1(a). Adult stem cells divide by mitosis to produce replacement stem cells as well as cells that can differentiate into specialized cells.

The immortal strand hypothesis suggests a mechanism for the production of both replacement stem cells and cells that can differentiate.

Fig. 21.1 is an outline of the immortal strand hypothesis.

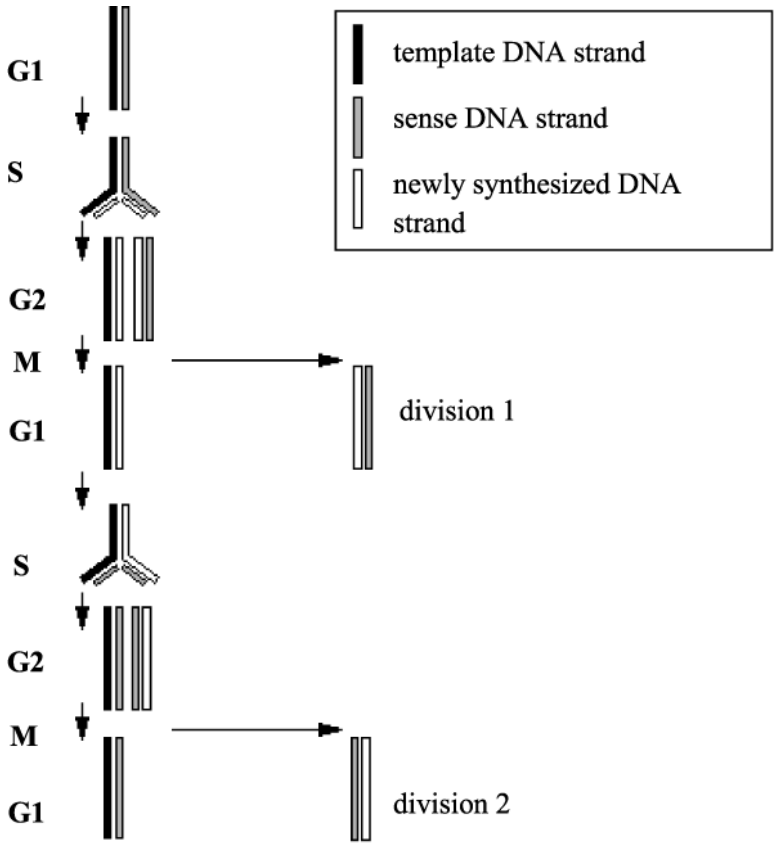


Fig. 21.1

- Cells that retain the template strand do not differentiate and remain stem cells.
- Cells without the template strand can differentiate.

(i) Name the processes happening at S and M in Fig. 21.1.

S

M

[1]

(ii) Name two **enzymes** that are essential for the process happening at S.

1.

2.

[2]

(iii) According to the immortal strand hypothesis, if a single stem cell undergoes **ten** cycles of division, how many new stem cells and how many cells capable of differentiating will be produced?
You should assume that all cells divide at the same rate.

Number of stem cells _____

Number of cells that can differentiate _____

[2]

(b). Fig. 21.2 summarizes the relationships between different types of stem cell. Arrows indicate the possible products from cell division.

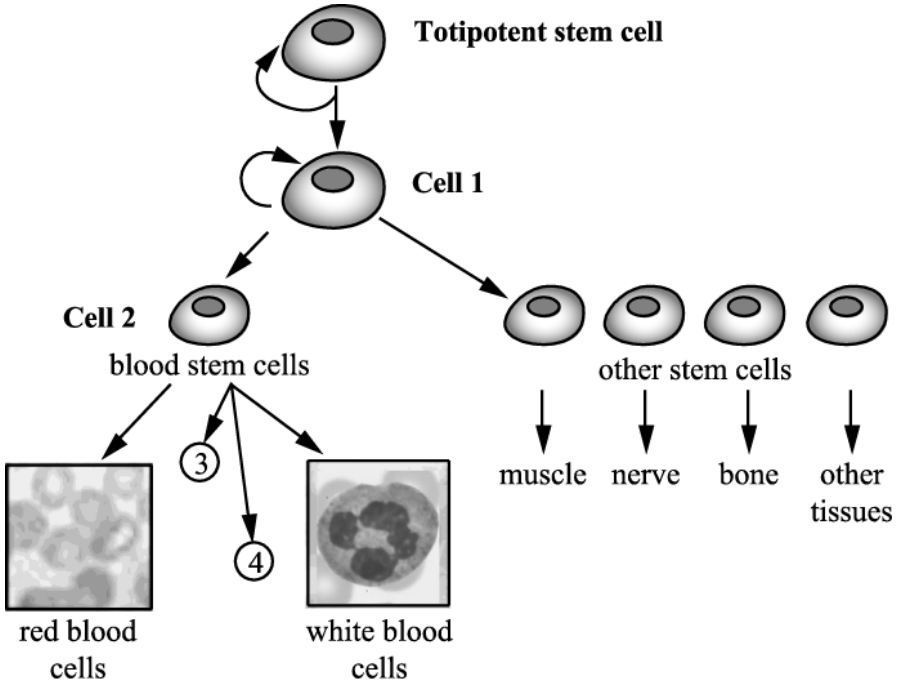


Fig.21.2

(i) Identify the **types** of stem cell represented by Cell 1 and Cell 2.

Cell 1 ----------

Cell 2 ----------

[1]

(ii) Cells 3 and 4 are white blood cells with a **different** structure to the white blood cell shown in Fig. 21.2 and to each other.

Suggest a possible identities for Cell 3 and Cell 4.

Cell 3 ----------

Cell 4 ----------

[2]

2. The cork layer develops into the bark of the tree.
The anticancer drug Paclitaxel has been isolated from the bark of the tree *Taxus brevifolia*.

- Paclitaxel causes polymerisation of microtubules in tumour cells.
- This prevents the formation of the mitotic spindle.
- Tumour cells then undergo apoptosis.

(i) Cork cambium cells such as those shown in Fig. 24.1 actively divide by mitosis.
Paclitaxel does not prevent mitosis in *Taxus brevifolia*.

Suggest what difference between mitosis in plant and animal cells could explain this observation.

---

[2]

(ii) Suggest the stage of **interphase** at which apoptosis occurs in tumour cells treated with Paclitaxel.

---

[1]

3(a). Apoptosis is programmed cell death. It is an important process in the formation of fingers and toes of a developing fetus.

Statements **A** to **E** below describe the process of apoptosis.

Put the statements in the correct order.

A ‘blebbing’ of the cell surface membrane occurs
B apoptotic bodies are engulfed by phagocytes
C the cell shrinks
D breakdown of the nucleus occurs
E receptors on phagocytes recognise surface phospholipids on the apoptotic bodies

_____ _____ _____ _____ _____

[3]

(b).

(i) **Fig. 6.1** shows the hands of a fetus at two different stages in development.

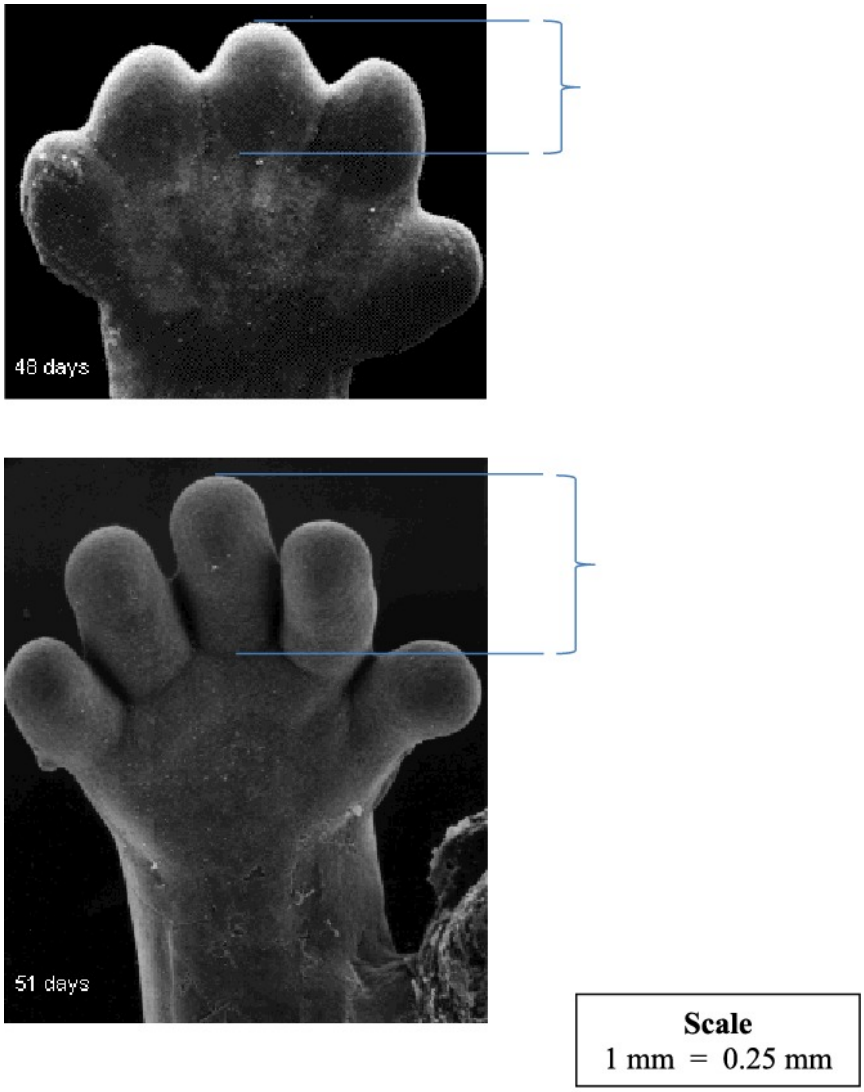


Fig. 6.1

Using **Fig. 6.1**, calculate the growth **rate** of the middle digit between 48 and 51 days.

Show your working.

growth rate _____ mm day^{-1} **[2]**

(ii) Name **one** nutrient that is required to support the growth of tissues in the developing fetus and state its role.

---

[1]

4. Mitosis results in the production of diploid cells.

Fig. 6.1 represents one cell cycle, of which mitosis is part.

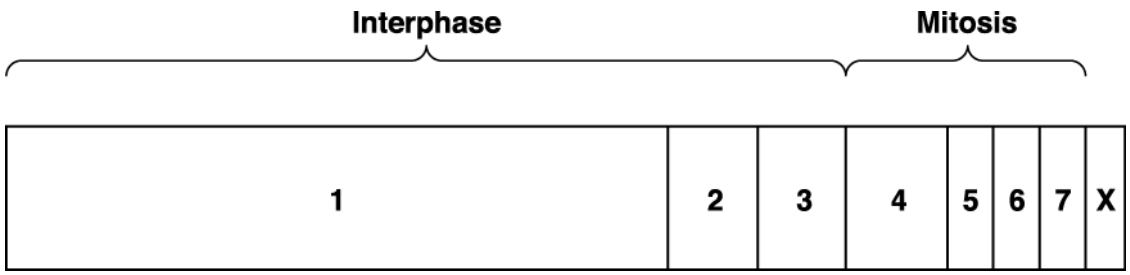


Fig. 6.1

(i) Describe what occurs in the stage labelled **X**.

---

[1]

(ii) Name the stage of the cell cycle labelled **1 and** explain why this stage takes up more than 50% of the cell cycle.

name of stage _____

explanation _____

---

[2]

(iii) Chromosomes become visible in stage **4** in Fig. 6.1.

Describe **two** further changes that occur in the cell in stage **4**.

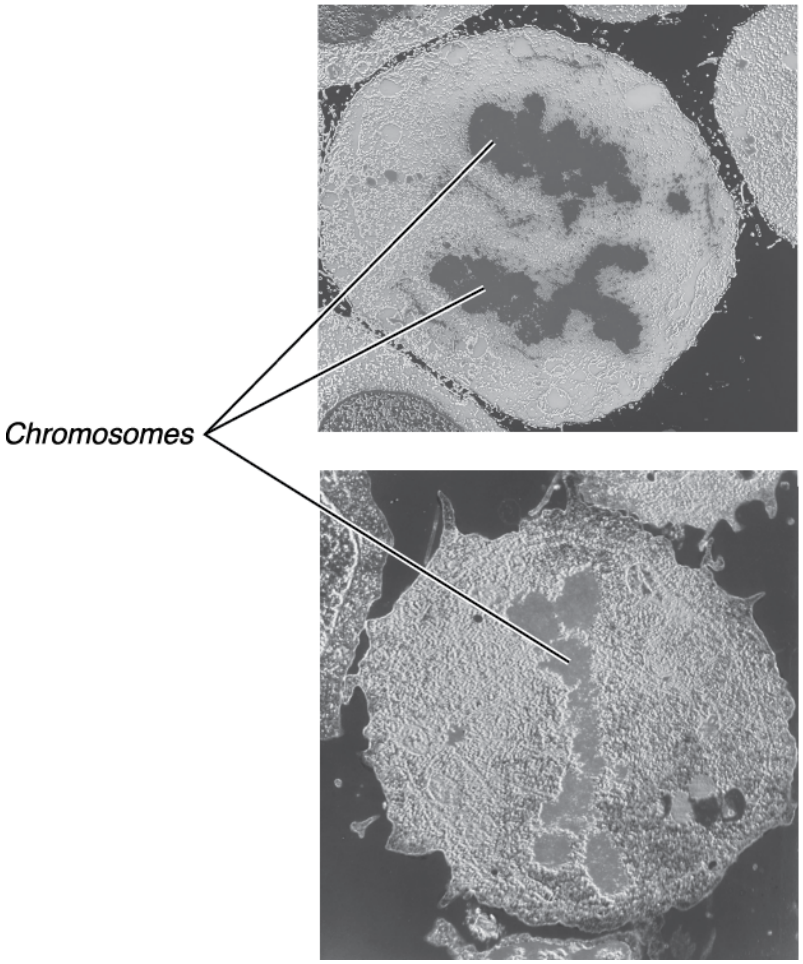
---

[2]

(iv) Fig. 6.2 is a photomicrograph showing two stages of mitosis in human cells.

In the box next to each image, state:

- the number of the stage (using the information in Fig. 6.1)
- the name of the stage shown.



Number of stage (see Fig. 6.1)

.....

Name of stage

.....

Number of stage (see Fig. 6.1)

.....

Name of stage

.....

Fig. 6.2

[2]

5. Chronic myeloid leukemia (CML) is a type of blood cancer.

About 95% of people with CML have an abnormality called the Philadelphia chromosome.
Breaks occur in chromosomes 9 and 22 and they exchange DNA resulting in two abnormal chromosomes.

The arrows in Fig. 24.1 indicate these two abnormal chromosomes.

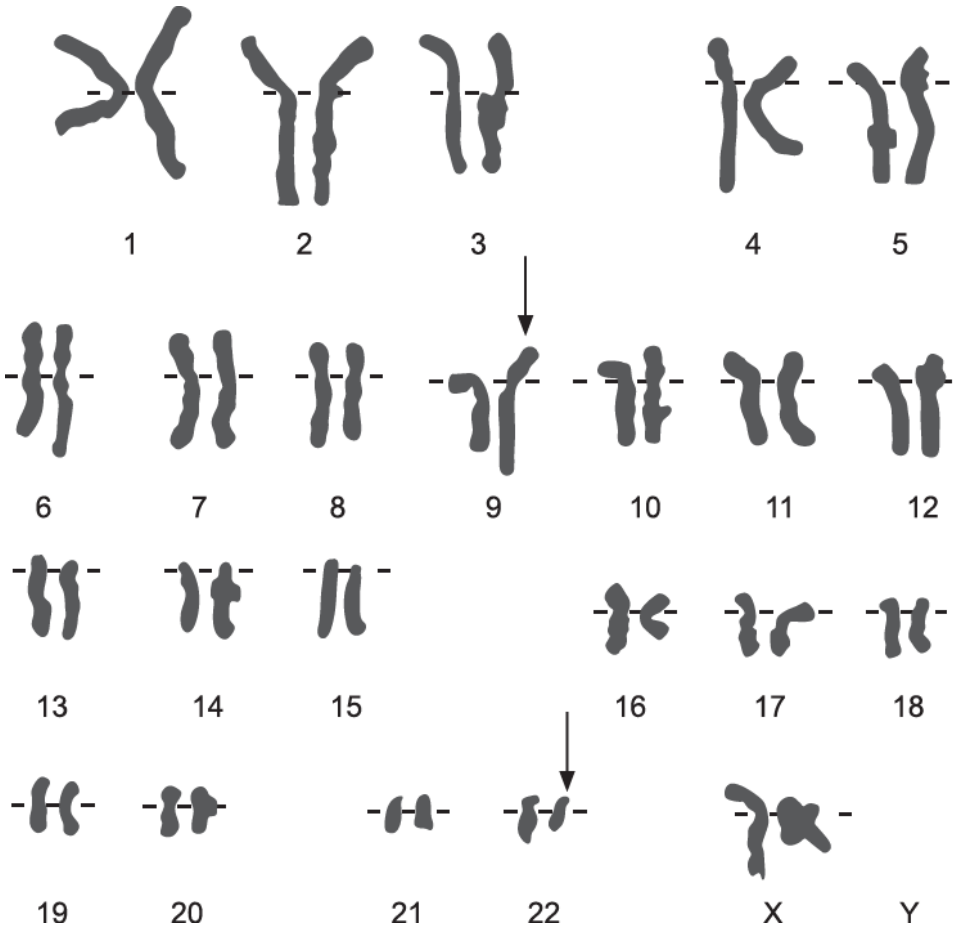


Fig. 24.1

(i) Philadelphia chromosome arises in bone marrow stem cells. These stem cells are described as being multipotent.

What is the significance of multipotency to the development of disease?

---

[1]

(ii) How does the appearance of the abnormal chromosomes indicated in Fig. 24.1 differ from those in a normal cell at the same stage in the cell cycle?

[1]

(iii) Describe the technique used to produce images of chromosomes, such as those shown in Fig. 24.1.

[3]

6. The cell cycle is a regulated process.

Fig. 5 shows three checkpoints in the cell cycle where mistakes may be corrected.

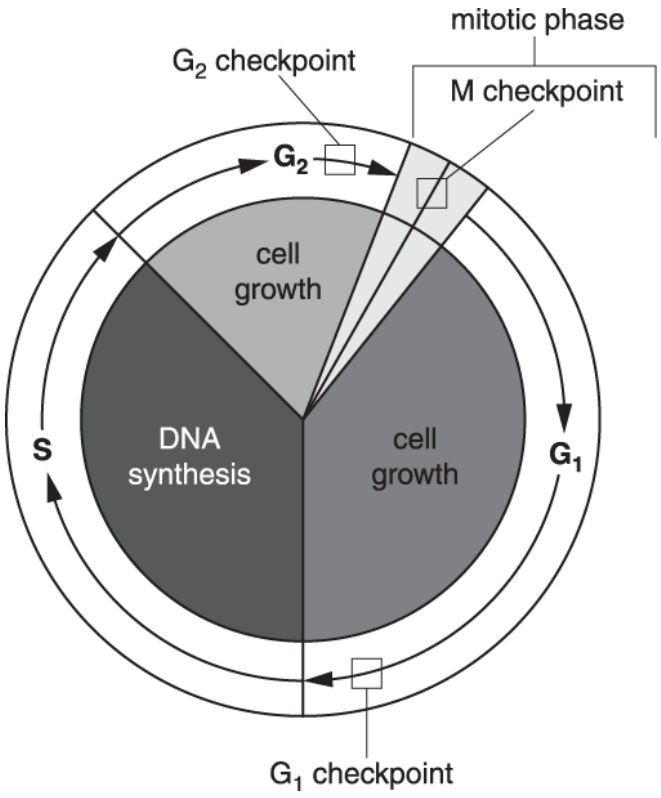


Fig. 5

Suggest how a faulty G_2 checkpoint may affect the cell cycle.

[2]

7(a). A scientist wanted to observe the different stages of nuclear division.

Table 6 describes some events that occur during mitosis and meiosis in **plant cell** samples.

Complete Table 6 by placing a tick (✓) if the event described does occur in the type of nuclear division or a cross (✗) if the event does not occur.

The first row has been completed for you.

Event	Mitosis	Meiosis I	Meiosis II
Chromosomes condense in prophase	✓	✓	✗
Nuclear envelope breaks down in prophase			
Bivalent pairs line up in metaphase			
Centromere splits during anaphase			
Centrioles move to opposite poles of the cell during prophase			

Table 6

[4]

(b). Explain how meiosis is significant in the life cycle of a plant.

---

[2]

8(a). Many researchers are involved in investigating the potential use of stem cells to treat a variety of human conditions.

Stem cells can be produced from a variety of sources. One possible source is known as somatic cell nuclear transfer (**SCNT**).

In **SCNT**:

- the nucleus is removed from a donor's oocyte
- a nucleus from the patient's somatic cell is introduced into the oocyte
- the resultant cell is allowed to divide to produce several cells
- some of these cells will be used to produce cultures of stem cells.

Insert a tick (✓) against the term that best describes the production of stem cells using SCNT.

Term	Insert a tick (✓)
Genetic engineering	
Therapeutic cloning	
Reproductive cloning	
ICSI	
IVF	

[1]

(b). Stem cells have the potential to be used to treat patients with conditions such as Parkinson's disease or Type 1 diabetes.

(i) Suggest the **type** of stem cell which is produced using SCNT.

---

[1]

(ii) State **two** properties of the stem cells produced by SCNT that would make them potentially suitable for treating conditions such as Parkinson's disease **or** Type 1 diabetes.

1 ---

---

2 ---

---

[2]

9(a). Erythrocytes have short lifespans and are constantly produced by the bone marrow stem cells.

Fig. 5.1 is a scanning electron micrograph of a bone marrow stem cell.

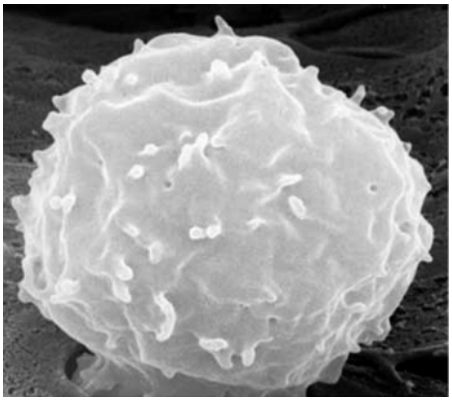


Fig. 5.1

Describe how a mature erythrocyte would differ in appearance from a bone marrow stem cell, such as the one in Fig. 5.1.

---

[1]

(b). At the eight cell stage of development, all the cells in an embryo are identical. These cells are capable of dividing to form any cell type in a fetus.

Describe how an embryonic cell gives rise to tissues and organs as a fetus develops **and** how the growth patterns of tissues differ.

In your answer you should include differences in the growth patterns of both reproductive and nervous tissue.

[8]

10. TIC10 is a promising anti-cancer drug that has been tested on mice.

It may be years before TIC10 can be used to treat cancer in humans.
The drug will first need to undergo clinical trials.

(i) Outline the role of NICE (National Institute for Health and Clinical Excellence) after a drug has undergone clinical trials.

---

[2]

(ii) TIC10 causes apoptosis in cancerous cells but not in healthy cells.

Complete the following passage, which describes how apoptosis works.

Apoptosis is triggered by extracellular and intracellular signals. Enzymes break down the cell's cytoskeleton.

The _____ condenses in a process known as pyknosis and then it fragments. The

_____ forms bulges called blebs. The cell breaks into vesicles. Macrophages

recognise and engulf the vesicles by _____.

[3]

11. State the correct term for the following definition.

A pair of chromosomes that contain genes for the same characteristics.

---

[1]

12(a) A group of microorganisms called slime moulds includes the species *Dictyostelium discoideum.*

.

The life cycle of *D. discoideum* is shown in Fig. 5.1.

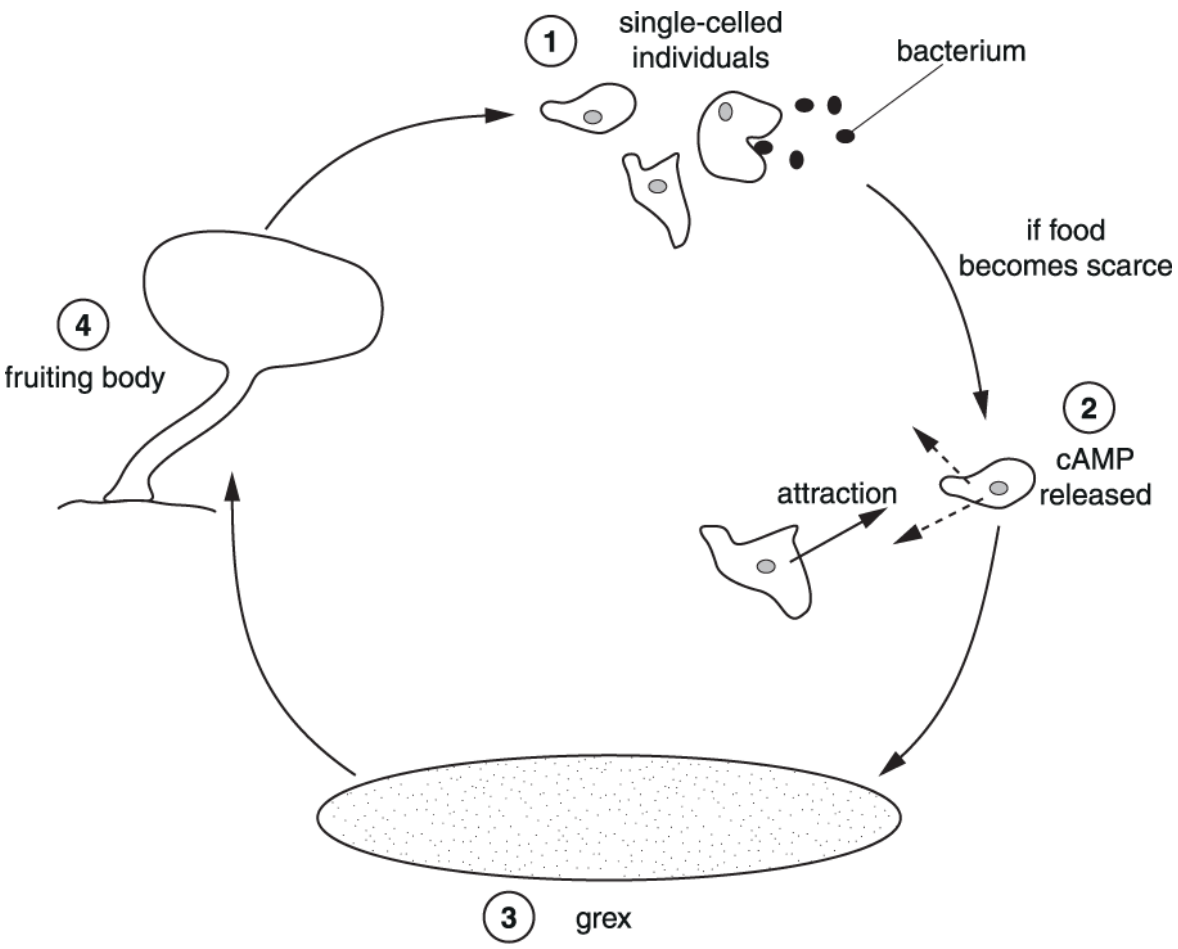


Fig. 5.1

① When plenty of food is available this slime mould exists as single-celled individuals which feed and reproduce asexually.

The slime mould cells feed on bacteria.

The slime mould cells are attracted to folic acid which has been released by the bacteria.

② When food becomes scarce the slime mould cells release a chemical (cAMP) which attracts other slime mould cells.

③ The slime mould cells then group and stick together to form a multicellular mass called a grex.

The grex moves in a coordinated way in search of a more suitable environment.

As the grex moves, the cells release the chemical DIF. DIF causes some cells to become stalk cells and others to become spore cells.

④ When the grex reaches suitable conditions, it forms a fruiting body consisting of a stalk and spores. These spores are released and develop into new, individual, slime mould cells.

(i) Suggest the type of cell division used by *D. discoideum* for reproduction during stage ① of its life cycle.

_____ [1]

(ii) At what stage of the life cycle does differentiation begin?

_____ [1]

(b). Individual cells of *D. discoideum* can divide once every hour. A grex may consist of 100 000 individual cells.

Calculate how many hours it would take for one cell to produce enough cells to form a grex.

Answer = _____ hours [1]

13.

Oogenesis occurs in the ovaries of female mammals, resulting in the production of gametes.

(i) Name the type of nuclear division that results in the production of **secondary** oocytes from **primary** oocytes during oogenesis.

_____ [1]

(ii) Complete the table below to indicate the stage and type of nuclear division in which the events being described occur.

Event	Type of nuclear division	Stage in nuclear division
Chromosomes line up on the equator; there is no association between homologous chromosomes.		
Homologous chromosomes form bivalents.		
Homologous chromosomes separate and are pulled to opposite poles.		
Crossing over occurs.		

[4]

14.

The rosy periwinkle, *Catharanthus roseus*, is one of the plant species found in Madagascar where it has evolved adaptations to survive in the hot and humid climate.

Genetic diversity was investigated in coloured variants of *C. roseus*.

Genetic data from an analysis of 56 genes showed that 10 of these genes were monomorphic.

Calculate the proportion of polymorphic genes in this population of *C. roseus*.

Give your answer to **two** significant figures.

Answer = ... **[2]**

15(a) (See insert for **H42202, June 2018**)

. This question is based on the Advance Notice article **SPINAL CORD INJURIES: HOW COULD STEM CELLS HELP?**, which is an insert.

The spinal cord contains both motor and sensory neurones.

(i) State one similarity and one difference between the structure of motor and sensory neurones.

similarity ----------

---

difference ----------

---

[2]

(ii) Explain why a spinal cord injury (SCI) causes both paralysis **and** loss of feeling below the site of the injury.

---**[2]**

(iii) Describe the role of the myelin sheath in the propagation of nerve impulses.

---

[2]

(iv) The Advance Notice discusses oligodendrocytes, which are cells found only in the central nervous system (CNS).

State the name of the cells that perform a function equivalent to oligodendrocytes in the peripheral nervous system.

[1]

(b). Treatment of injuries to the spinal cord, including with stem cell therapy, requires surgeons to determine the exact location and extent of the injury.

(i) State the name of an imaging technique that could be used for this purpose.

[1]

(ii) Describe how the technique you have given in **(i)** can be used to help surgeons to assess the location and extent of injury.

[3]

(c). The Advance Notice article describes several types of stem cell.

Stem cells can be classified as totipotent, pluripotent, and multipotent.

Suggest which of these types of stem cell have been used in the clinical trials described in the Advance Notice. Give reasons for your choice.

---

[3]

(d). * Using information from the Advance Notice, evaluate the risks, benefits and ethical issues related to the use of stem cells in the treatment of spinal cord injury (SCI).

In your answer, you should demonstrate an understanding of the current and future potential of stem cell therapy.

---

[6]

16(a). The yellow fever mosquito, *Aedes aegypti*, is one of the vectors responsible for transmitting pathogenic viruses such as the Zika virus.

Fig. 1 is a diagram of a cell from *A. aegypti* during prophase of mitosis.

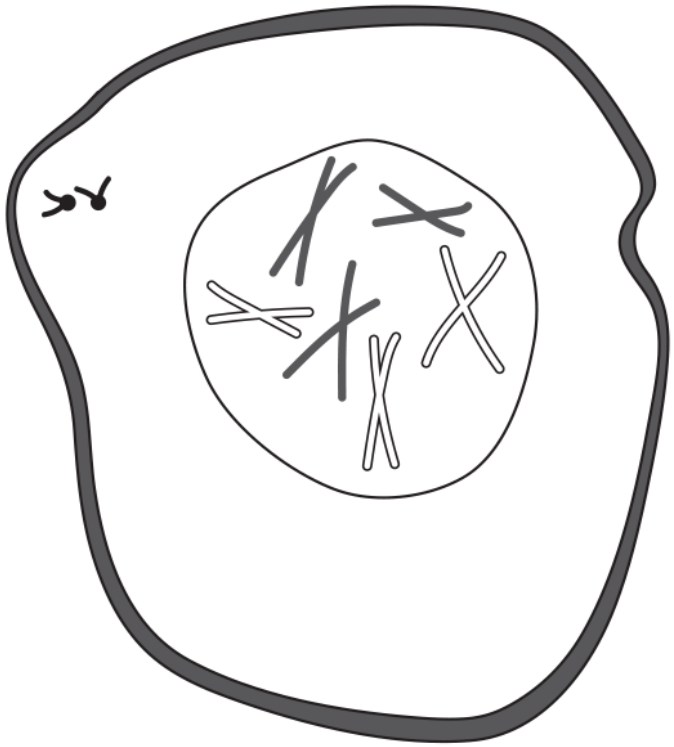
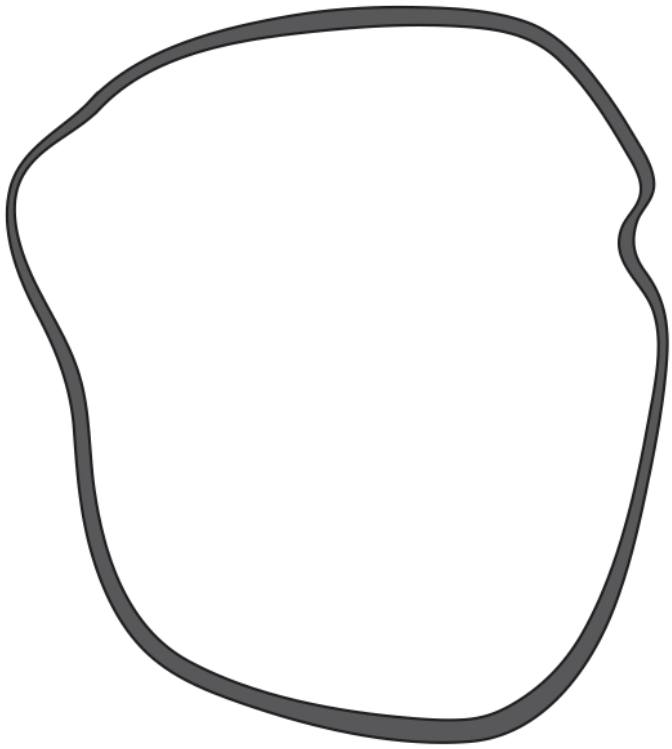


Fig. 1

(i) Using the information in Fig. 1 complete and label the diagram in the space below to show the cell during **metaphase** of mitosis.



[3]

(ii) Using Fig. 1 state the number of chromosomes that would be found in the following cells taken from *A. aegypti*.

A stem cell _____

A sperm cell (gamete) _____ [1]

(iii) Cells that develop mutations in DNA during the cell cycle can be destroyed to prevent the replication of damaged cells.

Name the process by which damaged cells are destroyed.

_____ [1]

(b). * Stem cells removed from *A. aegypti* embryos have been used in scientific research to develop potential strategies for limiting the transmission of the Zika virus.

Discuss the potential uses for **human** embryonic stem cells taking into account any concerns that could arise by using these cells for research purposes.

[6]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1	a	i	*S* (semi-conservative) DNA replication AND *M* mitosis	1	
		ii	*Any two from,* (DNA) polymerase (DNA) helicase (1) (DNA) ligase (1)	2	ALLOW in any order
		iii	*Number of stem cells* 1 (1) *Number of cells which can differentiate* 1023 (1)	2	
	b	i	*Cell 1* pluripotent AND *Cell 2* multipotent (1)	1	
		ii ii ii	 (T or B) lymphocyte (1) monocyte (1)	2	ALLOW in any order DO NOT ALLOW neutrophil ALLOW macrophage
			Total	8	
2		i	no centrioles (in plant cells) (1) no 'asters'/ AW form (1) plant cells don't change shape (before division) (1)	1	IGNORE reference to cell plate or lack of cleavage furrow
		ii	G2	1	ALLOW *idea of* G2 prophase transition
			Total	2	
3	a		C A D E B (1) (1) (1)	3	First correct C – one mark, last correct B – one mark, ADE anywhere in that order – 1 mark
	b	i	0.58 (1) (1)	2	ALLOW 2 marks for the correct answer with no working ALLOW 1 mark for calculation without final step 24 – 17 = 7 / 3 = 2.3

Question			Answer/Indicative content	Marks	Guidance
		ii	Any 1 from: protein for production of new cells / enzymes / skin / bone (1) vitamin D for production of, bones / teeth (1) phosphorus / calcium, for production of, bones / teeth (1)	1	
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
4		i	cytokinesis;	1	ACCEPT cytoplasmic cleavage Examiner's Comments This question focused on aspects of cell division, testing AO2. Candidates clearly understood both mitosis and meiosis and the question was well answered. Most candidates correctly offered the term 'cytokinesis' as their description. Only a few candidates incorrectly answered in terms of other stages in cell division.
		ii	G_1; proteins / cytoplasm / organelles, produced **AND** (this) is a slow process;	2	ACCEPT growth phase 1 Examiner's Comments The majority of candidates correctly stated G1 and described what took place. Unfortunately, very few candidates received both marks as they did not extend their explanation as to the length of time taken.
		iii	*Any two from* centrioles move to (opposite) poles spindle formation nuclear envelope disintegrates nucleolus disappears	2	If more than two answers given, mark the first two. Examiner's Comments Candidates answered this well.
		iv	6 **AND** anaphase; 5 **AND** metaphase;	2	IGNORE prompt lines but must be in correct order according to diagrams ACCEPT 7 **AND** telophase Examiner's Comments It was pleasing to see many candidates gaining marks for correctly identifying the stages from the images.
			Total	7	

Question			Answer/Indicative content	Marks	Guidance
5		i	(multipotent stem cells) can differentiate into different types of (blood) cell / AW ✓ mutation is passed onto (blood) cells ✓	1 max	DO NOT CREDIT any type of cell alone OR many types of cell unqualified Examiner's Comments This question addressed mainly AO1 and AO2. Candidates were required to demonstrate their mathematical skills by performing a percentage decrease calculation. The diagram of most of the correct responses were those in which candidates had described the meaning of a multipotent cell. Some misconceptions were evident, such as the idea that a multipotent cell could differentiate into any type of cell, which could not be credited.
		ii	(one of) chromosome 9 is longer AND (one of) chromosome 22 is shorter (than normal) ✓	1	CREDIT *idea that* each chromosome in normal pairs (of 22 and 9) would be same length Examiner's Comments This question addressed mainly AO1 and AO2. Candidates were required to demonstrate their mathematical skills by performing a percentage decrease calculation. The diagram was a straightforward question in which candidates were simply asked to compare an image of two abnormal chromosomes with what they would expect to see in an image of normal chromosomes. Candidates need to ensure that they clearly describe their observations to avoid ambiguity.

Question			Answer/Indicative content	Marks	Guidance
		iii	karyotyping ✓ take cells from sample of correctly **named** body fluid ✓ (cells) stimulated to divide by mitosis ✓ ***idea that*** mitosis is stopped in metaphase ✓ chromosomes stained ✓ *idea that* chromosomes are arranged in order (of size) to produce, image / photograph ✓	3 max	**CREDIT** cells taken using amniocentesis or CVS **ACCEPT** cell cycle for mitosis **Examiner's Comments** This question addressed mainly **AO1** and **AO2**. Candidates were required to demonstrate their mathematical skills by performing a percentage decrease calculation. Examiners reported that many candidates appeared confident in recognising that the technique was karyotyping, but descriptions were sometimes too vague to gain further credit.
			Total	5	
6			no response to / detection of, DNA damage / AW ✓ cells division / mitosis, continues ✓ apoptosis not triggered ✓	2 Max	**ACCEPT** DNA replication not checked **Examiner's Comments** Some candidates had clearly not read the question properly and wrote about what the G2 checkpoint does in general and didn't go as far as thinking about what would happen if it was faulty.
			Total	2	

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>7</td><td>a</td><td></td><td>
<table>
<tr><th>Event</th><th>Mitosis</th><th>Meiosis I</th><th>Meiosis II</th><th></th></tr>
<tr><td>Chromosomes condense in prophase</td><td>✓</td><td>✓</td><td>✗</td><td></td></tr>
<tr><td>Nuclear envelope breaks down in prophase</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Bivalent pairs line up in Metaphase</td><td>✗</td><td>✓</td><td>✗</td><td>✓</td></tr>
<tr><td>Centromere splits during Anaphase</td><td>✓</td><td>✗</td><td>✓</td><td>✓</td></tr>
<tr><td>Centrioles move to opposite poles of the cell during prophase</td><td>✗</td><td>✗</td><td>✗</td><td>✓</td></tr>
</table>
</td><td>4</td><td><u>Examiner's Comments</u>

Few candidates scored four marks, it was probably most common to see one or two correct rows in the table. This suggests that candidates are generally not very confident with what happens during the different stages of the types of cell division. The first row was most often correct and the last row the most often incorrect. Candidates often mixed up meiosis and mitosis and answered the question with statements referring to asexual reproduction and the production of genetically identical cells for growth or repair.</td></tr>
<tr><td></td><td>b</td><td></td><td>forms, haploid cells / gametes ✓
gametes that are genetically different / allows variation ✓
prevents doubling of the chromosome number ✓</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>6</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
8	a		<table><tr><th>Term</th><th>Insert a tick</th></tr><tr><td>Genetic engineering</td><td></td></tr><tr><td>Therapeutic cloning</td><td>✓</td></tr><tr><td>Reproductive cloning</td><td></td></tr><tr><td>ICSI</td><td></td></tr><tr><td>IVF</td><td></td></tr></table> ;	1	**Examiner's Comments** This question addressed **AO1** and **AO2** objectives. **DO NOT CREDIT** if more than one box has been ticked **DO NOT CREDIT** hybrid ticks **Examiner's Comments** While most candidates could identify therapeutic cloning, responses were seen that covered each of the options given with some candidates ticking more than one box. Part **(b)** was accessible although some candidates did make the same point twice regarding the ability to differentiate into a variety of different cells.
	b	i	embryonic / pluripotent ;	1	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer = **0 marks** **ALLOW** totipotent / multipotent **IGNORE** omnipotent
		ii	mark in any order can (continue to) divide ; pluripotent **OR** able to differentiate into / AW, (several) different types of, cells / tissues ; *idea that* have same antigens as patient / will not be rejected (by patient's immune system);	2	**Mark the first answer on each prompt line**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer = **0 marks** **IGNORE** 'totipotent'
			Total	**4**	

Question			Answer/Indicative content	Marks	Guidance
9	a		*Erythrocyte* disc-shaped / AW; nucleus absent; no organelles / named organelles; has haemoglobin; no projections from surface;	1	CREDIT reverse argument for stem cell IGNORE size ref (as no scale given) Examiner's Comments Similar numbers of AO1 and AO2 marks were available in this question. This was well answered. The most common answer was biconcave disc shape.
	b		1 cells divide by <u>mitosis</u>; 2 to produce, <u>genetically</u> identical cells / clones; 3 cells differentiate / become specialised for a particular function / AW; 4 as some genes switched, off / on; 5 (and) different proteins made; 6 group of / AW, cells form tissues; 7 group of / AW, (different) tissues form organs; nervous system, (fully) develops, early / AW; 8 *idea that* reproductive system not fully developed until, puberty; 9 correct reference to named, reproductive / nervous, tissue / organ;	7	CREDIT named examples throughout e.g. CNS / brain / spinal cord / seminal vesicles / ovaries / testes

Question			Answer/Indicative content	Marks	Guidance
			Any 7 QWC;	1	AWARD QWC if at least 2 marks from MP 1-7 have been awarded and at least 1 mark from MP 8-10 have been awarded. Examiner's Comments Similar numbers of AO1 and AO2 marks were available in this question. Candidates scored marks in this question but found it difficult to access the full range of marks due to not fully developing their answers or using imprecise statements. Most candidates talked about stem cells undergoing differentiation, but didn't explain about mitosis or gene switching. Few could give a correct definition of a tissue or organ as groups of cells or tissues working together. Where candidates had read the QWC guidance, they often gained credit but several discussed lymphatic system development, instead of nervous and reproductive systems.
			Total	9	

Question			Answer/Indicative content	Marks	Guidance
10		i	*idea of* evaluating effectiveness of (new) drugs (compared to existing drugs); *idea of* setting (NHS) guidelines for drug use; *idea of* ensuring treatment is, cost-effective / value for money;	2 max	IGNORE reference to side effects, and safety (as this would have been done during trials and licenced) Examiner's Comments Many candidates had a good understanding of the role of NICE, although several candidates incorrectly stated that they were involved in clinical trial work, rather than the pharmaceutical company developing the drug. NICE considers evidence on efficacy and provides guidelines based on all available treatment options, they do not test drugs themselves. Where dosage is concerned, they produce guidance on which dosages should be used and when, but they do not determine dosages or safe dosages as these are determined during trial work.
		ii	nucleus / DNA / chromosome / chromatin; plasma / cell surface, membrane; phagocytosis / endocytosis;	3	Examiner's Comments Nearly all candidates correctly identified that macrophages use phagocytosis or endocytosis, however, most candidates did not correctly name the plasma membrane or cell surface membrane forming blebs, merely calling it the 'cell membrane' or 'membrane'.
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
11					**Mark the first answer for each question part.** If the answer is correct and a further answer is given that is incorrect or contradicts the correct answer then = **0 marks** **Examiner's Comments** This was a straightforward question testing candidates' knowledge of terms. Most candidates knew many of the terms but a couple were less well known.
			homologous (chromosomes) **OR** homologue(s) ;	1	**IGNORE** bivalent **Examiner's Comments** This term was well known to the majority of candidates.
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
12	a	i	mitosis ;	1	CREDIT correct spelling only ACCEPT binary fission Examiner's Comments Most candidates were able to identify the type of cell division and the stage of the life cycle where differentiation takes place.
		ii	in the grex / 3 ;	1	Examiner's Comments Most candidates were able to identify the type of cell division and the stage of the life cycle where differentiation takes place.
	b		17 (hours) ;	1	Examiner's Comments A simple calculation was required to determine how many hours it would take a single cell to reproduce a sufficient number of times to produce a mass of at least 100 000 cells. The best candidates achieved this mark. Most candidates, however, were unable to make the calculation which simply needed them to double the number each hour until they reached a total of over 100 000.
			Total	3	

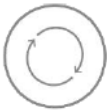
<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>13</td><td></td><td>i</td><td><u>Meiosis</u> ✓</td><td>1</td><td>IGNORE ref to I or II.

Examiner's Comments
The vast majority of candidates achieved the mark for (a)(i).</td></tr>
<tr><td></td><td></td><td>ii</td><td><table><tr><th>Event</th><th>Type of nuclear division</th><th>Stage in nuclear division</th></tr><tr><td>Chromosomes line up on the equator; there is no association between homologous chromosomes.</td><td>mitosis</td><td>(early / late) metaphase ✓</td></tr><tr><td>Homologous chromosomes form bivalents.</td><td>meiosis</td><td>prophase I ✓</td></tr><tr><td>Homologous chromosomes separate and are pulled to opposite poles.</td><td>meiosis</td><td>anaphase I ✓</td></tr><tr><td>Crossing over occurs.</td><td>meiosis</td><td>prophase I ✓</td></tr></table></td><td>4</td><td>1 mark per row – needs correct type and stage

Examiner's Comments
In (a)(ii) although most candidates scored, many failed to state the correct stage of nuclear division for meiosis by omitting I or II.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>5</td><td></td></tr>
<tr><td>14</td><td></td><td></td><td>0.82
OR
82 % ✓✓</td><td>2</td><td>If answer incorrect or incorrect number of sig. figs used
ALLOW 1 mark for:
46 ÷ 56
OR
0.8 / 0.821 / 82.1 %

<u>Examiner's Comments</u>

Whilst the majority of candidates were able to perform the calculation, some did not then give their response to two significant figures as requested and so were only credited with one mark. Candidates were credited for expressing their response for proportion as either a decimal or a percentage.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>2</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
15	a	i	*Similarity (presence of)* axon / cell bodies / dendrites / synaptic knobs / myelin (sheath) / Schwann cells / nodes of Ranvier ✓ *difference* cell body at end of motor neurone **AND** cell body in middle of sensory neurone **OR** sensory neurone has a dendron / sensory neurone has short axon **AND** motor neurone has long axon ✓	2	**IGNORE** ref to function or direction of impulse. **ALLOW** suitably labelled diagrams **DO NOT ALLOW** both have long axons Examiner's Comments Similarities were well answered with a good spread of answers. Candidates who did not gain the difference mark had difficulty explaining the position of the cell body. Many candidates described the direction of the impulse and so did not appreciate the key word 'structure' in the question.  Few candidates attempted diagrams to answer this but appropriately labelled diagrams would be an excellent way of illustrating both differences and similarities and avoid the difficulties some candidates encountered when trying to describe the position of the cell body for the two types of neurones. Candidates should not be restricted to text just because lines are provided.

Question			Answer/Indicative content	Marks	Guidance
		ii	both sensory and motor neurones are damaged ✓ impulse cannot, reach muscles / pass through motor neurone ✓ prevents impulse transmission, through sensory neurone / from receptors ✓	2 max	IGNORE signals/messages/information for 'impulses' ALLOW from stimulus for 'from receptors'. Examiner's Comments This was well answered with many candidates appreciating the relevance of the two consequences of damage to the two types of neurone. More candidates recognised the significance of the (damaged) motor neurone to paralysis than the (damaged) sensory neurone to loss of feeling.
		iii	insulates (the axon) / prevents passage of ions ✓ saltatory conduction ✓ (this) increases / speeds up , (rate of) transmission of impulses ✓	2 max	IGNORE signals/messages/information for 'impulses' ALLOW action potential jumps from node to node for 'saltatory conduction'. Examiner's Comments Most candidates recognised myelin as an insulator and could either state saltatory conduction or describe it. Myelin was often referred to as protecting the axon which suggests an analogy with adipose tissue in various parts of the body. This is not correct and myelin should be described purely in terms of its role in increasing the axon's membrane resistance and decreasing the membrane capacitance. Relating the role of myelin to symptoms of multiple sclerosis often helps to emphasise the importance of its function in a contextual sense. Succinct

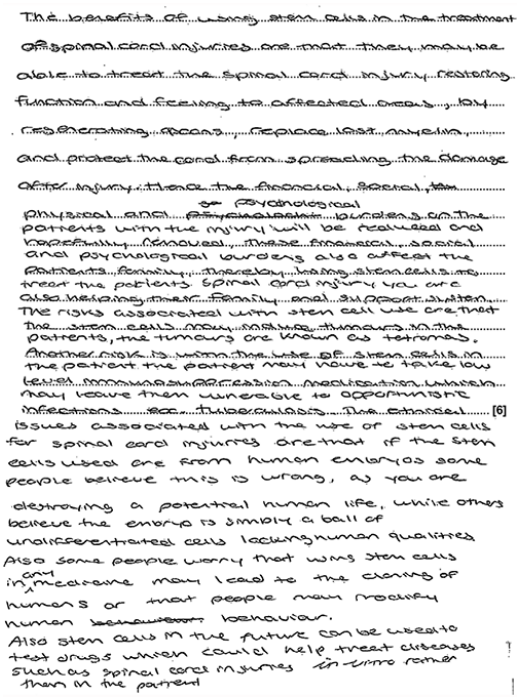
Question			Answer/Indicative content	Marks	Guidance
					descriptions can be found at: https://www.sciencedirect.com/topics/neuroscience/myelin (1aii & 1aiii) Too many candidates use terms like signals, messages and information to describe an action potential. When describing the propagation of an action potential, avoid using signalling or messaging as transitive verbs referring to the direction of impulse, e.g. avoid 'an impulse signals to the CNS'. This will help to remove these words in any context (verb or noun). Concentrate on using words e.g. transmitted, propagated. This should help candidates to disconnect the use of signals and messages when describing any aspect of nerve transmission. Key Misconception
		iv	Schwann cells	1	Examiner's Comments Generally, well answered although many candidates stated glial cells. There were a few NR for this question part.

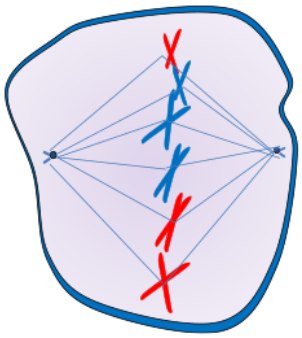
Question			Answer/Indicative content	Marks	Guidance
	b	i	MRI / fMRI (functional MRI) / CT ✓	1	ALLOW lower case letters Examiner's Comments Most candidates described MRI and recalled the use of a magnetic field and radio-waves to produce an image. Those who described a CT scan successfully recalled the use of X-rays and producing a 3D image.  Candidates described the resultant images as showing damaged areas, as if the whole image would focus only on areas of injury. It should be demonstrated that images would show damaged areas compared to surrounding healthy tissue. Many images can be found that illustrate small areas of damage compared to surrounding tissue. Videos can also be shown that can be in any context e.g. herniated disc, as it serves to illustrate the relevance and limitations of these techniques. https://www.bing.com/videos/search?q=herniated+disc+mri&view=detail&mid=26378AD9C02AB6505D1B26378AD9C02AB6505D1B&FORM=VIRE

Question			Answer/Indicative content	Marks	Guidance
		ii	1 (both) show difference, between healthy **and** damaged areas ✓ *MRI / fMRI* **M2** uses magnet(s) / magnetic field ✓ **M3** detects, increase in water (content) / swelling / inflammation / (changes in) blood flow ✓ **M4** (can be used to) detect areas of demyelination ✓ **OR** *CT* **C2** uses X-rays (and computer) ✓ **C3** builds up 3-D image (of the spinal cord) ✓ **C4** shows areas with, poor blood supply / bleeding / blood clot ✓	**3 max**	**IGNORE** ref to tumours or other conditions not related to SCI **IGNORE** ref to technique other than *1bi* answer **ALLOW** 3DMRI gives a 3D image Examiner's Comments Most candidates described MRI and recalled the use of a magnetic field and radio-waves to produce an image. Those who described a CT scan successfully recalled the use of X-rays and producing a 3D image. Candidates described the resultant images as showing damaged areas, as if the whole image would focus only on areas of injury. It should be demonstrated that images would show damaged areas compared to surrounding healthy tissue. Many images can be found that illustrate small areas of damage compared to surrounding tissue. Videos can also be shown that can be in any context e.g. herniated disc, as it serves to illustrate the relevance and limitations of these techniques. https://www.bing.com/videos/search?q=herniated+disc+mri&view=detail&mid=26378AD9C02AB6505D1B26378AD9C02AB6505D1B&FORM=VIRE

Question			Answer/Indicative content	Marks	Guidance
	c		1 neural stem cells / human brain tissue stem cells / MSCs, are multipotent ✓ 2 (as) derived from adult (stem cells) / able to differentiate into a limited range of cell types ✓ 3 embryonic stem cells are pluripotent ✓ 4 (as) they can differentiate into any type of cell ✓	3 max	ALLOW ref to trial names (e.g. Balgrist / Neuralstem) for 'neural stem cells/MSCs' ALLOW pluripotent in the context of iPSCs ALLOW ref to Asterias trial for 'embryonic stem cells' ALLOW embryonic stem cells are toti potent as early embryo used Examiner's Comments Well answered with most candidates clearly extracting relevant information from the Advance Notice article. Marks were lost for confusing pluripotent with totipotent stem cells. As both pluripotent and totipotent stem cells derive from embryos and can differentiate into any type of cell, candidates confuse the terms and focus on totipotent stem cells. It should be emphasised that the medical use of stem cells use pluripotent stem cells that are also called embryonic stem cells or ESC's.
	d		*Summary of instructions to markers:* *Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.)* *Using a 'best-fit' approach based on the science content of the answer, first decide which of the level descriptors,* ***Level 1****,* ***Level 2*** *or* ***Level 3****, best describes the overall quality of the answer.* *Then, award the higher or lower mark within the level, according to the* ***Communication Statement*** *(shown in italics):* ◦ award the higher mark where the Communication Statement has		

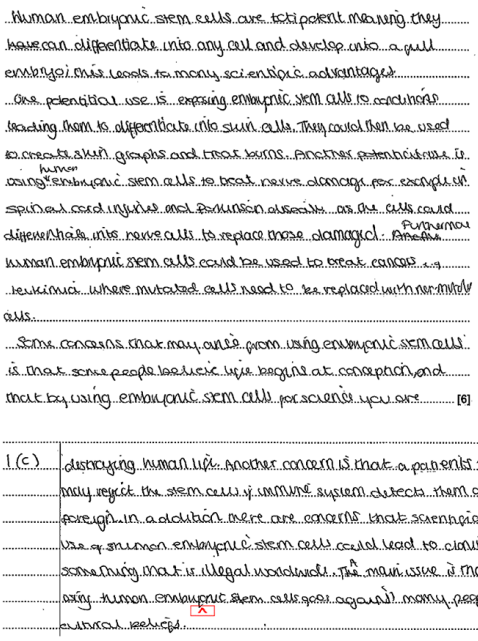
Question	Answer/Indicative content	Marks	Guidance
	been met. ◦ award the lower mark where aspects of the Communication Statement have been missed. • **The science content determines the level.** • **The Communication Statement determines the mark within a level.**		
	Level 3 (5–6 marks) An evaluation of the risks and benefits and the ethical issue of using stem cells. There is clear reference to the future potential of stem cell therapy. *There is a well-developed line of reasoning which is clear and logically structured and uses scientific terminology at an appropriate level. There are clear links to the information in the article. All the information presented is relevant and forms a continuous narrative.* **Level 2 (3–4 marks)** An evaluation of the benefits and risk or risks and benefit of using stem cells including any ethical issue surrounding this use. There is reference to the future potential of stem cell therapy. *There is a line of reasoning presented with some structure and use of appropriate scientific language. There is a link to the information in the article The information presented is mostly relevant.* **Level 1 (1–2 marks)** An evaluation of the risk or benefit and any ethical issue related to the use of stem cells. However, there is no reference to future potential. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of	6	**Indicative scientific points may include** *Risks* Risk of rejection Risk of infection with many injections or collection of MSCs Risk of further injury with many injections Need for immunosuppression Unknown long-term effect May not work Risk of teratogenesis / oncogenesis (with iPSCs) Too much emphasis on data with small sample size *Benefits* Reduces symptoms of SCI/ treats SCI Replace damaged cells Patients could walk/move, again Prevents further damage due to SCI Still under research/ not known Lack of other treatments Gives hope to patients No rejection if from own bone marrow Data used to help future sufferers *Ethical* Destroying embryos Use of iPSCs Use of human brain tissue Gives false hope *Future potential* Stem cell therapies will be approved Use of iPSCs Data gathered can be used in future Examiner's Comments

Question			Answer/Indicative content	Marks	Guidance
			credit.		Well answered with most candidates covering all aspects of ethical risks, benefits and potential future benefit. Many candidates had learned about the use and potential of induced pluripotent stem cells (iPSCs). Some candidates used up too much space (and time) discussing ethical issues in terms of playing god, embryos can't give consent, etc. without mentioning the obvious fact that producing embryonic stem cells usually means destroying an embryo. Candidates often lost marks for failing to appreciate the future potential of stem cell therapy. Exemplar 1  Good use of all available space on page. Clearly moves through ethical benefits, risks and potential for future benefit. There was good discussion of each, with no focus on any particular component and always related to SCI.
			Total	**20**	

Question			Answer/Indicative content	Marks	Guidance
16	a	i	*Drawing to include:* spindle fibres drawn **AND** six chromosomes drawn (vertically) at the equator ✓ centrioles drawn at both poles ✓	1	 **Two correctly labelled structures required for 1 mark**
			Labelling: Any **two** from: centromere spindle (fibres) centriole chromatid ✓	2	**Examiner's Comments** This was a straightforward opening question and more candidates should have scored three marks. Candidates often did not label their diagram. The candidates that did use labels did not label the chromatids or used the term centrosome instead of centromere. Quite a few candidates did not draw six chromosomes or missed the spindle fibres out. It should be noted that the spindle fibres connect the chromosomes to the centriole and this should obvious in the diagram, too many candidates drew vague or incomplete spindle fibres.

Question			Answer/Indicative content	Marks	Guidance
		ii	*A stem cell* = 6 **AND** *A sperm cell (gamete)* = 3 ✓	1	**Both** required for one mark. Must be in correct order. Examiner's Comments Quite a few candidates stated 46 and 23 for the number of chromosomes found in a stem cell and sperm cell found in the same organism. As they have just drawn a cell going through the process of mitosis found in the same organism, this suggests that they did not read the question properly.
		iii	apoptosis ✓	1	**ALLOW** programmed cell death

Question			Answer/Indicative content	Marks	Guidance
	b		*Summary of instructions to markers: Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.) Using a 'best-fit' approach based on the science content of the answer, first decide which of the level descriptors, **Level 1, Level 2** or **Level 3**, best describes the overall quality of the answer. Then, award the higher or lower mark within the level, according to the **Communication Statement** (shown in italics):* ◦ award the higher mark where the Communication Statement has been met. ◦ *award the lower mark where aspects of the Communication Statement have been missed.* • ***The science content determines the level.*** • ***The Communication Statement determines the mark within a level.*** **Level 3 (5–6 marks)** Provides a comprehensive description of how embryonic stem cells are used and the concerns that arise due to their use. *There is a well-developed line of reasoning which is clear and logically structured and uses scientific terminology at an appropriate level. All the information presented is relevant and forms a continuous narrative.* **Level 2 (3–4 marks)** Provides a brief description of how embryonic stem cells are used and the concerns that arise due to their use. *There is a line of reasoning presented with some structure and use of appropriate scientific language. The information presented is mostly relevant.* **Level 1 (1–2 marks)** Provides a brief description of how human embryonic stem cells are used or the	6	Uses for **human** embryonic stem cells taking into account any concerns that could arise by using these cells for research purposes. **Indicative scientific points may include** **Uses of Embryonic stem cells** totipotent / pluripotent able to express all the genes able to make all cells used to treat spinal cord injury heart disease stroke burns arthritis diabetes retina damage organ transplant **Concerns** could lead to reproductive cloning the potential risks and side effects are unknown embryos cannot give consent religious objection embryo could be used in fertility treatment. taken from embryo at less than 5 days old **Examiner's Comments** The use of stem cells is well known by candidates but the concerns arising were lacking in many cases. 'Religious belief' was the most common concern with 'potential risks' rarely are stated. The candidates should be taught that level of response questions require more than just stating facts relevant to the topic. This question required candidates to discuss the use of stem cells including references to the potential concerns such as it could lead to reproductive cloning, the potential risks and side effects are unknown, the embryos cannot give consent, religious objections, the embryo could be used in

Question			Answer/Indicative content	Marks	Guidance
			concerns that arise due to their use. *The information is communicated with only a little structure. Communication is hampered by the inappropriate use of technical terms.* **0 marks** No response or no response worthy of credit		fertility treatment or they are taken from an embryo at less than 5 days old. **Exemplar 1**  This was a good answer showing a clear understanding of what stem cells are and how they can be used. Giving a number of examples. A good appreciation was also shown of the concerns arising from using embryonic stem cells. Had there been references to an obvious lack of consent and objections due to religious beliefs and the answer would have been credited full marks.
			Total	**11**	