Avinashilingam Institute for Home Science and Higher Education for Women

(Deemed to be University under Category 'A' by MHRD, Estd. u/s 3 of UGC Act 1956)
Re-accredited with 'A+' Grade by NAAC.Recognised by UGC Under Section 12B
Coimbatore - 641 043, Tamil Nadu, India

Bachelor's Degree Examination – July 2020
IV Semester

Class : II UG **Time : 3 Hours**
Major : Botany **Max. Marks: 100**

18BBOC10 Cell Biology

Part A **10X1=10**
Choose the Correct Answer

1. Glycolipids in plasma membrane are usually located at
   a. Outer leaflet of plasma membrane
   b. Inner leaflet of plasma membrane
   c. Evenly distributed in both inner and outer leaves of plasma membrane
   d. Cannot be predicted, it various according to cell types
2. The average thickness of plasma membrane of eukaryotic cell is
   a. 5 to 10 nm b. 5 to 10 A^o
   c. 3 to 10µ m d. 5 to 10 µm
3. Chloroplast is similar to mitochondria in having a
   a. Double layered membrane b. DNA
   c. 70 s ribosome's d. All of these
4. Oxysomes of F0-F1 particles occur on
   a. Thylakoids b. Mitochondrial surface
   c. Chloroplast surface d. Inner mitochondrial membrane
5. Name the control center of the eukaryotic cell
   a. Nucleus b. Ribosome
   c. Cytoplasm d. Golgi complex
6. Nuclear membrane is in continuous connection with
   a.SER b.RER
   c. Golgi apparatus d. Lysosome
7. The DNA and protein ratio in chromatin is
   a. 3:1 b. 2:1
   c. 1:1 d. 4:1
8. The haploid set of chromosomes is called as
   a. Proteome b. Genomics
   c. Genome d. Genes
9. The function of the centrosome is
   a. Formation of spindle fibers b. Osmoregulation
   c. Secretion d. Protein synthesis
10. Which cell organelles is involved in apoptosis
   a. Lysosome b. ER
   c. Golgi d. Mitochondria

Part B **5 x 6 = 30**

Answer ALL questions

Each answer should not exceed 400 words or two pages

11. a. Draw and label the structure of Eukaryotic cell.

(or)

11. b. Enumerate the physical and chemical nature of cytoplasm.

12. a. Write a short note on Lysosome.

(or)

12. b. Describe the structure of Mitochondria.

13. a. Explain the structure and function of nucleolus.

(or)

13. b. Comment on nuclear pore.

14. a. Classify the chromosome based on its centromere position.

(or)

14. b. Differentiate euchromatin and heterochromatin.

15.a. Discuss the significance of meiosis and mitosis.

(or)

15. b. Give an account on mitosis.

Part C **5 x 12=60**

Answer ALL questions

Each answer should not exceed 800 words or four pages

16. a. Describe the fluid mosaic model of plasma membrane and write its functions.

(or)

16. b. Write a detailed account on plant cell wall.

17. a. Mitochondria is the power house of the cell- Discuss.

(or)

17. b. Enumerate the structure and functions of chloroplast.

18. a. Give a brief account on Nucleus.

(or)

18. b. Write a detailed account on nuclear envelope.

19. a. Discuss about the special types of chromosomes.

(or)

19. b. Explain the structure of chromosome.

20. a. Give a detailed account on cell cycle.

(or)

20. b. Write an essay on meiosis.

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Scheme of Evaluation

Class : II UG **Time:3hours**
Major : Botany **Max. Marks: 100**

Paper Code and Title of the Paper: 18BBOC10, Cell Biology

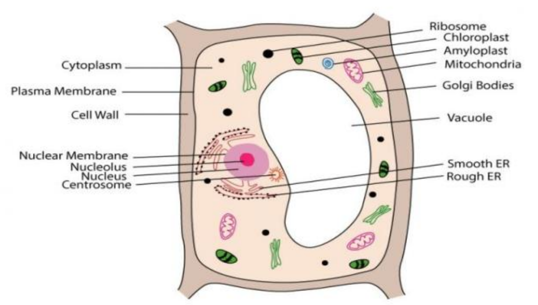
Part A

1. a. Outer leaflet of plasma membrane
2. a. 5 to 10 nm
3. d. All of these
4. d. Inner mitochondrial membrane
5. a. Nucleus
6. a. SER
7. c. 1:1
8. c. Genome
9. a. Formation of spindle fibers
10. d. Lysosome

Part B

11. a. Draw and label structure of Eukaryotic cell

Eukaryotic Plant Cell



11.b Physical and chemical nature of cytoplasm

Physical Characteristics:

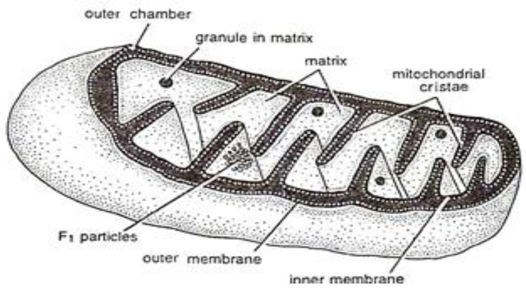
● It is a transparent , jelly like material which fills the cell between nucleus and cell membranes. ●It contains many tiny components or structures called cell organelles.●All the life functions and many chemical reactions takes place in the cytoplasm.● Cytoplasm is the contents of the cell.●In most of the cells the majority of cytoplasm is protein.●Mostly we can say that it is made up of water and salt.●Cytoplasm is essential for the existence of life.●Cytoplasm is Colorless.●The cytoskeleton which is present in the cytoplasm gives the cell its shape.● The physical nature of cytoplasm is colloidal.

Chemical Characterstics: The main components of the cytoplasm are cytosol – a gel-like substance, the organelles – the cell's internal sub-structures, and various cytoplasmic inclusions. The cytoplasm is about 80% water and usually colorless.

12.a Lysosomes

Lysosomes are globular or granular in appearance of 0.2-0.5µm size without any characteristic shape or structure. These are bounded by a single lipoprotein membrane containing enzymes in crystalline form. The enzymes present are phosphatase, nuclease, lipase, protease, glycosidase, sulfates, amylase.The membrane is impermeable to substrates of the enzymes contained in the lysosome. Certain substances, called labializes, cause instability of the lysosomal membrane, leading to release of enzymes from the lysosome. Other substances, called stabilizers, have a stabilizing action on the membrane. This prevents uncontrolled digestion of the cell contents and thus protects the cell from autolysis.The lysosomes show polymorphism in different cell types. There are two basic types of lysosomes. Golgi complex buds off primary lysosomes containing hydrolytic enzymes. The vacuole or phagosome arising by endocytosis associates and fuses with primary lysosome to form secondary lysosome.Incomplete digestion results in residual bodies. Lysosomes sometimes include intracellular part like mitochondria or endoplasmic reticulum for digestion are called auto-phagosome.

12.b. Structure of mitochondria.



1. Mitochondria are commonly called the "Power house" of the cell.
2. Benda (1897) was the first to coin the term mitochondrion.
3. Usually, mitochondria are 0.5 to 1 n in diameter and 3-6n in length. They, however, vary in their size and are also capable of changing their size.
4. They are generally rod shaped but may be in the form of granules or spherical bodies.
5. Their number may vary from 50 to 50,000 in different kinds of cells.
6. They are surrounded by two membranes, i.e., outer membrane and inner membrane. Both these membranes are separated by a narrow gap known as perimitochondrial space.
7. The inner membrane of mitochondria has large number of invaginations towards the inner cavity, known as cristae which increase the mitochondrial surface.
8. Chemically, the mitochondria are lipoprotein-aceous in nature. They consist of about 60-65% proteins and 35-40% lipids, mainly phospholipids. The presence of RNA and a little amount of DNA has also been reported.

13.aStructure and function of nucleolus.

Structure of the Nucleolus

In eukaryotic cells, nucleolus has a well-ordered structure with four main ultrastructural components. The components can be further identified as:

Fibrillar Centers: It is the place where the ribosomal proteins are formed. Granular Components: Before ribosomes are formed, these components have rRNA that binds to ribosomal proteins.DenseFibrillar Components: It has new transcribed RNA which connects to the ribosomal proteins.Nucleolar vacuoles: It is present only in Plant cell.The ultrastructure of the nucleolus can be easily visualized through an electron microscope. The arrangement of the nucleolus within the cell can be clearly studied by the techniques – fluorescent recovery after photobleaching and fluorescent protein tagging.The nucleolus of several plant species has very high concentrations of iron in contrast to the human and animal cell nucleolus.

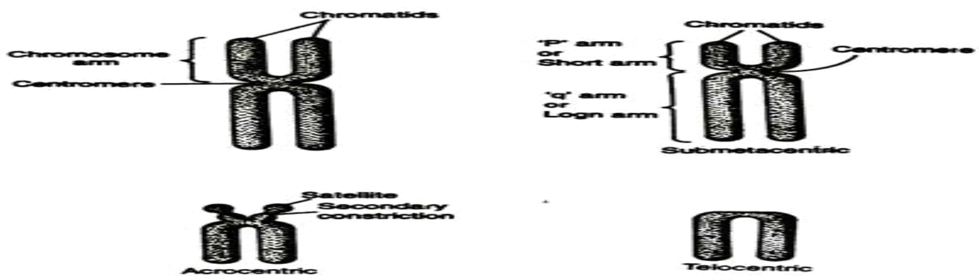
Nucleolus Function

The nucleolus is considered as the brain of the nucleus. It occupies around 25% of the volume of the nucleus. It is mainly involved in the production of subunits which then together form ribosomes. Therefore, nucleolus plays an important role in protein synthesis and the production of ribosomes in eukaryotic cells.

13.b. Nuclear pore

The nuclear envelope in all eukaryotes—from yeast to humans—is perforated by nuclear pores. At - margin - outer and inner membranes -fused. Pores provide direct channel between the nucleus and cytoplasm.plant cells - irregularly - distributed over the surface of the nucleus, but in the amphibian oocyte - the pores are numerous and regularly arranged.The number of nuclear pores - correlated - transcriptional activity of the cell.The diameter of nuclear pore is about 100 nm. The pores - enclosed by circular and cylindrical structures called annuli.The annulus is an electron dense material. The pores and annuli are collectively called the nuclear pore complex.Nuclear pore complexes have - eight-fold symmetry. Computerised image-processing techniques have shown that the pore complex consists of two rings or annuli with an inside diameter of 80 nm.Each complex - formed from - set of large protein granules arranged - octagonal pattern.
The central granule - inactive ribosome or a newly made ribosome attached to the periphery of the pore complex or other particles caught in transit. Eight radial spokes - extend from plug to rings.

14.a



Chromosomes are classified based on the position of centromere. A chromosome having a terminal centromere is called. Chromosomes are classified into four types based on the position of the centromere.These are metacentric,sub-metacentric,telocentricand acrocentric.A chromosome having centromere at the center is called as metacentric chromosome.In this, centromere divides chromosome into two equal arms. A chromosome having centromere slightly away from the center is called as sub-metacentric chromosome.A chromosome having centromere close to one of the end is called as acrocentric chromosome.A chromosome having a terminal centromere is called as telocentric chromosome.

14.b

BASIS FOR COMPARISON	HETEROCHROMATIN	EUCHROMATIN
Meaning	The tightly packed form of DNA in the chromosome is called as heterochromatin.	The loosely packed form of DNA in the chromosome is called as euchromatin.
DNA density	High DNA density.	Low DNA density.
Kind of stain	Stained dark.	Lightly stained.
Where they are present	These are found at the periphery of the nucleus in eukaryotic cells only.	These are found in the inner body of the nucleus of prokaryotic as well as in eukaryotic cells.
Transcriptional activity	They show little or no transcriptional activity.	They actively participate in the process of transcription.
Other features	They are compactly coiled.	They are loosely coiled.
	They are late replicative.	They are early replicative.
	Regions of heterochromatin are sticky.	Regions of euchromatin are non-sticky.
	Genetically inactive.	Genetically active.
	Phenotype remains unchanged of an organism.	Variation may be seen, due to the affect in DNA during the genetic process.
	It permits the gene expression regulation and also maintains the structural integrity of the cell.	It results in genetic variations and permits the genetic transcription.

15.aSignificance of mitosis:

- Maintains nucleo-cytoplasmic ratio between parent and daughter cells. Maintains qualitative and quantitative ratio of genetic material b/w parent cell & daughter cell.Helps in growth of multicellular organisms.Helps in reproduction of unicellular organisms.Brings about regeneration of lost body parts in some animals.Helps in repairing injured cells.Brings about replacement of dead cells by new cells.Maintains haploid and diploid nature of cells.

Significance of meiosis:

- An essential process in all sexually reproducing animals.Maintain diploidity of zygote (i.e. maintenance of chromosomal number in zygote). Meiosis show crossing over, resulting in genetic recombination.Meiosis show increased incidences of mutation.

15.b Mitosis is a process where a single cell divides into two identical daughter cells (cell division).

- During mitosis **one** cell[?] divides *once* to form **two** identical cells.The major purpose of mitosis is for growth and to replace worn out cells.If not corrected in time, mistakes made during mitosis can result in changes in the DNA[?] that can potentially lead to genetic disorders[?].

Mitosis is divided into five phases:

1. Interphase:

- The DNA in the cell is copied in preparation for cell division, this results in two identical full sets of chromosomes[?].
- Outside of the nucleus[?] are two centrosomes, each containing a pair of centrioles, these structures are critical for the process of cell division.
- During interphase, microtubules extend from these centrosomes.

2. Prophase:

- The chromosomes condense into X-shaped structures that can be easily seen under a microscope.
- Each chromosome is composed of two sister chromatids, containing identical genetic information.
- The chromosomes pair up so that both copies of chromosome 1 are together, both copies of chromosome 2 are together, and so on.

- At the end of prophase the membrane around the nucleus in the cell dissolves away releasing the chromosomes.
- The mitotic spindle, consisting of the microtubules and other proteins, extends across the cell between the centrioles as they move to opposite poles of the cell.

3. Metaphase:

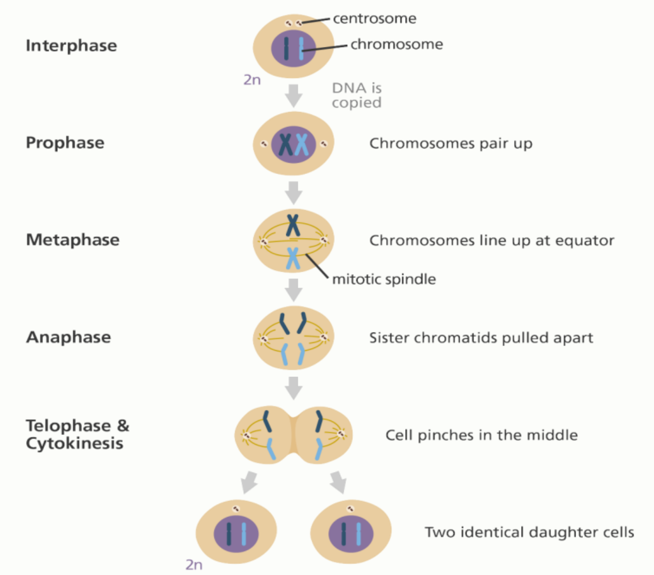
- The chromosomes line up neatly end-to-end along the centre (equator) of the cell.
- The centrioles are now at opposite poles of the cell with the mitotic spindle fibres extending from them.
- The mitotic spindle fibres attach to each of the sister chromatids.

4. Anaphase:

- The sister chromatids are then pulled apart by the mitotic spindle which pulls one chromatid to one pole and the other chromatid to the opposite pole.

5. Telophase:

- At each pole of the cell a full set of chromosomes gather together.
- A membrane forms around each set of chromosomes to create two new nuclei.
- The single cell then pinches in the middle to form two separate daughter cells each containing a full set of chromosomes within a nucleus. This process is known as cytokinesis.



Part C

16.a

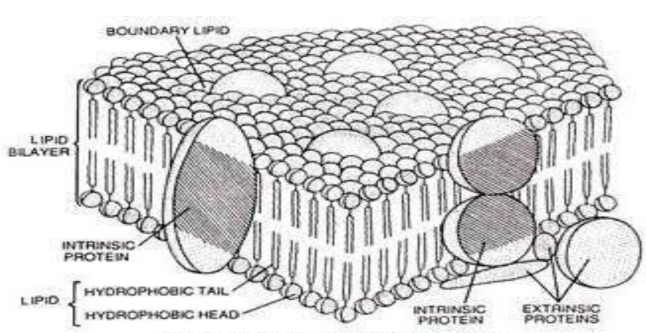


Fig 2.5 Fluid mosaic model of cell membrane.

Fluid mosaic model of a cell membrane

The **fluid mosaic model** explains various observations regarding the structure of functional cell membranes. It is a lipid bilayer (two molecules thick layer) in which protein molecules are embedded. The lipid bilayer gives fluidity and elasticity to the membrane.

In biology, **membrane fluidity** refers to the viscosity of the lipid bilayer of a cell membrane or a synthetic lipid membrane. Viscosity of the membrane can affect the rotation and diffusion of proteins and other bio-molecules within the membrane, there-by affecting their functions.

It is considered a 2-D fluid since material only rotates or translates along in one plane, rather than freely in 3 dimensions.

The fluid mosaic model is the most acceptable model of the plasma membrane. Its main function is to give shape to the cell.

It is referred to as a mosaic since it is composed of an arrangement of its components (1) Phospholipids (2) Proteins (3) Carbohydrates (4) Cholesterol.

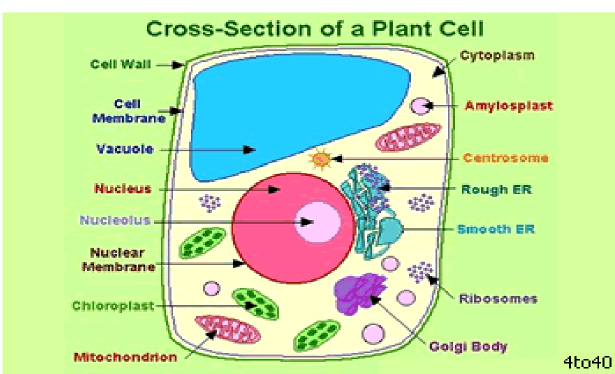
The plasma membrane is composed of a lipid bilayer

The lipid molecules are arranged in such a way that their polar head are towards the outer side and the hydrophobic tails are on the inner side.

This arrangement of lipid molecules ensures that the non-polar tail of hydrocarbons does not come in contact with the aquatic environment present.
The proteins are of two types. Integral proteins which are either partially or totally embedded in the lipid bilayer and peripheral proteins which are present on the surface of the membrane.
The quasi fluid nature of lipid enables the lateral movements of proteins within the lipid bilayer.
The fluid nature of the membrane enables functions such as cell growth, secretion, endocytosis, cell division and formation of the intercellular junction.

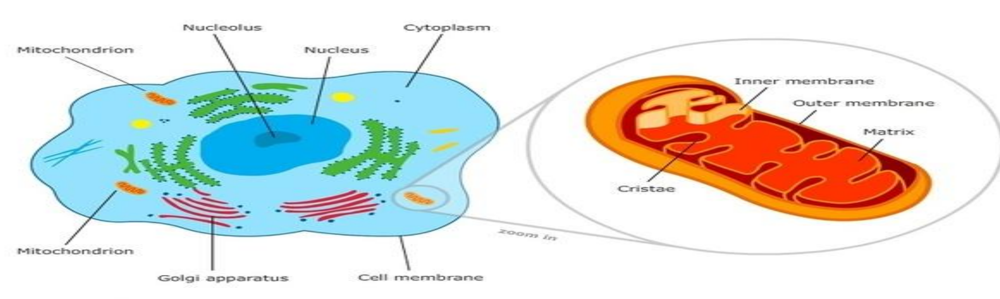
16.b. **Plant Cell Walls**

The main component of the plant cell wall is cellulose, a carbohydrate that forms long fibers and gives the cell wall its rigidity. Cellulose fibers group together to form bundles called microfibrils. Other important carbohydrates include hemicellulose, pectin, and liginin.
These carbohydrates form a network along with structural proteins to form the cell wall. Plant cells that are in the process of growing have primary cell walls, which are thin.
Once the cells are fully grown, they develop secondary cell walls. The secondary cell wall is a thick layer that is formed on the inside of the primary cell wall. This layer is what is usually meant when referring to a plant's cell wall. There is also another layer in between plant cells called the middle lamella; it is pectin-rich and helps plant cells stick together.
The cell walls of plant cells help them maintain turgor pressure, which is the pressure of the cell membrane pressing against the cell wall. Ideally, plants cells should have lots of water within them, leading to high turgidity.
Whereas a cell without a cell wall, such as an animal cell, can swell and burst of too much water diffuses into it, plants need to be in hypotonic solutions (more water inside than outside, leading to lots of water entering the cell) to maintain turgor pressure and their structural shape.
The cell wall efficiently holds water in so that the cell does not burst. When turgor pressure is lost, a plant will begin to wilt. Turgor pressure is what gives plant cells their characteristic square shape; the cells are full of water, so they fill up the space available and press against each other.
This diagram of a plant cell depicts the cell wall in green, surrounding the contents of the cell.



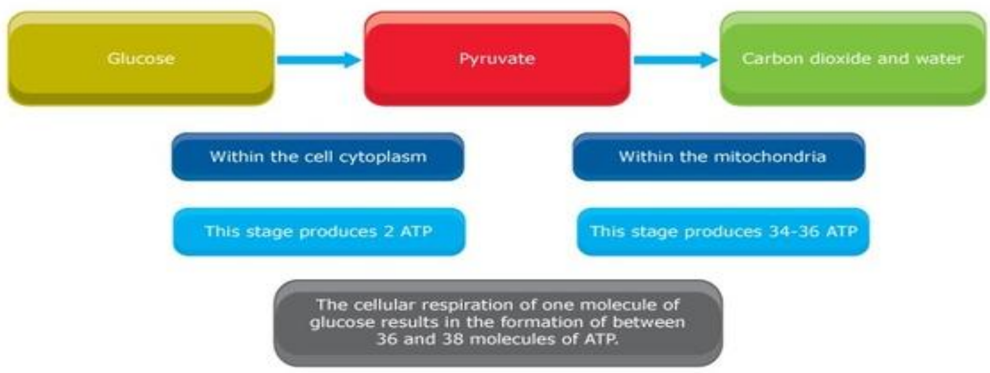
17.a

Mitochondria are tiny organelles inside cells that are involved in releasing energy from food.
This process is known as cellular respiration.
It is for this reason that mitochondria are often referred to as the powerhouses of the cell.
Cells that need a lot of energy, like muscle cells, can contain thousands of mitochondria.



Cell featuring mitochondria
Mitochondria are tiny organelles inside cells that are involved in releasing energy from food. This process is known as cellular respiration.
Apart from cellular respiration, mitochondria also play a key role in the ageing process as well as in the onset of degenerative disease.
The powerhouse function
When the breakdown products from the digestion of food find their way into the cell, a series of chemical reactions occur in the cytoplasm.

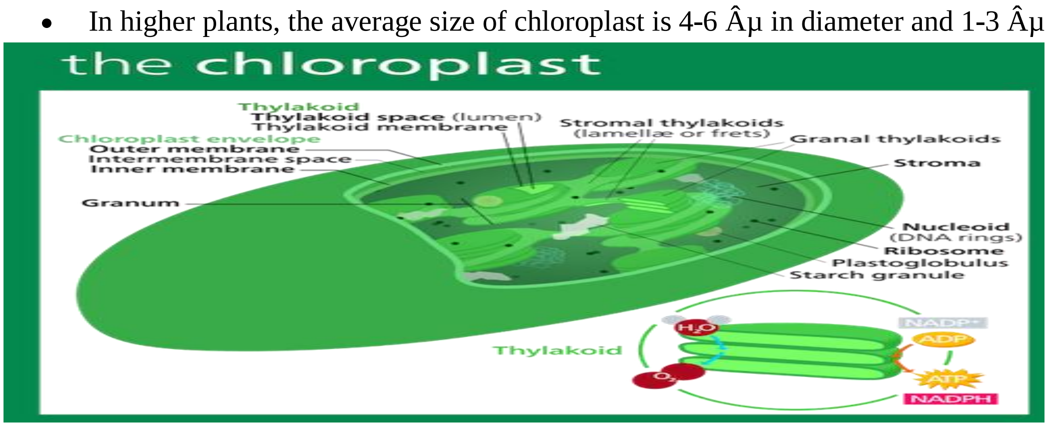
This allows some of the energy locked up in these products to be released and incorporated into the universal energy supplier in cells known as ATP (adenosine triphosphate).
Remaining molecular fragments from this process then enter the mitochondria, and in a complex series of steps, they are finally converted into carbon dioxide and water.
The energy locked up in these fragments is incorporated into more ATP.
The ATP molecules produced in this way can then be used by the cell to supply the energy needed to function. ATP → ADP + P + energy to function.



17.b**Structure of Chloroplasts**

Structure of Chloroplasts

- Chloroplasts found in higher plants are generally biconvex or planoconvex shaped.
- Chloroplasts can be found in the cells of the mesophyll in plant leaves.
- In different plants chloroplasts have different shapes, they vary from spheroid, filamentous saucer-shaped, discoid or ovoid shaped.
- They are vesicular and have a colorless center.
- Some chloroplasts are in shape of club, they have a thin middle zone and the ends are filled with chlorophyll.
- In algae a single huge chloroplast is seen that appears as a network, a spiral band or a stellate plate.
- The size of the chloroplast also varies from species to species and it is constant for a given cell type.
- In higher plants, the average size of chloroplast is 4-6 Âµ in diameter and 1-3 Âµ in thickness.

.

Functions of Chloroplast

1. Absorption of light energy and conversion of it into biological energy.
2. Production of NAPDH2 and evolution of oxygen through the process of photosys of water.
3. Production of ATP by photophosphorylation. NADPH2 and ATP are the assimilatory powers of photosynthesis. Transfer of CO2 obtained from the air to 5 carbon sugar in the stream during dark reaction.
4. Breaking of 6-carbon atom compound into two molecules of phosphoglyceric acid by the utilization of assimilatory powers.
5. Conversion of PGA into different sugars and store as stratch. The chloroplast is very important as it is the cooking place for all the green plants. All heterotrophs also depend on plasts for this food.
6. In plants all the cells participate in plant immune response as they lack specialized immune cells.
7. The chloroplasts with the nucleus and cell membrane and ER are the key organelles of pathogen defense.
8. The most important function of chloroplast is to make food by the process of photosynthesis.
9. Food is prepared in the form of sugars. During the process of photosynthesis sugar and oxygen are made using light energy, water, and carbon dioxide.
10. Light reactions takes place on the membranes of the thylakoids.
11. Chloroplasts, like the mitochondria use the potential energy of the H+ ions or the hydrogen ion gradient to generate energy in the form of ATP.
12. The dark reactions also known as the Calvin cycle takes place in the stroma of chloroplast.

13. Production of NADPH2 molecules and oxygen as a result of photolysis of water.
14. By the utilization of assimilatory powers the 6-carbon atom is broken into two molecules of phosphoglyceric acid.

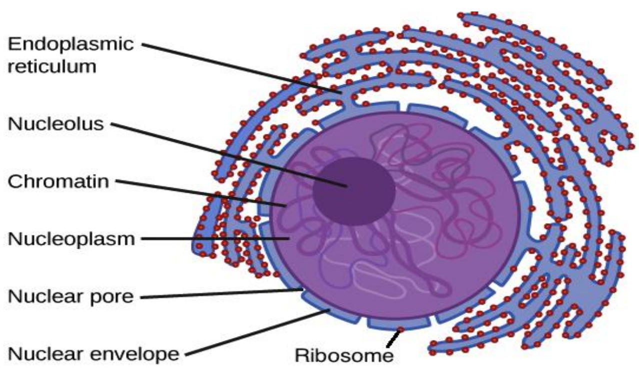
18.a**The nucleus**

The **nucleus** (plural, **nuclei**) houses the cell's genetic material, or DNA, and is also the site of synthesis for ribosomes, the cellular machines that assemble proteins. Inside the nucleus, chromatin (DNA wrapped around proteins, described further below) is stored in a gel-like substance called **nucleoplasm**.

Enclosing the nucleoplasm is the **nuclear envelope**, which is made up of two layers of membrane: an outer membrane and an inner membrane. Each of these membranes contains two layers of phospholipids, arranged with their tails pointing inward (forming a phospholipid bilayer). There's a thin space between the two layers of the nuclear envelope, and this space is directly connected to the interior of another membranous organelle, the endoplasmic reticulum.

Nuclear pores, small channels that span the nuclear envelope, let substances enter and exit the nucleus. Each pore is lined by a set of proteins, called the nuclear pore complex, that control what molecules can go in or out.

If you look at a microscope image of the nucleus, you may notice – depending on the type of stain used to visualize the cell – that there's a dark spot inside it. This darkly staining region is called the **nucleolus**, and it's the site in which new ribosomes are assembled.



18. b.**The nuclear envelope**

The nuclear envelope is a double membrane composed of an outer and an inner phospholipid bilayer. The thin space between the two layers connects with the lumen of the rough endoplasmic reticulum (RER), and the outer layer is an extension of the outer face of the RER. The inner surface of the nuclear envelope has a protein lining called the nuclear lamina, which binds to chromatin and other contents of the nucleus. The entire envelope is perforated by numerous nuclear pores. These transport routes are fully permeable to small molecules up to the size of the smallest proteins, but they form a selective barrier against movement of larger molecules. Each pore is surrounded by an elaborate protein structure called the nuclear pore complex, which selects molecules for entrance into the nucleus.Entering the nucleus through the pores are the nucleotide building blocks of DNA and RNA, as well as adenosine triphosphate, which provides the energy for synthesizing genetic material. Histones and other large proteins must also pass through the pores. These molecules have special amino acid sequences on their surface that signal admittance by the nuclear pore complexes. The complexes also regulate the export from the nucleus of RNA and subunits of ribosomes.DNA in prokaryotes is also organized in loops and is bound to small proteins resembling histones, but these structures are not enclosed by a nuclear membrane.

19.a) Special types of chromosomes

In Eukaryotic organisms certain chromosomes are found only in certain special tissues and are not seen in other tissues. These chromosomes are larger in size and are called giant chromosomes.In certain plants, they are found in the suspensors of the embryo. There are two types of giant chromosomes - polytene chromosome and lamp brush chromosome.Polytene chromosomes were observed by C.G. Balbiani in 1881 in the salivary glands of Drosophila. The characteristic feature of polytenechromosome is that along the length of the chromosome there is a series of dark bands alternate with clear zones called inter bands. The polytene chromosome has extremely large puff called Balbiani ring. It is also known as chromosomal puff. As this chromosome occurs in the salivary gland it is known as salivary gland chromosomes. Lamp brush chromosomes were first observed by Flemming in 1882. It looked like brushes. They occur at the diplotene stage of meiotic prophase in oocytes of an animal Salamandor and in giant nucleus of the unicellular alga Acetabularia. The highly condensed chromosome forms the chromosomal axis, from which lateral loops of DNA extend as a result of intense RNA synthesis.

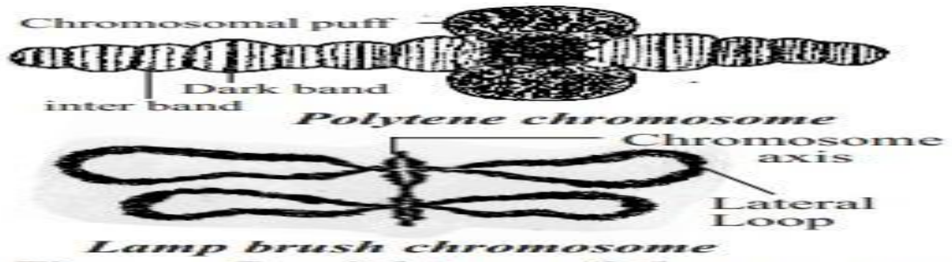
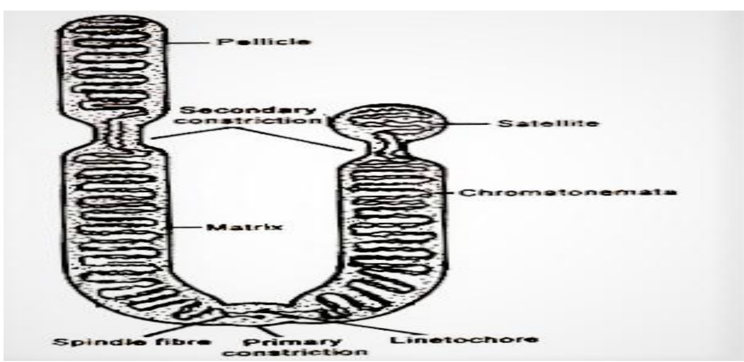


Fig. Special types of chromosomes

19.bA chromosome consists of pellicle, matrix, chromonema, chromomere, centromere, secondary constriction and telomere.

• Pellicle: It is the outermost thin proteinaceous covering of the chromosome.
• Matrix: It is the liquid non-genetic achromatic ground substance of chromosome, having different types of enzymes, minerals, water, proteins, lipids, etc.
• Chromonema (single chromonemata): It is a highly coiled thread chromatin which is spread throughout the length of the chromosome or the chromatid. Each thread of chromonemata consists of a single long thread of DNA associated with histones. Sometimes, bead-like structures appear on the chromonemafibres. These fibres are called chromomere.
• Centromere: It is the area where the two chromatids are attached to each other. It consists of two proteins disc called kinetochores. The kinetochore is the actual site where the spindle fibres are attached to the chromosomes during the cell division.
• Secondary constriction: The chromosomal arms may contain other constrictions which are called secondary constrictions. These secondary constrictions are present near the chromosomal ends.
• Telomere: The tips of chromosomes are called telomeres which are rich in GT nucleotides. Telomere facilitates the attachment of chromosomes with the nuclear envelope.



20.a.

Stages of the cell cycle

To divide, a cell must complete several important tasks: it must grow, copy its genetic material (DNA), and physically split into two daughter cells.

Cells perform these tasks in an organized, predictable series of steps that make up the cell cycle. The cell cycle is a cycle, rather than a linear pathway, because at the end of each go-round, the two daughter cells can start the exact same process over again from the beginning.

In eukaryotic cells, or cells with a nucleus, the stages of the cell cycle are divided into two major phases: **interphase** and the **mitotic (M) phase**.

- During *interphase*, the cell grows and makes a copy of its DNA.
- During the *mitotic (M) phase*, the cell separates its DNA into two sets and divides its cytoplasm, forming two new cells
- **Interphase**

Let's enter the cell cycle just as a cell forms, by division of its mother cell. What must this newborn cell do next if it wants to go on and divide itself? Preparation for division happens in three steps:

- **G_11start subscript, 1, end subscript phase.** During G_11start subscript, 1, end subscript phase, also called the first gap phase, the cell grows physically larger, copies organelles, and makes the molecular building blocks it will need in later steps.
- **S phase.** In S phase, the cell synthesizes a complete copy of the DNA in its nucleus. It also duplicates a microtubule-organizing structure called the centrosome. The centrosomes help separate DNA during M phase.
- **G_22start subscript, 2, end subscript phase.** During the second gap phase, or G_22start subscript, 2, end subscript phase, the cell grows more, makes proteins and organelles, and begins to reorganize its contents in preparation for mitosis. G_22start subscript, 2, end subscript phase ends when mitosis begins.

The G_11start subscript, 1, end subscript, S, and G_22start subscript, 2, end subscript phases together are known as **interphase**. The prefix *inter-* means between, reflecting that interphase takes place between one mitotic (M) phase and the next.

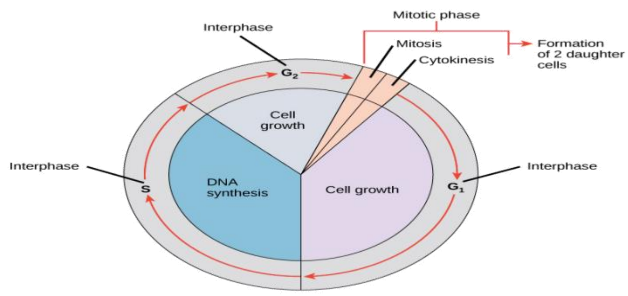


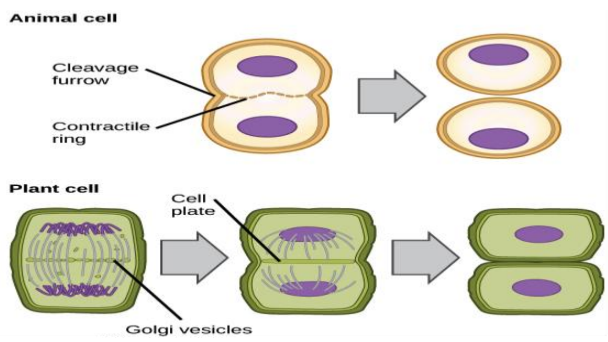
Image of the cell cycle. Interphase is composed of G1 phase (cell growth), followed by S phase (DNA synthesis), followed by G2 phase (cell growth). At the end of interphase comes the mitotic phase, which is made up of mitosis and cytokinesis and leads to the formation of two daughter cells. Mitosis precedes cytokinesis, though the two processes typically overlap somewhat.

M phase

During the mitotic (M) phase, the cell divides its copied DNA and cytoplasm to make two new cells. M phase involves two distinct division-related processes: mitosis and cytokinesis.

In **mitosis**, the nuclear DNA of the cell condenses into visible chromosomes and is pulled apart by the mitotic spindle, a specialized structure made out of microtubules. Mitosis takes place in four stages: prophase (sometimes divided into early prophase and prometaphase), metaphase, anaphase, and telophase.

In **cytokinesis**, the cytoplasm of the cell is split in two, making two new cells. Cytokinesis usually begins just as mitosis is ending, with a little overlap. Importantly, cytokinesis takes place differently in animal and plant cells.



Cytokinesis in animal and plant cells.

In an animal cell, a contractile ring of cytoskeletal fibers forms at the middle of the cell and contracts inward, producing an indentation called the cleavage furrow. Eventually, the contractile ring pinches the mother cell in two, producing two daughter cells.

In a plant cell, vesicles derived from the Golgi apparatus move to the middle of the cell, where they fuse to form a structure called the cell plate. The cell plate expands outwards and connects with the side walls of the cell, creating a new cell wall that partitions the mother cell to make two daughter cells.

In animals, cell division occurs when a band of cytoskeletal fibers called the **contractile ring** contracts inward and pinches the cell in two, a process called contractile cytokinesis. The indentation produced as the ring contracts inward is called the **cleavage furrow**. Animal cells can be pinched in two because they're relatively soft and squishy.

- Plant cells are much stiffer than animal cells; they're surrounded by a rigid cell wall and have high internal pressure. Because of this, plant cells divide in two by building a new structure down the middle of the cell. This structure, known as the **cell plate**, is made up of plasma membrane and cell wall components delivered in vesicles, and it partitions the cell in two.

Cell cycle exit and G_00start subscript, 0, end subscript

What happens to the two daughter cells produced in one round of the cell cycle? This depends on what type of cells they are. Some types of cells divide rapidly, and in these cases, the daughter cells may immediately undergo another round of cell division. For instance, many cell types in an early embryo divide rapidly, and so do cells in a tumor.

Other types of cells divide slowly or not at all. These cells may exit the G_11start subscript, 1, end subscript phase and enter a resting state called **G_00start subscript, 0, end subscript phase**. In G_00start subscript, 0, end subscript, a cell is not actively preparing to divide, it's just doing its job. For instance, it might conduct signals as a neuron (like the one in the drawing below) or store carbohydrates as a liver cell. G_00start subscript, 0, end subscript is a permanent state for some cells, while others may re-start division if they get the right signals.

20.b**Phases of meiosis**

In many ways, meiosis is a lot like mitosis. The cell goes through similar stages and uses similar strategies to organize and separate chromosomes. In meiosis, however, the cell has a more complex task. It still needs to separate **sister chromatids** , as in mitosis. But it must also separate **homologous chromosomes**, the similar but nonidentical chromosome pairs an organism receives from its two parents.

These goals are accomplished in meiosis using a two-step division process. Homologue pairs separate during a first round of cell division, called **meiosis I**. Sister chromatids separate during a second round, called **meiosis II**.

Since cell division occurs twice during meiosis, one starting cell can produce four gametes (eggs or sperm). In each round of division, cells go through four stages: prophase, metaphase, anaphase, and telophase.

Meiosis I

Before entering meiosis I, a cell must first go through interphase. As in mitosis, the cell grows during G_11 start subscript, 1, end subscript phase, copies all of its chromosomes during S phase, and prepares for division during G_22start subscript, 2, end subscript phase.

During **prophase I**, differences from mitosis begin to appear. As in mitosis, the chromosomes begin to condense, but in meiosis I, they also pair up. Each chromosome carefully aligns with its homologue partner so that the two match up at corresponding positions along their full length.

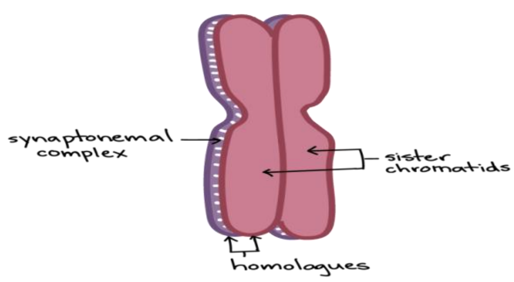
For instance, in the image below, the letters A, B, and C represent genes found at particular spots on the chromosome, with capital and lowercase letters for different forms, or alleles, of each gene. The DNA is broken at the same spot on each homologue—here, between genes B and C—and reconnected in a criss-cross pattern so that the homologues exchange part of their DNA.

Image of crossing over. Two homologous chromosomes carry different versions of three genes. One has the A, B, and C versions, while the other has the a, b, and c versions. A crossover event in which two chromatids—one from each homologue—exchange fragments swaps the C and c genes. Now, each homologue has two dissimilar chromatids.

One has A, B, C on one chromatid and A, B, c on the other chromatid.

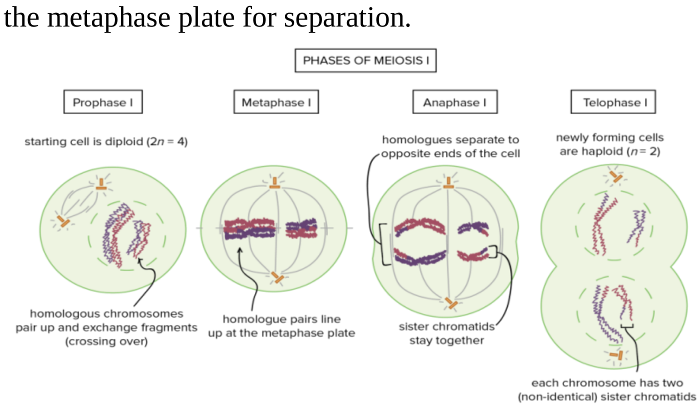
The other homologue has a, b, c on one chromatid and a, b, C on the other chromatid.

Image credit: based on "The process of meiosis: Figure 2" by OpenStax College, Biology, CC BY 3.0



This process, in which homologous chromosomes trade parts, is called **crossing over**. It's helped along by a protein structure called the **synaptonemal complex** that holds the homologues together. The chromosomes would actually be positioned one on top of the other—as in the image below—throughout crossing over; they're only shown side-by-side in the image above so that it's easier to see the exchange of genetic material.

After crossing over, the spindle begins to capture chromosomes and move them towards the center of the cell (metaphase plate). This may seem familiar from mitosis, but there is a twist. Each chromosome attaches to microtubules from just one pole of the spindle, and the two homologues of a pair bind to microtubules from opposite poles. So, during **metaphase I**, homologue pairs—not individual chromosomes—line up at the metaphase plate for separation.



The phases of meiosis I.

Prophase I: The starting cell is diploid, 2n = 4. Homologous chromosomes pair up and exchange fragments in the process of crossing over.

Metaphase I: Homologue pairs line up at the metaphase plate.

Anaphase I: Homologues separate to opposite ends of the cell. Sister chromatids stay together.

Telophase I: Newly forming cells are haploid, n = 2. Each chromosome still has two sister chromatids, but the chromatids of each chromosome are no longer identical to each other.

When the homologous pairs line up at the metaphase plate, the orientation of each pair is random. For instance, in the diagram above, the pink version of the big chromosome and the purple version of the little chromosome happen to be positioned towards the same pole and go into the same cell. But the orientation could have equally well been flipped, so that both purple chromosomes went into the cell together. This allows for the formation of gametes with different sets of homologues.

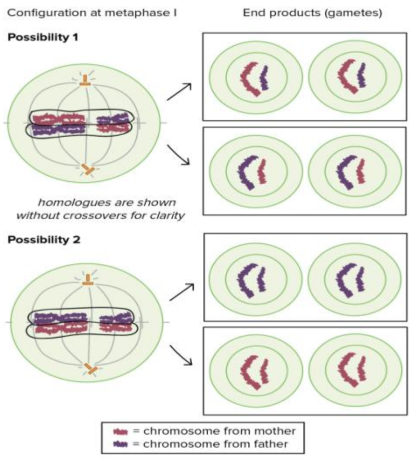


Diagram showing the relationship between chromosome configuration at meiosis I and homologue segregation to gametes. The diagram depicts a simplified case in which an organism only has 2n = 4 chromosomes. In this case, four different types of gametes may be produced, depending on whether the maternal homologues are positioned on the same side or on opposite sides of the metaphase plate.

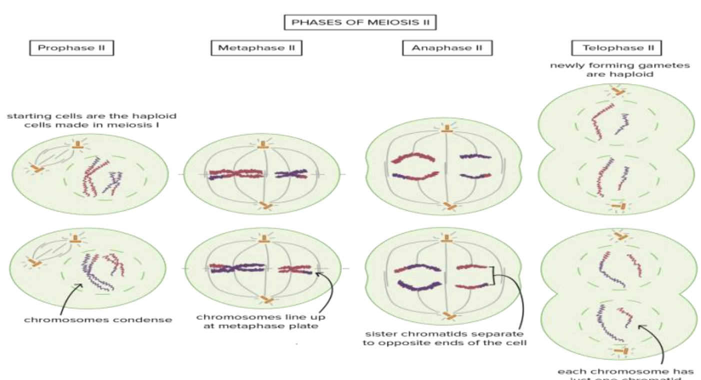
In **anaphase I**, the homologues are pulled apart and move apart to opposite ends of the cell. The sister chromatids of each chromosome, however, remain attached to one another and don't come apart.

Finally, in **telophase I**, the chromosomes arrive at opposite poles of the cell. In some organisms, the nuclear membrane re-forms and the chromosomes decondense, although in others, this step is skipped—since cells will soon go through another round of division, meiosis II^{2,3}2,3start superscript, 2, comma, 3, end superscript. Cytokinesis usually occurs at the same time as telophase I, forming two haploid daughter cells.

Meiosis II

Cells move from meiosis I to meiosis II without copying their DNA. Meiosis II is a shorter and simpler process than meiosis I, and you may find it helpful to think of meiosis II as "mitosis for haploid cells."

The cells that enter meiosis II are the ones made in meiosis I. These cells are haploid—have just one chromosome from each homologue pair—but their chromosomes still consist of two sister chromatids. In meiosis II, the sister chromatids separate, making haploid cells with non-duplicated chromosomes.



Phases of meiosis II

Prophase II: Starting cells are the haploid cells made in meiosis I. Chromosomes condense.
Metaphase II: Chromosomes line up at the metaphase plate.
Anaphase II: Sister chromatids separate to opposite ends of the cell.
Telophase II: Newly forming gametes are haploid, and each chromosome now has just one chromatid.

During **prophase II**, chromosomes condense and the nuclear envelope breaks down, if needed. The centrosomes move apart, the spindle forms between them, and the spindle microtubules begin to capture chromosomes. The two sister chromatids of each chromosome are captured by microtubules from opposite spindle poles. In **metaphase II**, the chromosomes line up individually along the metaphase plate. In **anaphase II**, the sister chromatids separate and are pulled towards opposite poles of the cell.

In **telophase II**, nuclear membranes form around each set of chromosomes, and the chromosomes decondense. Cytokinesis splits the chromosome sets into new cells, forming the final products of meiosis: four haploid cells in which each chromosome has just one chromatid. In humans, the products of meiosis are sperm or egg cells.