CELL CYCLE AND CELL DIVISION

The cell theory by Schleiden and Schwann not only explains the cell as a basic unit of life but also that all cells come from pre- existing cells. All organisms, multicellular and unicellular, start as a single cell [Zygote in sexual reproduction]. This cell divides again and again and after cell differentiation forms an organism. A cell cannot live forever. The continuity of life depends on cell division. Cell can undergo two kinds of division.

i. Mitosis

ii. Meiosis

There are two major events which occur both in mitosis and meiosis. These are:

i. The divisions of nuclear material called as **karyokinesis**, and
ii. The division of cytoplasm called as **cytokinesis.**

Mitosis retains the same number of chromosomes in daughter cells and results in the multiplication of cells while meiosis halves the number of chromosomes in daughter cells and results in the formation of gametes.

Amitosis:

Amitosis is a simple division also called as direct cell division. Amitosis is most common in certain lower algae, fungi and some protozoans [like Amoeba] and certain old cells in higher plants.

- During amitosis the nucleus simply elongates and then undergoes a constriction, dividing into two daughter nuclei without any differentiation of chromosomes or spindle formation.
- The nuclei during amitosis may or may not be of equal size.

Important terms related to cell division:

1. **Diploid** [2n]. It means having two sets of chromosomes which are referred as homologous.
    - A cell that contains two sets of chromosomes is said to be diploid cell. For example, human body cells, are diploid in nature. Also body cells of all higher animals and plants are diploid.
    - It is represented by 2n.
    - A diploid cell has 2n number of chromosomes.

    This number remains constant for a species, for example cells of human beings have 46 chromosomes, that of onion have 16, garden pea 14 and so on.

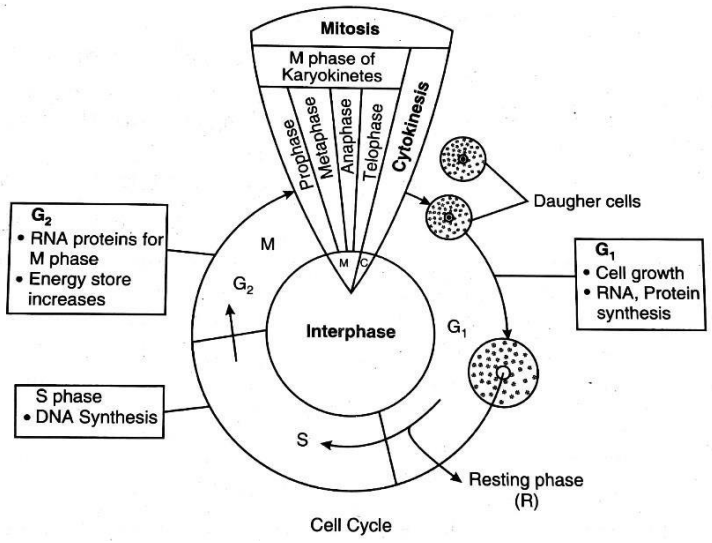
2. **Haploid** [n]. It refers to having only one set of chromosomes.
    - The gametes of all living organisms are haploid in nature.
    - It is represented as n.
    - A haploid cell has n number of chromosomes.

In sexually reproducing organisms, all the body cells are diploid except gametes. Gametes are formed by meiosis. During meiosis a diploid cell undergoes two successive divisions to produce haploid gametes.

3. **Homologous chromosomes-** It refers to a pair of chromosomes in a diploid cell that are exactly similar in shape and size and have the centromere at the same location. They have genes for the same traits throughout their length. In each pair, one of the chromosomes is inherited from mother by the egg cell and one from the father by the sperm cell. A human cell has 23 pairs of homologous chromosomes.
4. **Centromere-** It is constricted region of a chromosome. During cell division, a chromosome consists of two chromatids. The two chromatids of a chromosome are attached at the centromere.
    - Also, chromosomes are attached to the spindle fibres at the centromere.
5. **Chromatid**- One of the two identical parts of a chromosome after its duplication. During cell division, two chromatids make up a chromosome.

CELL CYCLE

All cells go through a basic cell cycle. They may vary in the amount of time they spend in different stages. For example, bacteria divide once in every 20minutes, epithelial cells every 8-10 minutes and onions root tip cells every 20 hours. There are three main stages in cell cycle.



1. Interphase
2. Mitotic [M] Phase or Karyokinesis
3. Cytokinesis [C]
    - Out of 18-20 hours that an epithelial cell takes to divide in the tissue culture, it remains for one hour only in the mitotic [M] phase.

INTERPHASE

It is very active phase in the cell cycle, in which DNA is duplicated. Although the cell looks to be restive, physiologically it is a very active stage. It is a **preparatory phase** in which a number of molecules needed for the M phase or divisions of cell are synthesized. It is further divided into three stages:

1. **G_1 Phase**- Cell grows in size and RNA, proteins and enzymes needed for the next synthetic [s] phase are synthesized.
2. **S phase or synthetic phase**—DNA synthesis takes place.
3. **G_2 Phase**- Spindle and aster rays are formed.
   [There is no DNA synthesis during G_1 and G_2]

1. **G_1 Phase-**
   - **First growth phase.** Cell grows in size. Cytoplasm of cell increases.
   - Mitochondria, chloroplasts, lysosomes, endoplasmic reticulum, golgi complex, vacuoles and vesicles are produced.
   - Structural and functional proteins are formed.
   - Nucleolus produces rRNA, mRNA and tRNA.
   - Ribosomes are synthesized.
   - Metabolic rate of cell becomes very high.
     At these stage one of the two paths is taken up by the cells. Some cells withdraw and go to resting phase [R] and others continue to divide and proceed to the next S-phase.
2. **S phase or synthetic phase-**
   - Replication of DNA takes place. Chromosomes are duplicated.
   - Protein molecules called as histones are synthesized that cover each strand of DNA.
   - Each chromosome is in the form of two chromatids.
3. **G_2 Phase-**
   - Second growth phase in which synthesis of RNA and protein continues.
   - Centriole replicates in animal cells. Plant cells do not have centriole.
   - Mitotic spindle and aster rays begin to get formed.
   - Energy store increases.
   - Increased metabolic rate.

MITOTIC PHASE OR KARYOKINESIS

Technically it is a precise division of nuclear material especially of chromosomes called karyokinesis. There is equal division of genes and DNA in the daughter cells. The daughter cells contain chromosomes which are identical to mother cell.

Nuclear division or karyokinesis occurs in four distinct stages, prophase, metaphase, anaphase and telophase.

CYTOKINESIS

After the M phase or karyokinesis, the cytoplasm is ready to divide. This referred to as a cytoplasmic division or cytokinesis. In this phase the cytoplasm divides, dividing cell into two daughter cells. The cell membrane gets formed in the middle of a cell and divides the cell organelles and the cytoplasm in a way that the daughter cells formed are identical in all aspects.

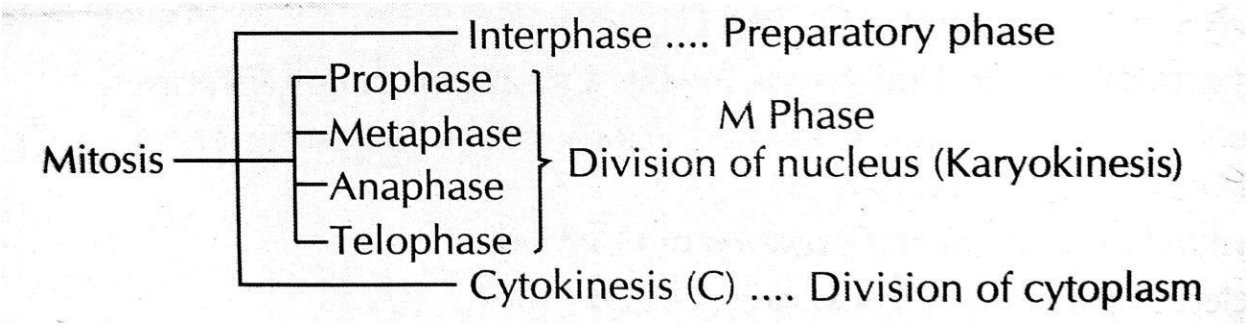
There is an equal distribution of cytoplasm and organelles into each daughter cells.

MITOSIS

Important features of Mitosis:

1. It occurs in somatic cells or all body cells except germ cells.
2. A cell nucleus divides to produce two daughter nuclei which contain identical sets of chromosomes as in a parent cell.
3. It is followed by an equal division of cytoplasm.
4. It results in an increase in number of cells.
5. It helps in growth replacement and repair of cells and is a method of asexual reproduction in some unicellular organisms.
6. The nuclear division is divided into four phases:
   a. Prophase
   b. Metaphase
   c. Anaphase
   d. Telophase
7. Just before the division of the cell, the cell prepares itself for the change. This is known as Interphase. After interphase, the nucleus passes through the above four phases.

Various stages of mitosis:

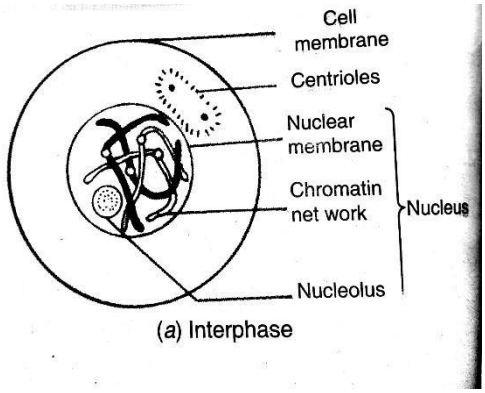


Interphase:

- Physiologically most active stage, although the cell looks to be in a resting stage.
- Chromosomes are in the form of fine thread- like structures, hence they appear as a **chromatin network**.
- Chromosomes undergo **duplication** i.e., make exact copies of themselves.

Now each chromosome is in the form of a pair of chromatids [the chromatids of a chromosome are not visible]

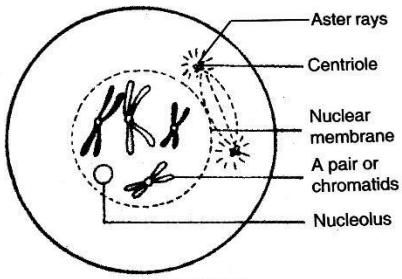
- Nucleus is distinct.
- Nuclear membrane around the nucleus is intact and nucleolus is visible.
- In animal cells, the centrioles begin to divide.



(a) Interphase

Prophase-

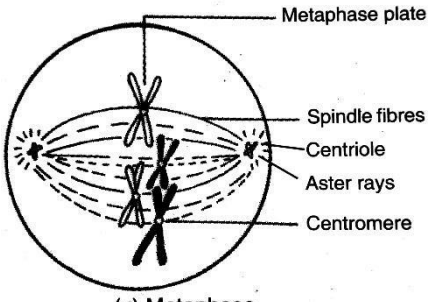
- Longest phase of division.
- **Chromosomes shorten** by thickening.
- Each chromosome consists of two chromatids joined by a centromere.
- **Nuclear membrane tends to disintegrate** [break down].
- Nucleolus start disappearing.
- Centrioles move to opposite poles of the cell.
- Aster rays radiate from centrioles.



(b) Prophase

Metaphase-

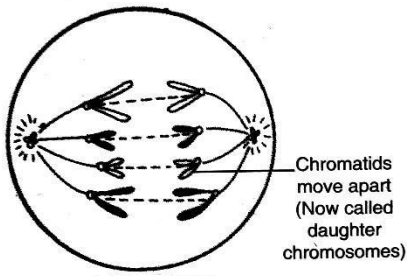
- Formation of spindle fibers.
- Chromosomes line up at the centre forming **equatorial** or **metaphase plate.**
- Chromosomes are attached to spindle fibres at the centromere region.
- Nuclear membrane is absent.
- Nucleolus absent.
- Centrioles at the opposite poles.



(c) Metaphase

Anaphase-

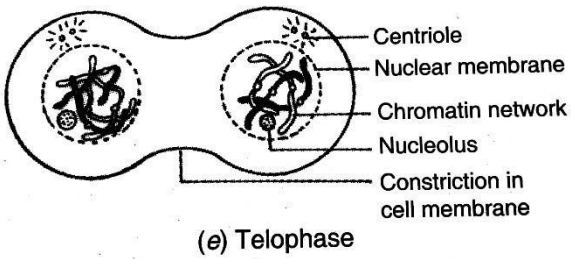
- A very rapid stage.
- Centromere of each chromosome splits into two.
- **Two chromatids of a chromosome separate** and get pulled to opposite sides by the spindle fibres.
- Separated chromatids are now called as chromosomes of daughter cells.
- **Shrinking of spindle fibres.**



(d) Anaphase

Telophase-

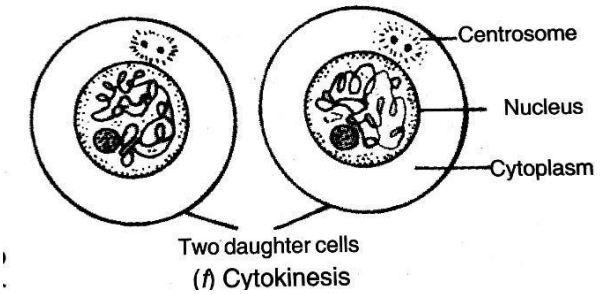
- Chromatids now called as chromosomes reach the poles of the cell
- **Chromosomes uncoil, lengthen and form chromatin network again.**
- Spindle fibres disappear.
- A constriction may appear in the centre of the cell.
- **Nuclear membrane reappears** and two nuclei are formed.
- Nucleoi reappear in each daughter nucleus.
- Leads to cytokinesis.
  Telophase marks the completion of nuclear division, i.e., **Karyokinesis.**



(*e*) Telophase

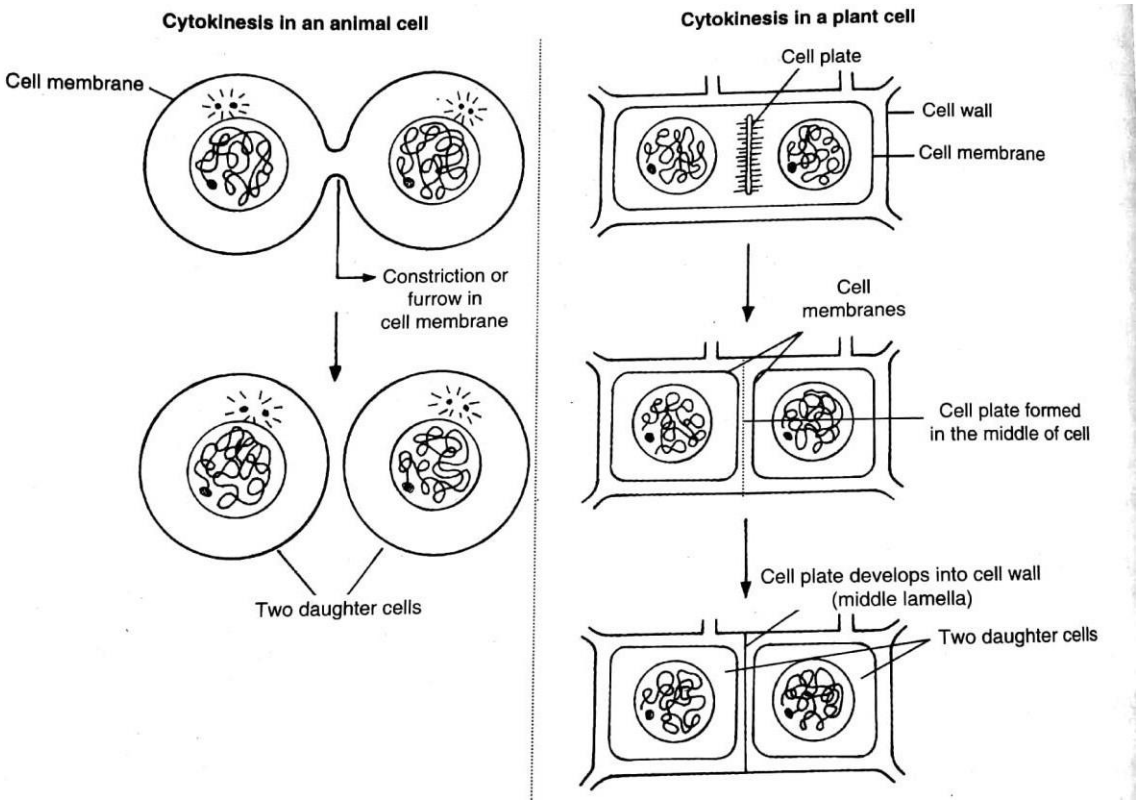
Cytokinesis-

After the nuclear division, the cytoplasm gets divided into two equal parts. This is called cytokinesis. The cytoplasmic division differs in animal and plant cells



(*f*) Cytokinesis

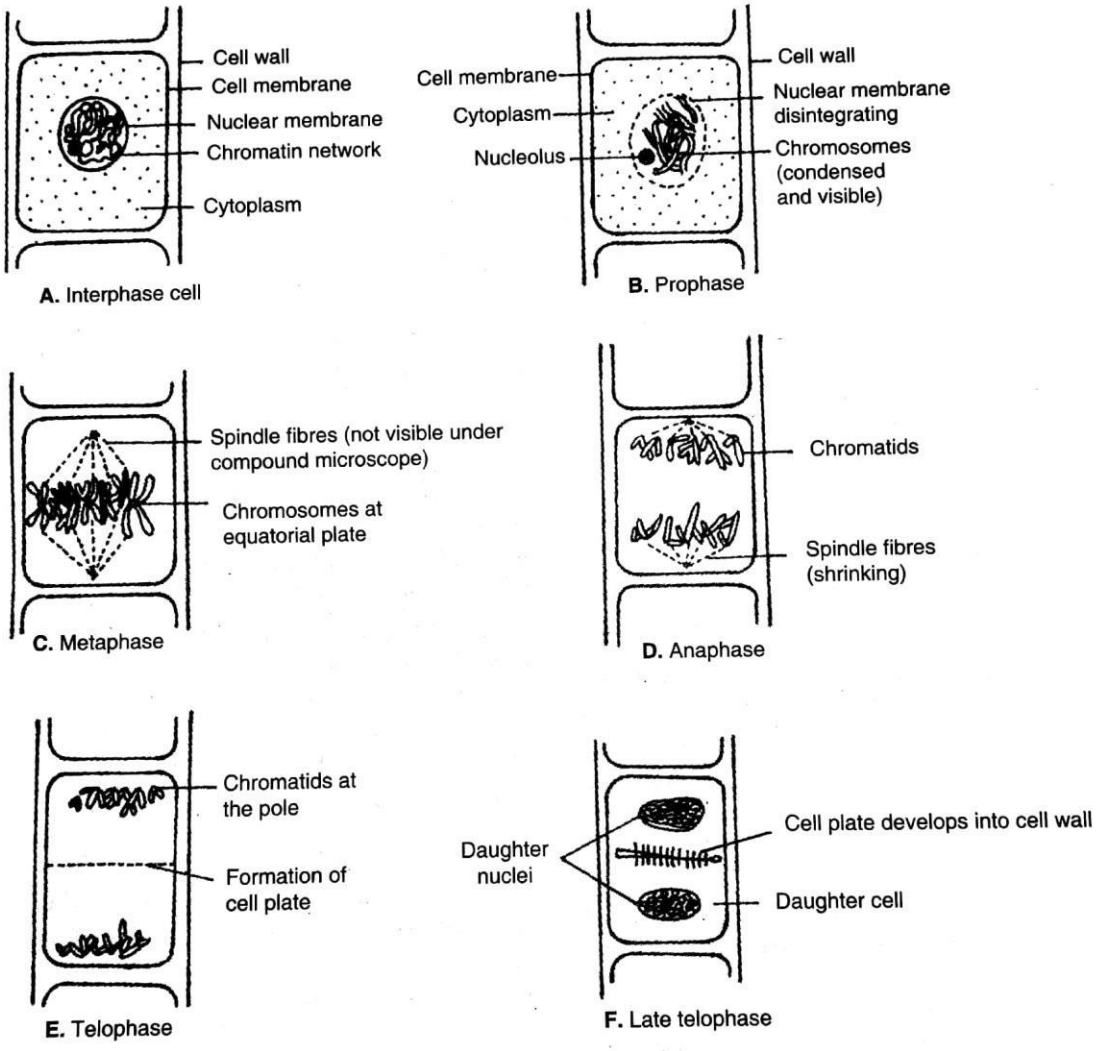
- In animal cells, the cell membrane begins to constrict at the equator during telophase. The constriction deepens and eventually the cell membranes of opposite sides meet at centre. The cell finally divides into two daughter cells.
- In plant cells, the presence of rigid cell wall does not allow cytokinesis by constriction of cell membrane. Instead cytokinesis, begins by the formation of a cell plate in the middle of cell during late anaphase and continues through telophase. The spindle fibres do not disappear at the equatorial plane and form a cell plate. As the cell plate gradually becomes distinct and develops into a new cell wall, it divides a plant cell into two.



Difference between Mitosis of Animal and plant cells:

Mitosis in animal cell	Mitosis in plant cell
▪ Presence of centriole ▪ Formation of aster- rays ▪ No cell plate formation ▪ Furrowing of cell membrane during cytokinesis ▪ Occurs in animal tissues throughout the body	▪ Absence of centriole ▪ Absence of aster- ray formation ▪ Cell plate formation ▪ Furrow formation is absent ▪ Occurs in plant cells mainly at the meristems.

MITOSIS IN PLANT CELLS



SIGNIFICANCE OF MITOSIS

1. **Identical gene composition:**
   [a] The cells contain same number of chromosomes as the parent cell.
   [b] The daughter cells carry the same hereditary information as the parent cell
   [c] There is no variation in genetic information
2. **Growth:** Leads to increase in number of cells, that brings about the body growth and development of an organisms.

3. **Healing of wounds and replacement of cells:** Mitosis helps in healing and replacement of cells during normal wear and tear of the body, i.e., skin cells, blood cells, cells of digestive tract, etc.
4. **Regeneration and Asexual reproduction:** In some animals regeneration of the lost part leads to a mode of multiplication as in planaria, sponges, etc. in plants the asexual reproduction of cells.

5. Uncontrolled mitotic division may give rise to tumors and cancerous growth in the body.