5. The Mitotic Cell Cycle

5.1 Replication and Division of Nuclei and Cells

Paper 2

Question Paper

1 During interphase of the cell cycle, individual chromosomes cannot be seen within the nucleus. The genetic material is termed chromatin during this stage.

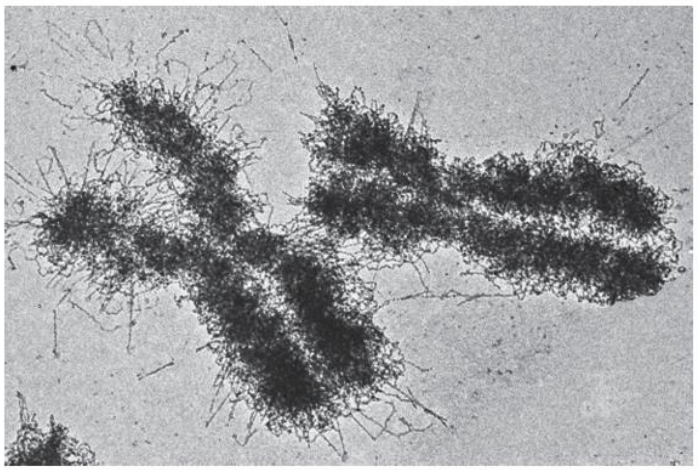
(a) Changes occur to chromatin during mitosis so that chromosomes become visible.

State what happens to chromatin so that individual chromosomes can be seen during mitosis.

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..... [1]

(b) Fig. 5.1 is a transmission electron micrograph of two human chromosomes at metaphase of mitosis.



magnification = ×14 000

Fig. 5.1

Describe the structure of chromosomes at metaphase, such as the two chromosomes shown in Fig. 5.1.

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..... [4]

2 Adult stem cells are undifferentiated cells that are found in most animal tissues.

Adult stem cells can divide by mitosis throughout their lifespan to form identical stem cells (self-renewal) or to form cells that can differentiate into the functioning cells of that tissue.

(a) Mitosis is important for the repair of tissues.

Explain what is meant by repair of tissues.

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..... [1]

(b) Uncontrolled cell division is a characteristic feature of tumour formation from a differentiated cell.

Describe **other** features of tumour formation from a fully differentiated cell.

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..... [2]

(c) Telomeres prevent loss of genes.

Adult stem cells have chromosomes with long telomeres.

Explain why long telomeres are an advantage to cells that carry out many cell cycles.

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..... [2]

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.

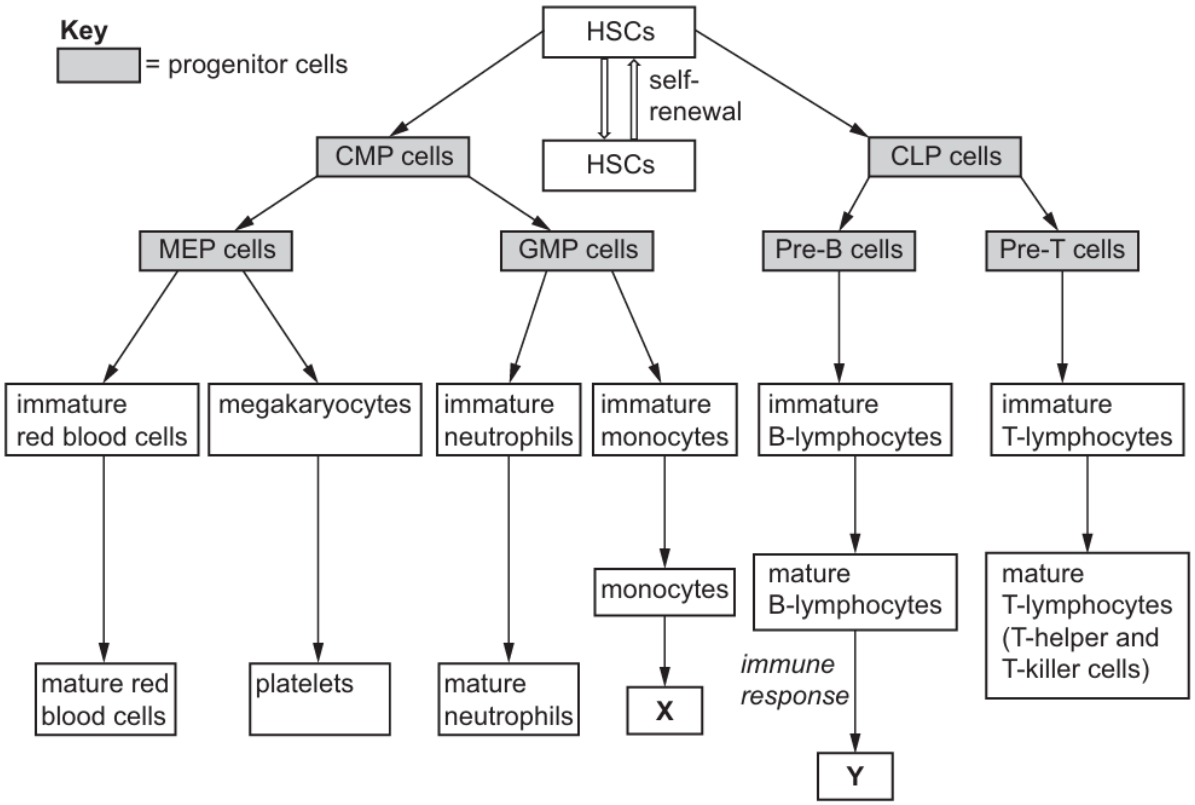


Fig. 4.1

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

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..... [3]

3 Cells of the immune system respond to the presence of non-self antigens.

(c) The cell cycle can be divided into different parts.

Complete sentences **A**, **B** and **C** to provide more information about the mitotic cell cycle.

A The part of the cell cycle that occurs immediately after mitosis is

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B The part of the cell cycle in which the S phase occurs is

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C The main event that occurs during the S phase is

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[3]

4 The gene for the enzyme catalase is on chromosome 11 in humans.

(c) Fig. 4.2 is a diagram of chromosome 11 at metaphase of mitosis.

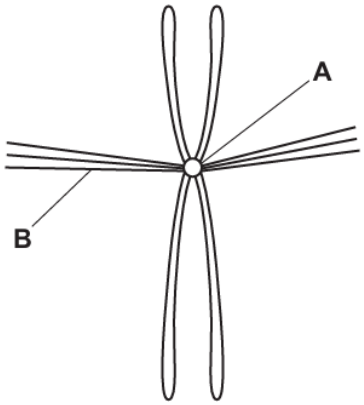


Fig. 4.2

(i) State the names **and** functions of structures **A** and **B**.

structure **A** .....

function .....

.....

structure **B** .....

function .....

.....

[2]

5 During interphase and mitosis of the cell cycle, the chromosomes within a cell go through a number of changes. Each chromosome is composed of DNA complexed with proteins.

(a) In interphase, individual chromosomes are too diffuse (long and thin) to be visible using a microscope. In this stage, the chromosomal material is known as chromatin.

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

..... [1]

6 **(a)** **(i)** State the name of the phase of the mitotic cell cycle during which DNA replication occurs.

..... [1]

7 Epithelial cells in the small intestine have cell structures known as microvilli. The microvilli of these cells are found only on the surface that borders the gut lumen.

Fig. 1.1 shows images of microvilli of intestinal epithelial cells. These images have been obtained using a scanning electron microscope and a transmission electron microscope.

Fig. 1.1**A** is at a different magnification to Fig. 1.1**B**.

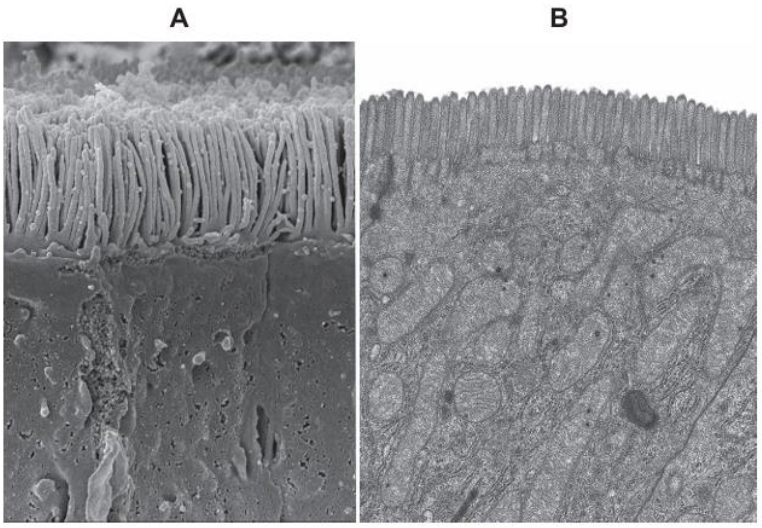


Fig. 1.1

(d) Stem cells are also located in the wall of the small intestine. These cells divide by mitosis continuously.

Suggest **and** explain the importance of mitosis by stem cells in the small intestine.

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..... [4]

8 Human cytomegalovirus (HCMV) is a common virus affecting humans. In people with a fully functioning immune system, infection by HCMV usually causes no, or only mild, symptoms.

Fig. 2.1**A** is a diagram of a section through HCMV. In Fig. 2.1**B**, only the outer part of HCMV is sectioned.

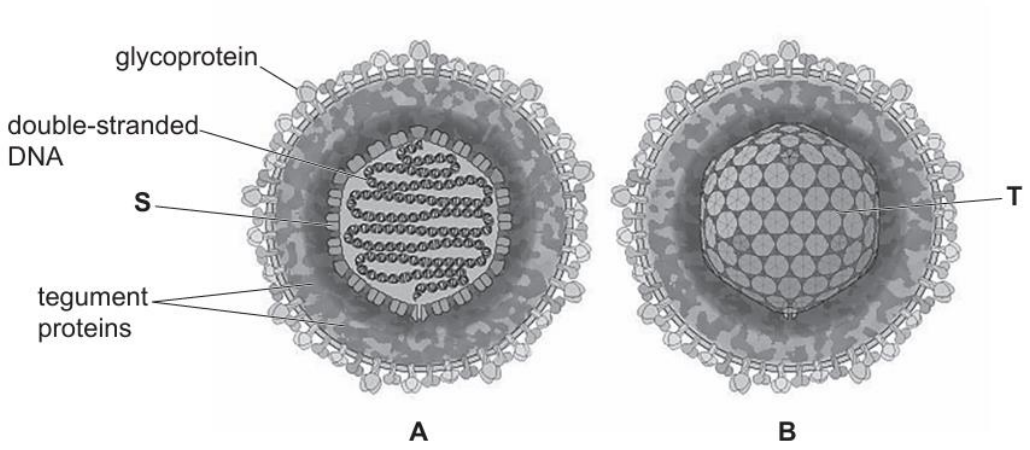


Fig. 2.1

The viral DNA shown in Fig. 2.1 contains genes that code for proteins important in viral replication and viral structure, including viral DNA polymerase and proteins known as tegument proteins.

Viruses can only replicate in host cells as they need to use processes and contents of the host cell. Complete viral particles that are released from the host cell are known as virions.

(f) HCMV is known to infect some types of human cell that carry out the mitotic cell cycle.

Studies have shown that in the presence of one tegument protein, UL69, the cell cycle stops in the G1 stage.

Outline the effects the presence of UL69 will have on the normal activity of the mitotic cell cycle.

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..... [3]

9 **(a)** Fig. 6.1 is a photomicrograph of plant cells in stages of the mitotic cell cycle.

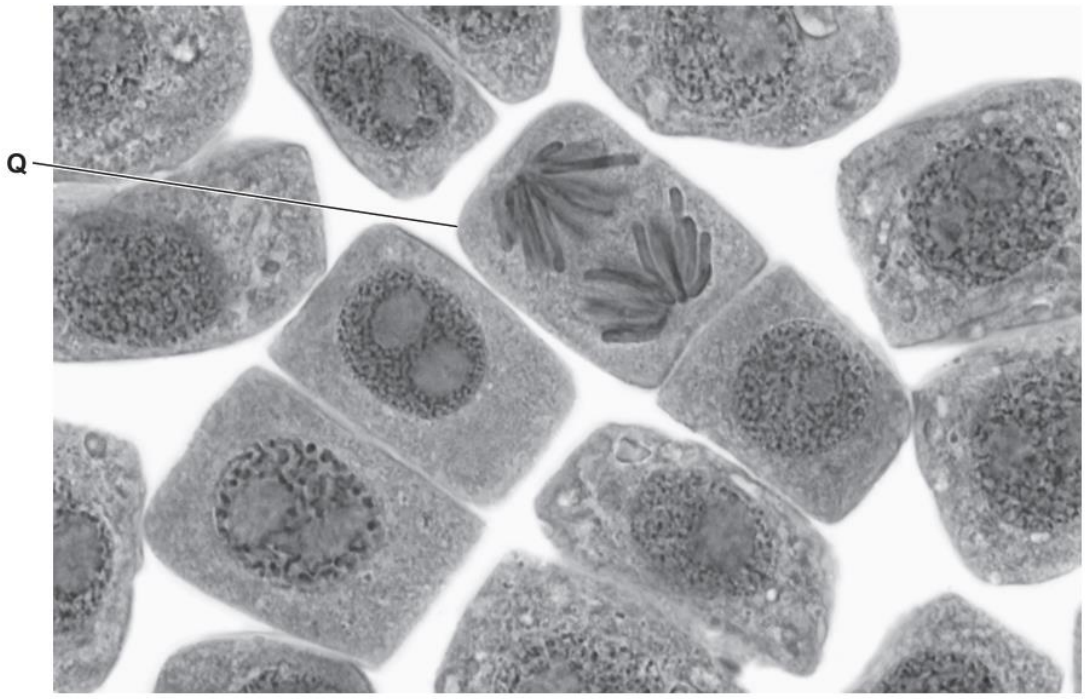


Fig. 6.1

(ii) Outline the roles of mitosis in a healthy plant.

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..... [2]

10 A person who is exposed to tobacco smoke is at greater risk of lung cancer and chronic obstructive pulmonary disease (COPD).

Many people with COPD have both chronic bronchitis and emphysema. These diseases cause changes in the gas exchange system. For example, changes occur in the total lung surface area to volume ratio (SA:V).

(a) Tar in tobacco smoke has a number of effects on the cells lining the gas exchange system.

State the main effects of tar on the cells lining the gas exchange system that are related to lung cancer **and** to chronic bronchitis.

lung cancer .....

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11 **(b)** Telomeres are located at the ends of each chromosome.

Telomeres progressively shorten each time a healthy human cell divides, until the cell is no longer able to divide.

Stem cells have an enzyme called telomerase that prevents the telomeres shortening during the cell cycle.

(i) Suggest why telomerase activity is important in stem cells.

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..... [2]

(ii) Suggest why tumour cells produce high concentrations of telomerase.

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..... [1]

12 The mitotic cell cycle in dividing cells is very carefully controlled.

(a) Complete Table 6.1 to show the correct order of stages in the mitotic cell cycle.

Some of the stages have been completed for you.

Table 6.1

stage of cell cycle	
G_1 phase	.....
.....	
.....	
.....	mitosis
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.....	
telophase	
cytokinesis	

[3]

At various points during the mitotic cell cycle, checks are made. A cell goes through cell death (apoptosis) if errors occur that cannot be repaired. This makes sure that the daughter cells produced are genetically identical to each other and to the original cell.

Drugs have been developed that can inhibit the mitotic cell cycle and cause the cell to carry out apoptosis. These drugs are used in the treatment of cancer.

(b) Vincristine and 5-fluorouracil are chemical compounds that act as cell cycle inhibitors and can lead to apoptosis.

- Vincristine binds to spindle microtubules and prevents the spindle from carrying out its function.
- 5-fluorouracil prevents the synthesis of thymine nucleotides.

Complete Table 6.2 to show which event in the cell cycle will occur when Vincristine or 5-fluorouracil are added to healthy dividing cells at the start of the interphase stage of the cell cycle.

Place a tick (✓) if the event will occur or a cross (✗) if the event will **not** occur.

All boxes in the table should be completed.

Table 6.2

event in cell cycle / compound	S-phase completes	cell enters prophase of mitosis	chromosomes line up at spindle equator	sister chromatids move towards opposite poles
Vincristine				
5-fluorouracil				

[2]

(c) Vincristine has been used in the treatment of certain types of leukaemia.

Fig. 6.1 is a photomicrograph of a blood smear of a person with one form of leukaemia, which affects lymphocytes.

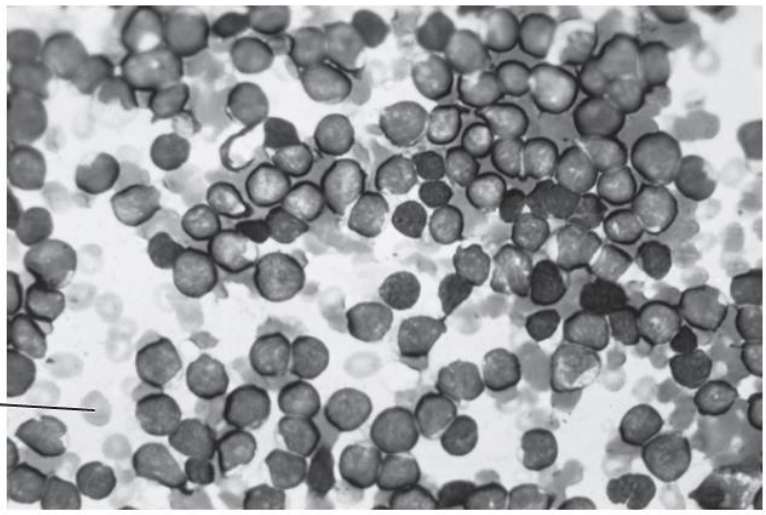


Fig. 6.1

Describe how:

- the blood smear shown in Fig. 6.1 differs from a blood smear of a healthy person
- the lymphocytes in a person with leukaemia, such as those shown in Fig. 6.1, differ from those of a healthy person.

blood smear differences .....

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lymphocyte differences .....

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..... [3]

13 Fig. 2.1 shows some stages of the cell cycle in the meristematic tissue in the root tip of a plant. Three of these stages, **P**, **Q** and **R**, are identified in Table 2.1.

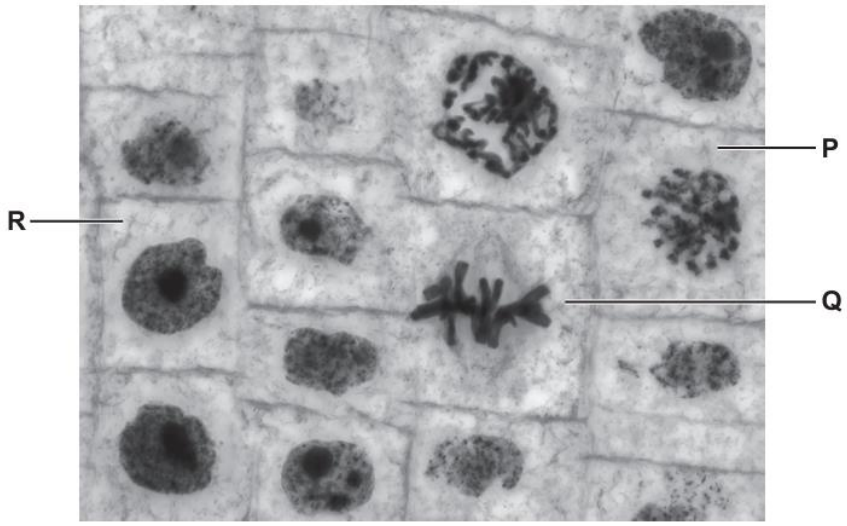


Fig. 2.1

(b) (i) Draw a labelled diagram to show **one** chromosome at metaphase of mitosis.

On the chromosome you have drawn add labels to show:

- the position of a telomere
- a chromatid
- the centromere.

[4]

(ii) State the type of protein that is associated with DNA in chromosomes.

..... [1]

14 **(a)** Fig. 1.1 is a diagram of a human chromosome at a stage in mitosis.

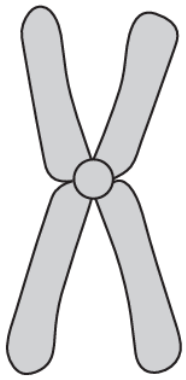


Fig. 1.1

(i) The paragraph describes the structure of the chromosome shown in Fig. 1.1.

Complete the paragraph using the most appropriate term in each space provided.

The chromosome shown in Fig. 1.1 has two genetically identical ..... joined at a ..... . The chromosome is composed of two DNA molecules, each wrapped around proteins known as ..... proteins.

[3]

15 **(a)** Mutations in body cells can sometimes result in a tumour. Some tumours are cancerous.

(i) Outline how mutations can result in the development of a tumour.

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..... [2]

16 In the immune system, a plasma cell develops from an activated B-lymphocyte. Mature plasma cells synthesise and secrete antibody molecules.

(b) The transition from the activated B-lymphocyte to the fully mature plasma cell requires a number of mitotic cell cycles to occur. This process, which is known as clonal expansion, results in a large number of genetically identical plasma cells.

Fig. 4.2 describes events, **A** to **F**, that occur during the mitotic cell cycle of the B-lymphocyte.

A centrioles replicate

B DNA polymerase catalyses the formation of phosphodiester bonds

C condensation of chromosomes

D nuclear envelope reassembles around each set of daughter chromosomes

E centromeres move towards poles

F chromosomes line up at spindle equator

Fig. 4.2

Table 4.1 lists the stages occurring during one cell cycle of the B-lymphocyte. These stages are not in the correct order.

Table 4.1

stage of cell cycle	**correct letter from Fig. 4.2**
G_2 phase	
metaphase	**F**
cytokinesis	
prophase	
S phase	
anaphase	
G_1 phase	
telophase	

Complete Table 4.1 by writing the letter of the event described in Fig. 4.2 that correctly matches the stage of the cell cycle listed.

Leave a **blank space** if there is **no** matching description for the stage in the list. Use each letter **once** only.

One of the letters in Table 4.1 has already been added for you.

[5]

17 **(b)** Floxuridine is a drug used to treat cancer.

(i) Floxuridine inhibits DNA replication.

Suggest why the inhibition of DNA replication is an effective treatment for cancer.

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..... [1]

(c) Fig. 6.1 is a scanning electron micrograph of a lung cancer cell in a stage of the cell cycle.

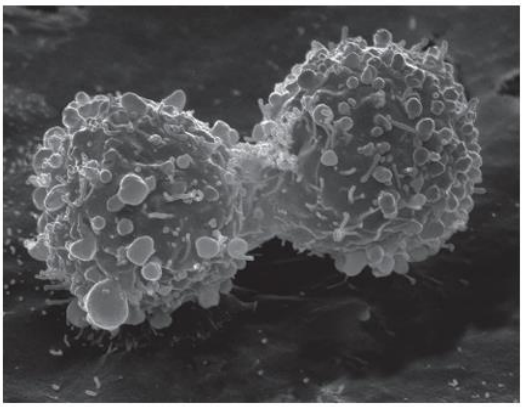


Fig. 6.1

(ii) Explain why smoking tobacco increases the risk of developing lung cancer.

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..... [3]

18 Telomerase is an enzyme that is important in maintaining the telomeres that are located at the ends of chromosomes.

(a) Explain the importance of telomeres.

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..... [2]

(b) Suggest why telomerase is present in much higher quantities in stem cells and cancer cells than in other cell types.

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..... [1]

19 Meristematic tissue is found in the growing regions of plants, such as shoot tips. Meristematic cells have a similar role to stem cells in animals.

Fig. 4.1 shows some of the stages in the formation of a mature phloem sieve tube element and companion cells from a meristematic cell.

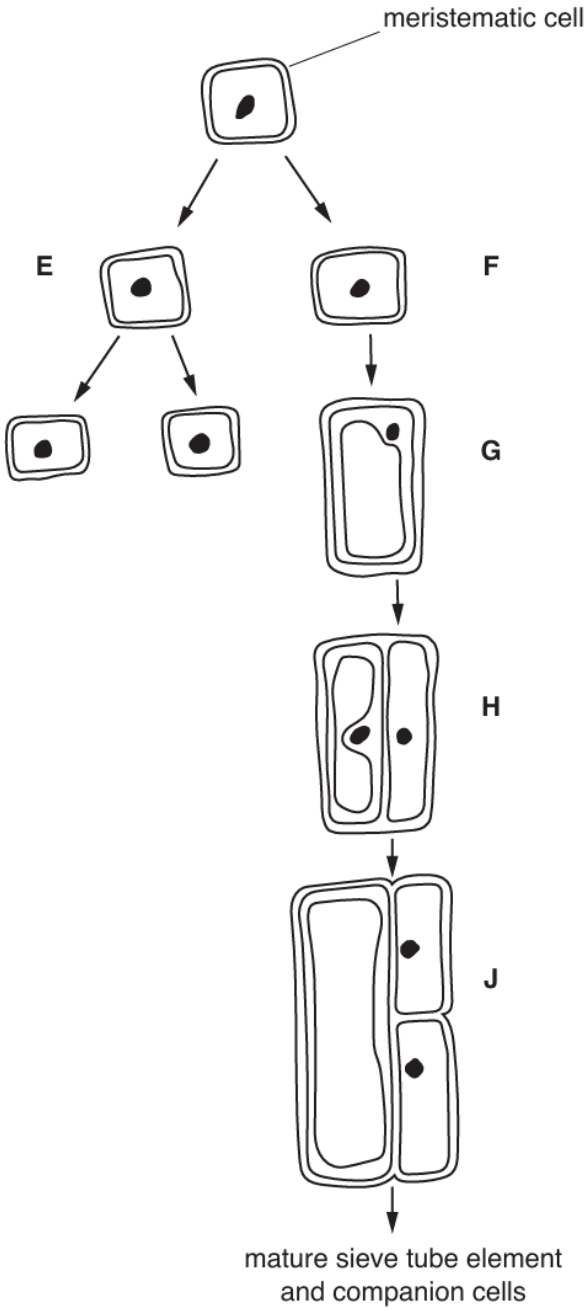


Fig. 4.1

(a) Cells **E** and **F** in Fig. 4.1 are daughter cells produced when the meristematic cell divides in the shoot tip.

Explain why it is important that one of the daughter cells (cell **E**) is a meristematic cell.

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..... [1]

20 Some tissues of the gas exchange system include cells that are able to produce and secrete mucins. Mucins are stored in vesicles in these cells, ready for secretion. Once outside the cell, mucins adsorb water to form mucus.

(e) The gas exchange system includes some cells that are able to divide by mitosis.

Explain why it is important to have these cells in the gas exchange system.

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..... [3]

21 Fig. 3.1 is a photomicrograph of human blood cells from a healthy individual who lives at sea level. The cells labelled **C**, **D** and **E** are white blood cells.

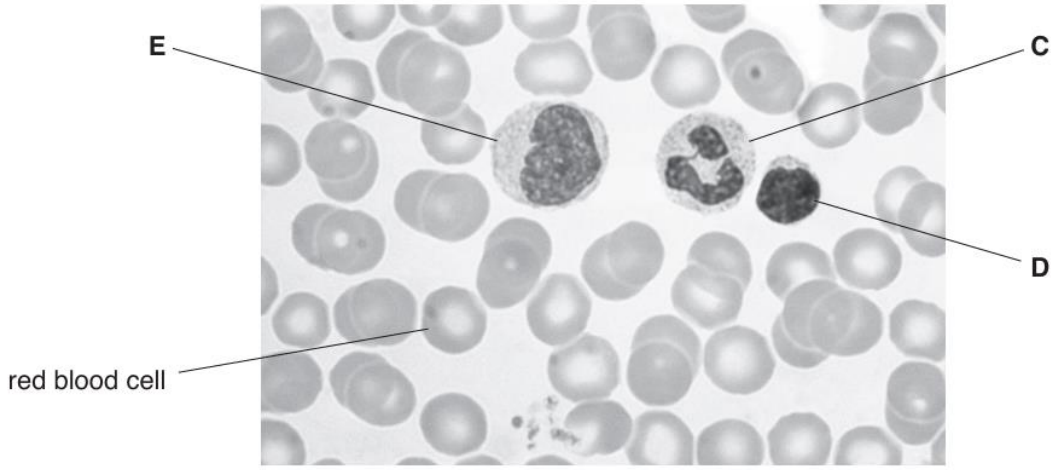


Fig. 3.1

(b) In humans, an increase in the white blood cell count can be associated with leukaemias and with infectious diseases, such as measles.

Chronic lymphocytic leukaemia (CLL) is a type of cancer that starts in the bone marrow. In the early stages, many people with CLL feel well. The disease is sometimes diagnosed by chance during a routine blood analysis, when a high white blood cell count is noticed. Many of these white blood cells are only partially mature.

(i) Suggest why CLL starts in the bone marrow and **not** in any other location in the body.

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..... [2]

(ii) Explain why a high white blood cell count is a feature of measles and of CLL.

measles .....

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CLL .....

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..... [3]

22 Fig. 4.1 is a photomicrograph showing some cells in interphase and some cells in stages of mitosis.

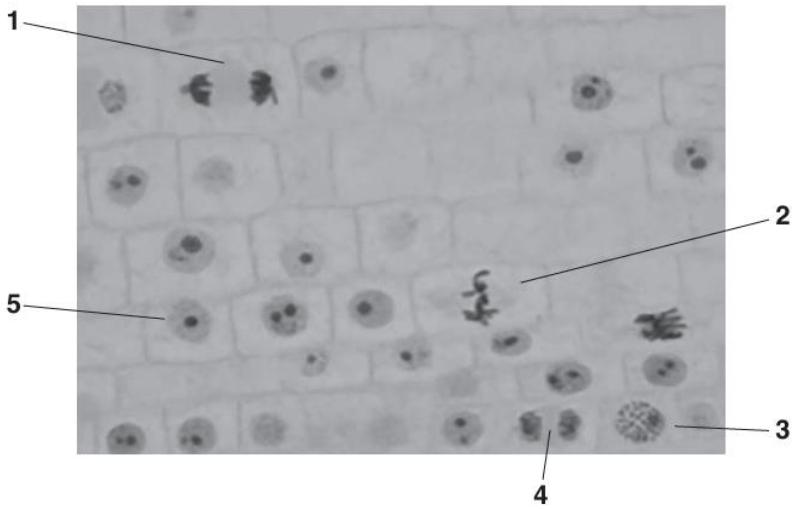


Fig. 4.1

(c) Suggest why some cells in Fig. 4.1 appear empty, with no nucleus or chromosomes.

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.....[1]

23 The response of the human body to tissue damage depends on the types of tissues involved. Epithelial tissue, liver tissue and cardiac muscle tissue each respond differently to damage.

- Epithelial tissue of the gas exchange system contains stem cells.
- Liver tissue contains cells in a non-dividing state that can enter a cell cycle when stimulated.
- Cardiac muscle tissue contains cells that cannot divide at all. Damage is permanent and is associated with scar tissue formation.

(a) Explain the importance of mitosis in the repair of damaged tissue.

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..... [2]

(b) Explain why stem cells are important in tissue repair.

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..... [2]

24 Fig. 4.1 is a photomicrograph of a cross-section of a tubular structure in the kidney made from epithelial cells.

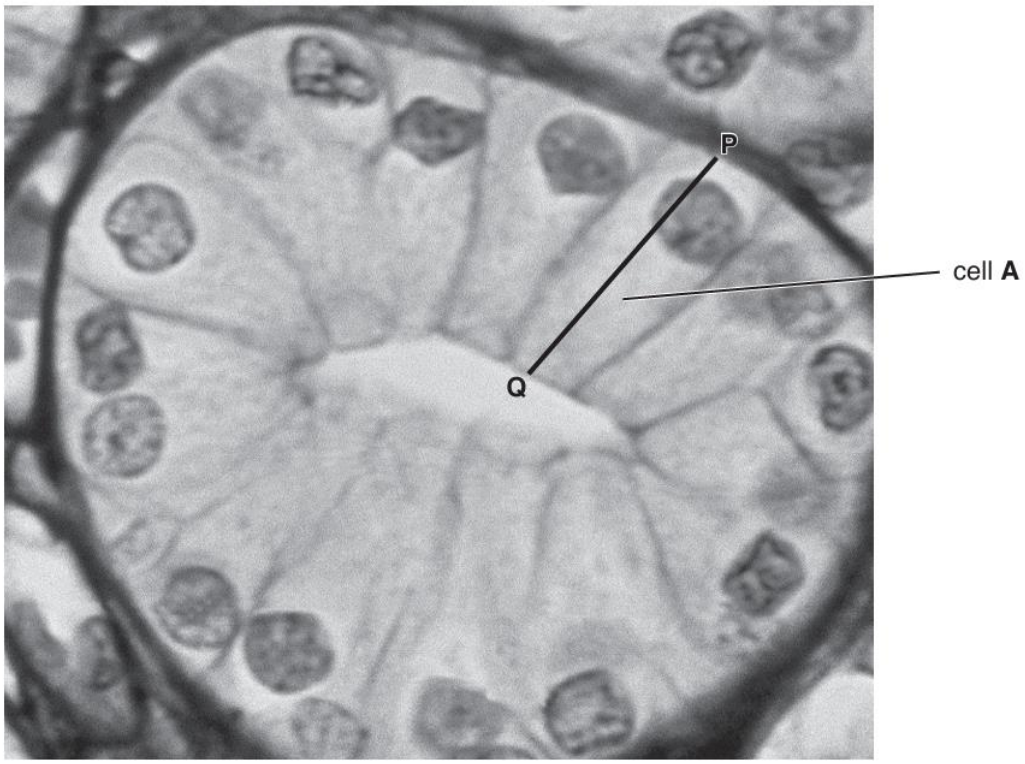


Fig. 4.1

(b) Some epithelial cells in the kidney release the protein vascular endothelial growth factor (VEGF). This protein is a cell signalling molecule that stimulates cell division in endothelial cells in blood vessels.

(i) State what occurs during interphase to prepare a cell for division.

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..... [2]