts : (i) forebrain, (ii) midbrain and (iii) hindbrain. The forebrain consists of cerebrum, thalamus and hypothalamus. The cerebrum is longitudinally divided into two halves that are connected by the corpus callosum. A very important part of the forebrain called hypothalamus controls the body temperature, eating and drinking. Inner parts of cerebral hemispheres and a group of associated deep structures form a complex structure called limbic system which is concerned with olfaction, autonomic responses, regulation of sexual behaviour, expression of emotional reactions, and motivation. The midbrain receives and integrates visual, tactile and auditory inputs. The hindbrain comprises pons, cerebellum and medulla. The cerebellum integrates information received from the semicircular canals of the ear and the auditory system. The medulla contains centres, which control respiration, cardiovascular reflexes, and gastric secretions. Pons consist of fibre tracts that interconnect different regions of the brain. The entire process of involuntary response to a peripheral nervous stimulation is called reflex action. Information regarding changes in the environment is received by the CNS through the sensory organs which are processed and analysed. Signals are then sent for necessary adjustments. The wall of the human eye ball is composed of three layers. The external layer is composed of cornea and sclera. Inside sclera is the middle layer, which is called the choroid. Retina, the innermost layer, contains two types of photoreceptor cells, namely rods and cones.

The daylight (photopic) vision and colour vision are functions of cones and twilight (scotopic) vision is the function of the rods. The light enters through cornea, the lens and the images of objects are formed on the retina.

The ear can be divided into the outer ear, the middle ear and the inner ear. The middle ear contains three ossicles called malleus, incus and stapes. The fluid filled inner ear is called the labyrinth, and the coiled portion of the labyrinth is called cochlea. The organ of corti is a structure which contains hair cells that act as auditory receptors and is located on the basilar membrane. The vibrations produced in the ear drum are transmitted through the ear ossicles and oval window to the fluid-filled inner ear. Nerve impulses are generated and transmitted by the afferent fibres to the auditory cortex of the brain. The inner ear also contains a complex system located above the cochlea called vestibular apparatus. It is influenced by gravity and movements, and helps us in maintaining balance of the body and posture.

Endocrine Glands and Hormones

Endocrine glands lack ducts and are hence, called **ductless glands**. Their secretions are called **hormones**.

Hormone is a chemical produced by endocrine glands and released into the blood and transported to a distantly located target organ.

Hormones are non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts.

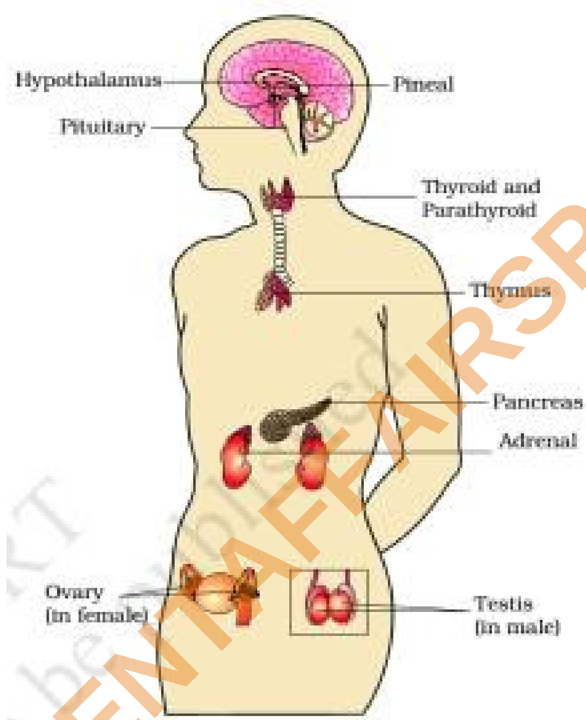


Figure 22.1 Location of endocrine glands

Invertebrates possess very simple endocrine systems with few hormones whereas a large number of chemicals act as hormones and provide coordination in the vertebrates. The human endocrine system is described here.

The endocrine glands and hormone producing diffused tissues/cells located in different parts of our body constitute the endocrine system. **Pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus** and **gonads (testis in males and ovary in females)** are the organized endocrine bodies in our body.

In addition to these, some other organs, e.g., **gastrointestinal tract, liver, kidney, heart** also produce hormones.

A brief account of the structure and functions of all major endocrine glands and hypothalamus of the human body is given in the following sections.

Hypothalamus

Hypothalamus is the part of the forebrain and it regulates a wide spectrum of body functions.

It contains several groups of neurosecretory cells called nuclei which produce hormones.

These hormones **regulate the synthesis and secretion of pituitary hormones**.

However, the hormones produced by hypothalamus are of two types, the **releasing hormones** (which stimulate secretion of pituitary hormones) and the **inhibiting hormones** (which inhibit secretions of pituitary hormones).

For example a hypothalamic hormone called **Gonadotrophin** releasing hormone (GnRH) stimulates the pituitary synthesis and release of gonadotrophins.

On the other hand, **somatostatin** from the hypothalamus inhibits the release of growth hormone from the pituitary.

These hormones originating in the hypothalamic neurons, pass through axons and are released from their nerve endings. These hormones reach the pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary. The posterior pituitary is under the direct neural regulation of the hypothalamus.

Pituitary Gland

The pituitary gland is located in a bony cavity called **sella tursica** and is attached to hypothalamus by a stalk.

It is divided anatomically into an **adenohypophysis** and a **neurohypophysis**.

Adenohypophysis consists of two portions, **pars distalis** and **pars intermedia**.

The pars distalis region of pituitary, commonly called **anterior pituitary**, produces

Growth Hormone (GH),

Prolactin (PRL),

Thyroid Stimulating Hormone (TSH),

Adrenocorticotrophic Hormone (ACTH),

Luteinizing Hormone (LH) and

Follicle Stimulating Hormone (FSH).

Pars intermedia secretes only one hormone called **Melanocyte Stimulating Hormone (MSH).**

However, in humans, the pars intermedia is **almost merged** with pars distalis.

Neurohypophysis (pars nervosa) also known as posterior pituitary, stores and releases two hormones called **oxytocin** and **vasopressin**, which are actually synthesised by the **hypothalamus** and are transported axonally to neurohypophysis.

Over-secretion of GH stimulates abnormal growth of the body leading to gigantism and low secretion of GH results in stunted growth resulting in **pituitary dwarfism**.

Prolactin regulates the growth of the **mammary glands** and **formation of milk** in them.

TSH stimulates the synthesis and secretion of **thyroid hormones** from the thyroid gland.

ACTH stimulates the synthesis and secretion of **steroid hormones** called **glucocorticoids** from the **adrenal cortex**.

LH and FSH stimulate **gonadal activity** and hence are called **gonadotrophins**.

In males, LH stimulates the synthesis and secretion of hormones called **androgens** from testis. In males, FSH and androgens regulate **spermatogenesis**.

In females, LH induces **ovulation** of fully mature follicles (**graafian follicles**) and maintains the corpus luteum, formed from the remnants of the graafian follicles after ovulation. FSH stimulates growth and development of the ovarian follicles in females.

MSH acts on the **melanocytes (melanin containing cells)** and **regulates pigmentation of the skin.**

Oxytocin acts on the **smooth muscles** of our body and stimulates their contraction. In females, it stimulates a vigorous contraction of uterus at the time of **child birth**, and **milk ejection** from the mammary gland.

Vasopressin acts mainly at the kidney and **stimulates resorption of water and electrolytes** by the distal tubules and thereby reduces loss of water through urine (**diuresis**). Hence, it is also called as **Anti-Diuretic Hormone (ADH).**

Pineal Gland

The pineal gland is located on the dorsal side of forebrain.

Pineal secretes a hormone called **melatonin**.

Melatonin plays a very important role in the regulation of a **24-hour (diurnal) rhythm of our body**.

For example, it helps in maintaining the normal rhythms of sleep-wake cycle, body temperature.

In addition, melatonin also influences **metabolism, pigmentation**, the **menstrual cycle** as well as our **defense capability**.

Thyroid Gland

The thyroid gland is composed of two lobes which are located on either side of the **trachea**.

Both the lobes are interconnected with a thin flap of connective tissue called **isthmus**.

The thyroid gland is composed of follicles and stromal tissues. Each thyroid follicle is composed of follicular cells, enclosing a cavity. These follicular cells synthesize two hormones, **tetraiodothyronine** or **thyroxine (T4)** and **triiodothyronine (T3)**.

Iodine is essential for the normal rate of hormone synthesis in the thyroid. Deficiency of iodine in our diet results in **hypothyroidism** and enlargement of the thyroid gland, commonly called **goitre**.

Hypothyroidism during pregnancy causes **defective development** and maturation of the growing baby leading to stunted growth (cretinism), mental retardation, low intelligence quotient, abnormal skin, deaf-mutism, etc.

In adult women, hypothyroidism may cause menstrual cycle to become irregular.

Due to cancer of the thyroid gland or due to development of nodules of the thyroid glands, the rate of synthesis and secretion of the **thyroid hormones is increased to abnormal high levels** leading to a condition called hyperthyroidism which adversely affects the body physiology.

Thyroid hormones play an important role in the regulation of the **basal metabolic rate**.

These hormones also support the process of **red blood cell formation**.

Thyroid hormones control the **metabolism** of carbohydrates, proteins and fats.

Maintenance of **water and electrolyte balance** is also influenced by thyroid hormones.

Thyroid gland also secretes a protein hormone called **Thyrocalcitonin (TCT)** which regulates the **blood calcium levels**.

Parathyroid Gland

In humans, four parathyroid glands are present on the back side of the thyroid gland, one pair each in the two lobes of the thyroid gland.

The parathyroid glands secrete a peptide hormone called **Parathyroid Hormone (PTH)**. The secretion of PTH is regulated by the circulating levels of calcium ions. Parathyroid hormone (PTH) **increases the Ca2+ levels in the blood**.

PTH acts on bones and stimulates the process of **bone resorption** (dissolution/ demineralisation).

PTH also stimulates reabsorption of Ca2+ by the renal tubules and increases Ca2+ absorption from the digested food.

It is, thus, clear that PTH is a **Hypercalcemic Hormone**, i.e., it increases the blood Ca2+ levels.

Along with TCT, it plays a significant role in calcium balance in the body.

Thymus

The thymus gland is a lobular structure located between lungs behind sternum on the ventral side of aorta.

The thymus plays a major role in the development of the **immune system**.

This gland secretes the peptide hormones called **Thymosins**.

Thymosins play a major role in the differentiation of **T-lymphocytes**, which provide cell-mediated immunity.

In addition, thymosins also promote production of **antibodies** to provide humoral immunity.

Thymus is degenerated in old individuals resulting in a decreased production of thymosins. As a result, the immune responses of old persons become weak.

Adrenal Gland

Our body has one pair of adrenal glands, one at the anterior part of each kidney. The gland is composed of two types of tissues. The centrally located tissue is called the **adrenal medulla**, and outside this lies the **adrenal cortex**.

The adrenal medulla secretes two hormones called **adrenaline or epinephrine** and **noradrenaline or norepinephrine**. These are commonly called as **catecholamines**.

Adrenaline and noradrenaline are rapidly secreted in response to **stress** of any kind and during emergency situations and are called **emergency hormones** or **hormones of Fight or Flight**.

These hormones increase alertness, pupilary dilation, piloerection (raising of hairs), sweating etc.

Both the hormones increase the **heartbeat**, the strength of heart contraction and the rate of respiration.

Catecholamines also stimulate the breakdown of glycogen resulting in an **increased concentration of glucose in blood**.

In addition, they also stimulate the breakdown of lipids and proteins.

The adrenal cortex secretes many hormones, commonly called as **corticoids**. The corticoids, which are involved in carbohydrate metabolism are called glucocorticoids. In our body, **cortisol** is the main glucocorticoid.

Corticoids, which regulate the balance of water and electrolytes in our body are called mineralocorticoids. **Aldosterone** is the main mineralocorticoid in our body.

Glucocorticoids stimulate gluconeogenesis, lipolysis and proteolysis; and inhibit cellular uptake and utilisation of amino acids.

Cortisol is also involved in maintaining the cardio-vascular system as well as the kidney functions.

Glucocorticoids, particularly cortisol, produces anti-inflammatory reactions and suppresses the immune response.

Cortisol stimulates the RBC production.

Aldosterone acts mainly at the renal tubules and stimulates the reabsorption of Na+ and water and excretion of K+ and phosphate ions. Thus, aldosterone helps in the maintenance of electrolytes, body fluid volume, osmotic pressure and blood pressure.

Small amounts of androgenic steroids are also secreted by the adrenal cortex which play a role in the growth of axial hair, pubic hair and facial hair during puberty.

Pancreas

Pancreas is a **composite gland** which acts as **both exocrine and endocrine gland**.

The endocrine pancreas consists of '**Islets of Langerhans**'. There are about 1 to 2 million Islets of Langerhans in a normal human pancreas representing only 1 to 2 per cent of the pancreatic tissue.

The two main types of cells in the Islet of Langerhans are called a-cells and p-cells. The a-cells secrete a hormone called **glucagon**, while the p-cells secrete **INSULIN**.

Glucagon is a peptide hormone, and plays an important role in maintaining the normal **blood glucose levels**. Glucagon acts mainly on the **liver cells (hepatocytes)** and stimulates **glycogenolysis** resulting in an increased blood sugar **(hyperglycemia)**.

In addition, this hormone stimulates the process of **gluconeogenesis** which also contributes to hyperglycemia. Glucagon **reduces** the cellular glucose uptake and utilisation. Thus, glucagon is a **hyperglycemic hormone**.

Insulin is a peptide hormone, which plays a major role in the regulation of **glucose homeostasis**. Insulin acts mainly on **hepatocytes** and **adipocytes** (cells of adipose tissue), and **enhances cellular glucose uptake and utilisation**. As a result, there is a rapid movement of glucose from blood to hepatocytes and adipocytes resulting in decreased blood glucose levels **(hypoglycemia)**.

Insulin also stimulates conversion of **glucose to glycogen** (glycogenesis) in the target cells. The **glucose homeostasis** in blood is thus maintained jointly by the two - insulin and glucagons.

Prolonged hyperglycemia leads to a complex disorder called **diabetes mellitus** which is associated with loss of glucose through urine and formation of harmful compounds known as **ketone bodies**. Diabetic patients are successfully treated with insulin therapy.

Testis

A pair of testis is present in the scrotal sac (outside abdomen) of male individuals. Testis performs dual functions as a **primary sex organ** as well as an **endocrine gland**.

Testis is composed of seminiferous tubules and stromal or interstitial tissue. The Leydig cells or interstitial cells, which are present in the intertubular spaces produce a group of hormones called **androgens** mainly **testosterone**.

Androgens regulate the development, maturation and functions of the **male accessory sex organs** like epididymis, vas deferens, seminal vesicles, prostate gland, urethra etc.

These hormones stimulate muscular growth, growth of facial and axillary hair, aggressiveness, low pitch of voice etc.

Androgens play a major stimulatory role in the process of **spermatogenesis** (formation of spermatozoa).

Androgens act on the central neural system and influence the **male sexual behavior (libido)**.

These hormones produce anabolic (synthetic) effects on protein and carbohydrate metabolism.

Ovary

Females have a pair of ovaries located in the abdomen. Ovary is the primary female sex organ which produces one ovum during each menstrual cycle. In addition, ovary also produces two groups of steroid hormones called estrogen and progesterone.

Ovary is composed of ovarian follicles and stromal tissues. The **estrogen** is synthesized and secreted mainly by the growing ovarian follicles. After ovulation, the ruptured follicle is converted to a structure called corpus luteum, which secretes mainly **progesterone**.

Estrogens produce wide ranging actions such as stimulation of growth and activities of **female secondary sex organs**, development of growing ovarian follicles, appearance of female secondary sex characters (e.g., high pitch of voice, etc.), mammary gland development. Estrogens also regulate **female sexual behavior**.

Progesterone supports pregnancy. Progesterone also acts on the mammary glands and stimulates the formation of **alveoli** (sac-like structures which store milk) and milk secretion.

Hormones of Heart, Kidney and Gastrointestinal Tract

As mentioned earlier, hormones are also secreted by some tissues which are not endocrine glands. For example, the atrial wall of our heart secretes a very important peptide hormone called **Atrial Natriuretic Factor (ANF)**, which **decreases blood pressure**. When blood pressure is increased, ANF is secreted which causes dilation of the blood vessels. This reduces the blood pressure.

The **juxtaglomerular cells** of kidney produce a peptide hormone called **erythropoietin** which stimulates **Erythropoiesis (formation of RBC)**.

Endocrine cells present in different parts of the gastro-intestinal tract secrete four major peptide hormones, namely **Gastrin, Secretin, Cholecystokinin (CCK)** and **Gastric Inhibitory Peptide (GIP)**.

Gastrin acts on the gastric glands and stimulates the secretion of **hydrochloric acid** and **pepsinogen**.

Secretin acts on the exocrine pancreas and stimulates secretion of **water and bicarbonate ions.**

CCK acts on both pancreas and gall bladder and stimulates the secretion of **pancreatic enzymes and bile juice**, respectively.

GIP **inhibits gastric secretion** and motility.

Several other non-endocrine tissues secrete hormones called growth factors. These factors are essential for the normal growth of tissues and their repairing/regeneration.

Mechanism of Hormone Action

Hormones produce their effects on target tissues by binding to specific proteins called **hormone receptors** located in the target tissues only.

Hormone receptors present on the cell membrane of the target cells are called membrane-bound receptors and the receptors present inside the target cell are called intracellular receptors, mostly nuclear receptors (present in the nucleus).

Binding of a hormone to its receptor leads to the formation of a hormone-receptor complex. Each receptor is specific to one hormone only and hence receptors are specific.

Hormone-Receptor complex formation leads to certain biochemical changes in the target tissue. Target tissue metabolism and hence physiological functions are regulated by hormones.

Hormones which interact with membrane-bound receptors normally do not enter the target cell, but generate second messengers which in turn regulate cellular metabolism.

Hormones which interact with intracellular receptors (e.g., steroid hormones, iodothyronines, etc.) mostly regulate gene expression or chromosome function by the interaction of hormone-receptor complex with the genome. Cumulative biochemical actions result in physiological and developmental effects.

On the basis of their chemical nature, hormones can be divided into groups:

peptide, polypeptide, protein hormones (e.g., insulin, glucagon, pituitary hormones, hypothalamic hormones, etc.)

steroids (e.g., cortisol, testosterone, estradiol and progesterone)

iodothyronines (thyroid hormones)

amino-acid derivatives (e.g., epinephrine).

Summary

There are special chemicals which act as hormones and provide chemical coordination, integration and regulation in the human body.

These hormones regulate metabolism, growth and development of our organs, the endocrine glands or certain cells.

The endocrine system is composed of hypothalamus, pituitary and pineal, thyroid, adrenal, pancreas, parathyroid, thymus and gonads (testis and ovary). In addition to these, some other organs, e.g., gastrointestinal tract, kidney, heart etc., also produce hormones.

The pituitary gland is divided into three major parts, which are called as pars distalis, pars intermedia and pars nervosa.

Pars distalis produces six trophic hormones. Pars intermedia secretes only one hormone, while pars nervosa (neurohypophysis) secretes two hormones.

The pituitary hormones regulate the growth and development of somatic tissues and activities of peripheral endocrine glands.

Pineal gland secretes melatonin, which plays a very important role in the regulation of 24-hour (diurnal) rhythms of our body (e.g., rhythms of sleep and state of being awake, body temperature, etc.).

The thyroid gland hormones play an important role in the regulation of the basal metabolic rate, development and maturation of the central neural system, erythropoiesis, metabolism of carbohydrates, proteins and fats, menstrual cycle.

Another thyroid hormone, i.e., thyrocalcitonin regulates calcium levels in our blood by decreasing it.

The parathyroid glands secrete parathyroid hormone (PTH) which increases the blood Ca2+ levels and plays a major role in calcium homeostasis.

Thyroid and adrenals secrete their hormones when they receive orders from the pituitary through its hormones.

Metamorphosis in insects is controlled by insect hormones. In a frog, it is controlled by thyroxine, the hormone produced by thyroid. Thyroxine production requires the presence of iodine in water. If the water in which the tadpoles are growing does not contain sufficient iodine, the tadpoles cannot become adults.

The thymus gland secretes thymosins which play a major role in the differentiation of T-lymphocytes, which provide cell-mediated immunity. In addition, thymosins also increase the production of antibodies to provide humoral immunity.

Adrenal glands secrete hormones which maintain the correct salt balance in the blood.

The adrenal gland is composed of the centrally located adrenal medulla and the outer adrenal cortex. The adrenal medulla secretes epinephrine and norepinephrine. These hormones increase alertness, pupilary dilation, piloerection, sweating, heart beat, strength of heart contraction, rate of respiration, glycogenolysis, lipolysis, proteolysis.

The adrenal cortex secretes glucocorticoids and mineralocorticoids. Glucocorticoids stimulate gluconeogenesis, lipolysis, proteolysis, erythropoiesis, cardio-vascular system, blood pressure, and glomerular filtration rate and inhibit inflammatory reactions by suppressing the immune response.

Mineralocorticoids regulate water and electrolyte contents of the body. The endocrine pancreas secretes glucagon and insulin.

Glucagon stimulates glycogenolysis and gluconeogenesis resulting in hyperglycemia. Insulin stimulates cellular glucose uptake and utilisation, and glycogenesis resulting in hypoglycemia. Insulin deficiency and/or insulin resistance result in a disease called diabetes mellitus.

The testis secretes androgens, which stimulate the development, maturation and functions of the male accessory sex organs, appearance of the male secondary sex characters, spermatogenesis, male sexual behaviour, anabolic pathways and erythropoiesis.

The ovary secretes estrogen and progesterone. Estrogen stimulates growth and development of female accessory sex organs and secondary sex characters. Progesterone plays a major role in the maintenance of pregnancy as well as in mammary gland development and lactation.

The atrial wall of the heart produces atrial natriuretic factor which decreases the blood pressure. Kidney produces erythropoietin which stimulates erythropoiesis.

The gastrointestinal tract secretes gastrin, secretin, cholecystokinin and gastric inhibitory peptide. These hormones regulate the secretion of digestive juices and help in digestion.

Immunity – Innate Immunity - Acquired Immunity, Active - Passive Immunity. Vaccination and Immunization, Allergies, Auto Immunity, Immune System in the Body.

Immunity is of two types: (i) Innate immunity and (ii) Acquired immunity.

Innate Immunity

Innate immunity is **non-specific** type of defense, that is present at the time of **birth**.

Innate immunity is accomplished by providing different types of barriers to the entry of the foreign agents into our body.

Innate immunity consist of four types of barriers. These are —

Physical Barriers: Skin on our body is the main barrier which prevents entry of the micro-organisms. Mucus coating of the epithelium lining the respiratory, gastrointestinal and urogenital tracts also help in trapping microbes entering our body.

Physiological Barriers: Acid in the stomach, saliva in the mouth, tears from eyes-all prevent microbial growth.

Cellular Barriers: Certain types of **leukocytes (WBC)** of our body like polymorpho-nuclear leukocytes (PMNL-neutrophils) and **monocytes** and natural killer (type of **lymphocytes**) in the blood as well as **macrophages** in tissues can **phagocytose** and destroy microbes.

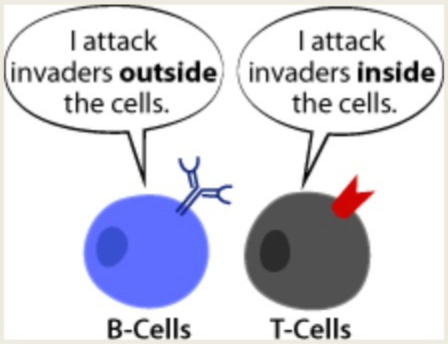
Cytokine Barriers: Virus-infected cells secrete proteins called **interferons** which protect non-infected cells from further viral infection.

Acquired Immunity

Acquired immunity is **pathogen specific**. It is characterized by **memory**. This means that our body when it encounters a pathogen for the first time produces a response called **primary response** which is of low intensity.

Subsequent encounter with the same pathogen elicits a highly intensified **secondary or anamnestic response**. This is ascribed to the fact that our body appears to have memory of the first encounter.

The primary and secondary immune responses are carried out with the help of two special types of lymphocytes present in our blood, i.e., **B-lymphocytes** and **T-lymphocytes**.



The B-lymphocytes produce an army of **proteins** in response to pathogens into our blood to fight with them. These proteins are called **Antibodies [**a blood protein produced by the body in response to and counteracting an antigen**]**.

The T-cells themselves do not secrete antibodies but **help B cells** produce them.

Each antibody molecule has **four peptide chains**, two small called light chains and two longer called heavy chains. Hence, an antibody is represented as H2L2.

Different types of antibodies are produced in our body. IgA, IgM, IgE, IgG are some of them.

Because these antibodies are found in the blood, the response is also called as **humoral immune response**. This is one of the two types of our acquired immune response – **antibody mediated**. The second type is called **cell-mediated** immune response or cell mediated immunity (CMI). The **T-lymphocytes mediate CMI**.

Very often, when some human organs like heart, eye, liver, kidney fail to function satisfactorily, transplantation is the only remedy to enable the patient to live a normal life. Then a search begins - to find a suitable donor. Why is it that the organs cannot be taken from just anybody? What is it that the doctors check?

Grafts from just any source - an animal, another primate, or any human beings cannot be made since the grafts would be rejected sooner or later. **Tissue matching, blood group matching** are essential before undertaking any graft/transplant and even after this the patient has to take **immuno-suppresants** all his/her life. The body is able to differentiate 'self' and 'nonself' and the **cell-mediated immune response** is responsible for the **graft rejection**.

Active and Passive Immunity

When a host is exposed to **antigens [**a substance which the body recognizes as alien and which induces an immune response**]**, which may be in the form of living or dead microbes or other proteins, antibodies are produced in the host body. This type of immunity is called **active immunity**.

Active immunity is **slow** and takes time to give its full effective response. *Injecting the microbes deliberately during immunization or infectious organisms gaining access into body during natural infection induce active immunity.*

When **ready-made antibodies** are directly given to protect the body against foreign agents, it is called **passive immunity**.

Do you know why mother's milk is considered very essential for the newborn infant? The yellowish fluid **colostrum** secreted by mother during the initial days of lactation has abundant **antibodies (IgA)** to protect the infant.

The foetus also receives some antibodies from their mother, through the placenta during pregnancy. These are some examples of **passive immunity**.

Vaccination and Immunization

The principle of immunization or vaccination is based on the property of '**memory**' of the immune system.

In vaccination, a preparation of **antigenic proteins of pathogen** or **inactivated/weakened pathogen (vaccine)** are introduced into the body.

The antibodies produced in the body against these antigens would neutralize the pathogenic agents during actual infection.

The vaccines also generate memory - **B and T-cells** that recognize the pathogen quickly on subsequent exposure and overwhelm the invaders with a massive production of antibodies.

If a person is infected with some deadly microbes to which quick immune response is required as in **tetanus**, we need to directly inject the preformed antibodies, or **antitoxin** (a preparation containing antibodies to the toxin).

Even in cases of snakebites, the injection which is given to the patients, contain preformed antibodies against the snake venom. This type of immunization is called **passive immunization**.

Recombinant DNA technology has allowed the production of **antigenic polypeptides** of pathogen in **bacteria or yeast**. Vaccines produced using this approach allow large scale production and hence greater availability for immunization, e.g., hepatitis B vaccine produced from yeast.

Allergies

Did this happen to you? When you have gone to a new place and suddenly you started sneezing, wheezing for no explained reason, and when you came away, your symptoms disappeared?

Some of us are sensitive to some particles in the environment. The above-mentioned reaction could be because of allergy to pollen, mites, etc., which are different in different places.

The **exaggerated** response of the immune system to certain antigens present in the environment is called allergy. The substances to which such an immune response is produced are called **allergens**. The antibodies produced to these are of **IgE type**.

Common examples of allergens are mites in dust, pollens, animal dander, etc.

Symptoms of allergic reactions include sneezing, watery eyes, running nose and difficulty in breathing.

Allergy is due to the release of chemicals like **histamine** and **serotonin** from the **mast cells**.

For determining the cause of allergy, the patient is exposed to or injected with very small doses of possible allergens, and the reactions studied.

The use of drugs like **anti-histamine, adrenalin** and **steroids** quickly reduce the symptoms of allergy.

Somehow, modern-day life style has resulted in lowering of immunity and more sensitivity to allergens - more and more children in metro cities of India suffer from allergies and asthma due to sensitivity to the environment. This could be because of the protected environment provided early in life.

Auto Immunity

Memory-based acquired immunity evolved in higher vertebrates based on the ability to differentiate foreign organisms (e.g., pathogens) from self-cells.

While we still do not understand the basis of this, two corollaries of this ability have to be understood.

One, higher vertebrates can distinguish foreign molecules as well as foreign organisms. Most of the experimental immunology deals with this aspect.

Two, sometimes, due to genetic and other unknown reasons, the **body attacks self-cells**. This results in damage to the body and is called **auto-immune disease**.

Rheumatoid arthritis which affects many people in our society is an auto-immune disease.

Immune System in the Body

The human immune system consists of **lymphoid organs**, tissues, cells and soluble molecules like antibodies. As you have read, immune system is unique in the sense that it recognizes foreign antigens, responds to these and remembers them. The immune system also plays an important role in allergic reactions, auto-immune diseases and organ transplantation.

Lymphoid Organs: These are the organs where origin and/or maturation and proliferation of **Lymphocytes** occur.

The primary lymphoid organs are **bone marrow** and **thymus** where immature lymphocytes differentiate into antigen-sensitive lymphocytes.

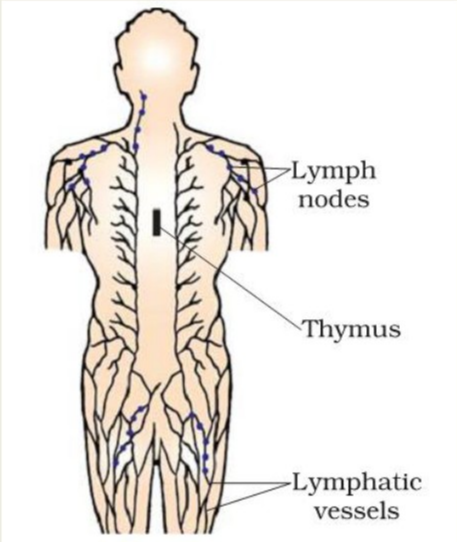
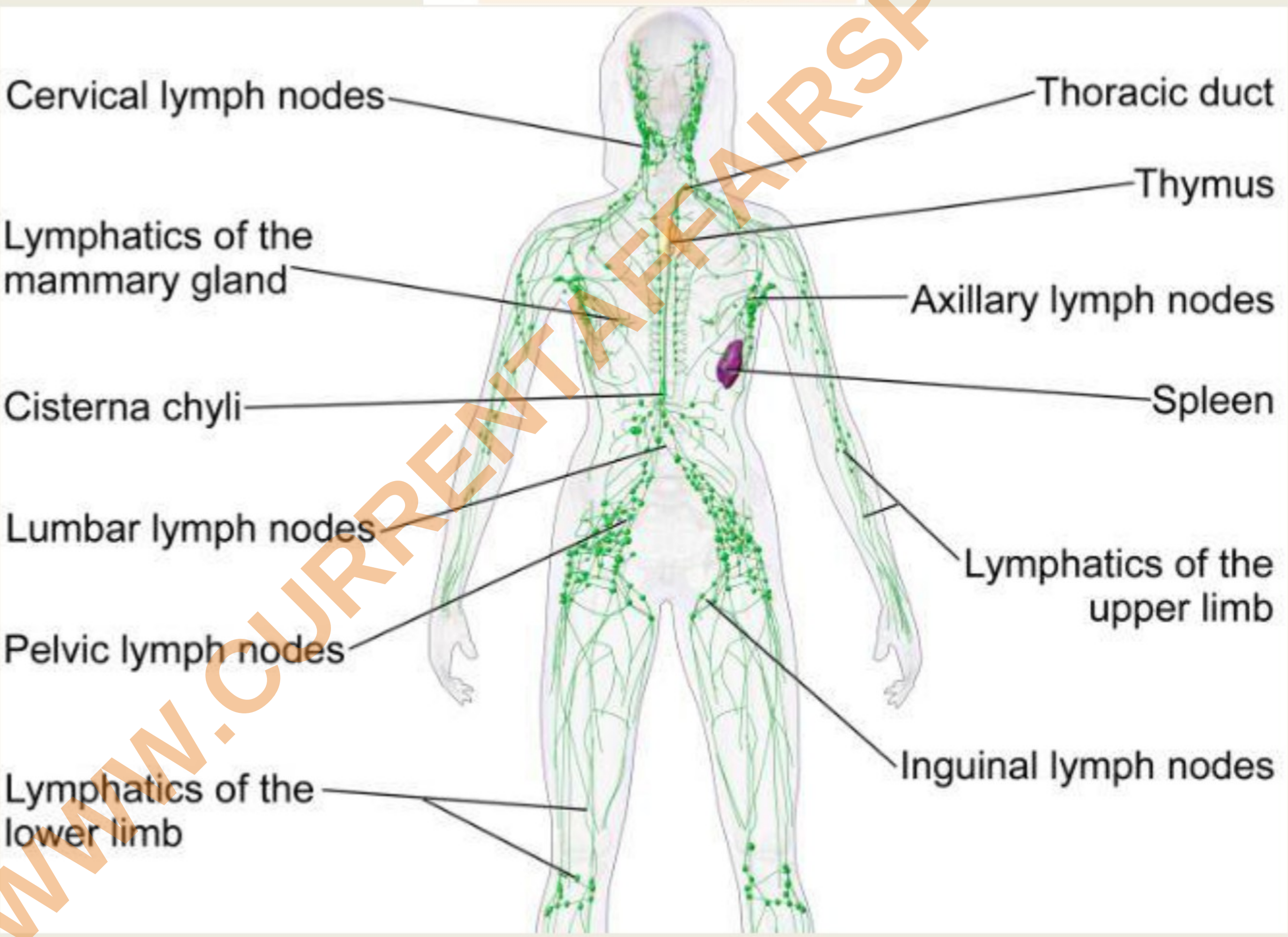
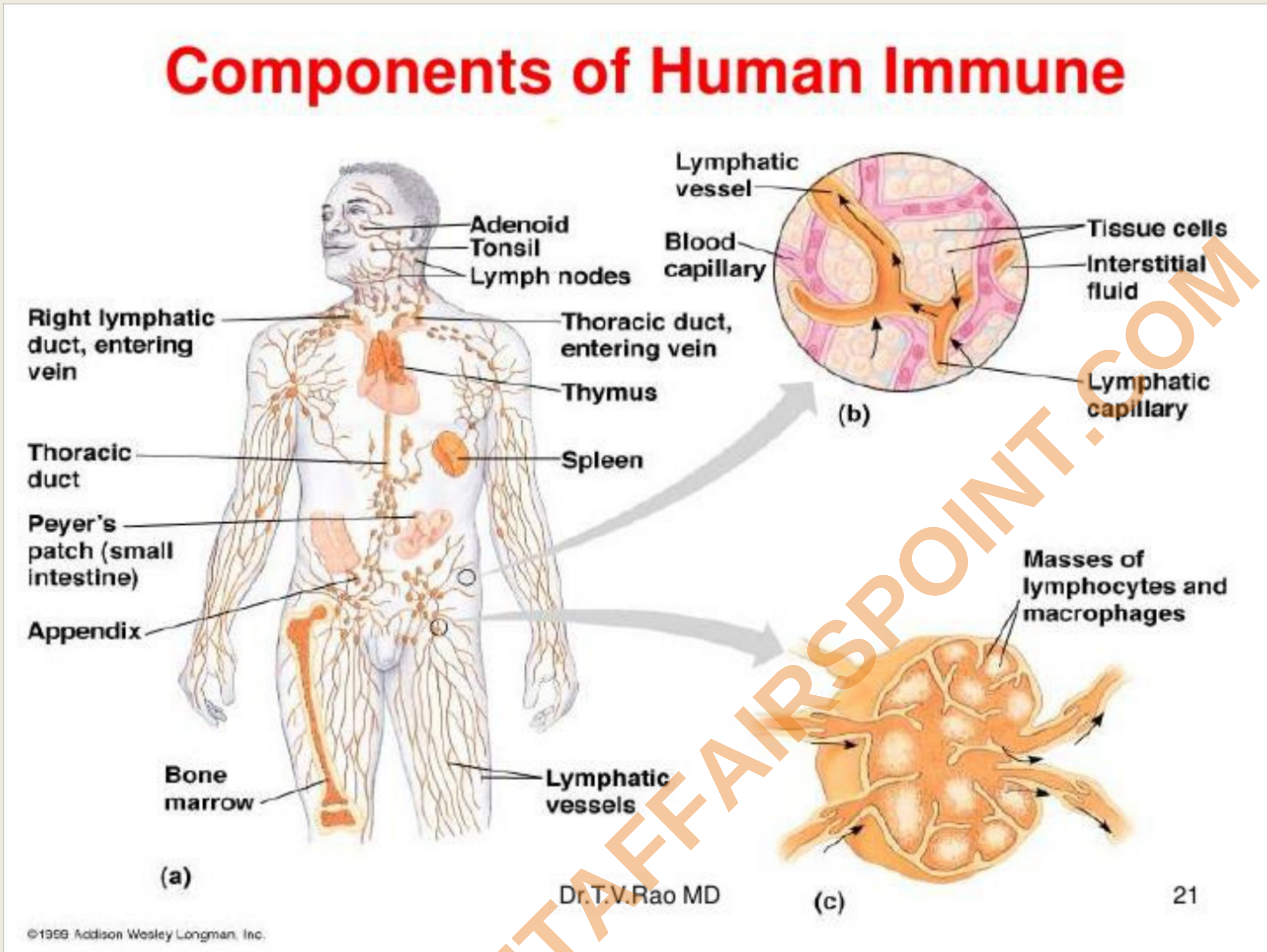


Figure 8.5 Diagrammatic representation of Lymph nodes





After maturation the lymphocytes migrate to **secondary lymphoid organs** like **spleen, lymph nodes, tonsils, Peyer's patches of small intestine** and **appendix**.

The secondary lymphoid organs provide the sites for interaction of lymphocytes with the antigen, which then proliferate to become **effector cells**.

The **bone marrow** is the main lymphoid organ where all blood cells including lymphocytes are produced.

The **thymus** is a lobed organ located near the heart and beneath the breastbone. The thymus is quite large at the time of birth but keeps reducing in size with age and by the time puberty is attained it reduces to a very small size.

Both bone-marrow and thymus provide micro-environments for the development and maturation of **T-lymphocytes**.

The spleen is a large bean shaped organ. It mainly contains **lymphocytes** and **phagocytes**. It acts as a filter of the blood by trapping blood-borne micro-organisms. Spleen also has a large reservoir of **erythrocytes**.

The lymph nodes are small solid structures located at different points along the lymphatic system. Lymph nodes serve to trap the micro-organisms or other antigens, which happen to get into the lymph and tissue fluid.

Antigens trapped in the lymph nodes are responsible for the activation of lymphocytes present there and cause the immune response.

There is lymphoid tissue also located within the lining of the major tracts (respiratory, digestive and urogenital tracts) called **mucosal-associated lymphoid tissue (MALT)**. It constitutes about 50 per cent of the lymphoid tissue in human body.

Summary

Health is not just the absence of disease. It is a state of complete physical, mental, social and psychological well-being.

Diseases like typhoid, cholera, pneumonia, fungal infections of skin, malaria and many others are a major cause of distress to human beings.

Vector-borne diseases like malaria especially one caused by **Plasmodium falciparum**, if not treated, may prove fatal.

Our immune system plays the major role in preventing these diseases when we are exposed to disease-causing agents.

The innate defenses of our body like skin, mucous membranes, antimicrobial substances present in our tears, saliva and the phagocytic cells help to block the entry of pathogens into our body.

If the pathogens succeed in gaining entry to our body, specific antibodies (humoral immune response) and cells (cell mediated immune response) serve to kill these pathogens.

Immune system has memory. On subsequent exposure to same pathogen, the immune response is rapid and more intense. This forms the basis of protection afforded by vaccination and immunization.

Source: NCERT Science Textbooks Class 6-12

AIDS – Acquired Immuno Deficiency Syndrome – Causes of AIDS – Mechanism of HIV Proliferation in Human Body – Prevention of AIDS.

AIDS – Acquired Immuno Deficiency Syndrome

The word AIDS stands for **Acquired Immuno Deficiency Syndrome**. This means deficiency of immune system, acquired during the lifetime of an individual indicating that it is not a **congenital disease** [disease or abnormality present from birth]. 'Syndrome' means a group of symptoms.

AIDS was first reported in 1981 and in the last twenty-five years or so, it has spread all over the world.

Causes of AIDS

AIDS is caused by the **Human Immuno Deficiency Virus (HIV)**, a member of a group of viruses called **Retrovirus**, which have an **envelope enclosing the RNA genome**.

Transmission of HIV-infection generally occurs by

sexual contact with infected person,

by transfusion of contaminated blood and blood products,

by sharing infected needles as in the case of intravenous drug abusers and

from infected mother to her child through placenta.

So, people who are at high risk of getting this infection includes

individuals who have multiple sexual partners,

drug addicts who take drugs intravenously,

individuals who require repeated blood transfusions and

children born to an HIV infected mother.

It is important to note that HIV/AIDS is not spread by mere touch or physical contact; it spreads only through **body fluids**. It is, hence, imperative, for the physical and psychological well-being, that the HIV/AIDS infected persons are not isolated from family and society.

There is always a time-lag between the infection and appearance of AIDS symptoms. This period may vary from a few months to many years (usually 5-10 years).

Mechanism of HIV Proliferation in Human Body

After getting Into the body of the person, the virus enters into **macrophages** where **RNA genome** of the virus replicates to form **viral DNA** with the help of the enzyme **Reverse Transcriptase**.

This viral DNA gets incorporated into host cell's DNA and directs the infected cells to produce virus particles. The **macrophages** continue to produce virus and in this way acts like a HIV factory.

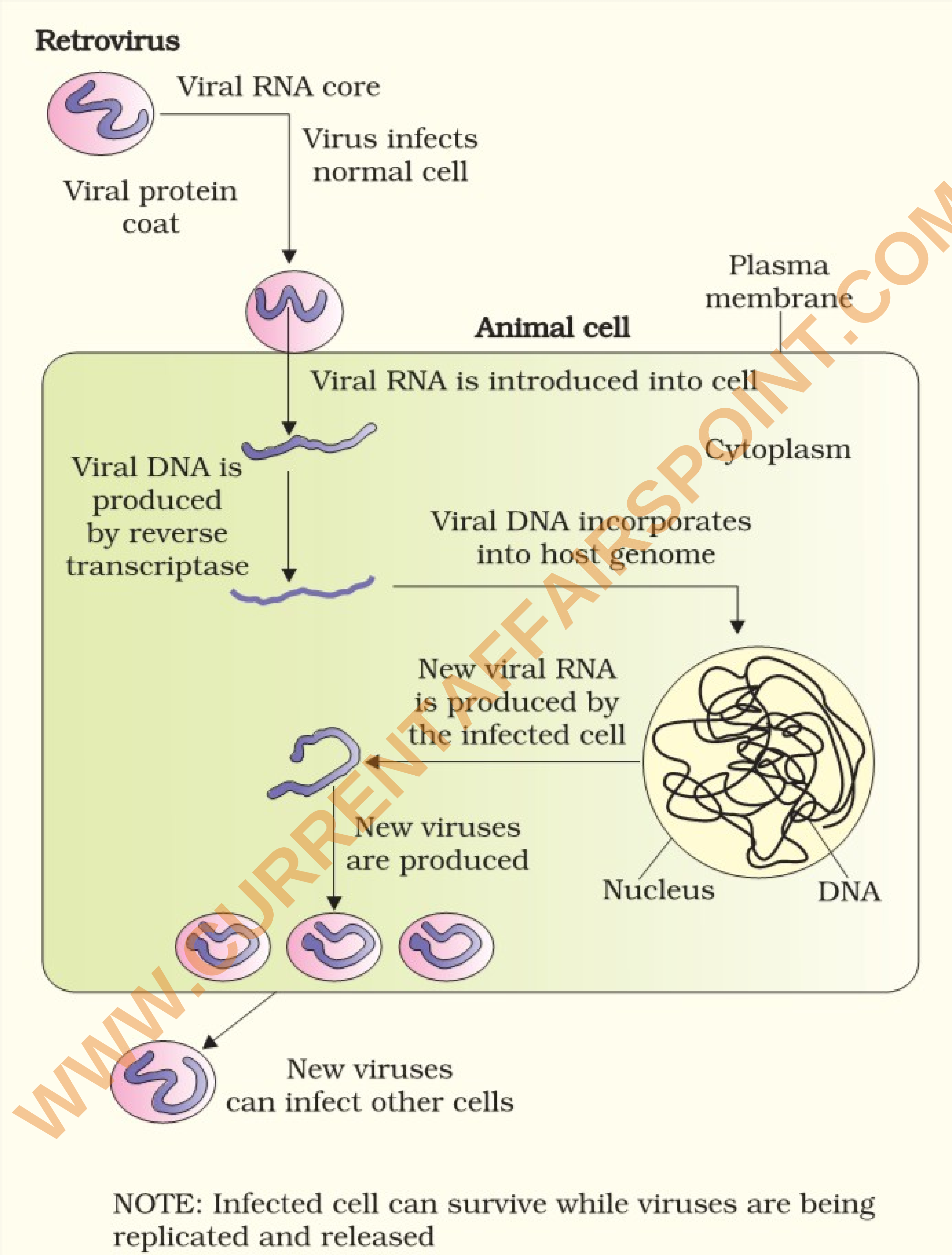


Figure 8.6 Replication of retrovirus

Simultaneously, HIV enters into helper **T-lymphocytes (Th)**, replicates and produce progeny viruses. The progeny viruses released in the blood attack other helper T-lymphocytes. This is repeated leading to a progressive decrease in the number of helper T-lymphocytes in the body of the infected person. During this period, the person suffers from bouts of **fever, diarrhoea** and **weight loss**.

Due to decrease in the number of **helper** T lymphocytes, the person starts suffering from infections that could have been otherwise overcome such as those due to bacteria especially Mycobacterium, viruses, fungi and even parasites like Toxoplasma. The patient becomes so immuno-deficient that he/she is unable to protect himself/herself against these infections.

Prevention of AIDS

A widely used diagnostic test for AIDS is **Enzyme Linked Immuno-Sorbent Assay (ELISA)**.

Treatment of AIDS with **anti-retroviral drugs** is only partially effective. They can only prolong the life of the patient but cannot prevent death, which is inevitable.

As AIDS has no cure, prevention is the best option. Moreover, HIV infection, more often, spreads due to conscious behavior patterns and is not something that happens inadvertently, like pneumonia or typhoid.

Of course, infection in blood transfusion patients, new-borns (from mother) etc., may take place due to poor monitoring. The only excuse may be ignorance and it has been rightly said - “don’t die of ignorance”.

In our country the **National AIDS Control Organization (NACO)** and other non-governmental organizations (NGOs) are doing a lot to educate people about AIDS.

WHO has started a number of programmes to prevent the spreading of HIV infection.

Making blood (from blood banks) safe from HIV, ensuring the use of only disposable needles and syringes in public and private hospitals and clinics, free distribution of condoms, controlling drug abuse, advocating safe sex and promoting regular check-ups for HIV in susceptible populations, are some such steps taken up.

Infection with HIV or having AIDS is something that should not be hidden - since then, the infection may spread to many more people.

HIV/AIDS-infected people need help and sympathy instead of being shunned by society.

Unless society recognizes it as a problem to be dealt with in a collective manner - the chances of wider spread of the disease increase manifold.

It is a malady that can only be tackled, by the society and medical fraternity acting together, to prevent the spread of the disease.

Cancer

Cancer is one of the most dreaded diseases of human beings and is a major cause of death all over the globe.

More than a million Indians suffer from cancer and a large number of them die from it annually.

The mechanisms that underlie development of cancer or **oncogenic** transformation of cells, its treatment and control have been some of the most intense areas of research in biology and medicine.

In our body, cell growth and differentiation is highly controlled and regulated. In cancer cells, there is **breakdown** of these regulatory mechanisms.

Normal cells show a property called **contact inhibition** by virtue of which contact with other cells inhibits their uncontrolled growth.

Cancer cells appears to have lost this property of contact inhibition. As a result of this, cancerous cells just continue to divide giving rise to masses of cells called **tumors**.

Types of Tumors

Tumors are of two types: **benign** and **malignant**.

Benign tumors normally remain confined to their original location and **do not spread** to other parts of the body and cause little damage.

The malignant tumors, on the other hand are a mass of **proliferating cells** called **neoplastic** or **tumor cells**. These cells grow very rapidly, invading and damaging the surrounding normal tissues.

As these cells actively divide and grow they also starve the normal cells by competing for vital nutrients.

Cells sloughed from such tumors reach distant sites through blood, and wherever they get lodged in the body, they start a new tumor there. This property called **Metastasis** is the most feared property of malignant tumors.

Causes of Cancer

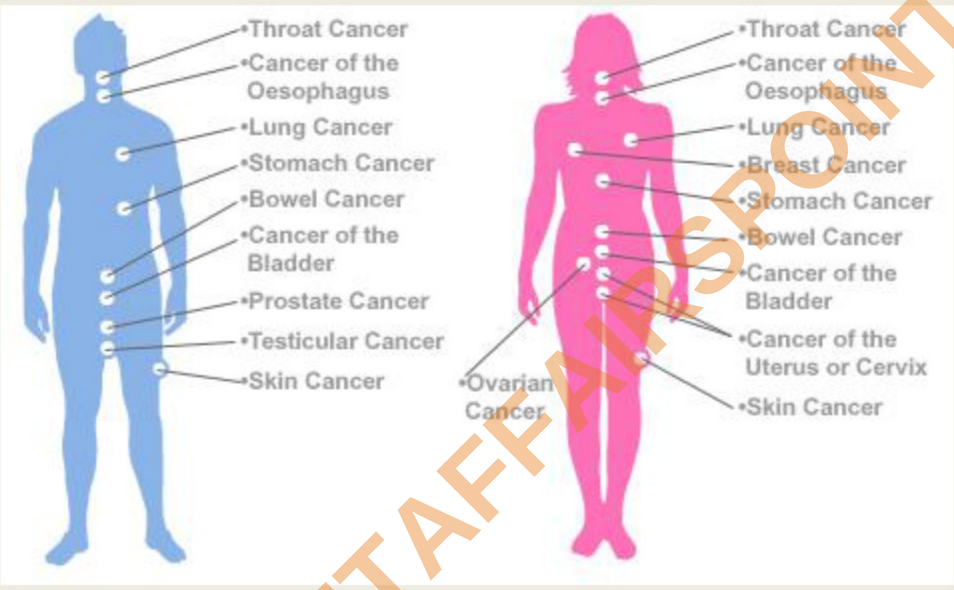
Transformation of normal cells into **cancerous neoplastic cells** may be induced by physical, chemical or biological agents. These agents are called **carcinogens**.

Ionizing radiations like **X-rays** and **gamma rays** and **non-ionizing radiations** like **UV** cause DNA damage leading to neoplastic transformation.

The chemical carcinogens present in tobacco smoke have been identified as a major cause of lung cancer.

Cancer causing viruses called **oncogenic viruses** have genes called **viral oncogenes**.

Furthermore, several genes called **cellular oncogenes (c-onc) or proto oncogenes** have been identified in normal cells which, when activated under certain conditions, could lead to oncogenic transformation of the cells.



Cancer Detection and Diagnosis

Early detection of cancers is essential as it allows the disease to be treated successfully in many cases.

Cancer detection is based on **biopsy** and histopathological studies of the tissue and blood and bone marrow tests for increased cell counts in the case of **leukemias**.

In biopsy, a piece of the suspected tissue cut into thin sections is stained and examined under microscope (histopathological studies) by a pathologist.

Techniques like **radiography (use of X-rays)**, **CT (computed tomography)** and **MRI (magnetic resonance imaging)** are very useful to detect cancers of the internal organs.

Computed tomography uses **X-rays** to generate a three-dimensional image of the internals of an object.

MRI uses strong **magnetic fields** and **non-ionising** radiations to accurately detect pathological and physiological changes in the living tissue.

Antibodies against cancer-specific antigens are also used for detection of certain cancers.

Techniques of molecular biology can be applied to detect genes in individuals with inherited susceptibility to certain cancers. Identification of such genes, which predispose an Individual to certain cancers, may be very helpful in prevention of cancers.

Such individuals may be advised to avoid exposure to particular carcinogens to which they are susceptible (e.g., tobacco smoke in case of lung cancer).

Treatment of cancer

The common approaches for treatment of cancer are **surgery, radiation therapy** and **immunotherapy**.

In radiotherapy, tumor cells are Irradiated lethally, taking proper care of the normal tissues surrounding the tumor mass.

Several chemotherapeutic drugs are used to kill cancerous cells. Some of these are specific for particular tumors. Majority of drugs have side effects like hair loss, anemia, etc.

Most cancers are treated by combination of surgery, radiotherapy and chemotherapy.

Tumor cells have been shown to avoid detection and destruction by immune system. Therefore, the patients are given substances called **biological response modifiers** such as **a-interferon** which activate their immune system and help in destroying the tumor.

Source: NCERT Science Textbooks Class 6-12

Cell Organelles | Plant Cell vs. Animal Cell
Carbohydrates | Monosaccharides | Polysaccharides
Proteins | Amino Acids | Enzymes
Vitamins and Minerals – Deficiency Diseases
Fats | Healthy Fats and Unhealthy Fats
Animal Tissues – Epithelium, Connective Tissues
Human Digestive System | Digestive Glands
Respiratory System – NCERT General Science
Endocrine Glands and Hormones
Human Neural System | Human Brain
Muscular and Skeletal System
Nucleic acids – DNA and RNA | Recombinant DNA
Mitosis | Cell Cycle | Cell Division
Meiosis | Mitosis – Meiosis Comparison
Inheritance – Mendel's Laws of Inheritance
Chromosomal Theory | Human Genome Project
Sex Determination | Genetic Disorders

Diseases Caused by Microorganisms
Microbes In Human Welfare | Useful Microbes
Immunity | Human Immune System

Drugs and Alcohol Abuse

The drugs, which are commonly abused are **opioids, cannabinoids** and **coca alkaloids**.

Majority of these are obtained from **flowering plants**. Some are obtained from **fungi**.

Opioids are the drugs, which bind to specific **opioid receptors** present in our central nervous system and gastrointestinal tract.

Heroin, commonly called smack is chemically **diacetylmorphine** which is a white, odourless, bitter crystalline compound. This is obtained by acetylation of **morphine**, which is extracted from the latex of **poppy** plant **Papaver somniferum**. Generally taken by snorting and injection, heroin is a **depressant** and **slows down body functions**.

Cannabinoids are a group of chemicals, which interact with **cannabinoid receptors** present principally in the brain.

Natural cannabinoids are obtained from the inflorescences of the plant **Cannabis sativa**. The flower tops, leaves and the resin of cannabis plant are used in various combinations to produce **marijuana, hashish, charas** and **ganja**. Generally taken by inhalation and oral ingestion, these are known for their effects on **cardiovascular system** of the body.

These days cannabinoids are also being abused by some sportspersons.

Coca alkaloid or cocaine is obtained from coca plant **Erythroxylum coca**, native to South America. It interferes with the transport of the **neuro-transmitter dopamine**.

Cocaine, commonly called coke or crack is usually snorted. It has a potent stimulating action on central nervous system, producing a sense of euphoria and increased energy. Excessive dosage of cocaine causes **hallucinations**.

Other well-known plants with hallucinogenic properties are **Atropa belladona** and **Datura.**

Drugs like barbiturates, amphetamines, benzodiazepines, lysergic acid diethyl amides (LSD), and other similar drugs, that are normally used as medicines to help patients cope with mental illnesses like depression and insomnia, are often abused.

Morphine is a very effective **sedative** and **painkiller**, and is very useful in patients who have undergone surgery.

Several plants, fruits and seeds having hallucinogenic properties have been used for hundreds of years in folk-medicine, religious ceremonies and rituals all over the globe.

When these are taken for a purpose other than medicinal use or in amounts/frequency that impairs one's physical, physiological or psychological functions, it constitutes drug abuse.

Smoking also paves the way to hard drugs. Tobacco has been used by human beings for more than 400 years. It is smoked, chewed or used as a snuff. Tobacco contains a large number of chemical substances including **nicotine**, an alkaloid.

Nicotine stimulates **adrenal gland** to release **adrenaline** and **nor-adrenaline** into blood circulation, both of which raise **blood pressure** and increase heart rate.

Smoking is associated with increased incidence of cancers of lung, urinary bladder and throat, bronchitis, emphysema, coronary heart disease, gastric ulcer, etc.

Tobacco chewing is associated with increased risk of cancer of the oral cavity. Smoking increases **carbon monoxide (CO)** content in blood and reduces the concentration of **haembound oxygen**. This causes oxygen deficiency in the body.

When one buys packets of cigarettes one cannot miss the statutory warning that is present on the packing which warns against smoking and says how it is injurious to health. Yet, smoking is very prevalent in society, both among young and old.

Knowing the dangers of smoking and chewing tobacco, and its addictive nature, the youth and old need to avoid these habits. Any addict requires counselling and medical help to get rid of the habit.

Effects of Drug/Alcohol Abuse

The immediate adverse effects of drugs and alcohol abuse are manifested in the form of reckless behavior, vandalism and violence.

Excessive doses of drugs may lead to coma and death due to respiratory failure, heart failure or cerebral hemorrhage.

A combination of drugs or their intake along with alcohol generally results in overdosing and even deaths.

The most common warning signs of drug and alcohol abuse among youth include drop in academic performance, unexplained absence from school/college, lack of interest in personal hygiene, withdrawal, isolation, depression, fatigue, aggressive and rebellious behaviour, deteriorating relationships with family and friends, loss of interest in hobbies, change in sleeping and eating habits, fluctuations in weight, appetite, etc.

There may even be some far-reaching implications of drug/alcohol abuse. If an abuser is unable to get money to buy drugs/alcohol he/she may turn to stealing.

The adverse effects are just not restricted to the person who is using drugs or alcohol. At times, a drug/alcohol addict becomes the cause of mental and financial distress to his/ her entire family and friends.

Those who take drugs intravenously (direct injection into the vein using a needle and syringe), are much more likely to acquire serious infections like **AIDS** and **hepatitis B**.

The viruses, which are responsible for these diseases, are transferred from one person to another by sharing of infected needles and syringes.

Both AIDS and Hepatitis B infections are chronic infections and ultimately fatal. AIDS can be transmitted to one's life partner through sexual contact while Hepatitis B is transmitted through infected blood .

The use of alcohol during adolescence may also have long-term effects. It could lead to heavy drinking in adulthood. The chronic use of drugs and alcohol damages nervous system and **liver (cirrhosis)**. The use of drugs and alcohol during pregnancy is also known to adversely affect the foetus.

Another misuse of drugs is what certain sportspersons do to enhance their performance. They (mis)use **narcotic analgesics, anabolic steroids, diuretics** and **certain hormones** in sports to increase muscle strength and bulk and to promote aggressiveness and as a result increase athletic performance.

The side-effects of the use of anabolic steroids in females include masculinization (features like males), increased aggressiveness, mood swings, depression, abnormal menstrual cycles, excessive hair growth on the face and body, enlargement of clitoris, deepening of voice.

In males it includes acne, increased aggressiveness, mood swings, depression, reduction of size of the testicles, decreased sperm production, potential for kidney and liver dysfunction, breast enlargement, premature baldness, enlargement of the prostate gland. These effects may be permanent with prolonged use.

In the adolescent male or female, severe facial and body acne, and premature closure of the growth centers of the long bones may result in stunted growth.

Prevention and Control

The age-old adage of 'prevention is better than cure' holds true here also. It is also true that habits such as smoking, taking drug or alcohol are more likely to be taken up at a young age, more during adolescence. Hence, it is best to identify the situations that may push an adolescent towards use of drugs or alcohol, and to take remedial measures well in time. In this regard, the parents and the teachers have a special responsibility.

Parenting that combines with high levels of nurturance and consistent discipline, has been associated with lowered risk of substance (alcohol/drugs/tobacco) abuse. Some of the measures mentioned here would be particularly useful for prevention and control of alcohol and drugs abuse among adolescents

Avoid undue peer pressure - Every child has his/her own choice and personality, which should be respected and nurtured. A child should not be pushed unduly to perform beyond his/her threshold limits; be it studies, sports or other activities.

Education and counselling - Educating and counselling him/ her to face problems and stresses, and to accept disappointments and failures as a part of life. It would also be worthwhile to channelize the child's energy into healthy pursuits like sports, reading, music, yoga and other extracurricular activities.

Seeking help from parents and peers - Help from parents and peers should be sought immediately so that they can guide appropriately. Help may even be sought from close and trusted friends. Besides getting proper advise to sort out their problems, this would help young to vent their feelings of anxiety and guilt.

Looking for danger signs - Alert parents and teachers need to look for and identify the danger signs discussed above. Even friends, if they find someone using drugs or alcohol, should not hesitate to bring this to the notice of parents or teacher in the best interests of the person concerned. Appropriate measures would then be required to diagnose the malady and the underlying causes. This would help in initiating proper remedial steps or treatment.

Seeking professional and medical help - A lot of help is available in the form of highly qualified psychologists, psychiatrists, and de-addiction and rehabilitation programmes to help individuals who have unfortunately got in the quagmire of drug/alcohol abuse. With such help, the affected individual with sufficient efforts and will power, can get rid of the problem completely and lead a perfectly normal and healthy life.

Summary

Health is not just the absence of disease. It is a state of complete physical, mental, social and psychological well-being.

Diseases like typhoid, cholera, pneumonia, fungal infections of skin, malaria and many others are a major cause of distress to human beings.

Vector-borne diseases like malaria especially one caused by **Plasmodium falciparum**, if not treated, may prove fatal.

Our immune system plays the major role in preventing these diseases when we are exposed to disease-causing agents.

The innate defenses of our body like skin, mucous membranes, antimicrobial substances present in our tears, saliva and the phagocytic cells help to block the entry of pathogens into our body.

If the pathogens succeed in gaining entry to our body, specific antibodies (humoral immune response) and cells (cell mediated immune response) serve to kill these pathogens.

Immune system has memory. On subsequent exposure to same pathogen, the immune response is rapid and more intense. This forms the basis of protection afforded by vaccination and immunization.

Acute and Chronic Diseases, Communicable Diseases, Organ-Specific Diseases, Principles of Treatment, Principles of Prevention, Childhood Diseases in Indian Children.

Some important concepts related to diseases are discussed in the below posts:

Vitamins and Minerals – Deficiency Diseases
Sex Determination | Genetic Disorders
Diseases Caused by Microorganisms
Immunity | Human Immune System
AIDS | Acquired Immuno Deficiency Syndrome
Cancer | Causes of Cancer – NCERT

Acute and Chronic Diseases

Some diseases last for only very short periods of time, and these are called **acute diseases**. We all know from experience that the common cold lasts only a few days.

Other ailments can last for a long time, even as much as a lifetime, and are called **chronic diseases**. An example is the infection causing **elephantiasis**, which is very common in some parts of India.

Communicable Diseases

Microbial diseases that can spread from an infected person to a healthy person through air, water, food or physical contact are called **communicable diseases**.

Examples of such diseases include **cholera, common cold, chicken pox** and **tuberculosis**.

Example of a carrier is the **female Anopheles mosquito**, which carries the parasite of **malaria**. **Female Aedes mosquito** acts as carrier of **dengue virus**.

Robert Köch (1876) discovered the **bacterium** (**Bacillus anthracis**) which causes **anthrax** disease.

How do infectious diseases spread? Many microbial agents can commonly move from an affected person to someone else in a variety of ways. In other words, they can be 'communicated', and so are also called **communicable diseases**.

Such disease-causing microbes can spread through the air. Examples of such diseases spread through the air are the **common cold, pneumonia** and **tuberculosis**.

Diseases can also be spread through water. This occurs if the excreta from someone suffering from an infectious gut disease, such as **cholera**, get mixed with the drinking water used by people living nearby.

The sexual act is one of the closest physical contact two people can have with each other. Not surprisingly, there are microbial diseases such as **Syphilis or AIDS** that are transmitted by sexual contact from one partner to the other.

Other than the sexual contact, the aids virus can also spread through **blood-to-blood contact** with infected people or from an infected mother to her baby during pregnancy or through **breast feeding**.

We live in an environment that is full of many other creatures apart from us. It is inevitable that many diseases will be transmitted by other animals. These animals carry the infecting agents from a sick person to another potential host. These animals are thus the intermediaries and are called **vectors**. The commonest vectors we all know are mosquitoes.

In many species of mosquitoes, the **females** need highly nutritious food in the form of blood in order to be able to lay mature eggs. Mosquitoes feed on many warm-blooded animals, including us. In this way, they can transfer diseases from person to person.

Organ-Specific And Tissue Specific Diseases

Different species of microbes seem to have evolved to home in on different parts of the body. In part, this selection is connected to their point of entry.

If they enter from the air via the nose, they are likely to go to the lungs. This is seen in the bacteria causing **tuberculosis**.

If they enter through the mouth, they can stay in the gut lining like **typhoid** causing bacteria. Or they can go to the liver, like the viruses that cause **jaundice**.

An infection like HIV, that comes into the body via the sexual organs, will spread to lymph nodes all over the body.

Malaria-causing microbes, entering through a mosquito bite, will go to the liver, and then to the red blood cells.

The virus causing **Japanese Encephalitis**, or **brain fever**, will similarly enter through a mosquito bite. But it goes on to infect the brain.

The signs and symptoms of a disease will thus depend on the tissue or organ which the microbe targets. If the lungs are the targets, then symptoms will be cough and breathlessness. If the liver is targeted, there will be jaundice. If the brain is the target, we will observe headaches, vomiting, fits or unconsciousness.

In addition to these tissue-specific effects of infectious disease, there will be other common effects too.

Most of these common effects depend on the fact that the body's immune system is activated in response to infection.

An active immune system recruits many cells to the affected tissue to kill off the disease-causing microbes. This recruitment process is called **inflammation**. As a part of this process, there are local effects such as swelling and pain, and general effects such as fever.

In some cases, the tissue-specificity of the infection leads to very general-seeming effects. For example, in HIV infection, the virus goes to the immune system and damages its function. Thus, many of the effects of HIV-aids are because the body can no longer fight off the many minor infections that we face every day. Instead, every small cold can become **pneumonia**. Similarly, a minor gut infection can produce major diarrhoea with blood loss. Ultimately, it is these other infections that kill people suffering from HIV-aids.

Principles of Treatment

There are two ways to treat an infectious disease. One would be to reduce the effects of the disease and the other to kill the cause of the disease.

For the first, we can provide treatment that will reduce the symptoms. The symptoms are usually because of inflammation. For example, we can take medicines that bring down fever, reduce pain or loose motions. We can take bed rest so that we can conserve our energy. This will enable us to have more of it available to focus on healing.

But this kind of symptom-directed treatment by itself will not make the infecting microbe go away and the disease will not be cured. For that, we need to be able to kill off the microbes.

How do we kill microbes? One way is to use medicines that kill microbes. We have seen earlier that microbes can be classified into different categories. They are viruses, bacteria, fungi or protozoa.

Each of these groups of organisms will have some essential biochemical life process which is peculiar to that group and not shared with the other groups. These processes may be pathways for the synthesis of new substances or respiration. These pathways will not be used by us either.

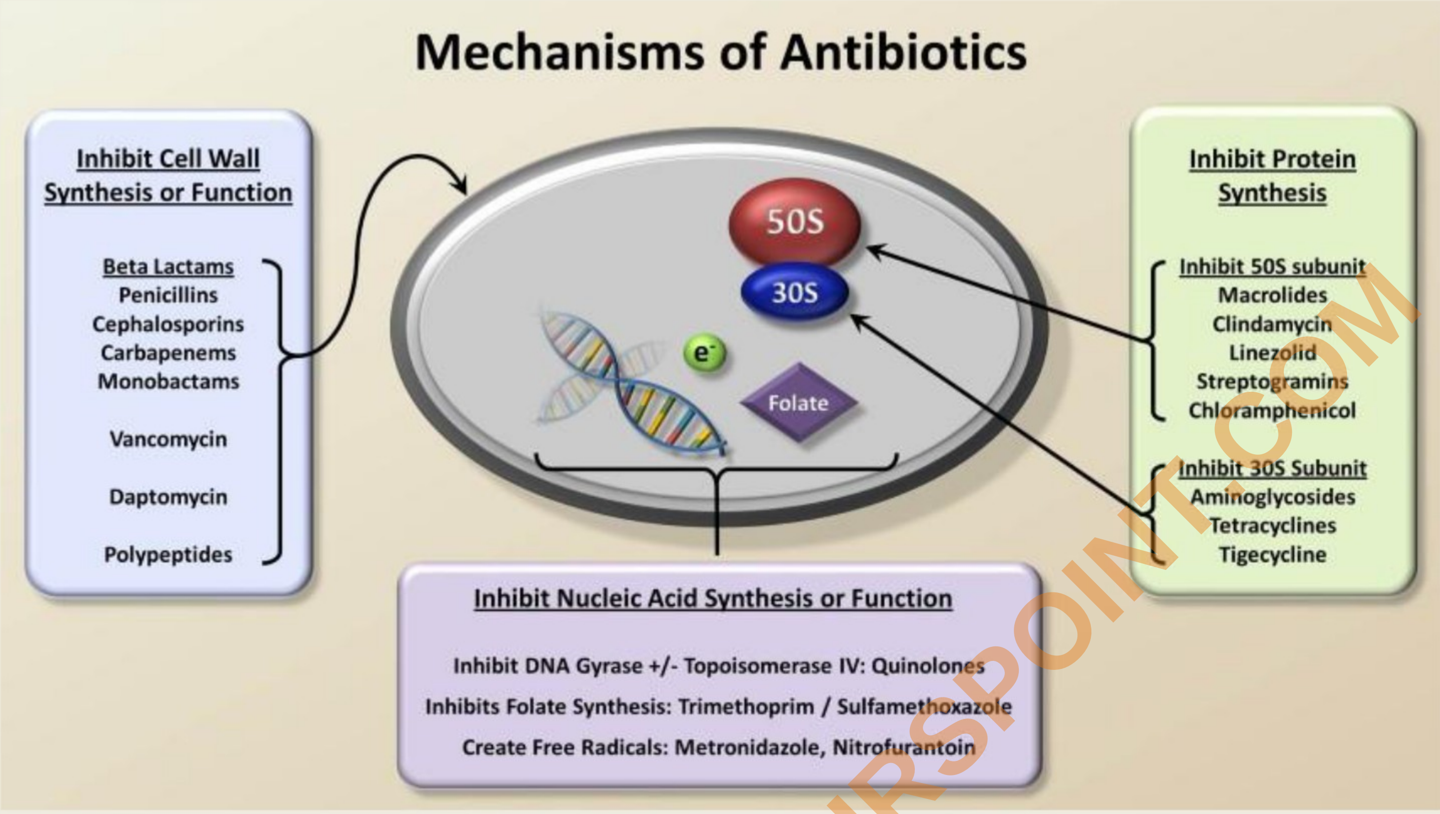
For example, our cells may make new substances by a mechanism different from that used by bacteria. We have to find a drug that blocks the bacterial synthesis pathway without affecting our own. This is what is achieved by the **antibiotics** that we are all familiar with. Similarly, there are drugs that kill protozoa such as the malarial parasite.

Why are Antibiotics effective against Bacterial Infections but not Viral Infections?

One reason why making anti-viral medicines is harder than making antibacterial medicines is that viruses have **few biochemical mechanisms of their own**. This means that there are relatively few virus-specific targets to aim at.

Despite this limitation, there are now effective anti-viral drugs, for example, the drugs that keep HIV infection under control.

Taxonomically, all bacteria are closely related to each other than to viruses and vice versa. This means that many important life processes are similar in the bacteria group but are not shared with the virus group. As a result, drugs that block one of these life processes in one member of the group is likely to be effective against many other members of the group. But the same drug will not work against a microbe belonging to a different group.



As an example, let us take antibiotics. They commonly block biochemical pathways important for **bacteria**. Many bacteria, for example, make a cell-wall to protect themselves. The antibiotic penicillin blocks the bacterial processes that build the cell wall. As a result, the growing bacteria become unable to make cell-walls, and die easily.

Human cells don't make a cell-wall anyway, so penicillin cannot have such an effect on us. Penicillin will have this effect on any bacteria that use such processes for making cell-walls. Similarly, many antibiotics work against many species of bacteria rather than simply working against one group.

But viruses do not use these pathways at all, and that is the reason why antibiotics do not work against viral infections. If we have a common cold, taking antibiotics does not reduce the severity or the duration of the disease. However, if we also get a bacterial infection along with the viral cold, taking antibiotics will help. Even then, the antibiotic will work only against the bacterial part of the infection, not the viral infection.

Principles of Prevention

What are the specific ways of prevention? They relate to a peculiar property of the immune system that usually fights off microbial infections.

Let us cite an example to try and understand this property. These days, there is no smallpox anywhere in the world. But as recently as a hundred years ago, smallpox epidemics were not at all uncommon.

In such an epidemic, people used to be very afraid of coming near someone suffering from the disease since they were afraid of catching the disease.

However, there was one group of people who did not have this fear. These people would provide nursing care for the victims of smallpox.

This was a group of people who had had smallpox **earlier** and survived it, although with a lot of scarring. In other words, if you had smallpox once, there was no chance of suffering from it again.

So, having the disease once was a means of preventing subsequent attacks of the same disease. This happens because when the immune system first sees an infectious microbe, it responds against it and then remembers it specifically.

So the next time that particular microbe, or its close relatives enter the body, the immune system responds with even greater vigour. This eliminates the infection even more quickly than the first time around. This is the basis of the principle of '**vaccination**' has come into our usage.

We can now see that, as a general principle, we can 'fool' the immune system into developing a memory for a particular infection by putting something, that mimics the microbe we want to vaccinate against, into the body. This does not actually cause the disease but this would prevent any subsequent exposure to the infecting microbe from turning into actual disease.

Many such vaccines are now available for preventing a whole range of infectious diseases, and provide a disease-specific means of prevention.

There are vaccines against *tetanus, diphtheria, whooping cough, measles, polio* and many others.

Introducing fishes like **Gambusia** in ponds that feed on mosquito larvae, spraying of insecticides in ditches, drainage areas and swamps, etc. can prevent proliferation of mosquitoes. Such precautions have become all the more important especially in the light of recent widespread incidences of the vector-borne (**Aedes mosquitoes**) diseases like **dengue** and **chikungunya** in many parts of India.

Traditional Indian and Chinese medicinal systems sometimes deliberately rubbed the skin crusts from smallpox victims into the skin of healthy people. They thus hoped to induce a mild form of smallpox that would create resistance against the disease.

Famously, two centuries ago, an English physician named **Edward Jenner**, realized that milkmaids who had had cowpox did not catch smallpox even during epidemics.

Cowpox is a very mild disease. Jenner tried deliberately giving cowpox to people, and found that they were now resistant to smallpox. This was because the smallpox virus is closely related to the cowpox virus. 'Cow' is 'Vacca' in latin, and cowpox is 'Vaccinia'.

Childhood Diseases in Indian Children

Gastroentitis

Gastroentitis is an infection in the digestive system and it is one of the most common childhood illnesses.

Symptoms of gastroentitis include diarrhoea, nausea and vomiting, tummy cramps, and fever.

One of the main risks with gastroentitis is that it causes **dehydration** in children.

Rickets

Rickets occurs due to **Vitamin D deficiency**.

Deficiency of Vitamin D occurs in a child because of **lack of exposure to sunlight**.

Lack of adequate **calcium** in the diet can also cause rickets.

Rickets is a disease which involves softening and **weakening of bones** in children.

Children between the ages of 6 to 24 months are at the highest risk of developing the disease because that is the age when their bones are rapidly growing.

Conjunctivitis

Conjunctivitis is caused due to inflammation of the **conjunctiva**.

Conjunctiva is the outermost layer of the eye and the inner surface of the eyelids.

Conjunctivitis often starts in one eye at first and then spreads to the other eye.

For children suffering from conjunctivitis it is important to see a doctor to know what kind of conjunctivitis it is.

Symptoms of conjunctivitis include redness of eyes, irritation in the eye, and eye watering.

Scabies

Scabies is an infection of the skin.

Scabies is caused by tiny insects called **mites**.

These scabies mites burrow into the skin and lay eggs which become adult mites very soon.

Symptoms of this infection include superficial burrows, rash and severe itching.

Blisters on the palm and soles of the feet are characteristic symptoms of scabies in infants.

Scabies is one of the highly contagious diseases and a child can develop it by coming into contact with someone else who has been infected.

Children with scabies must not be sent to school or day care until it gets completely cured.

Upper Respiratory Tract infection (URTI)

Upper Respiratory Tract Infections are extremely common due to air pollution and vehicular emission.

Upper respiratory tract infections include common cold, influenza and sore throat.

Tonsillitis is also one of upper respiratory tract infections.

Tonsillitis is caused due to infection of the tonsils.

Tonsils are the areas of **lymphoid tissue** on either side of the throat.

Symptoms of tonsillitis include a severe sore throat, coughing, headache and difficulty swallowing.

Tuberculosis

Tuberculosis also affects children and is known as Primary Complex or Childhood Tuberculosis infection.

Children under the age of two years are more at risk of developing tuberculosis because their immune system is under developed or still developing.

Tuberculosis is completely curable and early diagnosis can help in effective treatment.

Typhoid

It is a water borne disease rampant in children due to poor sanitation.

Cases of typhoid are more common in countries like India and some other South Asian countries and in other low developed nations and have been seen lesser in countries like the USA.

Symptoms of typhoid in children are poor appetite, body ache, discomfort in abdomen, lethargy and weakness, fever with rising and falling pattern.

Some children may also experience headache, chest congestion, diarrhoea and vomiting and rose spots on the abdomen.

Bronchitis and Asthma

Bronchitis and asthma are common in children.

Bronchitis and asthma are caused due to high exposure to air borne pollutants.

Bronchitis and asthma need to be treated with antibiotics and bronchodilators.

Some Other Diseases

Diseases Caused by Worms

Ascaris, the common **round worm** and **Wuchereria**, the **filarial worm**, are some of the **helminths** which are known to be pathogenic to man. Ascaris, an intestinal parasite causes **ascariasis**.

Symptoms of these disease include internal bleeding, muscular pain, fever, anemia and blockage of the intestinal passage. The eggs of the parasite are excreted along with the faeces of infected persons which contaminate soil, water, plants, etc. A healthy person acquires this infection through contaminated water, vegetables, fruits, etc.

Wuchereria (W. bancrofti and **W. malayi)**, the filarial worms cause a slowly developing chronic inflammation of the organs in which they live for many years, usually the lymphatic vessels of the lower limbs and the disease is called **elephantiasis or filariasis.** The genital organs are also often affected, resulting in gross deformities. The pathogens are transmitted to person through the bite by the female mosquite.

Old Age Diseases: Dementia

Dementia is "one of the major causes of disability and dependency among older people worldwide"

Pollution related diseases: Silicosis

Silicosis is a lung disorder caused by inhalation, retention and pulmonary reaction to crystalline silica, as a result of exposure during mining, stone crushing and quarrying activities.

Zoonotic Diseases

zoonotic diseases — are spread between animals and humans, and are common in societies where poverty is widespread

Chikungunya, dengue, Avian influenza, plague, SARS and acute encephalitis syndrome (AES) are some of the zoonotic diseases.

Blood – Blood Vessels, Body Fluids and Circulation: Plasma, Formed Elements: Red Blood Cells (RBC), White Blood Cells (WBC), Platelets, Coagulation of Blood, Blood Groups.

Blood

It transports substances like digested food from the small intestine to the other parts of the body. It carries oxygen from the lungs to the cells of the body. It also transports waste for removal from the body.

Blood is a liquid, which has cells of various kinds suspended in it. The fluid part of the blood is called **plasma**.

One type of cells are the **red blood cells (RBC)** which contain a red pigment called **haemoglobin**.

Haemoglobin bind with oxygen and transports it to all the parts of the body and ultimately to all the cells. The presence of haemoglobin makes blood appear **red**.

The blood also has **white blood cells (WBC)** which **fight against germs** that may enter our body.

The **clot** is formed because of the presence of another type of cells in the blood, called **platelets**.

Blood Vessels

They are two types of blood vessels namely **arteries** and **veins**.

Veins are the blood vessels that carry **carbon dioxide-rich blood [impure blood]** from all parts of the body back to the heart. Pulmonary vein is an exception as it carries **oxygen-rich blood [pure blood]** from lungs to heart. The veins have **thin walls**.

Arteries are the blood vessels that carry **oxygen-rich blood** from heart to all parts of the body. **Pulmonary artery** is an exception as it carries carbon dioxide-rich blood from heart to lungs. The arteries have **thick walls** as the pressure acting on then is high.

Blood FROM Heart → Artery

Blood TO Heart → Vein

Arteries divide into smaller vessels. On reaching the tissues, they divide further into extremely thin tubes called **capillaries**. The capillaries join up to form veins which empty into the heart.

Body Fluids and Circulation

Blood is a **special connective tissue** consisting of a fluid matrix, plasma, and formed elements.

Plasma

Plasma is a straw coloured, viscous fluid constituting nearly 55 per cent of the blood.

90-92 per cent of plasma is water and proteins contribute 6-8 per cent of it.

Fibrinogen, globulins and **albumins** are the major proteins.

Fibrinogens are needed for **clotting or coagulation** of blood.

Globulins primarily are involved in **defense** mechanisms of the body

Albumins help in **osmotic balance**.

Plasma also contains small amounts of minerals like Na^+, Ca^{++}, Mg^{++}, HCO_3^-, Cl^-, etc. Glucose, amino acids, lipids, etc., are also present in the plasma as they are always in transit in the body.

Factors for coagulation or clotting of blood are also present in the plasma in an inactive form. Plasma without the clotting factors is called **serum**.

Formed Elements

Erythrocytes, leucocytes and **platelets** are collectively called **formed elements** and they constitute nearly 45 per cent of the blood.

Red Blood Cells (RBC)

Erythrocytes or red blood cells (RBC) are the most abundant of all the cells in blood.

A healthy adult man has, on an average, 5 million to 5.5 million of RBCs mm^{-3} of blood.

RBCs are formed in the **red bone marrow** in the adults. RBCs are **devoid of nucleus** in most of the mammals and are **biconcave** in shape.

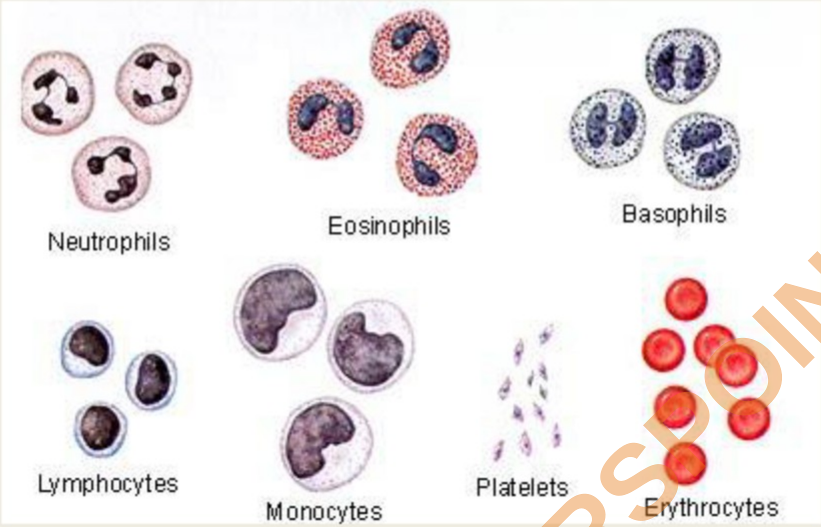
They have a red coloured, iron containing complex protein called haemoglobin, hence the colour and name of these cells.

RBCs have an average life span of **120 days** after which they are destroyed in the **spleen (graveyard of RBCs)**.

White Blood Cells (WBC)

Leucocytes are also known as **white blood cells (WBC)** as they are colorless due to the lack of haemoglobin. They are **nucleated** and are relatively lesser in number which averages 6000-8000 mm-3 of blood. Leucocytes are generally **short lived**. We have two main categories of WBCs - **granulocytes** and **agranulocytes**.

Neutrophils, eosinophils and **basophils** are different types of granulocytes, while **lymphocytes** and **monocytes** are the agranulocytes.



http://www.biosbcc.net/doohan/sample/htm/Blood%20cells.htm

Neutrophils are the most abundant cells (60-65 per cent) of the total WBCs and basophils are the least (0.5-1 per cent) among them.

Neutrophils and monocytes (6-8 per cent) are **phagocytic cells** which destroy foreign organisms entering the body.

Basophils secrete **histamine, serotonin, heparin**, etc., and are involved in **inflammatory reactions**.

Eosinophils (2-3 per cent) **resist infections** and are also associated with **allergic reactions**.

Lymphocytes (20-25 per cent) are of two major types - 'B' and 'T' forms. Both B and T lymphocytes are responsible for **immune responses** of the body.

Platelets

Platelets also called **thrombocytes**, are cell fragments produced from **megakaryocytes (special cells in the bone marrow)**.

Blood normally contains 1,500,00-3,500,00 platelets mm-3.

Platelets can release a variety of substances most of which are involved in the **coagulation or clotting of blood**.

Coagulation of Blood

Blood exhibits coagulation or clotting in response to an injury or trauma. This is a mechanism to prevent excessive loss of blood from the body.

Dark reddish brown scum is formed at the site of a cut or an injury over a period of time. It is a **clot or coagulam** formed mainly of a network of threads called **fibrins** in which **dead and damaged** formed elements of blood are trapped.

Fibrins are formed by the conversion of inactive fibrinogens in the plasma by the enzyme **thrombin**.

Thrombins, in turn are formed from another inactive substance present in the plasma called **prothrombin**. An enzyme complex, **thrombokinase**, is required for the above reaction. This complex is formed by a series of linked enzymic reactions (cascade process) involving a number of factors present in the plasma in an inactive state.

An injury or a trauma stimulates the platelets in the blood to release certain factors which activate the mechanism of coagulation. Certain factors released by the tissues at the site of injury also can initiate coagulation. **Calcium ions** play a very important role in clotting.

Lymph (Tissue Fluid)

As the blood passes through the capillaries in tissues, some water along with many small water soluble substances move out into the spaces between the cells of tissues leaving the larger proteins and most of the formed elements in the blood vessels. This fluid released out is called the **interstitial fluid or tissue fluid**.

Interstitial fluid or tissue fluid has the same mineral distribution as that in plasma. Exchange of nutrients, gases, etc., between the blood and the cells always occur through this fluid.

An elaborate network of vessels called the **lymphatic system** collects this fluid and drains it back to the major veins. The fluid present in the lymphatic system is called the **lymph**.

Lymph is a colourless fluid containing **specialized lymphocytes** which are responsible for the **immune responses** of the body. Lymph is also an **important carrier** for nutrients, hormones, etc.

Fats are absorbed through lymph in the lacteals present in the intestinal villi.

Blood Groups

As you know, blood of human beings differ in certain aspects though it appears to be similar. Various types of grouping of blood has been done. Two such groupings - the ABO and Rh - are widely used all over the world.

ABO grouping

ABO grouping is based on the presence or absence of **two surface antigens** (chemicals that can induce immune response) on the **RBCs** namely A and B.

Similarly, the plasma of different individuals contain **two natural antibodies** (proteins produced in response to antigens).

The distribution of antigens and antibodies in the four groups of blood, A, B, AB and O are given in Table below.

TABLE 18.1 Blood Groups and Donor Compatibility

Blood Group	Antigens on RBCs	Antibodies in Plasma	Donor's Group
A	A	anti-B	A, O
B	B	anti-A	B, O
AB	A, B	nil	AB, A, B, O
O	nil	anti-A, B	O

ABO blood groups are controlled by the **gene I**. The plasma membrane of the red blood cells has **sugar polymers** that protrude from its surface and the kind of sugar is controlled by the gene. **The gene (I) has three alleles IA, IB and i**.

The alleles **IA and IB produce a slightly different form of the sugar** while allele **i does not produce any sugar**.

Because humans are diploid organisms, each person possesses any two of the three I gene alleles.

IA and IB are completely dominant over i, in other words when IA and i are present only IA expresses (because i does not produce any sugar), and when IB and i are present IB expresses.

But when IA and IB are present together they both express their own types of sugars: this is because of **co-dominance**. Hence red blood cells have both A and B types of sugars.

Since there are three different alleles, there are six different combinations of these three alleles that are possible, and therefore, a total of six different genotypes of the human ABO blood types. How many phenotypes are possible?

Table 5.2: Table Showing the Genetic Basis of Blood Groups in Human Population

Allele from Parent 1	Allele from Parent 2	Genotype of offspring	Blood types of offspring
I^A	I^A	$I^A I^A$	A
I^A	I^B	$I^A I^B$	AB
I^A	i	$I^A i$	A
I^B	I^A	$I^A I^B$	AB
I^B	I^B	$I^B I^B$	B
I^B	i	$I^B i$	B
i	i	$i\,i$	O

Here there are 6 Genotypes and 4 Phenotypes [A, B, AB and O].

You probably know that during blood transfusion, any blood cannot be used; the blood of a donor has to be carefully matched with the blood of a recipient before any blood transfusion to avoid **severe problems of clumping (destruction of RBC)**.

From the above mentioned table it is evident that group 'O' blood can be donated to persons with any other blood group and hence 'O' group individuals are called **'universal donors'**.

Persons with 'AB' group can accept blood from persons with AB as well as the other groups of blood. Therefore, such persons are called **'universal recipients'**.

Rh grouping

Another **antigen**, the **Rh antigen** similar to one present in **Rhesus monkeys** (hence Rh), is also observed on the surface of RBCs of majority (**nearly 80 per cent**) of humans. Such individuals are called **Rh positive (Rh+ve)** and those in whom this antigen is absent are called **Rh negative (Rh-ve)**.

An Rh-ve person, if exposed to Rh+ve blood, will form specific antibodies against the Rh antigens. Therefore, Rh group should also be matched before transfusions.

A special case of Rh incompatibility (mismatching) has been observed between the Rh-ve blood of a pregnant mother with Rh+ve blood of the foetus.

Rh antigens of the foetus do not get exposed to the Rh-ve blood of the mother in the first pregnancy as the two bloods are well separated by the placenta.

However, during the delivery of the first child, there is a possibility of exposure of the maternal blood to small amounts of the Rh+ve blood from the foetus.

In such cases, the mother starts preparing antibodies against Rh antigen in her blood.

In case of her subsequent pregnancies, the Rh antibodies from the mother (Rh-ve) can leak into the blood of the foetus (Rh+ve) and destroy the foetal RBCs.

This could be fatal to the foetus or could cause severe **anaemia** and **jaundice** to the baby. This condition is called **erythroblastosis foetalis**.

This can be avoided by administering **anti-Rh antibodies** to the mother immediately after the delivery of the first child.

Circulatory System – Human Circulatory System: Heart, Heartbeat, Cardiac Cycle, Electrocardiograph (ECG), Double Circulation, Disorders of Circulatory System.

Circulatory System

The English physician, **William Harvey** (A.D.1578–1657), discovered the circulation of blood.

The circulatory patterns are of two types - **open** or **closed**.

Open circulatory system is present in **arthropods** and **molluscs** in which blood pumped by the heart passes through large vessels into open spaces or body cavities called **sinuses**.

Annelids and **chordates** have a closed circulatory system in which the blood pumped by the heart is always circulated through a closed network of blood vessels. This pattern is considered to be more advantageous as the flow of fluid can be more precisely regulated.

All vertebrates possess a muscular chambered heart. **Fishes** have a **2-chambered** heart with an atrium and a ventricle. **Amphibians** and the **reptiles (except crocodiles)** have a **3-chambered heart** with two atria and a single ventricle, whereas **crocodiles, birds and mammals** possess a **4-chambered heart** with two atria and two ventricles.

In fishes the heart pumps out deoxygenated blood which is oxygenated by the gills and supplied to the body parts from where deoxygenated blood is returned to the heart **(single circulation)**.

In amphibians and reptiles, the left atrium receives oxygenated blood from the gills/lungs/ skin and the right atrium gets the deoxygenated blood from other body parts. However, they get mixed up in the single ventricle which pumps out **mixed blood (incomplete double circulation)**.

In birds and mammals, oxygenated and deoxygenated blood received by the left and right atria respectively passes on to the ventricles of the same sides. The ventricles pump it out without any mixing up, i.e., two separate circulatory pathways are present in these organisms, hence, these animals have **double circulation**. Let us study the human circulatory system.

Does sponges and hydra also have blood? Animals such as **sponges** and **Hydra** do not possess any circulatory system. The water in which they live brings food and oxygen as it enters their bodies. The water carries away waste materials and carbon dioxide as it moves out. Thus, these animals do not need a circulatory fluid like the blood.

Human Circulatory System

Heart

The heart has **four chambers**. The two upper chambers are called the **atria** (singular: atrium) and the two lower chambers are called the **ventricles**.

The partition between the chambers helps to avoid mixing up of blood rich in oxygen with the blood rich in carbon dioxide.

Heartbeat

The walls of the chambers of the heart are made up of muscles. These muscles contract and relax rhythmically. This rhythmic contraction followed by its relaxation constitutes a heartbeat.

Human circulatory system, also called the **blood vascular system** consists of a muscular chambered heart, a network of closed branching blood vessels and blood, the fluid which is circulated.

Heart, the mesodermally derived organ [the middle layer of cells or tissues of an embryo, or the parts derived from this (e.g. cartilage, muscles, and bone)], is situated in the thoracic cavity, in between the two lungs, slightly tilted to the left. It has the size of a clenched fist.

It is protected by a double walled **membranous bag, pericardium**, enclosing the **pericardial fluid**.

Our heart has four chambers, two relatively small upper chambers called **atria** and two larger lower chambers called **ventricles**.

A thin, muscular wall called the **interatrial septum** separates the right and the left atria, whereas a thick-walled, the **inter-ventricular septum**, separates the left and the right ventricles.

The atrium and the ventricle of the same side are also separated by a thick fibrous tissue called the **atrio-ventricular septum**. However, each of these septa are provided with an opening through which the two chambers of the same side are connected.

The opening between the right atrium and the right ventricle is guarded by a valve formed of three muscular flaps or cusps, the **tricuspid valve**, whereas a **bicuspid or mitral valve** guards the opening between the left atrium and the left ventricle.

The openings of the right and the left ventricles into the **pulmonary artery** and the **aorta** respectively are provided with the **semilunar valves**.

The valves in the heart allows the flow of blood only in one direction, i.e., from the atria to the ventricles and from the ventricles to the pulmonary artery or aorta. These valves prevent any backward flow.

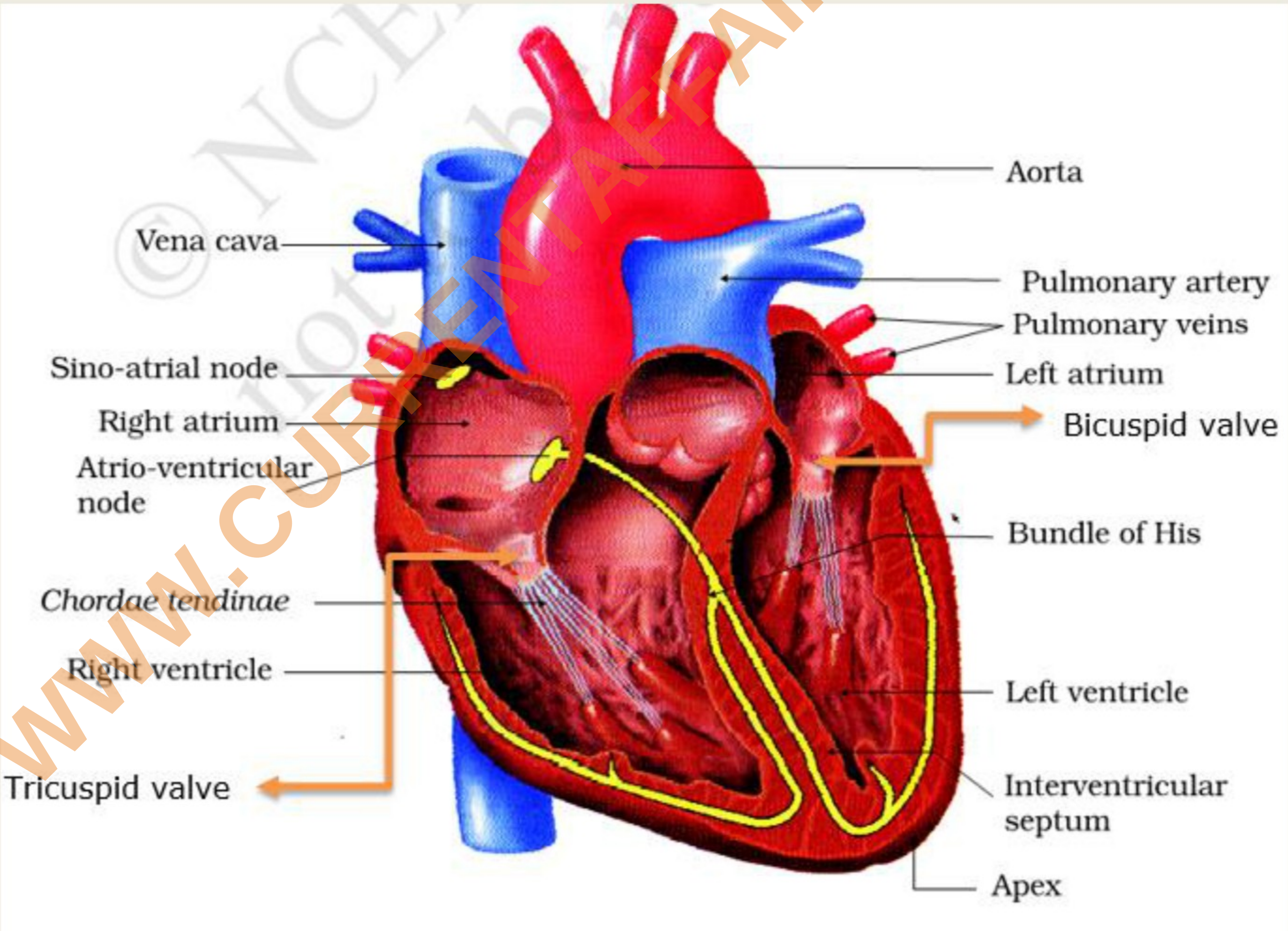


Figure 18.2 Section of a human heart

The entire heart is made of **cardiac muscles**. The walls of ventricles are much thicker than that of the atria.

A specialized cardiac musculature called the **nodal tissue** is also distributed in the heart. A patch of this tissue is present in the right upper corner of the right atrium called the **sino-atrial node (SAN)**.

Another mass of this tissue is seen in the lower left corner of the right atrium close to the atrio-ventricular septum called the **atrio-ventricular node (AVN)**.

A bundle of nodal fibres, atrioventricular bundle (AV bundle) continues from the AVN which passes through the atrio-ventricular septa to emerge on the top of the inter-ventricular septum and immediately divides into a right and left bundle. These branches give rise to minute fibres throughout the ventricular musculature of the respective sides and are called **purkinje fibres**. These fibres along with right and left bundles are known as **bundle of His**.

The nodal musculature has the ability to generate **action potentials** without any external stimuli, i.e., it is **autoexcitable**.

However, the number of action potentials that could be generated in a minute vary at different parts of the nodal system.

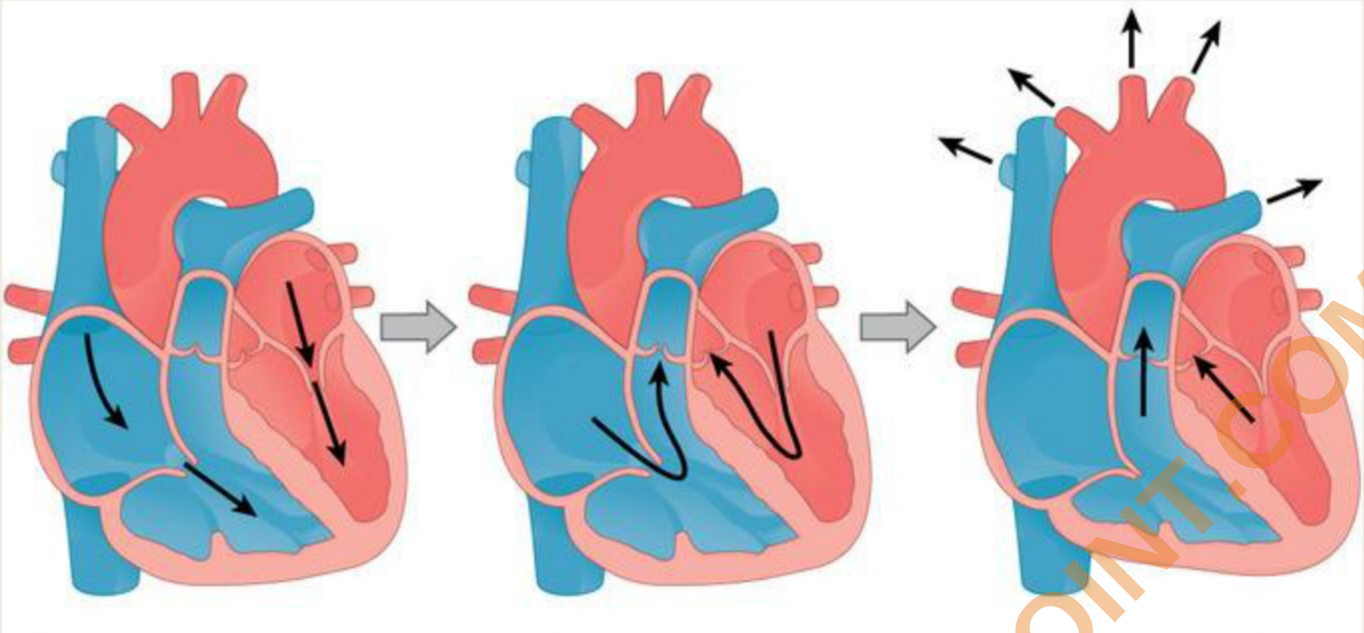
The SAN can generate the maximum number of action potentials, i.e., 70-75/min, and is responsible for initiating and maintaining the rhythmic contractile activity of the heart. Therefore, it is called the **pacemaker**. Our heart normally beats 70-75 times in a minute (average 72 beats/min).

Cardiac Cycle

Watch these videos for easy understanding

https://www.youtube.com/watch?v=gn6QmETEm8s;

https://www.youtube.com/watch?v=yGlFBzaTuoI;



(a) **Cardiac diastole**: all chambers are relaxed, and blood flows into the heart.

(b) **Atrial systole, ventricular diastole**: atria contract, pushing blood into the ventricles.

(c) **Atrial diastole, ventricular systole**: after the atria relax, the ventricles contract, pushing blood out of the heart.

To begin with, all the four chambers of heart are in a **relaxed state**, i.e., they are in **joint diastole**.

As the tricuspid and bicuspid valves are open, blood from the pulmonary veins and vena cava flows into the left and the right ventricle respectively through the left and right atria. The semilunar valves are closed at this stage.

The SAN now generates an action potential which stimulates both the atria to undergo a simultaneous contraction - the **atrial systole**. This increases the flow of blood into the ventricles by about 30 per cent.

The action potential is conducted to the ventricular side by the AVN and AV bundle from where the bundle of His transmits it through the entire ventricular musculature. This causes the ventricular muscles to contract, (**ventricular systole**), the atria undergoes relaxation (diastole), coinciding with the ventricular systole.

Ventricular systole increases the ventricular pressure causing the closure of tricuspid and bicuspid valves due to attempted backflow of blood into the atria.

As the ventricular pressure increases further, the semilunar valves guarding the pulmonary artery (right side) and the aorta (left side) are forced open, allowing the blood in the ventricles to flow through these vessels into the circulatory pathways.

The ventricles now relax (ventricular diastole) and the ventricular pressure falls causing the closure of semilunar valves which prevents the backflow of blood into the ventricles.

As the ventricular pressure declines further, the tricuspid and bicuspid valves are pushed open by the pressure in the atria exerted by the blood which was being emptied into them by the veins. The blood now once again moves freely to the ventricles. The ventricles and atria are now again in a relaxed (**joint diastole**) state, as earlier.

Soon the SAN generates a new action potential and the events described above are repeated in that sequence and the process continues.

This sequential event in the heart which is cyclically repeated is called the **cardiac cycle** and it consists of **systole** and **diastole** of both the atria and ventricles.

As mentioned earlier, the heart beats 72 times per minute, i.e., that many cardiac cycles are performed per minute. From this it could be deduced that the duration of a cardiac cycle is 0.8 seconds.

During a cardiac cycle, each ventricle pumps out approximately 70 mL of blood which is called the stroke volume. The stroke volume multiplied by the heart rate (no. of beats per min.) gives the cardiac output.

Therefore, the cardiac output can be defined as the volume of blood pumped out by each ventricle per minute and averages **5000 mL or 5 litres** in a healthy individual.

The body has the ability to alter the stroke volume as well as the heart rate and thereby the cardiac output. For example, the cardiac output of an athlete will be much higher than that of an ordinary man.

During each cardiac cycle two prominent sounds are produced which can be easily heard through a stethoscope. The first heart sound **(lub)** is associated with the closure of the **tricuspid** and **bicuspid** valves whereas the second heart sound **(dub)** is associated with the closure of the **semilunar valves**. These sounds are of clinical diagnostic significance.

Electrocardiograph (ECG)

Electro-cardiograph is used to obtain an **electrocardiogram (ECG)**. ECG is a graphical representation of the electrical activity of the heart during a cardiac cycle.

To obtain a standard ECG, a patient is connected to the machine with three electrical leads (one to each wrist and to the left ankle) that continuously monitor the heart activity.

For a detailed evaluation of the heart's function, multiple leads are attached to the chest region. Here, we will talk only about a standard ECG.

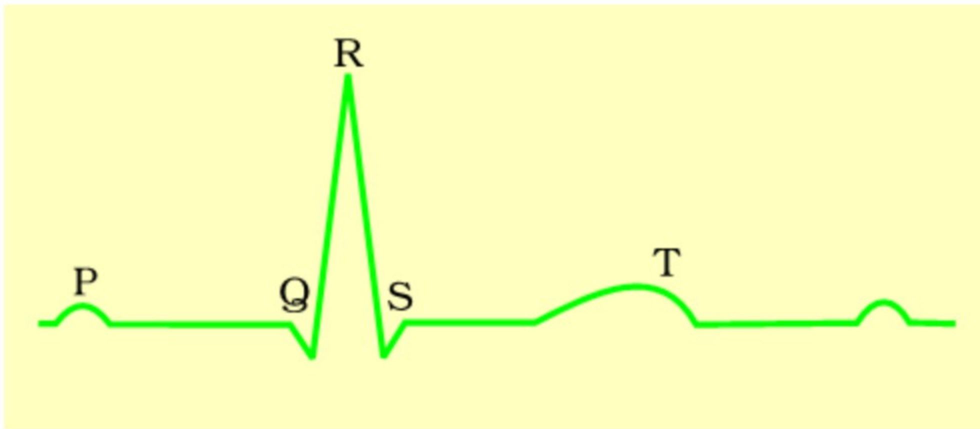


Figure 18.3 Diagrammatic presentation of a standard ECG

Each peak in the ECG is identified with a letter from P to T that corresponds to a specific electrical activity of the heart.

The P-wave represents the electrical excitation (or depolarisation) of the atria, which leads to the contraction of both the atria.

The QRS complex represents the depolarisation of the ventricles, which initiates the ventricular contraction. The contraction starts shortly after Q and marks the beginning of the systole.

The T-wave represents the return of the ventricles from excited to normal state (repolarization). The end of the T-wave marks the end of systole.

Obviously, by counting the number of QRS complexes that occur in a given time period, one can determine the heart beat rate of an individual.

Since the ECGs obtained from different individuals have roughly the same shape for a given lead configuration, any deviation from this shape indicates a possible abnormality or disease. Hence, it is of a great clinical significance.

Double Circulation

As mentioned earlier, the blood pumped by the right ventricle enters the pulmonary artery, whereas the left ventricle pumps blood into the aorta. The deoxygenated blood pumped into the pulmonary artery is passed on to the lungs from where the oxygenated blood is carried by the pulmonary veins into the left atrium. This pathway constitutes the **pulmonary circulation**.

The oxygenated blood entering the aorta is carried by a network of arteries, arterioles and capillaries to the tissues from where the deoxygenated blood is collected by a system of venules, veins and vena cava and emptied into the right atrium. This is the **systemic circulation**.

The systemic circulation provides nutrients, O2 and other essential substances to the tissues and takes CO2 and other harmful substances away for elimination.

A unique vascular connection exists between the digestive tract and liver called **hepatic portal system**. The hepatic portal vein carries blood from **intestine to the liver** before it is delivered to the systemic circulation.

A special coronary system of blood vessels is present in our body exclusively for the circulation of blood to and from the cardiac musculature.

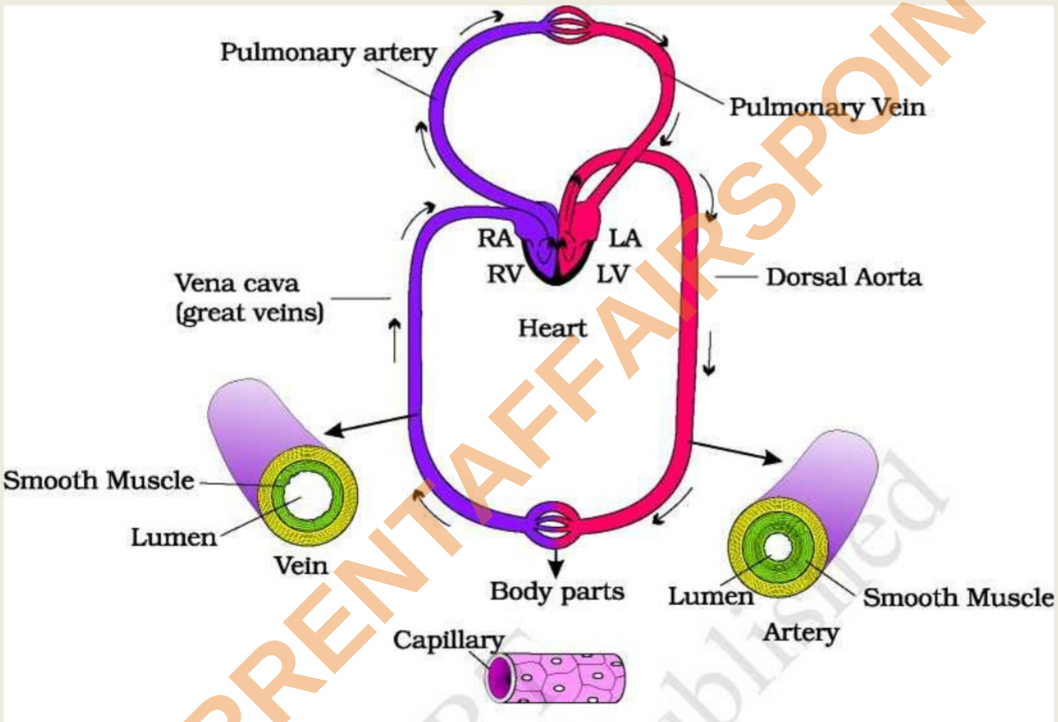


Figure 18.4 Schematic plan of blood circulation in human

Regulation of Cardiac Activity

Normal activities of the heart are regulated intrinsically, i.e., auto regulated by specialized muscles (nodal tissue), hence the heart is called **myogenic**.

A special neural center in the **medulla oblangata** can moderate the cardiac function through **autonomic nervous system (ANs)**.

Neural signals through the **sympathetic nerves (part of ANS)** can increase the rate of heart beat, the strength of ventricular contraction and thereby the cardiac output.

On the other hand, **parasympathetic neural signals (another component of ANS)** decrease the rate of heart beat, speed of conduction of action potential and thereby the cardiac output. **Adrenal medullary hormones** can also increase the cardiac output.

Disorders of Circulatory System

High Blood Pressure (Hypertension)

Hypertension is the term for blood pressure that is higher than normal (120/80).

In this measurement 120 mm Hg (millimetres of mercury pressure) is the systolic, or pumping, pressure and 80 mm Hg is the diastolic, or resting, pressure.

If repeated checks of blood pressure of an individual is 140/90 (140 over 90) or higher, it shows **hypertension**.

High blood pressure leads to heart diseases and also affects vital organs like brain and kidney.

Coronary Artery Disease (CAD)

Coronary Artery Disease, often referred to as **atherosclerosis**, affects the vessels that supply blood to the heart muscle. It is caused by deposits of **calcium, fat, cholesterol** and **fibrous tissues**, which makes the lumen of arteries narrower.

Angina

It is also called **'angina pectoris'**. A symptom of acute chest pain appears when **no enough oxygen** is reaching the heart muscle.

Angina can occur in men and women of any age but it is more common among the middle-aged and elderly. It occurs due to conditions that affect the blood flow.

Heart Failure

Heart failure means the state of heart when it is not pumping blood effectively enough to meet the needs of the body. It is sometimes called **congestive heart failure** because congestion of the lungs is one of the main symptoms of this disease.

Heart failure is not the same as **cardiac arrest (when the heart stops beating)** or a **heart attack** (when the heart muscle is suddenly damaged by an inadequate blood supply).

Summary

Vertebrates circulate blood, a fluid connective tissue, in their body, to transport essential substances to the cells and to carry waste substances from there. Another fluid, lymph (tissue fluid) is also used for the transport of certain substances.

Blood comprises of a fluid matrix, plasma and formed elements. Red blood cells (RBCs, erythrocytes), white blood cells (WBCs, leucocytes) and platelets (thrombocytes) constitute the formed elements. Blood of humans are grouped into A, B, AB and O systems based on the presence or absence of two surface antigens, A, B on the RBCs.

Another blood grouping is also done based on the presence or absence of another antigen called Rhesus factor (Rh) on the surface of RBCs. The spaces between cells in the tissues contain a fluid derived from blood called tissue fluid. This fluid called lymph is almost similar to blood except for the protein content and the formed elements.

All vertebrates and a few invertebrates have a closed circulatory system. Our circulatory system consists of a muscular pumping organ, heart, a network of vessels and a fluid, blood.

Heart has two atria and two ventricles. Cardiac musculature is auto-excitable. Sino-atrial node (SAN) generates the maximum number of action protentials per minute (70-75/min) and therefore, it sets the pace of the activities of the heart. Hence it is called the Pacemaker.

The action potential causes the atria and then the ventricles to undergo contraction (systole) followed by their relaxation (diastole). The systole forces the blood to move from the atria to the ventricles and to the pulmonary artery and the aorta. The cardiac cycle is formed by sequential events in the heart which is cyclically repeated and is called the cardiac cycle.

A healthy person shows 72 such cycles per minute. About 70 mL of blood is pumped out by each ventricle during a cardiac cycle and it is called the stroke or beat volume.

Volume of blood pumped out by each ventricle of heart per minute is called the cardiac output and it is equal to the product of stroke volume and heart rate (approx 5 litres).

The electrical activity of the heart can be recorded from the body surface by using electrocardiograph and the recording is called electrocardiogram (ECG) which is of clinical importance.

We have a complete double circulation, i.e., two circulatory pathways, namely, pulmonary and systemic are present.

The pulmonary circulation starts by the pumping of deoxygenated blood by the right ventricle which is carried to the lungs where it is oxygenated and returned to the left atrium.

The systemic circulation starts with the pumping of oxygenated blood by the left ventricle to the aorta which is carried to all the body tissues and the deoxygenated blood from there is collected by the veins and returned to the right atrium.

Though the heart is autoexcitable, its functions can be moderated by neural and hormonal mechanisms.