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Introduction

A cell is a functional basic unit of life discovered **by Robert Hooke** in **Cork cells** and is the smallest unit of life that is classified as a living thing, and is often called the building block of life. The organisms which have a single cell are unicellular and the organisms that have multiple cells are multicellular.

- ✓ There are 1 trillion cells is a human body.
- ✓ The size of a typical cell is 10 micrometer and largest cells in human body are nerve cells called neurons.
- ✓ The largest known cells are unfertilized ostrich egg cells which weigh 3.3 pounds.

In the beginning of the 18th century, **Antonie van Leeuwenhoek**, a Dutch tradesman and scientist built a microscope and drew the protozoa from rainwater and bacteria from his own mouth. He is known as the "Father of Microbiology".

In 1665 Robert Hooke discovered cells in cork, then in living plant tissue using an early microscope. He was the first person to use the term "cell".

In 1833 Brown observed a "nucleus" in the cell. Dujardin in 1836, observed the living matter in the cell and called it "Sarcode". In the same year Schleiden discovered the Nucleolus, later in 1839 Purkinje coined the term "protoplasm' for the living matter inside a cell.

✍ In 1839 Theodor Schwann and Matthias Jakob Schleiden elucidated the principle that plants and animals are made of cells, concluding that cells are a common unit of structure and development. This was the **cell theory**.

In 1855, Nageli and Crammer coined the term "cell membrane'. Later in 1866 Haeckel saw the color bodies in the cells and named them "Plastids". Strasburger in 1875 discovered the thread like structures in the cells, which were named chromosomes by Waldeyer in 1888. Fleming in 1882, discovered how the cells divide and reproduce and coined the term "Mitosis".

In 1882, Strasburger differentiated between the cytoplasm and nucleoplasm. Schimper identified various kinds of plastids in cells in 1883.

"***Life can occur spontaneously***" this idea was **contradicted** by Louis Pasteur. In 1931, Ernst Ruska built the first transmission electron microscope (TEM) at the University of Berlin. By 1935, he has built an EM with twice the resolution of a light microscope, revealing previously unknown organelles. In 1953, Watson and Crick made their first

announcement on the double-helix structure for DNA, in 1972 Singer and Nicholson proposed the fluid mosaic model of the cell membrane and in 1981, Lynn Margulis published Symbiosis in Cell Evolution detailing the endosymbiotic theory.

Cell Theory

Cell Theory was proposed by Scheilden and Schwann and this theory stated that:

1. The body of all organisms is made up of cells
2. New cells arise from the pre existing cells
3. Cells are structural units of all organisms
4. Cells are units of all biological functions.

Prokaryotic and Eukaryotic cells

There are two groups of cells. All cells are either prokaryotic or eukaryotic.

✓ Prokaryotic cells are primitive and don't possess a well defined nucleus. The nuclear membrane is absent and DNA material remains scattered in the Cytoplasm. The cells organelles like mitochondria, chloroplasts, Golgi Bodies are absent in the prokaryotic cells.
✓ The cytoplasm of the prokaryotic cells has no cytoskeleton while the cytoplasm of the Eukaryotic cells possesses the Cytoskeleton which is made up of protein Filaments.
✍ The ribosome in prokaryotic cells are of **70S** type while those in the Eukaryotic cells is **80S** type.
✓ The DNA is circular, scattered in the prokaryotic cell and not associated with the histones. While in Eukaryotic cells the DNA is long and associated with the histones.
✓ The same compartment is used in the Prokaryotic cells for synthesis of RNA and protein while in the Eukaryotic cells the RNA is synthesized in the Nucleus while the protein in the cytoplasm.
✓ There is no sexual reproduction in Prokaryotic cells and only genetic recombination is present in the name of sexual reproduction while in eukaryotic cells, the true sexual reproduction is present.
✓ The examples of prokaryotic cells are bacteria, blue green algae and mycoplasms. The example of Eukaryotic cells are green algae and higher plants and animals.

Plant cells and Animal cells

✓ The animal cells don't contain the cell wall and the outer boundary of the animal cells is cell membrane. In Plant cells the cell wall is present which is made up of mostly cellulose, is located outside the cell membrane and provides these cells with structural support and protection, and also acts as a filtering mechanism.
✍ In bacteria the cell was is made of peptidoglycan.
✓ There are no plastids in animal cells. There is no photosynthesis in animal cells. Cytokinesis which is a process by which cytoplasm of a single eukaryotic cell is divided to form two daughter cells, is by equatorial furrowing from periphery to the centre in animal cells and by disk formation in plant cells.
✓ In animal cells the ribosome are of 55S and 80S types while in the plant cells they are of 70s and 80S types. (S is Svedberg unit discussed later in this chapter)

Cell Wall

✓ The major function of the cell wall is to act as a pressure vessel, which prevents the over-expansion when water enters the cell and creation of a stable osmotic environment by preventing osmotic lysis and helping to retain water.
✓ Cell walls are found in plants, bacteria, fungi, algae etc. and absent in animals and protozoa.
✓ Major component of the cell wall is Cellulose, which is a carbohydrate and organic compound with the formula $(C_6H_{10}O_5)_n$. It's a polysaccharide consisting of a linear chain of several hundred to over ten thousand D-glucose units.
✍ In industrial used the cellulose is mainly obtained from wood pulp and cotton and used to produce the textiles and paper.

✓ The cell walls of diatoms are composed of silicic acid. Other than cellulose the cell wall is made up of hemicelluloses and pectin.
✓ The Bacterial cell walls are made of peptidoglycan which is also called murein. The peptidoglycan is a polysaccharide chains cross-linked by unusual peptides containing D-amino acids.

Cell membrane

Cell membrane is found around all cells and is selectively-permeable and controls the movement of substances in and out of cells. Main function is to protect the intracellular components from the extracellular environment.

The cell membrane is often differentially permeable and able to regulate what enters and exits the cell. The cell membrane facilitates the transport of materials needed for survival. The movement of substances across the membrane can be passive, occurring without the input of cellular energy, or active, requiring the cell to expend energy in moving it.

Cytoplasm & Nucleus

✓ Part of a cell that is enclosed within the cell membrane except the nucleus is cytoplasm.
✓ Contents of the cell nucleus are not part of the cytoplasm and are instead called the nucleoplasm. Cytoplasm contains organelles, such as mitochondria, Golgi bodies etc.
✓ Cytoplasm is the site where most cellular activities occur, such as metabolism, glycolysis, and cell division.
✓ It is divided into two parts, the inner, granular mass is called the endoplasm and the outer, clear and glassy layer is called the cell cortex or the ectoplasm. The cell membrane is the outermost layer of the cytoplasm.

Fluid Mosaic Model for Cell Membrane structure

Fluid mosaic model was given by S. J. Singer and Garth Nicolson in 1972. It is the latest and most widely accepted model of the structure of the plant membranes.

✓ As per this model, the membrane is a continuous **lipid bilayer having protein molecules embedded**.
✓ It is a two-dimensional liquid sheet where all lipid and protein molecules diffuse more or less easily. The membrane has globular proteins which are integral (intrinsic) and peripheral (extrinsic).
✓ The peripheral proteins are loosely bound at the polar surfaces of the lipid layers and the integral proteins penetrate deeply. Both the integral & peripheral protein molecules along with the lipid layer create a kind of mosaic pattern and the two scientists called it as protein icebergs in sea of lipids.

Functions of the cell membrane

- ✓ Permeability: this is the most important function which allows the selective movement of particles inside and outside the cells.
- ✓ Respiration: The cell membrane plays an important role in the respiration and electron transport chains.
- ✓ Cell secretion: The Golgi apparatus or body is important in the function of process and package macromolecules, such as proteins and lipids, after their synthesis and before they make their way to their destination; it is particularly important in the processing of proteins for secretion.
- ✓ This secretion is carried out with the help of cell membranes. The Golgi vesicles containing the secreted products from the endoplasmic reticulum fuse with the plasma membranes and releases the products to the outside of the cell.
- ✓ Exocytosis and endocytosis: These are the processes by which the materials are taken in or out of a cell.

Cell Organelles

There are two kinds of organelles in the cytoplasm viz. living and non living. The living organelles include the Plastids, Mitochondria, Endoplasmic reticulum, Golgi Bodies, Ribosome, lysosomes, Micro bodies such as peroxisomes, Microtubules, Centrosomes, Cilia and Flagella. There are nonliving substances as well and they are called ergastic substances. These include the reserve products such as carbohydrates Fats, Oils and nitrogenous substances, Secretary

products such as pigments, enzymes and nectar and execratory products such as tannins, resins, latex, alkaloids, essential oils, mineral crystals etc.

Plastids

These are major organelles found in the cells of plants and algae. The term plastid was used by Schimper for the first time. Major function of the plastids includes photosynthesis, storage of products like starch. They are of 3 types:

1. Leucoplasts: Colorless plastids,
2. Chloroplasts: Green plastids.
3. Chromoplasts: Colored plastids.

The plastids are of various shapes. Plastids have the ability to differentiate, or re-differentiate, between the above forms & and many shapes. This means that the above plastids are interchangeable.

✓ For example due to continuous absence of the sunlight the green chloroplast may turn to colorless leucoplasts.
✓ In tomato, when it ripes, the chloroplasts change into Chromoplasts and this turns the color of tomato from green to red.

The leucoplasts don't have any color. So they have no role in photosynthesis. Their major function is of storing. On the basis of the stored material they have been divided into 3 types:

1. Amyloplats: which store the carbohydrates.
2. Elaioplasts: which store the fats
3. Aleuroplats: which store proteins

Chloroplasts have a green pigment in them which is called Chlorophyll. They are responsible for photosynthesis. The number, shape and size of the chloroplasts vary from plants to plants. In higher plants they are biconvex in shape.

Each chloroplast is covered by a double membrane envelope. This envelope is made up of lipoproteins. The space between these two membranes is called periplastidial space. Inside these membranes are located the membrane-bound compartment called thylakoid which is basically a sac. This sac has stacks of disks referred to as "grana", (singular: granum). Each grana is connected to other grana by intergrana or stroma thylakoid. The space enclosed by a thylakoid is called lumen. All lumens are collectively called thylakoid space. Each chloroplast has 40-60 grana. The inner side of the thylakoid membrane has some particles which are called quantasomes. Each quantasome has around 230-250 chlorophyll pigments.

Chlorophylls

The chlorophylls are pigments responsible for Photosynthesis.

✍ The chlorophyll absorbs light most strongly in the blue portion of the electromagnetic spectrum, followed by the red portion. But it is a poor absorber of green and near-green portions of the spectrum, hence the color of the tissues which contain chlorophyll is Green.

The chlorophyll was first isolated by Joseph Bienaimé Caventou and Pierre Joseph Pelletier in 1817.

Carotenoids

There are two types of pigments Chlorophyll a and Chlorophyll b. Apart from these pigments , there are Carotenoids occurring in the chloroplasts and Chromoplasts. These Carotenoids are responsible for different colors. There are more than 600 known Carotenoids. Among them the most important are carotenes and Xanthophylls.

✍ Carotenes are pure hydrocarbons, means they are basically made up of Carbon and Hydrogen. The Xanthophylls have oxygen too.

✍ The Carotenoids absorb blue light of the spectrum generally.

Absorption of blue light serves a major purpose and that is they save the chloroplasts from the photo damage.

✍ Most fruits have Carotenoids. The Beta carotene is one example which gets converted into Vitamin A.
✍ Beta carotene is the precursor of Vitamin A.
✍ Vitamin A occurs in many forms. One form of Vitamin A is retinal, which is vitamin A aldehyde. The four kinds of Carotenoids viz. beta-carotene, alpha-carotene, gamma-carotene, and beta-cryptoxanthin can be converted in human beings in retinal.
✍ This retinal form of Vitamin A is a Chromophore and is responsible for its color, it absorbs certain wavelengths of visible light and transmits or reflects others.
✍ Retinal binds to some proteins called Opsins in the Eye's retina. This Vitamin A + Opsins bond is the chemical basis of vision.

The Carotenoids also get converted to another type of Vitamin A called Retinol. Retinol is fat-soluble vitamin important in vision and bone growth.

✍ All Retinol, retinal (aldehyde form), retinoic acid (acid form) and retinyl esters (ester forms) are converted from the carotenes and thus important for Human vision.

Mitochondria

Mitochondria (singular: mitochondrion) are the Power houses of the cells. They were discovered by Fleming, however the term was used by Benda & Meeves. Another name for mitochondria is Chondriosomes.

✍ They are absent in Prokaryotic cells.

Since they are the "Power houses of the Cells" the number of mitochondria in cells is directly proportional to the metabolic activity of the cells. This means that the more active a cells is metabolically, more is the number of mitochondria in that cell.

The shape of the mitochondria may be spherical, filamentous or even rod shaped.

✓ Like the chloroplasts, they are also bound by double unit membranes.

The space between these two membranes is called perimitochondrial space. The liquid inside these membranes is called matrix. The matrix contains the enzymes. Apart from the enzymes matrix contains ribosomes, double stranded DNA and RNA.

✍ Due to presence of double stranded DNA along with the RNA and Ribosome, the mitochondria are called semiautonomous structures. Both chloroplasts and mitochondria are semiautonomous structures.

Mitochondria are the sites of oxidation of food material. This oxidation is called aerobic respiration. It is carried out by **Krebs cycle or TCA cycle**. The Krebs cycle is also known as Citric Acid Cycle which is basically a series of enzyme-catalyzed chemical reactions.

✍ The raw material in the Krebs cycle is carbohydrates, fats and proteins and the final products are Carbon Dioxide and Water and Energy.
✍ The usable energy which is produced by the Krebs cycle is in the form of ATP which is Adenosine triphosphate.
✍ The correct name of ATP is Adenosine-5'-triphosphate.
✍ This is the unit of energy in intracellular energy transfers. It can be compared to a unit of currency in the whole currency market of a body.

ATP is a nucleotide.

✍ Another nucleotide which serves as a source of chemical energy is guanosine triphosphate or GTP.

As the name suggests ATP has three Phosphate groups. The ATP is created out of **ADP and AMP** which is Adenosine Diphosphate and Adenosene Monophosphate.

The conversion of ATP to ADP and AMP is reversible and so the making of ATP is a continuous process.

✍ This continuous process is supported by an enzyme called ATP synthase .

Endoplasmic reticulum

The interconnected network of tubules, vesicles, and cisternae within cells is called "Endoplasmic reticulum". The term was coined by Keith R. Porter in 1945. The tubules are narrow long structures, vesicles are round structures and cisternae are long, flat unbranched structures which are parallel to each other.

They are of two types, Rough endoplasmic reticulum which synthesize proteins and the smooth endoplasmic reticulum which synthesize lipids and steroids, metabolize carbohydrates and steroids, and regulate calcium concentration, drug detoxification, and attachment of receptors on cell membrane proteins.

Another function of the endoplasmic reticulum is that it provides the mechanical support to the cytoplasm and provides larger surface area for exchange of materials and transportation.

During the cell division, the endoplasmic reticulum organizes the nuclear envelope at the telophase stage of cell division.

Golgi apparatus

These are named after Camillo Golgi who identified them in 1898. These are not present in the Prokaryotic cells. The size of the Golgi body changes as per the metabolic activity of the cells and they are bigger in young cells and metabolically active cells.

Function of the Golgi apparatus is to process and package proteins, polysaccharides and lipids. During the cell division they provide a cell plate. At the end of the cell division (telophase) the Golgi vesicles fuse and make the new plasma membrane.

✍ The Lysosomes which digest excess or worn-out organelles, food particles, and engulfed viruses or bacteria etc. are formed by the Golgi Body.

Golgi Bodies , unlike the Chloroplasts and Mitochondria are bound by the single membranes.

Lysosomes

Lysosomes are very small sacs with irregular shapes. These are bags of Hydrolytic or digestive enzymes and also called **Suicide Bags.**

✍ The major function is the autolysis of a cell by release of the enzymes within the cells. It also helps in the intracellular digestion of dead, injured or defective cells. Intracellular digestion of the material taken from the endocytosis.

Ribosome

Ribosomes were discovered by Palade in 1955. They are not enclosed by any unit membrane. They are made up of RNA and proteins. There are two basic types of Ribosomes - 70S and 80S.

✍ The 70S Ribosomes are present in the prokaryotic cells and chloroplast and mitochondria of the Eukaryotic cells.
✍ The 80S Ribosomes are found in cytoplasm.

65% part of a Ribosome is ribosomal-RNA and 35% part of a ribosome is ribosomal proteins. These proteins are also known as a ribonucleoprotein or RNP.

The 80S and 70S ribosome are differentiated by their S Units. S units are Svedberg Units. This unit is named after the Swedish chemist Theodor Svedberg who was given Nobel Prize in chemistry in 1926 for his work in the chemistry of colloids and his invention of the ultracentrifuge. The Ribosomes are distinguished by their behavior in sedimentation processes such as centrifugation.

✍ In centrifugation, the more-dense components of a mixture migrate away from the axis of the centrifuge, while less-dense components of the mixture migrate towards the axis.

This is used in differentiation as well as many chemical / industrial processes.

✍ Please note the centrifugation is the most common method used for **uranium enrichment.** This is because there is a little mass difference between the atoms of U238 and U235 in uranium hexafluoride gas (UF_6)
✍ The Uranium Ore which is known as **Yellow Cake** is by some chemical processes is converted to Uranium hexafluoride which later is enriched to get more of U235 , which is fissile.
✍ 95% of the depleted uranium produced to date is stored as Uranium hexafluoride. In Nuclear industry this poisonous gas is called "hex" .

The 80S and 70S Ribosomes are consisted of smaller units as follows:

✓ 70S : 50S + 30S
✓ 80S : 60S + 40S

Please note that Svedberg unit is not a scale and that is why the 50S+30S are not 80S but 70S. This basically shows the behavior of the smaller units in comparison to the Bigger Units.

These smaller units are called sub units. The sub units unite and disintegrate before and after the protein synthesis. In the Reunion and separation process the magnesium Mg^{++} plays a very important role.

Peroxisomes

These are also sac like structures bound with single membranes. They have enzymes and take part in the metabolism of fatty acids, respiration and many other metabolic processes.

Glyoxisomes

They are mainly found in plants particularly in plants the fat storage tissues of germinating seeds such as castor seed. The major function is in the conversion of the fatty acids in Carbohydrates.

Spherosomes

Spherosomes are present in the endosperm and cotyledons of seeds. They have the enzymes which are necessary in synthesis of oils and fats.

Centrioles

Centrioles are present in animal cells mostly and not in higher plants. They organize the spindle fibers in cell division.

Cilia and Flagella

Both Cilia and Flagella are present in the motile cells. Both help in cell mobility. Both are made up of fibrils. When they cut in a section, they show 9+2 arrangement which shows that they have 9 pairs of fibrils on the circumference and 2 pairs of fibrils at the centre.

Nucleus

Among all the organelles, Nucleus is most distinct and was the first cell organelle to be discovered. It was seen by Antonie van Leeuwenhoek in the red blood cells of salmon fish but called it a "Lumen".

✓ Its worth note that mammalian red blood cells have no nucleus.

The credit of discovery of nucleus is given to Scottish Botanist Robert Brown in 1833. He saw the nucleus as opaque area in the cells of an orchid flower.

✓ A distinct nucleus is absent in the prokaryotic cells and that is why they are called Prokaryotic (karyos: center).

Nucleus is the master of a cell. It controls the cell functions such as metabolism, reproduction and development. It consists of Nuclear membrane, Nuclear Sap, Nucleolus and Chromatin.

The nuclear membrane is again a double membrane and the space between the two membranes is called pronuclear space. The outer membrane is continuous with the endoplasmic reticulum which indicates its firm position in the cell.

During the cell division the membrane disintegrates and reappears once the division is almost complete.

Nucleoplasm is a transparent and gel like matrix. It contains the nucleolus, chromatin threads and Ribosomes.

Nucleolus also disappears in the later phase of cell division and reappears once the process is almost complete. It is made of RNA and protein and is the site of RNA synthesis.

Chromatins

Chromatins are long thread like structures, which are *inter-coiled and intermingled*. This network has been named Chromatin Reticulum. It consists of DNA, RNA and Histones.

Cell Division

Cell Division is of two type's viz. Mitosis and Meiosis. The Nucleus divides first and it is known as karyokinesis. Karyokinesis is followed by the division of the cytoplasm, which is known as Cytokinesis.

The cell division is of two types. Mitosis and Meiosis.

In mitosis chromosomes separates and form into two identical sets of daughter nuclei, and it is followed by Cytokinesis (division of cytoplasm).

✍ Basically, in mitosis the mother cell divides into two daughter cells which are genetically identical to each other and to the parent cell.

The Chromosomes separate and for into two identical sets of daughter nuclei during the Karyokinesis and it is followed by Cytokinesis.

Meiosis is also called reductional cell division and the number of chromosomes is divided into half in this process.

✍ Meiosis is required to create the Gametes in animals and Spores in other organisms. Meiosis is a prerequisite for sexual reproduction in organisms with Eukaryotic cells.

Mitosis

Mitosis occurs exclusively in eukaryotic cells. In the prokaryotic cells, there is no Nucleus and cell division takes place by a process called binary fission. Further, in animals there is Open Mitosis which means that nuclear envelope breaks down

before the chromosomes separate. In some kinds of fungi, such as *Aspergillus*, the process is "Close Mitosis", in which the nucleus remains intact while the chromosomes divide.

W. Flemming (1882) was the first scientist to use the term mitosis. The cell cycle in mitosis is divided into interphase, Mitosis and Cytokinesis.

Further, the interphase is divided into 3 stages viz. G1 stage, S stage and G2 stage.

A. Interphase:

In the Interphase, DNA is duplicated and other essential substances are synthesized so that the cell grows and gets ready for the division. The first stage is G1-stage in which RNA and proteins are synthesized. When the cell reaches certain size, the S-stage starts. In the S-stage, The DNA molecule replicates and becomes two stranded as a consequence of replication. With the replicated DNA, the cell enters into G2 stage. In this stage some spindles called mitotic spindles start forming out of spindle microtubules, associated proteins, and any centrosomes or asters. The amount of DNA gets doubled.

B. Prophase:

Each chromosome in the beginning of the Prophase is a two thread like structure. These threads are called Chromatids. The Chromatids remain coiled with each other. The point, where both Chromatids remain joined to each other is known as a centromere. Each Chromatid has small granule like structure. This granule like structure is called Chromomere. This process is followed by disappearing of Nucleolus and Nuclear membrane.

C. Metaphase:

During the metaphase, the chromosomes lie at the equator and become thick and short. The Chromatids which were coiled to each other in the prophase, get uncoiled but lay side by side. In the metaphase stage, two kinds of spindle apparatus' are formed. One type of fibers are called supporting fibers which are spread from pole to pole without any contact with the Chromosomes. The another kind of spindle is called tractile fibers, which are attached to the centromere on the one hand and pole to the other hand. During the last phase of the Metaphase, there is a division of the centromeres and the sister Chromatids get separated and independent from each other.

D. Anaphase:

The independent Chromatids are now called Chromosomes. These now start moving towards the opposite poles of the spindle. The Anaphase stage lasts till the chromosomes assemble at each pole of the spindle.

E. Telophase:

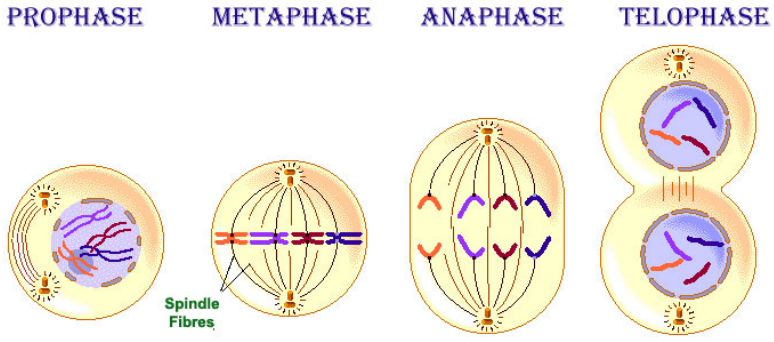
In the beginning of the Telophase, the nucleolus starts reappearing and the spindle apparatus starts disappearing. The nuclear membrane starts forming around each group of new Chromosomes.

F. Cytokinesis:

A the end of the telophase, the division of the cytoplasm begins.

In the plant cells, granular bodies formed from the Golgi apparatus and microtubules start collecting in the equatorial region of the cell. They together make the cell plate and the apparatus made for this particular purpose is called Phragmoplast. Phragmoplast is concerned with the formation of the cell plate. When the cell plate forms completely, it divides the cell into two daughter cells. This is called Plate method and is applicable to Plant Cells.

In the animal cells, the division of the cytoplasm occurs by the furrowing method in which the cell membrane constricts parallel to the equator.



PROCESS OF CELL DIVISION - MITOSIS

Mitosis: significance:

- ✓ The number of the Chromosomes in Parent and daughter cells remains constant
- ✓ The parent and daughter cells are similar in all respects.
- ✓ The parent and daughter cells are genetically identical
- ✓ The purpose of Mitosis is growth by increasing number of cells.
- ✓ In most plants and animals the regeneration of the lost parts and vegetative propagation in some plant species takes place by Mitosis.

Meiosis

The cell division in the reproductive cells takes place by Meiosis. In meiosis the number of the chromosomes is reduced to half of that in the parent cells.

a. Meiosis maintains the number of Chromosomes constant in all sexually reproducing organisms.

The term "Meiosis" was proposed by Farmer and Moore in 1905.

The main phases in Meiosis are similar to those in mitosis, but the outcome of the process is entirely different. Since, the chromosome number of the parent cell gets reduced in the Meiosis; four daughter cells are produced, each with one-half the chromosome number of the parent cell. Each daughter cell contains only one chromosome from each homologous pair.

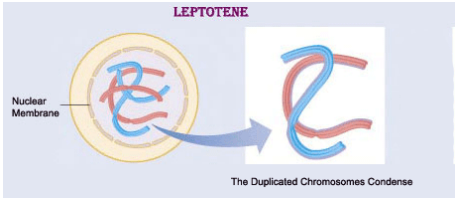
Thus, Meiosis has been divided into two divisions called Meiosis I and Meiosis II. Meiosis I is also known as heterotypic division or reduction division and in this phase the Chromosome number is reduced to half. In meiosis II, the reduced number of Chromosomes is reproduced and total result is 4 cells.

Meiosis I

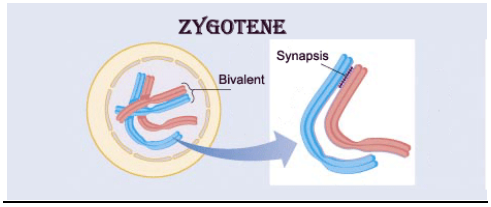
A. Prophase:

Prophase in the meiosis is a long and complicated process. It has been divided into 5 sub phases called Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis. Each of them has been discussed here:

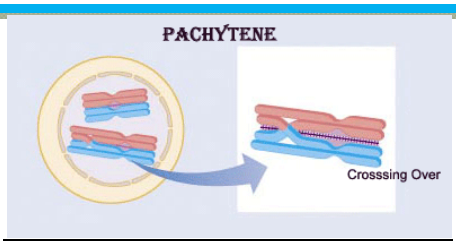
a. Leptotene: In Leptotene, the Chromosomes are long thread like structures with Chromomeres. Half of the Chromosomes are from male parent and half of the Chromosomes are female parent.



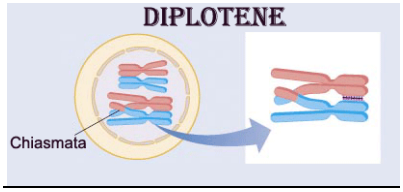
b. Zygotene: In the Zygotene sub phase, a process called "synapsis" takes place. In synapsis, the homologous chromosomes start paring and each pair is called bivalent. The Chromosomes become thicker and shorter.



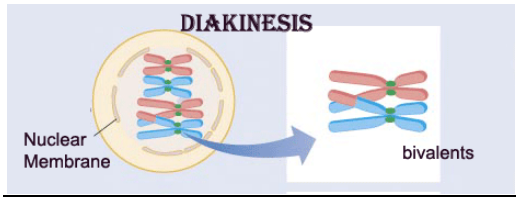
c. Pachytene: There is further coiling in the Chromosomes and they become more thick. Each chromosome appears double and it is a 4 stranded stage. In this stage each chromosome are in "tetravalent" stage and each chromosome is called a "tetrad". This is followed by exchange of pieces of homologous chromosomes which is called "Crossing Over".



d. Diplotene: In this sub phase, the chromosomes move apart, however the homologous chromosomes don't separate completely but remain joined at one or more point called Chiasmata. The Chromatids of the homologous chromosomes begin to separate from the centromere. Chiasmata move towards the telomeres and this is called terminalization.



e. **Diakinesis:** In this phase, the spirilization and condensation of chromosomes continues and the nucleolus & nuclear membranes disappear.



B. Metaphase-I

A nuclear spindle forms in this stage. The Chromosomes arrange themselves on the equator of the spindle and spindle fibers get attached to the centromeres of two homologous Chromosomes.

C. Anaphase-I

In this stage the homologous chromosomes start moving towards the opposite poles and as a sequel to this the chromosome number is reduced to half. Each chromosome at this stage consists of two Chromatids which are joined by a centromere.

D. Telophase-I

In this stage, the Chromosomes reach the opposite poles. Nuclear membrane is formed but nucleolus is NOT formed. The Chromosomes uncoil. The cell membrane at this stage may or may not be formed. The single nucleus is divided into two daughter nuclei and the number of chromosomes is halved.

Meiosis –II

The main purpose of making the number of Chromosomes halved is done in the Meiosis-I and now there is another division, which is just similar to the Mitosis process. It has the same phases viz. Prophase, metaphase, Anaphase, and Telophase. Each of them is suffixed by II so that study becomes easy.

A. Prophase-II

The nuclear membrane again gets disappeared. The two Chromatids of each chromosome remain separate from each other except at centromere. Nucleolus is also disappears at the end of Prophase II

B. Metaphase-II

The nuclear spindle is formed. Chromosomes arrange themselves on the equator of the spindle.

C. Anaphase –II

There is a division of centromere in this stage. The sister Chromatids which are now eligible to get themselves called by Chromosomes move to opposite poles.

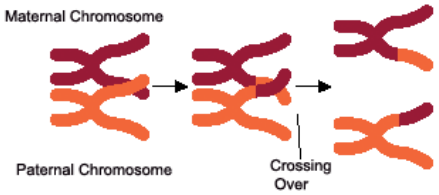
D. Telophase –II

E. The sister Chromatids or chromosomes assemble at the poles. The nucleolus and nuclear membrane re appear.

At the end of telophase II, Cytokinesis again takes place and thus 4 daughter cells are produced. The result number of chromosomes in each cell is Haploid which is represented by n.

Meiosis : significance

✓ The 4 cells formed as a result of meiosis contain the half number of Chromosomes.
✓ During sexual reproduction, the doubling of the Chromosomes takes place. Meiosis keeps the number of Chromosomes constant from generation to generation.
✓ By meiosis, new combinations of Chromosomes and genes are produced. This new combination occurs during crossing over and random distribution of paternal and maternal chromosomes occurs in the daughter cells.



Important Pointers

- ✓ In some algae and fungi, a different method of cell division takes place which is called Amitosis. In that, the nucleus gets elongated and bifurcates in two unequal nuclei.
- ✓ Phragmoplast are necessary for cell division in Plant cells.
- ✓ The shape, size and number of Chromosomes are best studied in the metaphase stage.
- ✓ The segments of Nucleotides formed during the DNA replication are called Okazaki Segments.
- ✓ To study the chromosomes, Acetocarmine is used for staining the Chromosomes.
- ✓ Interphase is the most active phase in cell division.
- ✓ The cell division in Prokaryotic cells is also called "Amitotic Division".
- ✓ The haploid Chromosome number which is the result of meiosis is called genome.
- ✓ DNA is Feulgen Positive. , it refers to Feulgen stain, which is used to stain the Chromosomes to study DNA. Presence of DNA makes Feulgen positive.
- ✓ It is Pachytene stage in which 4 stranded Chromosomes are found.
- ✓ When a cell reaches S stage, Cell division is certain.
- ✓ G1 stage takes 50% of the total time taken in Cell division.
- ✓ Telomere is the terminal end of the Chromosomes.
- ✓ Crossing over takes place during 4 stranded stage.
- ✓ Anastral mitotic division is a characteristic feature of Higher Plants
- ✓ The Angstrom Unit is 1×10^{-10} meters and is also equal to .1 nanometer or 0.0001 Micrometer.
- ✓ A nanometer is also known as millimicron which is equal to 1×10^{-9} meters or 1×10^{-3} micrometers.
- ✓ Out of Lysosome, Centrosome, Spherosome and Golgi Body, the Golgi body is a system and rest are organelles.
- ✓ Protoplasm is the main difference between the living and non living.
- ✓ Pleuropneumonia-Like Organisms (PPLO) which are now known as mycoplasma are the smallest cells.

- ✓ The Anthocyanin pigment is responsible for sky blue color of the floral parts.
- ✓ Cuticle in plant cells is the outermost part even out of the cell wall and makes the protective covering.
- ✓ Cell membrane is selectively permeable.
- ✓ The cell walls of fungi are made up of Chitin.
- ✓ The pectate decreases in the middle lamella of the fruit cells when the ripe and this is what makes them softer.
- ✓ Sudan IV is the name of a dye which is staining of lipids, triglycerides and lipoproteins it is very much used in the cell studies.
- ✓ Endoplasmic reticulum is also called endoskeleton of a cell.
- ✓ Chloroplasts contain DNA
- ✓ Ribosome is the smallest cell organelle
- ✓ Lysosomes are responsible for autolysis, they are abundant in Digestive cells.
- ✓ The cycle which converts the Fatty acids to carbohydrates is Glyoxalate cycle.
- ✓ Vacuole is a cell organelle which is surrounded by Tonoplast.
- ✓ Safranin is a dye which can color the cell nucleus red. It is also used to color Lignin.
- ✓ ATP is the energy currency of the cell.
- ✓ Mesosome is the structure which is connected to respiration in Bacterial cells.
- ✓ Creation of ATP is an endergonic reaction which means that the energy is absorbed. When ATP is converted to ADP or AMP, the reaction is Exergonic means energy is released.
- ✓ Mitosis is one of the cell division type. A sudden and uncontrolled mitosis would lead to cancer.
- ✓ Golgi complex is formed by the Endoplasmic reticulum.
- ✓ r-RNA is synthesized in Nucleolus
- ✓ Phragmoplasts are necessary for cytoplasmic division in Plant cells.
- ✓ Cellulose, hemicelluloses, pectin and lignin are the material a cell wall is composed of.
- ✓ Tubulin is a protein which is present in flagella, Cilia and microtubules which are necessary for cell movements.
- ✓ Blue green algae are prokaryotic cells.
- ✓ Actinomycin is an antibiotic which inhibits the formation of RNA.
- ✓ Bacterial DNA is called gonophore.
- ✓ Dicotyosome is another name of a Golgi Body.
- ✓ The centers of oxidation and reduction reactions are Mitochondrial cristae.
- ✓ Cystoliths are nonliving cell organelle. They are composed of calcium carbonate.
- ✓ Idiogram is the diagram which represents the shape of a Chromosome.
- ✓ Acetocarmine is used to stain the chromosomes.
- ✓ The germ plasm theory was proposed by Weismann.
- ✓ Cork cells are impervious to water because of the presence of Suberin.
- ✓ The size of mitochondria is 4-20 angstrom .
- ✓ There are 20 essential amino acids.
- ✓ Xanthophylls are of Yellow color.

Tissues

A group of cells is known as a Tissue. The cells may be of same type or different type. The term Tissue was first proposed by "Grew". The study of plant tissues and animal tissues is known as "Histology". The study of a diseased tissue is "Histopathology".

Plant Tissues

In plants, there are two kinds of tissues viz. Meristematic tissues and Permanent Tissues. The Meristematic tissues are divisible and cells in these tissues retain the power of division, so that plant keeps growing. The cells which lose the power of division form permanent tissue.

- ✓ The Meristematic tissues are living while the permanent tissues may be living or dead.
- ✓ The Meristematic tissues are found in the vegetative regions of the plant cells, while the permanent tissues are mostly in protective regions.
- ✓ The cellulose cell wall of the Meristematic tissue are thin, while in permanent tissues, it is generally thick.
- ✓ The Meristematic tissue cells have dense cytoplasm.

Meristems:

Karh Wilhelm von Nägeli coined the term Meristem. The Meristematic tissues made by Meristematic cells cells are found in all those parts of the plants where the growth can take place.

- ✓ The group of youngest Meristematic cells of a growing organ is called Promeristem. It is usually found on the stem tip and root tip.
- ✓ Promeristem gets developed into the Primary Meristem and Secondary Meristem.
- ✓ If the cell division in a Meristem occurs in all sides, giving rise to irregular mass of a tissue, then it is called "Mass Meristem". Mass Meristem is found in Endosperm of a seed of a flowering plant.
- ✓ If the cells divide along a particular axis, effecting the growth in a particular plane or axis, then the Meristem is called, " Rib Meristem". It is found in cortex and pith. Cortex is the outermost layer of plant stem or root and is bounded by epidermis.
- ✓ If the cell division of the Meristematic cells takes place in a plane or as parallel sheets or layers, it is called Plate Meristem. The cells divide on two planes so that a plate like structure is formed. It can be found in leaf lamina and plant epidermis.
- ✓ The Meristems found on the tip of an organ such as a root or stem is called "Apical Meristem".
- ✓ If the Meristem is found either at the joints or nodes or base of leaves and later gives rise to the primary and secondary Meristem, it is called "Intercalary Meristem".
- ✓ If the Meristem is found on the lateral sides, it is called Lateral Meristems for example vascular tissues
- ✓ If the Meristem makes the outermost layer of the young growing region, it is called "protoderm" and it develops into epidermal tissue system.
- ✓ If the Meristem composed of long elongated cells, that give rise to vascular tissue system, it is called Procambium.
- ✓ If the Meristem consists of large cells, which later develops into the ground tissues, then it is called Ground Meristem.
- ✓ Flower Meristem: When plants begin flowering, the shoot apical Meristem is transformed into an inflorescence Meristem which goes on to produce the floral Meristem. It produces the sepals, petals, stamens, and carpel of the flower

Type	Summary
Promeristem	Youngest Cells,
Mass Meristem	Cell Division in all sides, e.g. endosperm
Rib Meristem	Cell division on an axis.
Plate Meristem	Cell division on a plate
Apical Meristem	Found on tips
Intercalary Meristem	Found at joints , nodes and bases of leaves in some plants
Lateral Meristem	Found on lateral parts
Protoderm	Outermost division of young growing tissue
Procambium	Long elongated cells
Ground Meristem	Large cells
Flower Meristem	Floral Tissues

The concept of Apical Dominance:

Which among the following plant hormone is responsible for **Apical Dominance**?

A. Auxin
B. Gibberellins
C. Ethylene
D. Cytokinin

One Meristem inhibits the growth of other Meristems and this phenomenon is called **Apical dominance**. The result of the apical dominance is that a plant has one clearly defined main trunk. The tip of the main trunk bears the dominant Meristem and grows rapidly. It is not shadowed by branches. If the dominant Meristem is cut off, one or more branch tips will assume dominance. The branch will start growing faster and the new growth will be horizontal. To get a bushy growth, the tip of the main trunk is removed. This mechanism is based upon **Auxin hormone** which is produced in the apical Meristem and transported towards the roots in the cambium.

Permanent Tissues

The permanent tissues in plants are either simple or complex. The simple permanent tissues are made-up of one type of cells and form a homogenous mass. The complex tissue is made up of more than one type of cells, working together as unit.

The simple tissues are of three types, parenchyma, Collenchyma & Sclerenchyma. The complex tissues are also known as vascular tissues in plants and they include Xylem and Phloem.

A. Simple Tissues:

☑ **Parenchyma:** They are considered as precursors of all living tissues and are most primitive tissues. They are centers of important physiological functions of the plants such as respiration, photosynthesis, storage, secretion etc. The parenchymal permanent tissues have power of cell division. They mostly help in wound healing and formation of adventious[1] roots and buds, tubers such as potato etc. In succulent plants[2], they store water while in aquatic plants they store air. If the parenchyma contains chloroplast, they are known as "Chlorenchyma".

[1] Adventitious roots originate from the stem, branches, leaves, or old woody roots, rather than the normal root system. For example in Strawberry and Willow.

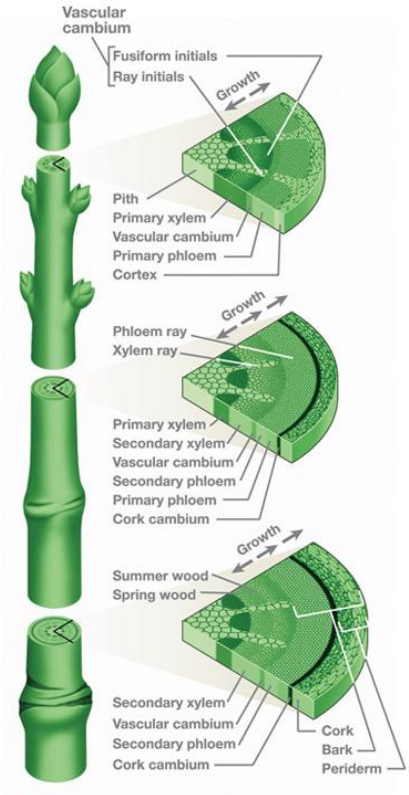
[2] Succulent plants are water-retaining plants adapted to arid climate or soil conditions, such as *Carissa carandas* or Karonda (करोंदा) found in India.

☑ **Collenchyma:** Collenchyma tissue is composed of elongated cells with unevenly thickened walls and looks polygonal in cross sections. It provides the tensile strength and elasticity to the growing organs. Some Collenchyma may have chloroplast and they perform the photosynthetic work.

✍ Collenchyma works both as a mechanical and vital tissue in plants.

☑ **Sclerenchyma** is dead cells. They act as mechanical tissues. They are long and narrow cells, and pointed at both ends. The cell walls are lignified. The Sclerenchyma may be either fibres or sclerids. The fibers are long, narrow, thick and lignified cells while the sclerids have no definite shape.

Complex Tissues: [3]



Xylem:

Xylem is a complex Tissue which contains 4 different elements viz. tracheids, vessels, xylem fibers and xylem parenchyma. Xylem performs various functions such as to conduct water and minerals from the root to the leaf and provide mechanical strength to the plant body. The first xylem formed is called primary xylem. The xylem which is formed later is called secondary Xylem.

Primary xylem is formed by the activity of Procambium of the apical Meristem. The secondary xylem develops from the vascular cambium.

Phloem:

Phloem or bast is another type of the complex tissue found in the vascular system of plants. **It conducts the prepared food material from the leaves to the storage organs and growing organs**.

✍ **If we remove the Phloem, the roots and other organs will starved to death.**

The phloem formed from the Procambium is called primary phloem and phloem formed from the vascular cambium is called the secondary phloem.

Generally Phloem is found outside the vascular cambium, but in some plants it may be found inside the pith and it is called intraxylary phloem. Phloem is composed of 1. sieve tubes, which tube like structures and composed of elongated cells. They perform the function of longitudinal transport of the food content. 2. Companion cells which help the sieve tubes to perform their duty better.

B. Secretory Tissues:

The Secretory tissues are modified for secretory functions. They are either external or internal.

☑ **External Secretory tissues:**

Examples of external Secretory tissues are haydathodes or water stomata through which water is relased in the form of liquid. This phenomenon of releasing water through "haydathodes" or water stomata is called Guttation. The water stomata are found in aquatic plants. *Pistia* is one such water plant also known as water cabbage or water lettuce.

[3] Image from Wikipedia

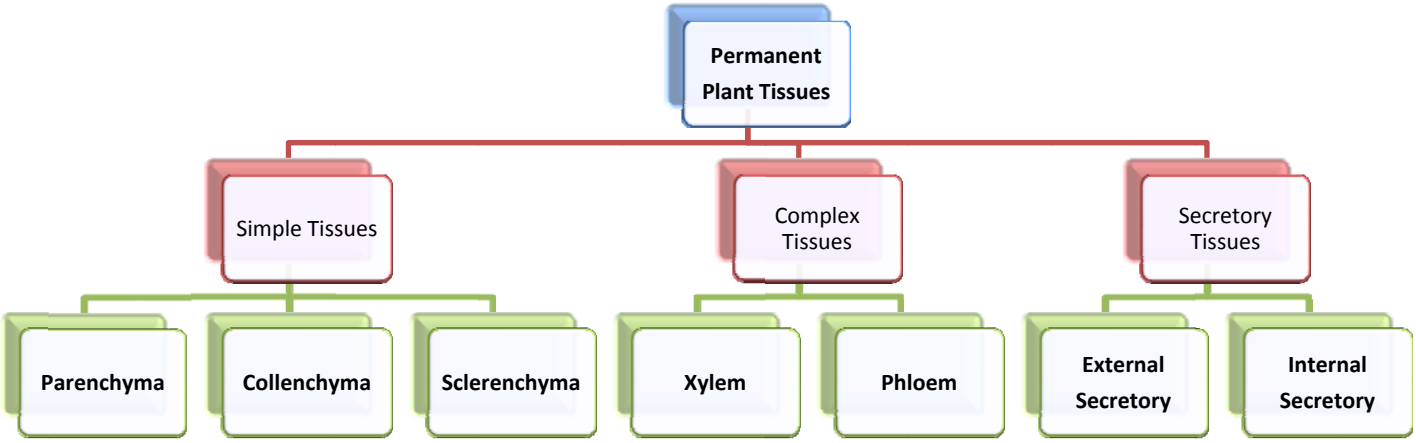
There are external digestive glands found in the insectivorous plants such as *Nepenthes*[4], *Utricularia*[5], and *Drosera*[6].

Apart from the above there are external Secretory glands such as nectar secreting glands which secrete nectar on floral and vegetative parts of some plants.

In *Urtica* or nettle the hairs secrete the irritating, poisonous substance, which is again an external Secretory tissue.

☑ **Internal Secretory Tissues:**

The most common example of the internal Secretory tissue is laticiferous tissue which secretes latex in the plants such as Rubber.



Some Pointers

- ✓ Nageli was the first person to use the word "Meristem" and Grew was the first person to use the word "Tissue".
- ✓ Most families of the flowering plants (Angiosperms) have vessels.
- ✓ The porous wood contains vessels while the nonporous wood does not contain vessel.
- ✓ The sieve cells of the Phloem and companion cells are called sister cells because they develop from a single type of cell.
- ✓ Companion cells are found only in flowering plants.
- ✓ A protein called P-protein is found in Phloem, which helps in the movement of materials.
- ✓ Latex of banana plant contains Tanin.
- ✓ An enzyme papain is found in the latex of Papaya.
- ✓ The latex is generally white, but it may be yellow or colorless.
- ✓ **The crops which produce latex are called "petrocrops".**
- ✓ Rubber plant is a latex plant and Rubber is obtained from the latex of *Ficus elastica* and *Havea brasiliensis.*
- ✓ Opium is obtained / prepared from the latex of *Papaver somniferum.* The source of the latex is poppies. Opium contains up to 12% morphine, an opiate alkaloid, which is most frequently processed chemically to produce heroin for the illegal drug trade. The other opiate alkaloids in opium are *thebaine, codeine, papaverine,* and *noscapine.*

[4] pitcher plants or monkey cups
[5] commonly called bladderworts
[6] Commonly called Sundews

- ✓ The cotton fibers are neither lignified nor cells. They are not true fibres. They develop from the outer layer of the seed.
- ✓ The coconut fibers develop from the mesocarp of the fruit and called coir.
- ✓ Xylotomy is the study of xylem.
- ✓ Knots in the woody trees is due to formation of callous by the parenchymal cells near a wound.
- ✓ In pulses (leguminous plants), special kind of parenchymal cells get associated with the phloem which help in the transfer of the highly nutritious food material. These cells are called "Transfer cells".
- ✓ Meristematic tissues are capable of cell division, but Cambium tissue is responsible for secondary growth.
- ✓ All the tissues outside the vascular cambium is known as Bark.
- ✓ Collenchyma is the only mechanical tissue which is living.

Animal Tissues

In almost all the higher animals, the tissues develop from all the three basic layers of the embryo. These layers are ectoderm, mesoderm and endoderm. The animals in which the blastula[7] comprises of these 3 layers are called triploblastic animals. There are 4 categories of animal tissue:

1. Epithelial Tissue
2. Connective Tissue
3. Muscular Tissue
4. Nervous Tissue

Epithelial Tissues

Epithelial word means growing upon one another. It is the simplest and non specialized tissue in animal cells. It is formed of one or more layers of the cells upon all external and internal exposed surfaces of the body as well as organs. The internal covering of the organs is also made up of Epithelial tissue.

☑ The cells in the epithelial tissue are placed very close to each other. The intercellular space is almost absent in most epithelial tissues. The cells are connected by various connections to each other and matrix is made up of mainly the glycoproteins, which are secreted by the epithelial cells themselves.
☑ The epithelial tissue make the covering of the internal organs, so they may also contain the microvillus, cilia and flagella.
☑ The main feature of epithelial tissue is that the cells rest upon a membrane which is called basement membrane. This basement membrane is composed of the glycoprotein, mucopolysachharides, reticular fibers etc.
☑ The epithelial tissue originates from "All the three embryonic layers" viz. Ectoderm, Mesoderm and Ectoderm.

The epithelial tissue is of two types simple and compound. They are further subdivided into several classes.

Functions:

1. Protection from dehydration, infection, mechanical and chemical injuries.
2. Acts as absorptive surface in kidney, intestine etc.

[7] early stage of embryonic development

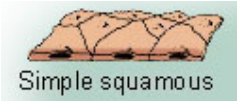
3. Selective barrier across the surface of the organs
4. Exclusive receptors in receptor organs such as eye and ear.
5. Regeneration in some organs.

Types of Epithelial Tissues:

a. Simple Epithelia:

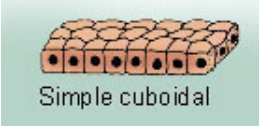
Simple epithelium is one cell thick. Every cell is in contact with the underlying basement membrane. Simple epithelium can be subdivided further as per the shape and function of its cells. Simple epithelium is divided into 8 categories:

1. Simple Squamous Epithelium



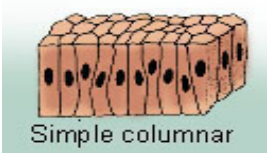
It is a scale like structure in which the cells are flattened and fitted together by means of junctions so that it looks like a mosaic of tiles. The other name used for these tissues is pavement epithelium. It is found in pleural [8], pericardial[9] and peritoneal cavities[10]. Some other examples are lining of the heart, lungs, blood & lymph vessels, lining of internal ear and uriniferous tubule[11]. **Nucleus is Flat.**

2. Simple Cuboidal Epithelium:



Cuboidal cells are roughly cuboidal in shape, appearing square in cross section. Each cell has a **spherical nucleus** in the centre. These cells occur in sweat gland, uriniferous tubules, ciliary body[12], Choroid of Eye[13] and thin bronchioles. This kind of simple epithelia do the secretive, absorptive and excreationary functions.

3. Simple Columnar Epithelium



Elongated and column-shaped, tall and prismatic cells with **elongated nucleus**, which is placed basally. These cells secrete mucous and have a short lifespan of 2-3 days. They are transformed from the adjacent epithelial cells. They are found on the inner lining of stomach, intestine, urinal and genital organs.

4. Simple Ciliated Epithelium:

The cells in these tissues may be cuboidal or columnar, but their free ends bear cilia. The cilia exhibit movements. They are found in cornea of eye, where they bear pigments and neck of uriniferous tubules.

5. Simple Glandular Epithelium:

The columnar cells and important components of glands.

6. Simple sensory epithelium:

[8] Cavity in which lungs reside is pleural cavity
[9] Pericardium contains the heart
[10] Supports abdominal organs
[11] In Nephron , the basic structure in Kidneys.
[12] circumferential tissue inside the eye composed of the ciliary muscle and ciliary processes
[13] vascular layer containing connective tissue, of the eye lying between the retina and the sclera

They are usually columnar cells with neurosensory hairs on outer ends, and inner ends attached to nervous fibers. They are found in eye retina, epithelial covering of tongue, lining of internal ear, ampulae and lining of buccal cavity (mouth).

7. Simple germinal Epithelium:

These are again cuboidal cells, but they have an immense power of cell division. They are found in the seminiferous tubules[14] and ovary.

8. Pseudostratified Epithelium:

These are single layered but composed of cells of different sized so they seem to be stratified, but are not. This inequality of size makes them look like made up of stratas and that is why called Pseudostratified. Example is Olfactory Chamber[15].

b. Stratified Epithelia

The stratified epithelia are the main protective epithelium of the body and are found at parts which are regions of friction. It can be two layered or multilayered. The cells in different layers may not be of same size, and cells towards the outer surface are more flattened.

They are of following two types:

1. Non-keratinized: The cells in Non-keratinized epithelia don't loose the nucleous and keratin is almost absent. The wet surfaces of the body such as Cornea of eye, lining of the oral cavity, vagina etc. have these cells as protective layer.

2. Keratinized: the keratinized cells have a hard insoluble fibrous protein in themselves and they **don't have nucleus.** The skin is made up of keratinized cells.

Consider the following cells?

a. Cells in the outermost layers of the Oral Cavity
b. Cells on the outermost layers of Cornea
c. Cells of Skin

Which among the above cells have nucleus?

(Only a and b.)

c. Transitional Epithelium:

The transitional epithelium consists of partly flattened non keratinized plastic cells. The superficial cells are in the form of large cuboidal plates and lowers ones small & irregular cuboidal. They have in all 2-6 layers. They are found in the urinary system.

d. Glandular Tissue in Animals:

The glands are made up of either single cells or by the aggregation of many cells. Accordingly the glandular tissues are unicellular or multicellular. Example of unicellular cells is goblet cells. The goblet cells perform the sole function of secreting mucin, which dissolves in water to form mucus. Goblet cells are found in the epithelial lining of organs, such as trachea, bronchus, and larger bronchioles in respiratory tract, small intestines, the colon and conjunctiva in the upper eye lid .

[14] located in the testes, and are the specific location of meiosis, responsible to create sperms

[15] Olfactory Chamber is a part of our nose

Multicellular glands are made up of many cells. They are exocrine or endocrine. The exocrine cells retain the duct contact with the epithelial.

Connective Tissues

The tissues that bind several tissues in the body are called connective tissues. They do the function of supporting the organs and packaging of the organs. Please note that except muscles all the connective tissue is derived from the mesoderm of the embryonic blastula.

☑ 30% of the body by mass is composed of connective tissue.

The connective tissue is made up of both the cellular components and extracellular components. Former plays a role of active defense while the later serves mechanical functions.

Unlike the epithelial tissues which have no or very less intercellular matrix, in the connective tissue, the intercellular matrix is homogenous semi-fluid, which is mainly composed of Hyaluronan. The connective tissue are divided into 3 categories: Connective Tissue Proper, Skeletal Tissue and Fluid Tissue.

a. Connective Tissue Proper:

The connective tissue proper is the least differentiated and is a prototype connective tissue. It is made of fibrous part as well as nonfibrous part. The fibrous part is made up of 3 kinds of Fibers.

i. **White Collagen Fibers**: They are generally collected in bundles bound by mucoproteins. They are elastic but with advancing age they become less elastic. 1/3 part of human body has while collagen fibers. The white fibrous tissue of made up of collagen fibers. They constitute the tendons, the fibrous connective tissue that usually connects **muscle to bone.**

Vitamin C is recommended for the children to avoid Scurvy. What does Vitamin C do in the body?

1. It helps in strengthen the bones
2. It helps in synthesis of collagen
3. It helps in synthesis of bony tissues

Answer of the above question is 2. Vitamin C helps in synthesis of Collagen and lack of vitamin C is a connective tissue related disease called "Scurvy".

ii. **Yellow Elastic Fibers:** They are branched and bound by a protein called elastin. They are present in the arteries which need elasticity to propel the blood.

A mummy found in Egypt was dissected. Which among the following internal organ of this mummy would be found in most intact condition?

1. Kidney 2. Arteries 3. Liver 4. Lungs

Answer of the above question is artery. This is because of the elastin protein. This protein is resistant to chemical changes. However, the elasticity diminished with the age of a person. Please note that Yellow elastic tissue makes Ligaments. *Ligaments join **bones to bones**.*

iii. **Reticular Fibers:** The protein found in them is reticulin. They are inelastic and mostly found in embryo and new born babies.

iv. **Raphe:** It is similar to ligaments but are stretchable.

Please Note:

☑ Tendons Join Muscles to Bones

☑ Ligaments Join Bone to Bones.

b. Skeletal Tissue:

From which of the following the skeletal of a human being is derived?
i. Endoderm
ii. Exoderm
iii. Mesoderm

This is a common question in many examinations. Skeleton is derived from the Mesoderm of the embryonic blastula. There are two types of skeletal tissues:

1. **Cartilage:** Cartilage is also known as *chondros* or *gristle.* It is a connective tissue formed of cells which are called *Chondrocytes* and fibers which are either white collagen or yellow elastic fibers. The cartilage is MORE elastic than bone, because the collagen is embedded in the matrix which is rich of mucopolysachharides. This matrix helps the collagen to get nutrition because there are no blood vessels. The main cartilages are as follows:

a. Embryonic cartilage
b. Articular cartilage
c. Bronchial cartilage
d. Cartilage of nose
e. Cartilage of larynx
f. Intervertebral disc
g. Epiglottis
h. Cartilage of ear pinnae

2. Bone:

Bone is a tissue. It is a highly mineralized tissue in which connective tissue part is $\frac{1}{3}$ and mineral part is $\frac{2}{3}$. It functions as a mechanically dynamic tissue which works as a homeostatic reservoir for ions such as calcium, magnesium and phosphorous. So bones have a very important function in acid base balance in the body. There are 270 bones in a new born baby and 206 in a adult human.

Bones are made up of osteocytes and please note that amateur osteocytes can divide but mature osteocytes don't divide. The intercellular part of the bone tissue is made up of casein $\frac{1}{3}$ part and inorganic phosphates $\frac{2}{3}$ parts. The bone tissue is highly vascular and has a greater regenerative power than any other tissue of the body except Blood. A series of tubes around narrow channels in the bone tissue are called "haversian canals". Another type of canals is found in the bone tissue known as "Volkmann's Canals". There are total 3 types of canals found in the bones: 1. The network of blood vessels 2. Haversian canals and 3. Volkmann's canals.

The thin plates of the bony tissue are called lamellae.

Formation of Bones is called "osteogenesis" or "ossification".

c. Liquid Connective Tissue: Blood, Lymph & CSF

The Blood and Lymph are liquid connective tissues and they circulate the body and help in transportation of the metabolites. They have a common matrix called plasma. They have various kinds of cells which are called "corpuscles". There are no fibers. There is no matrix.

A. Blood:

9% of the total body mass in a adult human being is Blood. In an average man, blood is 90 milliliter per kg of body weight and in an average woman blood is 65 milliliter per kg of body weight. Its specific gravity[16] is 1.060 and Ph is 7.33 to 7.41 (average 7.4). Its osmotic pressure at room temperature is 7.6 atmosphere. Plasma is 55% of the blood by volume and hemoglobin in normal adult is 14-16 gm per 100 milliliter.

Plasma constitutes 5% of the body weight. It is pale yellow in color and transparent clear fluid. Water content of plasma is 90-92% and 8-10% is organic and inorganic constituents.

Organic constituent are mainly proteins. The proteins are albumin, globulin prothombrin and fibrinogen. The globulin proteins such as ∃ macroglobulin, (globulin and immunoglobulin are the chief sites for antibody formation. Then , the proteins such as prothombrin and fibrinogen are essential for clotting.

The albumins are responsible for maintenance of osmotic pressure of Blood.

Glucose, Fructose, cholesterol, nucleosides, Vitamins, hormones, uric acid etc, are other organic substances. Gases such as Oxygen and carbon dioxide which remain in dissolved phase are inorganic substances.

Red Blood Corpuscles:

They are non nucleated. They are biconcave in shape, the diameter ranges from 6-9 micrometer (average 7.5).

The main constituent of RBC is hemoglobin and constitutes about 31-33% and is distributed in the stroma.

The concentration of RBC is same in both man & woman. In adults the concentration of RBC is as follows:

- ☑ Male: 52,00,000 ±3,00,000
- ☑ Female: 47,00,000 ±3,00,000

In the embryonic stage RBC are produced in Liver, spleen and Lymph nodes. (note all three)

Up to 20 years of age, they are produced in bone marrow of long bones[17]. After 20 years they are produced in the bone marrows of membranous bones.

RBCs complete a circulation in the body in 20 seconds.

Their life is 100-120 days.

Consider the following statements:
1. Blood Doping involves transfusion of blood of same group before a competition
2. Blood doping is dangerous for the life of an athlete

Which among the above statements hold correct?

[16] Relative density
[17] Such as femur

Answer of the above question is 2 only.

Blood doping is a menace among athletes. The problem is that blood doping cannot be detected so easily. In blood Doping, around 1 liter blood of the athlete is extracted. The RBC's are then isolated by using centrifugation process. The separated RBCs can be conserved for 5 weeks at −79 °C. Shortly before the competition, these RBCs are reinjected in the body. This improves the performance of the athlete because more RBCs can carry more oxygen. It is dangerous because, the cardiovascular system of the athlete may not be able to deal with higher viscosity blood. Statement 1 is incorrect because Blood Transfusion is the process of transferring blood or blood-based products from one person into the circulatory system of another. In doping RBCs are of the same person.

Some RBC Disorders:

☑ **Sickle-cell disease:** Red Blood Cells alter shape and threaten to damage internal organs. It is a genetic disease.
☑ **Anemia:** It may happen because of low RBC count or low hemoglobin or abnormality of the RBCs. It is characterized by low oxygen transport capacity of the blood.
☑ **Thalassemia** results in the production of an abnormal ratio of hemoglobin subunits. It's a genetic **disease.**
☑ **Pernicious anemia** is an autoimmune disease wherein the body lacks intrinsic factor, required to absorb vitamin B12 from food. Vitamin B12 is needed for the production of hemoglobin.
☑ **Aplastic anemia** is caused by the inability of the bone marrow to produce blood cells.
☑ **Pure red cell aplasia** is caused by the inability of the bone marrow to produce only red blood cells.

Consider the following statements:
1. Both sickle-cell disease and Thalassemia are Genetic Disorders.
2. Both sickle-cell disease and Thalassemia are more common in Malaria prone areas

Which among the above statements is / are correct?

Answer of this question is: Both are correct statements.

First statement is correct and is a plain truth. The second statement is correct because, the malaria parasite spends big part of its life-cycle in Red Blood Cells. During this period it feeds on the hosts hemoglobin and then breaks them apart. This causes fever at several intervals. Both sickle-cell disease and Thalassemia are more common in malaria prone areas, because these mutations convey some protection against the parasite.