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Subject : Botany
Topic : **Cell Biology**

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CELL BIOLOGY

THE CELL - BASIC UNIT OF LIFE

- ❖ A cell is a structural and functional unit of all living organisms.
- ❖ Organisms contain organs, organs composed of tissues, tissues are made up of cells; and cells are formed of organelles and organelles are made up of molecules.
- ❖ Loewy and Siekevitz defined cell as a unit of an organism delimited by a plasma membrane in animal cells and cell wall and plasma membrane in plant cells. Thus cell forms the basic unit of life.
- ❖ Anton van Leewenhoek (1632-1723) studied the structure of bacteria, protozoa spermatozoa, red blood cells under the simple microscope which he examined under a simple microscope.
- ❖ The word cell was first coined by Robert Hooke in 1665 to designate the empty honey-comb like structures viewed in a thin section of bottle cork which he examined.
- ❖ In 1838, the German botanist Schleiden proposed that all plants are made up of plant cells.
- ❖ Theodore Schwann studied and concluded that all animals are also composed of cells.
- ❖ Cell theory was again rewritten by Rudolf Virchow in 1858.
- ❖ Robert Brown in 1831 discovered the presence of nucleus in the cells of orchid roots.
- ❖ Purkinje coined the term protoplasm for the slimy substance that is found inside the cells.
- ❖ On the basis of the structure, the cells are classified into prokaryotic and eukaryotic cells.
- ❖ The smallest cells are found among bacteria (0.2 to 0.5 microns). The largest plant cell is the ovule of Cycas.
- ❖ The DNA is constantly read out into a particular set of mRNA (transcription) which specify a particular set of proteins (translation).
- ❖ As these proteins function they are being degraded and replaced by new ones and the system is so balanced that the cell neither grows, shrinks, nor changes its function.

DIFFERENCES BETWEEN PLANT AND ANIMAL CELL

Plant cell	Animal cell
Plant cell has outer rigid cell wall, made up of cellulose	Cellwall is absent. Plasma membrane is the outermost covering.
Plant cell has a distinct, definite shape because of the rigid cell wall. So, the shape of cell is permanent.	The shape of the animal cell is not so definite. It can change its shape.
Plant cell contains plastids. Most important of this is the green chloroplast.	Plastids are absent.
Vacuoles are fewer and larger.	Vacuoles are either absent or very small in number and size.
Centrosome is present only in the cells of some lower plants.	All the animal cells have centrosomes
Dictyosome (Golgi complex) is dispersed throughout the cytoplasm. It comprises stacks of single membranous lamellar discs.	Golgi complex is organized in the cytoplasm. It appears as shallow saucer shaped body or narrow neck bowl - like form. It consists of interconnecting tubules in distal region.
Lysosomes are found only in the eukaryotic plant cells.	Found in all cells.
Plant cell is larger than the animal cell.	Animal cell is small in size.
Mostly, starch is the storage material.	Glycogen is the storage material
During cytoplasmic division a cell plate is formed in the centre of the cell.	During cytoplasmic division a furrow appears from the periphery to the centre of the cell.

- ❖ In the cell cycle DNA is duplicated during synthesis (S) Phase and the copies are distributed to daughter cells during mitotic (M) phase.
- ❖ Programmed Cell Death (PCD) plays a very important role by balancing cell growth and multiplication. In addition, cell death also eliminates unnecessary cells.

CELL THEORY

- ❖ In the year (1839) Schleiden and Schwann have jointly proposed the “Cell Theory”

The important aspects of cell theory are:

1. All living organisms are made up of minute units, the cells which are the smallest entities that can be called living.
2. Each cell is made up of protoplasm with a nucleus and bounded by plasma membrane with or without a cell wall.
3. All cells are basically alike in their structure and metabolic activities.
4. Function of an organism is the sum total of activities and interaction of its constituent cells.

Exception to cell Theory

1. Viruses are biologists' puzzle. They are an exception to cell theory. They lack protoplasm, the essential part of the cell.
2. Bacteria and cyanobacteria (Blue Green algae) lack well organized nucleus.
3. Some of the protozoans are acellular.
4. The coenocytic hyphae of some fungi eg. Rhizopus have undivided mass of protoplasm, in which many nuclei remain scattered.
5. Red Blood Corpuscles (RBC) and mature sieve tubes are without nuclei.

Cell Principle or Cell Doctrine

The important features of cell doctrine are:

1. All organisms are made up of cells.
2. New cells are produced from the pre-existing cells.
3. Cell is a structural and functional unit of all living organisms.
4. A cell contains hereditary information which is passed on from cell to cell during cell division.
5. All the cells are basically the same in chemical composition and metabolic activities.
6. The structure and function of the cell are controlled by DNA.
7. Sometimes the dead cells may remain functional as tracheids and vessels in plants and horny cells in animals.

PROKARYOTIC AND EUKARYOTIC CELL (PLANT CELLS)

- ❖ These plasmids are very much used in genetic engineering where the plasmids are separated and reincorporated, genes (specific pieces of DNA) can be inserted into plasmids, which are then transplanted into bacteria using the techniques of genetic engineering. peroxysomes, in which fatty acids and amino acids are degraded.
- ❖ The cytosol of eukaryotic cells contains an array of fibrous proteins collectively called the cytoskeleton.

The differences between Prokaryotes and Eukaryotes

Size	Prokaryotes	Eukaryotes
General	Most of them are very small. Some are larger than 50 μ m.	Most are large cells (10-100 μ m). Some are larger than 1 mm.
Characteristics	All are microbes. Unicellular or colonial. The nucleoid is not membrane bound.	Some are microbes; most are large organisms. All possess a membranebound nucleus.
Cell Division	No mitosis or meiosis. Mainly by binary fission or budding.	Mitosis and meiosis types of cell division occur.
Sexual system	Absent in most forms, when present unidirectional altrans fero genetic material from donor to recipient.	Present in most forms, equal male and female participation in fertilization.
Development	No multi-cellular development from diploid zygotes. No extensive tissue differentiation.	Haplo id forms are produced by meiosis and diploid from zygotes. Multicellular organisms show extensive tissue differentiation.
Flagella Type	Some have simple bacterial flagella composed of only one fibril.	Flagella are of 9 + 2 type
Cell Wall	Madeup of peptidoglycan (mucopeptide). Cellulose is absent.	Cell wall is madeup of cellulose in plants and chitin in fungi.
Organelles	Membrane bound organelles such as endoplasmic reticulum, golgi complex, mitochondria, chloroplasts and vacuoles are	Membrane bound organelles such as endoplasmic reticu lum, golgi complex, mitochondria,

	absent.	chloroplasts and vacuoles are present.
Ribosomes	Ribosomes are smaller made of 70s units (s refers to Svedberg unit, these dimension coefficient of a particle in the ultra centrifuge).	Ribosomes are larger and made of 80s units.
DNA	Genetic material (DNA) is not found in well-organized chromosomes.	Genetic material is found in well organized chromosomes.

CELL WALL

1. The cells of all plants, bacteria and fungi have a rigid, protective covering outside the plasma membrane called cell wall.
2. Among the vascular Plants, only certain cells connected with the reproductive processes, are naked, all other cells have walls.

Chemical Composition

- ❖ In bacteria the cell wall is composed of peptidoglycan, in Fungi it is made up of chitin.
- ❖ The plant cell wall is made up of cellulose. Besides cellulose certain other chemicals such as hemicellulose, pectin, lignin, cutin, suberin, silica may also be seen deposited on the wall.

Functions of cell wall

1. It gives definite shape to the cell.
2. It protects the internal protoplasm against injury.
3. It gives rigidity to the cell
4. It prevents the bursting of plant cells due to endosmosis.
5. The walls of xylem vessels, tracheids and sieve tubes are specialized for long distance transport.
6. In many cases, the cell wall takes part in offense and defence.

CELL MEMBRANE

- ❖ All the prokaryotic and eukaryotic cells are enclosed by an elastic thin covering called plasma membrane.

- ❖ It is selectively permeable since it allows only certain substances to enter or leave the cell through it.
- ❖ In addition to this eukaryotic cells possess intracellular membranes collectively called cytoplasmic membrane system, that surround the vacuole and cell organelles.
- ❖ Plasma membrane and the sub-cellular membranes are together known as biological membranes.

Structure of cell Membrane

1. About 75 Å thick
2. The Outer and inner layers are formed of protein molecules where as the middle one is composed of two layers of phospholipid molecules.

Fluid Mosaic Model

- ❖ It explains the molecular structure of plasma membrane.

Functions of plasma membrane

- ❖ Transporting nutrients into and metabolic wastes out of the cell. Preventing unwanted materials from entering the cell. In short, the intercellular and intra cellular transport is regulated by plasma membrane.
- ❖ The plasma membrane maintains the proper ionic composition pH(~7.2) and osmotic pressure of the cytosol.

Membrane Transport:

Substances are transported across the membrane either by:

1. Passive Transport or
2. Active Transport

PASSIVE TRANSPORT

Physical processes

- ❖ Passive Transport of materials across the membrane requires no energy by the cell and it is unaided by the transport proteins.
- ❖ The physical processes through which substances get into the cell are
 1. Diffusion
 2. Osmosis

Diffusion

- ❖ Diffusion is the movement of molecules of any substance from a region of it's higher to a region of it's lower concentration.
- ❖ This can be described as 'down hill transport'. Diffusion through the bio membrane takes place in two ways.

Osmosis

- ❖ It is the special type of diffusion where the water or solvent diffuses through a selectively permeable membrane from a region of high solvent concentration to a region of low solvent concentration.

Role of Osmosis

1. It helps in absorption of water from the soil by root hairs.
2. Osmosis helps in cell to cell movement of water.
3. Osmosis helps to develop the turgor pressure which helps in opening and closing of stomata. (For more about Osmosis see unit 5.4)

Active transport

- ❖ It is vital process. It is the movement of molecules or ions against the concentration gradient. i.e the molecules or ions move from the region of lower concentration towards the region of higher concentration.
- ❖ The movement of molecules can be compared with the uphill movement of water.

Endocytosis and exocytosis

- ❖ Endocytosis and exocytosis are active processes involving bulk transport of materials through membranes, either into cells(endocytosis) or out of cells (exocytosis).

CELL ORGANELLES

- ❖ All eukaryotic cells contain a membrane bound nucleus and numerous other organelles in their cytosol.
- ❖ A Typical plant cell contains the following organelles and parts:

Mitochondria

1. They are bounded by two membranes with the inner one extensively folded.
2. Enzymes in the inner mitochondrial membrane and central matrix carry out terminal stages of sugar and lipid oxidation coupled with ATP synthesis.

Plastids

- ❖ Plastids are the largest cytoplasmic organelles bounded by double membrane. These are found in most of the plant cells and in some photosynthetic protists. These are absent in prokaryotes and in animal cells. Plastids are of three types namely **chloroplasts**, **Chromoplasts** and **leucoplasts**.

Chloroplasts

- ❖ Chloroplasts can be as long as 10mm and are typically 0.5-0.2mm thick but they vary in size and shape in different cells, especially among the algae.
- ❖ They are the sites of Photosynthesis. They are found only in plant cells. They are surrounded by an inner and outer membrane, a complex system of thylakoid membranes in their interior contains the pigments and enzymes that absorb light and produce ATP.
- ❖ Chromoplasts are coloured plastids other than green. They are found in coloured parts of plants such as petals of the flower, pericarp of the fruits etc.

Leucoplasts

- ❖ Leucoplasts are the colourless plastids. These colourless plastids are involved in the storage of carbohydrates, fats and oils and proteins. The plastids which store carbohydrates are called amyloplasts. The plastids storing fats and oils are called elaioplasts. The plastids storing protein are called proteinoplasts.

Nucleus

- ❖ It is surrounded by an inner and outer membrane. These contain numerous pores through which materials pass between the nucleus and cytosol.
- ❖ The outer nuclear membrane is continuous with the rough endoplasmic reticulum.
- ❖ The nuclear membrane resembles the plasma membrane in its function. The nucleus mainly contains DNA organized into linear structures called chromosomes.

Endoplasmic reticulum

- ❖ These are a network of inter connected membranes. Two types of Endoplasmic Reticulum are recognised.
 1. Rough E.R
 2. Smooth E.R

Rough ER

- ❖ The endoplasmic reticulum is responsible for protein synthesis in a cell. Ribosomes are sub organelles in which the amino acids are actually bound together to form proteins.
- ❖ There are spaces within the folds of ER membrane and they are known as Cisternae.


Smooth ER

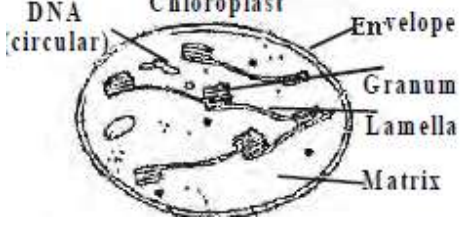
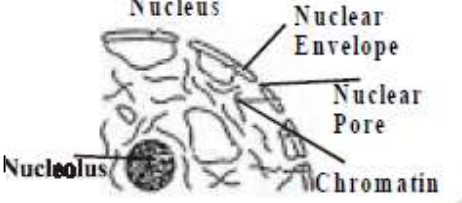
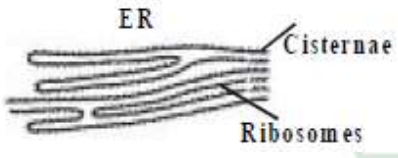

- ❖ This type of ER does not have ribosomes.

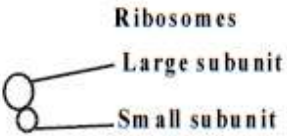
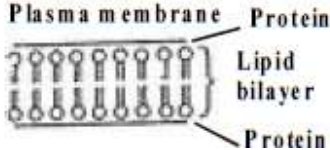


Three researchers, who made the crystal structure of the ribosomes received the Nobel Prize for chemistry in the year 2009. Venkatraman Ramakrishnan, an Indian born U.S.A scientist. Thomas Steitz U.S.A and Ada Yoath of Isrel.

Vacuoles

1. The vacuoles form about 75% of the plant cell. In the vacuole the plant stores nutrients as well as toxic wastes.
2. If pressure increases within the vacuole it can increase the sing of the cell. In this case the cell will become swollen. If the pressure increases further the cell will get destroyed.

Diagram	Structure	Functions
	It has an envelope made up of two membranes; the inner is folded to form cristae. Matrix with ribosomes is present. A circular DNA is also there.	Cristae are the sties of oxidative phosphorylation and electron transport, Matrix is the site of Krebs' cycle reactions.

	<p>It has an envelope made up of two membranes. Contains gel like stroma and a system of membranes called grana. Ribosomes and a circular DNA are present in the stroma.</p>	<p>Photosynthesis takes place here. It is a process in which light energy is converted into chemical energy.</p>
	<p>It has an envelope made up of two membranes. They have nuclear pores. It contains nucleolus and chromatin.</p>	<p>Nuclear division is the basis of cell replication and thus reproduction. Chromosomes contain DNA, the molecule responsible for inheritance.</p>
	<p>Structure: Consists of membrane – bounded sacs called cisternae.</p>	<p>Smooth ER, (no ribosomes) is the site of lipid synthesis. Rough ER (with ribosomes) transports proteins made by the ribosomes through the cisternae.</p>
	<p>It is formed by a stack of flattened membrane bound sacs, called cisternae.</p>	<p>Often involved in secretion.</p>
<p>Vacuoles</p>	<p>It is bounded by a single membrane called the tonoplast. It contains cell sap.</p>	<p>Stores various substances including waste products. It helps in the osmotic properties of the cell.</p>

 <p>Ribosomes</p> <p>Large subunit</p> <p>Small subunit</p>	<p>It consists of a large and a small sub unit. They are made of protein and RNA. Ribosome are found in mitochondria and chloroplasts also. They may form polysomes i.e. collection of ribosomes strung along messenger RNA.</p>	<p>They are the sites of protein synthesis.</p>
 <p>Plasma membrane</p> <p>Protein</p> <p>Lipid bilayer</p> <p>Protein</p>	<p>Two layers of lipid (bilayer) sandwiched between two protein layers.</p>	<p>Being a differentially permeable membrane it controls the exchange of substances between the cell and its environment</p>
 <p>Micro bodies</p>	<p>Spherical organelle bound by a single membrane</p>	<p>They are the sites of glyoxylate cycle in plants.</p>
 <p>Cell wall</p> <p>Plasma membrane</p> <p>Middle lamella</p> <p>Plasma Desma</p>	<p>It consists of cellulose microfibrils in a matrix of hemicellulose and pectic substances. Secondary thickening may be seen.</p>	<p>It provides mechanical support and protection.</p>

Golgi Apparatus

The electron microscopic observation of Golgi bodies reveals the presence of three membranous components, namely,

1. Disc shaped group of flattened sacs or cisternae
2. Small vesicles
3. Large vacuoles.

Functions

1. It produces secretory vesicles like zymogen granules that may have enzymes inside.
2. It forms the certain yolk substances in the developing oocytes.
3. It helps in retinal pigment formation in the retinal cells.
4. It helps in the formation of acrosome in sperm cells.

Lysosomes

- ❖ Lysosomes are kind of waste disposal system of the cell.
- ❖ Lysosomes originate either from the Golgi apparatus or directly from the endoplasmic reticulum. Each lysosome is a round structure. It is filled with a dense material.

Functions

1. Lysosomes help to keep the cell clean by digesting any foreign material as well as worn out cell organelles.
2. When the cell gets damaged lysosomes may burst and the enzymes digest their own cell.
3. Therefore lysosomes are also known as suicidal bags of a cell.

Mitochondria

- ❖ In the cytoplasm of most cells, large size filamentous, rounded or rodlike structure known as mitochondria may be seen. The mitochondria are bounded by two membranes made of proteins.
- ❖ The outer membrane forms a bag like structure around the inner membrane which gives out many finger like folds on the lumen of the mitochondria. The folds of inner mitochondrial membrane are known as cristae.
- ❖ Are self perpetuating semi-autonomous bodies.

Function

1. Mitochondria are considered to be the power houses of the cell because they are the seat of cellular respiration.
2. They also synthesize the energy rich compound ATP- Adenosine Tri Phosphate.

Ribosomes

- ❖ Ribosomes are found in all cells, both prokaryotic and eukaryotic except in mature sperm cells and RBCs.
- ❖ In eukaryotic cells they occur freely in the cytoplasm and also found attached to the outer surface of rough ER.
- ❖ Ribosomes are the sites of protein synthesis.

Centrioles

- ❖ Centrioles were first described by Henne-guy and Leuhossek in 1897.
- ❖ The Centrioles are micro tubular structures, found in two shapes-rod shaped and granules located near the nucleus of animal cell.
- ❖ At the time of cell division, the centrioles produce the spindle fibres and astral bodies. They also decide the plan of cell division.

Nucleus

- ❖ Nucleus is the most obvious sub cellular organelle. It is round or oval in outline and possesses four parts. They are :
 1. Nuclear Membrane
 2. Nucleoplasm
 3. Chromatin Reticulum
 4. Nucleolus
- ❖ The nuclear membrane is the outer delicate covering of the nucleus.
- ❖ It contains pores of different dimensions.
- ❖ The nucleoplasm is the protoplasmic substance of the nucleus. It is also known as nuclear sap.
- ❖ Chromatin Reticulum is composed of a network with highly elongated chromatin threads which overlap one another and are embedded in the nucleoplasm.
- ❖ At the time of the cell division, the chromosomes become clearly visible.
- ❖ The nucleolus is generally present in the nucleus of most of the cells.
- ❖ The nucleolus become enlarged during active period of cell division and are less developed in quiescent stage. It is often called as cell organizer

Functions

1. It controls all metabolic processes and hereditary activities of the cell.
2. The nuclear membrane allows exchange of ions between nucleoplasm and cytoplasm.

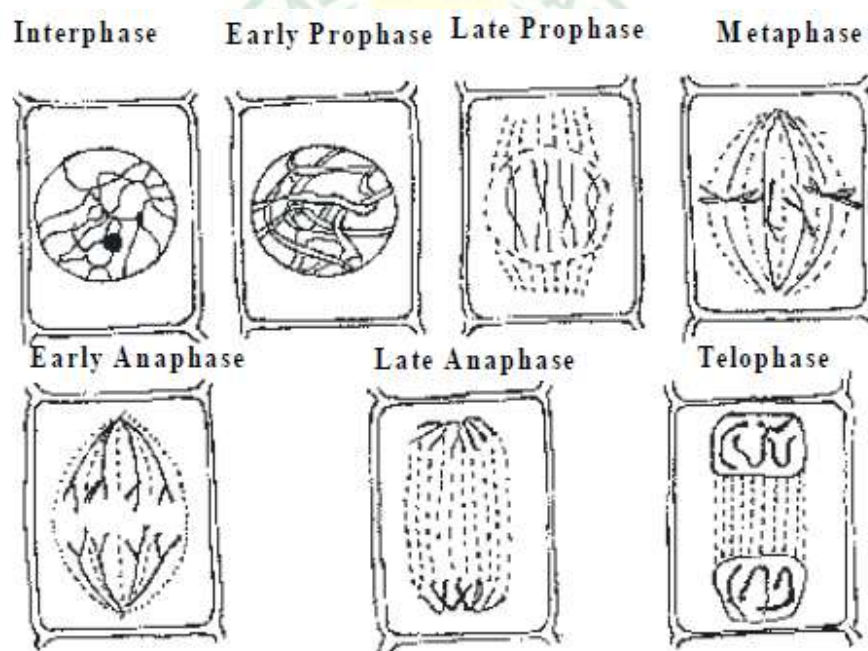
CELL DIVISION

- ❖ A matured cell divides into two daughter cells. Unicellular animalcules like amoeba, undergo binary fission without any change in the chromatin reticulum by a type of cell division called Amitosis.
- ❖ Body cells of all animals and plants undergo a cell division called Mitosis, involving changes in the structure of chromosomes, but without any change in the chromosomal number.
- ❖ The germinal epithelial cells of animals undergo Meiosis cell division, involving changes in the structure and number of chromosomes.

Mitosis

Mitosis is divided into the following 4 sub stages.

- 1. Prophase 2. Metaphase 3. Anaphase 4. Telophase**



Mitosis – Equational Cell Division

Prophase

- ❖ The chromatin network begins to coil and each chromosome becomes distinct as long thread like structure. Each chromosome at this stage has two chromatids that lie side by side and held together by centromere. The nucleus gradually disappears. The nuclear membrane also starts disappearing.

Metaphase

- ❖ The disappearance of nuclear membrane and nucleolus marks the beginning of metaphase. The chromosomes become shorter by further coiling. Finally, the chromosomes become distinct and visible under the compound microscope. The chromosomes orient themselves in the equator of the cell in such a way that all the **centromeres** are arranged in the equator forming metaphase plate or equatorial plate. Out of the two chromatids of each chromosome, one faces one pole and the other one faces the opposite pole. At the same time spindle fibres arising from the opposite poles are seen attached to the centromeres. The fibres are made up of proteins rich in sulphur containing amino acids.
- ❖ At late metaphase, the **centromeres divide** and now the chromatids of each chromosome are ready to be separated.

Anaphase

- ❖ Division of centromere marks the beginning of anaphase. The spindle fibres start contracting and this contraction pulls the two groups of chromosomes towards the opposite poles. As the chromosomes move toward opposite poles they assume **V or J or I** shaped configuration with the centromere proceeding towards the poles with chromosome arms trailing behind. Such variable shapes of the chromosomes are due to the variable position of centromere.

Telophase

- ❖ At the end of anaphase, chromosomes reach the opposite poles and they uncoil, elongate and become thin and invisible. The nuclear membrane and the nucleolus reappear. Thus, two daughter nuclei are formed, one at each pole.

Cytokinesis

- ❖ The division of the cytoplasm is called cytokinesis and it follows the nuclear division by the formation of cell wall between the two daughter nuclei. The formation of cell wall begins as a cell plate also known as **phragmoplast** formed by the aggregation of vesicles produced by Golgi bodies. These vesicles which contain cell wall materials fuse with one another to form cell membranes and cell walls. Thus, at the end of mitosis, **two identical** daughter cells are formed.

Significance of Mitosis

1. As a result of mitosis two daughter cells which are identical to each other and identical to the mother cell are formed.
2. Mitotic cell division ensures that the daughter cells possess a genetical identity, both quantitatively and qualitatively.
3. Mitosis forms the basis of continuation of organisms.
4. Asexual reproduction of lower plants is possible only by mitosis.
5. Vegetative reproduction in higher plants by grafting, tissue culture method are also a consequence of mitosis.
6. Mitosis is the common method of multiplication of cells that helps in the growth and development of multi- cellular organism.
7. Mitosis helps in the regeneration of lost or damaged tissue and in wound healing.
8. The chromosomal number is maintained constant by mitosis for each species.

Meiosis

- ❖ Meiosis is a kind of cell division, which occurs in the germinal epithelial cells of the gonads to form the gametes.
- ❖ Meiosis takes place in the specialized diploid cells of gonads and produces four haploid gametes, each having half the number of chromosomes as compared to the parent cell.
- ❖ Meiosis is completed in two successive divisions – Meiosis-I and Meiosis-II. In Meiosis-I, as the chromosomal number is reduced to half, it is called Reduction division. Meiosis-II is similar to Mitosis.

Meiosis - I

- ❖ The various events of Meiosis-I are studied under four substages namely Prophase-I, Metaphase-I, Anaphase-I and Telophase-I.

Prophase - I

- ❖ The chromatin reticulum unweaves and individual chromosomes are liberated from one another.
- ❖ The nuclear membrane dissolves. The chromosomes undergo, marked differences in their shape and structure.
- ❖ Based on the shape of the chromosomes, this stage is studied under five subdivisions as Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

Leptotene

- ❖ The chromosomes condense and appear like threads. Each chromosome splits up longitudinally, except at the centromere.

Zygotene

- ❖ The homologous chromosomes come closer and start pairing. (A homologous pair of chromosomes consist of a paternal chromosome and maternal chromosome with similar genes).
- ❖ The pairing starts from the tip or from the middle and get attached laterally throughout the length.
- ❖ This pairing is called Synapsis, the paired chromosomes are called Bivalents.

Pachytene

- ❖ The paired chromosomes become shorter and thicker. Each bivalent appears to have four strands called as, tetrads or quadrivalents.
- ❖ The point of contact between the homologous pair of chromosomes are called, Chiasmata.
- ❖ At the point of chiasmata, exchange of chromosomal segment takes place, between the chromatids of the homologous pairs.
- ❖ This exchange of segments of chromatids between homologous chromosomes, is called crossing over.

Diplotene

- ❖ After the crossing over is completed, the homologous chromosomes separate and this separation is called terminalization.
- ❖ Terminalization may begin in chiasmata and move to the terminal end of the chromosomes.

Diakinesis

- ❖ The nuclear membrane and the nucleolus disappear. The spindle apparatus is formed in the cytoplasm.

Metaphase - I

- ❖ The chromosomes get condensed. Bivalents now appear on the equator of the spindle with their chromatids, pointing towards the equatorial plate and the centromere pointing towards the poles.

Anaphase - I

- ❖ The spindle fibres contract pulling the chromosomes, towards the opposite poles.
- ❖ The entire chromosome, with the two chromatids move to the opposite poles. This involves, a reduction in the number of chromosomes. Now two groups of chromosomes are produced, one at each pole with half the number of chromosomes.

Telophase - I

- ❖ At the poles, around the group of chromosomes, a nuclear membrane develops. Thus two daughter nuclei each with half the number of chromosomes, are formed at the poles. The spindle fibres disappear.
- ❖ At the end of Meiosis-I at right angle to the position of the nuclei, the cytoplasmic constriction takes place leading to the division of the cell. The cytoplasmic division is called Cytokinesis.

Meiosis - II

- ❖ Meiosis-II is similar to Mitosis and so it is called Meiotic Mitosis. The events of Meiosis-II are studied in four sub-divisions as, Prophase-II, Metaphase-II, Anaphase- II and Telophase-II.

Prophase - II

- ❖ The bivalent chromosomes gets shortened. The centrioles form asters and move to the poles. The nucleolus and nuclear membrane disappear.

Metaphase - II

- ❖ Chromosomes, each consisting of two chromatids held together by a centromere are arranged at the equator of the spindle fibres. The centromeres are attached with the spindle fibres.

Anaphase - II

- ❖ The centromere divides into two and the two chromatids separate and now they are called as daughter chromosomes or new chromosomes. The daughter chromosomes move towards the opposite poles.

Telophase - II

- ❖ The haploid set at the two poles coil to form chromatin material. The nuclear membrane and nucleolus reappear. Thus two daughter nuclei are formed.

Cytokinesis

- ❖ The cytoplasmic division takes place at right angles to the position of the nuclei, resulting in the formation of four gametes.

Significance of Meiosis

1. Haploid sex cells are produced, in order to maintain the constancy in the number of chromosomes of a species.
2. Crossing over results in variation of genetic traits in the offspring.
3. Variations form the raw material for evolution.

