CELL DIVISION

Cells undergo a series of changes in their life time during which they produce new daughter cells. Indeed, every cell is formed from an already existing cell by cell division i.e. where a cell exists, there must have been a pre-existing cells.

Cell division occurs due to the presence of **chromosomes** in the nucleus of the cell. **Chromosomes** are thread like structures in the nucleus of the cell made of DNA molecules and histone protein. Structurally a chromosome contains a pair of elongated structures called **chromatids** which are joined together by the structure in the middle of the chromosomes called **centromere**.

A diploid cell (2n) is the one in which there 2 sets of chromosomes of which one set is inherited from the mother and another set from the mother. This implies that human beings have a chromosome number of 46 in their somatic cells or body cells and 23 chromosomes in their gamete cells. A **haploid** cell is one having only one set of chromosomes in the nucleus.

NOTE; the sequence of events which occur between one cell division and the next is called the *cell cycle.* Sister chromatids are pairs of chromatids located on the same chromosome while non-sister chromatids are pairs of chromatids located on different chromosomes. *Homologous* chromosomes refer to structurally similar chromosomes one obtained from the mother and another from the father during fertilization which exist in the nucleus of a somatic cell of an organism.

THE CELL CYCLE

This is the sequence of events which occur between one cell division and the next. A dividing cell duplicates its DNA and allocates the two copies of DNA to opposite ends of the cell and then splits into daughter cells, thereby making the daughter cells identical

Interphase. Prior to cell division, either mitosis or meiosis, the mother cell undergoes a preparation stage known as interphase. During interphase the chromosomes are usually seen as tiny coiled threads known as chromatids and are therefore described as invisible chromosomes because details of the chromosome structure cannot be seen. During interphase four important changes take place in the cells

In addition replication of the centrioles occurs in animal cells.

- There is synthesis of a lot of ATP so that there is sufficient energy for the next cell division.
- There is replication of cell organelles like mitochondria, endoplasmic reticulum, and Golgi body.
- There is synthesis of histone proteins, RNA and other types of proteins occurs
- The chromosomes are seen as tiny thread like structures that are highly coiled and therefore described as invisible.
- The nucleus becomes enlarged and thin

Interphase is divided into three stages, namely $\mathbf{G_1}$, **S** and $\mathbf{G_2}$. The following occur at each stage of interphase

$\mathbf{G_1}$	- Intensive cellular synthesis occurs in which many new cell organelles are made - metabolic rate increases -the cell grows
S	-DNA & chromosome replication occurs -histone proteins are synthesised

G_2	-intensive cellular synthesis - mitochondria replicate -mitotic spindle begins to form

N.B: There are two forms of cell division which occur in both mitosis and meiosis which are;

- Nuclear division. This is where the contents of the nucleus divide and is distributed in the daughter cells.
- Cytokinesis. This is where the cytoplasm content divides and is distributed in the daughter cells.

MITOSIS

This is a type of cell division in which the mother cell divides into two identical daughter cells which are similar to the mother cell with the same number of chromosomes as the mother cells.

STAGES OF MITOSIS

1. PROPHASE

This is the longest stage of cell division. It is sub-divided into two sub stages, early prophase and late prophase. During early prophase the following changes occur in the cell;

- Establishment of the poles and migration of the centrioles to opposite poles of the cell. In case of animal cells.
- The centrioles begin to synthesis spindle fibers that grow towards the nuclear membrane.
- The chromosomes coil and condense (shorten & fatten) and become visible as single threads with bead like structures in the middle known as centromere.
- The nucleus starts shrinking.

By the late phase the following changes will have taken place in the cell;

- Further condensation of chromosomes takes place and each chromosome is seen to consist of a pair of chromatids joined at the centromere i.e. the chromosomes become visible.
- The spindle fiber development is completed and these meet at the centre of the cell a point known as the equator of the spindle.
- The nucleus completely disappears.
- The nuclear membrane completely breaks down.

Note:

- An aster refers to a radial array of short microtubules that extend from a centromere to the cell surface.
- Spindle fibres originate from Golgi apparatus in plant cell
- A centrosome is non-membranous region at the pole of the cell containing centrioles which organizes the microtubules of the cell

2. **METAPHASE**

This is the second stage of mitosis also having early metaphase and late metaphase. During this stage the chromosomes line up at the equator of the spindle independently attached by their centromere to the spindle fibers i.e. homologous chromosomes do not associate together.
At late metaphase the sister chromatids slightly repel each other at the centromere due the contraction of the spindle fibres which also occurs slightly, thereby orienting the chromatids towards opposite poles.

3. ANAPHASE

This is the third and shortest stage of mitosis. It is divided into early anaphase and late anaphase. During early anaphase, the centromere split and the spindle fibers contract and start pulling the daughter centromeres formed together with the sister chromatids attached to opposite poles of the cell, the fibres continue coiling thereby becoming shorter and this process uses a lot of energy in form of ATP.
By late anaphase the chromatids will have reached the poles of the cell.

4. TELOPHASE

This is the last stage of mitosis and it involves the following changes;

- The chromatids at the pole uncoil and lengthen to form chromatin and become invisible again i.e. the chromatids become chromosomes which uncoil and gain their thread like nature
- The nucleolus and nuclear membrane reappears.
- The spindle fibers breakdown
- A nuclear membrane reforms around the chromosomes at each pole.
- The cell constricts in the middle which separates the mother cell into two daughter cells each having the same number of chromosomes as the mother cell.

Separation of the mother cell into two daughter cells including the division of the cytoplasm is described as cytokinesis. Cytokinesis in animal cells is brought about by the alignment of the micro filament in the middle of the cell. When the microfilament contract, a furrow is formed from either side of the cell and when these furrows become big enough, the mother cell divides into two daughter cells.

Cytokinesis in plant cells

Mitosis in plant cells is similar to that in animal cells except that,

- Plants do not have centrioles and their spindle fibers are produced by the Golgi body
- in plants does not involve formation of furrows but instead a primary cell wall develops in the middle of the mother cell to separate it into two daughter cells.
- The development of the primary cell wall begins with small vesicles that line up across the mother cell and eventually fuse together to form a cell plate which later becomes the primary cell wall

Importance of mitosis

- It maintains the chromosome number of the daughter cells similar to that to the parent cell i.e. it creates genetic stability.
- It promotes growth and repair of the body as it increases the number of cells within an organism to cause growth. In addition cells are constantly dying and being replaced by mitosis to form new cells.
- It is a basis for sexual reproduction.
- It promotes formation of gametes in organisms that reproduce by parthenogenesis (in animals) e.g. male bees called drones, aphids i.e. the development of an organism from unfertilized eggs e.g. bees, aphids and parthenocarpy in plants e.g. pineapples.
- Mitosis enables regeneration to occur. During regeneration, some animals are able to regenerate (re-develop) whole parts of their bodies such as legs in crustacean and arms in starfish.

MEIOSIS

- This is the form of cell division in which the diploid mother cell undergoes two successive nuclear divisions to form four haploid daughter cells which are genetically different from each other and also have half the number of chromosomes of the mother cell.

STAGES OF MEIOSIS

Meiosis is sub divided into two phases i.e. meiosis I (first meiotic division) and meiosis II (second meiotic division), each of which is subdivided into four stages namely: prophase, metaphase, anaphase and telophase.

MEIOSIS I

1. **Prophase I.** This is the longest part of meiosis 1 and it is subdivided into five sub stages namely;
   a. **Leptotene**
      This is the first step of prophase I and it involves the following changes
      - Establishment of the poles of the cell
      - The centrioles migrate to opposite poles of the cell
      - The centrioles begin to synthesize spindle fibres
      - The chromosome begin to condense and are seen as single threads with beadlike structures in the middle called centromeres
      - The nucleolus and the nuclear membrane begin to break down and eventually they disappear completely

   b. **Zygotene**
      In this stage, **f**urther condensation of the chromosomes occurs and each chromosome is seen to consist of a pair of sister chromatids joined at the centromere.The homologous chromosomes move close to each other, one from the male parent and the other pair from the female parent.
      The process by which the homologous chromosomes come together in prophase I of meiosis to form a pair of bivalent is known as **synapsis**.
      The homologous chromosomes move close together to form a pair called **bivalen**t of which one pair comes from the male parent and the other pair from the female parent.

   c. **Pachytene**
      At this sub stage the homologous chromosomes repel each other and are partially separate but remain joined together at a point called **chiasma**.
      In this stage the non-sister chromatids of the homologous chromosomes overlap and join together at a points known as chiasmata. At the chiasmata the non-sister chromatids break as the homologous chromosomes continue repelling each other and then the broken segments portions which contain genes are exchanged between the non-sisters chromatids to form new chromosomes.
      This process by which the non-sister chromatids break and exchange their genetic material is known as **crossing over**. This is the basis for genetic variation among the gametes and among the off springs that are formed later. During crossing over, the genes from one chromosome are exchanged with the genes from the other chromosome in a pair, leading to a new combination of genes in the resulting chromatids.
      Note:
      - Crossing over occurs by chance in the chromosomes
      - The chromosomes formed by the exchange of genetic material during crossing over are called recombinant chromosomes and the gametes which contain such chromosomes are called **combinantchromosomes**.
      - Chromosomes which do not undergo crossing over are known as parental chromosomes

   d. **Diplotene**
      In this stage, the chromatids of homologous chromosomes continue to repel each other and this makes bivalents to assume particular shapes depending upon the number of chiasmata.

e. **Diakinesis (Terminalisation)**
During diakinesis continued repulsion of homologous chromosomes occurs between the homologous chromosomes that are still fixed by chiasmata, this pushes the chiasmata towards the ends of the chromatids a process known as **terminalisation**.However the chiasmata remains holding the non-sister chromatids towards the end of the chromatids.
After terminalisation, the chromosomes completely separate and this marks the end of prophase I.

2. **Metaphase I**
During this stage, the homologous chromosomes live up together at the equator of the spindle inform of bivalents. The chromosomes occupy one spindle fibre at the equator of the spindle and so the chromosomes are said to have associated.
During this stage chromosomes are distributed randomly at the equator of the cell and **segregate (separate) independently** which leads to the mixing of genes in the daughter cells formed at the end of meiosis. This results into genetic variation.
3. **Anaphase I**
The spindle fibers undergo spiral coiling thereby pulling the homologous chromosomes on them to opposite poles due to contraction of the proteins that make up these fibres. The homologous chromosomes part company and move towards the pole of the cell. By late anaphase1, the chromosomes will have reached the poles.
4. **Telophase I**
This stage occurs when homologous chromosomes arrive at the poles. The following events take place;
   - The mother cell constricts to divide into two daughter cells.
   - Homologous chromosomes regain their thread-like nature at the poles and become invisible again
   - The nucleolus and the nuclear membrane reappear so as to enclose the chromosome.
   - The spindle fibers breakdown and cytokinesis then occurs as in mitosis.
     This halves the diploid chromosome number into the haploid number into the two daughter cells. The chromosomes arrange themselves across the middle of the two daughter cells and each daughter cell undergoes a second meiotic division to form two more daughter cells.

MEIOSIS II

After meiosis II, each of the daughter cells formed enters a short interphase period. During this period, the cells synthesize more ATP and replication of cell organelles such centrioles occur. **However**, during this interphase period replication of DNA chromosomes does not occur. Meiosis II is also sub divided into four stages namely; prophase II, metaphase II, anaphase II, and telophase II.

two haploid daughter cells formed in meiosis I immediately undergoe metaphase II in most cases, prophase II is very rare BUT when it occurs the following events occur;

- The centrioles move to opposite poles
- The nucleolus and nuclear membrane break down
- New spindle fibres are formed in each of the two daughter cells of meiosis I

a. **Metaphase II**
The chromosomes line up individually on the equator of the spindle as in meiosis.

b. **Anaphase II**
The centromeres split and chromatids of the two chromosomes in each cell separate and move to opposite poles due to spiral coiling of spindle fibers.

c. **Telophase II**

Each cell divides by constricting across in the middle. The chromatids unwind and become indistinct so as to become chromosomes. Four new cells form each half the number of chromosomes compared to the original parent cell. The genetic compositionof a chromosome is altered by the crossing over of prophase I and events of metaphase I.
As in mitosis the spindle fibers disappear and the nucleus, nucleolus as well as the nuclear membrane reform such that the cells enter interphase.

Importance of meiosis

- It leads to the production haploid gametes in sexual reproduction.
- It brings about genetic variation among organisms which is a raw material for evolution of new species.
- It maintains the diploid chromosomes number of organisms by ensuring that doubling of chromosomes at each succeeding generation does not occurs. When gametes with haploid number of chromosomes fuse together at fertilization to form the zygote, the diploid number is restored in the offspring form.

Meiosis brings about genetic variation in the following ways

- By crossing over between homologous chromosomes during the pachytene stage of prophase I which separates linked genes on the chromosomes and rearranges these genes which were originally located on the same chromosome. This leads to a variety of new gene recombinations on the chromosome in the daughter cells which leads to genetic variation.
- During metaphase I, homologous chromosomes are distributed randomly at the equator of the cell and aggregate independently leading to the mixing of genes in the daughter cells formed.
- It results into the formation of haploid cells (gametes) which when fused randomly at fertilization results into off springs with different genetic constitution due to the recombination of the parental genes.

COMPARISON BETWEEN MITOSIS AND MEIOSIS

SIMILARITIES

- Both involve four stages of cell division namely; prophase, metaphase, anaphase and telophase.
- Both require the interphase period before they occur.
- Both are energy consuming processes i.e. they require ATP.
- Both can lead to the formation of gametes.
- Both involve condensation of the chromosomes.
- Both involve nuclear division and cytokinesis.

DIFFERENCES

MITOSIS	**MEIOSIS**
It results into formation of two daughter cells	It results into formation of four daughter cells
Daughter cells which identical to the mother cell	Daughter cells are different to the mother cell
It occurs in somatic cells during growth and developing and in asexual reproduction	It occurs during the formation of gametes in germ cells
No crossing over occurs	Crossing over occurs.

It occur in haploid, diploid and polyploidy cells	It occurs in diploid cells only
Prophase is sub divided into early and late stages	Prophase I is sub divided into five stages namely; leptotene, zygotene, pachytene, diplotene and diakinesis.
Chiasmata are not formed	Chiasmata are formed
Homologous chromosomes do not associate	Homologous chromosomes associate
There is no formation of bivalents	Bivalents are formed in prophase I.
It involves only one nuclear division	It involves two successful nuclear divisions