Unit- II
(Nucleic Acid, Chromosome and Cell Division)

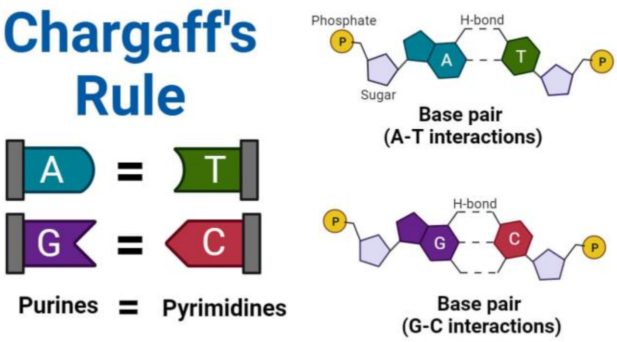
Part – A

Short answer type questions :

1. Name the enzyme which unites two strands of DNA?
Ans: Ligase

2. Write one pyrimidine of ribonucleic acid?
Ans: Uracil

3. Write about Chargaff's rule?
Ans:



Chargaff, an Austrian biochemist, in the year 1950, reported that the amount of guanine equals that of cytosine in DNA, and this has become a universal law which holds true for every replicating DNA present in nature. This pattern exists in both strands of DNA.
According to this law, A = T and G = C are always equal to one, except for the D x 14 coliphage, where the A : T and G : C ratio is not one.
Chargaff's rule is also called the "Base Rule" or base ratios.

4. Metacentric chromosomes are of which shape?
Ans: V-shape

5. Write the function of chromosomes.
Ans: Chromosomes are the carriers of genes, and through these, genes are transmitted from parents to the progeny.

6. By which division does a diploid cell form four haploid cells?
Ans: By meiotic division

7. Define terminalization?
Ans: Displacement of chiasmata is termed as terminalization.

8. Write one function of spindle fibers?
Ans: During cell division, microtubules present in the spindle help in the movement of

chromosomes.

9. Define crossing over?

Ans: Crossing over is a process in which the mutual exchange of segments among the chromatids takes place, leading to gene exchange.
Crossing over always occurs between non-sister chromatids at similar points.

10. In how many hours is mitosis completed in Vicia faba?

Ans: 31 hours.

11. The kinetocore (centromere) of a chromosome is divided in which stage of meiotic division?

Ans In the **Metaphase** stage.

12. Amitosis is found in which organisms?

Ans Amitosis is found in **yeast**, **protozoa**, and **bacteria**.

13. Define the cell cycle.

Ans: The **cell cycle** is the sequence of events that occurs from the time a cell is formed until it divides. It consists of two main phases: **Interphase** and **Mitotic phase** (or **M phase**).

14. Why is amitosis called direct division?

Ans: **Amitosis** is called **direct division** because it **lacks the typical nuclear division stages** such as prophase, metaphase, anaphase, and telophase.

15. Write one significance of crossing over.

Ans: **Crossing over** is important for **gene exchange** and promotes genetic variation.

16. What is the chromosome number in the somatic cell of pea?

Ans: The chromosome number in the somatic cells of **pea** is **14**.

17. In which plant is trisomy found?

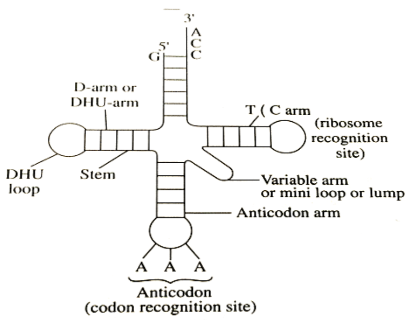
Ans: **Trisomy** is found in **Datura**.

18. Molecular model of DNA proposed by whom ?

Ans: The **molecular model of DNA** was proposed by **James Watson** and **Francis Crick** in **1953**.

19. Draw structure of t-RNA.

Ans:



Structure of t-RNA.

20. What is Polytene Chromosome.

Ans: A **polytene chromosome** is a giant chromosome found in tissues like the **salivary glands** of insects and are active in **protein synthesis**.

It forms when DNA replicates multiple times without cell division, resulting in **multiple chromatids** aligned together. These chromosomes display **distinct banding patterns.**

Part – B

Long answer type questions :

1. Write experiments to prove that DNA is the genetic material.

Ans. In 1952, Alfred Hershey and Martha Chase proved beyond doubt that genes are made of DNA. While experimenting with the T2 phage, they found that this virus infects and finally kills *E. coli* bacteria.

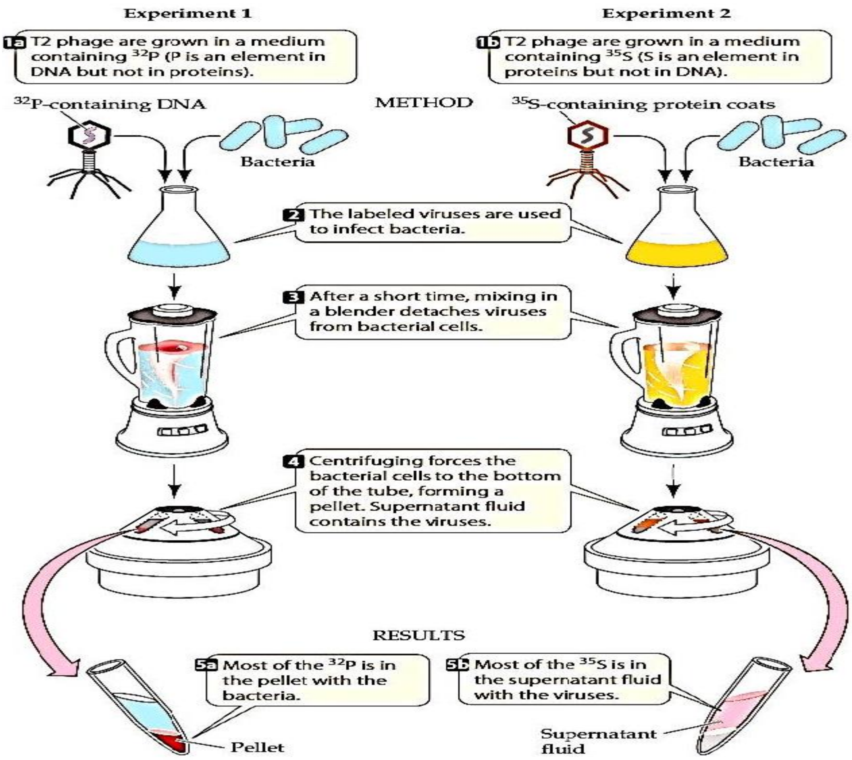
The structure of the virus consists of a head and a tail.

The tail has a tail cone, tail sheath, and tail fibers.

The viruses behave like little molecular syringes, i.e., their genetic material is injected into the host bacteria while the empty head of the virus remains outside.

Hershey and Chase Experiment:

- Once the viral genetic material enters the cell, it directs the formation of new virus particles. In a few minutes, the infected cell breaks down, releasing thousands of newly formed viral particles into the medium, which then infect new bacterial cells. This process continues.
- To prove that the genetic material was DNA, it was made radioactive by growing infected bacteria in a culture medium containing 32P.



- Since the T2 phage proteins do not contain phosphorus, only the DNA could be labeled.
- In the same manner, SO4 was used to label proteins.
- Since DNA does not contain sulfur, only proteins could be labeled with 35S.

- With the help of differential labeling (without using any chemical tests), the DNA and proteins of the phage could be identified.
- Hershey and Chase, in their experiment, allowed these labeled phages to infect bacteria.
- After infection, the mixture was agitated in a Waring blender to separate the infected bacteria from the empty viral heads.
- When the phage progeny was examined, it was found that the phage progeny contained 32P, which proved that DNA entered the bacteria, carrying all the genetic information for the synthesis of new viral particles. The 35S-labeled proteins remained in solution.
- Through this critical experiment, carried out at the Cold Spring Harbor Laboratory on Long Island, New York, it was clearly demonstrated and proved that DNA was the genetic material and not protein.

2. Write an essay on the molecular model of DNA by Watson and Crick.

Ans. By using chemical and physical information, along with X-ray diffraction data, Watson and Crick built a model of DNA that strongly suggested the double helical structure of DNA. The two helical chains were made up of polynucleotides held together by base pairing between the neighboring chains.

James Watson and **Francis Crick**, in 1953, proposed the double helical model of DNA, for which they were awarded the Nobel Prize in 1962.

Watson and Crick's DNA Model:

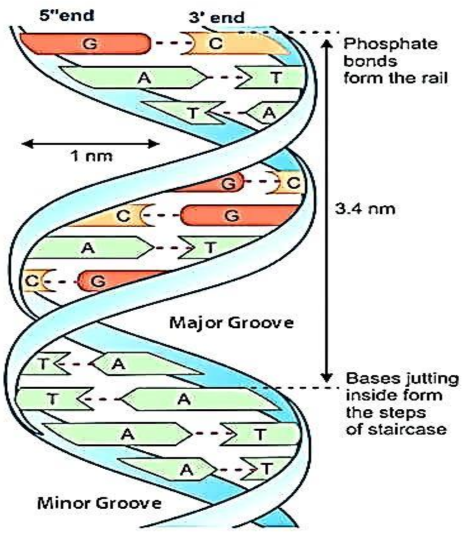
It had the following important characteristics:

- The DNA molecule has two polynucleotide chains, hence it is a double helix, with a diameter of 20 Å and a pitch of 34 Å for one complete turn.
- The helices are arranged in a right-handed manner, called B-DNA, except for Z-DNA, which has a left-handed helix.
- The two polynucleotide chains are coiled plectonemically around each other, in such a way that they can be easily separated by uncoiling.
- One of the most remarkable features of the double helix duplex is that the two strands are oriented in opposite directions. For example, if one strand runs 3' to 5', the complementary strand runs 5' to 3'.
- This is known as reverse polarity, meaning that the sequences of atoms in the duplex move in opposite directions.

  The complete chain depicts polarity, where all 5' carbons point in the same direction, so that the strand ends with 5' at one end and 3' at the other end.
- In the spirally coiled double helix, one complete turn of the spiral contains 10 base pairs.
- In the double helix, the phosphate groups of the nucleotides are oriented towards the outside, while the bases are on the inner side.
- The nucleotides are placed in planes at right angles to the axis of the helix and are spaced 3.4 Å apart.
- The two strands are held together by hydrogen bonds, i.e., the bases of one nucleotide strand are bonded by hydrogen bonds to the bases of the other strand.
- Base pairing in the DNA duplex is highly specific, as shown by X-ray crystallography.

  There is a fixed spacing of 10 or 11 Å between two sugar molecules in opposite nucleotides.
- Purine bases always pair with pyrimidine bases. This is because the distance between the two helices is just enough to accommodate a purine and a pyrimidine effectively. Therefore, A pairs with T, and C pairs with G, forming the base pairs.

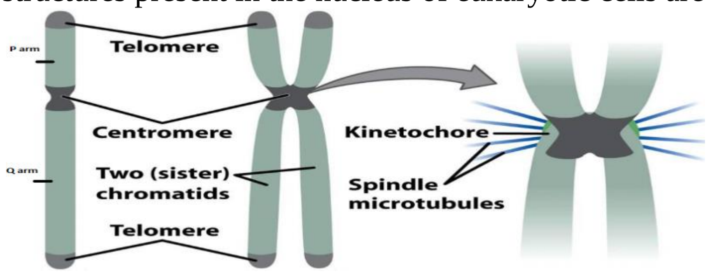
- Adenine and thymine are joined by two hydrogen bonds, while cytosine and guanine are joined by three hydrogen bonds. These hydrogen bonds are weaker than covalent bonds.
- The base sequences of the two strands of DNA are complementary. However, the sequence of bases in a polynucleotide chain is not fixed.
- For a given DNA strand, the base sequences are fixed and different for each strand.



DNA model of Watson and Crick.

3. Write an essay on chromosome structure with the help of a diagram.

Ans. In the nucleus, chromosomes are thread-like structures made up of proteins and a single molecule of DNA, which helps carry the genomic information from one cell to another.
During nuclear division, E. Strassburger observed thread-like structures in 1857.
These were named by N. Roux in 1883 as hereditary factors.
W. Waldeyer named these structures as chromosomes in 1888.
These thread-like structures present in the nucleus of eukaryotic cells are called chromosomes.



Chromosome structure

Number of chromosomes:

In higher organisms, the number of chromosomes is diploid, represented by somatic chromosomes (2n).

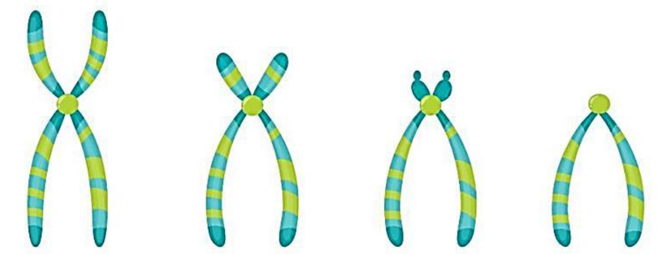
Size of chromosomes:

The size varies from species to species, for example:

- Fungi and birds: 0.2 µm
- Trillium plants: 30 µm
- Humans: 5 µm
- Drosophila: 3.5 µm
- Zea mays: 8-10 µm
- Giant chromosomes: 1500-2000 µm

Shape of chromosomes:
Chromosomes are categorized based on the position of the centromere.

- **Telocentric**: The centromere is at the extreme end, and the chromosome contains only one arm. These are rod-shaped and are rarely present in plants.
- **Acrocentric**: The centromere is positioned near one end, resulting in one small arm and one long arm.
- **Sub-metacentric**: The centromere is positioned near the median, resulting in two unequal arms, shaped like the letters J or L.
- **Metacentric**: The centromere is near the middle, resulting in two equal arms, and the chromosome has a V shape.



4. Write an essay on special chromosome structures with the help of diagrams.

Ans. In a few species, certain chromosomes are present which are different in their structure and function when compared with the normal chromosomes. Hence, these are called special **chromosomes.**

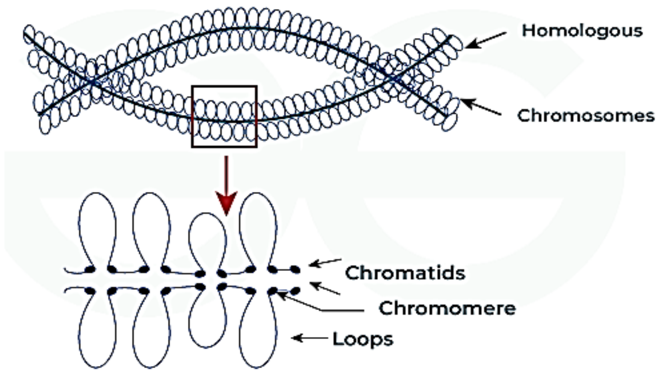
Examples:

1. Lampbrush chromosomes
2. Polytene chromosomes

1. Lampbrush Chromosomes

They were named due to their structure, which appears like a brush. It was first observed by Elemming in 1882. However, the name *lampbrush* was coined by Ruckert in 1892. These special types of giant chromosomes occur in the nuclei of oocytes of vertebrates and invertebrates, such as fishes, amphibians, birds, mollusks, and insects, during the prophase-I sub-stage (diplotene) of the first meiosis. They also occur in spermatocytes of *Drosophila*.

Structure of Lampbrush Chromosomes:



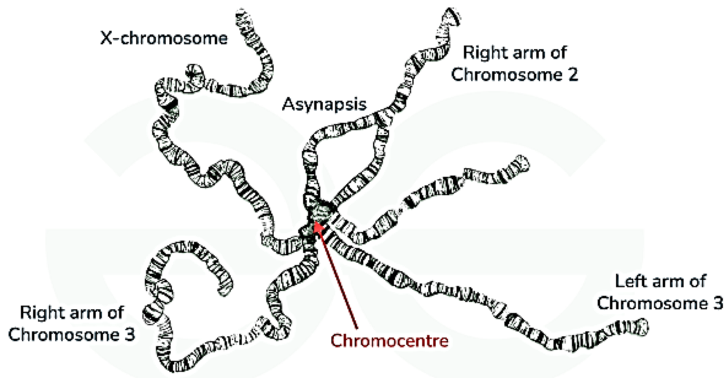
- It has a central or main axis, which bears many lateral loops or projections, giving it the appearance of a brush.

- The main axis has four chromatids.
- The chromonemata of these chromatids form live loops or projections along their lateral sides. Here, it should be noted that the kinetochore consists of no loops.
- Electron microscopic studies reveal that the loops are integral segments of chromonemata, which are extended in the form of major coils. The number of loops could vary from one to nine loops per chromosomal area.

Loop:

- The size of the loops varies from almost 9.5 microns in frogs to 200 microns in newts.
- These loops are made up of one DNA double helix from which fibrils project out. These are covered by a matrix, which contains RNA and proteins.
- When the loops are treated with deoxyribonuclease, ribonuclease, and trypsin or pepsin (which break down DNA, RNA, and protein), the loops break down. This shows that the matrix consists of DNA, RNA, and protein.
- The number of pairs of loops increases in prophase I (diplotene) of meiosis I. After this stage, the number of loop pairs decreases and finally disappears at metaphase I.

2. Polytene or Salivary Gland Chromosome:



These chromosomes were first reported in cells of salivary glands, gut, and trachea of dipteran insects by E.G. Balbiani in 1881. However, the name *polytene* was coined by Kollar for these giant chromosomes. These chromosomes are 100-200 times longer than normal chromosomes and from 1000 to 2000 times larger in volume.

Polytene chromosomes contain dark-staining bands separated by light-staining bands. The distance between bands varies. The order of bands on the chromosome is fixed for a particular chromosome

.

Bands:

- Bands are present on polytene salivary gland chromosomes and stain dark with basic and Feulgen-positive stains. These are considered sites of high DNA concentration.

Interbands:

- These strips are present between two bands. They are light-staining areas and are Feulgen-negative.

Puffs:

- Some of the bands are seen in a swollen form, which are called puffs. The process of puff formation at various areas of a polytene chromosome is called puffing.

- When a puff becomes much enlarged, it is termed as a Balbiani ring.
- These puffs are reversible and are known as regions of active genetic activity. They are rich in DNA and RNA.

5. Write an essay on different stages present in mitosis.

Ans. It is the process of cell division in somatic cells where the mother cell produces two daughter cells that are genetically alike.

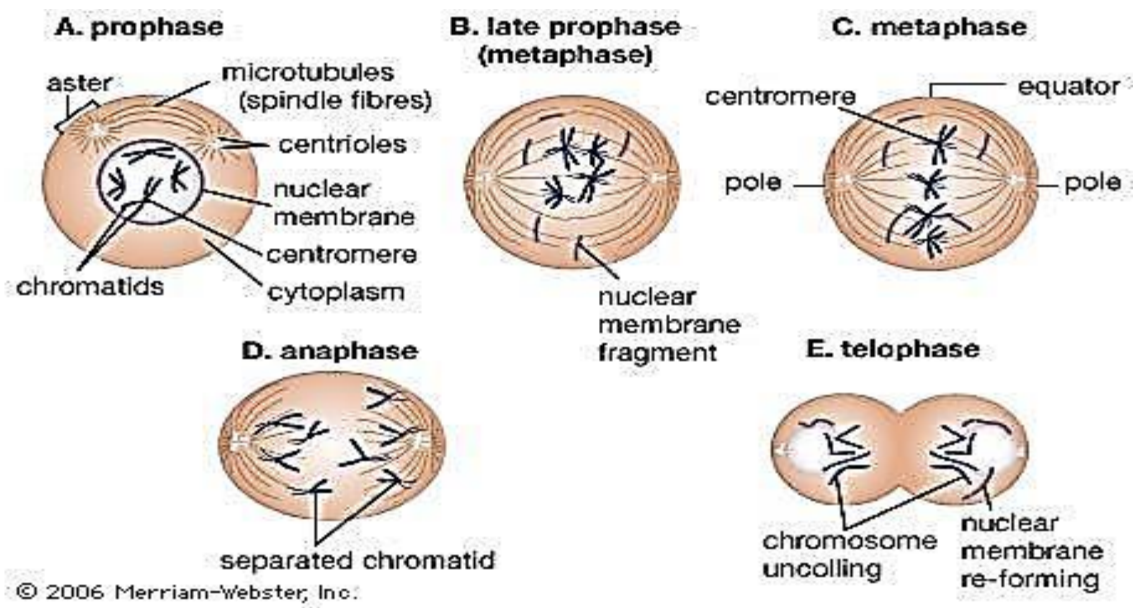
Mitosis division occurs in two stages:

A. Karyokinesis (Nuclear division)

B. Cytokinesis (Cytoplasm division)

A. Karyokinesis:

It is an intranuclear division in which spindle formation occurs, chromosomes split, and enter the two newly formed daughter cells. The name *karyokinesis* for the division of nuclei was coined by Moreis in 1941. It is divided into the following stages.



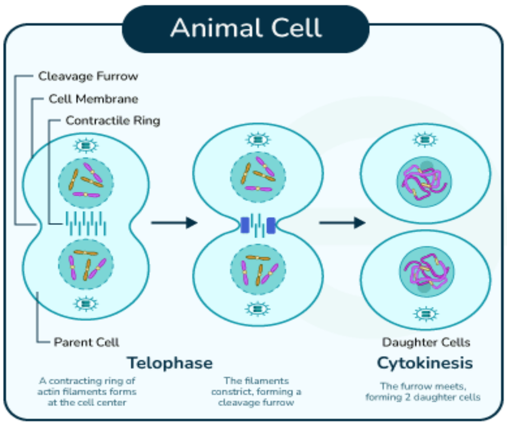
1. **Prophase:**
   - Chromosomes, which were slender, uncoiled, and invisible, start appearing clearly, and this is the characteristic feature of prophase.
   - In this stage, due to dehybridation in the chromatin network with the help of ATP and the enzyme topoisomerase, the chromosomes gradually become thick, coiled, small, and clear.
   - Each chromosome divides longitudinally into two chromatids, which remain united by the centromere.
   - The two chromatids are termed as sister chromatids.
   - In this way, during the process of cell division, the cell's diameter starts increasing.
   - Chromatids of the chromosome during prophase exhibit plectonemic coiling.
   - During late prophase, the following changes take place:
     1. Nuclear membrane disappears.
     2. Nucleolus starts reducing and later disappears.
     3. Formation of spindle fibers.
     4. Sister chromatids remain attached to the centromere, and this is the position where the two chromatids get attached to the spindle to pull.

2. **Metaphase:**
    - In this stage, the nuclear membrane and nucleolus disappear completely.
    - During this stage, spindle tubules start appearing, and these get attached to the chromosome at the centromere point.
    - Each chromosome has two chromatids, a centromere, primary constriction, etc. Chromosomes are very distinct, and hence their number and morphology can be easily studied at this stage.
    - The spindle attachment region determines the morphology of the chromosomes. For example:
        (a) Rod-shaped
        (b) J-shaped
        (c) V-shaped
3. **Anaphase:**
    - In mitosis, this stage is of shorter duration.
    - In this stage, the centromere splits into two. Chromosomes also split into two chromatids, thus each chromatid has one centromere.
    - Chromatids are short and thick at this stage.
    - During anaphase, the sister chromatids begin to move apart and towards the poles of the spindle.
    - In the anaphase stage, depending upon the position of the chromosome, they acquire characteristic shapes. Hence, these chromosomes are designated as follows:
        (a) Telocentric – This is 'I' or rod-shaped.
        (b) Sub-telocentric – This appears as 'J' shaped.
        (c) Sub-metacentric – This appears as 'L' shaped.
        (d) Metacentric – This appears as 'V' shaped.
4. **Telophase:**
    - This stage of mitosis starts only when the chromosomes have reached the poles.
    - The number of chromosomes is the same as it was in prophase.

B. Cytokinesis:

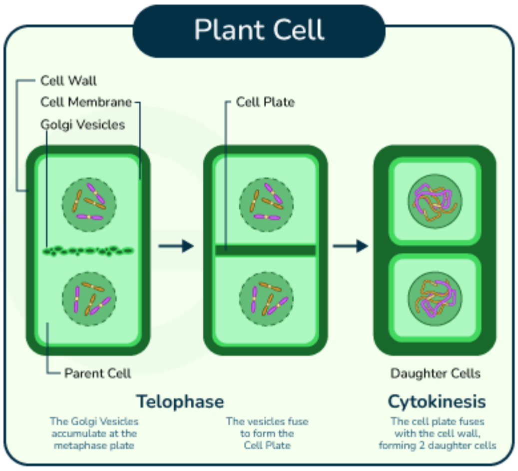
After nuclear division in the late telophase stage, the process of cytokinesis starts and results in the formation of two identical cells.

(i) **Furrow formation method / Inveganation formation method:**



- This is commonly found in animals and lower plants like unicellular algae and bacteria, etc. In this method, a circular constriction appears at the equator of the cell, which converges on all sides, ultimately separating the two cells.

(ii) **Cell plate formation method:**



- In plants, which possess rigid cell walls, cytokinesis occurs by the cell plate method. In this case, pieces of disintegrated spindle fibers, pieces of endoplasmic reticulum, and vesicles from the Golgi body get accumulated in the center of the cell.
- These are collectively called phragmosomes, and these unite to form the cell plate. Therefore, the cell plate is also known as the phragmoplast.
- After the cell plate is laid down, primary walls are laid on either side, and thick secondary walls made up of cellulose may be laid down later.

6. Describe in detail the changes taking place during prophase I of meiosis.

Ans. During meiotic division, the first nuclear division is termed meiosis-I or reductional division or heterotypic division. This division forms two haploid cells (n) from a diploid cell (2n).

Prophase I: This phase is of the longest duration, which is further subdivided into the following five sub-stages:

(a) **Leptotene:**

- This is a very short substage that initiates the process of meiosis.
- In this stage, the nucleus increases in size.
- The chromosomes appear to be long, slender, and thread-like structures, which have a beaded appearance due to the presence of chromomeres on them.
- The chromomeres are of different sizes and are located at particular sequences on each chromosome.
- The chromosome number is diploid at this stage.

(b) **Zygotene:**

- At the initial stage, the homologous chromosomes start pairing due to attraction between the two homologs of a chromosome pair.
- The pairing is present between chromosomes that are morphologically and genetically alike in their length, thickness, gene number, chromomeres, and chemical nature.
- On chromosome Pn, each pair of homologs comes from the mother (maternal) and the other from the father (paternal). This phenomenon of chromosome pairing is termed synapsis, which results in the formation of bivalents.

(c) **Pachytene:**

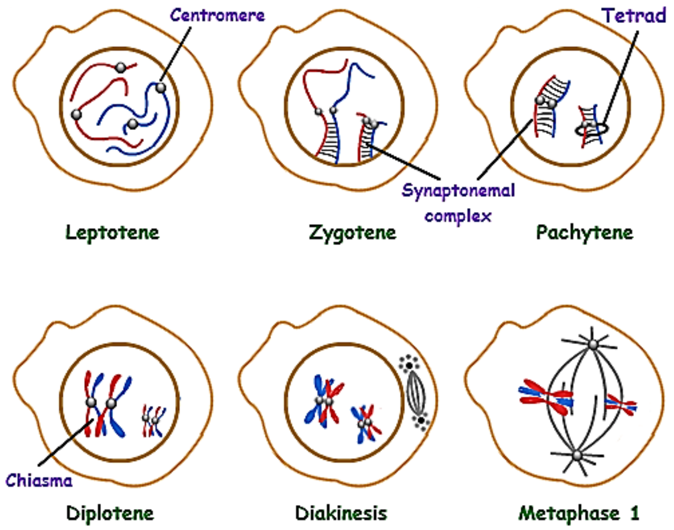
- This sub-stage is of long duration and occurs when pairing is complete and the chromosomes have shortened and thickened.
- Two threads of the chromosome now appear distinct and are known as chromatids. Here, the chromosome is a bivalent, which is joined at the centromere.
- The two components of each bivalent coil around each other by rotational coiling. This is supposed to occur due to some internal forces exerted by the chromosomal threads.
- At this stage, the homologous chromosomes of all bivalents split longitudinally, and hence, in late pachytene, the bivalents appear to be four-stranded. These are called tetravalents.

(d) **Diplotene:**

- In diplotene, further thickening and shortening of chromosomes occur, and the attraction forces between the two homologous chromosomes cease. Due to repulsion forces, the two partners of the bivalent become distinct, and therefore, the name diplotene is given to this sub-stage of prophase.
- At the chiasma point, the sister chromatids of the bivalent separate and rejoin crosswise. This rejoining occurs between fragments of non-sister chromatids.
- This phenomenon is termed *crossing over*.
- Chiasma formation is regarded as not the cause but the consequence of crossing over.

(e) **Diakinesis:**

- This sub-stage resembles the diplotene stage. However, the difference is that in this stage, chromosomes appear highly contracted as major coils are formed.
- The separation of homologous chromosomes is completed.
- At this substage, due to the highly contracted nature, the bivalents look like rounded bodies, which are seen all over the cell.



Miosis Division Stage in prophase - I