

CELL

The cell is the basic unit of every living organism. All forms of life are made up of cells. A cell has an important similarity in all organisms. The cell of all organisms normally consists of the **two** most important parts. These two most important parts of the cell are the:

- i. Nuclear portion (or the nucleus)
- ii. Non-nuclear portion (or the cytoplasm)

Some organisms have distinct nucleus, whereas some do not have well defined nucleus. Those organisms with well defined nucleus are called **eukaryotes**, while those without distinct nucleus are called the **prokaryotes** and these include bacteria and blue green algae. Examples of single-celled eukaryotic organisms include the **yeast (*Saccharomyces cerevisiae*)**, the **ciliate (*Paramecium aurelia*)**, **fungi**. For the higher eukaryotes, examples include fruit fly, corn, mouse and human being.

Apart from the two major components of cells (i.e. the nucleus and cytoplasm), there are also the organelles. The organelles divide the cell into compartments.

General components of the cell

1. The nucleus: is at the core of every cell, usually the eukaryotics. The nucleus is the house of genetic material called DNA. The DNA can organize into units called the **gene**, which direct metabolic activity of cells. The genes can organized into threadlike structure called the **chromosome**, which serves as vehicle for transmission of genetic information. Apart from the chromosomes contained in the nucleus, **nucleolus** is also found in the nucleus. The nucleolus is a large body that contains **RNA and proteins** and it represents the site of synthesis and storage of the cell ribosomes. The chromosomes in the nucleus contained chromosomal material called **chromatin**. Chromatin is a complex of **DNA and protein** that associate during non-divisional phases of cell.

In the nucleus, synthesis and assembly of ribosomal RNA (rRNA) occur. In prokaryotes, there are no nuclear envelope and membraneous organelle. The genetic material, (DNA) is compacted into an area called **nucleoid region**. Generally, the prokaryotic cells, do not have a distinct nucleus, but do contain genes that specify rRNA molecules.

2. The cytoplasm: This is the non-nuclear portion of the cell. Cytoplasm contains soluble **enzyme, free ribosome, colloidal material called cytosol**, which surrounds and encompasses the cellular organelles. **Cytoplasm also contain cytoskeletal fibres**, which maintains the cell shape and anchors the various organelles.

3. The cell organelles: The cell organelles are many and include:

a. Endoplasmic reticulum (ER): It may be smooth in which case it serves as the site for synthesis of fatty acids and phospholipids. It may be rough when studded or bound with ribosomes. The function of both smooth and rough ER is to increase the surface area available for biochemical synthesis. ER is also called **ergastoplasm**.

b. Ribosomes; the ribosomes are the structures that are involved in protein synthesis. It serves as the sites for the translation of genetic information contained in rRNA into proteins in the *central dogma of molecular genetics*.

c. Mitochondria: This is found in both plant and animal cells. It is called the power house of the living cell. There is a large generation of adenosine triphosphate (an energy-rich molecule) in the mitochondria. The chloroplast is found in plants, similar to mitochondria, it contain green pigment (chlorophyll) and is essential for photosynthesis. The mitochondria are the site for oxidative phases of cell respiration. Chloroplasts and mitochondria posses chromosomes of their own. **Energy transformation occurs in mitochondria.**

d. Golgi bodies or apparatus is popularly known as dictyosomes. This organelle is important for the synthesis of many proteins that are secreted from the cell.

e. The centrosome and centrioles are involved in cell division from generation to generation for continual inheritance. The centrioles are found within the centrosomes which are associated with the organization of spindle fibres.

Apart from these major organelles, there are also some minor organelles that can be found on the cell.

Both plant and animal cells are almost alike. As seen under the light microscope, plant cell contain cell wall, cell membrane, cytoplasm (clear fluid), the dense fluid or the centre which is the nucleus, which is also surrounded by nuclear membrane. Typical animal cell is like plant cell except for the absence of **cell wall**.

In active dividing cell, there is always threadlike structures called chromosomes and this is found within the nucleus. The cytoplasm of the cell is highly organized system of membranes where cellular functions such as protein synthesis (on ribosomes), carbohydrate synthesis (in chloroplast) and energy transformation (in mitochondria) take place.

THE CELL CYCLE

The cell cycle can be regarded as the series of sequence or stages of cell growth and DNA replication that occur during the interphase stage. In eukaryotes, the DNA synthesis leading to chromosomes replication takes place throughout the interphase and ceases only during the brief period of mitotic nuclear and cell division.

The cell cycle involves some stages designated as:

G_1 = growth phase I or Gap I

S-phase = synthesis period

G_{II} = growth phase II or Gap II

and M = mitosis

Note that, G = gap, and S = Synthesis

During G_1 -phase (this is the period of pre-DNA synthesis), but essentially there is no DNA replication or synthesis. During G_1 , cells only engage in growth and metabolic activity but not in chromosome replication. It last for some minutes. There are two periods during interphase before and after the S-phase. These periods or phases are called Gap I and Gap II respectively. During Gap I and II (i.e. G_1 and G_{II}) i.e before and after S-phase, there is no DNA synthesis. DNA synthesis or replication only occurs during a discrete interval of the interphase and this period is known as S-phase or S-period. It must be noted that the S-period occur between G_1 and G_{II} phases. The G_{II} period is ordinarily followed by mitosis (M), and the sequence $G_1 \rightarrow S \rightarrow G_{II} \rightarrow M$, followed by another G_1 , is known as **cell cycle**.

During G_1 , S, G_{II} phases, there are cell growth and metabolic activity, followed by DNA replication, and cell growth and metabolic activity, respectively and there is differentiation of cell. At the end of G_{II} -phase, the volume of the cell has doubled, DNA has been replicated and mitosis is initiated. When nutrients become scarce, the cell shift into a stationary phase (G_0) in which cellular metabolism essentially shifts into a holding pattern until nutrients are replenished.

After G_{II} , mitosis is initiated and are sub-divided into phases in the order of: **Prophase, metaphase, anaphase and telophase**, respectively.

CELL DIVISION

Cell division means the production of at least two cells from a pre-existing one. The division will consequently result in the division of nuclear material and the cytoplasm. Cell division partitions the cytoplasm and nucleus of a pre-existing cell into two daughter cells in such a way that the two daughter cells are more or less identical.

KARYOKINESIS AND CYTOKINESIS

Division of the nucleus is called **karyokinesis**, while the division of the cytoplasm is called **cytokinesis**. Usually, cytokinesis often followed karyokinesis. The process of cytokinesis usually occurs in the telophase stage of mitosis.

MITOSIS AND MEIOSIS

Two types of nuclear division that are characteristics of most plant and animal cells are mitosis and meiosis. Mitosis is regularly associated with nuclear division of vegetative or somatic cells. Meiosis occurs in conjunction with formation of reproductive cells (either gametes or meiospores) in sexually reproducing species.

MITOSIS

The mechanism by which new cells are formed and by which these cells retain identical chromosomes numbers and hereditary factors before and after every cell division is referred to as **mitosis**. Mitosis is responsible for the production of body cell. Mitosis is a form of cell division in which the mother cells possess the diploid number of chromosome ($2n$) and produce daughter possessing the same chromosome complement.

Mitosis is a smoothly continuous process, but is divided arbitrarily into several stages or phases for convenience reference. As a process, mitosis is remarkably similar in all, but relatively minor details in both plants and animals.

The stages of mitosis are: (i) Interphase, (ii) Prophase, (iii) Metaphase, (iv) Telophase, (v) Anaphase.

The interphase stage is as described for cell cycle above. i.e. during interphase there is non-dividing nucleus and there is G_1 -S- G_{II} -phases (i.e. before and after S-phase) (i.e. G_1 and G_{II} -phase) there is cell growth and metabolic activity, but no chromosome replication except in the S-phase.

Prophase

As the G_{II} of interphase gives way to prophase and the following occur:

- Chromosome progressively shortens and thickens to form individually recognizable structures arranged randomly in the nucleus.
- Two sister chromatids of each chromosome are formed and closely aligned and coiled on themselves. The two parts of the chromosome are called the chromatids. The sister chromatids are similar genetically.
- The two sister chromatids are held together in a specialized or condensed region called the centromere. The centromere contain granules called kinetochores and one for each sister chromatid.
- During prophase, nucleolus gradually disappears in most organisms
- During prophase, there is degeneration and disappearance of the nuclear membrane
- As prophase progresses, spindle fibres begins to form or have been laid down. These are football-shaped mitotic apparatus between the centrioles which are now at opposite ends of the cell. At this stage, the nucleus and nuclear membrane are no longer visible and sister chromatids now appeared as part of each chromosome.

Prometaphase

This is the period of chromosome movement to the equatorial plane.

Metaphase

- Is the period of time in which centromeres of chromosomes occupy the plane of the equator of the mitotic apparatus.
- At metaphase, sister chromatids are still held together by connecting fibres at the centromere regions.
- During metaphase, chromosomes are shortest and thickest.

Anaphase

- During anaphase, sister chromatids of each double chromosomal structure separate from each other and migrate to opposite ends of the cell
- Centromeric region must divide into two and once this occurs, the chromatids are called daughter chromosomes.

Telophase

Is the final stage of mitosis

- Telophase begins with the arrival of daughter chromosomes at the spindle poles.
- Telophase terminates by the reorganization of two new nuclei and their entry into G₁ stage of interphase.
- New nuclear membranes are constructed from endoplasmic reticulum or from remnants of original materials
- Mitotic apparatus disappears

- Nucleoli are reformed and chromosomes resume their long, slender, extended form as their coils relax.
- Replication of chromosome materials also occurs during telophase.

Significance/importance of mitosis

1. In mitosis, the chromosomal material is distributed in equal quantity to two daughter cells in a precise manner.
2. In mitosis, there exists a process in which equal distribution of structures called chromosomes can be carried through cell generation after cell generation.

DURATION OF MITOSIS

The duration of mitosis most especially prophase, metaphase, anaphase and telophase varies from species to species.

In onion, the total duration for PMAT = 84 minutes

In pea, total time for (PMAT) = 110 minutes

In bean = 155 minutes

In fowl = 34 – 52 minutes

In mouse = 59 minutes

In grasshopper = 181 minutes

MEIOSIS

Is the process by which chromosomes numbers in organisms are halved in the process of formation of **sex cells or gametes**. Meiosis normally occurs in organs that produce sex cells or gametes **e.g testes and ovaries in mammals**. Meiosis is a form of nuclear division. It consists of two successive divisions each with its own prophase, metaphase, anaphase and telophase, respectively.

Meiosis results in four daughter nuclei instead of two as in mitosis. The nuclear products of a meiotic division have a haploid number of chromosomes as opposed to the two sets (diploid) of the parent nucleus; the nuclear products are genetically unlike the original diploid nucleus and often genetically unlike each other.

The **two meiotic divisions are the first meiotic division and the second meiotic division**. The first meiotic division is also known as the reductional division because it results in the halving of the chromosomal complement from $2N$ to N . It is divided into some phases. Similarly, the second meiotic division is also divided into some phases.

KEY FEATURES OF MEIOSIS

1. The net effect of meiosis is to reduce a cell's chromosome number by half usually from an initial $2N$ to N
2. Each haploid product (N) of meiosis is allotted one complete set of chromosomes information pertaining to that species.
3. It is the stage in eukaryotic development in which new gene combinations are generated. These gene combinations come about in two ways:
 - a. Maternally and paternally derived homologous chromosomes that coexist in a $2N$ organism are distributed among the organism's haploid meiotic combinations.
 - b. Maternally and paternally derived homologous chromosomes frequently take part in genetic exchange during meiotic prophase.

STAGES OF MEIOSIS

Meiosis is a very lengthy process. It is longer than mitosis. A complete cycle of meiosis takes days or weeks rather than hours.

The two successive division of meiosis are:

1. First meiotic division or reductional division
2. Second meiotic division

The first meiotic division includes:

- a. Prophase I
- b. Metaphase I
- c. Anaphase I, and
- d. Telophase I

Similarly, the second meiotic division is also divided into:

Prophase II

Metaphase II

Anaphase II

Telophase I

FIRST MEIOTIC DIVISION OR REDUCTIONAL DIVISION

Prophase I: prophase I is the most complex and in animals, it takes about 5 days to complete. Prophase I is broken down into five sub-stages called: *Leptonema, Zygonema, Pachynema, Diplonema and Diakinesis (LZPDD)*

The adjectives that can also be used to describe the first four stages are leptotene, zygotene, pachytene and diplotene. These stages are defined arbitrarily and they flow from one to another.

Leptonema = Leptotene

In the leptonema stage, the following occur:

- Chromatin begins to condense
- Chromosome begins to become visible or recognizable as fine thread.

- Chromosome shortens and thickens progressively.

Zygotenema = Zygotene

Chromosomes continue to shortening and thickened

- There is initial alignment of chromosomes and this result in rough pairing called synapsis.

Pachynema = Pachytene

- Coiling, shortening and thickening of chromosomes continues
- There is intimate pairing of chromosomes called **synapsis**
- Synapsed homologs are clearly seen to be composed of two chromatids. (i.e pairing of homologue is completed)
- There is formation of chiasmata (i.e a point at which non-sister chromatids have undergone genetic exchange through the process of crossing over)
- Physical homologues exchanges that result in chromosomal crossing over occur during pachynema.

Diplonema = Diplotene

In diplonema stage, there is

- Separation of homologues (except at points where chiasmata occur) is initiated
- Chromosomes continue to contract.
- Nucleolus begins to disappear

Diakinesis

This is the last stage of prophase I. In diakinesis stage, the following occur

- Chromosome reach maximum contraction
- Synapsed homologs become well spaced out in the nucleus.
- Chiasmata gradually terminalize i.e. they appear to move toward the ends of the arm and slips off. This process is called **TERMINALIZATION**
- The chromosomes continue to shortening
- Nucleolus disappear or break down
- Nuclear membrane degenerate
- Spindle fibre is formed.

METAPHASE I

- This is characterized by spindle formation
- Synapsed homologue chromosome arrived at the equator of the spindle
- Each tetrad interacts with spindle fibres, facilitating movement to the metaphase plate.

ANAPHASE I

There is separation event or disjunction during anaphase I. This means that one double chromosome of each pair separate and moving to each pole, thereby completing the process of terminalization.

- Occasionally error in meiosis occurs and separation is not achieved. The term non-disjunction is used to describe such an error.
- Anaphase I of meiosis is characterized by separation of homologous entire chromosomes
- Arrival of chromosome at the poles of spindle signal end of anaphase I.

TELOPHASE I

- This commences with the arrival of chromosomes at the poles
- Chromosomes may persist for a while in a condensed state.
- Nucleolus and nuclear membrane begin to reconstitute.
- Cytokinesis (division of cytoplasm) may occur

Meiotic telophase is shorter than the corresponding stage in mitosis

SECOND MEIOTIC DIVISION

This also involves four other phases called Prophase II, Metaphase II, Anaphase II and Telophase II.

PROPHASE II

- Chromosomes become visible as threadlike in cell, become condensed and thickened

METAPHASE II

- Chromosomes appear shorter than prophase II
- Each chromosome appears double and the two chromatids are joined by centromeres
- Centromere connecting pairs of chromatids move to a metaphase plate.

ANAPHASE II

The centromere connecting the chromatids after moving to the metaphase plate then divides into two halves and moves to opposite poles at anaphase.

TELOPHASE II

Telophase II reveals one member of each pair of homologous chromosomes present at each pole. At the completion of telophase II, four haploid cells or **TETRAD** have derived from each original diploid cell and each haploid cell now returns to an interphase state. Each chromosome is then referred to as **MONAD**.

Significance of meiosis

- i. There is the formation of four monoploid (haploid) nuclei from a single diploid nuclei in two successive divisions, thus balancing off the doubling of chromosome number that result from syngamy (the union of gametes or sex cells to form a zygote).
- ii. In animals, meiosis lead to the formation of gametes, while in plants, haploid spores are produced which in turn lead to formation of haploid gametes.
- iii. Through meiosis, there is maintenance of constant amount of genetic information between generations
- iv. There is also extensive genetic variation as a result of meiosis

Differences between mitosis and meiosis

S/No.	Mitosis	Meiosis
1	Mitotic division leads to the production of daughter cells whose chromosome numbers are identical with that of the parent cell.	Meiosis results in the production of four daughter nuclei instead of two in mitosis. The nuclear products of meiosis are genetically unlike the original diploid nuclei and genetically unlike each other.
2	Mitosis is also known as equational division	Meiotic division are divided into two successive divisions. First meiotic division is called reductional division because it results in halving the chromosome complement from 2N to N
3	Mitotic stage are very simple	Meiotic stages are very complex and continous process
4	There is no pairing or synapsed chromosomes in mitosis	Homologous chromosome paired in meiosis (i.e there is synapsis of chromosomes)
5	There is no crossing over event in mitosis	The haploid cells produced during meiosis are not identical to parent cell because of crossing over.

6 Separation of duplicated centromeres There is absence of this separation in meiosis. Until occur in mitosis second meiotic division

GAMETOGENESIS

The formation of gametes is known as gametogenesis. In male it is called **spermatogenesis**, while in female, it is called **Oogenesis**. The production of male gamete (sperm) is called spermatogenesis, while the formation of the ovum (ova) is called Oogenesis in female.

Spermatogenesis occurs in the testes of male animal whereas Oogenesis occur in the ovaries of the female animal.

SPERMATOGENESIS

Occur in the testes of male animal. It begins with growth of an undifferentiated diploid germ cell called **spermatogonium**. This cell undergoes enlargement to become primary spermatocyte which is still diploid. The primary spermatocyte has undergone first meiotic division to give secondary **spermatocytes** (haploid). The secondary spermatocytes then undergo the second meiotic division and each of this cell produces two **haploid spermatids**.

The spermatids go through a series of developmental changes called spermiogenesis and become highly specialized motile sperm or spermatozoa. All sperms produced during spermatogenesis received equal amount of genetic material and cytoplasm.

Spermatogenesis may be continuous or occur periodically in mature male animals. Animals that reproduce year round produce sperm continuously, while those whose breeding period is confined to a particular season produce sperm only during that time.

OOGENESIS

In animal, Oogenesis which is the formation of ovum (ova) or eggs occur in the ovaries, which is the female reproductive organ. The process begin with the growth of undifferentiated diploid cell called oogonium located in the nucleus. Surrounding the nucleus that accommodates the oogonium is the cytoplasm. The oogonium undergone enlargement to produce the primary oocyte which is still diploid. The diploid primary oocyte undergo first meiotic division to produce haploid secondary oocyte and the first polar body which is also haploid but the polar body do not have cytoplasm.

The secondary oocyte undergone second meiotic division to produce the haploid ootid and second polar body which is also haploid and has no cytoplasm. The ootid then differentiates to mature ovum. Unlike spermatogenesis, oogenesis may not be continuous. (**N.B:** Note that the first and second polar bodies do not have cytoplasm).