5. The mitotic cell cycle

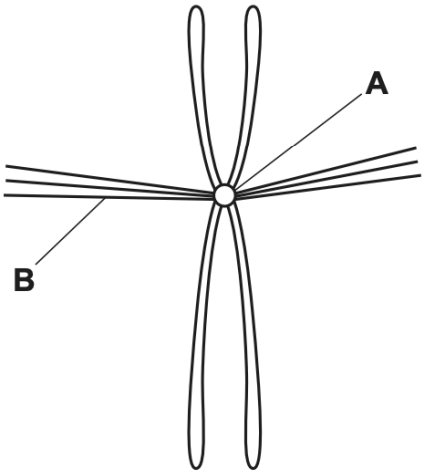
1. Describe the roles of DNA polymerase and DNA ligase in the replication of DNA.

   <u>DNA polymerase</u>
   - addition of activated / phosphorylated nucleotides
   - ref. to complementary nucleotides / bases / strands
   - forms phosphodiester bonds
   - between adjacent nucleotides and elongating / growing polynucleotide / strand / AW
   - ref. to proofreading ability of DNA polymerase

   <u>DNA ligase</u>
   - joins Okazaki fragments
   - on lagging strand
   - by catalysing formation of phosphodiester bonds between the fragments / adjacent nucleotides
   - completes the sugar-phosphate backbone

2. State the name of the stage of interphase in the cell cycle when DNA replication occurs.
   - S-phase / synthesis phase

3. Fig. 4.2 is a diagram of chromosome 11 at metaphase of mitosis.



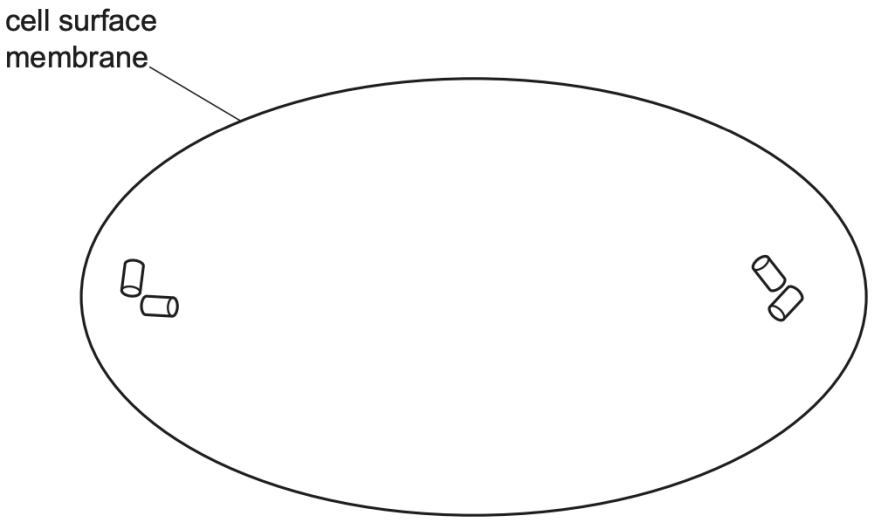
   State the names and functions of structures A and B.
   - <u>Structure A</u> = centromere
   - <u>Function</u> = site of attachment of chromatids / chromosomes to spindle fibres/ microtubules OR holds sister / identical chromatids together

   - <u>Structure B</u> = spindle fibres / microtubules

- Function = orientating chromosomes at the (spindle) equator OR separating chromatids at end of metaphase / at start of anaphase OR movement of chromatids / chromosomes to (opposite) poles

4.

Complete Fig. 4.3 to show what happens to chromosome 11 in anaphase, so that the daughter nuclei are genetically identical.

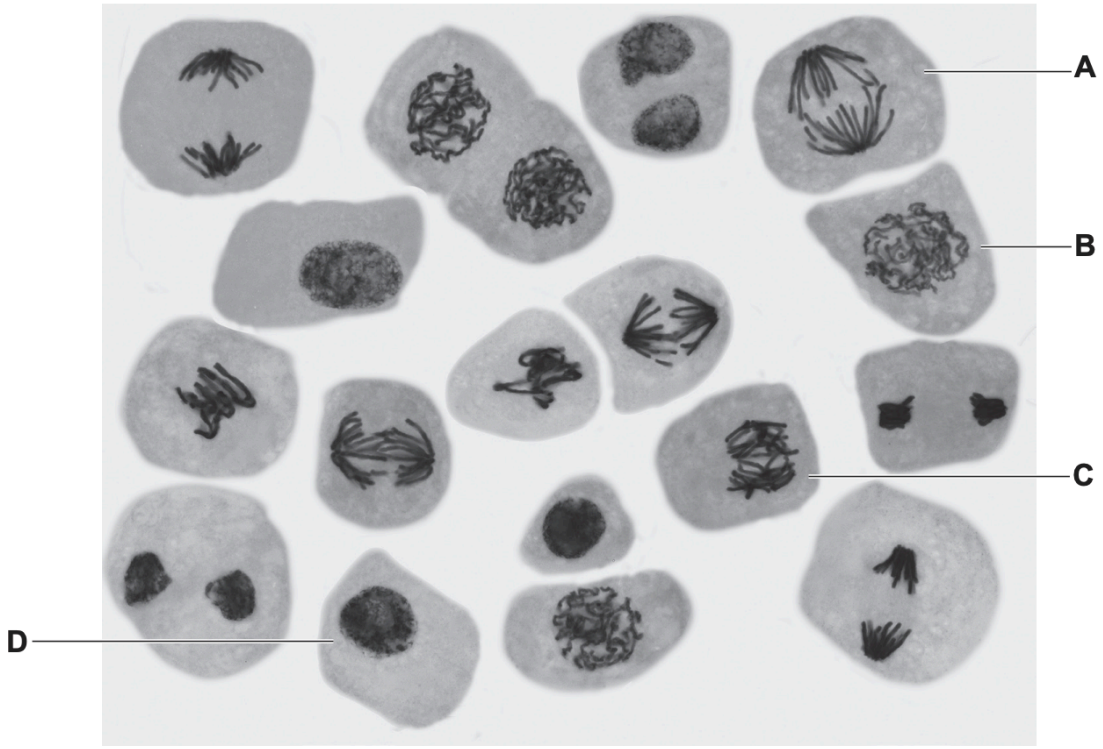


- two separate chromatids / single-stranded chromosomes ;
- chromatids attached to spindle with fibres drawn to poles / centrioles ;
- single chromatids drawn U-shaped or V-shaped pointing towards the poles ;
- centromeres drawn in both chromatids ;

5. Name the following:

The part of the cell cycle that occurs immediately after mitosis	Cytokinesis / division of cytoplasm
The part of the cell cycle in which the S phase occurs	Interphase
The main event that occurs during the S phase	Semi-conservative DNA replication

6.



a. Identify the stages of mitosis occurring in the cells labelled B and C

- B: prophase
- C: metaphase

NOTE: D is in interphase

b. Describe the behaviour of the chromosomes in the stage of mitosis shown in cell A

- identical sister chromatids of each chromosome separate
- centromeres divide at start of anaphase to separate sister chromatids
- movement of sister chromatids to opposite poles of cell
- movement to opposite poles by spindle fibres contracting / pulling centromeres leading during movement, so arms of chromosome lagging
- chromosomes become diffuse / become long and thin / decondense / uncoil

7. State the location of telomeres on a chromosome.
   - at both ends of interphase chromosomes

8. Suggest why a long lifespan could result from a higher telomerase activity.
   - telomeres maintained for longer / greater length of time
   - allows increased number of cell cycles / DNA replication cycles / cell division / mitosis
   - prevents loss of genes at ends of chromosomes for a longer time

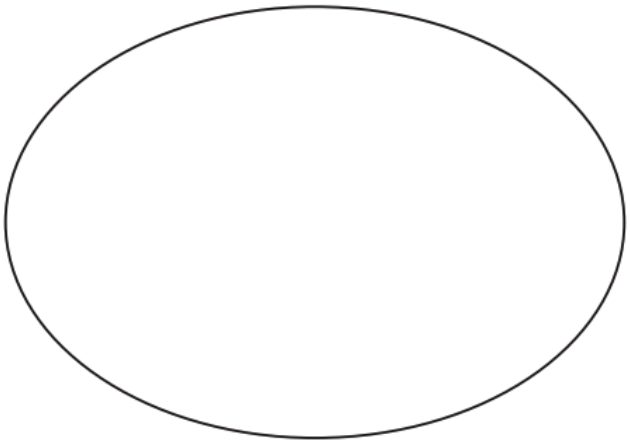
- greater ability to replace damaged / worn out / old cells for a longer period
- cell metabolism remains optimal / cell does not go through apoptosis (programmed cell death)

9. State the term used to describe the proteins that are complexed with DNA and form part of chromatin.
   - Histones

10.

When viewed through a microscope, a chromosome is most clearly visible during the metaphase stage of mitosis.

Complete Fig. 1.1 to produce a labelled diagram of the metaphase stage of mitosis in an **animal** cell with **two** chromosomes.



- 2 chromosomes each with 2 chromatids, drawn approximately along central equator area
- one other drawn feature: spindle OR spindle fibre from each pole connecting to centromere area of one chromosome OR centromere drawn holding sister chromatids together OR pair of centrioles at each pole
- any 3 labels: sister / identical chromatids, centromere, spindle / spindle fibres, spindle equator / metaphase plate, centrioles
  NOTE: label lines to touch structure

11. Outline the changes that occur to the structure and behaviour of a chromosome:
    • from the start of the S phase to the end of interphase
    • during prophase of mitosis

    <u>Interphase</u>
- chromosomal DNA replicates
- Each new molecule of DNA complexes / associates with histones / proteins

- Identical sister chromatids form after DNA replication /during/ end of S phase

Prophase
- chromatids / chromosome condense / become shorter and fatter / coiling of DNA / chromosomes / chromatids
- becomes visible / appears as two sister / identical chromatids
- becomes attached to the spindle fibres
- spindle microtubules attach to centromere / kinetochore formation

12.

Replication of nuclear DNA occurs just once in every mitotic cell cycle. Six named events associated with the mitotic cell cycle are listed. The events are **not** listed in any particular order.

Draw a circle around each event where replication of nuclear DNA occurs.

cytokinesis

interphase S phase

G_2 phase G_1 phase

mitosis

- S phase and interphase

13. Outline how DNA is replicated inside the nucleus.
- double helix unwinds, using helicase enzyme which breaks hydrogen bonds between strands
- both strands act as templates
- activated free DNA nucleotides in cytoplasm
- DNA polymerase adds complementary nucleotides to exposed strand
- forms phosphodiester bonds between adjacent nucleotides
- proofreading / checking for errors / checking for mismatches
- leading strand synthesised continuously
- lagging strand synthesised in Okazaki fragments
- DNA ligase joins fragments with phosphodiester bonds
- semi-conservative replication: both new double helices have one parental / conserved strand and one newly synthesised strand

14. Mitosis is important for the repair of tissues. Explain what is meant by repair of tissues
- replacing cells that are damaged / destroyed / worn out / old

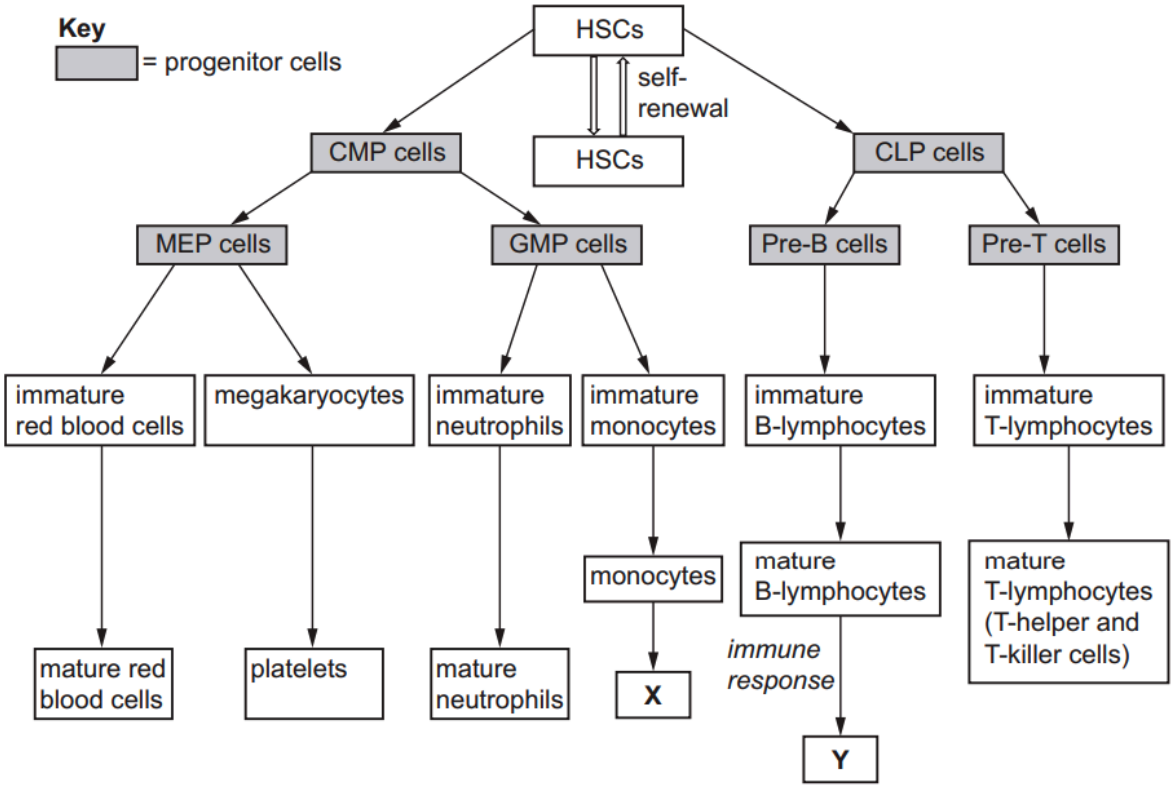
15. Uncontrolled cell division is a characteristic feature of tumour formation from a differentiated cell. Describe features of tumour formation from a fully differentiated cell.
    - loss of original / normal function
    - result of mutation
    - shorter/ faster / many / continuous cell cycles / cell divisions // shorter interphase
    - normal cell cycle checkpoints not occurring
    - cell cycle continues because fault in / errors in / no response to cell signalling
    - no contact inhibition / mitosis continues beyond space available / cell formation may spread to other nearby areas
    - cells do not carry out apoptosis / no programmed cell death
    - increase in telomerase activity
    - metastasis: cells travel in blood / lymph to form tumours elsewhere in body

16. Explain why long telomeres are an advantage to cells that carry out many cell cycles.
    - long telomeres allow long life span / many divisions to occur / many mitoses
    - after replication nucleotides at ends of DNA are lost
    - telomeres do not contain genes / genetic information / are non-coding
    - after each cell cycle / cell division / DNA replication telomeres shorten
    - long telomeres means that DNA replication can take place more times
    - ends of chromosomes are protected

17.

Haematopoietic stem cells (HSCs) are adult stem cells that are located in the bone marrow of bones. HSCs have a role in the formation of blood cells.

Fig. 4.1 is an outline summary showing the formation of some of the different types of blood cell that can be formed from HSCs. The first stage is the division of HSCs to produce progenitor cells. These cells are also able to divide by mitosis, but are **not** stem cells.



With reference to Fig 4.1, explain why GMP cells, which are progenitor cells, cannot be described as haematopoietic stem cells (HSCs).

- differentiation has already started // they are not undifferentiated // GMP cells are differentiated / specialised (compared to stem cells)
- no self-renewal // cannot produce a stem cell when they divide
- cannot form all blood cell types
- only forms immature neutrophils and monocytes

18. The differentiation of T-lymphocytes begins in the bone marrow and continues in an organ known as the thymus to produce fully differentiated T-helper and T-killer cells. In the thymus, T-lymphocytes that bind to self antigens are destroyed. Explain why T-lymphocytes that bind to self antigens need to be destroyed in the thymus.

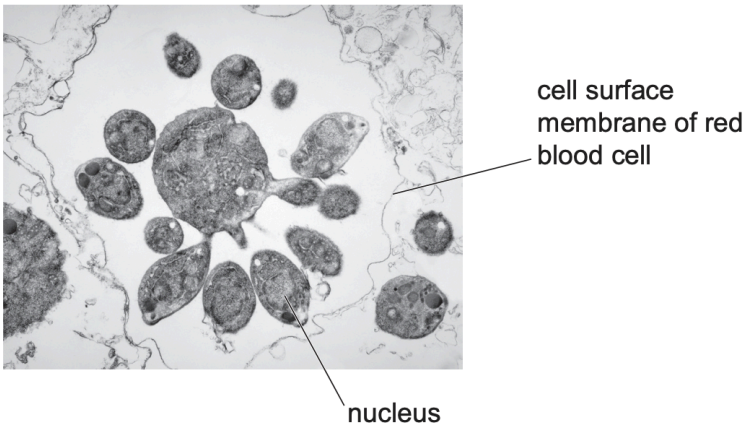
- next stage / after thymus is (T-lymphocyte) release into general circulation / blood
- if released, there will be exposure to / activation by self-antigens on body cells OR immune response occurs against body cells

- if released, there will be harm to / destruction of body cells
- need to prevent formation of memory T-cells
- AVP: if released, may cause autoimmune disease / response
- T-helper will release cytokines to enhance immune response against body cells, which may lead to phagocytosis / antibodies will be produced against body cells

19.

The malarial pathogen, *Plasmodium falciparum*, enters red blood cells after a person becomes infected. After some time, each cell of *P. falciparum* divides to form daughter cells.

Fig. 1.1 shows a cell of *P. falciparum* that is forming many daughter cells.



When P. falciparum divides there is unequal division of the cytoplasm to form small, genetically identical daughter cells. Outline the events that occur in the cell of P. falciparum to form the daughter cells shown in Fig. 1.1.

- pathogen feeds / grows / synthesises (named) biochemicals OR increase in volume / mass of cytoplasm
- production of (named) organelles
- Semi-conservative DNA replication / synthesis
- mitosis / mitoses / four named stages of mitosis
- production of several / many nuclei
- cytokinesis / described e.g. as ref. to formation of cleavage furrow
- daughter cells ‘bud off’ from the ‘parent’ (budding)

20. A root cluster is a dense arrangement of tiny side roots known as rootlets. Meristem cells have a similar role to stem cells in animals. Suggest how meristematic tissue activity leads to the formation of root clusters.

- (many) mitotic cell cycles / mitoses
- ref. to division of meristem cell also produces more meristem cells
- formation of rootlets by mitosis is growth / increase in number of cells
- idea of producing large number of cells
- differentiation / specialisation: new cells formed by stem cell division

21. Some mutations in the PTGS2 gene lead to an increased rate of transcription. These mutations have been linked to an increased risk of certain types of cancer. Suggest why mutations in PTGS2 may increase the risk of cancer.
    - more product / compounds produced that stimulate mitosis
    - increased DNA replication / cell division / mitosis
    - idea that may lead to / increases chance of other mutations
    - mutations can result in oncogenes
    - AVP: proof checking capacity impaired / increased chance of errors

22. Describe the function of centrioles and explain how they are involved in the cell cycle of a stem cell.
    - centrioles make / organise microtubules ; microtubular organising centre (MTOC)
    - to form the spindle / spindle fibres
    - during each cell cycle each centriole replicates / duplicates / forms two centrioles
    - during S phase / G2 phase / before mitosis
    - centriole pairs / centrioles move to the opposite poles of cell during prophase of mitosis
    - centrioles shorten the spindle fibres / microtubules

23. Explain what is meant by a gene mutation.
    - change in the sequence of base pairs in a DNA molecule
    - may result in an altered/ different polypeptide

24. State what happens to chromatin so that individual chromosomes can be seen during mitosis
    - coiling / supercoiling / condensation / becomes more compact: becomes shorter and fatter

25. Describe the structure of chromosomes at metaphase
    - each has two sister / identical chromatids
    - chromatids joined by a centromere
    - each chromatid has a single DNA molecule
    - DNA associated with histone proteins
    - telomeres / repeating non-coding sequences at ends of chromatids / chromosomes
    - chromosomes most condensed

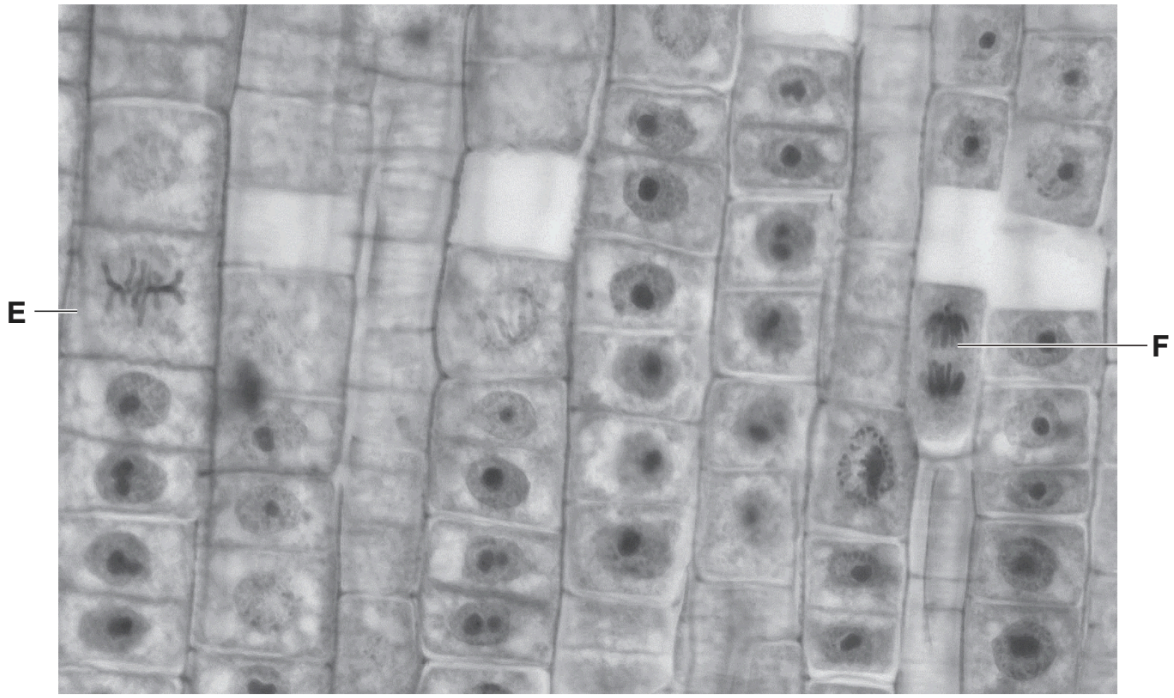
1. Outline what happens in the G1 phase of the mitotic cell cycle
    - RNA is synthesised / transcribed / translated
    - proteins / enzymes are synthesised

- increasing quantity of organelles
- increase in volume of cytoplasm
- at end of G1 phase = checkpoint passed for dividing or not

2. Outline what happens in the S phase of the mitotic cell cycle
    - semi-conservative DNA replication
    - mass / number of strands of DNA doubles
    - each chromosome now comprises two chromatids

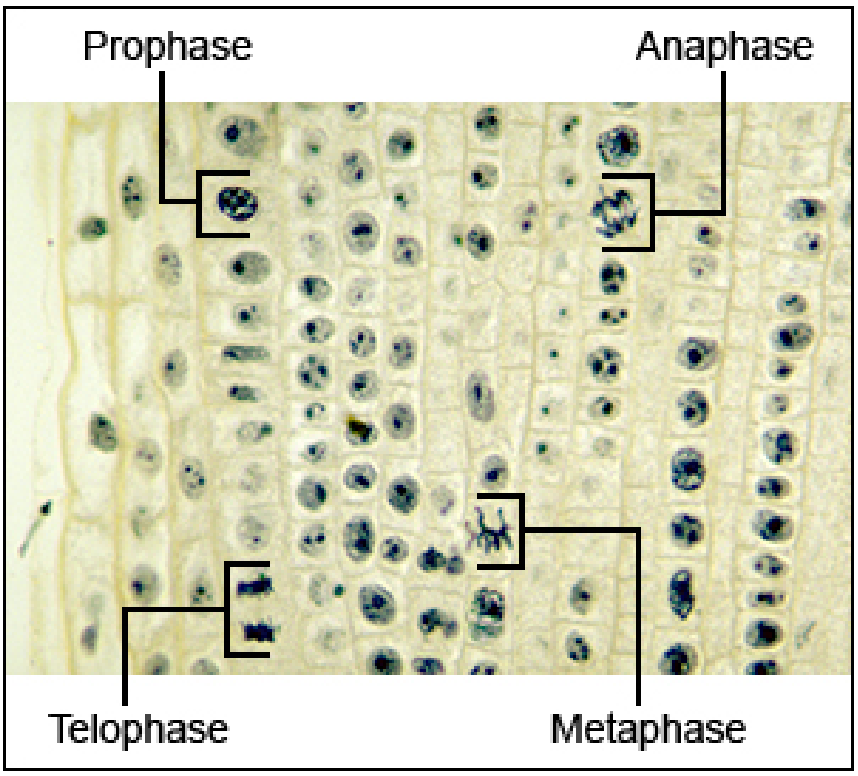
3. Mitogens bind to cell surface receptors of target cells. The target cells respond by progressing from the G1 phase to the S phase of the mitotic cell cycle. Suggest a possible consequence for target cells of increased concentrations of mitogens in the blood.
    - more cells move from the G1 to the S phase ;
    - uncontrolled / increased cell division / mitosis ;
    - resting cells could enter mitosis ;

4.



Identify which stage of mitosis is shown in cell E and in cell F

- E = metaphase
- F = anaphase



5. State the function of microtubules in mitosis.
   - (assemble) to form / become part of the spindle fibres / spindle.
   - attach to centromere / form (part of) kinetochore to connect chromatid / chromosome to spindle / spindle fibres.
   - Allow movement of chromosomes / chromatids: pull chromosomes / orientate chromosomes at equator // pull (sister) chromatids apart (at anaphase) // move sister chromatids / daughter chromosomes to poles.

6. Write the correct term in the spaces provided to complete each of statements A to D.

A The DNA double helix unwinds and is separated into two template strands when ..... bonds holding the two strands together are broken.

B One of the template strands of DNA is copied in fragments. The enzyme ..... is required to join the fragments together to form a continuous strand of DNA.

C Complementary DNA nucleotides are added to the template strands, catalysed by the enzyme ..... .

D ..... are regions of repeating nucleotide sequences at the ends of chromosomes that allow the continued replication of DNA, without the loss of genes.

- A = hydrogen
- B = DNA ligase
- C = DNA polymerase
- D = Telomeres

REMEMBER:

DNA polymerase	**RNA polymerase**
replication	transcription
produces double stranded DNA	produces single stranded RNA

7.

Fig. 6.1 is a scanning electron micrograph of a group of human chromosomes at metaphase.

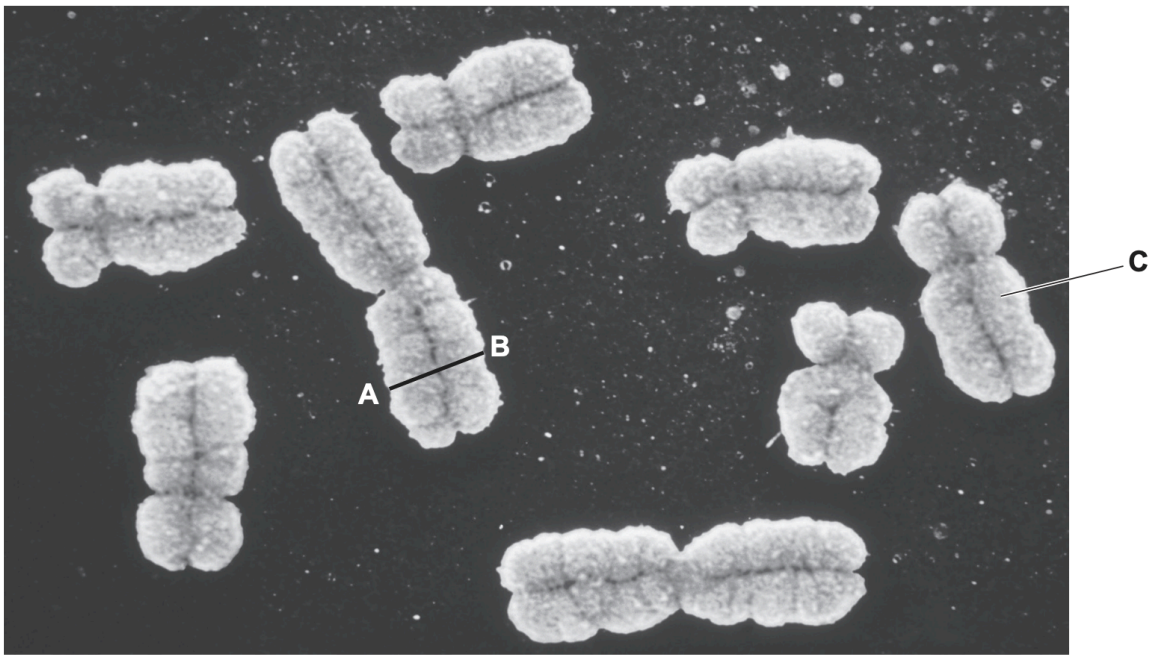


Fig. 6.1

any four from
two chromatids drawn with, non-metacentric centromere / chromosome arms unequal length ;

(sister) chromatid ;
centromere ; *allow as a constriction*
telomere ; *must be labelled at / towards the end*

AVP ; e.g. four telomeres labelled **or** telomere sectioned off at each chromatid end and one labelled
DNA and histones
gene / allele *must be shown as a section*

8. Suggest why the metaphase stage is the best time during a mitotic cell cycle to obtain a clear image of chromosomes.
   - Chromosomes are in their most condensed state
   - chromosomes (all) in one plane / focus ; all at the equator (so clearly visible)

9. Outline the roles of mitosis in a healthy plant.
   - growth ;
   - repair of tissues (by replacement of cells) ;
   - replacement of, old / dead /damaged / worn out, cells ;
   - asexual reproduction ;
   - production of genetically identical daughter cells ;

10.

(b) Uncontrolled mitosis can cause cancer in humans.
Paclitaxel is a drug used in the treatment of some forms of cancer.

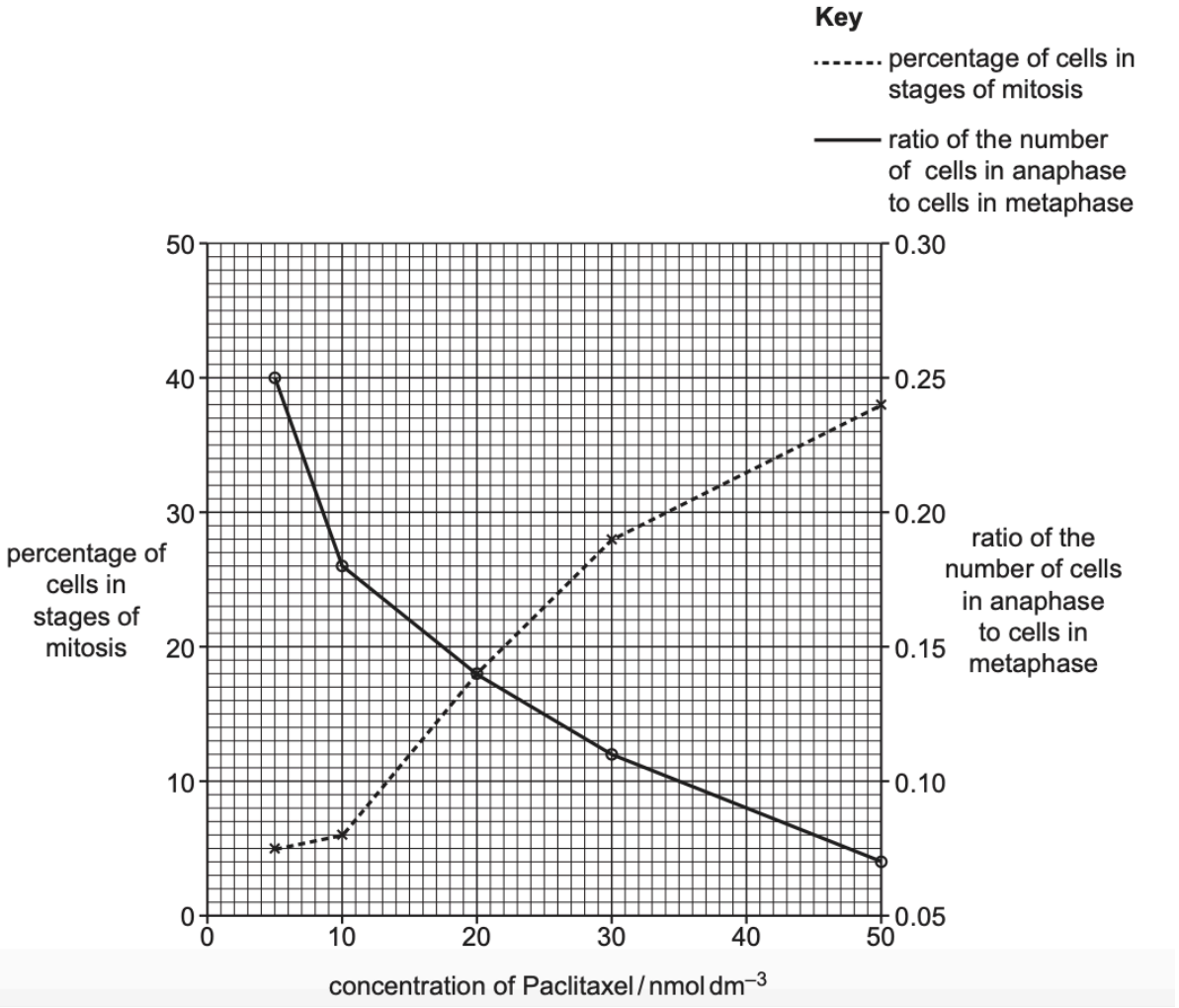
Researchers investigated the effect of Paclitaxel on the mitotic cell cycle of cancer cells.

- The cancer cells were grown for two days and then divided into groups.
- Each group was treated with a different concentration of Paclitaxel.

After 28 hours (one cell cycle):

- the percentage of cells in stages of mitosis was calculated
- the ratio of the number of cells in anaphase to the number of cells in metaphase was determined.

The results of the investigation are shown in Fig. 6.2.



With reference to Fig. 6.2, describe the results and suggest an explanation for the effect of Paclitaxel on the mitotic cell cycle.

- as concentration of Paclitaxel increases, the ratio of cells in anaphase to those in metaphase reduces / there are a greater proportion of cells in metaphase than in anaphase ;

- as the concentration of Paclitaxel increases, the percentage of cells in mitosis is increasing ;
- use of data to support a described trend ;
- idea that as the concentration increases, more cells, stop in metaphase / spend more time in metaphase / fewer cells are able to move into anaphase ;
- suggested mechanism for halt in metaphase ;
    - e.g. centromeres do not divide
    - prevents spindle fibres shortening
    - prevents movement of chromatids to opposite poles (because sister chromatids still held together) cells do not pass the (metaphase) checkpoint
- AVP ;

11. Suggest the role of viral DNA polymerase within a host cell.
    Replication of viral DNA

12. Studies have shown that in the presence of a particular protein found in a virus, the cell cycle stops in the G1 stage. Outline the effects the presence of this protein will have on the normal activity of the mitotic cell cycle.
    - No S phase / G2 phase / mitosis / cytokinesis ;
    - (semi-conservative) DNA, replication / synthesis, does not occur ; sister / identical, chromatids, do not form
    - failure to pass checkpoints / does not reach checkpoints ;
    - cell does not, grow / increase in size / increase cytoplasm for division; only grows to normal non-dividing size
    - cell does not, duplicate / synthesise, organelles / extra materials for cytokinesis