H2

CORE IDEA 2: GENETICS AND INHERITANCE
TOPIC 2.1: Cell Division and the Cell Cycle

Learning Outcomes:

You should be able to:

(n) describe the events that occur during the mitotic cell cycle and the main stages of mitosis *(including the behaviour of chromosomes, nuclear envelope, cell surface membrane and centrioles)*

(o) (modified) explain the significance of the mitotic cell cycle *(including growth, repair and asexual reproduction)*

(s) describe the events that occur during the meiotic cell cycle and the main stages of meiosis *(including the behaviour of chromosomes, nuclear envelope, cell surface membrane and centrioles) (names of the main stages are expected, but not the sub-divisions of prophase)*

(t) explain the significance of the meiotic cell cycle *(including how meiosis and random fertilisation can lead to variation)*

References:

Campbell, N. A., Reece, J. B., et al. (2018). Biology A Global Approach (Eleventh Edition)

- Chapter 12 Mitosis, p284 – 299
- Chapter 13 Sexual Life Cycles and Meiosis, p304 - 317

Note: Some of these references (including previous editions) are available in our library. You may wish to borrow them or visit the links to supplement your reading when necessary.

Contents

A Bridge to O Level Biology (6093 syllabus),

You should be able to:

(a)	state the importance of mitosis in growth, repair and asexual reproduction
(b)	explain the need for the production of genetically identical cells
(c)	identify, with the aid of diagrams, the main stages of mitosis
(d)	state what is meant by homologous pairs of chromosomes
(e)	identify, with the aid of diagrams, the main stages of meiosis (names of the sub-divisions of prophase are not required)
(f)	define the terms haploid and diploid, and explain the need for a reduction division process prior to fertilisation in sexual reproduction
(g)	state how meiosis and fertilisation can lead to variation

Note that there are no cell division in 5078 syllabus (Science (Biology))

1 INTRODUCTION

The cell cycle comprises interphase, nuclear division and cytokinesis. There are two types of nuclear division: mitosis and meiosis.

- A cell cycle that involves **mitosis** will give rise to **genetically identical cells** and this is important for growth, repair and the asexual reproduction of organisms.

- A cell cycle that involves **meiosis** occurs in the reproductive organs of organisms and is important for sexual reproduction. Meiosis results in **gametes having half the amount of genetic material present in somatic cells**.

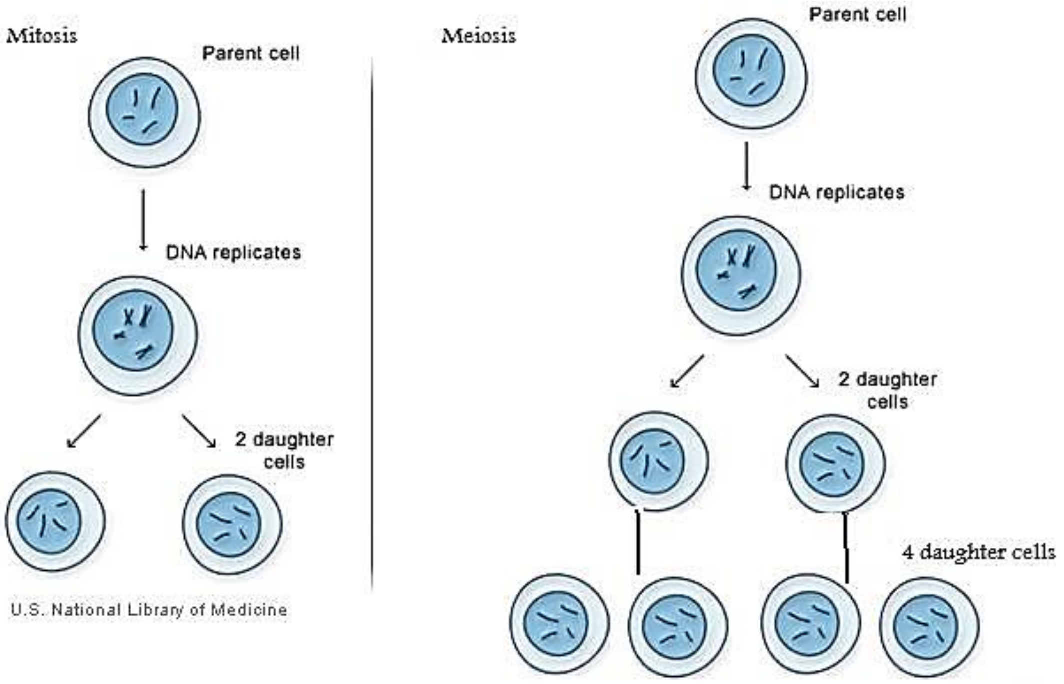


Fig. 1.1: Types of nuclear and cell division

OPTIONAL

There are some links in the SLS lesson to help you review and revise your knowledge on the following:

- *Cell Theory*

2 CHROMOSOMES IN A CELL

Homologous Chromosomes

In a **diploid** species, each type of chromosome is found in a pair and are called homologous chromosomes.

Homologous chromosomes **are similar** to each other as they

- are nearly identical in size;
- have the same banding pattern and same centromere location;
- have the same gene loci i.e. a gene found on one homolog will have a corresponding gene at the same position on the next homolog.

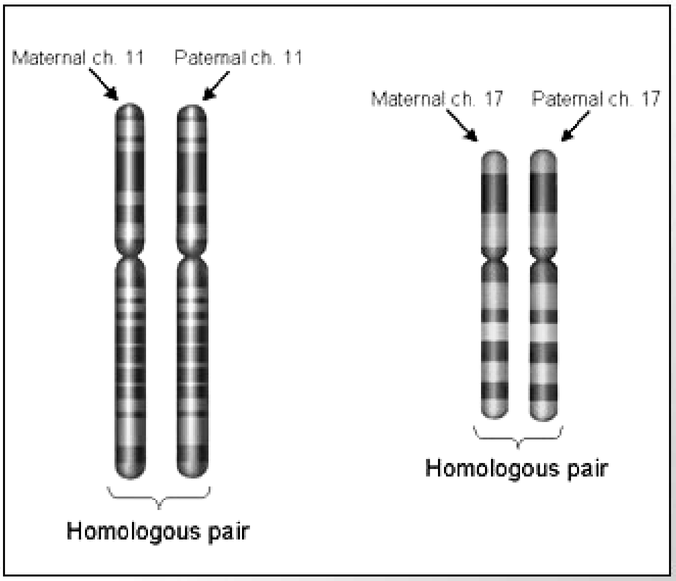


Fig. 2.1: Homologous chromosome pairs

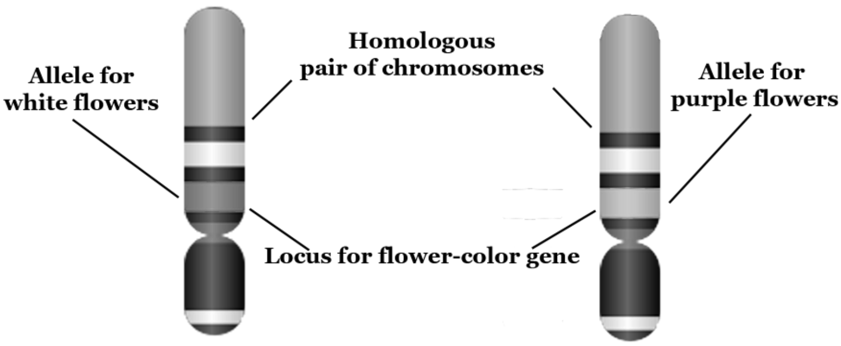


Fig. 2.2: Homologous chromosome pair

Homologous chromosomes are **not identical** to each other as they

- may have different alleles for the same gene;
- one chromosome originates from the male parent, while the other chromosome originates from the female parent.

OPTIONAL

There are some links in the SLS lesson to help you review and revise your knowledge on the following:

- *Karyotype and Homologous chromosomes*

Learning Outcome 2(n):

Describe the events that occur during the mitotic cell cycle and the main stages of mitosis *(including the behaviour of chromosomes, nuclear envelope, cell surface membrane and centrioles)*

3 PHASES OF THE MITOTIC CELL CYCLE

Cells do not divide continuously but undergo a regular cycle division separated by periods of cell growth. This is known as the cell cycle and has three stages.

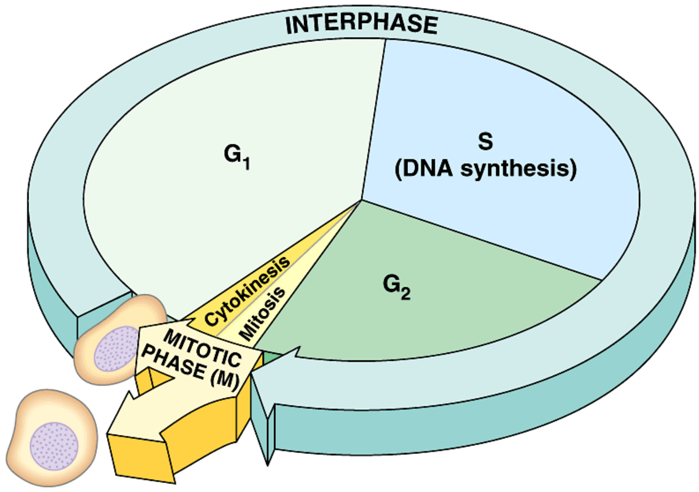


Fig. 3.1: A broad overview of the phases in the Cell Cycle

The cell cycle is divided into 3 stages, namely

- **Interphase**, which is sequentially further divided into 3 phases
  - Gap 1 (G_1) phase
  - Synthesis (S) phase
  - Gap 2 (G_2) phase
- **Mitotic phase**, which is sequentially further divided into
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase
- **Cytokinesis**

The duration of these cell cycle phases varies considerably in different kinds of cells.

3.1 INTERPHASE

Interphase occurs during most of the cell cycle, and is sometimes known as the resting phase, because no division takes place. However, interphase is marked by a period of intense chemical activity and sub-divided into three parts:

- First **growth (G_1) phase** is when the proteins from each cell organelles are synthesised are produced.
- **Synthesis (S) phase** is when the DNA is replicated.
- Second **growth (G_2) phase** is when organelles grow and divide, and energy stores are increased.

In summary, G_1 and G_2 are important phases to allow time for **cell growth**, **duplication of organelles**, **storing of energy** and **synthesis of proteins required for cell division**. G_1 and G_2 phases also provide time for the cell to monitor the internal and external environment to ensure that conditions are suitable and preparations are complete before the cell commits itself to the DNA synthesis and mitosis.

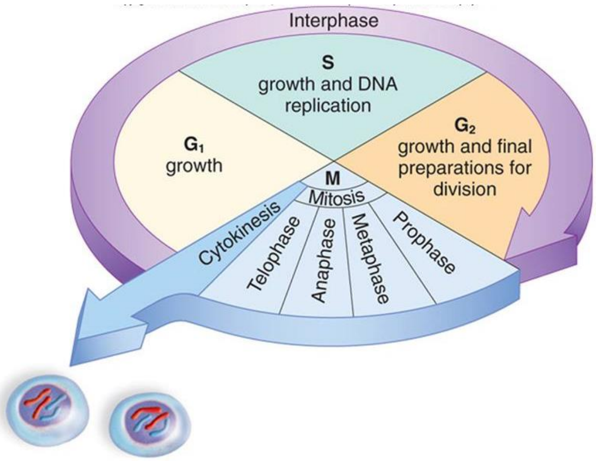


Fig. 3.1.1: Phases of the Cell Cycle

During interphase in eukaryotic cells, the **centrosome** duplicates.

The centrosome is the major **microtubule-organising centre (MTOC)** which comprised a **pair of centrioles.** Centrosomes are not present in plant cells because plant cells do not have centrioles.

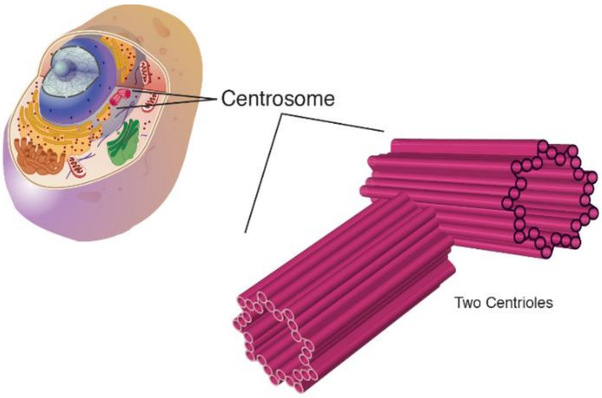


Fig. 3.1.2: Animal cell with centrosome

3.2 MITOSIS

Definition

Nuclear division followed by cytokinesis to form 2 **genetically identical** daughter cells with the same number of chromosomes and amount of DNA as the parent cell.

Stages of Mitosis

The mitotic division is divided into 4 phases – **(a) Prophase, (b) Metaphase, (c) Anaphase, (d) Telophase** after which cytoplasmic division known as **cytokinesis** will occur.

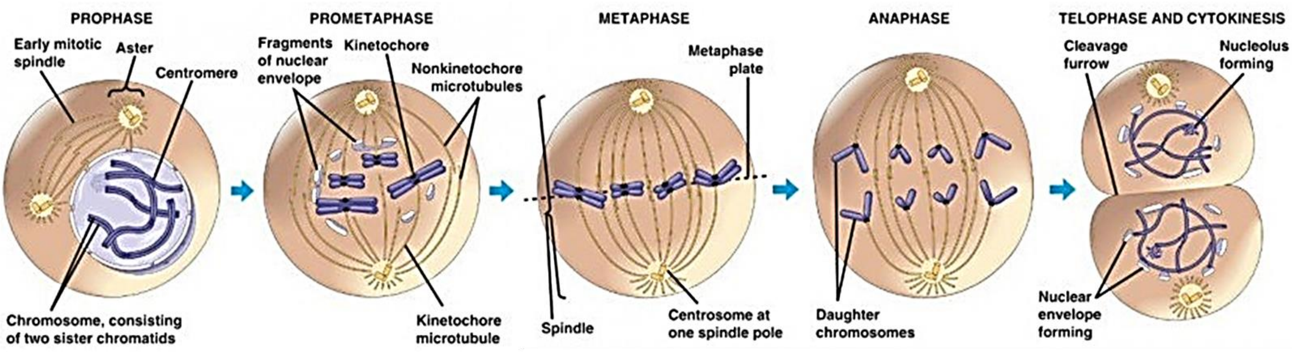


Fig. 3.2.1: Stages of Mitosis

a) Prophase

This is the longest phase of the cell cycle.

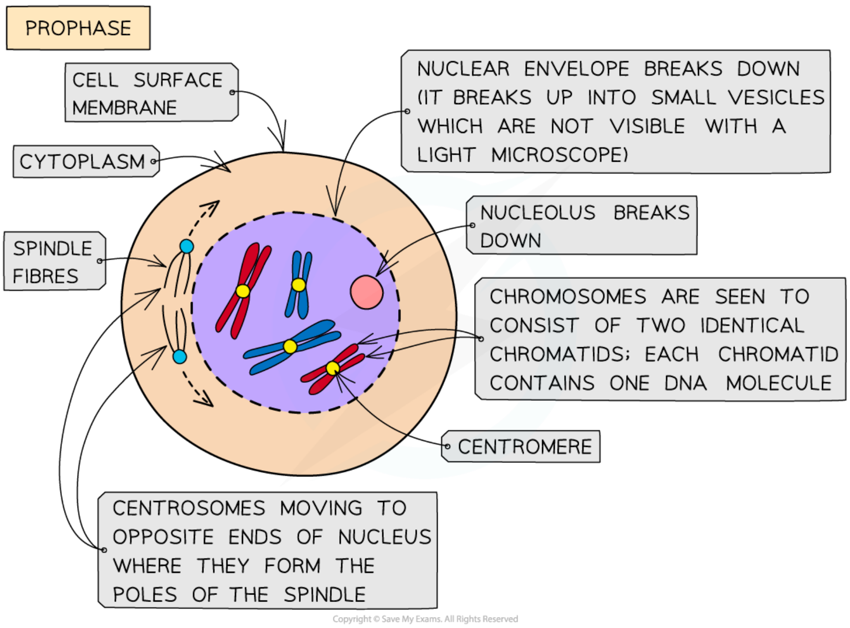


Fig. 3.2.2: Prophase

Behaviour of Chromosomes

- As DNA condenses, chromatin thread **shortens and thickens** to form visible **chromosomes**.
- Each chromosome appears as **2 sister chromatids held together at the centromere.**

Nucleus

- **Nucleoli disappear** and the **nuclear envelope breaks down** into small vesicles which disperse.

Spindle Fibres

- Outside the nucleus, **two centrosomes move towards opposite poles of cells and** organize microtubules into spindle fibres.

- Some **spindle fibres attach to the kinetochore (protein structure) at the centromere of the chromosome**. These spindle fibres are known as **kinetochore microtubules.**

Note that centromere is different from centrosome!

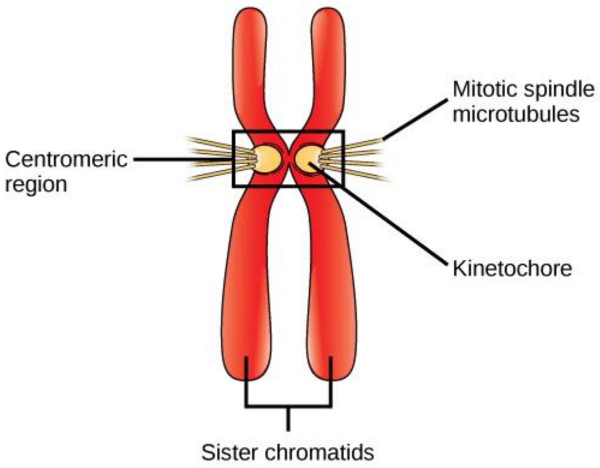


Fig. 3.2.3: Kinetochores on the chromosome

b) Metaphase

Behaviour of chromosomes

- **Chromosomes** will **randomly aligned** in a **single row at the metaphase plate**.

Nucleus

- Nucleus absent

Spindle fibres

- **Centrosomes** are now at **opposite poles** of the cell.
- The **kinetochore spindle fibres** will then attach to the kinetochore at the centromere region of the chromosomes.

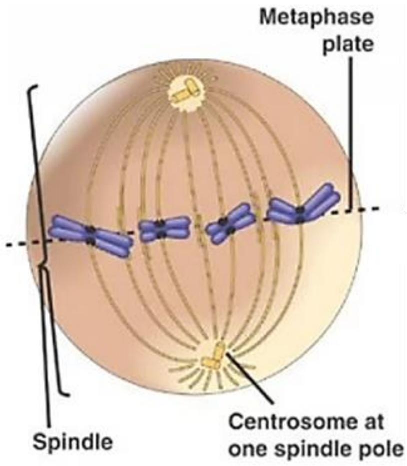


Fig. 3.2.4: Metaphase

c) Anaphase

Behaviour of chromosomes

- **Centromeres divide into two** and the **kinetochore microtubules shortens** to **pull sister chromatids apart**.

- Separated sister chromatids is each now known as a **chromosome.**

- Each daughter chromosome will be **led by its centromere to opposite spindle poles**.

Nucleus

- Nucleus absent

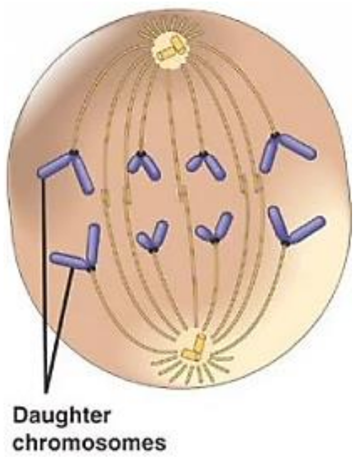


Fig. 3.2.5: Anaphase

Spindle fibres

- Kinetochore microtubules shorten, pulling the daughter chromosomes to opposite poles, centromeres first.
- **Non-kinetochore spindle fibres** from each pole **lengthen to elongate the cell.**

d) Telophase

Behaviour of chromosomes

- The two sets of daughter **chromosomes reach the respective spindle poles**.
- Chromosomes **decondense** to return to the original chromatin.

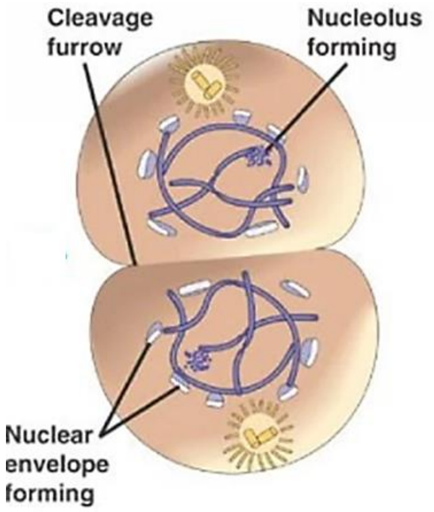


Fig. 3.2.6: Telophase

Nucleus

- **Nuclear envelope re-forms** around the chromosomes at each pole.
- **Nucleoli reappear** due to reorganization of the chromosomes within the nucleus.
- Two genetically identical daughter nuclei are formed.

Spindle Fibres

- **Spindle fibres disintegrate**.

3.3 Cytokinesis

- Cytokinesis is the final step of the cell cycle and involves the **division of the cytoplasm**.
- It typically **overlaps with the later stages of mitosis.**
- This process is different in animal and plant cells.

a) Cytokinesis in animal cells

- **Cell membrane invaginates** during end of telophase towards the centre of the elongated cell.
- A **contraction by ring of microfilaments** appears around the centre form a **cleavage furrow**.
- Furrow rapidly deepens until it completely divides the cell into two.

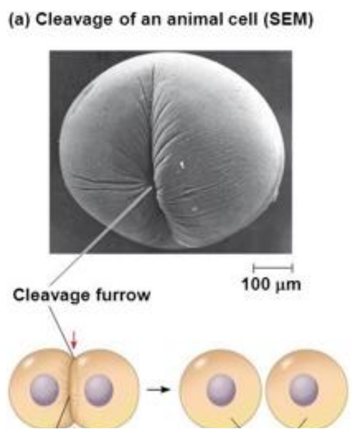


Fig. 3.3.1:
Cytokinesis in animal cell

b) Cytokinesis in plant cells

- **Golgi vesicles** move to the middle of the cell, **fuse to form the cell plate.**
- Vesicular contents contribute to the cell wall and its membranes form the cell surface membranes of the daughter cells.
- **Cell plate enlarges** until its surrounding membrane fuses with the plasma membrane along the perimeter of the cell, forming two daughter cells.

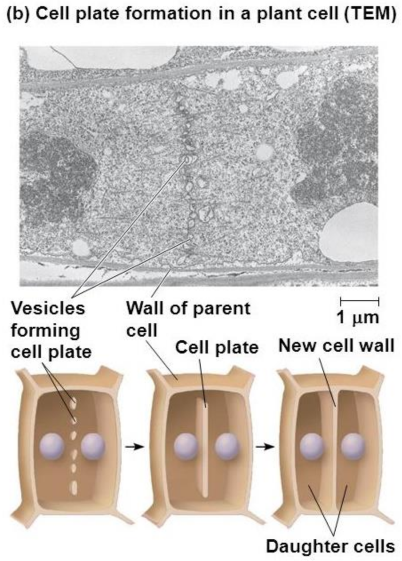


Fig. 3.3.2: Cytokinesis in plant cell

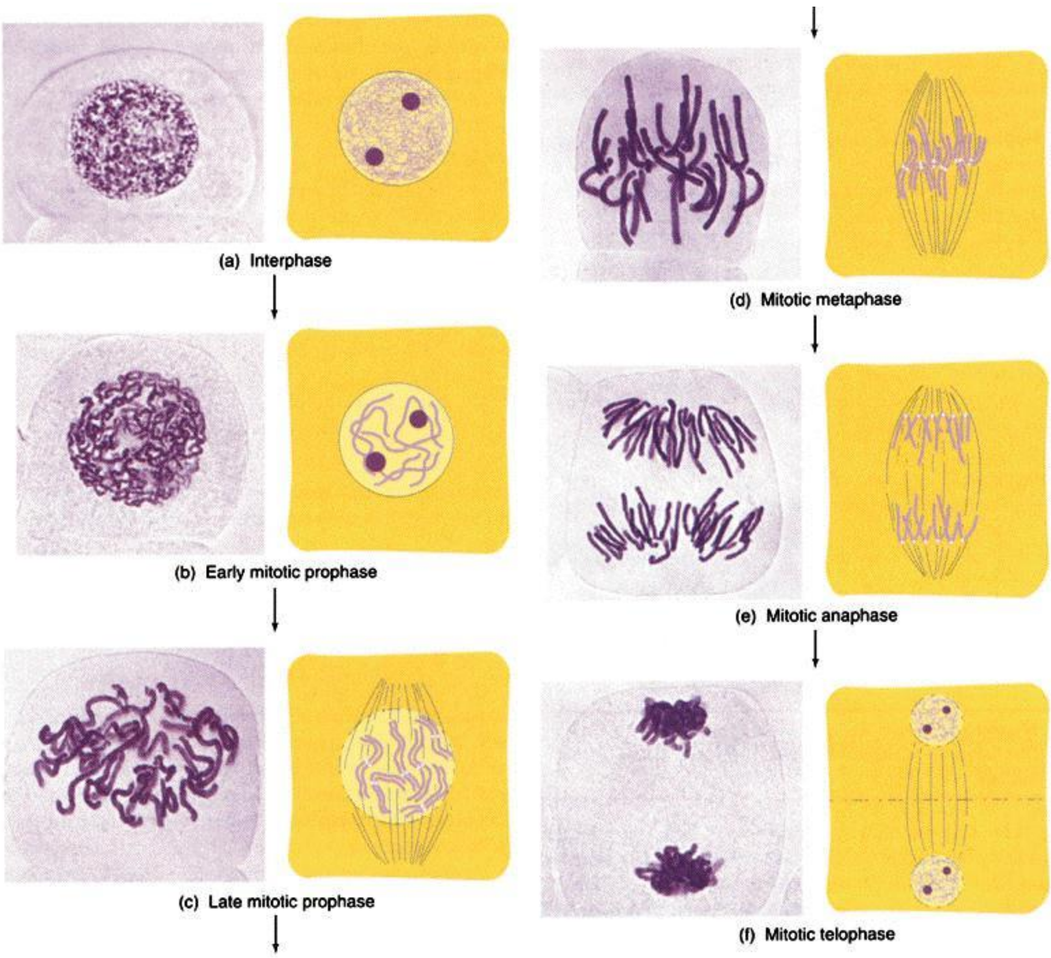


Fig. 3.3.3 Stages of mitosis in a plant cell

<u>CHECKPOINT 1</u>: Summarise the key points of *mitosis* and *cytokinesis* in the table below.

Stage + Sketch	**Behaviour of chromosomes**	**Nucleus**	**Spindle Fibres**
Prophase			
Metaphase			
Anaphase			
Telophase			

Cytokinesis in animal cells:	**Cytokinesis in plant cells:**

Learning Outcome 2(o) modified:

explain the significance of the mitotic cell cycle *(including growth, repair and asexual reproduction)*

4 SIGNIFICANCE OF MITOSIS

Mitosis results in 2 daughter cells containing the same number and type of chromosomes as the parental cell, hence **daughter cells are genetically identical to the parental cell**.

Mitosis hence allows for:

1. **Genetic Stability:** Daughter cells were directly derived from parent cell, similar to clones as there are no alternations in the genetic material, hence **maintaining the genetic stability** of an organism.

2. **Asexual Reproduction:** Cells of a parent organism can divide by mitosis to produce genetically identical daughter cells that can form new offspring.
   - Asexual reproduction is a relatively rapid form of reproduction because there is no delay as there is no need to search for a mate.
   - Hence, a large number can be quickly established to colonise the local area.
   - Examples include fungus, potato, onion, and ginger.

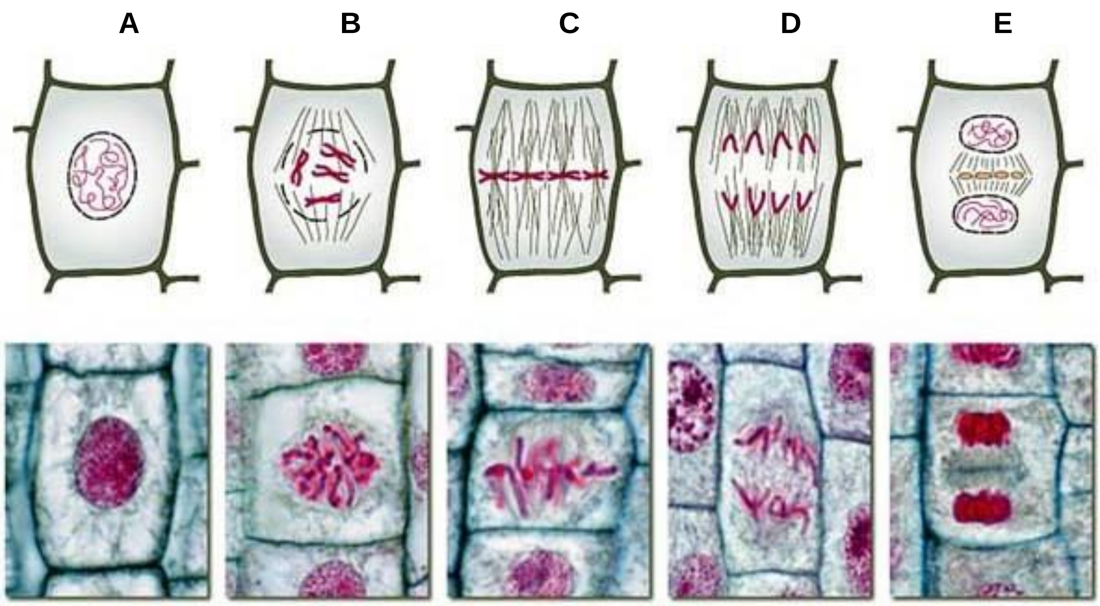
3. **Growth**
   - When two gametes fuse together to form a zygote, this cell has all the genetic information needed to for the new organism.
   - The cell first divides to give a group of genetically identical cells. This is growth by increase in cell numbers.

4. **Cell Repairment**
   - Mitosis supplies new cells required to repair worn out or damaged tissue.
   - Damaged and worn cells must be replaced by genetically identical cells to return a tissue to its former condition.

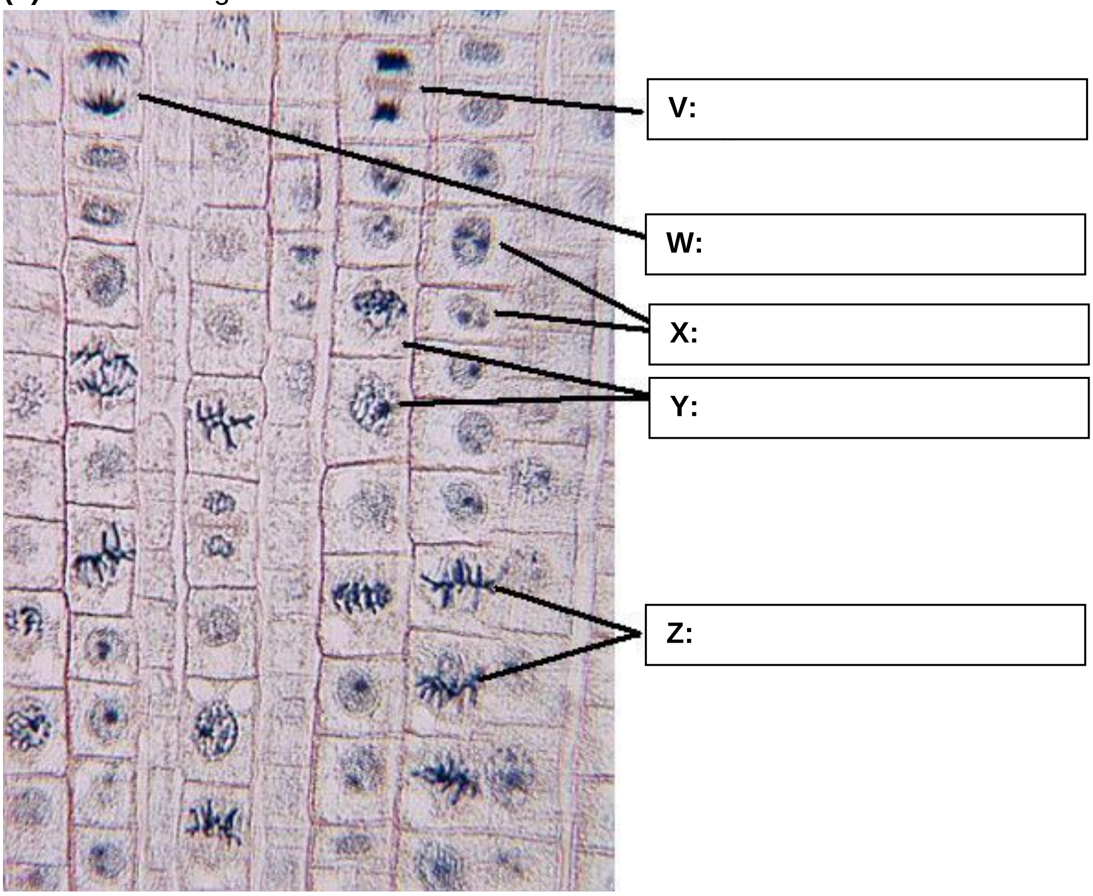
5. **Regeneration**
   - Some animals can regenerate whole parts of body (e.g. tail of lizard)
   - Regeneration involves the production of genetically identical cells to replace missing tissue.

CHECKPOINT 2

(a) State the stages of cell division that the cell is in for **A** – **E**.



(b) State the stages of cell division that the cell is in for **V** – **Z**.



Learning Outcome 2(s):
describe the events that occur during the meiotic cell cycle and the main stages of meiosis (*including the behaviour of chromosomes, nuclear envelope, cell surface membrane and centrioles) (names of the main stages are expected, but not the sub-divisions of prophase)*

5 PHASES OF THE MEIOTIC CELL CYCLE

5.1 MEIOSIS

Definition

Meiosis (*meio,* to reduce) is the **reductive division of a nucleus** to produce **4 daughter nuclei**, each containing **half the number of chromosomes** found in the original nucleus. A single **diploid** cell would give rise to **four haploid cells**. This occurs when one DNA replication is followed by two nuclear and cell divisions.

Daughter cells **may be genetically different** from the parental cell.

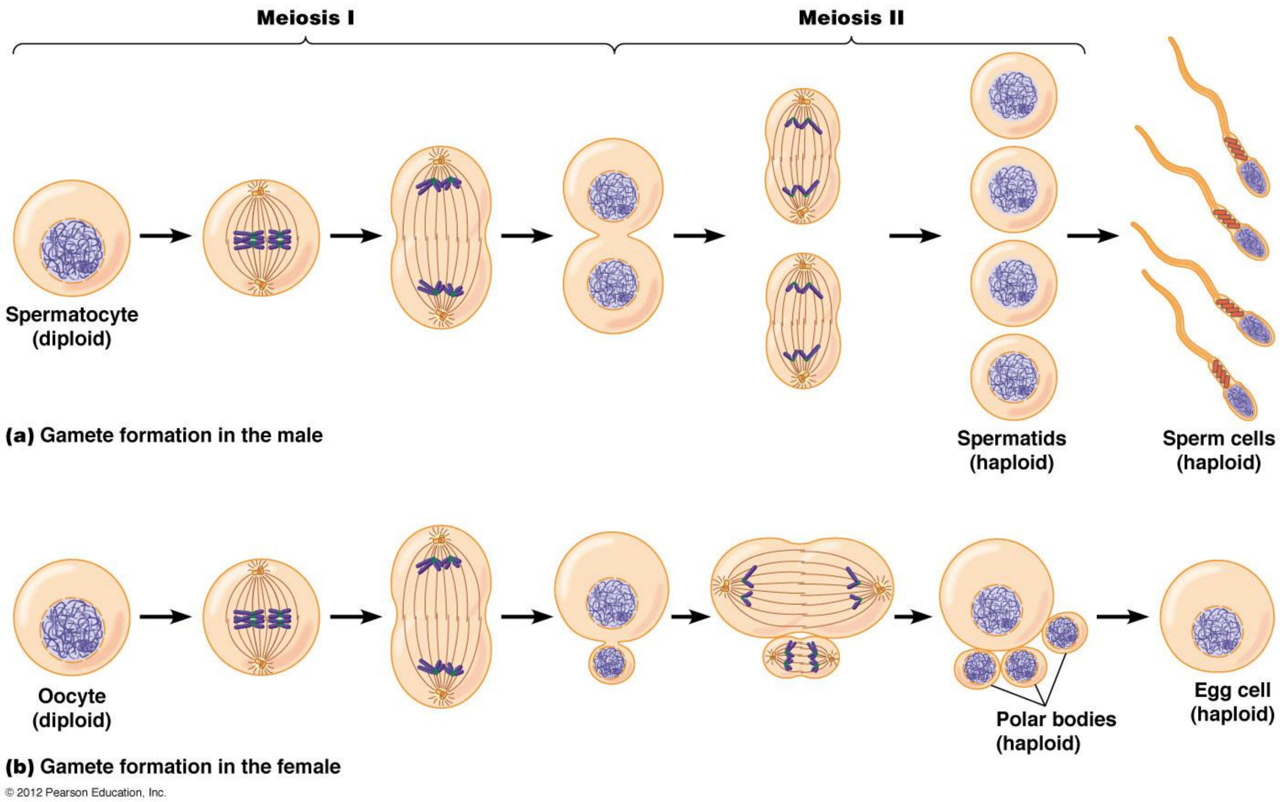


Fig. 5.1.1: Stages of meiosis in a human germ cell

Stages of Meiosis

Before undergoing nuclear division, the cell undergoes Interphase. The interphase stage is the same for all cells and involves G1, S and G2 phases.

In **S phase** of these interphase, **DNA replicates** so that the parent cell **contains twice the amount of DNA**. In G_2 phase, the centrosomes replicates.

The nuclear division is divided into 2 main phases with each phase further subdivided into another 4 sub-phases:

Meiosis I

- Prophase I
- Metaphase I
- Anaphase I
- Telophase I & cytokinesis

Meiosis II

- Prophase II
- Metaphase II
- Anaphase II
- Telophase II & cytokinesis

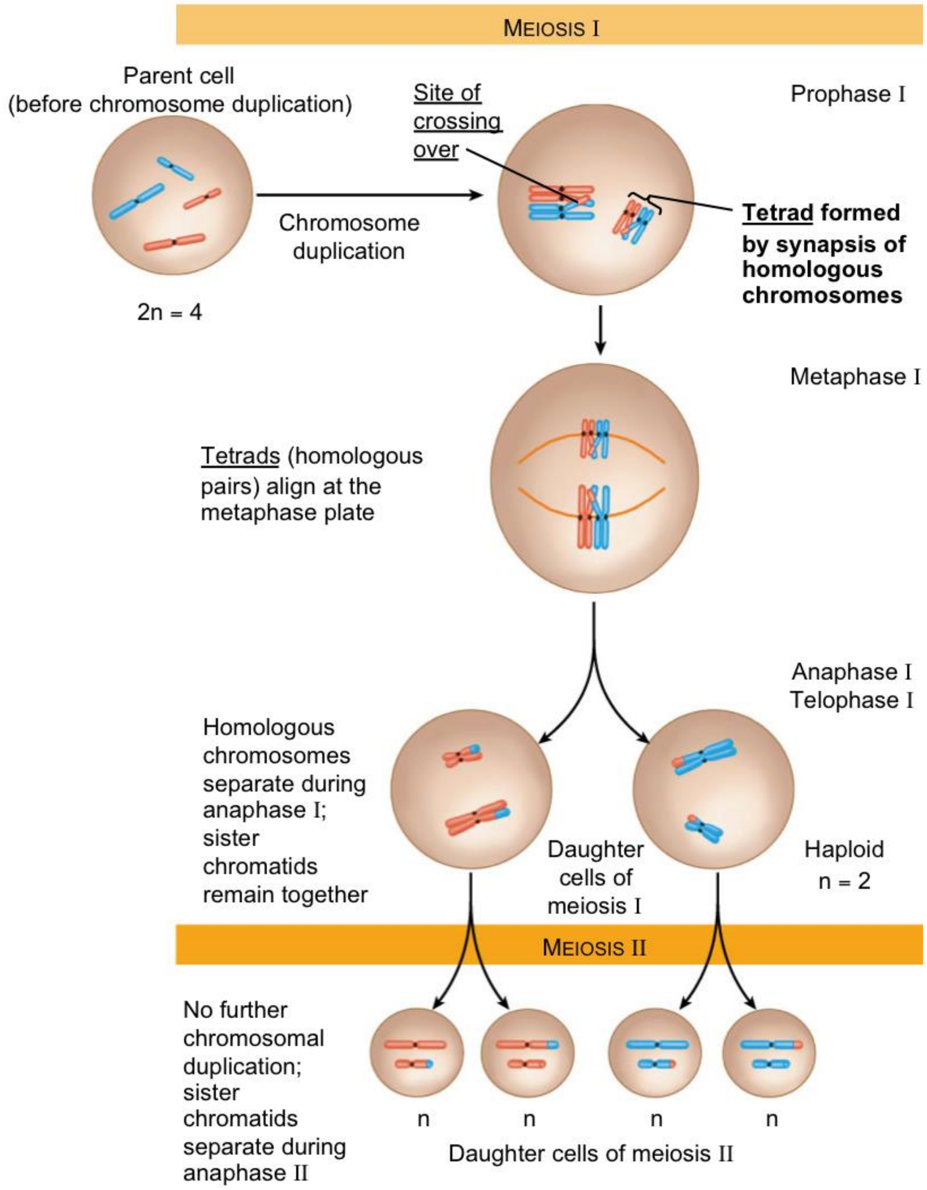


Fig. 5.1.2: Phases of meiosis illustrating changes in DNA content

5.1.2 MEIOSIS I

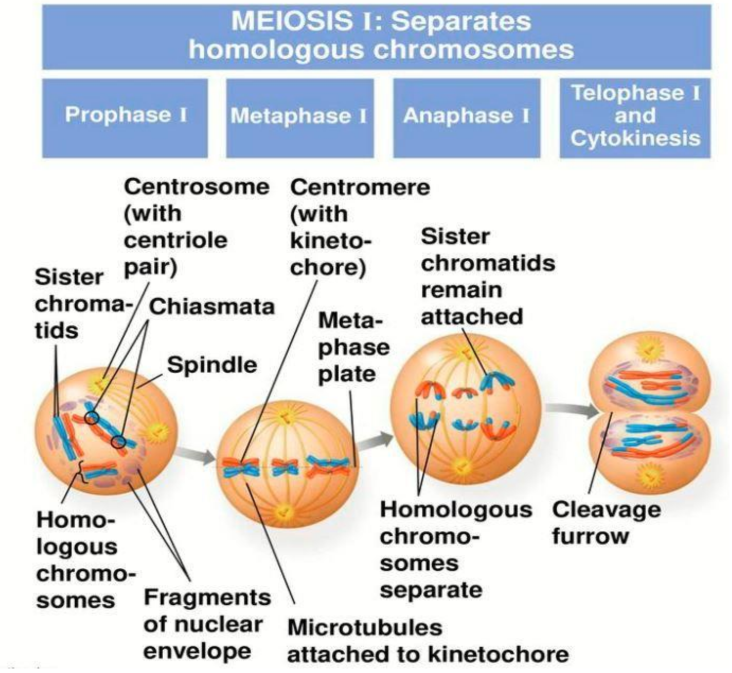


Fig. 5.1.2.1: Phases of Meiosis I

There are **four phases in Meiosis I**

- Prophase I
- Metaphase I
- Anaphse I
- Telophase I and Cytokinesis

a) Prophase I

<u>Behaviour of Chromosomes</u>

- Chromatin threads becomes more tightly coiled, **condensing** into visible **chromosomes.**
- Each chromosome is made up of **2 sister chromatids** held together by the centromere.
- **Synapsis: Homologous chromosomes** pair up to form **bivalents** in a process known as **synapsis**.
- **Crossing Over: Non-sister chromatids** may **cross over** at one or more **chiasmata** (singular: chiasma), allowing **reciprocal exchange of genetic material**, giving rise to genetic variation.
    - E.g. of Non-sister chromatids: 1 chromatid from **paternal chromosome** and 1 chromatid from **maternal chromosome** undergo crossing over

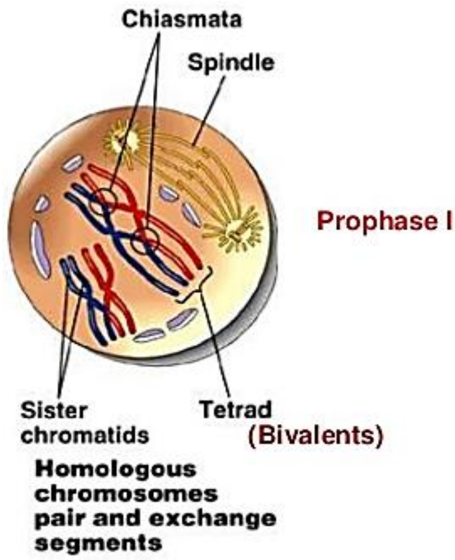


Fig. 5.1.2.2: Bivalent formation

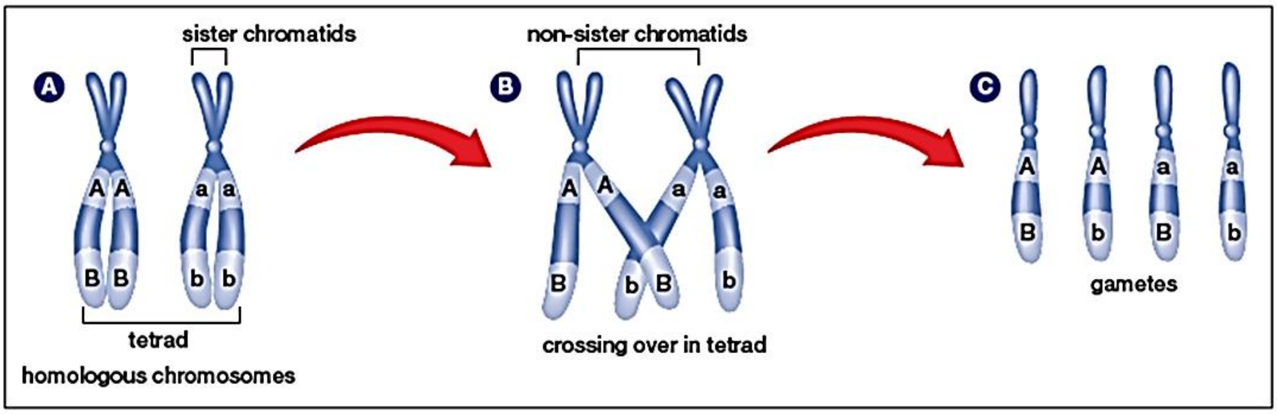


Fig. 5.1.2.3: Crossing over between homologous chromosomes.

<u>Nucleus</u>

- The **nuclear envelope** disintegrates, and the **nucleolus** disappear.

<u>Spindle Fibres</u>

- The **two centrosomes move** towards opposite ends of the cell, and organise microtubules into spindle fibres.

b) Metaphase I

<u>Behaviour of Chromosomes</u>

- Homologous pairs of chromosomes are aligned on metaphase plate, creating **2 rows**.
- **Independent assortment of homologous chromosomes occurs.**
  - Orientation of each bivalent along the metaphase plate is **random** and **independent** of the orientation of other bivalents.

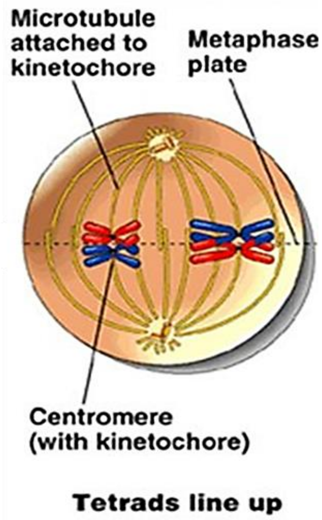


Fig. 5.1.2.4: Metaphase I

<u>Nucleus</u>

- Nucleus absent.

<u>Spindle Fibres</u>

- Kinetochore spindle fibres attach to centromere of each chromosome at the kinetochore.
- Non-kinetochore microtubules lengthen to elongate the cell.

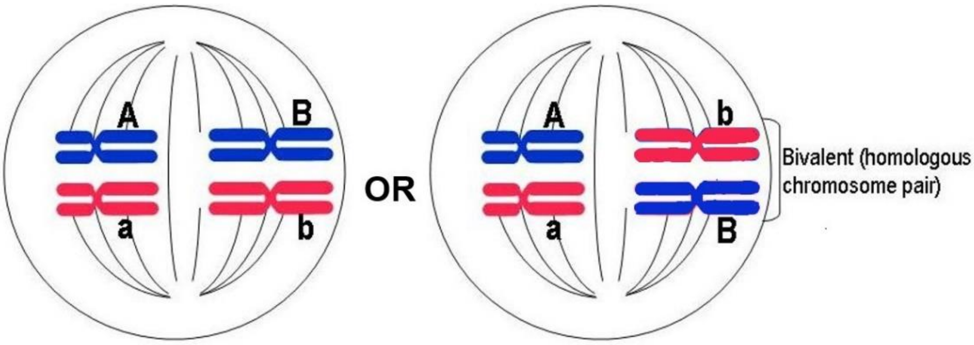


Fig. 5.1.2.5: Possible arrangements of bivalents on the metaphase plate (Independent assortment of homologous chromosomes)

c) Anaphase I

<u>Behaviour of chromosomes</u>

- Homologous chromosomes move towards opposite poles of the spindle.
  - Sister chromatids **do not separate** during anaphase I
  - **Each chromosome still = pair of sister chromatids.**
  - Sister chromatids will remain attached at the centromeric region until anaphase II

- This separates the chromosome into **two haploid sets**, one set at each end of the spindle.
  - Each daughter cell now has **half the number** of chromosomes as compared to parent cell.
  - For example, if parent cell has 46 chromosomes, each daughter cell now has 23 chromosomes.
  - This is known as **reductive division**.

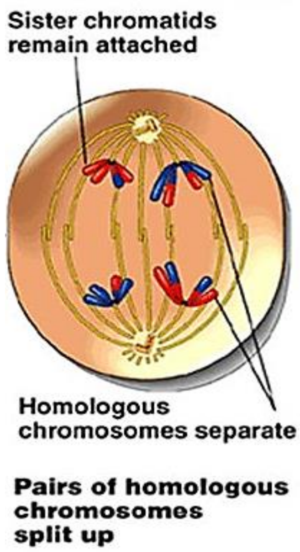


Fig. 5.1.2.6: Anaphase I

<u>Nucleus</u>

- Nucleus absent.

<u>Spindle Fibres</u>

- Kinetochore spindle fibres shorten and pull one homologous chromosome from each pair towards spindle poles.
- Non-kinetochore microtubules lengthen to elongate the cell.

d) Telophase I & Cytokinesis

Behaviour of chromosomes

- Chromosomes uncoil and **decondense** to form **chromatin threads**.

Nucleus

- **Nucleolus** and **nuclear envelope reforms** around chromosomes at each pole.

Spindle Fibres

- Spindle fibres disintegrate.

e) Cytokinesis

- In animal cells, cytokinesis takes place by invagination of cell membrane and furrowing of cytoplasm at the equator of the cell.
- In most plant cells, there is no telophase I and the cell goes directly into metaphase II.

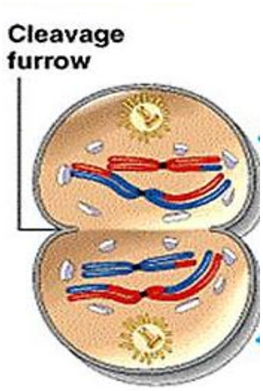


Fig. 5.1.2.7: Telophase I & Cytokinesis

At the end of meiosis I, from a parent cell which was diploid (2n), **two haploid (n) daughter cells are formed,** each with only 1 homologous chromosome from each pair. Each homologous chromosome still exists as two sister chromatids connected by a centromere.

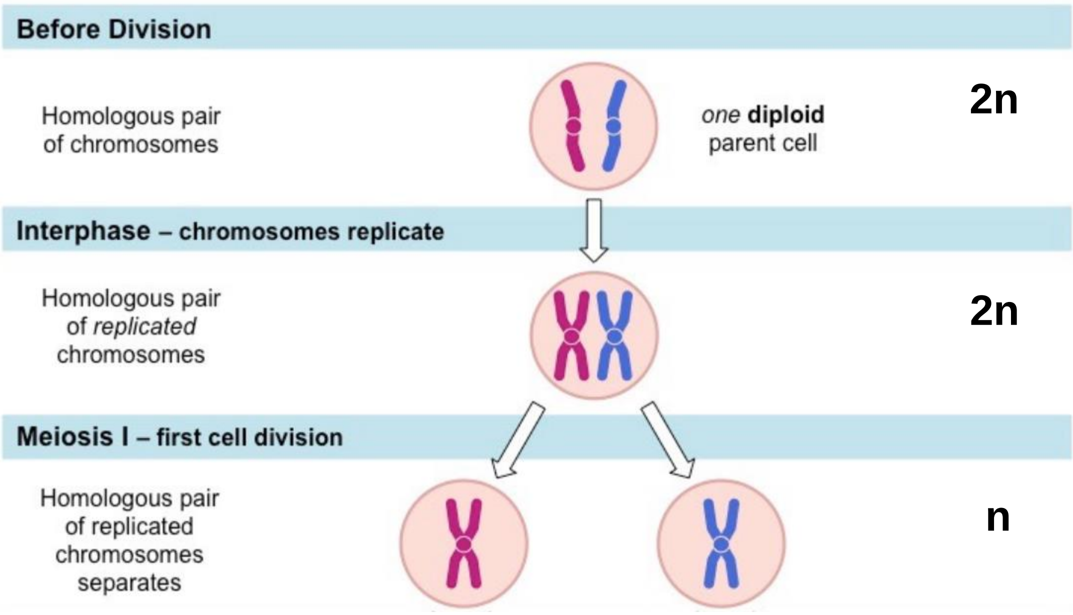
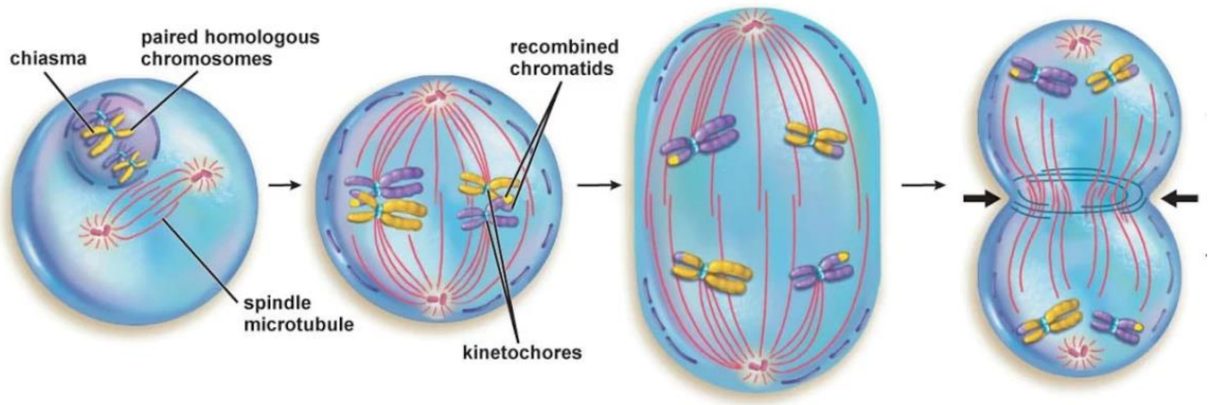


Fig. 5.1.2.8: Diploid cell (2n = 2) to haploid cells (n = 1) after Meiosis I

CHECKPOINT 3

Q1: Using information from the figure above, fill in the blanks below.



At the end of Meiosis I, two ___________ daughter cells would be produced from a ___________ germ cell.

The original diploid chromosome number, n = ___________ has been halved to n = ___________ in each of the daughter cell.

Both the cells would be genetically ___________.

<u>CHECKPOINT 4</u>: Summarise the key points of *meiosis I* in the table below.

Stage + Sketch	Behaviour of chromosomes	Nucleus	Spindle Fibres
Prophase I			
Metaphase I			
Anaphase I			
Telophase I			

5.1.3 MEIOSIS II

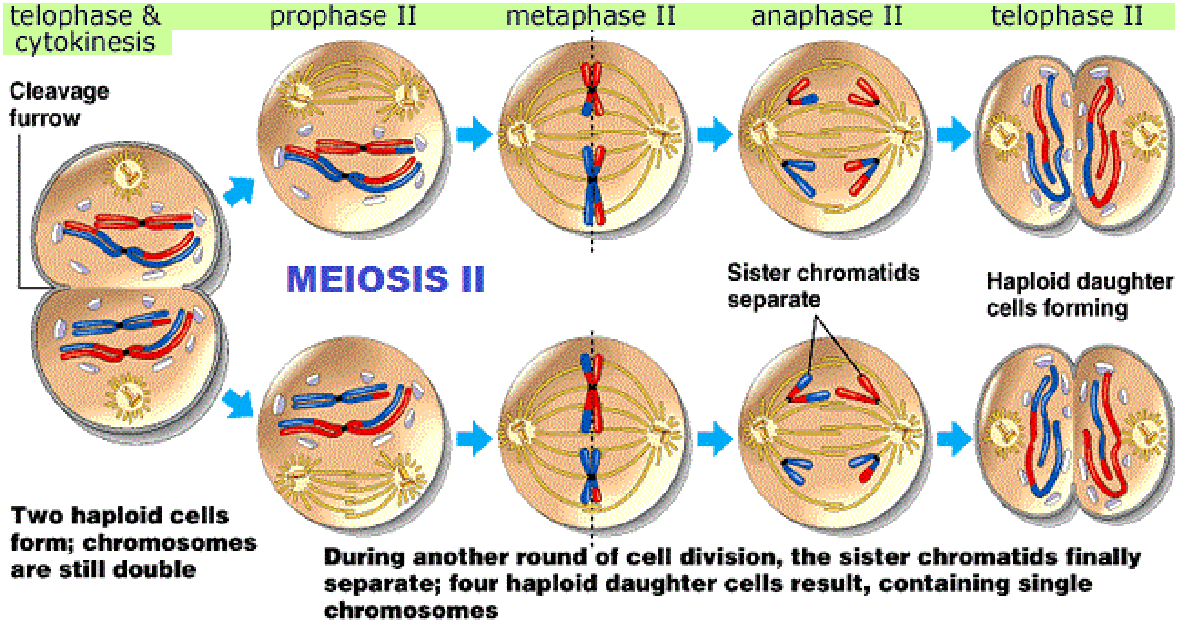


Fig. 5.1.3.1: Phase of Meiosis II

The events of the stages are similar to those occurring in mitosis.

a) Prophase II

Behaviour of Chromosomes

- As DNA condenses, chromatin thread **shortens and thickens** to form visible **chromosomes**.
- Each chromosome appears as **2 sister chromatids held together at the centromere.**

Nucleus

- **Nucleoli disappear** and the **nuclear envelope breaks down** into small vesicles which disperse.

Spindle Fibres

- Outside the nucleus, **two centrosomes move towards opposite poles of cells and** organize microtubules into spindle fibres.

- Some **spindle fibres attach to the kinetochore (protein structure) at the centromere of the chromosome**. These spindle fibres are known as **kinetochore microtubules.**

b) Metaphase II

Behaviour of chromosomes

- **Chromosomes** will **randomly align** in a **single row at the metaphase plate**.

Nucleus

- Nucleus absent

Spindle fibres

- **Centrosomes** are now at **opposite poles** of the cell.
- The **kinetochore spindle fibres** will then attach to the kinetochore at the centromere region of the chromosomes.

c) Anaphase II

Behaviour of chromosomes

- **Centromeres divide into two** and the **kinetochore microtubules shortens** to **pull sister chromatids apart**.
- Separated sister chromatids is each now known as a **chromosome.**
- Each daughter chromosome will be **led by its centromere to opposite spindle poles**.

Nucleus

- Nucleus absent

Spindle fibres

- Kinetochore microtubules shorten, pulling the daughter chromosomes to opposite poles, centromeres first.
- **Non-kinetochore spindle fibres** from each pole **lengthen to elongate the cell.**

d) Telophase II and Cytokinesis

Behaviour of chromosomes

- Chromosomes uncoil and **decondense** to form **chromatin threads**.

Nucleus

- **Nucleolus** and **nuclear envelope reforms** around chromosomes at each pole.

Spindle Fibres

- Spindle fibres disintegrate.

The meiotic division of **one parent cell produces 4 daughter** cells, each with only 1 set of chromosomes, **haploid (n) and half the amount of DNA as compared to the parent cell.**

CHECKPOINT 5

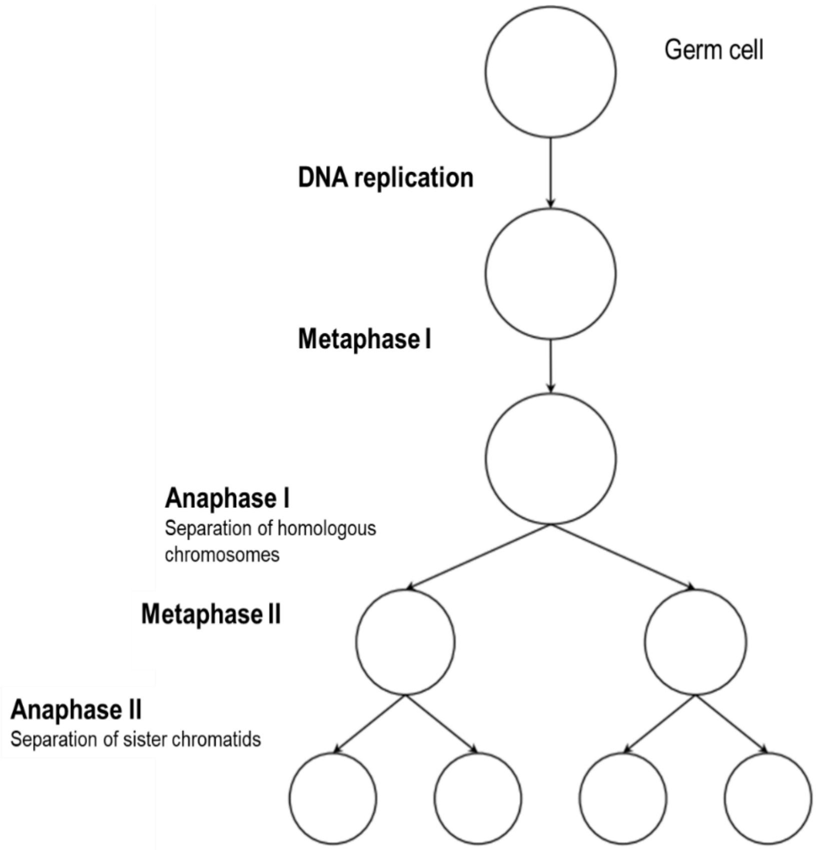
A diploid germ cell with 2n = 6 and undergoes meiosis to form haploid daughter cells. Assuming the germ cell has 10g of DNA before interphase, in the figure below,

(a) draw the number of chromosomes each of the cells below.

(b) state the ploidy of each cell

(c) state the amount of DNA in each cell

Diagrammatic Representaion of Process	Ploidy of each cell	DNA amount in each cell / g



Learning Outcome 2(t):

explain the significance of the meiotic cell cycle *(including how meiosis and random fertilisation can lead to variation)*

5.2 SIGNIFICANCE OF MEIOSIS

Meiosis results in the reduction of the number of chromosomes sets from diploid to haploid, allowing the production of gametes that are genetically different from the parent cell, contributing to **genetic variation** among offsprings.

Meiosis contributes to genetic variation by

a) Crossing over between homologous chromosomes during Prophase I to produce **recombinant chromosomes**.

During crossing over, there is a **reciprocal exchange of DNA** between the non-sister chromatids of the same homologous pair.

The resultant recombinant chromosomes carry a different genetic combination of alleles as compared to the parent cell.

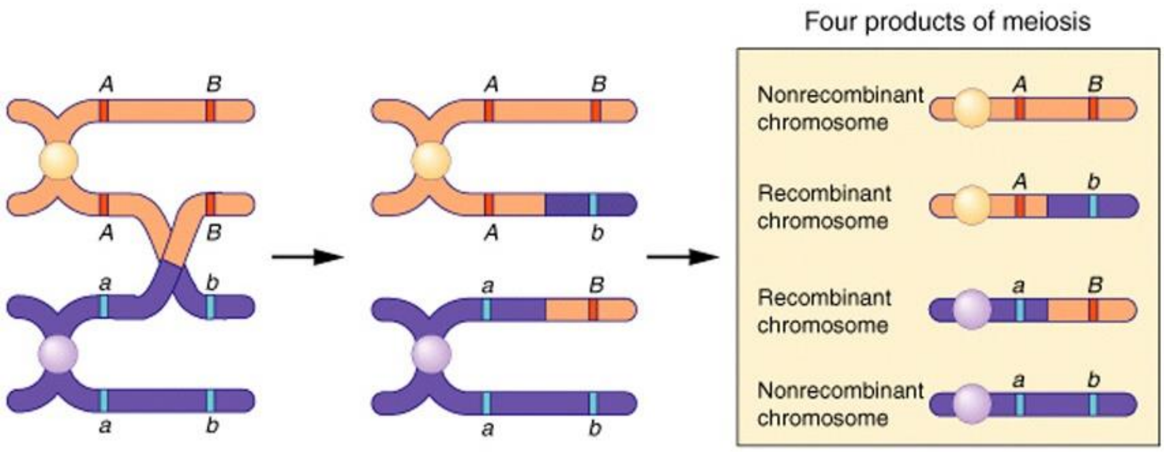


Fig. 5.2.1: Crossing over between homologous chromosomes

b) Independent assortment of chromosomes during Metaphase I

At **metaphase I**, the **homolgous pairs of chromosomes**, each consisting of one maternal and one paternal chromosome are **positioned independently of the other pairs** during metaphase I.

- Both pairs of paternal copy are on the left and maternal copy on the right **OR**
- One of the pair has the paternal copy on the left and maternal copy right, while the next pair has the maternal copy on the left and paternal copy on the right

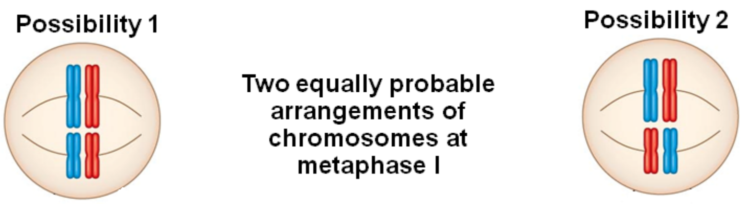


Fig. 5.2.2: Independent assortment of homologous chromosomes

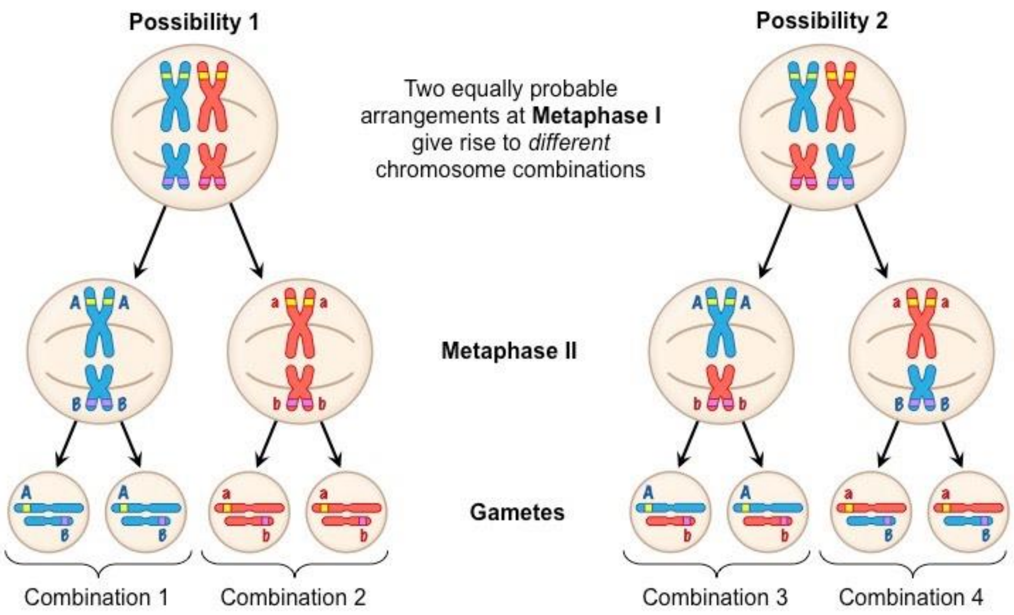


Fig. 5.2.3: Independent assortment of homologous chromosomes

The homolog of each pair will be separated into daughter cells **independently** of the other pair. Each daughter cell represents one outcome of all possible combination of maternal and paternal chromosomes. The number of possible combinations when chromosomes sort independently during meiosis is 2^n, where n is the haplod number of the organism.

c) Random fertilisation

Meiosis produces haploid daughter cells (gametes) with only half the number of chromosomes **(n)** as the parent cell **(2n).**

This is important for **sexual reproduction** because the chromosome number must be halved in gametes to ensure the **restoration of the diploid state upon gametes fusion** to form a **zygote** (diploid).

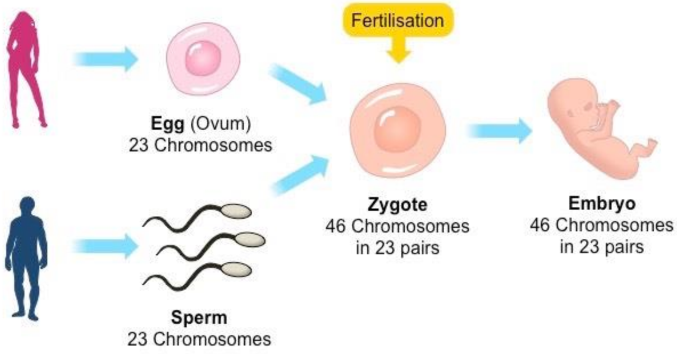


Fig. 5.2.4: Fusion of gametes

The fusion of a haploid male gamete with a haploid female gamete during fertilisation will produce a diploid zygote, restoring the diploid condition of the organism. As each gamete represents one out of the 2^n possible combinations of chromosomes, **random fertlisation will increase the possible diploid combnations for a zygote by 2^n x 2^n.**

CHECKPOINT 6

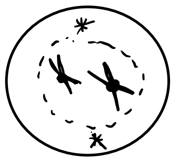
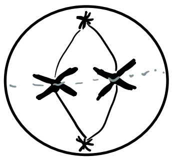
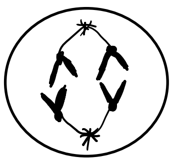
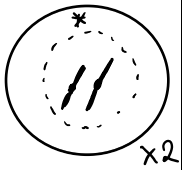
Compare the mitotic and meiotic processes.

Property	MITOSIS	MEIOSIS
Number of divisions		
Behaviour of homologous chromosomes in prophase		
Behaviour of chromosomes at the metaphase plate		
Behaviour of chromosomes during anaphase		
Ploidy of daughter cells		
Amount of DNA in each daughter cell		
Genetic composition of daughter cells		
Number of daughter cells formed from each parent cell		
Cell types involved		
Role		
Phases		
Product		
Starting point		

Answers

CHECKPOINT 1:

Summarise the key points of mitosis and cytokinesis in the table below.

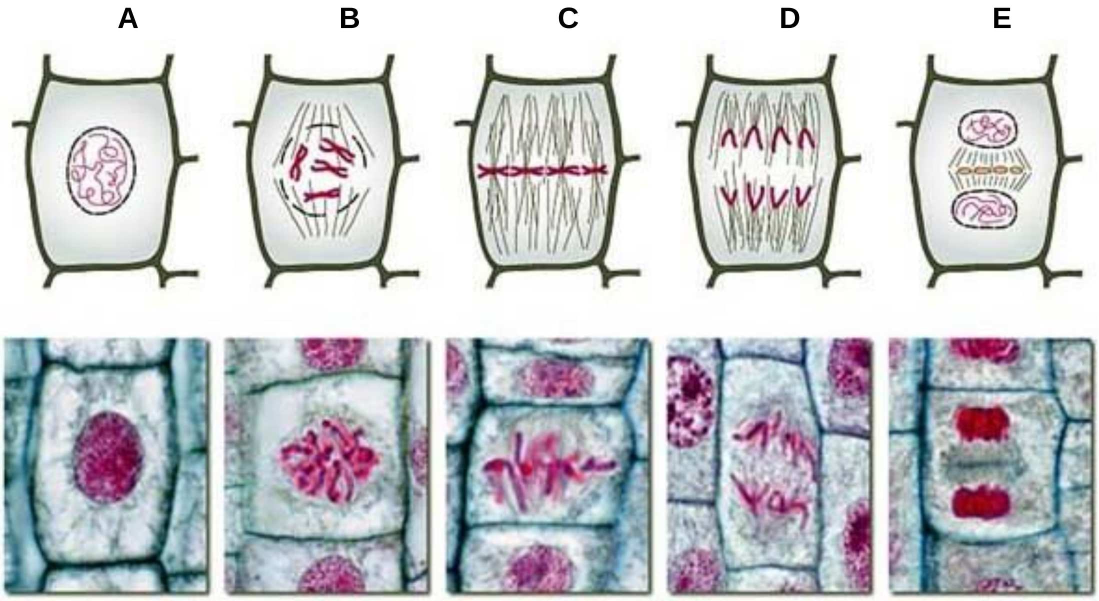
Stage + Sketch	Behaviour of chromosomes	Nucleus	Spindle Fibres
Prophase 	• Chromatin fibres tightly coiled • Condense into discrete chromosomes • **Two identical sister chromatids** • Joined at centromere	• Nuclear envelope disintegrates (To allow attachment of spindle fibres) • Nucleolus disappears	• Duplicated centrosomes move to opposite poles of cell • Kinetochore microtubules invade nuclear area • Attach to chromosome via kinetochore protein on centromere
Metaphase 	• Aligned on metaphase plate	Absent	• Centrosomes at opposite poles of cell
Anaphase 	• Centromere separate to two • Sister chromatids separate. • Each sister chromatid becomes chromosome	Absent	• Kinetochore microtubules shorten • Pull sister chromatids to opposite poles of cell • With centromere leading first • Non-kinetochore microtubules lengthen to elongate cell
Telophase 	• Daughter chromosomes arrived at poles. • Chromosome decondense to form chromatin	• Nucleoli reappear (To protect chromosomes which are decondensing) • Nuclear envelope reassembles	• Microtubule disassembles

Cytokinesis in animal cells:	**Cytokinesis in plant cells:**
• Starts at late anaphase • **Cleavage furrow** • **Contractile ring of filaments** • Contract to **pinch cell into two** • Forming two daughter cells with identical nuclei	• **Golgi vesicles** move to middle of cell and fuse to form **cell plate.** • **Cell plate enlarges** until surrounding membrane fuses with plasma membrane. • Forming two daughter cells

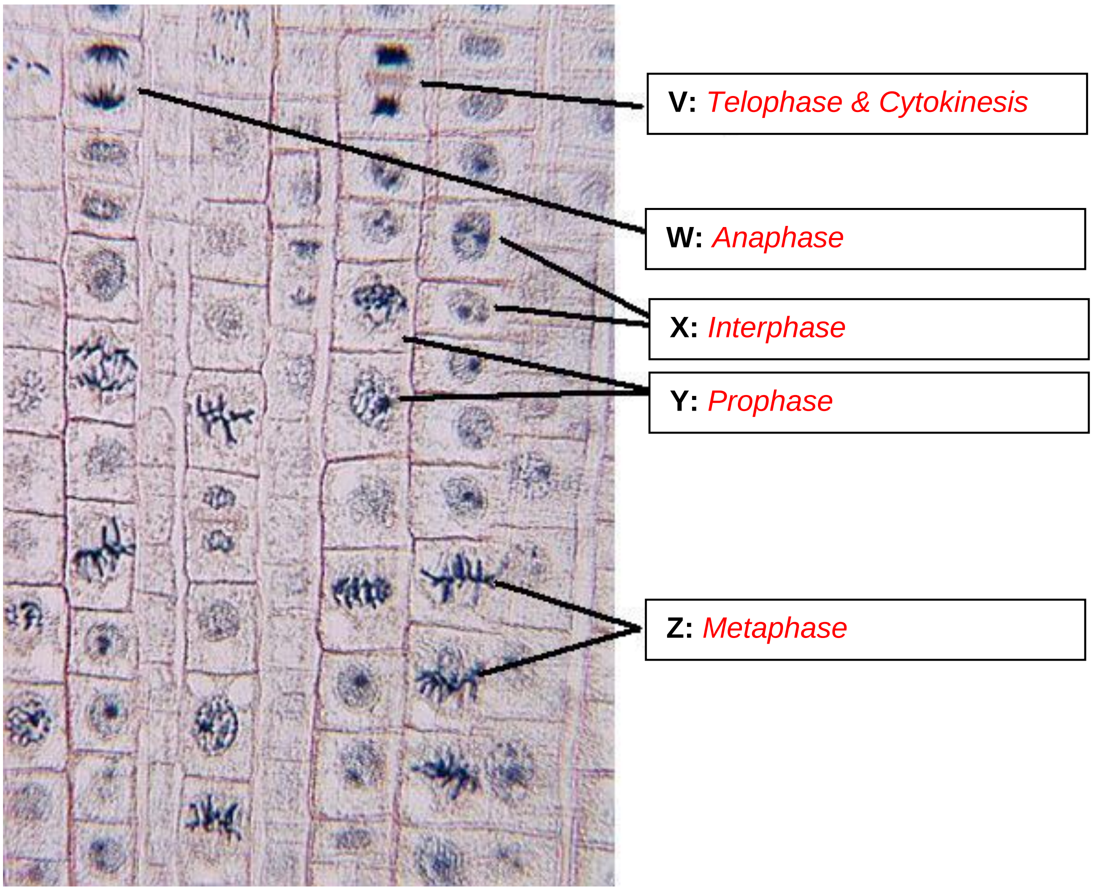
CHECKPOINT 2

(a) State the stages of cell division that the cell is in for **A – E**.

Ans: ***interphase*** ***prophase*** ***metaphase*** ***anaphase*** ***telophase***

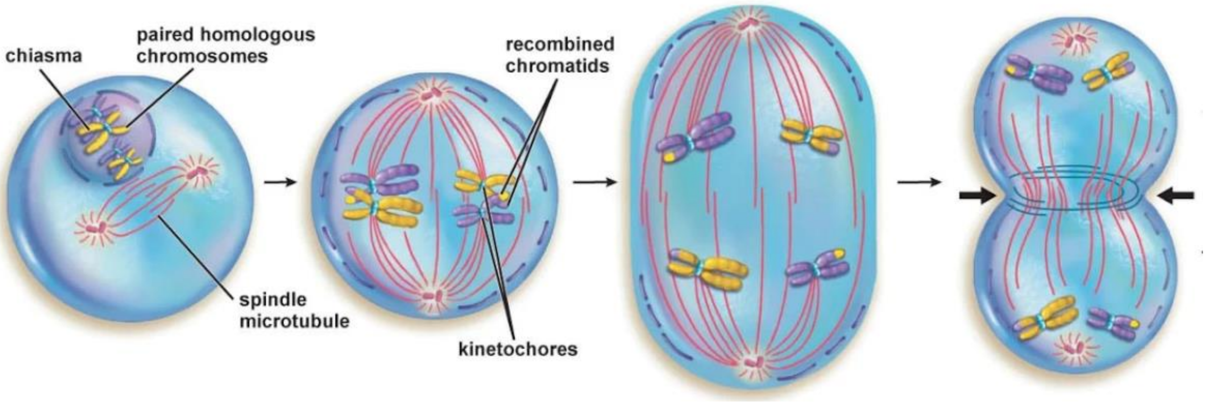


(b) State the stages of cell division that the cell is in for **V – Z**.



CHECKPOINT 3

Q1: Using information from the figure above, fill in the blanks below.



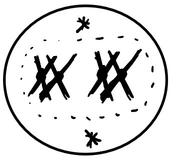
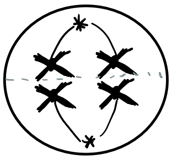
At the end of Meiosis I, two *haploid* daughter cells would be produced from a *diploid* germ cell.

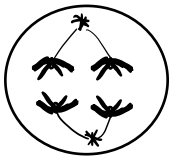
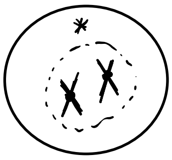
The original diploid chromosome number, n = *4* has been halved to n = *2* in each of the daughter cell.

Both the cells would be genetically *non-identical*.

CHECKPOINT 4:

Summarise the key points of meiosis I in the table below.

Stage + Sketch	Behaviour of chromosomes	Nucleus	Spindle Fibres
Prophase I 	• Chromatin fibres tightly coiled & condense into discrete chromosomes. • Homologous chromosomes pair up to **form bivalents via synapsis.** • Formation of chiasmata between non-sister chromatids • Crossing over at **homologous region b**etween non sister chromatids • **Chromatids carrying different combination of alleles.** • **Genetic variation in gametes**	• Nuclear envelope disintegrates. • Nucleolus disappears	• Duplicated centrosomes move to opposite poles of cell. • Kinetochore microtubules attach to chromosome via kinetochore protein on centromere • Kinetochore from one pole attach to centromere of a homologous chromosome from each bivalent • Kinetochore from opposite pole **attach to centromere of the other homologous chromosome from each bivalent**
Metaphase I 	• Aligned on metaphase plate • **One chromosome of each bivalent facing each pole** • **Independent assortment of homologous chromosomes** • Orientation of each bivalent is random and independent of orientation of other bivalents	Absent	• Centrosomes at opposite poles of cell • Centromeres equidistance

Anaphase I 	• Homologous chromosomes move to opposite ends of poles	Absent	• **Kinetochore microtubules** shorten. • Pull sister chromatids to opposite poles of cell • With centromere first • **Non-kinetochore microtubules** lengthen to elongate cell
Telophase I 	• Homologous chromosomes arrived at poles • Chromosome decondense to form chromatin	• Nucleoli reappear (To protect chromosomes which are decondensing) • Nuclear envelope reassembles	• Microtubule disassembles

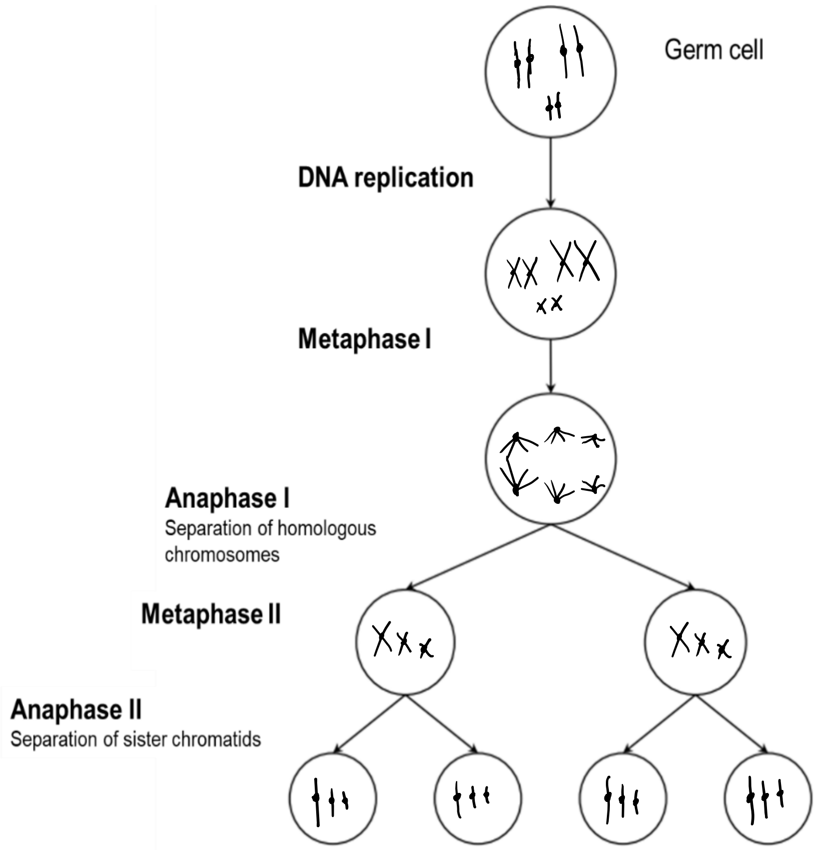
CHECKPOINT 5

A diploid germ cell with 2n = 6 and undergoes meiosis to form haploid daughter cells. Assuming the germ cell has 10g of DNA before interphase, in the figure below,

(a) draw the number of chromosomes each of the cells below.

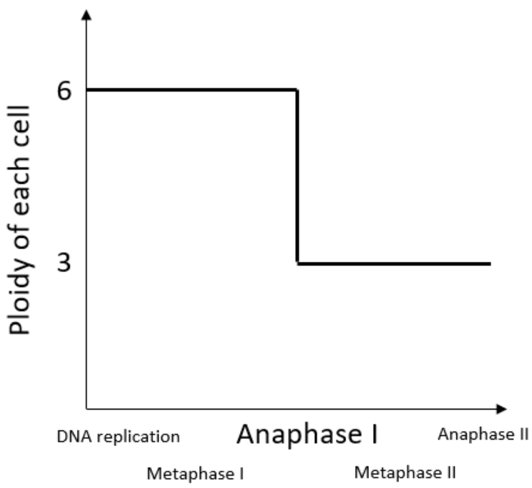
(b) state the ploidy of each cell

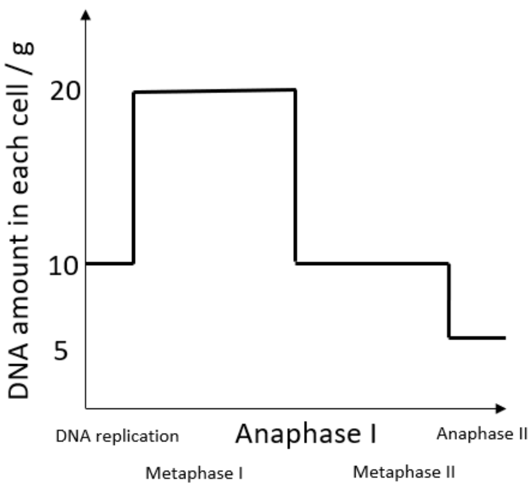
(c) state the amount of DNA in each cell



Diagrammatic Representation of Process	Ploidy of each cell	DNA amount in each cell / g
Germ cell	6	10
DNA replication	6	20
Metaphase I	6	20
Metaphase II	3	10
Anaphase II	3	5

Alternatively, you can express the ploidy of each cell and DNA amount in each cell in a graphical form.





CHECKPOINT 6

Compare the mitotic and meiotic processes.

Property	MITOSIS	MEIOSIS
Number of divisions	1 nuclear division	2 successive nuclear divisions
Behaviour of homologous chromosomes in prophase	Homologous chromosomes do not pair up. There is no crossing over between homologous chromosomes	Homologous chromosomes pair up to form a bivalent in prophase I. There maybe crossing over which results in a reciprocal exchange of genetic material between non-sister chromatids to produce recombinant chromosomes.
Behaviour of chromosomes at the metaphase plate	Chromosomes form a single row during metaphase	Chromosomes form two rows during metaphase I.
Behaviour of chromosomes during anaphase	Division of centromere and chromatids separate and move to opposite spindle poles.	No division of centromere. Homologous chromosomes separates during anaphase I and move to opposite spindle poles Division of centromere and chromatids separate and move to opposite spindle poles in anaphase II
Ploidy of daughter cells	Diploid	Haploid
Amount of DNA in each daughter cell	Same as the parent cell	Half of the parent cell
Genetic composition of daughter cells	Genetically identical to the parent cell and to each other	Genetically different from the parent cell and from each other
Number of daughter cells formed from each parent cell	2	4
Cell types involved	In all somatic cells	Only in germ cells
Role	Asexual reproduction, growth and repair	Increase genetic variation for sexual reproduction by producing gametes
Phases	Share same types of phases i.e. start cell cycle with interphase, followed by Prophase Metaphase, Anaphase, Telophase and end with cytokinesis	
Product	Produce new daughter cells	
Starting point	Both begin with a single diploid parent cell	