CELL DIVISION

Cell division is a fundamental and vital feature of all living organisms. Cell divisions mainly occur in organisms for the purpose of growth, repair of injured cells or tissues, replacement of worn out cells, reproduction, for gamete formation, for spore formation etc.

Reproduction of single-celled organisms and growth, development and reproduction of multi-cellular organisms are provided by cell division. A cell reaching a certain size divides, if it can not reach this certain size, than it can not divide. With cell division, proliferation of cells and the formation of gamete cells for sexual reproduction are formed.

The fundamental issue in cell proliferation is the replication of DNA, i.e. cloning of DNA and then transferring of this DNA to the two daughter cells.

Cell division is classified into three groups:

1) Amitosis
2) Mitosis
3) Meiosis

1) Amitosis:

Amitosis is a very primitive type of cell division. This type of cell division can be found in primitive type of organisms like Prokaryotes, Protozoans, Yeast, foetal membranes of mammals etc. Amitosis was first observed by Robert Remak and the term Amitosis was first coined by W. Flemming. In this type of cell division genetic material (Chromosomal or DNA material) is unequally distributed between the two newly formed cells. Hence, the nuclear division in this type of cell division is known as direct nuclear division.

Amitosis:

(a) It is also known as direct cell division.
(b) It occurs in some bacteria, yeast, Amoeba etc.
(c) There is no spindle synthesis. The nuclear membrane does not disappear.
(d) There are two steps in amitosis :
(i) Karyokinesis, (ii) Cytokinesis.
(e) A constriction is developed in the center of a nucleus. With the division of cytoplasm, a cell is divided into two daughter cells.

When amitosis occur in complex cells, then the cells are bound to die and they eventually die since they can not perform mitosis anymore. This can be seen in some degenerating cells during hunger, sometimes in some old cartilage cells and in blastoderm cells of a bird egg embro that have to divide rapidly. These cells divide by amitosis for a while and then switch back to mitosis. However, amitosis is never seen in gametes.

Sometimes, cytoplasm division does not follow the division of the nucleus. In this case, the divided nucleus stay in the same cell and cells having 2-3-4 nuclei arise. E.g. This may be seen in liver cells.

2) Mitosis:

Mitosis is a process in which the cells separate their chromosomes into two identical sets. Mitosis is cell division that take place to increase the number of cells. With mitosis tissues are formed, old cells are renewed, wounds are healed. It is the division of somatic cells. Mitosis is a kind of indirect division where two identical nuclei can be found in the two newly formed cells after the cell division.

- In plants mitotic cell division occur in actively growing parts of the plant where young meristematic tissue is present (meristematic tissue is present at the tips of the plant like root tip, stem tip, leaf tip etc.). Due to this, the growth of plants always occur at the tips.

- But in animals all growing cells are capable of undergoing mitotic cell division. Mitosis is most popularly known as equational division **because the two newly formed cells are exact similar copies of parent cells in all respects except in size.** Mitotic cell divisions can occur in haploid cells (cells with one set of chromosomes), diploid cells (cells with two sets of chromosomes) and polyploid cells (cells with many sets of chromosomes). If a cell undergoes abnormal and **uncontrolled mitosis** leads to cancerous outgrowth. Mitosis was first discovered in plants by Strasburger (1885) and in animals by W. Flemming (1882). The word mitosis was first coined by W. Flemming (1882).

Significance of Mitosis to organisms

1. Growth and increase in body size of the organism is possible only due to mitotic cell divisions which occur in the cells of the organism.

2. Repair of the wounded cells and tissue is possible through renewal of lost cells by mitotic cell divisions of the organism.

3. Replacement of worn out cells of the body like blood cells and skin cells of the animals, epidermal cells of plants is possible through mitotic cell divisions.

4. Growth and development of multicellular organism from a single zygote cell occurs through repeated mitotic cell divisions.

5. Every parent cell give two daughter cells after mitotic cell division. The two daughter cells will have the same chromosomal number and same genetic composition.

Mitosis is divided into two stages as karyokinesis (nucleus division) and cytokinesis (cytoplasm division).

Before mitosis starts, the cell goes through a long preparatory stage called **interphase**. During this stage, metabolic activities are very intense within the cell. This stage is also called **metabolic phase**. Interphase is divided into 3 stages as G_1, **S** and G_2 stages.

a) G_1 Phase:

This is the longest phase and lasts for 9-16 hours. In this phase the cell synthesizes RNA and proteins, however DNA synthesize does not begin, the cell makes preparations for this.

2) S (Synthesis) Phase:

RNA synthesis continues as in G_1. Lasts for 6 hours, protein synthesis peaks, DNA synthesis begins and centrosome starts to duplicate.

3) G_2 Phase:

This is the shortest phase, lasts for 3-4 hours or less. DNA synthesis stops, however RNA and protein synthesis continues as much as it is in G_1 phase. Centrosome completes its duplication.

Mitosis (M) phase: After the completion of **Interphase**, mitosis starts. It lasts for 65-131 minutes in animal cells and 2-3 hours in plant cells. The most important event in mitosis is the passing of DNA (replicated chromosomes) to the daughter cells.

i) Karyokinesis:

Karyokinesis occurs in all cells of living beings except for bacteria and blue-green algae that do not have nuclei. This is a very important stage because if the cell can not produce its identical copy, then all the achievements obtained through evolution would be lost in daughter cells. Karyokinesis is completed in 5 stages.

Prophase: The name of this stage of mitosis is derived from the Latin word *pro*, meaning *before*. It is completed in mammals in 30-60 minutes. The chromosomes become visible with a light microscope as they condense (that is, as they shorten, coil, and thicken). Also, a spindle apparatus begins to extend outward from each of the two centrosomes. Then the chromosomes are divided into two longitudinally and forms their counterparts and divide into two equal parts called chromatids. Centrosomes move to the opposite poles and start to extend their mitotic fibers to the chromosomes.

Metaphase: Metaphase begins when nuclear envelope disintegrates. The chromosomes, guided by the spindle fibers, line up in the middle of the dividing cell. The chromosomes are now maximally condensed. It is possible to count the number of chromosomes during this stage. The membrane of the nucleus and the nucleolus completely disappear during this stage. The duration of metaphase varies according to the tissue and the species, however it usually lasts for 2-6 minutes. The name of this stage of mitosis is derived from two Greek words, *meta*, meaning "after," "later" or "more advanced," and *phasis*, meaning "stage.

- **Anaphase:** During anaphase, the two sister chromatids of each chromosome are pulled apart by the spindle and dragged by their kinetochores toward opposite poles of the cell, that is, toward the opposite centrosomes. The movement results from a shortening of the spindle microtubules. Each chromosome is pulled along by its centromere. Formally, this phase begins when the duplicated centromeres of each pair of sister chromatids separates, and the resulting "daughter chromosomes" begin moving toward the poles. As the separated chromosomes move away from each other toward the poles, the cell elongates and the poles themselves move further apart

This stage lasts for 3-15 minutes. Centromere is very important at this stage. If centromere is destroyed by any means (e.g. X rays), chromosomes can not be pulled towards the pole and mitosis can not be completed.

The term *chromatid* is used only to refer to one of the two united halves of a replicated chromosome. Once the sister chromatids move apart, each is called a *daughter chromosome* or *unreplicated chromosome.*

The terms *prophase*, *metaphase*, and *anaphase* were coined by the Polish-German botanist Eduard Strasburger (Strasburger 1884, pp. 250 and 260), who together with Walther Flemming (1843-1905) and Edouard van Beneden (1846-1910) was the first to describe the process of chromosome distribution during cell division (telophase was only later given a distinct name).

The prefix *telo-* is from the Greek word *telos*, meaning end or completion.

Telophase: The chromosomes have reached the poles and they begin to uncoil and become less condensed (reversing the process that occurred during prophase). Two new nuclear envelopes begin to form around each of the two separated sets of unreplicated chromosomes. As decondensation of the chromosomes proceeds, the nucleoli (which disappeared during prophase) form once again. This stage lasts for 30-60 minutes in mammalian cells.

At the same time, there is a division of the cytoplasm (cytokinesis). In animal cells, a cleavage furrow — an indentation around the equator of the cell — appears. By the end of telophase, the cell has divided in two along the plane defined by the furrow.

ii) Cytokinesis:

This usually starts during anaphase or telophase following karyokinesis. A contractile ring containing actin and myosin proteins start to form just beneath the cell membrane. With the contraction of this ring, the cytoplasm is pulled inwards and as a result the cytoplasm is divided into two. Contractile ring disappears until the next cell division.

With mitosis, the number and structure of chromosomes within the cells of the same species are kept constant, thus the genetic structure of that species remains unchanged.

Substances that initiate mitosis are called **mitogenic substances**. E.g., sex hormones are mitogenic substances. In addition, there are also some substances that prevent mitosis (mitotic inhibitors or mitotic poisons) For example, colchicine prevents the formation of mitotic fibers and halts mitosis during metaphase. X rays also prevent mitosis. These mitotic inhibitors are used in cancer treatment.

3) Meiosis

This type of cell division occur in reproductive organs or reproductive cells or reproductive tissues of the organism. This type of cell division will help in the formation of haploid gametes or sex cells or sperm cells or egg cells or pollen grains or spore cells etc. In higher animal organism this type of cell division occurs in testis or ovaries or gonads of organisms. In plant organisms, this type of cell division occurs in anthers or ovary of flowers.

Meiosis occurs in diploid or polyploid reproductive cells of reproductive organs. Each parent diploid reproductive cell through meiosis form four haploid daughter cells are formed. Reproductive cells only undergo this type of cell division only once in their cell cycle. Meiosis cell division was first observed by Strasburger and the term Meiosis was first named by J.B. Farmer and Moore (1905). Meiosis is most popularly known as reductional division as the chromosomal number of the daughter cells will be halved to that of the parent cell.

Significance of Meiotic Cell Division

1. This cell division always occur in reproductive organs.

2. The four daughter cells formed from the parent diploid cells are quite different from the parent cell in their chromosomal number and genes composition.

3. The change in the genetic composition of these gamete cells bring about variations in the newly formed individuals by the fusion of these gametes during fertilization. These variations in individuals of every generations are responsible for evolution as well as **creation of new species** in the nature.

4. Reproductive cells of reproductive organs are diploid in nature. But the gametes or sex cells formed from these diploid reproductive cells are haploid in nature. When these haploid gametes fuse during fertilization leads to the formation of diploid zygote cell from which only our whole body will be derived. This haploid zygote cell by repeated mitotic cell division a new individual of the same size and form are created. Thus, the gamete formation is a must in sexual reproduction to restore the diploid condition of the original organism.

5. Cytological evidence for Mendel's laws is provided by Meiosis cell division.

Meiosis occurs as primary and secondary divisions that follow each other. In the first meiosis the number of chromosomes become haploid (reductional division). The second meiosis is actually a mitotic division. Chromatids are equally distributed to daughter cells (as haploid).

The stages of meiosis are as follows:

a) **1st Prophase:** During this phase of meiosis, the nuclear envelope breaks up and disappears. The nucleolus also vanishes. The chromosomes become visible as they shorten, coil, and thicken (that is, as they "condense"). Also, the spindle apparatus begins to extend outward from the two centrosomes, which move to the opposite ends ("poles") of the cell. This stage consists of **leptotene**, **zygotene**, **pachytene**, **diplotene** and **diakinesis** phases.

i) Leptotene (Greek: thin threads): Individual chromosomes begin to condense into long strands within the nucleus. The sister chromatids are still bound to each other.

ii) Zygotene (Greek: paired threads): This is the stage of meiotic prophase which immediately follows the leptotene and during which synapsis of homologous chromosomes (coming from the mother and the father) occurs.

iii) Pachytene: This is the third stage of the prophase of meiosis, during which the homologous chromosomes become short and thick and divide into four distinct chromatids and are called tetrads (homologue chromosome pair). However the chromatids are still bound to each other via their centromeres.

iv) Diplotene (Greek: two threads): **Crossing-over** occurs in this stage. Homologue chromosomes start to separate from each other, however they still touch each other at some points. Chromatids take the shape of an X due to this touching and this is called **chiasma (pl. Chiasmata)**. Chromosomes of homologue chromosomes break latitudinally (in width) at these points and exchange of parts occur. By this way, some properties of the mother/father are passed to the offspring.

v) Diakinesis (Greek: moving through): Homologue chromosomes condense, separate further and chiasmata terminalize. Nucleolus disappears, nuclear membrane disintegrates and prophase ends.

- b) **1st Metaphase:** Nuclear membrane disappears, centrioles go to the poles, spindle apparatus forms, tetramers formed by the homologue chromosomes are lined up equatorially.
- c) **1st Anaphase:** Homologue chromosomes do not divide yet, they are being caught from their centromeres and being pulled to the poles. Homologues having two chromatids each separate from each other start to move to the opposite poles. By this way, the number of diploid chromosomes reduce into haploid chromosomes.
- d) **1st Telophase:** Chromosomes start to take their places during interphase. The nuclear membrane starts to appear, however nucleolus does not form yet. The cell divides into two, and the 1st Meiosis ends with haploid chromosomes.

d) 2nd Telophase: Spirals of the chromosomes open, chromonema takes the form of threads. Nuclear membrane and nucleolus forms. Centrioles wait for the next division in pairs. Cytoplasm is divided and 4 haploid cells with n chromosomes form.

Differences between mitosis and meiosis:

MITOSIS	MEIOSIS
a) **It is the division of a chromosome and a nucleus.**	a) **It is the division of a chromosome and two nuclei.**
b) The number of chromosomes in the daughter cells equals to the number of chromosomes in the parent cell.	b) The number of chromosomes in the daughter cells is half the number of chromosomes in the parent cell
c) 2 daughter cells having the same structure as the parent cell form.	c) 4 daughter cells with chromosome numbers reduced to half form.
d) Lasts shorter.	**d)** Longer compared to mitosis (Especially 1st prophase is considerably longer.
e) Both of the homologue chromosomes are present in the daughter cells (diploid cells).	**e)** Only one of the homologue chromosomes are present in the daughter cells (haploid cells).