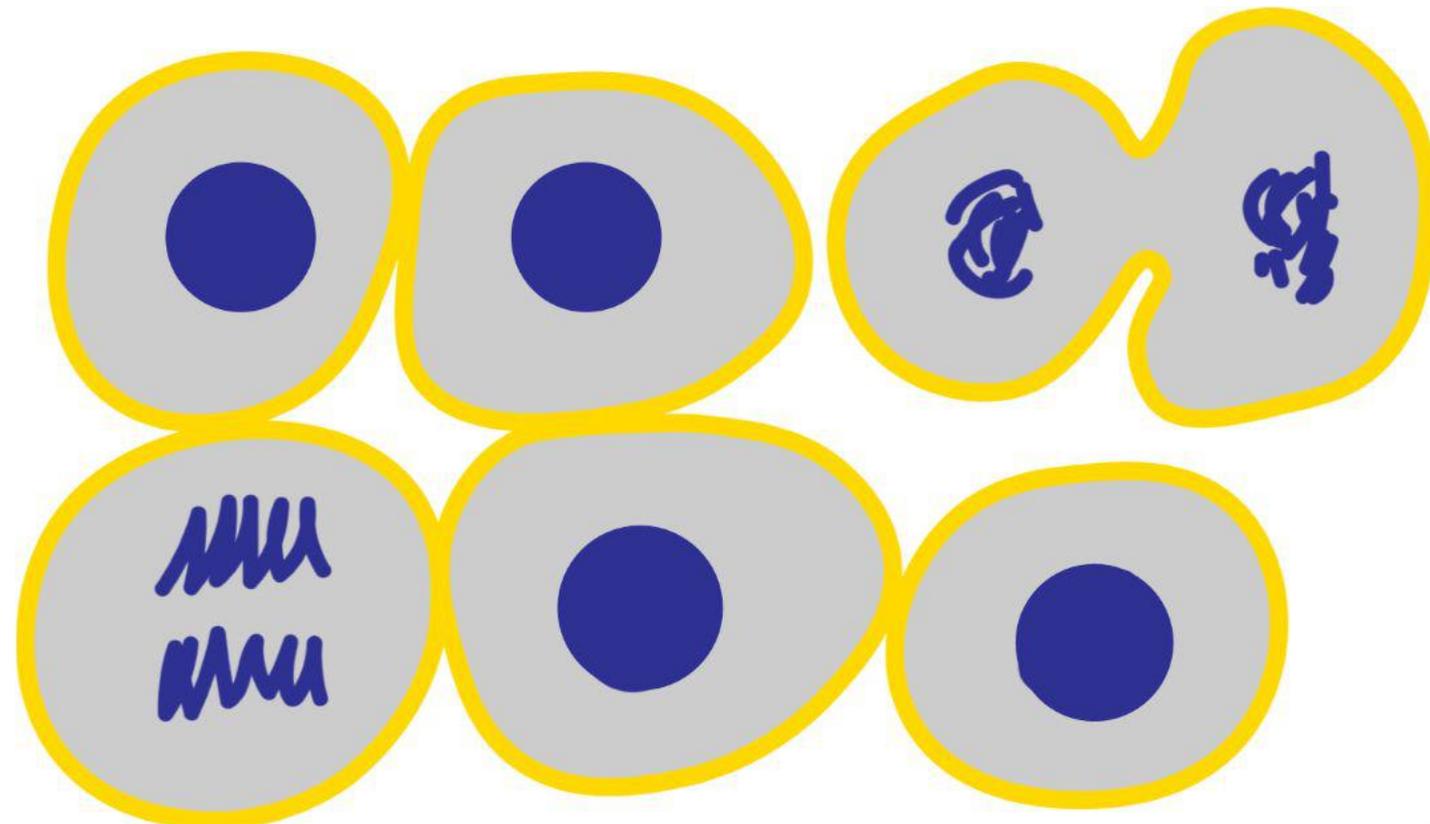


Cell Division



Material Covered

Outline of the Cell Cycle

1. The Cell Cycle

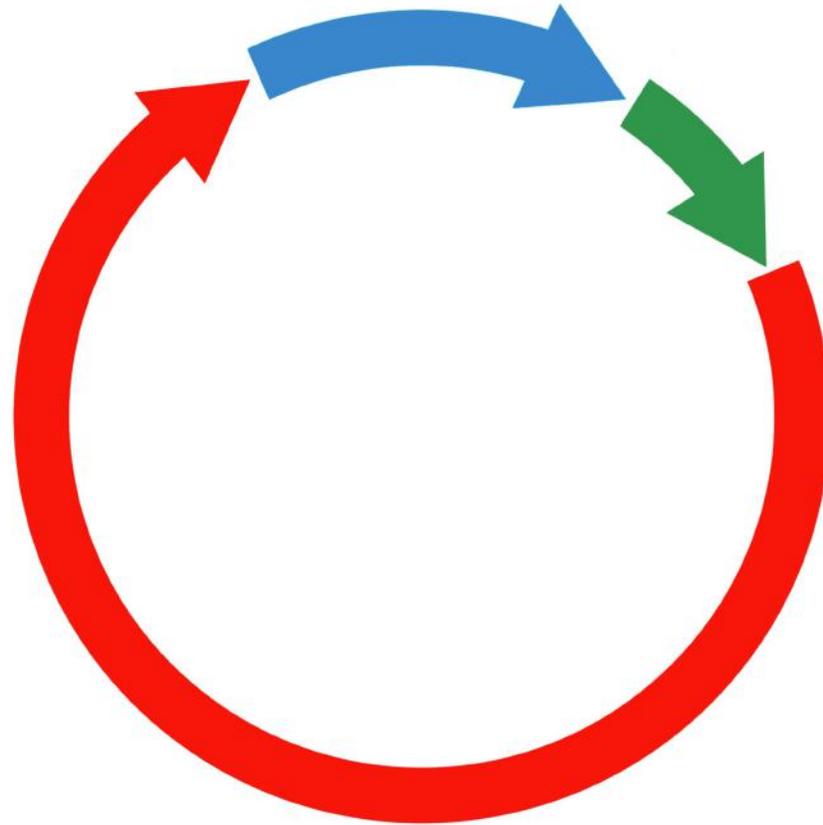
Mitosis and Cytokinesis

1. Stages of Mitosis
2. Cytokinesis

Meiosis

1. Meiosis I
2. Meiosis II
3. How Meiosis introduces Variation
4. Mitosis vs Meiosis

Outline of the Cell Cycle



Specification Points

AQA

3.2.2 All cells arise from other cells

Content	Opportunities for skills development
<p>Within multicellular organisms, not all cells retain the ability to divide.</p> <p>Eukaryotic cells that do retain the ability to divide show a cell cycle.</p> <ul style="list-style-type: none"> DNA replication occurs during the interphase of the cell cycle. Mitosis is the part of the cell cycle in which a eukaryotic cell divides to produce two daughter cells, each with the identical copies of DNA produced by the parent cell during DNA replication. <p>The behaviour of chromosomes during interphase, prophase, metaphase, anaphase and telophase of mitosis. The role of spindle fibres attached to centromeres in the separation of chromatids.</p> <p>Division of the cytoplasm (cytokinesis) usually occurs, producing two new cells.</p> <p>Meiosis is covered in section 3.4.3</p> <p>Students should be able to:</p> <ul style="list-style-type: none"> recognise the stages of the cell cycle: interphase, prophase, metaphase, anaphase and telophase (including cytokinesis) explain the appearance of cells in each stage of mitosis. <p>Mitosis is a controlled process. Uncontrolled cell division can lead to the formation of tumours and of cancers. Many cancer treatments are directed at controlling the rate of cell division.</p>	

OCR

2.1.6 Cell division, cell diversity and cellular organisation

Learning outcomes	Additional guidance
(a) the cell cycle	<p>To include the processes taking place during interphase (G_1, S and G_2), mitosis and cytokinesis, leading to genetically identical cells.</p> <p>HSW8</p>

Specification Points

Edexcel A

Topic 3: Voice of the Genome

Students should:

- 3.10 Understand the role of mitosis and the cell cycle in producing identical daughter cells for growth and asexual reproduction.

Edexcel B

Topic 2: Cells, Viruses and Reproduction of Living Things

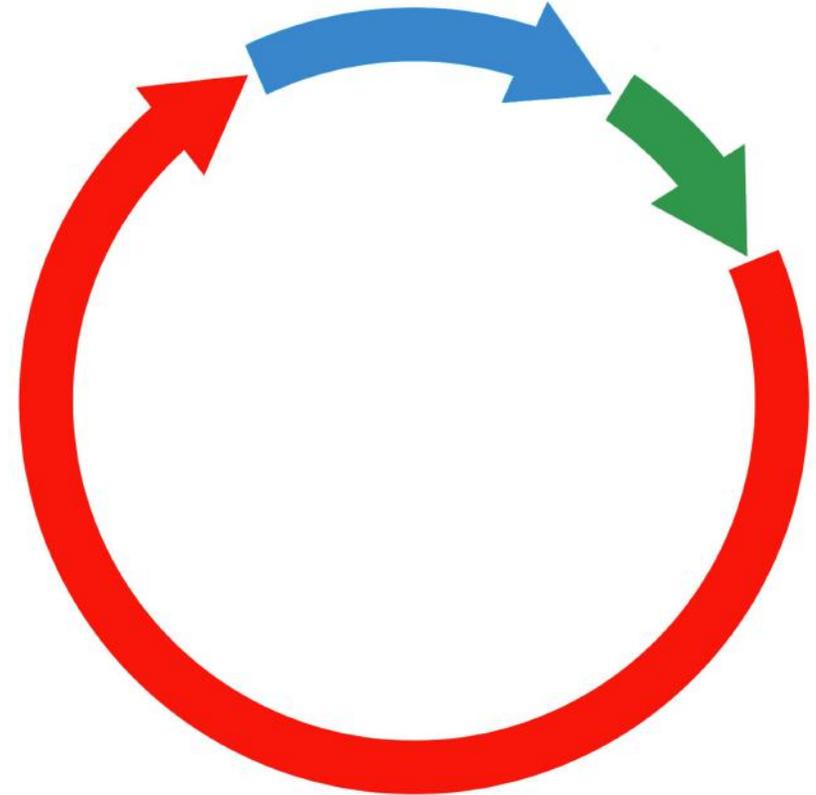
Students should:

2.3 Eukaryotic cell cycle and division

- i Know that the cell cycle is a regulated process in which cells divide into two identical daughter cells, and that this process consists of three main stages: interphase, mitosis and cytokinesis.

The Cell Cycle

- The cell cycle is important in **growth** and to **replace dead cells**
- There are **three phases** in the cell cycle: **interphase**, **mitosis** and **cytokinesis**
- **Interphase** is a period during which cells are **not dividing** – **DNA is replicated** in this phase
- The **mitosis phase** involves **nuclear division** of the **cell**
- **Cytokinesis** is the **splitting** of the cell into **two daughter cells**



AQA & Edexcel A: Do not need to know about checkpoints

Exemplar Exam Question - Calculation

1) In an investigation, a student observed a stained section of mammalian liver tissue. They counted how many cells could be seen in each stage of the cell cycle. The data is shown below:

Stage of Cell Cycle	Number of cells in stage
Interphase	410
Prophase	22
Metaphase	16
Anaphase	16
Telophase	36

Using the information provided above, calculate the percentage of the cell cycle taken up by nuclear division.

[3 marks]

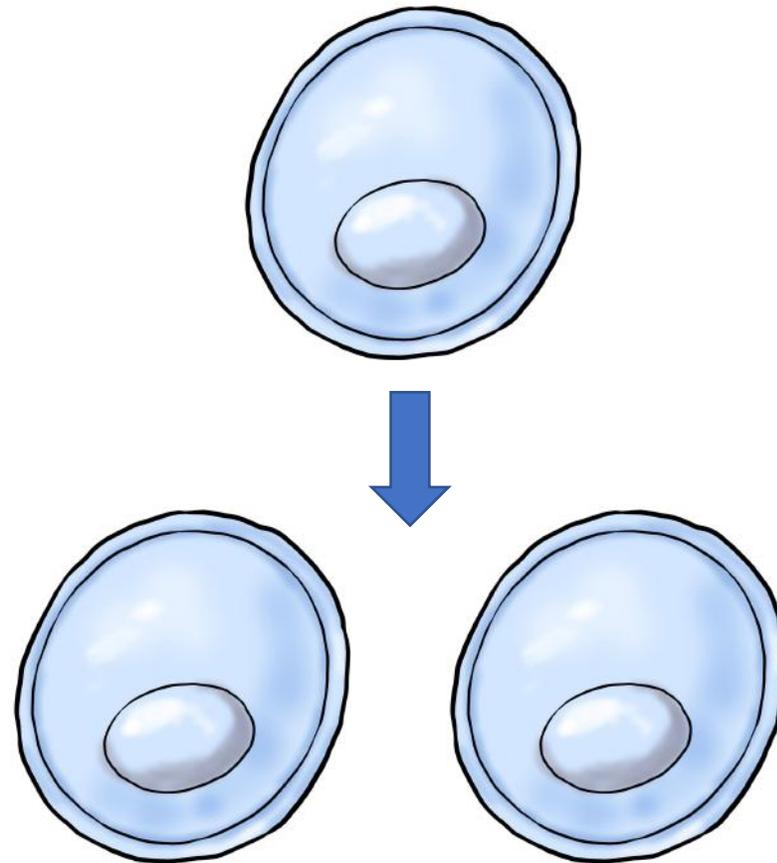
Command: a calculation is required

Direction: find where nuclear division occurs, calculate percentage

Context: provided data

Stage of Cell Cycle	Number of cells in stage
Interphase	410
Prophase	22
Metaphase	16
Anaphase	16
Telophase	36

Mitosis & Cytokinesis



Specification Points

AQA

3.2.2 All cells arise from other cells

Content	Opportunities for skills development
<p>Within multicellular organisms, not all cells retain the ability to divide.</p> <p>Eukaryotic cells that do retain the ability to divide show a cell cycle.</p> <ul style="list-style-type: none"> DNA replication occurs during the interphase of the cell cycle. Mitosis is the part of the cell cycle in which a eukaryotic cell divides to produce two daughter cells, each with the identical copies of DNA produced by the parent cell during DNA replication. <p>The behaviour of chromosomes during interphase, prophase, metaphase, anaphase and telophase of mitosis. The role of spindle fibres attached to centromeres in the separation of chromatids.</p> <p>Division of the cytoplasm (cytokinesis) usually occurs, producing two new cells.</p> <p>Meiosis is covered in section 3.4.3</p> <p>Students should be able to:</p> <ul style="list-style-type: none"> recognise the stages of the cell cycle: interphase, prophase, metaphase, anaphase and telophase (including cytokinesis) explain the appearance of cells in each stage of mitosis. <p>Mitosis is a controlled process. Uncontrolled cell division can lead to the formation of tumours and of cancers. Many cancer treatments are directed at controlling the rate of cell division.</p>	

OCR

2.1.6 Cell division, cell diversity and cellular organisation

Learning outcomes	Additional guidance
(c) the main stages of mitosis	To include the changes in the nuclear envelope, chromosomes, chromatids, centromere, centrioles, spindle fibres and cell membrane.
	HSW8

Specification Points

Edexcel A

Topic 3: Voice of the Genome

Students should:

- 3.10 Understand the role of mitosis and the cell cycle in producing identical daughter cells for growth and asexual reproduction.

Edexcel B

Topic 2: Cells, Viruses and Reproduction of Living Things

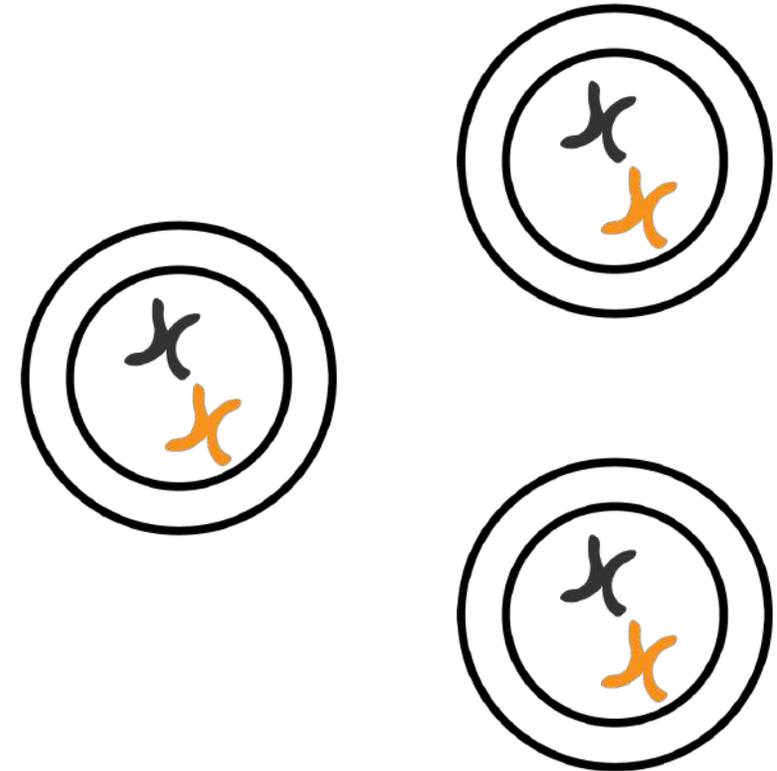
Students should:

2.3 Eukaryotic cell cycle and division

- ii Understand what happens to genetic material during the cell cycle, including the stages of mitosis.
- iii Understand how mitosis contributes to growth, repair and asexual reproduction.

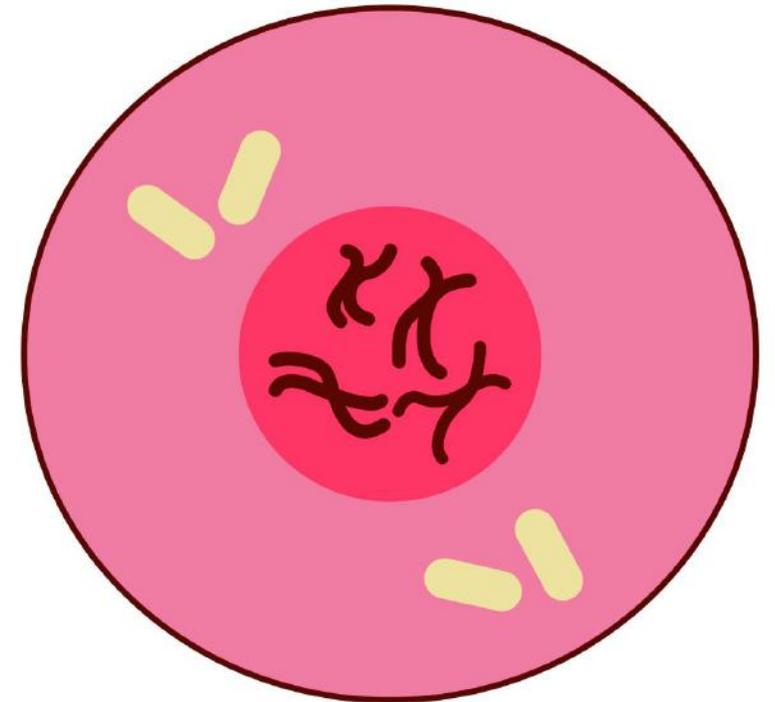
Mitosis

- Mitosis involves **one division** and creates **diploid cells**
- It produces **genetically identical** daughter cells
- It is used to form **somatic (body)** cells rather than **gametes** – and is critical for **growth** and **repair** of **multicellular organisms**
- It is used for **asexual reproduction** in **unicellular eukaryotes** (yeast)



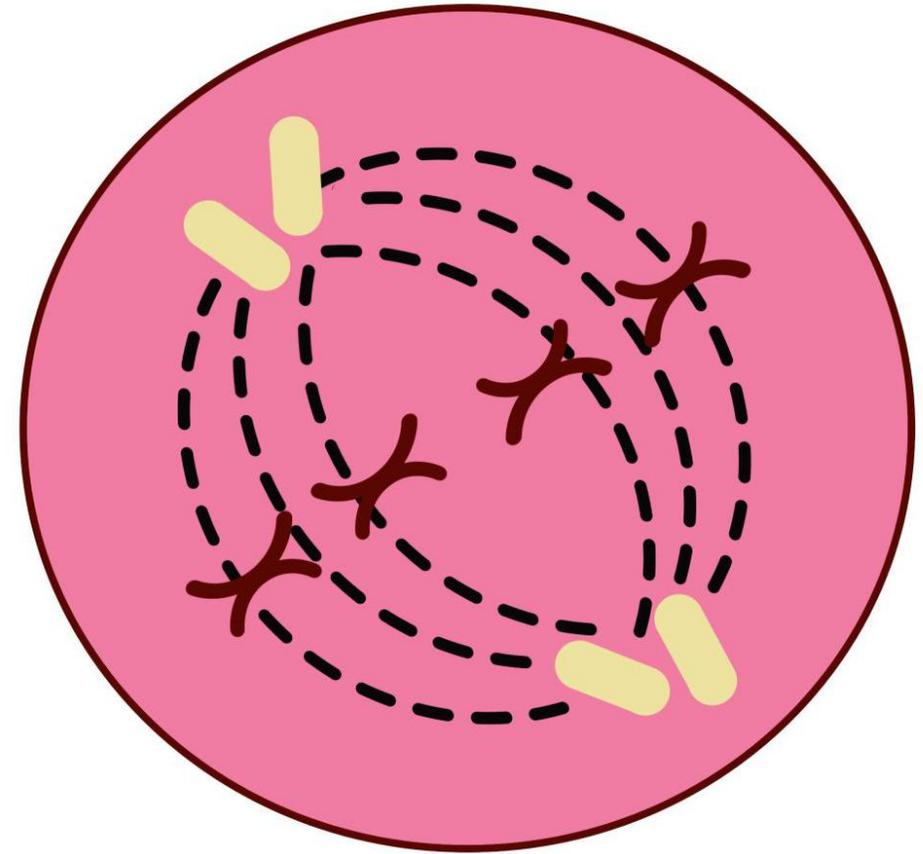
Mitosis - Prophase

- Prophase is the **first** stage of **mitosis**
- During prophase **DNA supercoils, condensing** to form **visible chromosomes**
- The **nuclear envelope disintegrates**
- The **centrioles** move to the **poles**
- **Spindle fibres** form from the **centrioles**



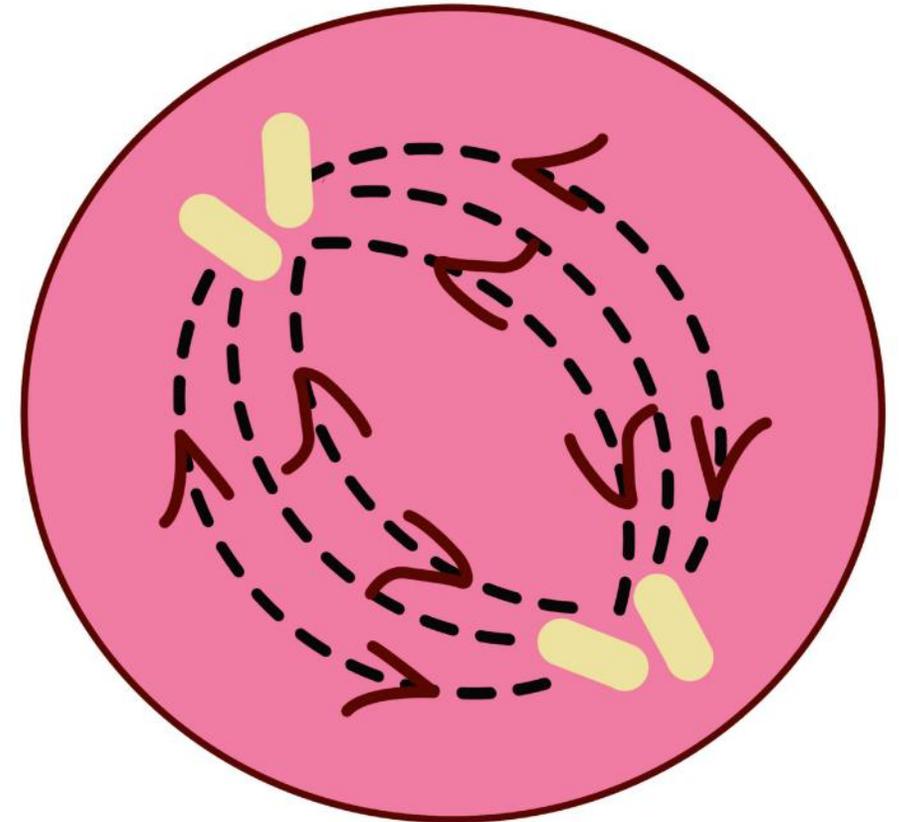
Mitosis - Metaphase

- In **metaphase** the chromosomes **line up** along the **equator** of the cell
- The **chromosomes** are first attached to **spindle fibres** at their **centromere**
- The chromosomes are then pulled along by the **spindle fibres** to the **equator** of the cell
- This prepares the **sister chromatids** for **separation**



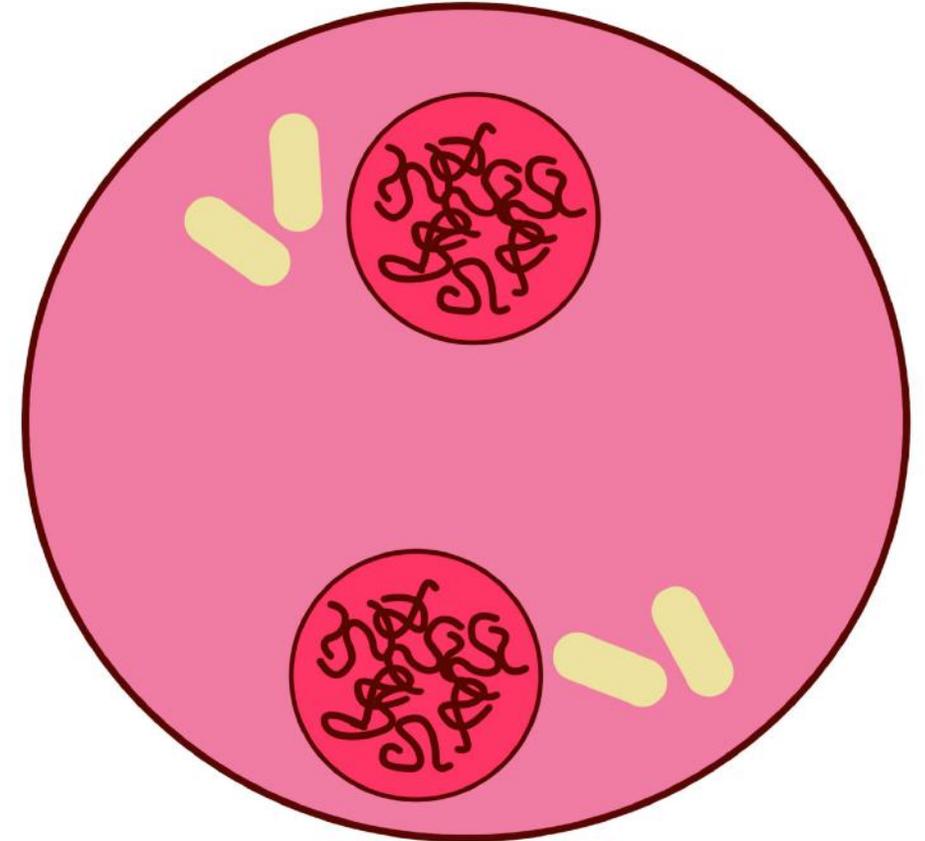
Mitosis - Anaphase

- In anaphase, the **sister chromatids** are **separated** at the **centromere** and pulled to **opposite poles** of the cell
- The chromatids are separated by the **spindle fibres** and moved to the **poles** aided by **motor proteins**
- This requires **ATP** so **mitochondria** gather around the **spindle fibres**
- Each pole of the cell ends up with **identical full sets of chromosomes**



Mitosis - Telophase

- During telophase the **nucleus reappears** and **chromosomes decondense**
- The **spindle fibres** begin to **disintegrate**
- The **chromosomes lengthen** and uncurl – meaning they can no longer be seen under a **microscope**
- The **nuclear envelope reforms** around the **chromosomes**



Exemplar Exam Question – Explanation

2) After fertilisation, a zygote rapidly divides to produce more cells. Each cell cycle may be as short as 30mins and only involves DNA replication and mitotic divisions.

State the type of cell division involved in this process, and suggest why the produced cells become smaller after each cell cycle.

[3 marks]

Command: state (one word) and suggest (application)

Direction: why each division cells get smaller

Context: rapid division to produce somatic cells

Exemplar Exam Question – Explanation

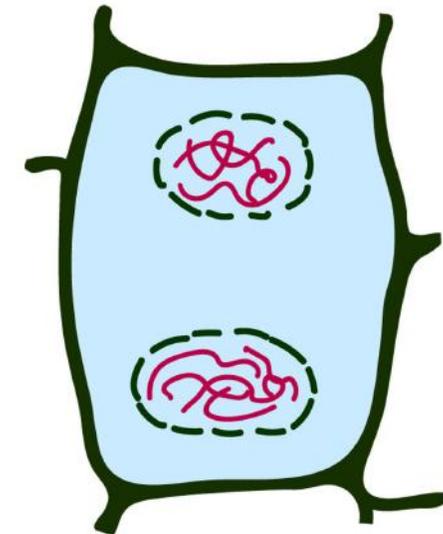
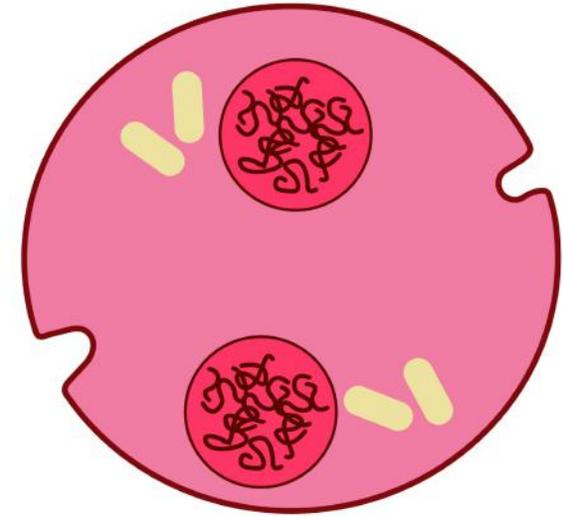
2) State the type of cell division involved in this process, and suggest why the produced cells become smaller after each cell cycle.

[3 marks]

Zygotes divide through mitosis as somatic cells are being produced. Usually cells spend more time in G1 and G2 phases where they undergo protein synthesis and make organelles. Without these stages the amount of cytoplasm and the number of organelles and proteins must be divided between the daughter cells, so there is less in each.

Mitosis - Cytokinesis

- In **cytokinesis** the cell splits into two to create two **identical daughter cells**
- In animals the **plasma membrane** folds inwards until the two **dents** meet – forming **two separate cells**
- In plants **cellulose** builds up at the equator, and a **plasma membrane** forms in the middle of the **end plate** – forming two separate **plant cells**



Exemplar Exam Question – Calculation

Context:
provided data

3) *E. coli* can divide as often as once every 20 minutes.

Assuming one *E. coli* cell weighs 1.5 pg (1 pg = 10^{-12} g), calculate the amount of time taken for 24 pg of *E. coli* to grow from a single cell.

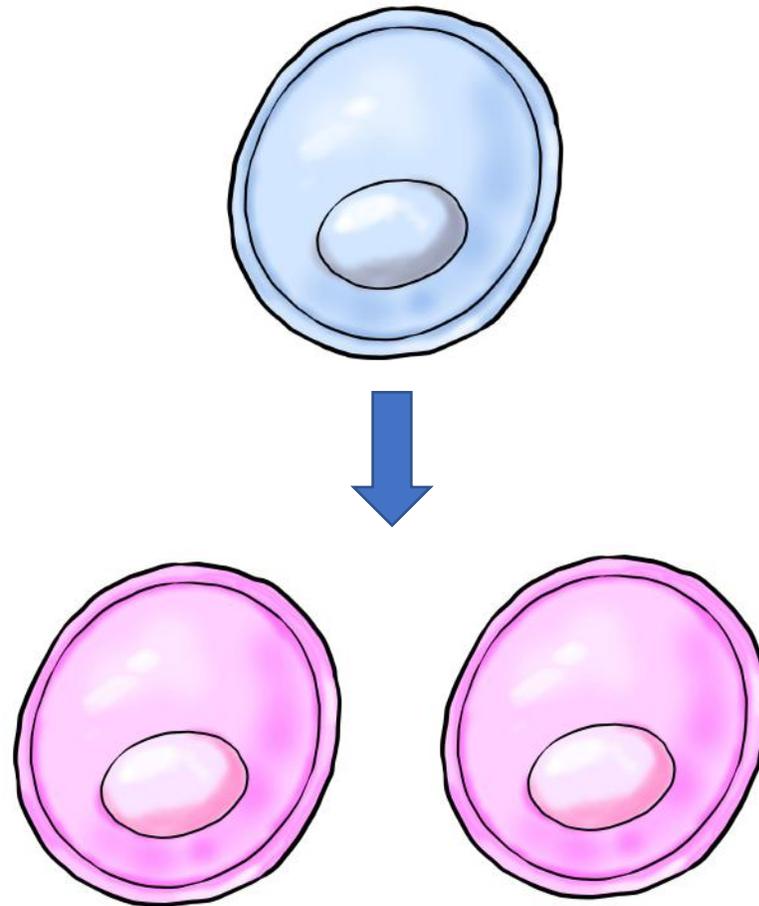
Directions
[3 marks]

Command

3) *E. coli* can divide as often as once every 20 minutes.

Assuming one *E. coli* cell weighs 1.5 pg ($1 \text{ pg} = 10^{-12} \text{ g}$), calculate the amount of time taken for 24 pg of *E. coli* to grow from a single cell.

Meiosis



Specification Points

AQA

3.4.3 Genetic diversity can arise as a result of mutation or during meiosis

Content	Opportunities for skills development
<p>Gene mutations involve a change in the base sequence of chromosomes. They can arise spontaneously during DNA replication and include base deletion and base substitution. Due to the degenerate nature of the genetic code, not all base substitutions cause a change in the sequence of encoded amino acids. Mutagenic agents can increase the rate of gene mutation.</p> <p>Mutations in the number of chromosomes can arise spontaneously by chromosome non-disjunction during meiosis.</p> <p>Meiosis produces daughter cells that are genetically different from each other.</p> <p>The process of meiosis only in sufficient detail to show how:</p> <ul style="list-style-type: none"> two nuclear divisions result usually in the formation of four haploid daughter cells from a single diploid parent cell genetically different daughter cells result from the independent segregation of homologous chromosomes crossing over between homologous chromosomes results in further genetic variation among daughter cells. <p>Students should be able to:</p> <ul style="list-style-type: none"> complete diagrams showing the chromosome content of cells after the first and second meiotic division, when given the chromosome content of the parent cell explain the different outcome of mitosis and meiosis recognise where meiosis occurs when given information about an unfamiliar life cycle explain how random fertilisation of haploid gametes further increases genetic variation within a species. 	<p>AT d</p> <p>Students could examine meiosis in prepared slides of suitable plant or animal tissue.</p> <p>MS 0.5</p> <p>Students could:</p> <ul style="list-style-type: none"> use the expression 2^n to calculate the possible number of different combinations of chromosomes following meiosis, without crossing over derive a formula from this to calculate the possible number of different combinations of chromosomes following random fertilisation of two gametes, <p>where n is the number of homologous chromosomes pairs.</p>

OCR

2.1.6 Cell division, cell diversity and cellular organisation

Learning outcomes	Additional guidance
(f) the significance of meiosis in life cycles	<p>To include the production of haploid cells and genetic variation by independent assortment and crossing over.</p> <p>HSW2, HSW5</p>
(g) the main stages of meiosis	<p>To include interphase, prophase 1, metaphase 1, anaphase 1, telophase 1, prophase 2, metaphase 2, anaphase 2, telophase 2 (no details of the names of the stages within prophase 1 are required) and the term <i>homologous chromosomes</i>.</p> <p>PAG1 HSW8</p>

Specification Points

Edexcel A

Topic 3: Voice of the Genome

Students should:

- 3.9 Understand the role of meiosis in ensuring genetic variation through the production of non-identical gametes as a consequence of independent assortment of chromosomes and crossing over of alleles between chromatids (details of the stages of meiosis are not required).

Edexcel B

Topic 2: Cells, Viruses and Reproduction of Living Things

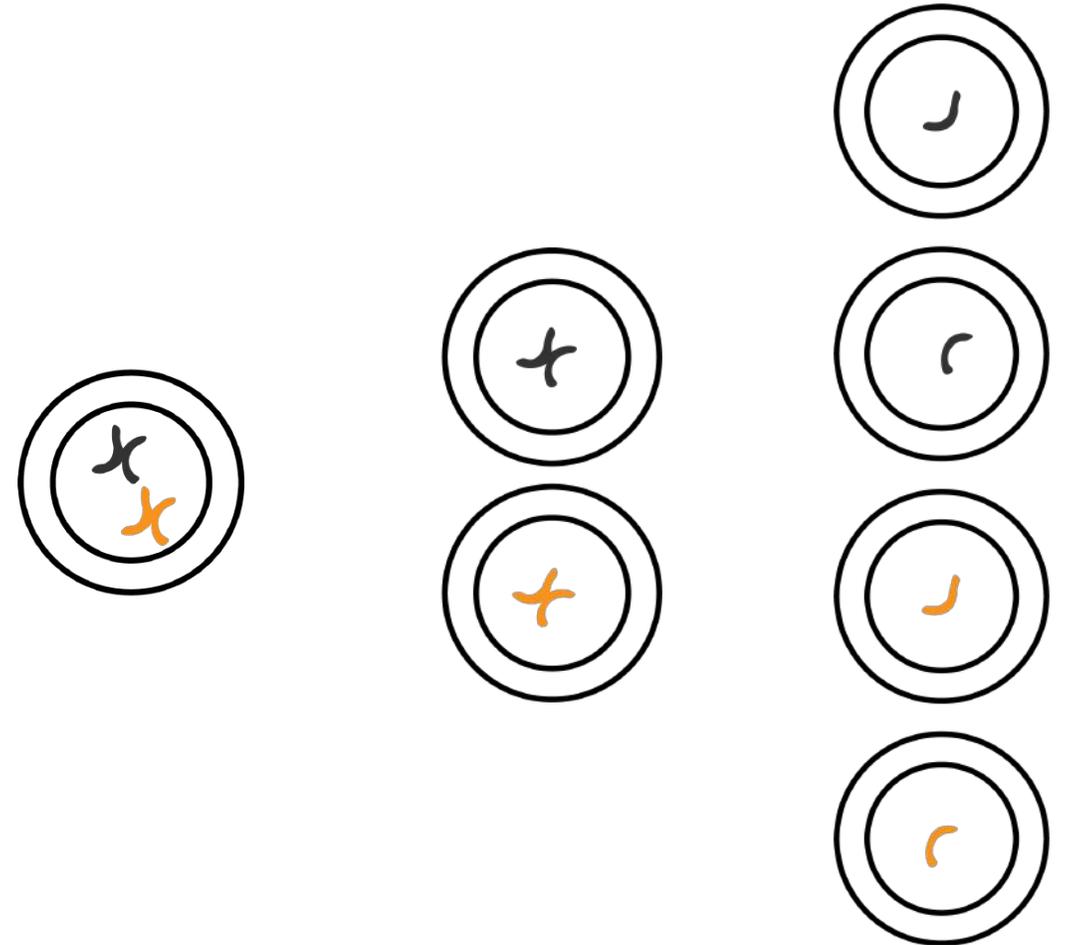
Students should:

2.3 Eukaryotic cell cycle and division

- iv Understand how meiosis results in haploid gametes, including the stages of meiosis.

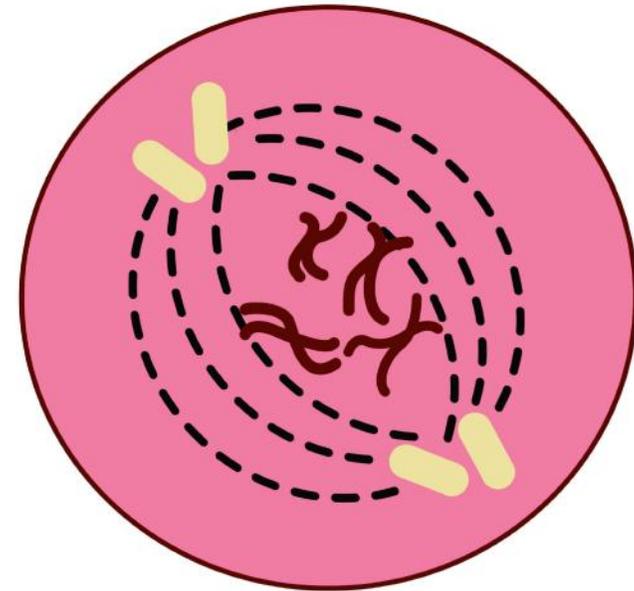
Meiosis

- Meiosis involves **two divisions** and creates **haploid cells** such as **gametes**
- **Meiosis I** occurs after **chromosome duplication** and separates **homologous chromosomes** into **different cells**
- **Meiosis II** separates **sister chromatids** of each chromosome into **different cells**



Meiosis I – Prophase

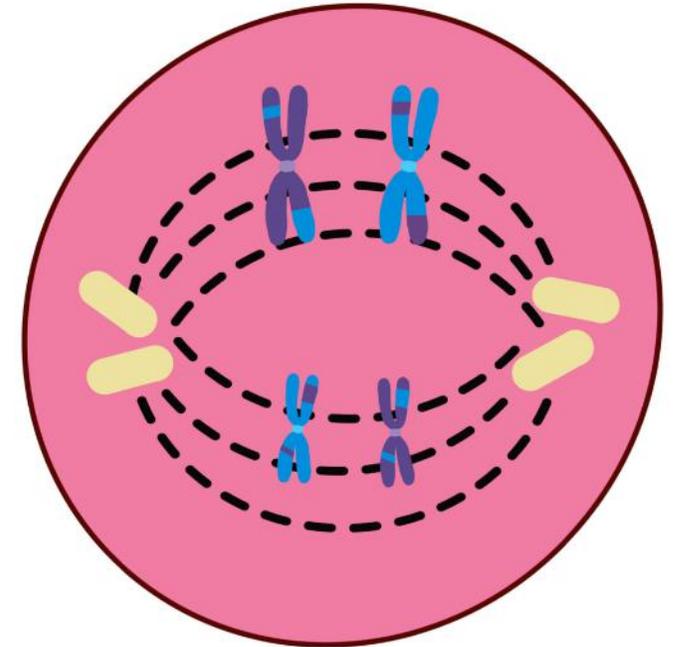
- In **prophase I** chromosomes **supercoil**, **nuclear envelopes** break down and **spindle fibres** form
- At the end of prophase I **crossing over** occurs and **DNA** is exchanged between **chromatids** on **homologous chromosomes**



AQA & Edexcel A: Do not need to know the stages of **meiosis**

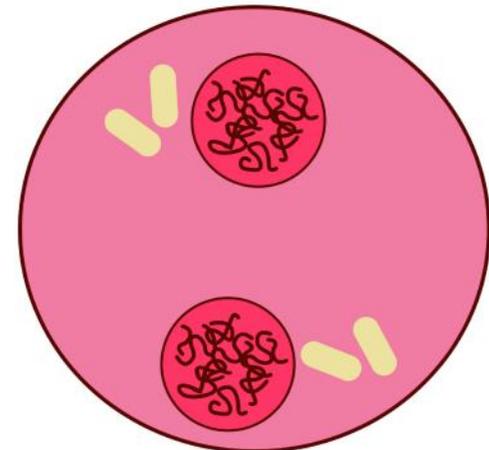
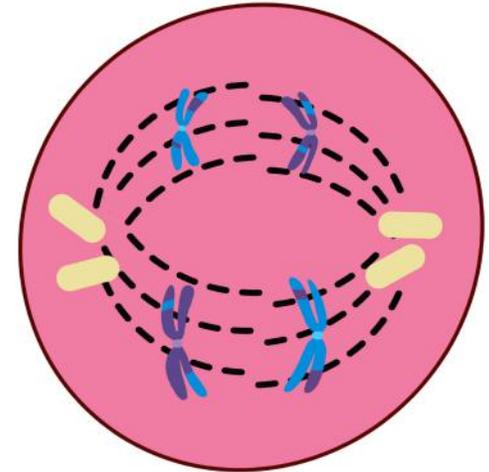
Meiosis I – Metaphase

- In **metaphase I** chromosomes **attach** to spindle fibres by their **centromeres** and line up at the cell **equator**
- The **position** of each **homologous chromosome** along the **equator** **determines** which **daughter cell** they are **separated** into
- This is called **independent assortment/segregation** and is a **random process** that introduces **variation**



Meiosis I – Anaphase and Telophase

- In **anaphase I** each **chromosome** from the **homologous pair** is pulled to **opposite poles** of the cell
- In **telophase I** the **chromosomes** then **uncoil/decondense**
- **Two nuclei** containing each set of chromosomes are **temporarily formed**



Exemplar Exam Question – Statement

4) Mitosis and meiosis are two types of cell division which produce somatic cells and gametes in mammals.

State another difference between the cells formed by mitosis and meiosis.

[1 mark]

Command: simple comparison without depth

Direction: focus on the differences of cells produced

Context: comparing mitosis and meiosis

Exemplar Exam Question – Statement

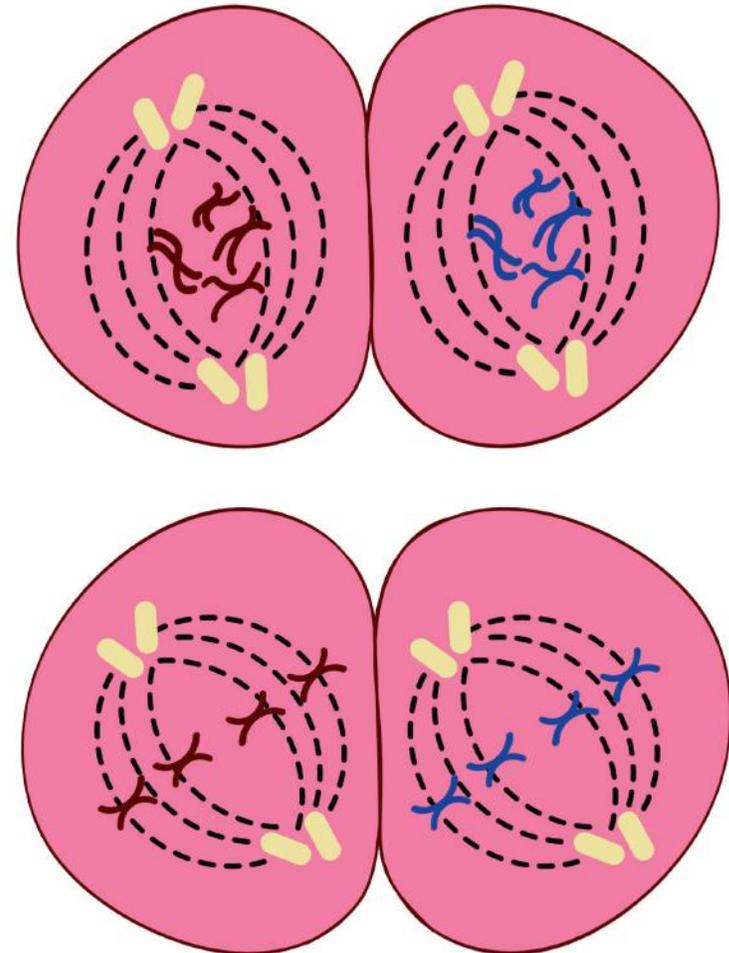
4) Mitosis and meiosis are two types of cell division which produce somatic cells and gametes in mammals.

State another difference between the cells formed by mitosis and meiosis.

[1 mark]

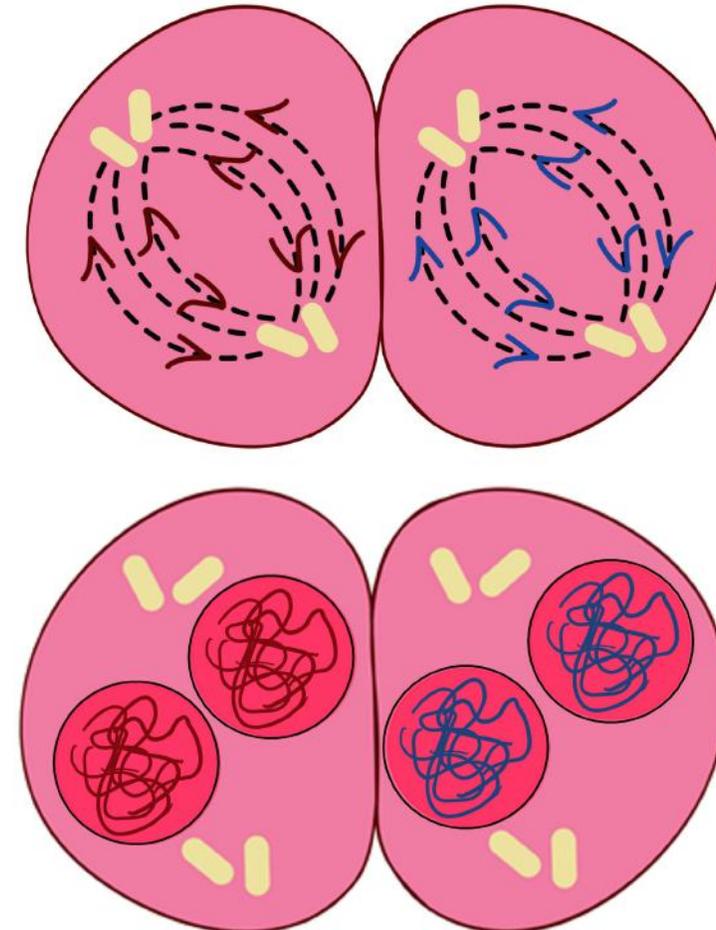
Meiosis II – Prophase and Metaphase

- **Meiosis I** produces **two haploid cells** – the **homologous pairs** of chromosomes have been separated
- In **prophase II**, the **DNA supercoils**, the **nucleus disintegrates** and new **spindle fibres form**
- In **metaphase II**, chromosomes are **lined up** at the **equator** of the cell
- **Sister chromatids** are **not identical** due to **crossing over**



Meiosis II – Anaphase and Telophase

- In **anaphase II**, the **genetically different chromatids** are **separated** to **opposite poles**
- This leads to a **second** round of **independent assortment/segregation**
- In **telophase II**, the **nuclei reform** and after telophase II, the cells each **split** in **two** by **cytokinesis**
- This results in **four, genetically different, haploid** cells



Exemplar Exam Question – Simple Explanatory

5) Meiosis is used by organisms to produce gametes such as sperm and egg cells.

Explain why meiosis requires two stages of cell division.

[2 marks]

Command: justify your choice and put it in context of question

Direction: what happens in the stages of meiosis I and II

Context: meiosis

Exemplar Exam Question – Simple Explanatory

5) Meiosis is used by organisms to produce gametes such as sperm and egg cells.

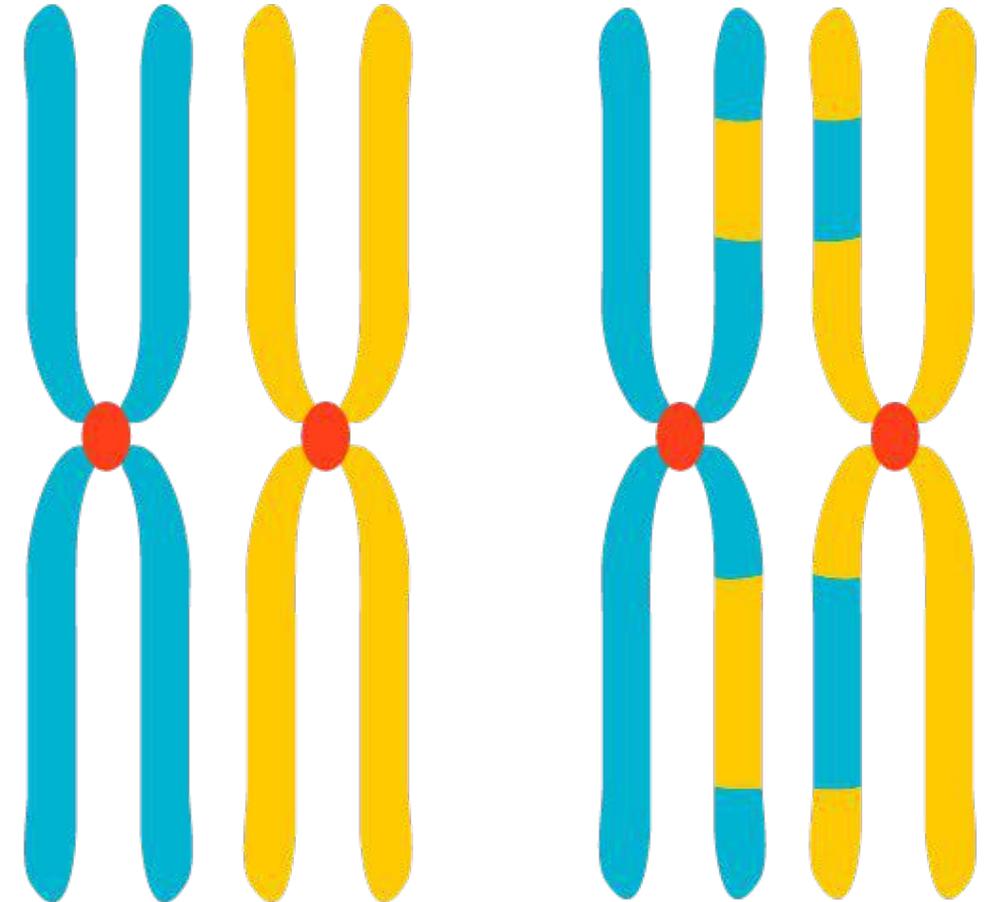
Explain why meiosis requires two stages of cell division.

[2 marks]

Meiosis requires two stages to halve the chromosome number and to separate homologous pairs of chromosomes and sister chromatids.

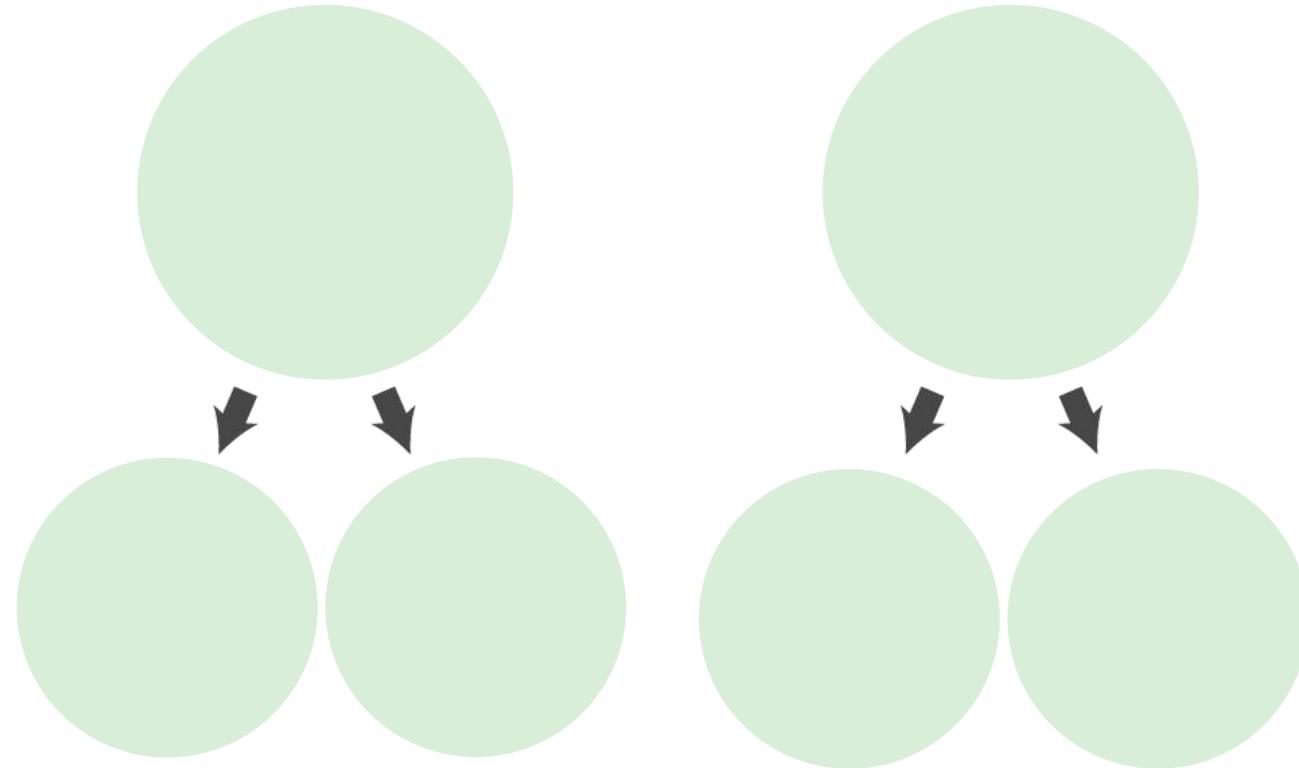
Meiosis – Crossing Over

- **Crossing over** occurs in **meiosis I** and allows **alleles** to be **swapped** between **homologous chromosomes**
- Homologous chromosomes **line up** and **twist** around each other
- The wrapping causes **sections** of the **chromatid** to **break** off - they are then **swapped** to the homologous chromosome
- Crossed over chromosomes have the **same genes** but **different alleles**



Meiosis – Independent Assortment/Segregation

- **Random distribution of homologous chromosomes** along the **cell equator** in **metaphase I** affects which **chromosomes** (and therefore **alleles**) end up in the **daughter cells**
- **Random distribution of sister chromatids** along the **cell equator** in **metaphase II** affects which **alleles** end up in the **daughter cells**



Exemplar Exam Question – Explanation

6) Crossing over and independent assortment are critical for introducing genetic diversity during meiosis.

Describe the process of crossing over.

[3 marks]

Command: explanation, without too much depth

Direction: focus only on crossing over

Context: meiosis and genetic diversity

Exemplar Exam Question – Explanation

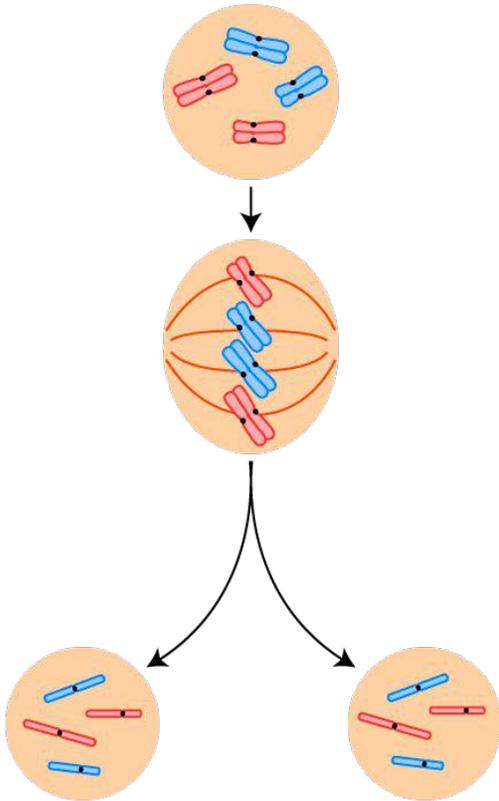
6) Crossing over and independent assortment are critical for introducing genetic diversity during meiosis.

Describe the process of crossing over.

[3 marks]

Crossing over occurs in meiosis I and allows alleles to be swapped between homologous chromosomes. Homologous chromosomes line up and wrap around each other, which causes bits of each chromatid to break off and exchange with each other, swapping alleles. The points where crossing over occurs are called chiasmata.

Mitosis vs. Meiosis



Mitosis

One cell division only
–makes **two daughter cells**

No recombination

Daughter cells are **genetically identical**

Daughter cells are **diploid** - they have two sets of chromosomes

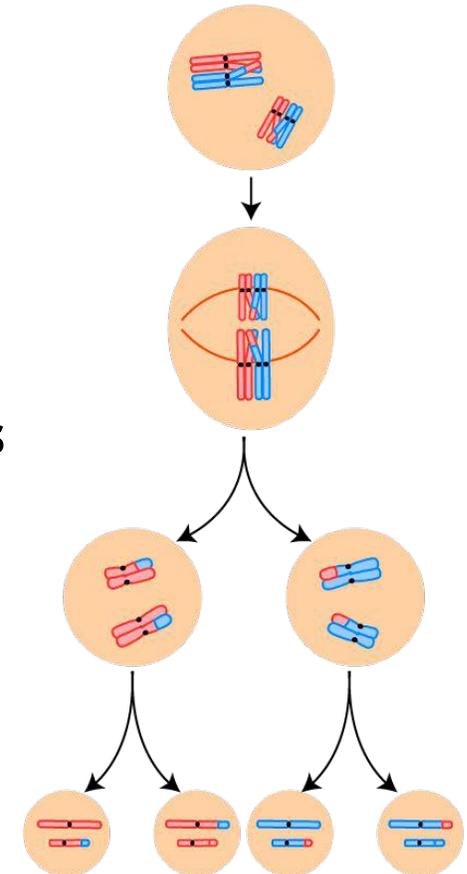
Meiosis

Two cell divisions –
makes **four daughter cells**

Recombination occurs

Daughter cells are **genetically distinct**

Daughter cells are **haploid** - they have only one set of chromosomes



Exemplar Exam Question – Extended Response

7) Explain how meiosis increases genetic variation and compare the products of meiosis and mitosis.

One mark is available for the quality of written communication.

[6

marks]

Command: detail
processes of meiosis

Direction: may require
comparative adjectives

Context: requires
knowledge of the
underlying process of
meiosis

Mitosis produces two genetically identical diploid daughter cells, whilst meiosis produces four genetically distinct haploid daughter cells. Variation in meiosis can be caused by recombination between homologous chromosomes (crossing over) during prophase I or by the independent assortment of homologous chromosomes in metaphase I and sister chromatids in metaphase II.

Mini Mock Paper



Microtubules are polymers that are important components making up the spindle fibres found in mitotic cells. During spindle fibre formation, microtubules are polymerised while they are depolymerised during spindle fibre contraction. Drugs targeting spindle activity are key chemotherapeutic (anti-cancer) agents.

- a) Vinblastine is an anti-cancer drug which works by preventing microtubule formation.

State which phase of mitosis human cells treated with vinblastine get stuck in.

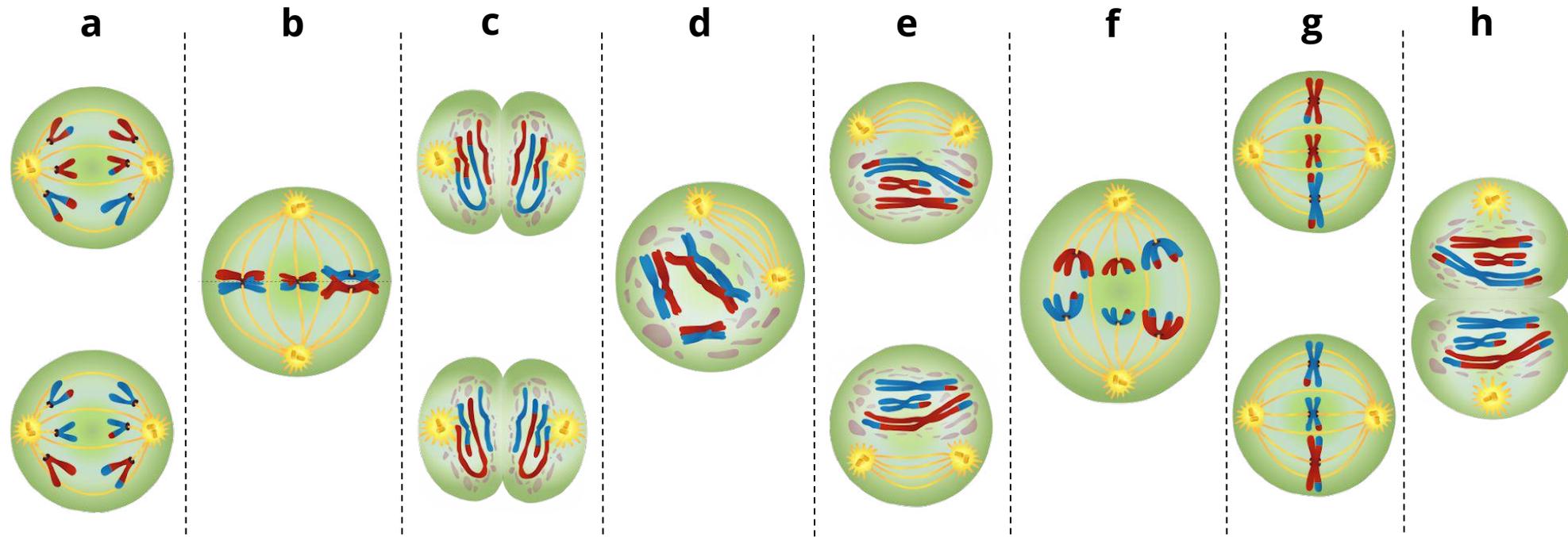
[1 mark]

b) Describe what you would expect to see under a microscope when examining a population of these vinblastine-treated and mitosis-arrested human cells.

[3 marks]

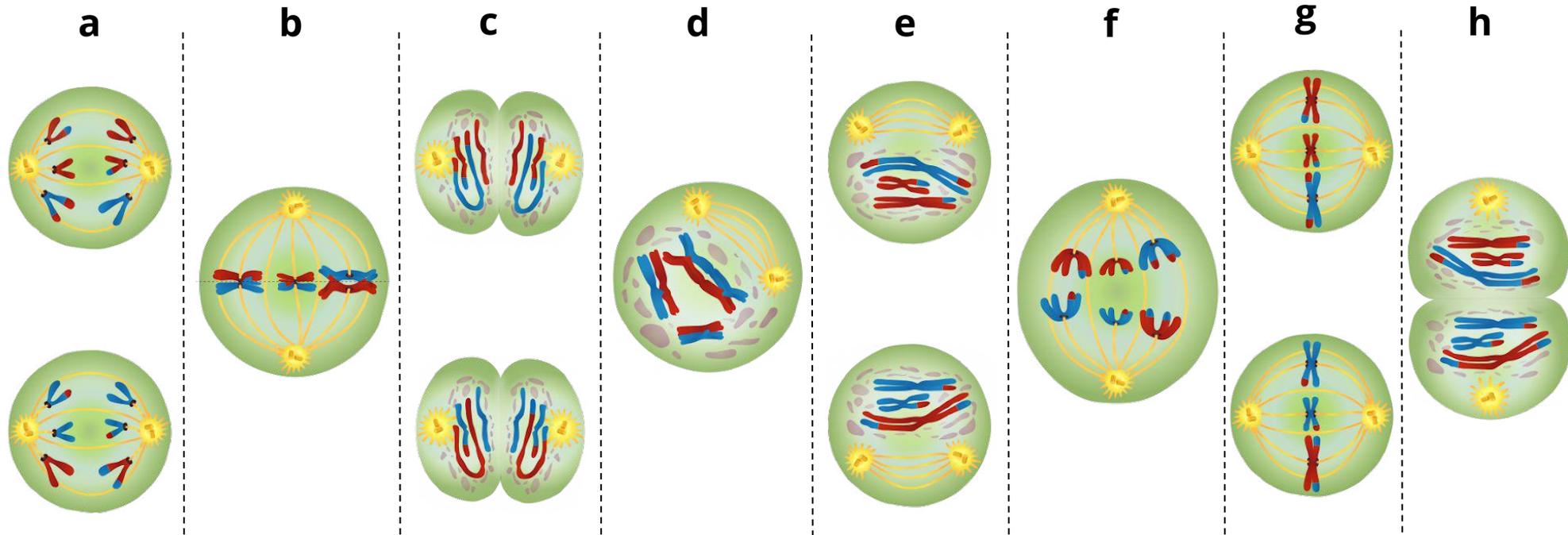
Q2. The pictures below show the various steps of meiosis.

(a) Sequence these pictures (A to G) in the chronological order they would happen in cells.



[4 marks]

(b) Independent assortment and crossing over are two ways in which genetic diversity is introduced into offspring. State the phase(s) in which both of these processes occur during production of gametes.



[2 marks]

Mini Mock Paper Answers



Microtubules are polymers that are important components making up the spindle fibres found in mitotic cells. During spindle fibre formation, microtubules are polymerised while they are depolymerised during spindle fibre contraction. Drugs targeting spindle activity are key chemotherapeutic (anti-cancer) agents.

- a) Vinblastine is an anti-cancer drug which works by preventing microtubule formation.

State which phase of mitosis human cells treated with vinblastine get stuck in.

[1 mark]

Prophase

b) Describe what you would expect to see under a microscope when examining a population of these vinblastine-treated and mitosis-arrested human cells.

[3 marks]

In some of these cells, the DNA will appear as long, tangled threads
while in others, the DNA will appear in a supercoiled form, which is a
shorter, more condensed structure. You would expect to see
disintegration or complete breakdown of the nuclear envelope
surrounding the DNA. Furthermore, you will find the centrioles to have
divided and moved to the opposite ends of the cells (the poles).

Figure 1

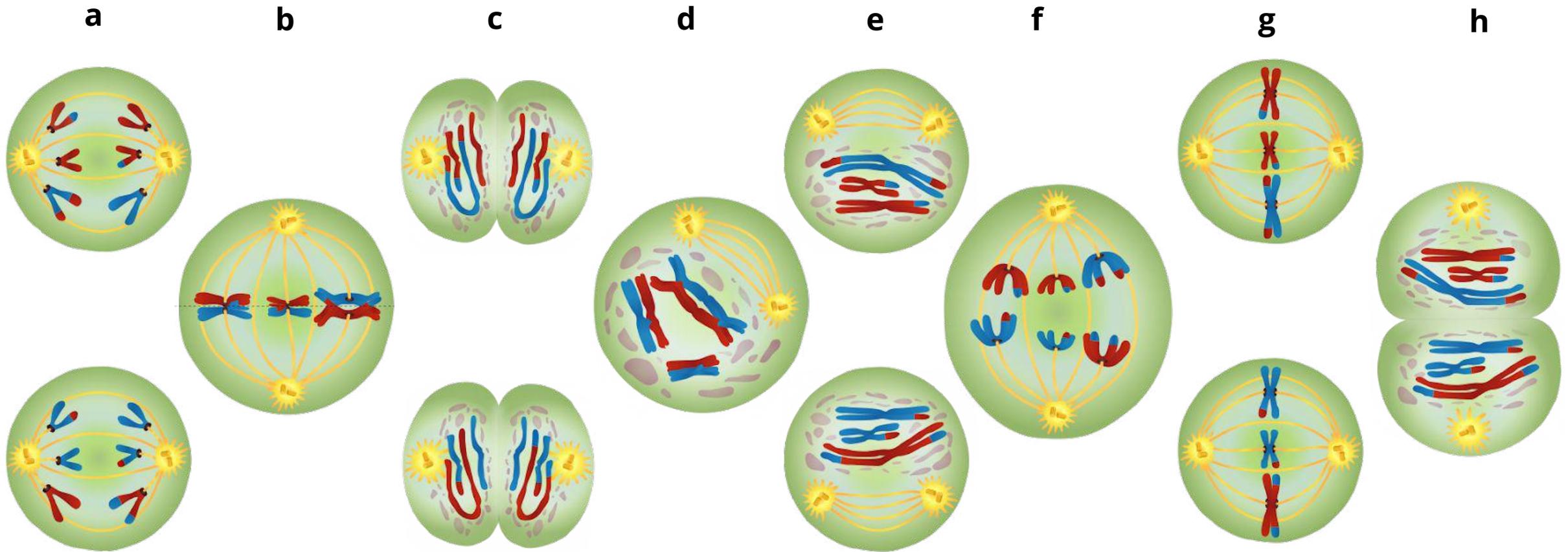


Figure 1 shows the various phases of meiosis.

- (a) Sequence these pictures (A to G) in the chronological order they would happen in cells.

[4 marks]

D, b, f, h, e, g, a, c

- (b) Independent assortment and crossing over are two ways in which genetic diversity is introduced into offspring. State the phase(s) in which both of these processes occur during production of gametes.

[4 marks]

Crossing over occurs only in (d).

Independent assortment occurs in (b) and (g).