Unit 4:

Cell Reproduction

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4.1 Cell cycle

- **A cell cycle** is a sequence of events that takes place in the parent cell as a means of distributing genetic materials thereby forming daughter cells.
- **The cell cycle** are an ordered series of events involving cell growth and cell division that produces two new **daughter cells**.
- There are two main divisions of the cell cycle:

✓ Interphase and

✓ cell division.

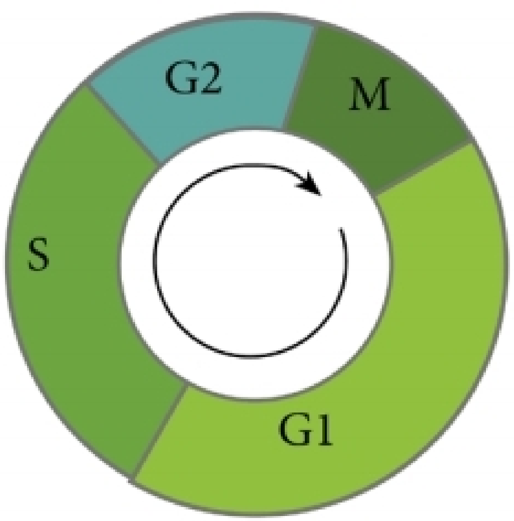
❑ **Interphase** is divided into three phases called G1, S, and G2.

➢ **G1 Phase (First Gap)**: is the first stage of interphase.

- cells are quite active metabolically.
- They accumulate the building blocks of chromosomal DNA and the associated proteins
- They store sufficient energy reserves to complete the task of **replicating** each chromosome in the nucleus.

- **S Phase (Synthesis of DNA)**: is the stage of DNA replication (Synthesis).
- **G2 Phase (second gap):** is the stage where the cell **replenishes its energy stores** and **synthesizes proteins** necessary for chromosome manipulation and movement.

- Some cell organelles are duplicated.
- Cells may continue growing during the G2 phase.
- Cells make the final preparations before entering into the mitotic phase.



G1 - growth

S - DNA synthesis

G2 - Growth and preparation for mitosis

M - Mitosis

Figure 4.1 Stages of the cell cycle

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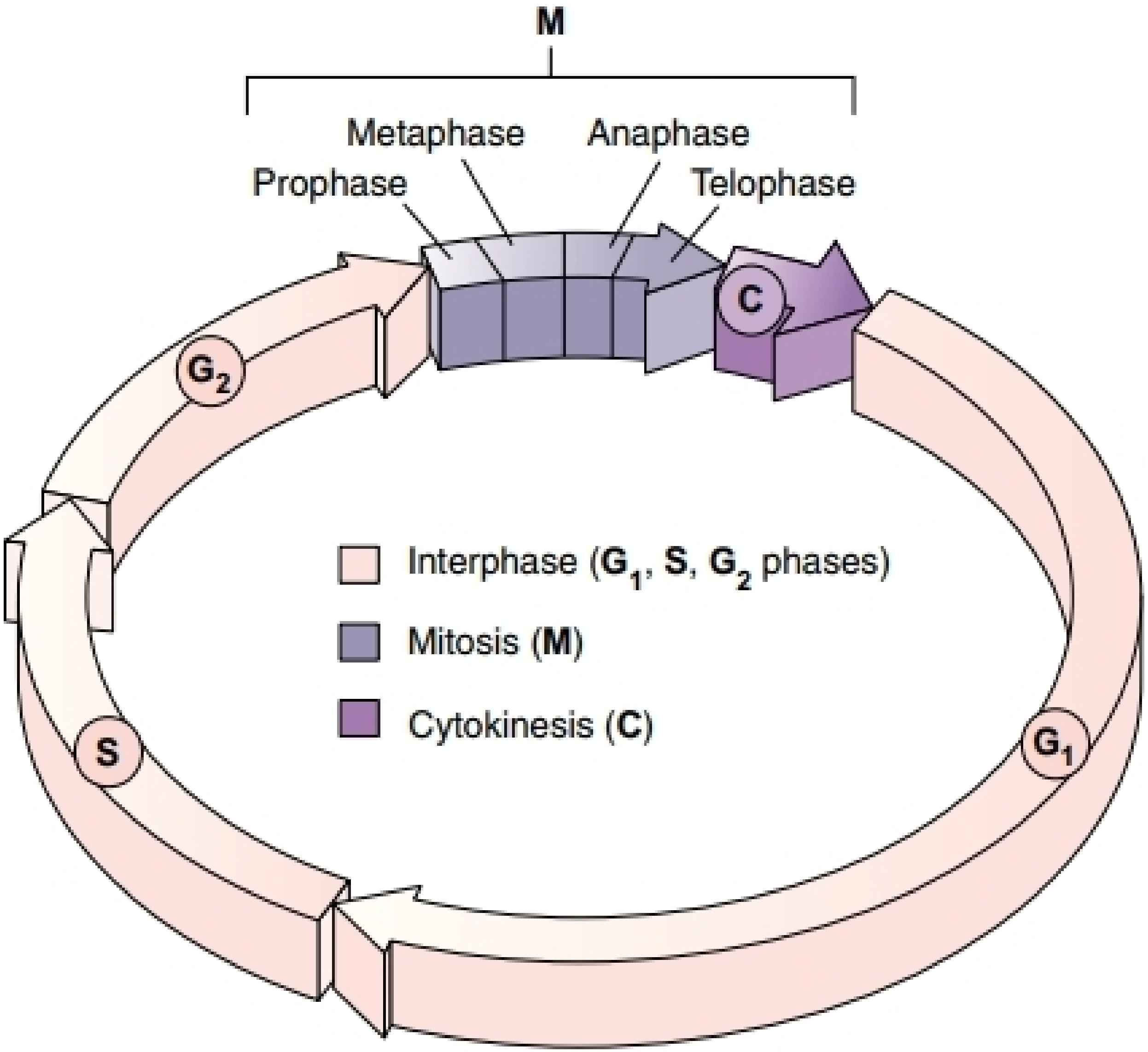

M
Metaphase
Anaphase
Prophase
Telophase
C
G2
S
G1
Interphase (G1, S, G2 phases)
Mitosis (M)
Cytokinesis (C)

- **The cell cycle/cell division** has an internal controlling system that enables it to follow regular pattern.
- If such regulatory system fails to work properly, the cells excessively divide,
- this may be called “cell madness”.

❖ Cancer can start when the controlling factors over cell division and cell growth fail.

- Cancer occurs in the absence of growth factors allowing a cell to divide continuously at very high density at the expense of other normal cells

❖ **Cancer cells can have a number of problems**:

•They might not be able to communicate with healthy cells.

•They may not be able to carry out normal cells.

•They may not securely anchor themselves like other cells do, which can make them more likely to travel somewhere and spread to other parts of the body.

4.2 The Cell division

- Cell division is a basic process in all living things where a parent or mother cell, divides into two daughter cells.
- As the cell grows the volume of cytoplasm relative to the cell membrane will be small that it will have low surface area to volume ratio.
- As a result material transport across the cell membrane by simple diffusion will be inadequate for the cell to survive.
- as the size of the cell increases the controlling power of the nucleus is highly minimized.
- Cell division consists of two sub divisions

i) Nuclear division (Karyokinesis) – results in the separation and distribution of duplicated genetic materials of mother cell (dividing cell) to daughter cells by **mitosis or meiosis**.

ii) Cytokinesis (cytoplasmic division) - is the separation of the cytoplasmic components into the daughter cells.

4.2.1 Mitosis

- **Mitosis** is a type of nuclear division where duplicated chromosomes of a single mother cell are distributed between two identical daughter cells,
- have the same number chromosomes as the parent nucleus.
- a **diploid** (2n) mother cell gives rise to **two diploid** (2n) identical daughter cells.
- The term **mitosis** was first coined by **Walther Flemming** in 1882 when he discovered that chromosomes during cell division split longitudinally to distribute themselves equally between two daughter cells.
- The end result of mitosis is:
  - ✓ growth of the eukaryotic organism and
  - ✓ replacement of damaged or dead cells.

- After fertilization (union of sperm cell and egg cell), the growth of the zygote occurs by cell division through mitosis into the 2 – cell stage, then 4 – cell stage, 8 – cell stage, 16 – cell stage, and so.
- This is called **Cleavage**.
- **The mitosis cell division** is divided into a series of phases namely; prophase, metaphase, anaphase, and telophase.

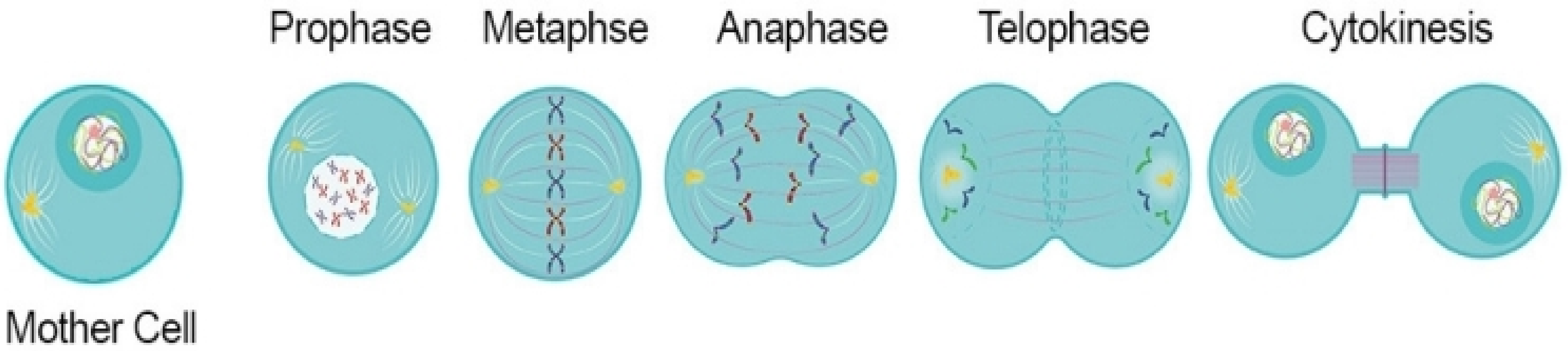

Figure 4.2 Illustration of cell division by mitosis

1. Prophase (the "first phase"): During this phase

- ✓ each duplicated chromosome, composed of two sister chromatids and, containing identical genetic material pairs up.
- ✓ the nuclear membrane breaks down, the nucleolus disappears.
- ✓ chromosomes shorten, thicken and become visible.
- The centrosomes begin to move to opposite poles of the cell, and spindle fibres emerge from the centrosomes (two in numbers and located outside the nucleus)

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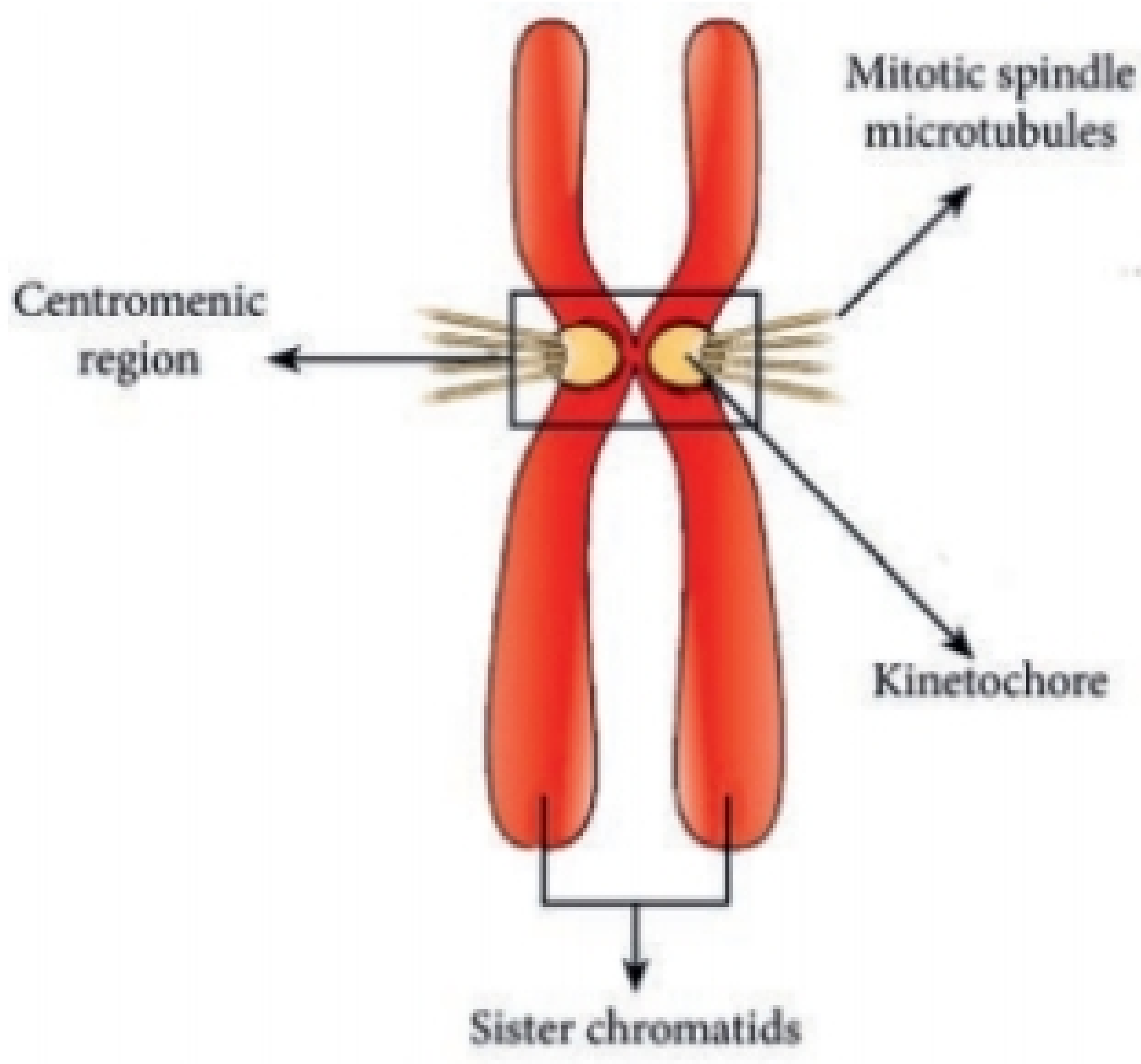


Figure 4.3 Sister chromatids: Mitotic spindle emerging from the centrosomes

2. Metaphase (arrangement phase) During this phase

- ✓ mitotic spindles are fully developed with centrosomes at the opposite poles.
- ✓ chromosomes line up (arrange themselves) end–to–end along the centre or metaphase plate (equatorial plane) of the cell.
- ✓ each sister chromatids are attached to a spindle fibre originating from opposite poles.

3. Anaphase (migrating phase) During this phase

- ✓ cohesion proteins binding the sister chromatids together known as centromere, breakdown.
- ✓ separated sister chromatids are pulled apart by the mitotic spindle which drags one chromatid to one pole and the other chromatid to the opposite pole.

4. Telophase (a reverse of prophase)

- ✓ nuclear membrane reappears and surrounds each set of chromosomes to create two new nuclei arriving at opposite poles.
- ✓ The mitotic spindle breaks down and disappears.
- **Cytokinesis** (cytoplasmic division), will take place after the four stages of mitosis (nuclear division) are completed.
- However, its completion in animal cell is different from plant cell.
- As animal cell is surrounded only by cell membrane, cytokinesis enables the cytoplasm of the mother cell to pinch or constrict in the middle.
- As a result the two daughter cells entirely separate.

- However, as plant cell is surround by hard cell wall in addition to the cell membrane ,
- the cytoplasm cannot simply pinch off and fully separate;
- the two adjacent cells remained joined together by the middle wall – called **middle lamella**.
- The process of mitosis is important to increase cell number, which in turn is essential for growth.
- The union of haploid (n) sperm and haploid (n) egg started as a zygote, which is diploid (2n).
- Then the zygote by repeated cell division through mitosis develops into **multicellular organism**.
- we human beings are made up of million cells
- **Unicellular organisms** like Amoeba also use cell division through mitosis to increase their number or population.

- **Spindle fiber** – is long protein fiber extending from structures called centrioles.
- It starts from the pole of the cell and extends up to the centre, where it is linked to duplicated chromosomes arranged for distribution.
- It is necessary to pull chromosomes separated towards the pole during the anaphase stage of cell division.

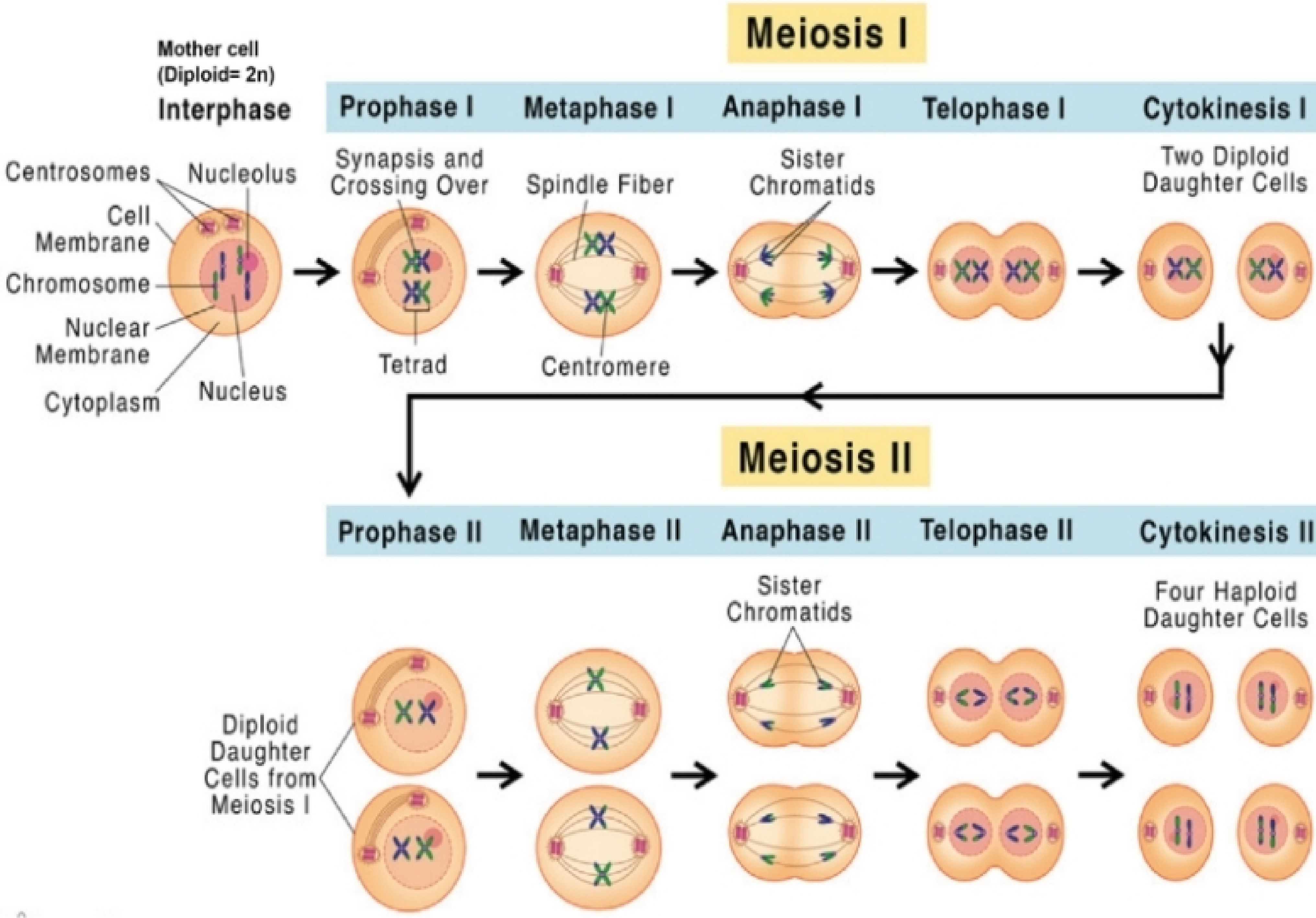
➢ **Homologous chromosomes** – are couples of one maternal and one paternal chromosome paired up during fertilization.

- They are paired chromosomes, each of which represents a parent for a unit character such as height, body colour, sex etc.
- The best analogy for homologus chromosomes, is **paired shoe** with the same number.

➢ **Sister chromatids**: Two copies of one maternal or paternal chromosome linked together by cohesive protein on the centromere.

4.2.2 Meiosis

- The process of meiosis is a characteristic feature of organisms that reproduce sexually.
- It occurs in reproductive organs such as ovaries of female animals, testes of male animals, anther and ovules of flowering plants.
- during gametogenesis (gamete formation) in human ovaries and testes, the 46 chromosomes in the initial mother will be reduced by half to 23 chromosomes by meiosis.
- As a result, the sperm or egg cells nuclei will have 23 chromosomes (haploid(n)).
- So, when sperm and egg join together at fertilization, a zygote that contains the normal number of 46 chromosomes (23 pairs, Diploid abbreviated as 2n) will be formed.



- **Figure 4.4** Illustration of meiosis I and Meiosis II

Table 4.1 Description of the different stages of Meiosis I and Meiosis II

Stage	Description
Prophase I	Each chromosome appears shortened and thickened form two chromatids Homologous chromosomes pair up
Metaphase I	Chromosomes align on spindle fiber; lining up in the middle or metaphase plate
Anaphase I	The centromere joining sister chromatids do not separate The pair of chromatids from each homologous pair moves to the end (pole) of the cell. Reduction to haploid (n) will take place because homologous chromosomes of male and female parents separate
Telophase I	The nuclear membrane reforms and the cells begin to divide. In some cells, the cell continues to full cytokinesis while in other cells there may be prolonged interphase but with no further DNA duplication
Prophase II	New spindles are formed and the chromosome, still made up of paired chromatids moves toward the middle of the cell.
Metaphase II	The chromosomes line up in the metaphase plate , with the spindle attached to the sister chromatids of each chromosome coming from the opposite poles.
Anaphase II	The centromeres divide and sister chromatids separate and pulled to the opposite ends of each cell
Telophase II	Nuclear membrane reappears, the chromosomes return to the interphase state Cytokinesis follows giving four daughter cells each with half the chromosome number of the initial parent (mother) cell

Comparison of mitosis and meiosis

✔ **Similarities between them.**

- both involve replication of DNA and
- the formation of daughter cells.
- Separation of sister chromatids.

Mitosis	Meiosis
Somatic cells (normal body cells)	Germ cells found in reproductive (sex) organ
Same number of chromosomes as original cell	Half the chromosome number of original cell
Two daughter cells are formed	Four daughter cells are formed
Daughter cells identical to parent cells	Daughter cells different from parent cells
DNA replication Always occurs	DNA replication Always occurs at first meiotic division,

4.3 Renowned Ethiopian Geneticist

- Dr. Melaku Worede
- He, a geneticist and agronomist, is renowned for employing science to benefit poor farmers and saving Africa’s seeds from extinction.
- He was awarded the “**Right livelihood Award**” in 1989” for preserving Ethiopia’s genetic wealth by building one of the finest seed conservation centres in the world.”
- He played key role in the establishment of the Plant Genetic Resource centre in Addis Ababa, where he became Director in 1979 and served for more than 14 years – until retirement.
- He developed his pioneer work on a framing based native seed (landrace) conservation, enhancement and utilization.
- He was able to develop and grow locally adapted native seeds (e.g durum wheat) without commercial fertilizers or other chemicals.
- He was able to show that his native seeds exceeded their high in put counterparts on the average by 10 – 15% and the original farmers’ cultivars by 20 – 25% in yield.