Biology

CELL AND CELL DIVISION

Chapter

The living and non-living things are composed of molecules made from chemical elements such as Carbon, Hydrogen, Oxygen, and Nitrogen. The organization of these molecules into cells is one feature that distinguishes living things from all other matter. **The cell is the smallest unit of matter that can carry on all the processes of life.** Every living thing - from the tiniest bacterium to the largest whale - is made of one or more cells. The term cell was coined by Robert Hooke. **Cell Theory** consists of **three** principles:

- All living things are composed of **one or more cells.**
- Cells are the **basic units of structure and function** in an organism**.**
- Cells come only from the **replication of existing cells.**

A first division of organisms is between those whose cells have within them a nucleus, the structure containing most of the genetic material in the form of DNA, and those whose cells don't. The nucleated cells are called eukaryotic and are found in animals, plants, fungi, protozoa and algae. In contrast, bacteria (and the less common archaea) do not have a nucleus and their DNA is spread throughout the cell. These cells are called **prokaryotic**. Eukaryotic organisms can be unicellular or multicellular while all prokaryotes are unicellular.

CELL STRUCTURE

The structures that make up a cell are determined by the specific functions carried out by the cell. Eukaryotic cells generally have the following components:

❒ Cell Membrane

A cell cannot survive if it is totally isolated from its environment. The cell membrane is a complex barrier separating every cell from its external environment. This "Selectively Permeable" membrane regulates what passes into and out of the cell. The cell membrane is a fluid mosaic of proteins floating in a phospholipid bilayer. The cell membrane functions like a gate, controlling which molecules can enter and leave the cell. The cell membrane controls which substances pass into and out of the cell. Carrier proteins in or on the membrane are specific, only allowing a small group of very similar molecules through. Hence, the cell membrane is said to be selectively permeable. The rest of the cell membrane is mostly composed of phospholipid molecules. The cell membrane is constantly being formed and broken down in living cells.

❒ Cytoplasm

Everything within the cell membrane which is not the nucleus is known as the cytoplasm. Cytosol is the jelly-like mixture in which the other organelles are suspended, so cytosol + organelles = cytoplasm. Organelles carry out specific functions within the cell. In Eukaryotic cells, most organelles are surrounded by a membrane, but in Prokaryotic cells there are no membrane-bound organelles.

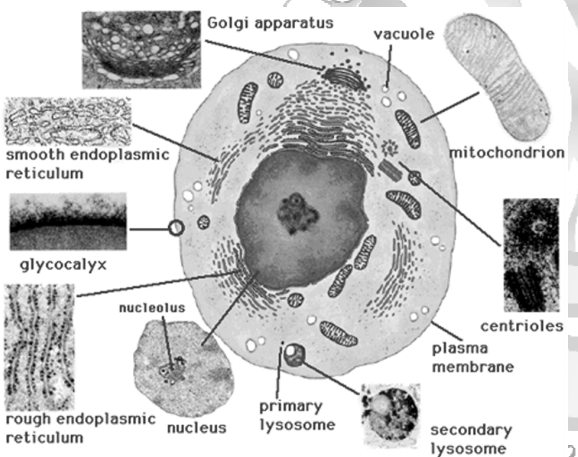
❒ Nucleus (pl. Nuvclei)

The nucleus is normally the largest organelle within a Eukaryotic cell. Prokaryotes have no nucleus, having a nuclear body instead. The nucleus contains the cell's chromosomes which are normally uncoiled to form a

Characteristic	Prokaryotes	Eukaryotes
Size of cell	Typically 0.2-2.0 mm in diameter	Typically 10-100 mm in diameter
Nucleus	No nuclear membrane or nucleoli (nucleoid)	True nucleus, consisting of nuclear membrane & nucleoli
Membrane-enclosed organelles	Absent	Present; examples include lysosomes, Golgi complex, endoplasmic reticulum, mitochondria & chloroplasts
Flagella	Consist of two protein building blocks	Complex; consist of multiple microtubules
Glycocalyx	Present as a capsule or slime layer	Present in some cells that lack a cell wall
Cell wall	Usually present; chemically complex (typical bacterial cell wall includes peptidoglycan)	When present, chemically simple
Plasma membrane	No carbohydrates and generally lacks sterols	Sterols and carbohydrates that serve as receptors present
Cytoplasm	No cytosketeton or cytoplasmic streaming	Cytoskeleton; cytoplasmic streaming
Ribosomes	Smaller size (70S)	Larger size (80S); smaller size (70S) in organelles
Chromosome (DNA) arrangement	Single circular chromosome; lacks histones	Multiple linear chromosomes with histones
Cell division	Binary fission	Mitosis
Sexual reproduction	No meiosis; transfer of DNA fragments only (conjugation)	Involves meiosis

chromatinic network, which contain both linear DNA and proteins, known as histones. These proteins coil up (dehydrate) at the start of nuclear division, when the chromosomes first become visible. The nucleus is surrounded by a double membrane called the nuclear envelope, which has many nuclear pores through which mRNA, and proteins can pass. Most nuclei contain at least one nucleolus (plural, nucleoli). The nucleoli are the site where ribosomes are synthesised. Ribosomes, translate mRNA into proteins. When a nucleus prepares to divide, the nucleolus disappears.

ANIMAL CELL STRUCTURES



❐ Mitochondria

Mitochondria are found scattered throughout the cytosol, and are relatively large organelles (second only to the nucleus and chloroplasts). Mitochondria are the sites of aerobic respiration**,** in which energy from organic compounds is transferred to ATP. For this reason they are sometimes referred to as the 'powerhouse' of the cell. ATP is the molecule that most cells use as their main energy 'currency'. Mitochondria have their own DNA, and new mitochondria arise only when existing ones grow and divide. They are thus semi-autonomous organelles.

❐ Ribosomes

These organelles are not surrounded by a membrane. Ribosomes are the site of protein synthesis in a cell. They are the most common organelles in almost all cells. Some are free in the cytoplasm (Prokaryotes); others line the membranes of rough endoplasmic reticulum (rough ER).

❐ Endoplasmic Reticulum (ER)

The ER is a system of membranous tubules and sacs. The primary function of the ER is to act as an internal transport system, allowing molecules to move from one part of the cell to another. The quantity of ER inside a cell fluctuates, depending on the cell's activity. The rough ER is the site of protein synthesis. It is an extension of the outer membrane of the nuclear envelope.

The smooth ER is where polypeptides are converted into functional proteins and where proteins are prepared for secretion. It is also the site of lipid and steroid synthesis, and is associated with the Golgi apparatus. It is also involved in the regulation of calcium levels in muscle cells, and the breakdown of toxins by liver cells.

❐ Golgi Apparatus

The Golgi apparatus is the processing, packaging and secreting organelle of the cell, so it is much more common in glandular cells. The Golgi apparatus is a system of membranes, made of flattened sac-like structures called cisternae. It works closely with the smooth ER, to modify proteins for export by the cell.

❐ Lysosomes

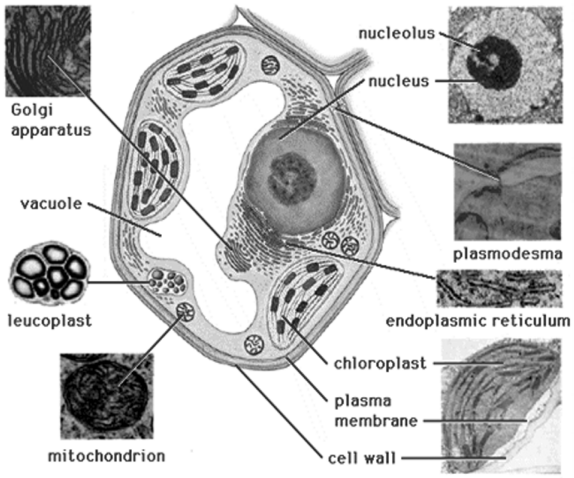
Lysosomes are small spherical organelles that enclose hydrolytic enzymes within a single membrane. They are the site of protein digestion, thus allowing enzymes to be

recycled when they are no longer required. They are also the site of food digestion in the cell, and of bacterial digestion in phagocytes. Lysosomes are formed from the pieces of the Golgi apparatus that break off.

❐ Cilia and Flagellae

Cilia and Flagellae are structures that project from the cell, where they assist in movement. Cilia (sing. cilium) are short, and numerous and hair-like. Flagellae (sing. flagellum) are much longer, fewer, and are whip-like.

PLANT CELL STRUCTURES



Most of the organelles and other parts of the cell are common to all Eukaryotic cells. Cells from different organisms have an even greater difference in structure. Plant cells have three additional structures not found in animal cells:

❐ Cellulose Cell Wall

The cell wall is freely permeable (porous), and so has no direct effect on the movement of molecules into or out of the cell. The rigidity of their cell walls helps both to support and protect the plant.

❐ Vacuoles

The most prominent structure in plant cells is the large vacuole. The vacuole is a large membrane-bound sac that fills up much of most plant cells. The vacuole serves as a storage area, and may contain stored organic molecules as well as inorganic ions. The vacuole is also used to store waste.

❐ Chloroplasts (and other plastids)

A characteristic feature of plant cells is the presence of plastids that make or store food. The most common of these are chloroplasts. Each chloroplast encloses a system of flattened, membranous sacs called thylakoids, which contain chlorophyll. Chloroplasts are semi-autonomous organelles. Other plastids store reddish-orange pigments that colour petals, fruits, and some leaves.

Cell Division

Cell division is an inherent property of living organisms. It is a process in which cells reproduce their own kind. The growth, differentiation, reproduction and repair take place through cell division. There are two types of cell division namely **Mitosis and Meiosis**. The cell capable of undergoing division passes through cell cycle.

CELL CYCLE

The cell cycle is the sequence of events or changes that occur between the formation of cell and its division into daughter cells. It has a nondividing, growing phase called **Interphase** and dividing phase called **mitotic** or **M-phase.**

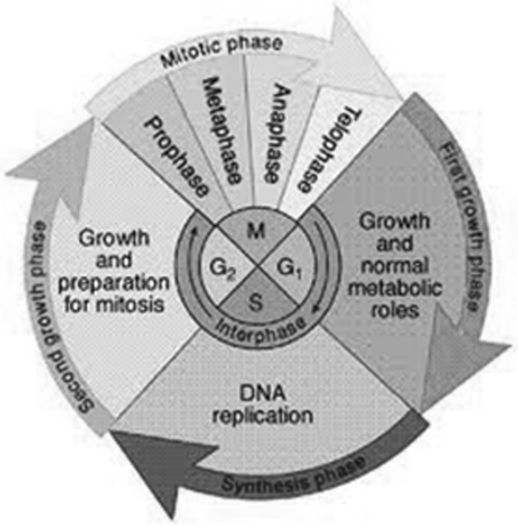
MITOSIS

1. **Interphase** (inter – between, phases – aspect) It is a long, metabolically active phase between two successive mitotic cell division. It has three sub stages.

G1 phase (post mitotic phase): The cell prepares for DNA, RNA and protein synthesis.

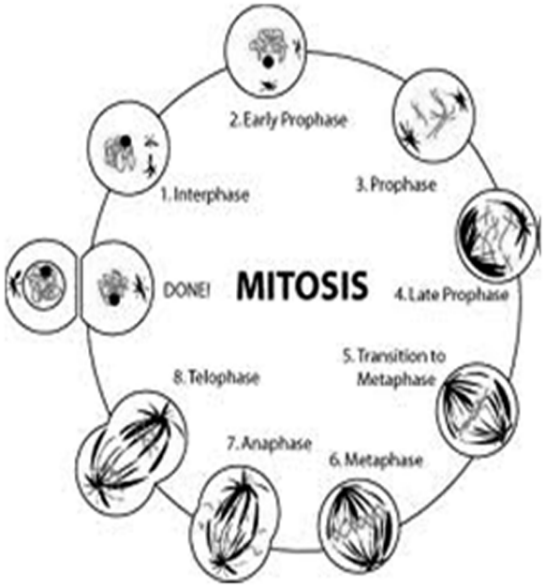
S phase (synthetic phase): The duplication or Replication of DNA and centriole take place.

G2 phase (post mitotic phase): The synthesis of proteins required for the synthesis of spindle fibres take place.



2. **M phase (Mitotic phase):** It is a short phase. It includes two important processes that occur simultaneously. They are Karyokinesis (division of the nucleus) and Cytokinesis (division of the cytoplasm), resulting in two daughter cells.

After 'M' phase the cell may enter either Interphase to repeat the cell cycle or G_0 phase to arrest cell cycle. Then the cells in G_0 phase may grow and differentiate into different cell types to perform different functions.



MITOSIS (Gr. Mitos – thread, osis – stage)

Walter Flemming (1882) studied mitotic cell division in animal cells and coined the term mitosis. Mitosis is a type of cell division in which a parental cell produces two similar daughter cells that resemble the parental cell in terms of chromosomal number. So it is also called Equational cell division (homotypic cell division). This maintains constant number of chromosomes in each cell of successive generation. It occurs in somatic cells of the body. So, it is also called somatic cell division. Mitosis occurs in two stages:

(**A) Karyokinesis** (Karyon – nucleus, kinesis – movement): It is the division of nuclear material.

It occurs in four stages as follows:

Prophase (Gr. Pro – before, phases – appearance)

It is the longest phase. During this phase the chromatin is organized into distinct chromosomes by coiling or spiralization. The centrioles develop into asters and move towards the opposite poles of the cell to establish the plane of cell division. Spindle apparatus begin to appear. Nucleolus and Nuclear membrane disintegrate and disappear. The chromosomes are set free in the cytoplasm.

Metaphase (Meta – after, phase – appearance)

Spindle fibres are completely formed. The chromosome become short and thick with two distinct chromatids each. All the chromosomes move towards the centre of the cell and arrange in the equatorial plane, right angles to the position of asters to form metaphasic plate. Chromosomes are attached to spindle fibres at their centromeres.

Anaphase (ana – up, phases - appearance)

The centromere of all the chromosomes undergo longitudinal splitting and the chromatids of each chromosome separate to form daughter chromosomes. The daughter

chromosomes move toward the opposite poles from the equator by the activity of spindle fibres.

Telophase (Telo – end, phases – appearance)

During this, the events of prophase will be reversed, the daughter chromosomes reach the opposite poles. The chromosomes undergo despiralization to form long, thin thread like structures called chromatin. Nucleolus and nuclear membrane reappears The spindle fibres disappear. Asters are not formed in plant cells as they do not have centrioles, hence called anastral cell division.

(**B) Cytokinesis** (cyto – cell, kinesis – movement)

It is the division of cytoplasm. A cleavage furrow develops in the middle of the cell in centripetal direction due to the contraction of microtubules. It occurs till the edges of the plasma membrane meet. They fuse to form a separate membrane. In plant cell, the cytokinesis occurs due to the formation of phragmoplast in centrifugal direction. The phragmoplast is formed by golgicomplex, ER and pectin containing vesicles.

Significance of Mitosis

- It maintains genetic stability within the population of cells derived from same parental cell.
- It helps the growth and tissue repair
- It helps in the replacement of dead and worn out cells
- It is a means of reproduction in lower organisms

MEIOSIS

The term meiosis was coined by **Former and Moore (1905).** It is a type of cell division in which the daughter cells receive only half of the original set of chromosome of the parental cell. Hence it is also called reductional division. Meiosis occurs only in germinal cells found in male gonad (testis), female gonad (ovary) and in spore mother cells of plants. The reproductive cells have diploid (2n) number of chromosomes. They are a haploid paternal set and a haploid maternal set. But the reproductive cells have to undergo meiotic division to produce the gametes containing haploid (n) number of chromosomes. The haploid (n) male gamete (sperm) fertilizes with the haploid (n) female gamete (ovum) to produce a diploid (2n) zygote which develops into a individual having diploid number of chromosomes in each cell of the body. Thus meiosis helps to maintain the constant number of chromosomes for a particular species. Meiosis takes place in two successive stages namely Meiosis I and Meiosis II. They include the following stages:

❐ Interphase I

During Interphase the duplication of DNA, centrioles and synthesis of RNA and proteins take place.

❐ Meiosis I

It is the reductional division in which a diploid parental cell produces two haploid daughter cells. Hence it is called reductional division. It includes following stages:

(A) Karyokinesis I

It is the division of nucleus that takes place in the following stages.

(i) Prophase I: It is the longest phase of meiosis. It has 5 sub stages.

Leptotene (bouquet stage)

The chromatin condenses to form chromosomes. The chromosomes appear as long, thin and thread like structures. They undergo coiling and become short and thick. Each chromosome has two chromatids that are not distinctly visible. Each chromosome

shows bead like structures called chromomeres. The telomeric ends of all the chromosomes converge towards one side of nuclear membrane, therefore they appear horse shoe shaped. Centrioles form into asters and keep moving towards opposite poles. Spindle apparatus begin to appear.

Zygotene (Zipper stage)

The pairing of homologous chromosomes takes place called synapsis. The pair is called bivalent. The chromosome continues to undergo condensation and asters keep moving towards opposite poles.

Pachytene (Tetrad stage)

The chromosomes become more short and thick. Each bivalent shows four chromatids called tetrad. In this stage the exchange of genetic material takes place between the non sister chromatids of homologous chromosomes. This process is called genetic crossing.

Synapsis: Pairing of the homologous chromosomes is called Synapsis

Bivalent: A paired unit formed of homologous chromosomes consisting of a paternal and a maternal chromosome is called Bivalent.

Crossing over: This results in genetic recombination which is responsible for variations. The region at which the crossing over occurs is called chiasmata (It is a visible expression of crossing over)

Diplotene

The chiasma move towards the tips of chromosomes as the homologous chromosomes of bivalent start moving apart. This event is called Terminalisation.

Diakinesis

The chromosomes at this stage appear thick, short and distinct. The tips of some chromosome show chiasma while Nucleolus and Nuclear membrane disappear. Chromosomes are set free in the cytoplasm.

(ii) Metaphase-I

Chromosomes are arranged in the equatorial region with their centromeres towards the poles and arms towards the equator.

(iii) Anaphase-I

The Centromeres do not undergo longitudinal splitting. The chromosome of each homologous pair move towards opposite poles by the activity of spindle fibres. This is called separation or disjunction of chromosomes.

(iv) Telophase-I

The homologous chromosomes separate and reach the opposite poles. The nuclear membrane reappears around the chromosomes at each pole. The spindle fibres disappear. Cytokinesis may or may not occur.

(B) Cytokinesis I (cyto – cell, kinesis – movement)

It is the division of cytoplasm. A cleavage furrow develops in the middle of the cell in centripetal direction due to contraction of microtubules. It occurs till the edges of the plasma membrane meet. They fuse to form separate membrane. It may or may not occur at the end of meiosis I.

❐ Interkinesis

The Interphase after the first meiotic division is called **Interkinesis**. It may be present or absent between meiosis-I and meiosis-II. If present it may be short or in some cases telophase-I directly enters to prophase-II.

It is similar to Interphase except for the absence of replication of DNA.

4. Meoisis-II.

❐ Tetrad

Each homologous chromosome pair (bivalent) shows four chromatids called tetrad.

❐ Crossing over

Exchange of identical parts between the

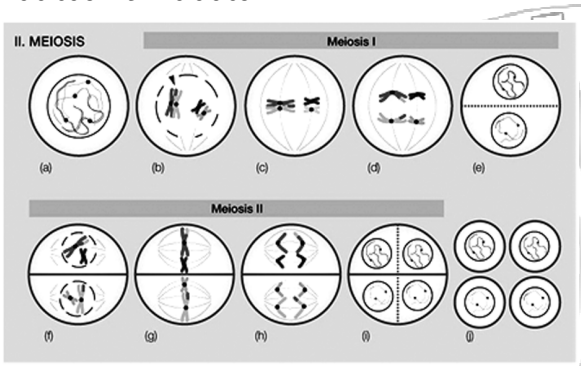
nonsister chromatids of homologous chromosomes is called Crossing over.

❐ Chiasma

These are the regions on homologous chromosomes at which crossing over occurs.

Meiosis-II occurs soon after meiosis-I. There is no duplication of chromosomes. Events recognized under four stages for convenience are:

(A) Karyokinesis II: It is the division of nucleus. It includes



(i) Prophase-II

The chromosomes start condensing again. Spindle apparatus begin to appear. The nuclear envelope and nucleolus disintegrate and disappear.

(ii) Metaphase-II

The Chromosomes arrange in the equatorial region at right angles to the asters. The Spindle fibres connect to the centromere.

(iii) Anaphase-II

The centromeres of all the chromosomes undergo longitudinal splitting. The chromatids of each chromosome separate and they move towards opposite poles.

(iv) Telophase-II

The chromosomes arrive at the poles and undergo decondensation to become thin and long chromatin fibres. A nuclear envelope is formed. Nucleolus also appears. The spindle fibres disappear.

(B) Cytokinesis II (cyto – cell, kinesis – movement)

It is the division of cytoplasm. A cleavage furrow develops in the middle of the cell in centripetal direction due to contraction of microtubules. It occurs till the edges of the plasma membrane meet. They fuse to form separate membrane.

Significance of Meiosis

- ❐ It helps to restore diploidy and maintain the constant number of chromosomes for a species.
- ❐ Meiosis produces new combination of chromosomes and genes by crossing over and by a random distribution of paternal and maternal chromosomes to daughter cells. These two events result in variations which are the food for speciation.

Differences between Mitosis and Meiosis.