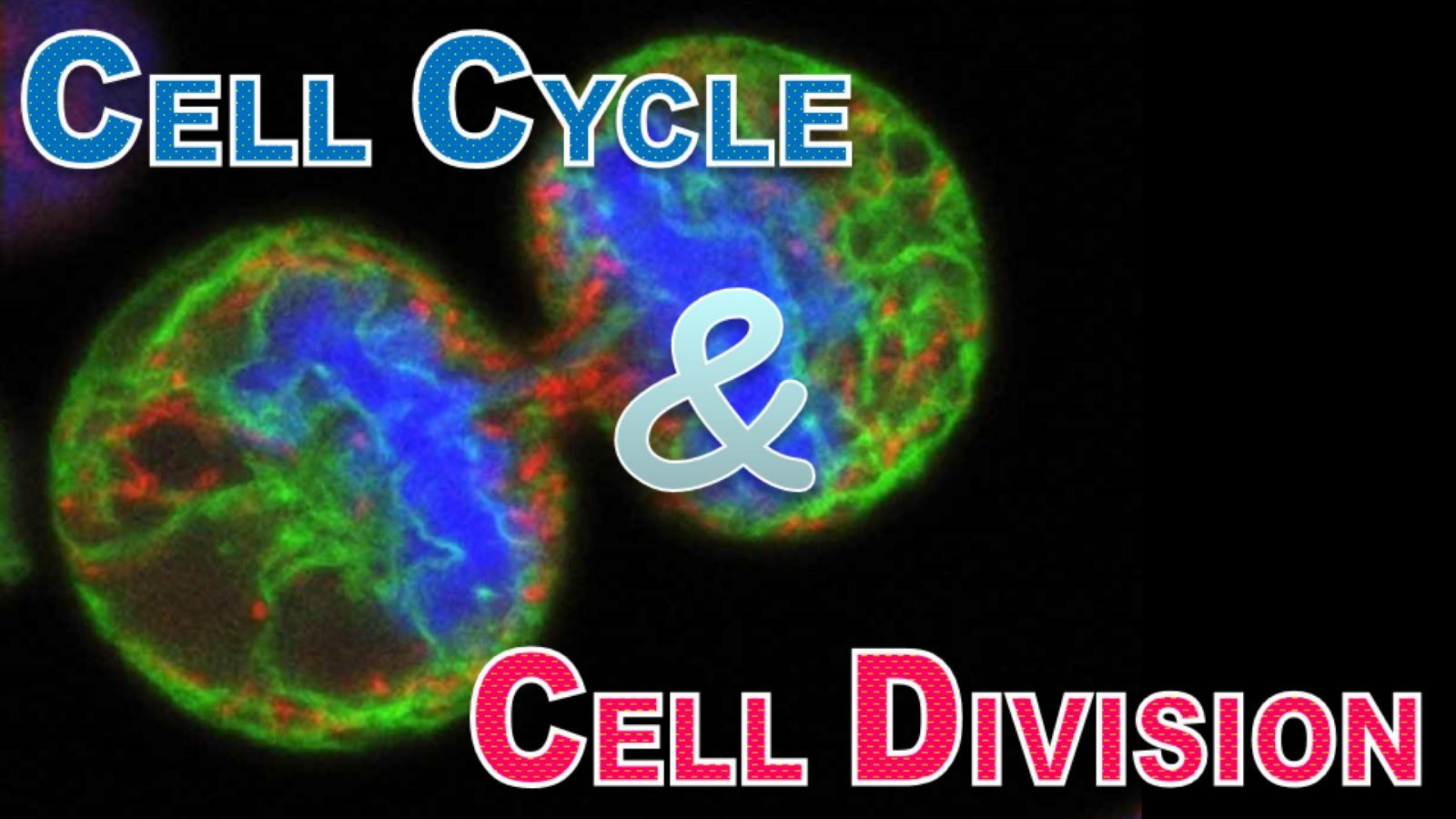
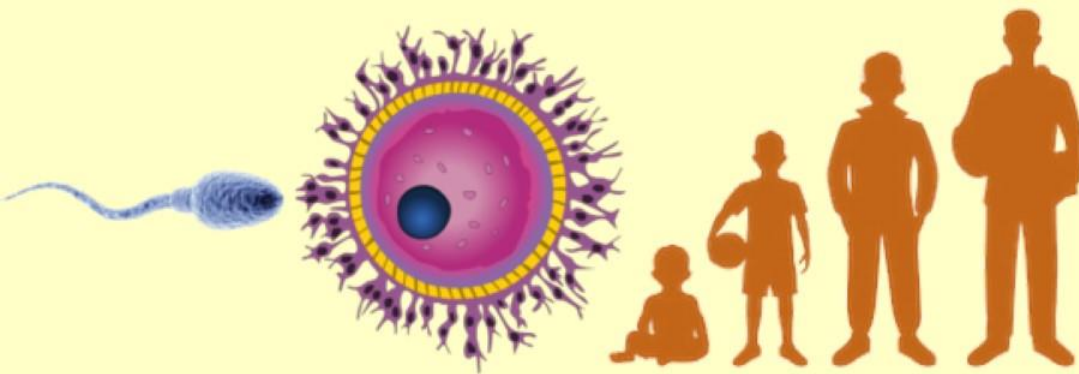


CELL CYCLE

&

CELL DIVISION



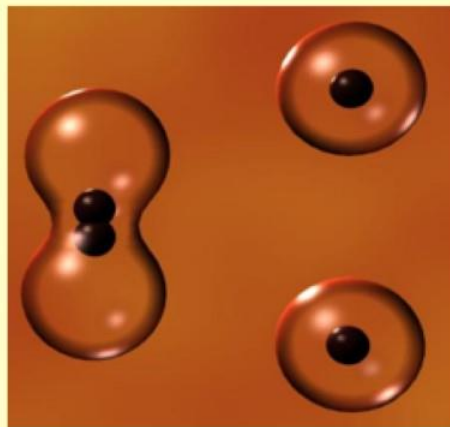
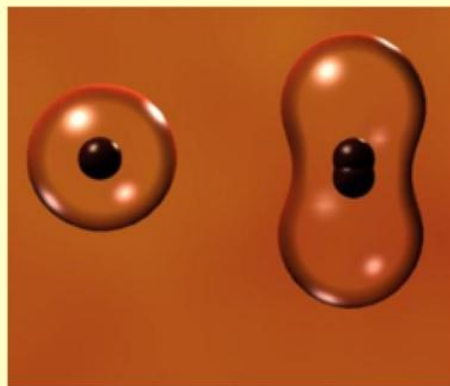


- **Growth and reproduction of all organisms depend on the division & enlargement of cells.**
- **The mechanisms of division and multiplication of cells together constitute cell reproduction.**



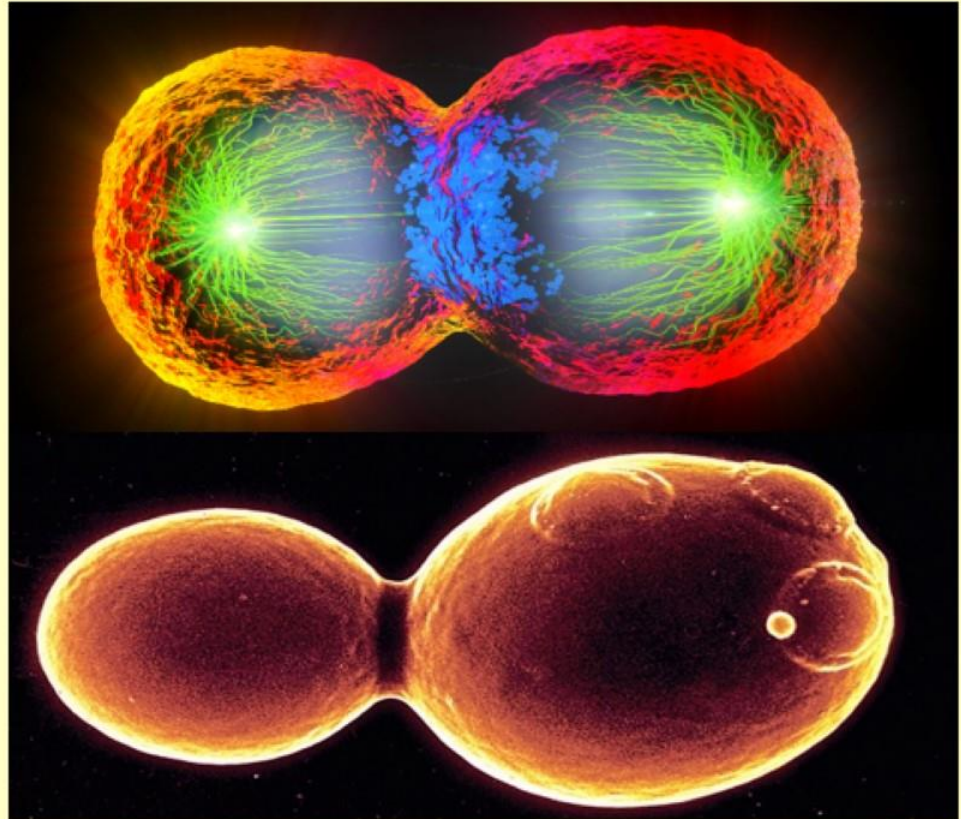
CELL CYCLE

- It is the life period of a cell during which a cell synthesizes DNA (replication), grows and divides into two daughter cells.
- Cell growth (cytoplasmic increase) is a continuous process.
- DNA synthesis occurs only at a specific stage.



CELL CYCLE

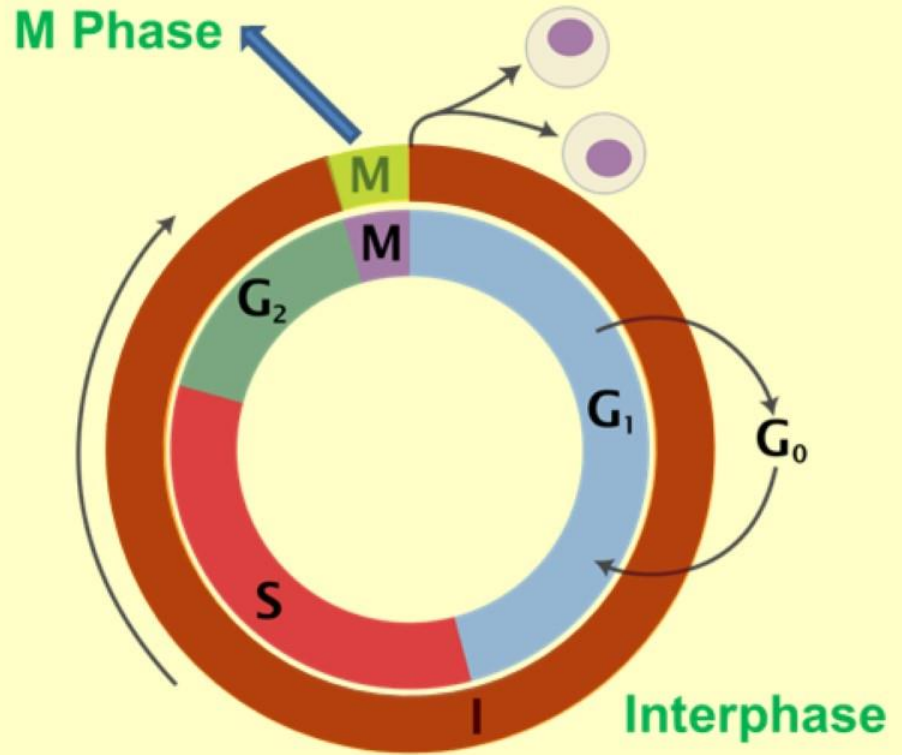
- Duration of cell cycle varies in each organism and each cell type.
- Duration of a typical eukaryotic cell cycle (e.g. human cell) is about 24 hrs.
- In Yeasts, it is only about 90 minutes.



CELL CYCLE

Cell cycle has 2 basic phases:

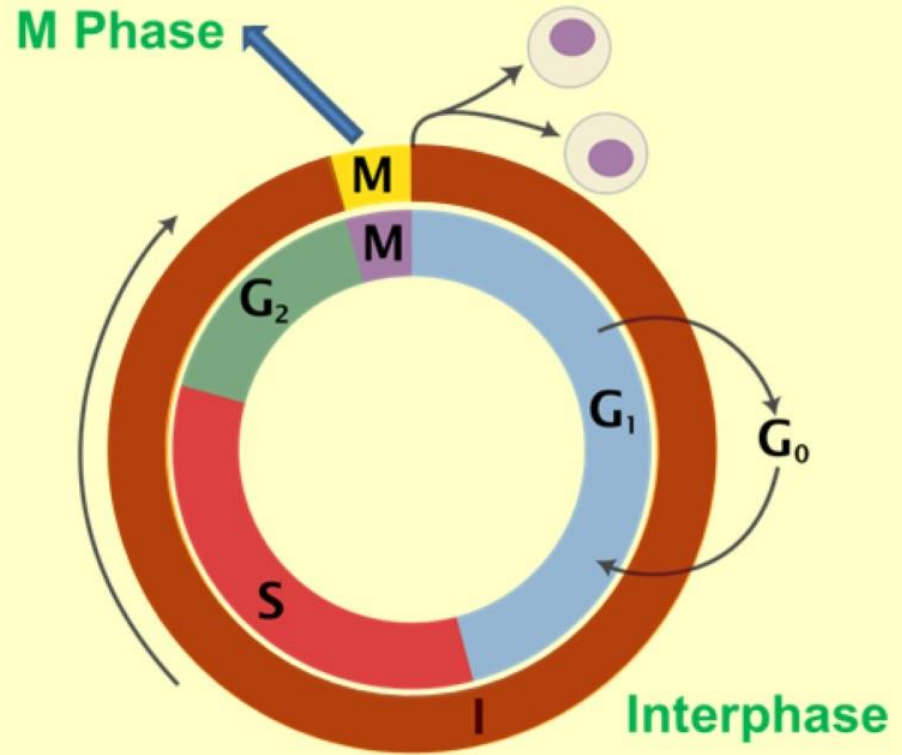
1. Interphase
2. M Phase



CELL CYCLE

1. Interphase (Resting phase)

- It is the phase between two successive M phases.
- It includes cell growth & DNA synthesis.
- It lasts more than 95% of the duration of cell cycle.

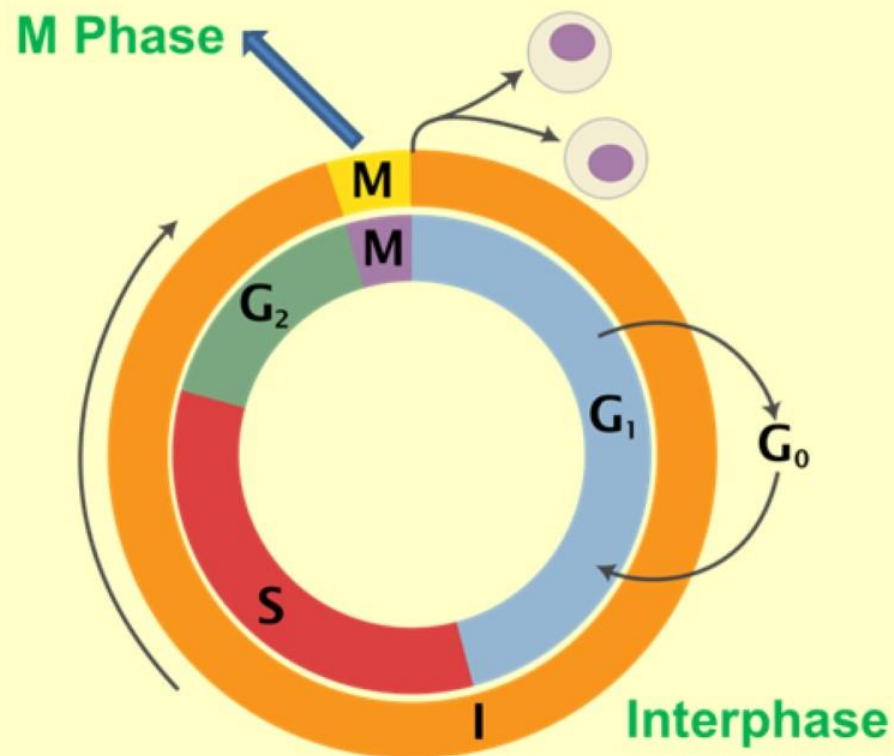


CELL CYCLE

1. Interphase (Resting phase)

Interphase has 3 phases:

- a. G_1 phase (Gap 1 or Antephase)
- b. S (Synthetic) phase
- c. G_2 (Gap 2) phase



CELL CYCLE

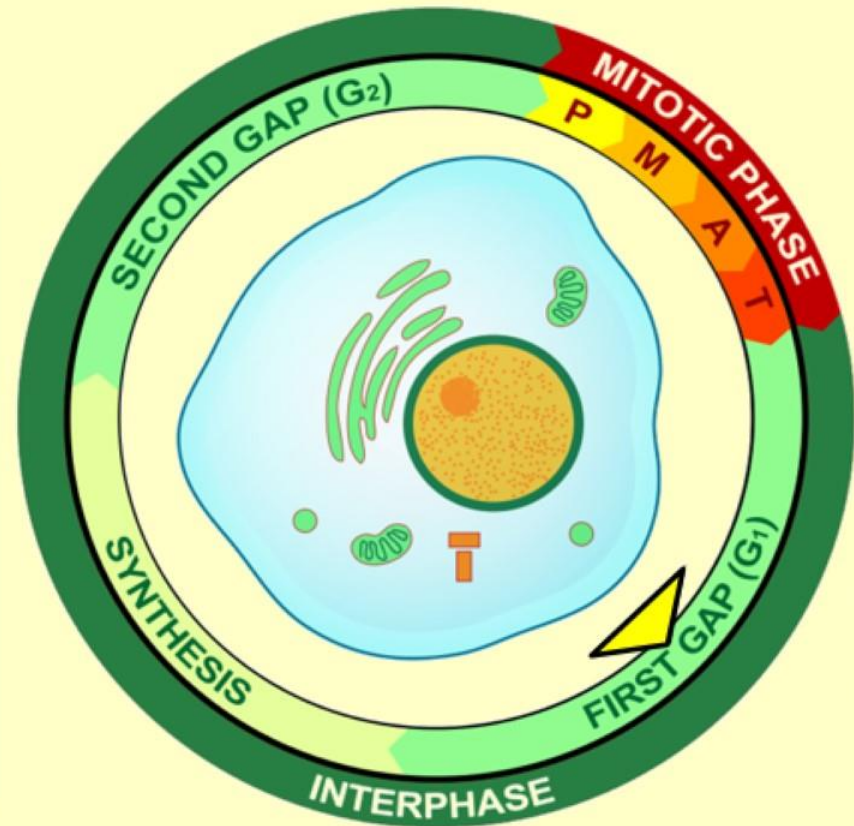
1. Interphase (Resting phase)

a. G_1 phase (Gap 1 or Antephase)

- First growth phase.
- It is the interval between mitosis and DNA replication.

Main events:

- Continuous growth of cell.
- Cell becomes metabolically active.
- Prepares machinery for DNA replication.
- Synthesizes RNA and proteins.

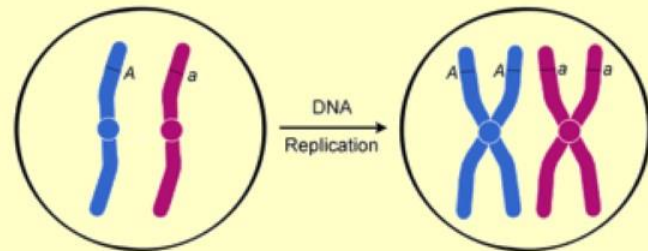
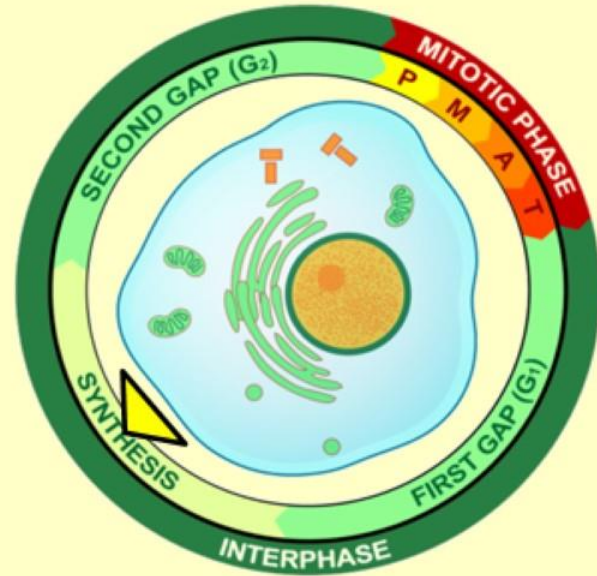


CELL CYCLE

1. Interphase (Resting phase)

b. S (Synthetic) phase

- In this, **DNA replication** takes place.
- Amount of DNA per cell doubles. But, chromosome number is not increased.
- In animal cells, replication begins in the nucleus, and the centriole duplicates in the cytoplasm.

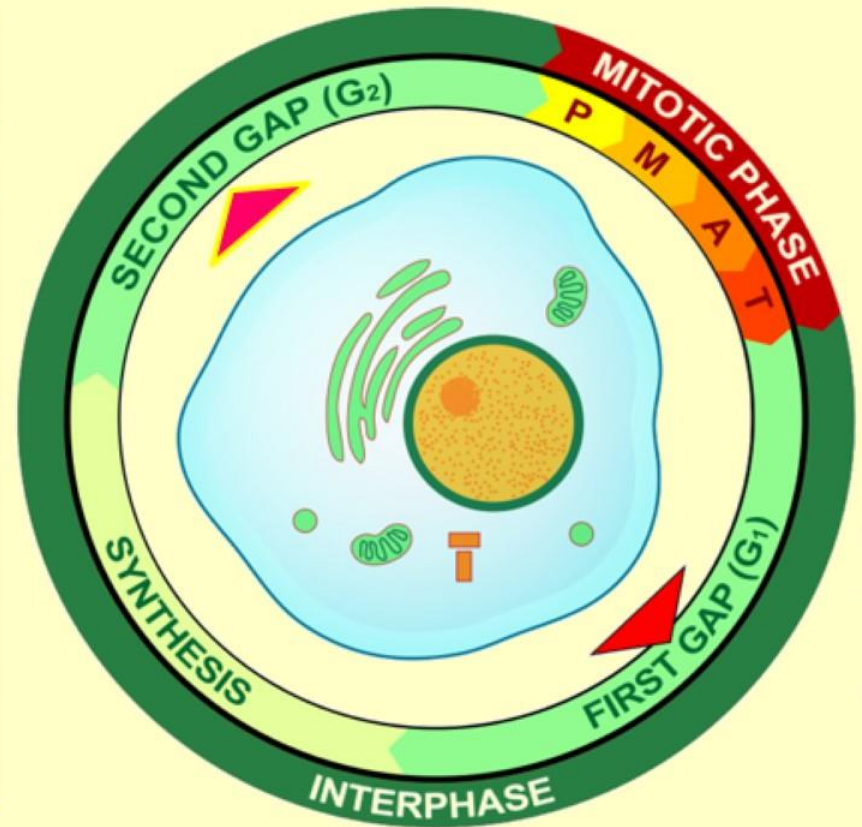


CELL CYCLE

1. Interphase (Resting phase)

c. G_2 phase (Gap 2)

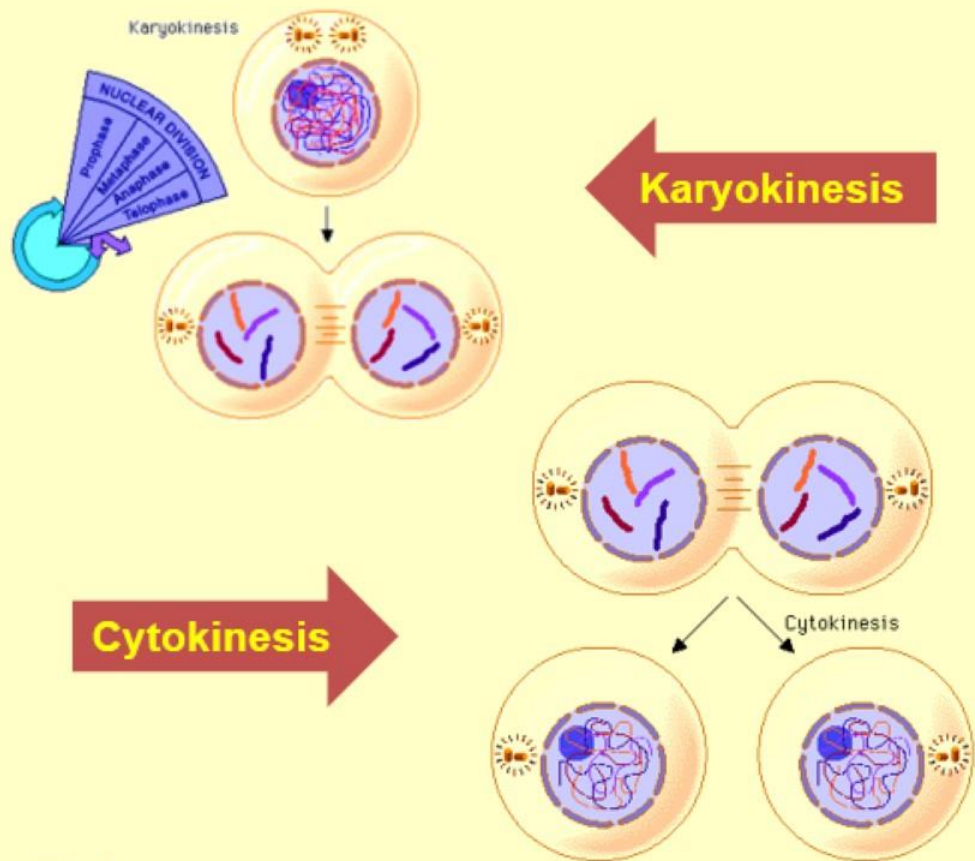
- Second growth phase.
- Cell growth continues.
- Synthesis of RNA and proteins continues.
- Cell is prepared for mitosis.



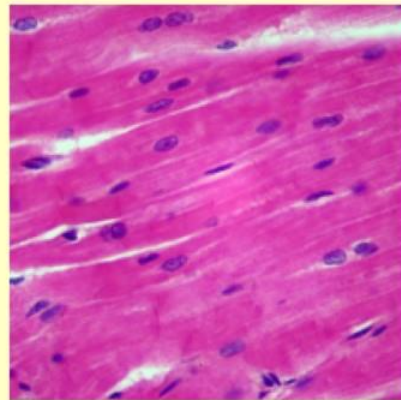
CELL CYCLE

2. M Phase (Mitosis phase)

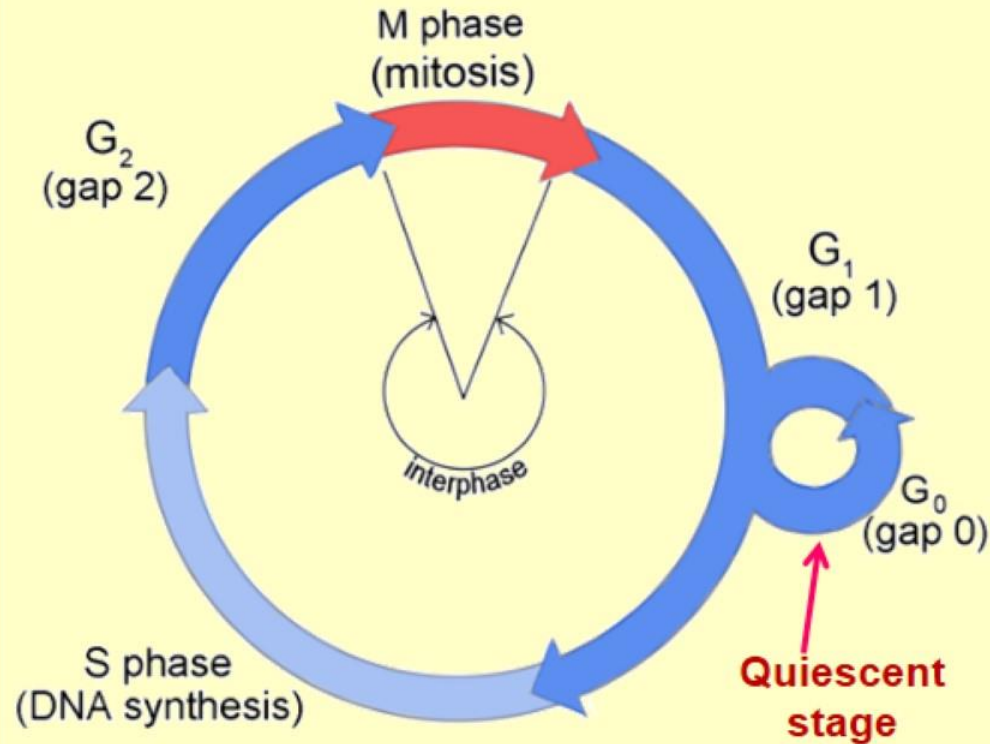
- It represents the **actual cell division (mitosis)**.
- In human cell cycle, it lasts for only about **an hour**.
- M Phase includes
 - ❖ **Karyokinesis: Nuclear division.**
 - ❖ **Cytokinesis: Division of cytoplasm.**



- Some cells do not show division. E.g. heart cells.
- Many other cells divide only occasionally to replace damaged or dead cells.



- The cells that do not divide further exit G_1 phase and enter an inactive stage called **quiescent stage (G_0)**.
- Such cells remain metabolically active but do not proliferate.

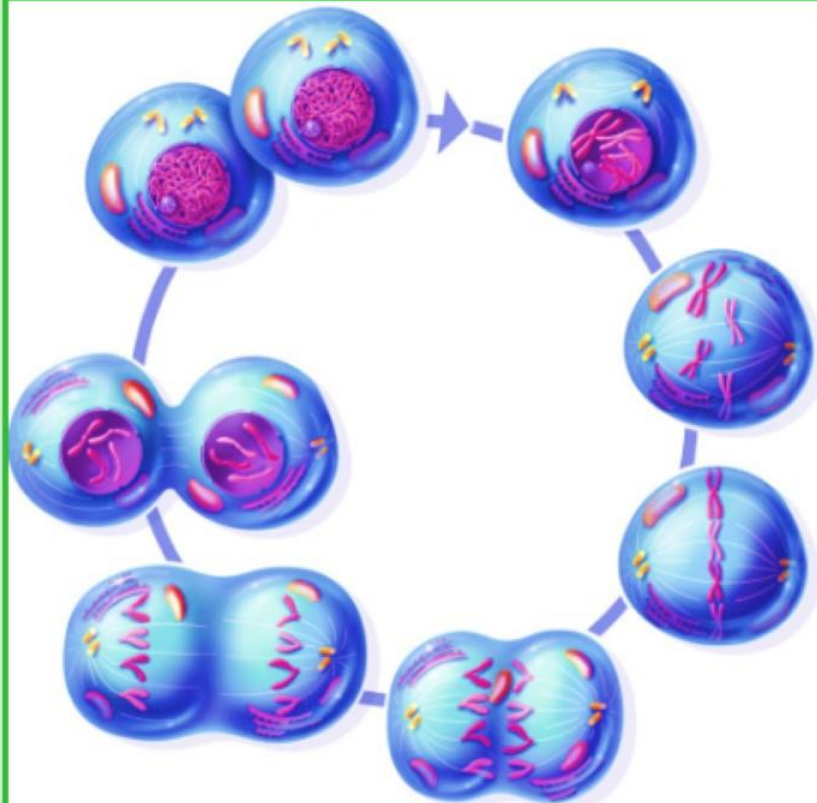


Part 2

MITOSIS

MITOSIS

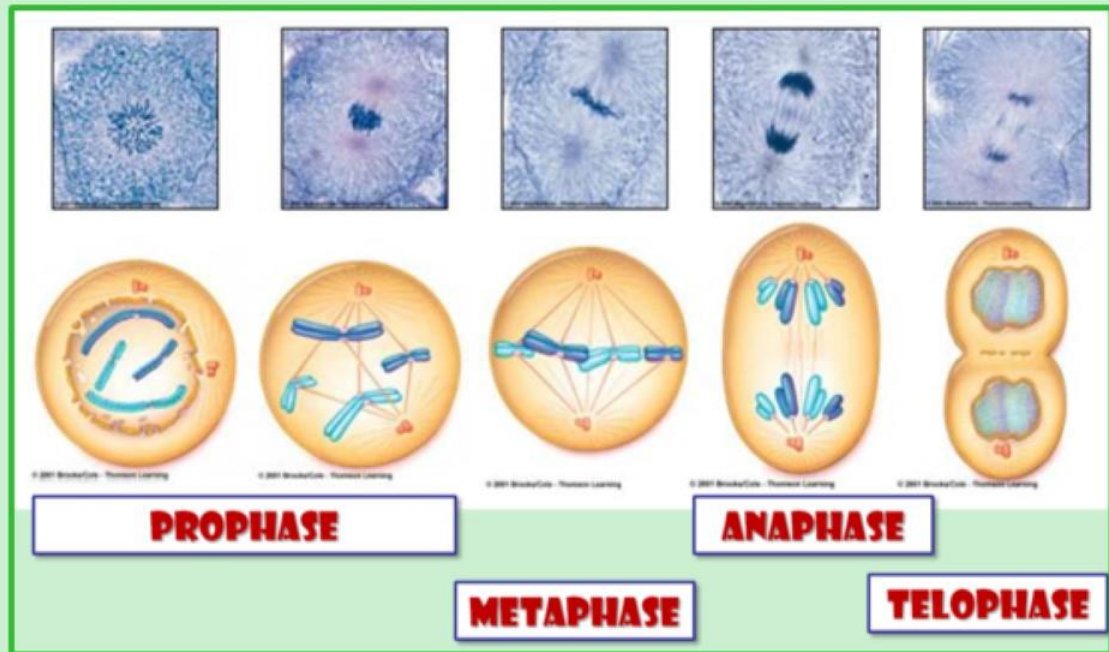
- It is the cell division occurring in **somatic cells**.
- It is also called as **equational division** as the number of chromosomes in the parent and progeny cells is same.
- Mitosis is generally seen in diploid cells. It also occurs in haploid cells of some lower plants and some social insects.
- It involves major reorganization of all cell components.



MITOSIS

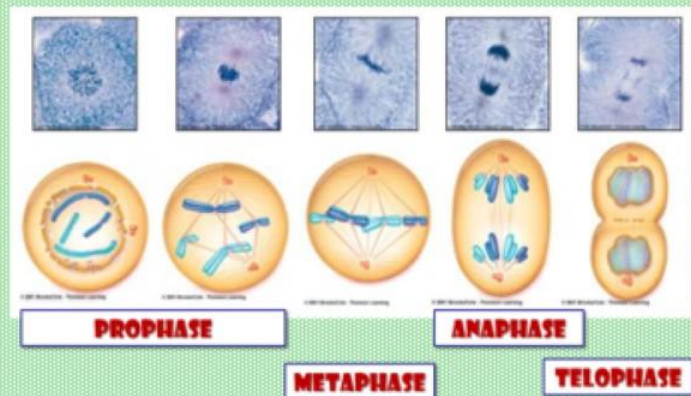
The **karyokinesis** of mitosis has 4 stages:

- Prophase
- Metaphase
- Anaphase
- Telophase

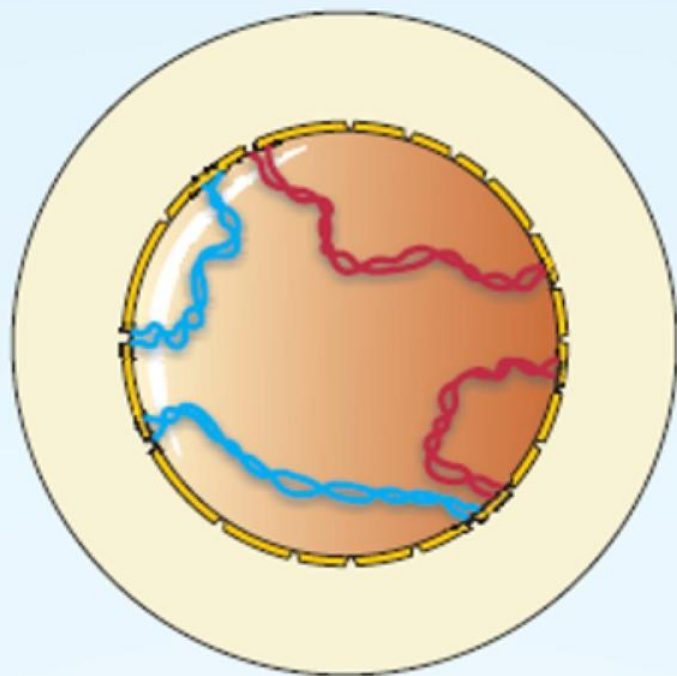


MITOSIS

1. Prophase



- It is the longest phase in mitosis.
- It follows the S and G2 phases of interphase.
- In the S & G2 phases, DNA molecules are intertwined.



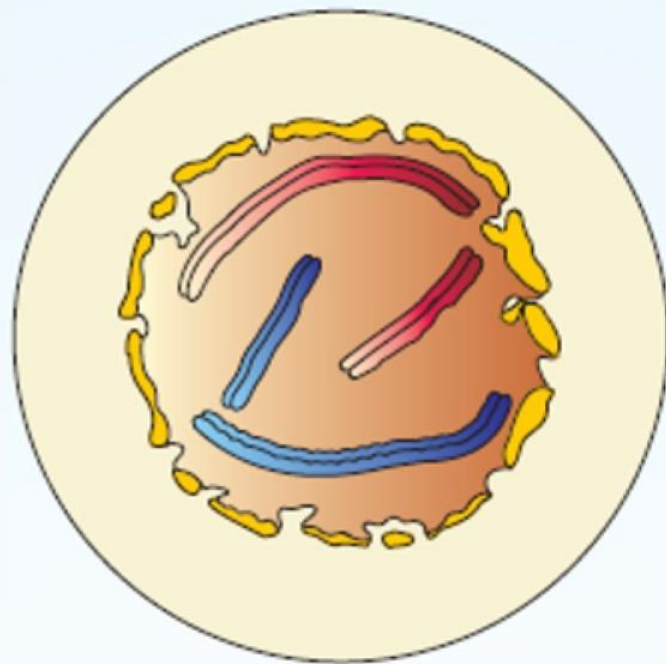
Early Prophase

MITOSIS

1. Prophase

Characteristic events

- Chromosomal materials (chromatin fibres) are untangled and condensed to form mitotic chromosomes. They are seen to be composed of two chromatids attached together at the centromere.
- Centrosomes begin to move towards opposite poles of the cell. Each centrosome radiates out microtubules called asters. The two asters together with spindle fibres forms mitotic apparatus.

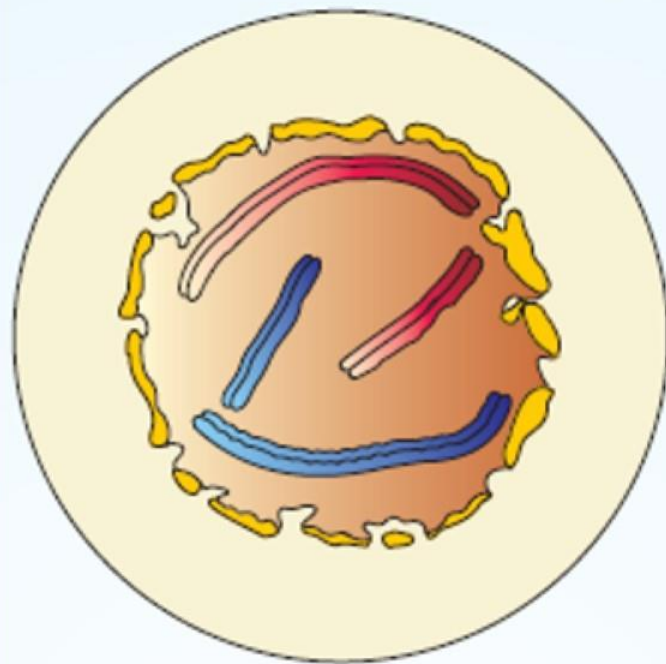


Late Prophase

MITOSIS

1. Prophase

Cells at the end of prophase do not show Golgi complexes, endoplasmic reticulum, nucleolus & nuclear envelope.

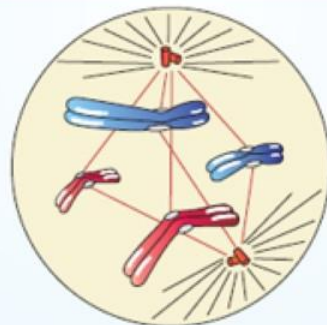


Late Prophase

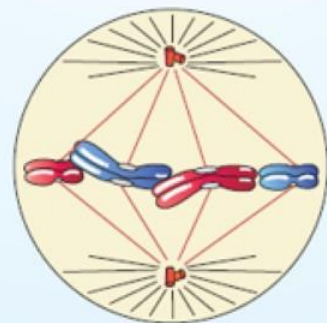
MITOSIS

2. Metaphase

- The nuclear envelope completely disintegrates. Hence the chromosomes spread through the cytoplasm of the cell.
- Chromosome condensation is completed. They can be studied easily under the microscope. They will have two sister chromatids.
- Chromosomes come to lie at the equator. The plane of alignment of the chromosomes at metaphase is called the **metaphase plate**.
- The **spindle fibres** from both poles are connected to chromatids by their kinetochores in the centromere.

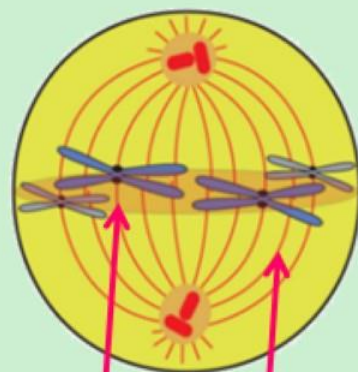


Transition to
Metaphase



Metaphase

Metaphase

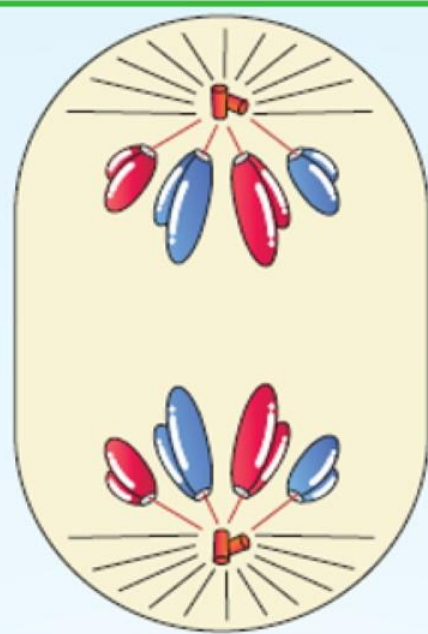
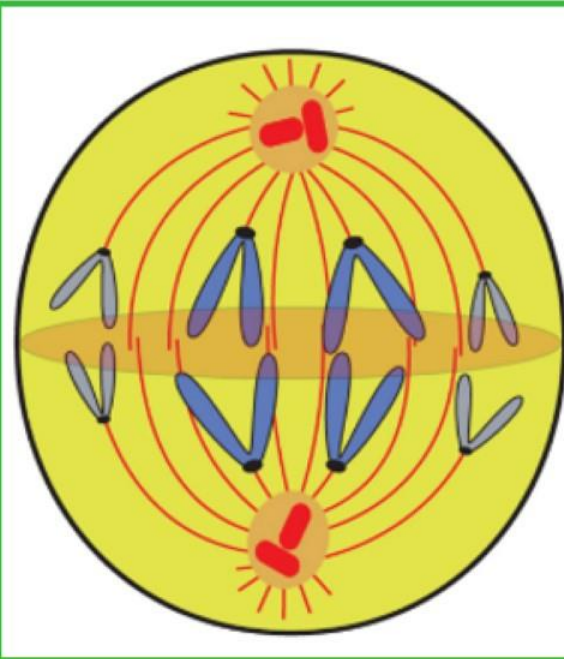


Metaphase
plate Spindle
fibres

MITOSIS

3. Anaphase

- It is the shortest phase in the mitosis.
- Centromere of each chromosome divides longitudinally resulting in the formation of two daughter chromatids (chromosomes of the future daughter nuclei).
- As the spindle fibres contract, the chromatids move from the equator to the opposite poles.

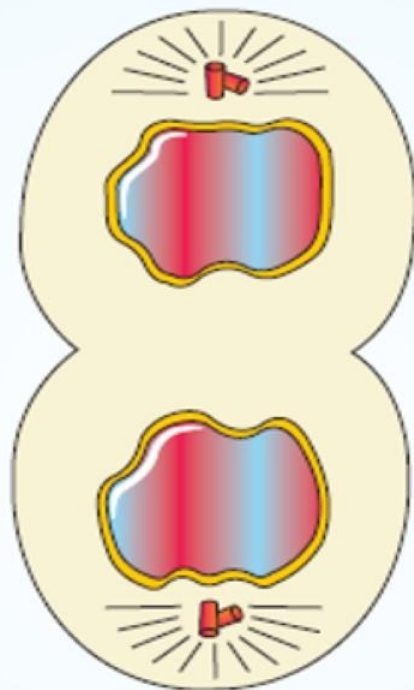


Anaphase

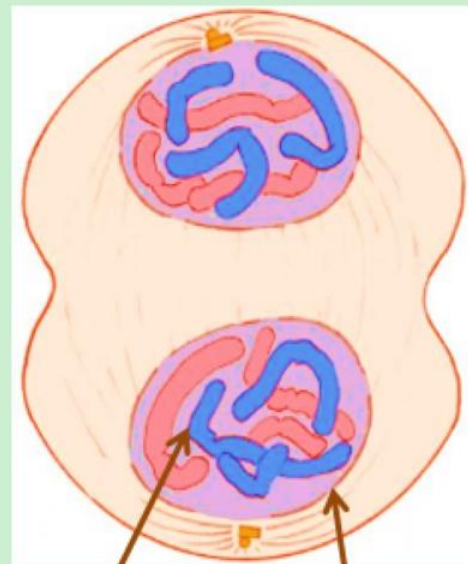
MITOSIS

4. Telophase

- Chromosomes cluster at opposite poles and uncoil into chromatin fibres.
- Nuclear envelope assembles around the chromatin fibres. Thus 2 daughter nuclei are formed.
- Nucleolus, Golgi complex and ER reappear.
- The spindle fibres disappear.



Telophase



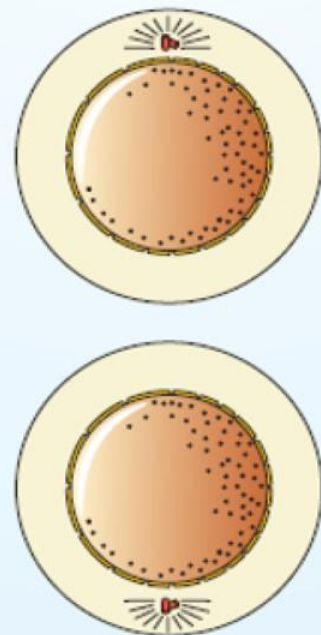
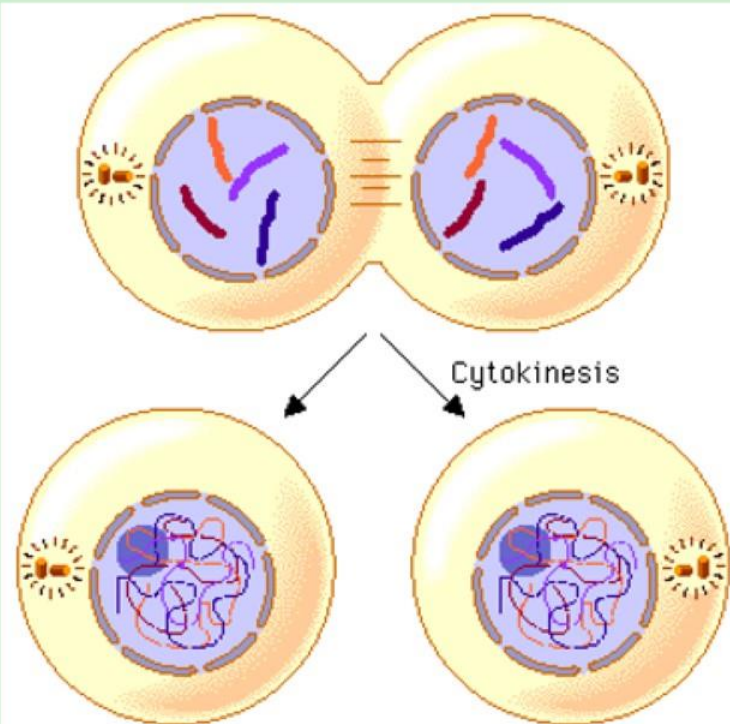
Chromatin
fibres

Nuclear
envelope

MITOSIS

Cytokinesis

- It is the **division of cytoplasm** resulting in the formation of 2 daughter cells.
- It starts when **telophase** is in progress.

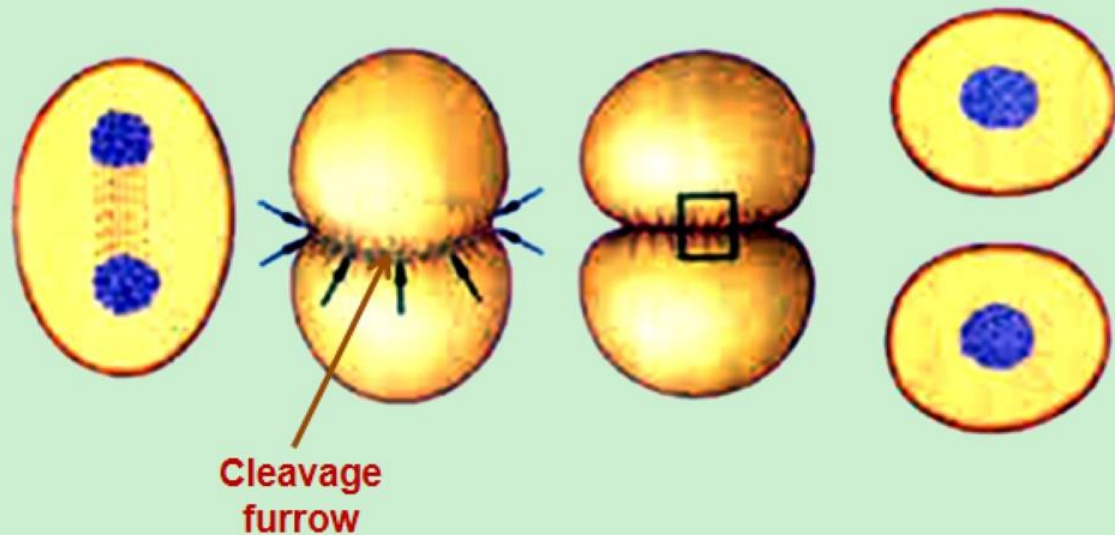


MITOSIS

Cytokinesis

In animal cell

- Here, a **cleavage furrow** is appeared in plasma membrane.
- It gradually deepens and joins in the centre dividing the cytoplasm into two.

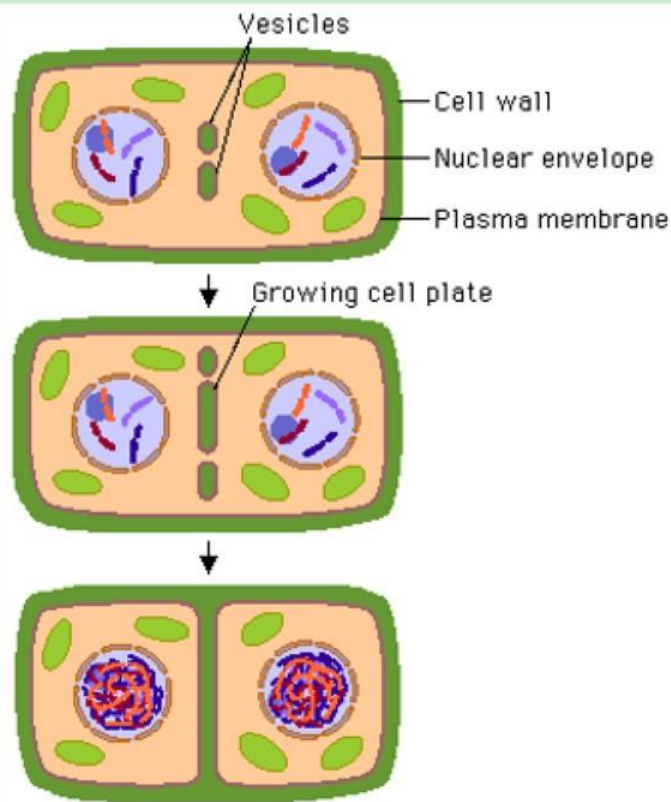


MITOSIS

Cytokinesis

In plant cell

- It is different from the cytokinesis in animal cells due to the presence of cell wall.
- In plant cells, the vesicles formed from Golgi bodies accumulate at the equator. It grows outward and meets the lateral walls. They fuse together to form the **cell-plate**. It separates the 2 daughter cells. Later, the cell plate becomes the middle lamella.

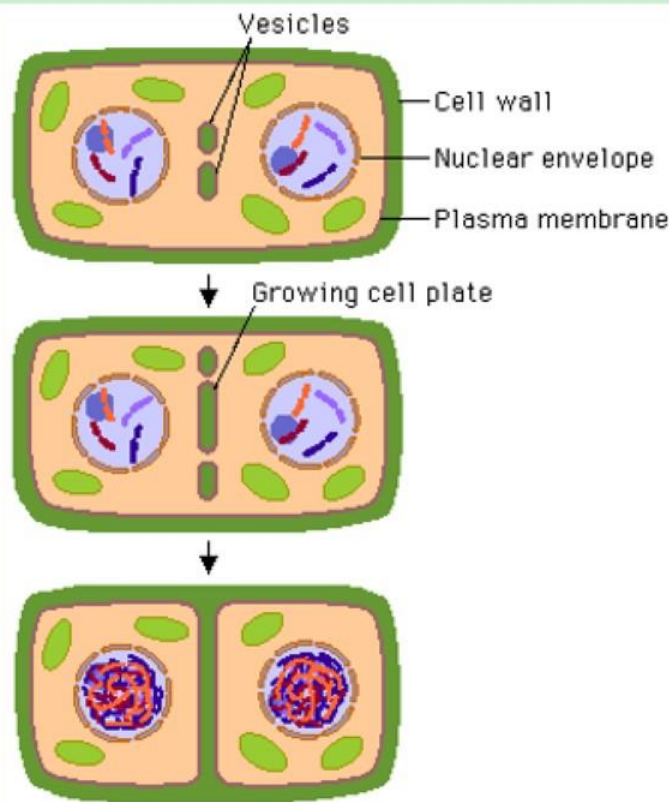


MITOSIS

Cytokinesis

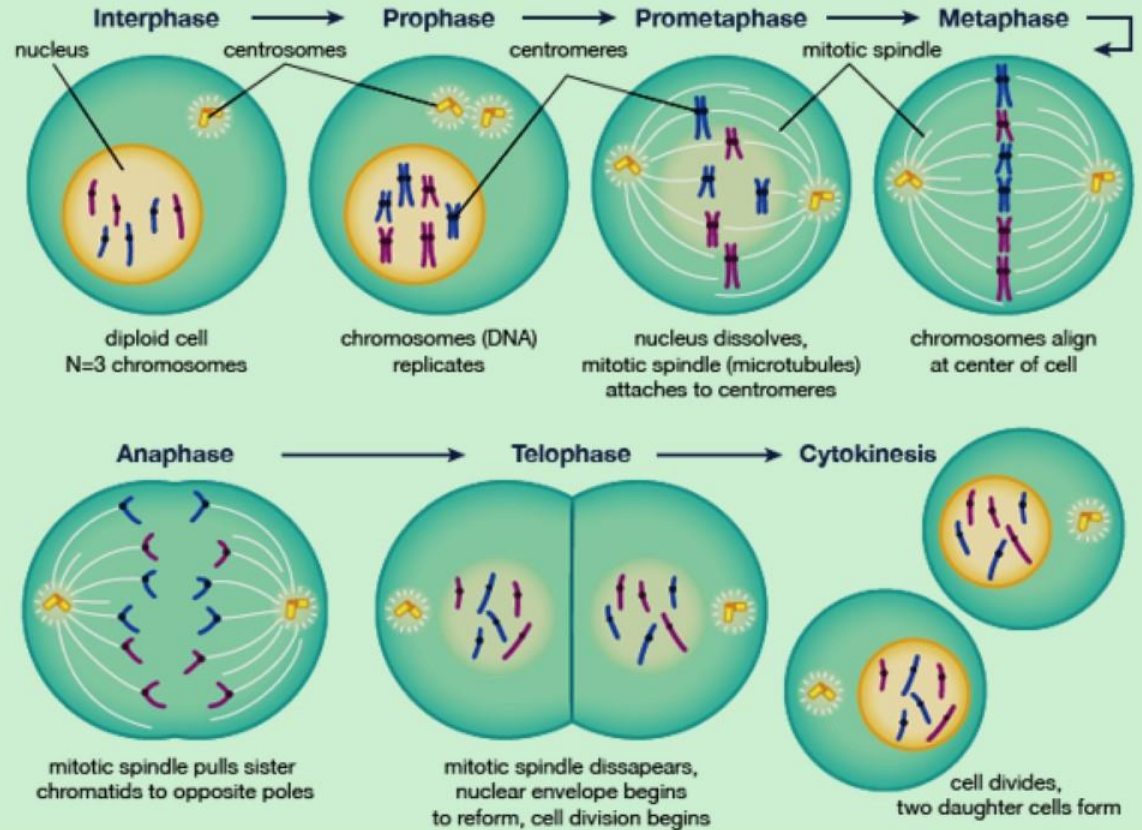
In plant cell

- During cytokinesis, organelles like mitochondria and plastids get distributed between the daughter cells.
- In some organisms, karyokinesis is not followed by cytokinesis. As a result, **multinucleate condition (syncytium)** arises. E.g. liquid endosperm in coconut.



MITOSIS

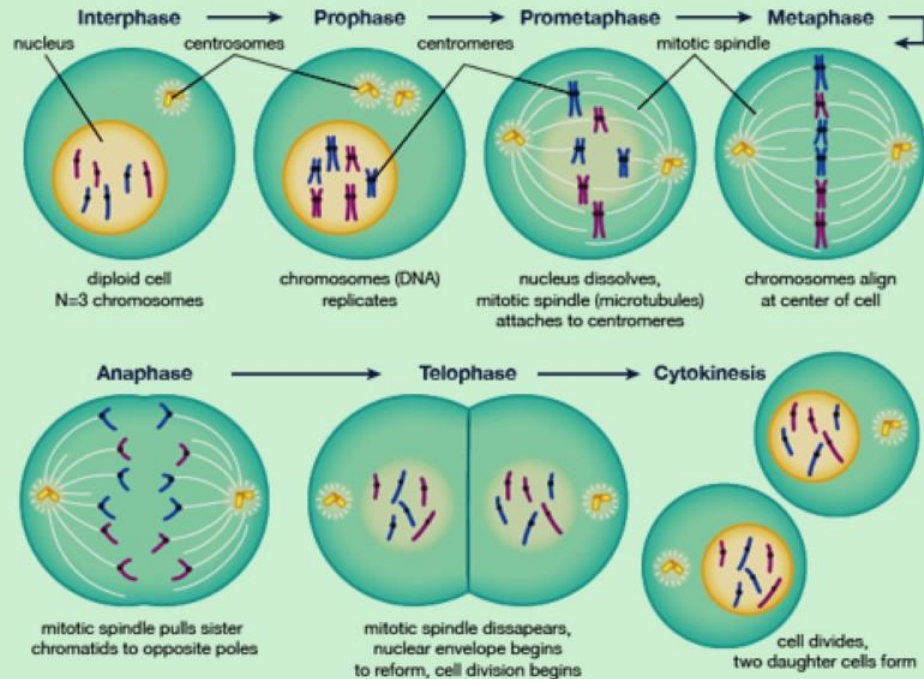
Overall Steps



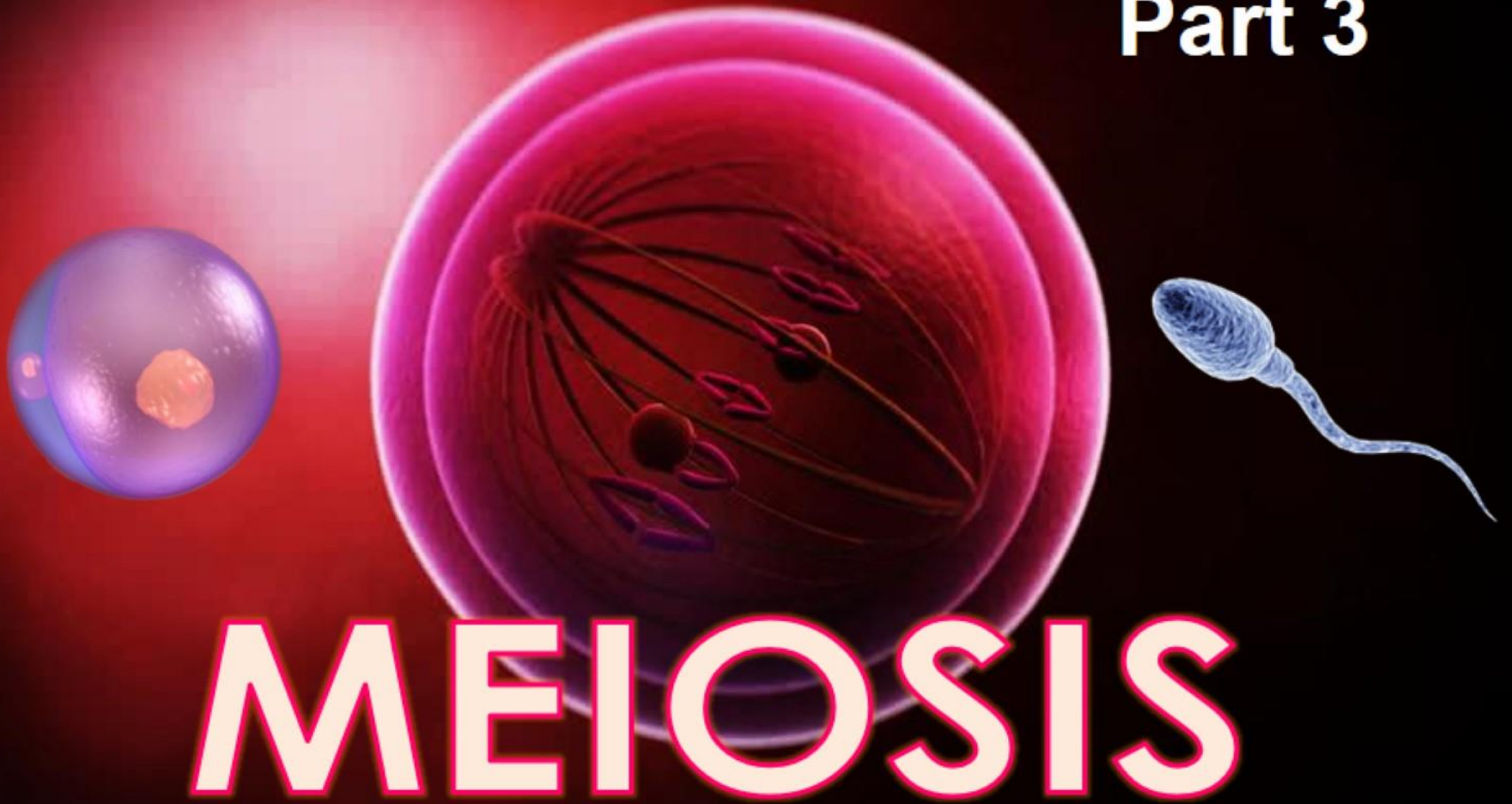
MITOSIS

SIGNIFICANCE OF MITOSIS

- ✓ It produces diploid daughter cells with identical genome.
- ✓ It helps to retain the same chromosome number in all somatic cells.
- ✓ It helps in the body growth of multicellular organisms. Mitosis in the meristematic tissues helps in a continuous growth of plants throughout the life.
- ✓ It restores the nucleo-cytoplasmic ratio that disturbed due to cell growth.
- ✓ It helps in cell repair & replacement. E.g. cells of the upper layer of the epidermis, lining of the gut & blood cells.



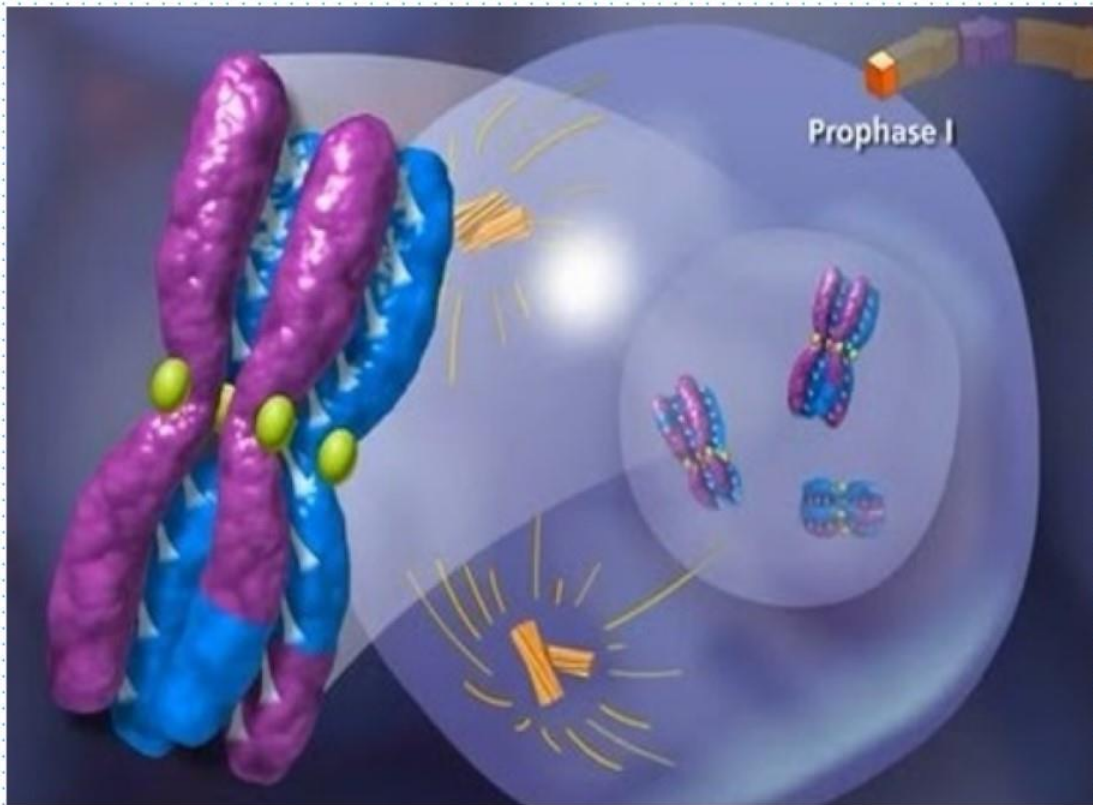
Part 3



MEIOSIS

MEIOSIS

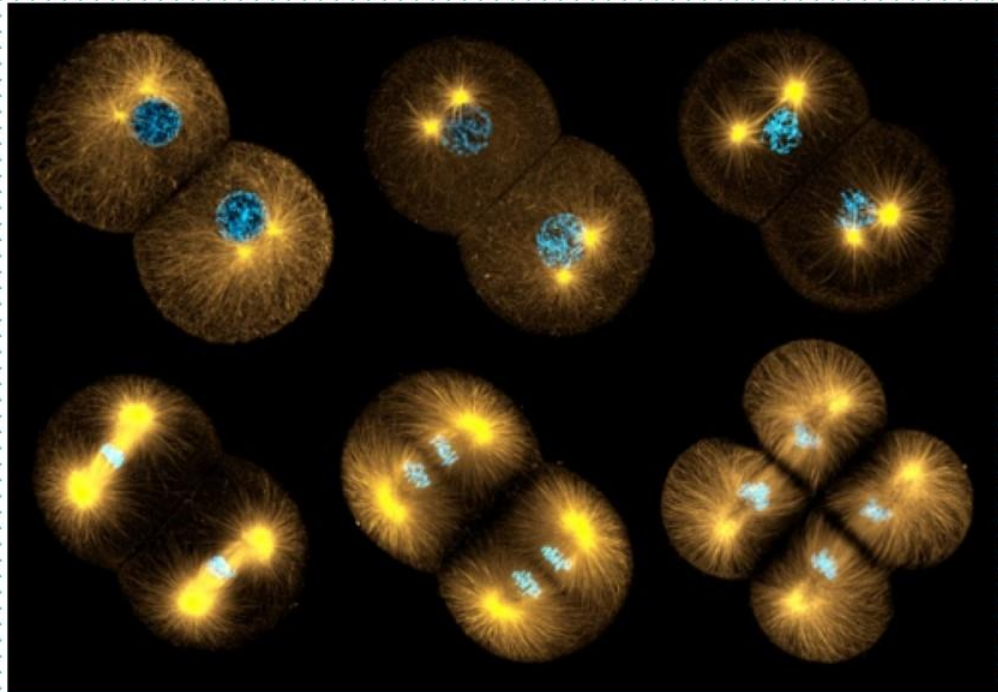
- It is the division of diploid germ cells that reduces the chromosome number by half forming **haploid daughter cells (gametes)**.
- It occurs during gametogenesis.
- It leads to **haploid phase** in the life cycle of sexually reproducing organisms. Fertilization restores the diploid phase.



MEIOSIS

Key features of Meiosis

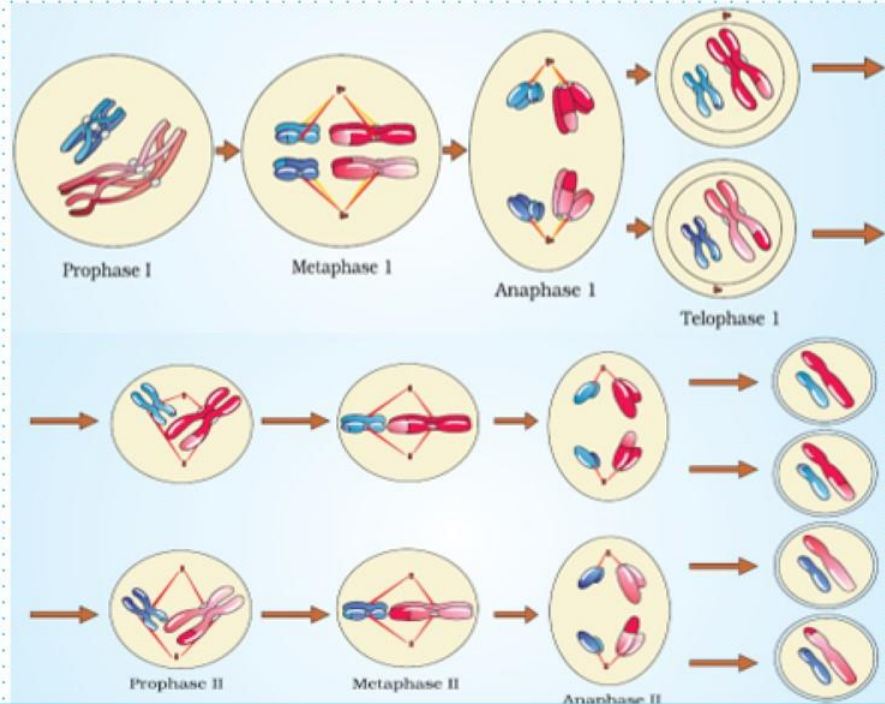
- It involves two cycles (**meiosis I & meiosis II**) but only a single cycle of DNA replication.
- It involves **pairing of homologous chromosomes** and **recombination** between them.
- Meiosis I begins after replication of parental chromosomes to form identical **sister chromatids** at the S phase.
- **4 haploid cells** are formed at the end of meiosis II.



MEIOSIS

Stages of Meiosis

Meiosis I	Meiosis II
Prophase I	Prophase II
Metaphase I	Metaphase II
Anaphase I	Anaphase II
Telophase I	Telophase II



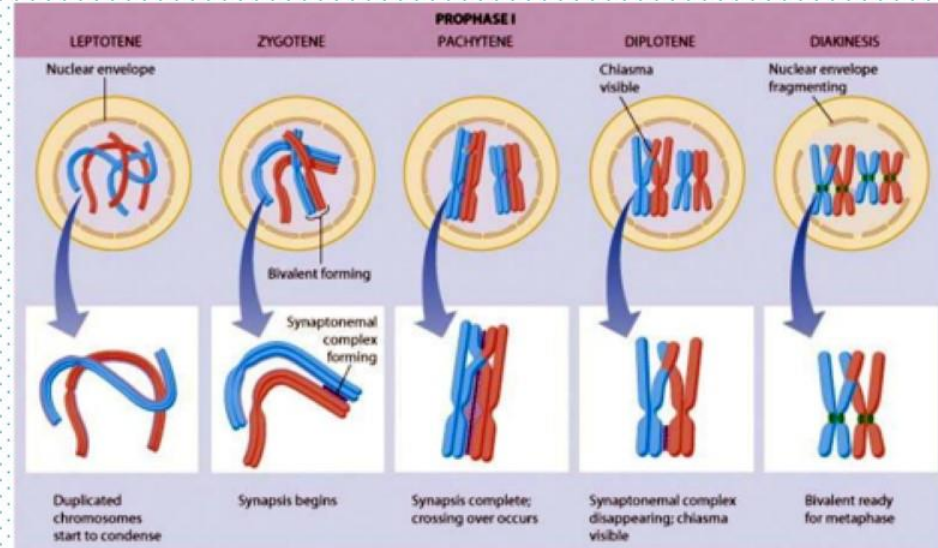
MEIOSIS

Meiosis I

- It is typically longer and more complex.
- It includes 5 phases based on chromosomal behaviour:

- ☐ Leptotene
- ☐ Zygotene
- ☐ Pachytene
- ☐ Diplotene
- ☐ Diakinesis

Prophase I



1

2

3

4

5

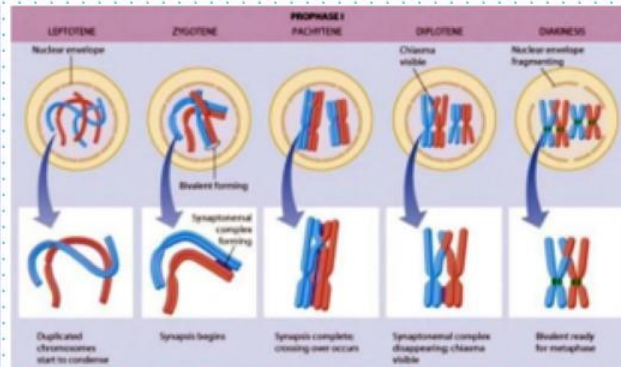
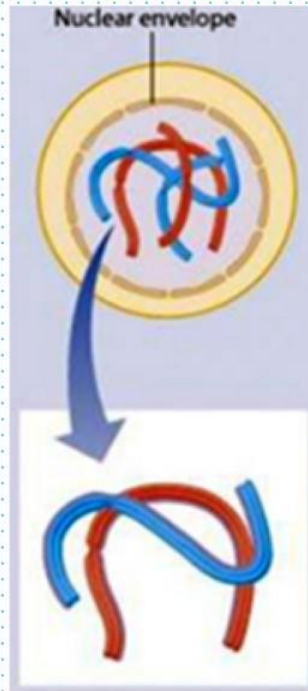
MEIOSIS

Meiosis I

Prophase I

Leptotene (Leptonema)

- Chromatin fibres become long slender chromosomes.
- Nucleus enlarges.



1
Leptotene

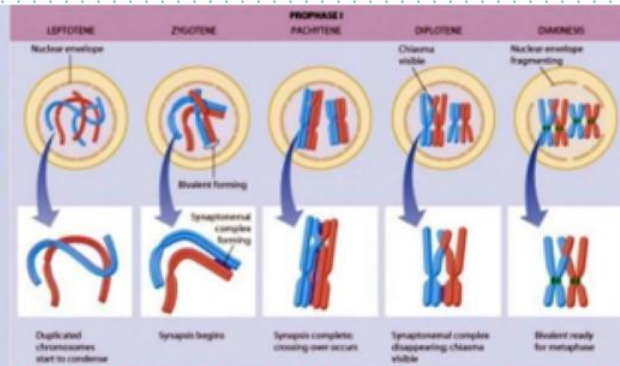
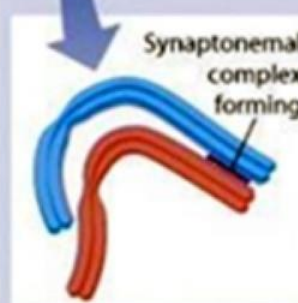
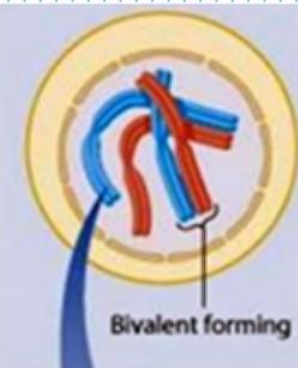
MEIOSIS

Meiosis I

Prophase I

Zygotene (Zygonema)

- Chromosomes become more condensed. Similar chromosomes start pairing together (**synapsis**) with the help of a complex structure called **synaptonemal complex**.
- The paired chromosomes are called **homologous chromosomes**. Each pair of homologous chromosomes is called a **bivalent**.



2
Zygotene

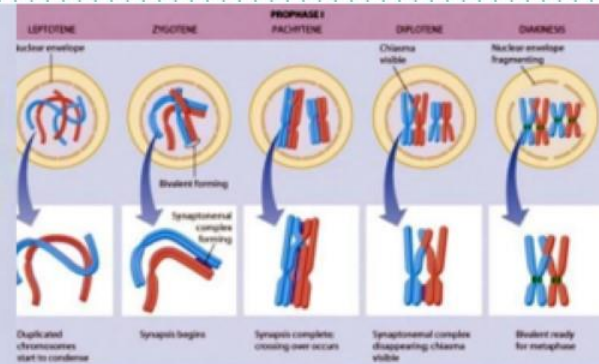
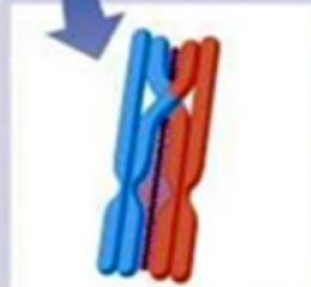
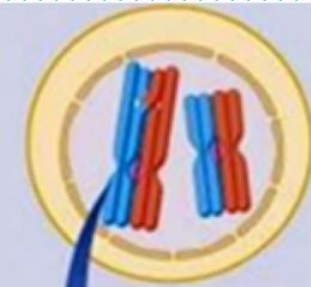
MEIOSIS

Meiosis I

Prophase I

Pachytene (Pachynema)

- Comparatively longer phase.
- Bivalent chromosomes split into similar chromatids. This stage is called **tetrads**.
- Appearance of **recombination nodules** at which **crossing over*** occurs. It leads to recombination of genetic material on the homologous chromosomes.
- Recombination is completed by the end of pachytene.



* Crossing over: The exchange of genetic material between non-sister chromatids of homologous chromosomes. It occurs during the pachytene stage of Prophase I of Meiosis I.

3
Pachytene

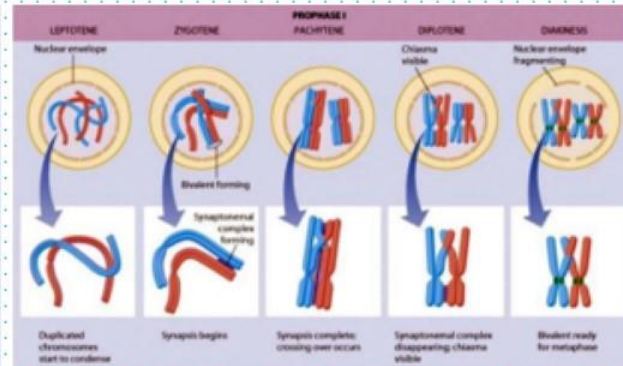
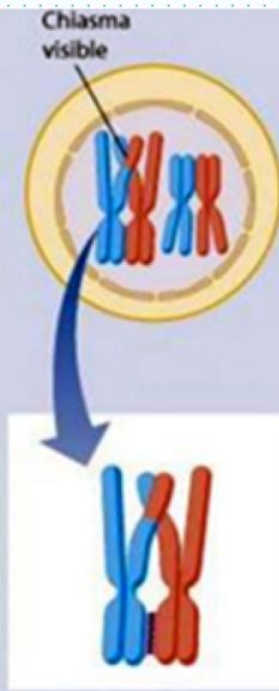
MEIOSIS

Meiosis I

Prophase I

Diplotene (Diplotene)

- Dissolution of the synaptonemal complex occurs. The recombined homologous chromosomes of the bivalents separate from each other except at the sites of crossovers. These X-shaped structures are called **chiasmata**.
- In oocytes of some vertebrates, diplotene lasts for months or years.



4
Diplotene

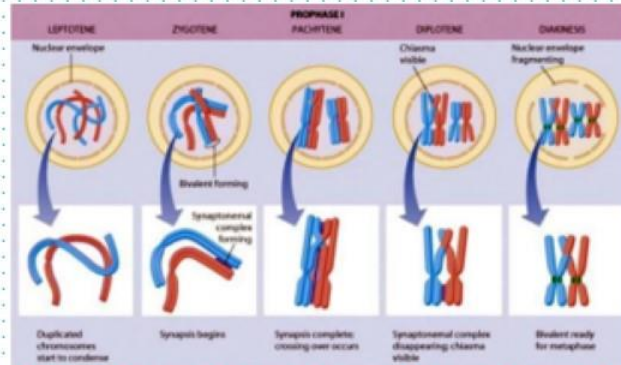
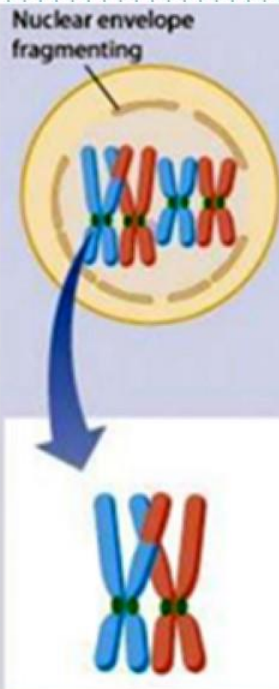
MEIOSIS

Meiosis I

Prophase I

Diakinesis

- Terminalisation of chiasmata.
- Chromosomes are fully condensed.
- The meiotic spindle fibres originate from the poles to prepare the homologous chromosomes for separation.
- Nucleolus & nuclear envelope disappear.



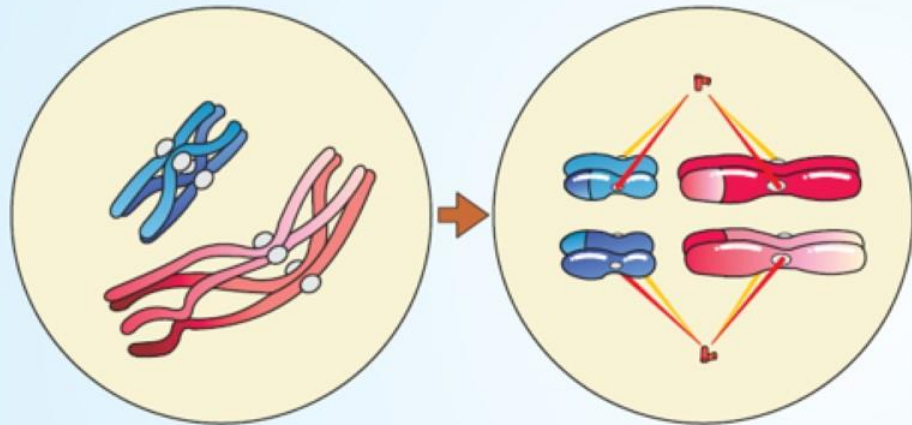
5
Diakinesis

MEIOSIS

Meiosis I

- Spindle formation is completed.
- The chromosomes align on the equatorial plate.
- The microtubules from the spindle attach to the pair of homologous chromosomes.

Metaphase I



Prophase I

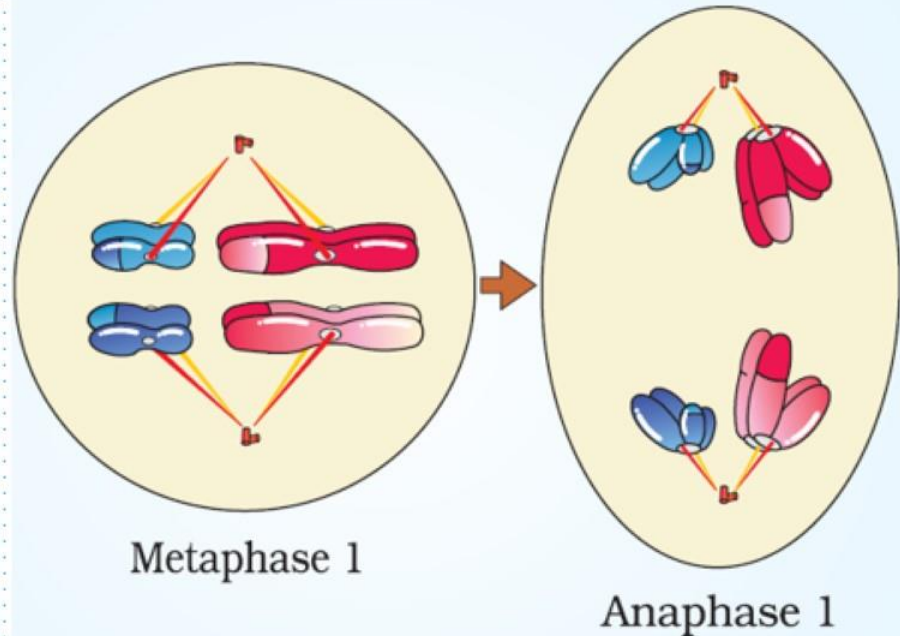
Metaphase I

MEIOSIS

Meiosis I

- The homologous chromosomes separate, while sister chromatids remain associated at their centromeres.

Anaphase I

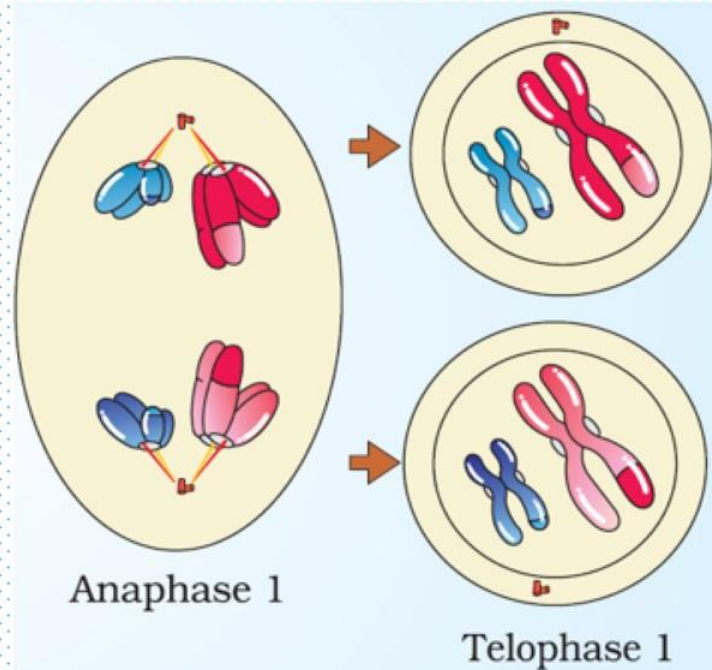


MEIOSIS

Meiosis I

- The nuclear membrane and nucleolus reappear and 2 haploid daughter nuclei are formed. This is called **diad**.
- After this, cytokinesis may or may not occur.
- After a short interphase, it is followed by meiosis II. This short stage between the two meiotic divisions is called **interkinesis**.
- DNA replication does not occur in this phase.

Telophase I



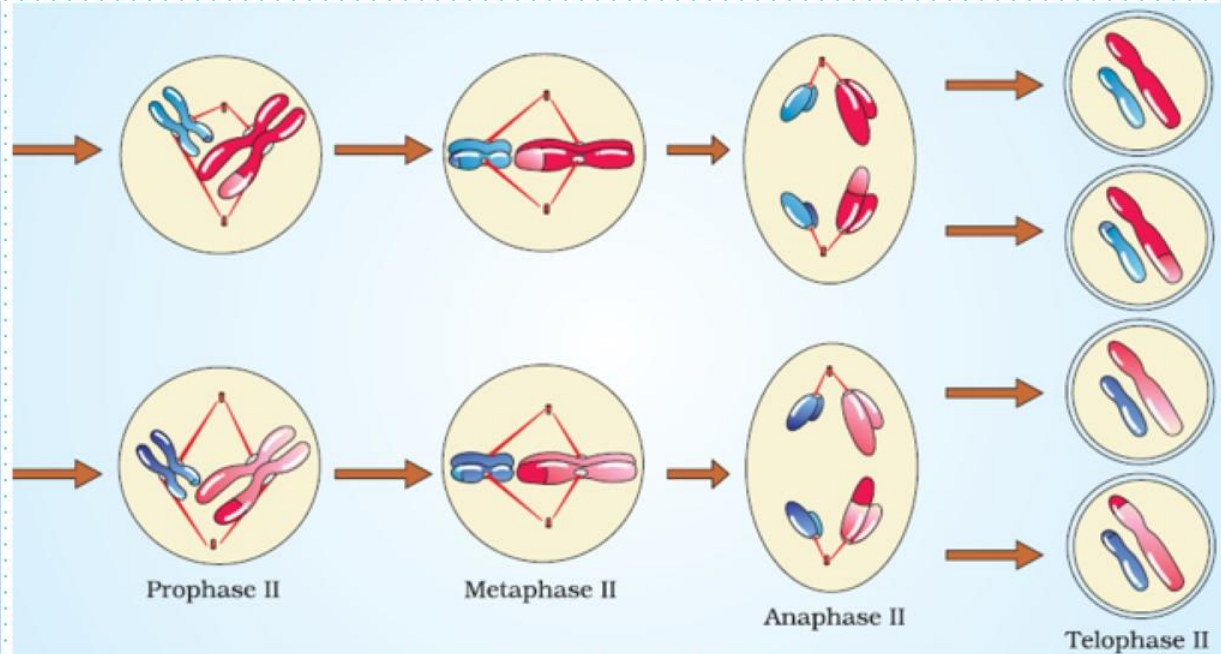
MEIOSIS

Meiosis II

It resembles the mitosis.

It has 4 phases:

- Prophase II
- Metaphase II
- Anaphase II
- Telophase II

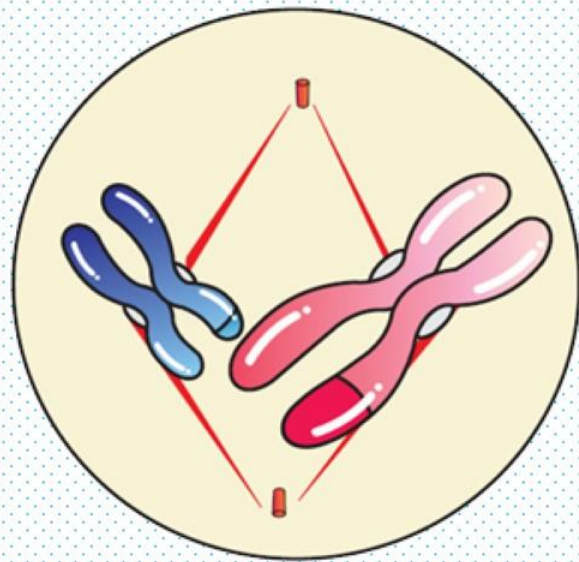


MEIOSIS

Meiosis II

- It is initiated immediately after cytokinesis. The chromosomes again become compact.
- Nucleolus and nuclear membrane disappear in both nuclei.

Prophase II



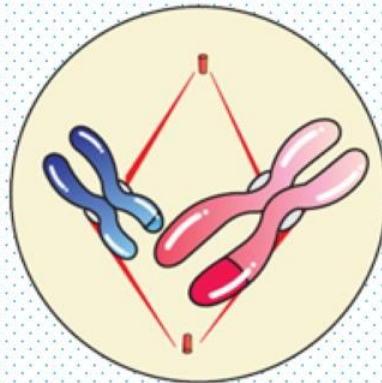
Prophase II

MEIOSIS

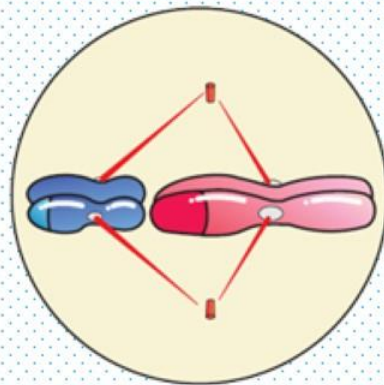
Meiosis II

- The chromosomes align at the equator and the microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids.

Metaphase II



Prophase II



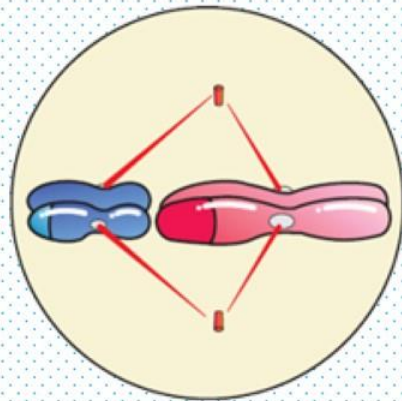
Metaphase II

MEIOSIS

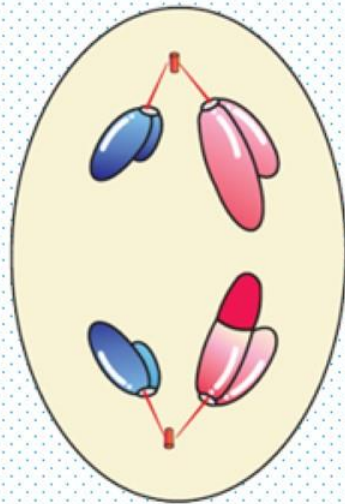
Meiosis II

- It begins with the simultaneous splitting of the centromere of each chromosome (which was holding sister chromatids together). Thus they move toward opposite poles of the cell.

Anaphase II



Metaphase II



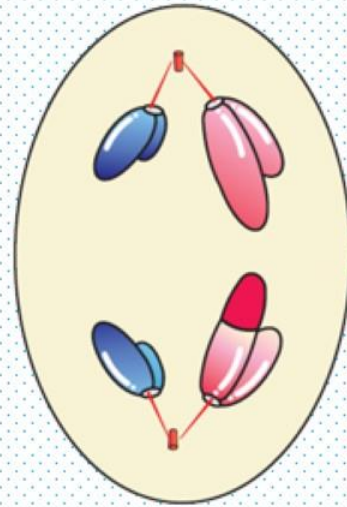
Anaphase II

MEIOSIS

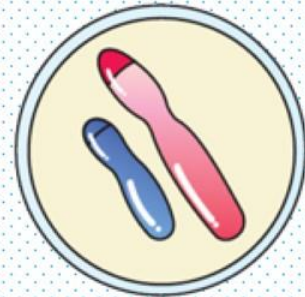
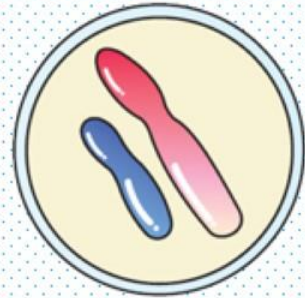
Meiosis II

- The two groups of chromosomes once again get enclosed by a nuclear envelope; cytokinesis follows resulting in the formation of tetrad of cells i.e., 4 haploid daughter cells.

Telophase II



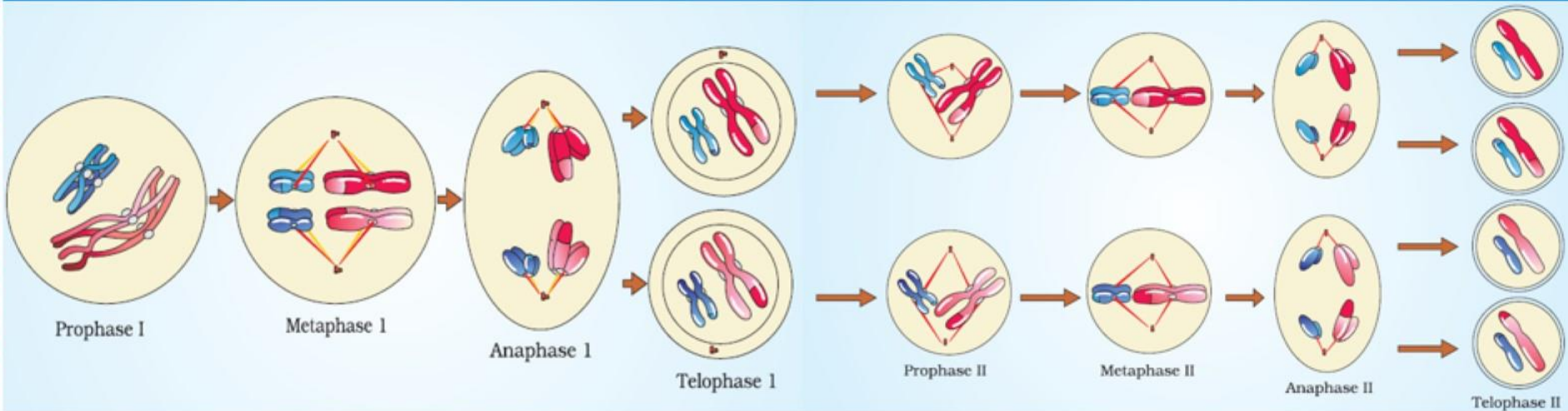
Anaphase II



Telophase II

MEIOSIS

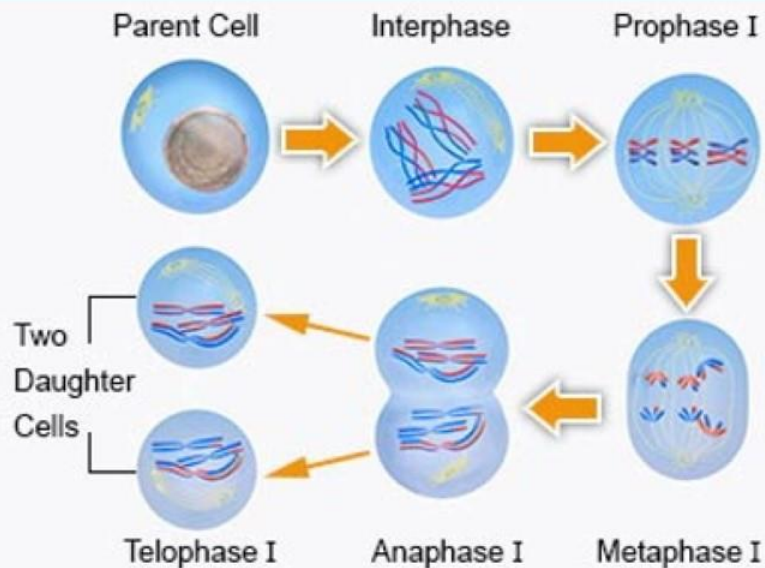
Overall Steps



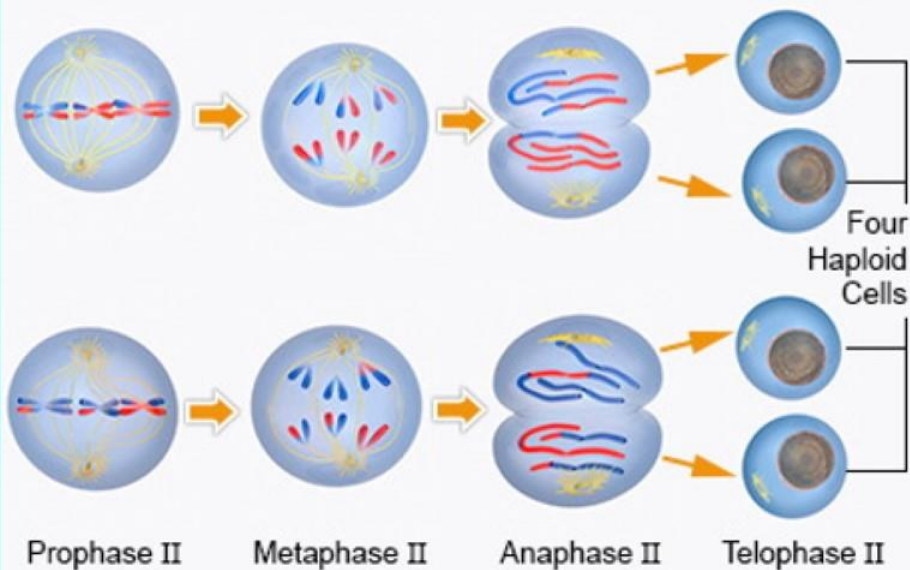
MEIOSIS

Overall Steps

Meiosis I



Meiosis II



MEIOSIS

Significance of Meiosis

- It conserves the chromosome number of each species.
- It causes genetic variation (due to crossing over) in the population of organisms. It is important for evolution.

