3B MITOSIS, MEIOSIS & REPRODCTION

1

Gametes are specialised for their role in sexual reproduction.

(a) The purpose of the cortical reaction is to

(1)

☒ **A** allow the haploid nuclei to fuse

☒ **B** attract the sperm towards the egg cell

☒ **C** cause the sperm cell membrane to fuse with the egg cell membrane

☒ **D** ensure that only one sperm fertilises the egg

(b) (i) Which adaptation allows a sperm cell to digest the zona pellucida?

(1)

☒ **A** acrosome

☒ **B** flagellum

☒ **C** haploid nucleus

☒ **D** streamlined shape

(ii) Give a reason for the high density of mitochondria found in the midpiece of a sperm cell.

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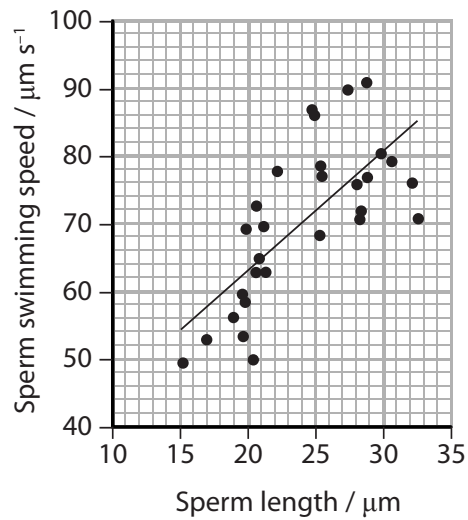
(c) The relationship between the length of a sperm cell and the speed at which it can swim was investigated.

The data collected are shown in the graph.

(i) Calculate the swimming speed of a sperm cell that is 40 μm long, as predicted by the line shown on the graph.

(2)

Answer ....

(ii) Explain the limitations of using the line on the graph to predict the swimming speed of sperm cells.

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Cell division can be affected by various chemicals. The effects of these chemicals can be studied by observing tissues.

(d) The photograph shows onion root cells undergoing mitosis.
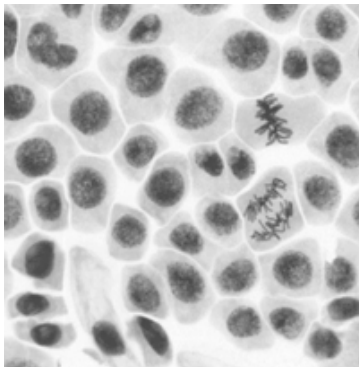
(i) Draw a line labelled **M** to one cell at metaphase and a line labelled **A** to one cell at anaphase.

(2)

(ii) The rate at which cells are dividing can be determined by calculating the mitotic index.

The mitotic index is the percentage of cells in a sample undergoing mitosis.

The table shows the number of cells at different stages of the cell cycle in one sample.

Stage	Number of cells
Interphase	462
Prophase	23
Metaphase	24
Anaphase	4
Telophase	16

Calculate the mitotic index for the sample of cells shown in the table.

(2)

Answer .... %

(e) Herbicides are chemicals used to kill weeds. Some herbicides work by disrupting the cell cycle.

An investigation was carried out to study the effect of different concentrations of the herbicide Agil on mitosis in onion root tips.

The roots of onions were exposed to different concentrations of Agil for 24 hours.

Root tip squashes were then prepared and the mean mitotic index was calculated for each Agil concentration.

The results are shown in the table.

Agil concentration / ppm	Mean mitotic index (% ± SE)
0.0	40.7 ± 0.22
0.5	33.7 ± 0.32
1.0	31.1 ± 0.15
1.5	30.8 ± 0.19

(i) Describe the effects of Agil concentration on mitosis in onion root tips.

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(ii) Devise an investigation to determine the effect of exposure time to Agil on the rate of mitosis in onion root tips.

(6)

(f) Chemotherapy is used to treat cancer. Cancer involves uncontrolled cell division. Some chemotherapy treatments have an effect on mitosis.

Paclitaxel is a chemical used in chemotherapy to treat various types of cancer. It works by preventing the shortening of spindle fibres.

Explain how preventing the shortening of spindle fibres affects mitosis.

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(Total for Question 5 = 21 marks)

4A PLANT STRUCTURE & FUNCTION

The electron micrograph shows a cross-section through part of a vascular bundle, containing phloem tissue.

2

5 μm
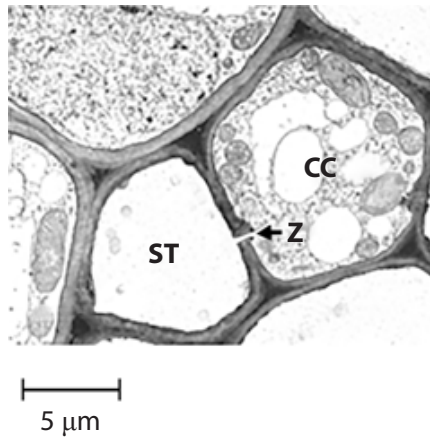
A sieve tube element is labelled '**ST**'. A cell called a companion cell is labelled '**CC**'.

(a) Calculate the magnification of this image.

(1)

Answer: × ....

(b) The wall of the sieve tube element contains

(1)

☒ **A** cellulose, lamellae and lignin

☒ **B** cellulose, lignin and pectin

☒ **C** hemicellulose, microfibrils and pectin

☒ **D** hemicellulose, peptidoglycan and pectin

(c) There is no nucleus in a mature sieve tube element.

Give **two** reasons why a sieve tube element does not require rough endoplasmic reticulum and ribosomes.

(2)

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(d) Companion cells are found next to sieve tube elements.

(i) Describe the structure labelled **Z** that connects the cytoplasm of the companion cell to the sieve tube element.

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(ii) The electron micrograph shows a difference in the number of mitochondria in the sieve tube element and in the companion cell.

Explain the difference in the number of mitochondria.

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(Total for Question 2 = 9 marks)

3

Svalbard Global Seed Vault (SGSV) is a seed bank. It keeps seeds from almost 4000 species of plants, focussing on food crops such as wheat, rice and maize.

(a) State suitable conditions for keeping seeds in a seed bank.

(2)

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(b) Many seeds in SGSV store food in the form of starch.

(i) Why does the food store in seeds contain starch rather than cellulose?

(1)

☒ **A** starch can be stored for longer because it has 1–4 bonds

☒ **B** starch has more mineral ions than cellulose

☒ **C** starch is branched and supplies energy more quickly than cellulose

☒ **D** starch is more compact than cellulose because it has 1–6 bonds

(ii) Explain why starch must be broken down before it can be used by the cells of the growing plant.

(2)

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(c) The purpose of SGSV is to store seeds for use in the future, 50 or more years from now.

Seeds from three varieties of maize were tested to see the effects of long periods of storage. The results of these tests are shown in the graph.
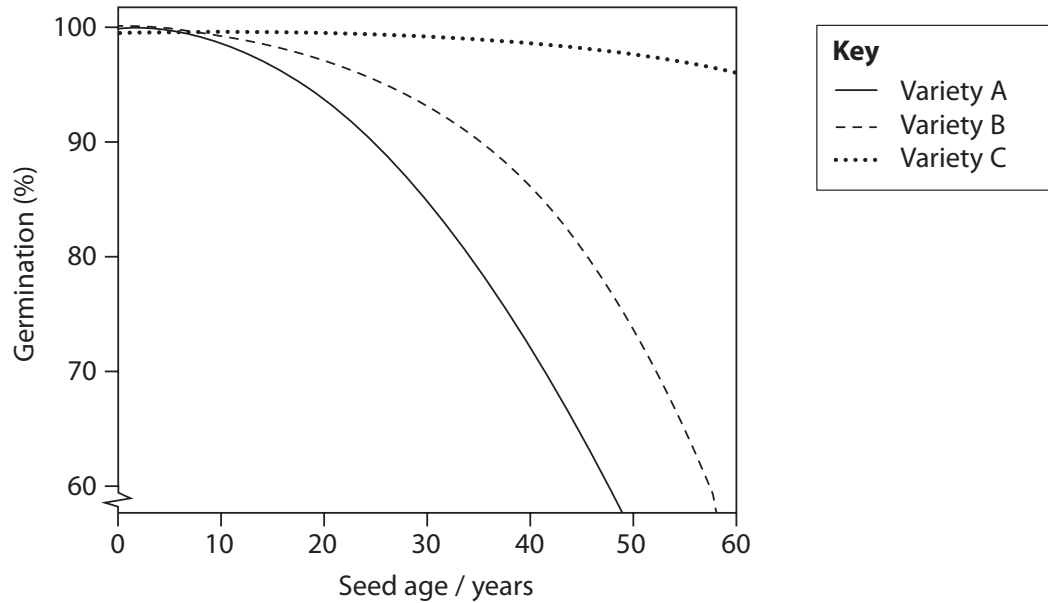
Explain how SGSV could make use of these results.

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(d) SGSV keeps seeds from more than 865 000 varieties of plant, including 200 000 varieties of wheat and rice. Some of these varieties are rare or extinct in the wild.

Since 2004, more than 410 million dollars have been spent on SGSV and other seed banks around the world.

However, it is estimated that 75% of global crop diversity is not stored in international seed banks.

Critics argue that many crop varieties stored in SGSV are not actually used for food, and that the money would be better spent supporting farmers who are growing food crops.

Justify the continued funding of SGSV.

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(Total for Question 6 = 11 marks)

4

Some fish live in very cold parts of the sea where ice can form.

Many of these fish produce anti-freeze proteins, which help to stop ice forming inside the fish.

(a) The production of anti-freeze proteins is an example of

(1)

☒ **A**   anatomical adaptation

☒ **B**   change in allele frequency

☒ **C**   physiological adaptation

☒ **D**   reproductive isolation

(b) Anti-freeze glycoprotein (AFGP) is one type of anti-freeze protein.

Messenger RNA coding for AFGP is translated at a ribosome to produce a polypeptide.

Describe how this polypeptide is then processed to make AFGP.

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(c) Some fish produce another anti-freeze protein, called AFP II.

The tissues of these fish were tested for the presence of AFP II and the mRNA coding for AFP II.

The results are shown in the table.

Molecule	Present in
AFP II protein	all tissues
AFP II mRNA	liver tissue only

Explain the distribution of the AFP II protein and AFP II mRNA.

(4)

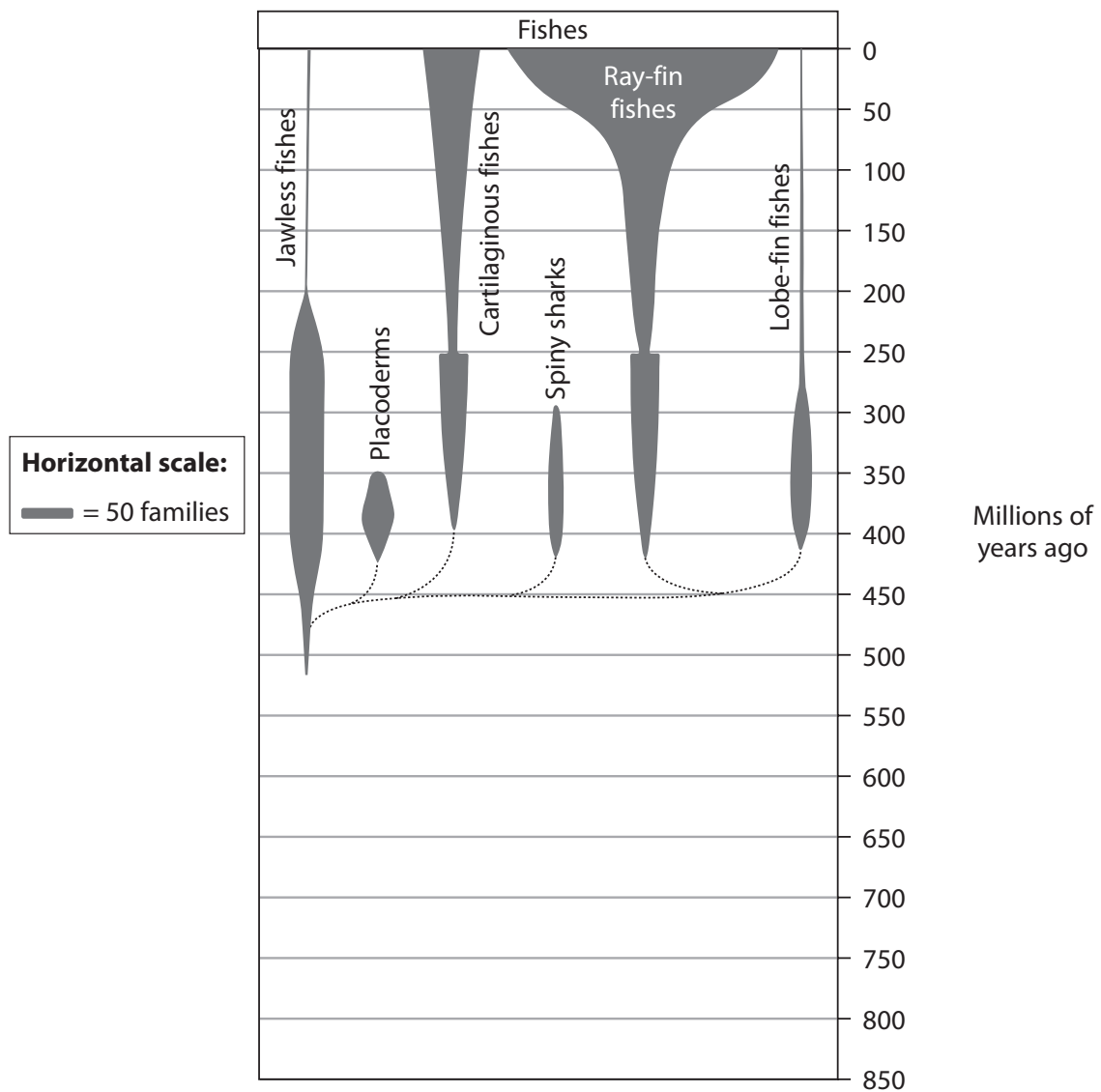...

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(d) Sea ice forms only during ice ages.

The table shows Earth's ice ages over the last 1000 million years.

Ice age	Time / millions of years ago
Quaternary	0 to 2.6
Karoo	260 to 360
Andean-Saharan	420 to 460
Cryogenian	630 to 850

The diagram shows how the number of families of fishes has changed over time.

(i) At which time does the diagram show a major loss of biodiversity?

(1)

☒ **A** 65 million years ago

☒ **B** 252 million years ago

☒ **C** 359 million years ago

☒ **D** 419 million years ago

(ii) Many different types of anti-freeze protein are produced by ray-fin fishes.

Analyse the data to explain when these ray-fin fish are likely to have evolved the ability to produce anti-freeze proteins.

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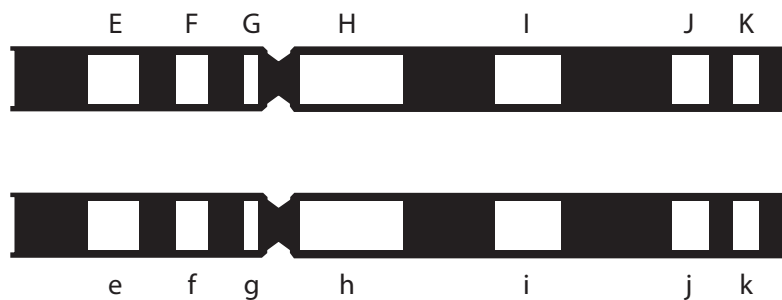
(Total for Question 7 = 13 marks)

The diagram shows two homologous chromosomes from a man.

The white regions are the loci of seven genes involved in different phenotypic traits. The letters E-K and e-k represent the alleles present at each locus.

(a) Alleles F and G are

(1)

☒ **A** autosomal and complementary

☒ **B** autosomal and linked

☒ **C** sex-linked and dominant

☒ **D** sex-linked and epigenetic

(b) This man produces gametes. Each gamete contains only one allele of each gene.

Describe how each gamete receives only one allele of each gene.

(2)

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(c) The gametes produced by this man may have different combinations of alleles.
Possible combinations of alleles are:

- E and K

- e and K

- h and i

- H and i

Assess the relative chances of this man's gametes containing these combinations
of alleles.

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(Total for Question 8 = 7 marks)

6 Plant cell walls contain cellulose. Cellulose molecules are polymers.

(a) (i) Name the monomer that makes up cellulose.

(1)

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(ii) Which of the following correctly describes how these monomers are held together in a cellulose molecule?

(1)

☒ **A** by glycosidic bonds in a branched chain

☒ **B** by glycosidic bonds in an unbranched chain

☒ **C** by hydrogen bonds in a branched chain

☒ **D** by hydrogen bonds in an unbranched chain

(iii) Cellulose molecules are held together in bundles called microfibrils.

These microfibrils are embedded in a matrix containing calcium pectate.

Calcium pectate can be found in the

(1)

☒ **A** amyloplast

☒ **B** chloroplast

☒ **C** middle lamella

☒ **D** tonoplast

(b) (i) The cell walls in some plant tissues have secondary thickening. This may contain a substance called lignin.

Which of the following properties can lignin give to cell walls in plants?

(1)

☒ **A** flexibility and permeability to water

☒ **B** flexibility and waterproofing

☒ **C** strength and permeability to water

☒ **D** strength and waterproofing

(ii) Name a plant tissue that has lignin in its cell walls.

(1)

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(c) Some plant cells also contain the polymer starch.

Explain how the structure and properties of starch are related to its function as a
storage molecule.

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(Total for Question 1 = 8 marks)

7 Lupus is a genetic condition that has various symptoms.

There are several different genes involved in the development of the disease. The symptoms that develop vary depending on genetic and environmental factors.

Stress and exposure to chemicals in the environment can influence the development of lupus.

(a) (i) What is the term that refers to the pattern of inheritance where a single characteristic is determined by more than one gene?

(1)

☒ **A** epigenetic

☒ **B** monogenic

☒ **C** polygenic

☒ **D** sex-linked

(ii) Which of the following is another environmental factor that could affect the development of lupus?

(1)

☒ **A** age

☒ **B** diet

☒ **C** gender

☒ **D** height

(b) Alleles of a gene linked to the development of lupus have been located on the X chromosome.

Scientists tested 13 different alleles of the IRAK1 gene, which is located on the X chromosome. Five of these alleles were associated with lupus.

If these five alleles are recessive, explain how this could affect the ratio of males to females who develop lupus.

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(Total for Question 2 = 5 marks)

8

Conservation programmes are used to save endangered species.

The Scottish wildcat, shown in the photograph, is a subspecies of the European wildcat, *Felis silvestris silvestris*.

The Cairngorms Wildcat Project estimates that there are 150 breeding pairs left, but the Scottish Wildcat Association believes that only 35 cats remain.

A conservation group proposed that a captive breeding programme, and the relocation of Scottish wildcats, would be necessary to prevent extinction.

(a) (i) State why the Scottish wildcat has been described as **endemic**.

(1)

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(ii) The Scottish wildcat can interbreed successfully with domestic cats.

Explain the effect this could have on the genetic diversity of the Scottish wildcat.

(2)

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(b) Explain how molecular phylogeny could be used to determine the relationships between the Scottish wildcat and other subspecies of European wildcat.

(2)

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(c) Describe how the proposed conservation programme could prevent the Scottish wildcat from becoming extinct.

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(Total for Question 3 = 9 marks)

8

Plasmodium falciparum is a single-celled eukaryotic organism. *P. falciparum* causes the disease malaria when it invades red blood cells.

If untreated, malaria can result in a shorter than normal life span.

The high mortality rate of people with malaria has been claimed to be one of the greatest selection pressures on the human genome in recent history.
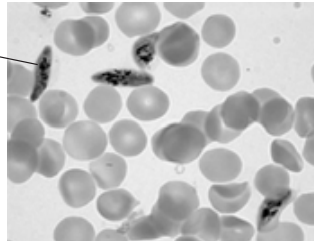
(a) The photograph shows *P. falciparum* in a sample of human blood.

P. falciparum

Describe how scientists could have determined that *P. falciparum* is a eukaryotic organism and not a prokaryotic organism.

(4)

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(b) Sickle cell anaemia is a genetic condition.

People who are homozygous for the sickle cell allele have red blood cells that become deformed in shape when they are deoxygenated.

The electron micrograph shows these deformed sickle cells alongside normal red blood cells.

sickle cell

normal red blood cell

Magnification ×3000
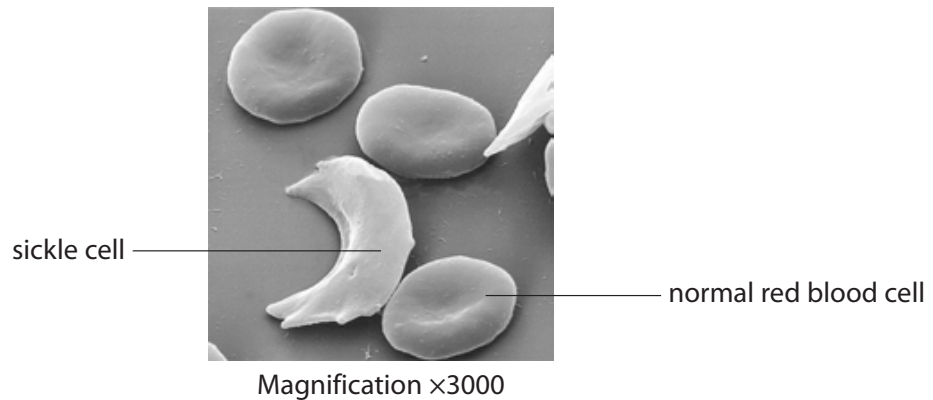
(i) The image of the normal red blood cell labelled in the electron micrograph has a diameter of 2 cm.

Which of the following is the actual diameter of this red blood cell?

(1)

☒ **A** 0.67 μm

☒ **B** 6.7 μm

☒ **C** 67 μm

☒ **D** 670 μm

(ii) People with a heterozygous genotype for this condition do not develop severe sickle cell anaemia.

The Yoruba are a group of people who live in West Africa.

In a population of 600 Yoruba individuals, 24 were found to have severe sickle cell anaemia.

Calculate the number of heterozygous individuals in this population.

Use the Hardy Weinberg equation, $p^2 + 2pq + q^2 = 1$.

(3)

Answer..

*(iii) Individuals who are heterozygous for this condition are resistant to a severe form of malaria, called cerebral malaria, that affects the brain. Individuals who are homozygous for the sickle cell allele are more likely to develop severe sickle cell anaemia.

The maps show the percentage of the population with the allele for sickle cell anaemia and the distribution of *P. falciparum* in Africa. The location of the Yoruba people is indicated with a cross (✖).
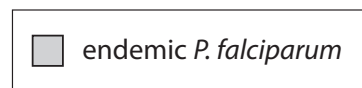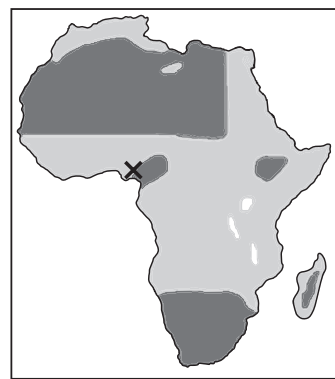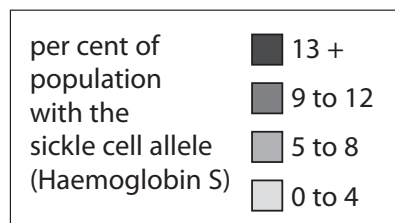
per cent of population with the sickle cell allele (Haemoglobin S)	■ 13 +
	■ 9 to 12
	■ 5 to 8
	□ 0 to 4

| □ endemic *P. falciparum* |

Analyse the data to explain how malaria has affected the percentage of individuals in the Yoruba population with the allele for sickle cell anaemia.

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(Total for Question 4 = 14 marks)

7

Textiles are often made from plant fibres. The use of plant fibres is more sustainable than the use of synthetic fibres made from fossil fuels.

(a) Give reasons why the use of fibres from plants is sustainable.

(2)

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(b) The tensile strength of plant fibres from different plant species can be measured.

(i) Which of the following are variables that would need to be controlled when testing the tensile strength of these fibres?

(1)

☒ **A** humidity and light intensity

☒ **B** light intensity and temperature

☒ **C** temperature and humidity

☒ **D** temperature and pH

(ii) Describe how the tensile strength of these fibres can be measured.

(3)

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(c) Fibres of curaua, jute and sisal were examined using an electron microscope.
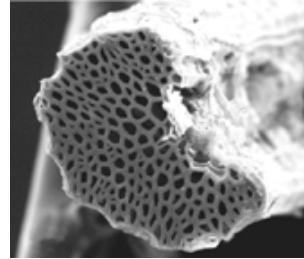
These electron micrographs were examined and the physical features of the fibres were measured.
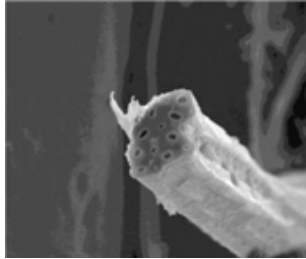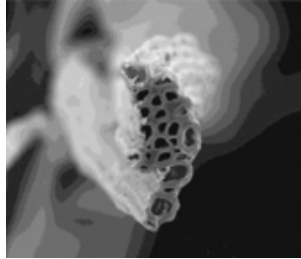
| Curaua | Jute | Sisal |

Type of fibre	Cell wall thickness / μm	Diameter of lumen / μm	Mean tensile strength / MPa
Curaua	3.5	4.0	543
Jute	2.5	6.7	249
Sisal	2.6	8.2	484

Analyse these data to evaluate the relationship between the structure of these plant fibres and their tensile strength.

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(Total for Question 6 = 10 marks)

3C DEVELOPMENT OF ORGANISM

8

In humans, different types of stem cell are found in the bone marrow.

The photograph shows some mesenchymal stem cells from bone marrow.

Mesenchymal stem cells can differentiate to give rise to a variety of cell types, including bone cells, cartilage cells, muscle cells and fat cells.
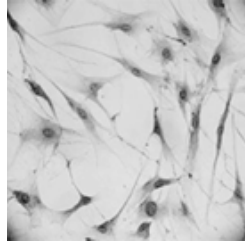
The skeletal system consists of bone tissue, muscle tissue and cartilage tissue.

(a) (i) Describe how a tissue differs in structure from a system.

(2)

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(ii) Describe how mesenchymal stem cells can give rise to different types of cell.

(4)

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(b) The proportion of mesenchymal stem cells to other cells in the bone marrow changes with age.

The graph shows the relationship between age and the percentage of mesenchymal stem cells in bone marrow.
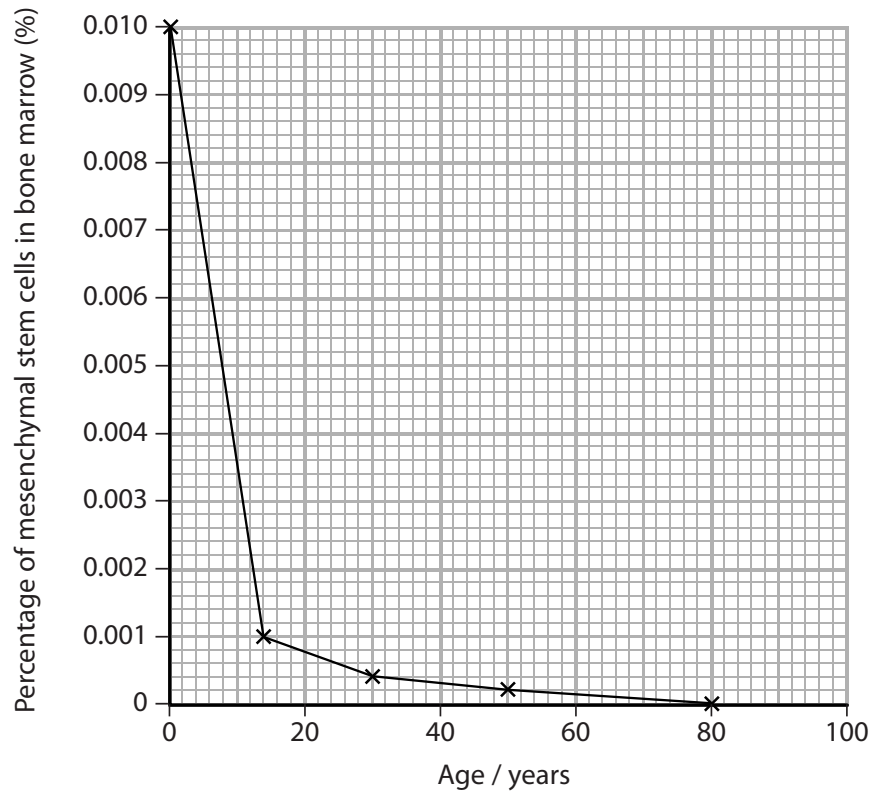
Calculate the rate at which the percentage of mesenchymal stem cells in the bone marrow changes between the ages of 14 and 30.

(2)

Answer .... % y^{-1}

(c) Deduce why age affects the time taken to recover from injuries.

(3)

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(Total for Question 7 = 11 marks)

4A/7 DEVELOPMENT OF NEW DRUG (PLANT MEDICINE)

9

Medicinal drugs undergo clinical trials before they are licensed to be used.

(a) Albuterol is a drug used to reduce the symptoms of asthma.

In a clinical trial, people with asthma were given either Albuterol, a placebo or no treatment.

Measured improvement (FEV improvement) can be used to indicate the effectiveness of the treatment in reducing the symptoms of asthma. FEV is forced expiratory volume. Asthma reduces FEV.

The people in the trial were also asked to describe their improvement and this was recorded as 'subjective improvement'.

Key
☐ Measured FEV improvement
☐ Subjective improvement

Comment on the measured improvement (FEV improvement) and subjective improvement for the different treatments.

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(b) In January 2016, a clinical trial of a different drug involved 128 healthy volunteers aged 18 to 55. In this trial, different doses of the drug were given to 90 of these volunteers and the others were given a placebo.

Six people, who were given the drug, became ill and had to be treated in hospital.

(i) Explain why healthy volunteers were given different doses of the drug or a placebo.

(2)

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(ii) The trial tested increasing the dose of the drug. The six people who fell ill were the first to receive higher doses over the course of several days.

Which of the following is the correct ratio of those who took the drug to those who fell ill?

(1)

☒ **A** 14 : 1

☒ **B** 15 : 1

☒ **C** 18 : 1

☒ **D** 21 : 1

(iii) Compare and contrast this drug testing protocol with that used by William Withering when he tested digitalis soup.

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(C) Bald's Leechbook was written in the 9th Century. This book contains details of medical treatments used over 1000 years ago.

The recipe for a 'salve', used to treat infections, is shown in the photograph.
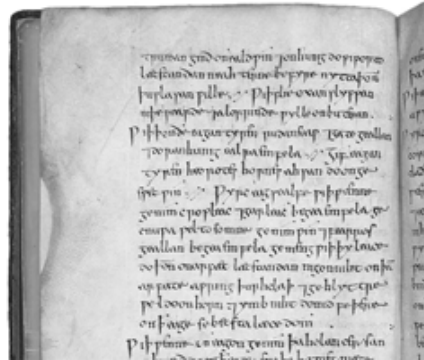
Scientists followed the recipe to make this salve and tested it in the laboratory.

They found that the salve was very effective against *Staphylococcus aureus*. This bacterium commonly causes infections in humans.

Describe **two** aseptic techniques that should be used when working safely with bacteria.

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(d) The salve was also tested on mice.

These mice had skin wounds infected with *S. aureus.* The salve was very effective in treating these infections.

(i) Explain why some bacteria can grow rapidly in skin wounds.

(3)

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(ii) *S. aureus* can cause infections which are difficult to treat in humans.

Describe how scientists, after testing the salve on mice, could test whether the salve is an appropriate treatment for humans with wounds infected with *S. aureus*.

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(Total for Question 4 = 18 marks)

Egg cells vary in size between different species of animal.

Egg cells from different animals were measured and some further information about each species was recorded. The data are shown in the table.

Animal	Diameter of egg cell	Mass of adult / kg	Site of fertilisation	Site of offspring development
Domestic cow (mammal)	85 µm	540	inside the body	in the uterus
Human (mammal)	150 µm	62	inside the body	in the uterus
American eel (fish)	1.1 mm	6.8	in the sea	floating in the sea
Hermann's tortoise (reptile)	2.3 cm	3.4	inside the body	inside an egg shell, in a nest
Great spotted kiwi (bird)	7.8 cm	2.3	inside the body	inside an egg shell, in a nest

(a) The human egg cell and the eel egg cell are approximately spherical.
The formula for the volume of a sphere is

$$V = \frac{4}{3}\pi r^3$$

where V is the volume and r is the radius of the sphere.

The volume of the human egg cell is $1.8 \times 10^6 \, \mu m^3$.

Calculate how many times larger the volume of the eel egg cell is than the volume of the human egg cell.

(3)

Answer .... times larger

11

There is considerable variation in the ecosystems that occur in the continent of North America. These include coniferous forest, prairie grassland, scrub and desert. Large areas of land that once contained natural ecosystems are now used for agriculture.

(a) Explain how the variation in ecosystems in North America contributes to biodiversity.

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(b) The diversity of some beetle species that feed on animal dung (faeces) was investigated at two types of grassland site in North America. The first type of grassland site was grazed by cattle and the second type of site was not grazed.

Dung beetles were collected, identified and counted from two areas of the same total size. Some of the results are shown in Table 8.1.

Table 8.1

beetle species	number of dung beetles on grassland grazed by cattle	number of dung beetles on grassland not grazed
Onthophagus pennsylvanicus	4267	6641
Canthon ebenus	2005	774
Canthon pilularius	353	108
Onthophagus hecate	218	85
total	6843	7608

(i) State the null hypothesis for a statistical test comparing the data from the two types of site.

....

.... [1]

(ii) State how many genera and how many species of beetle are shown in Table 8.1.

genera ....   species ....
[1]

(iii) Simpson's Index of Diversity for the beetles on the grassland grazed by cattle was calculated as 0.521 using the formula:

$$D = 1 - \left(\Sigma \left(\frac{n}{N} \right)^2 \right)$$

n = number of individuals of each species present in the sample
N = the total number of all individuals of all species

Calculate Simpson's Index of Diversity for the beetles on the grassland that was not grazed. Complete Table 8.2 to show your working. Show all working to **three** decimal places. Write your final answer on the dotted line.

Table 8.2

species	number on grassland not grazed	$\frac{n}{N}$	$\left(\frac{n}{N} \right)^2$
Onthophagus pennsylvanicus	6641		
Canthon ebenus	774		
Canthon pilularius	108		
Onthophagus hecate	85		
total	7608		

Simpson's Index of Diversity = ...   [3]

(iv) Describe what the results in Table 8.1 **and** both figures for Simpson's Index of Diversity show about the effect of grazing on the diversity of dung beetles.
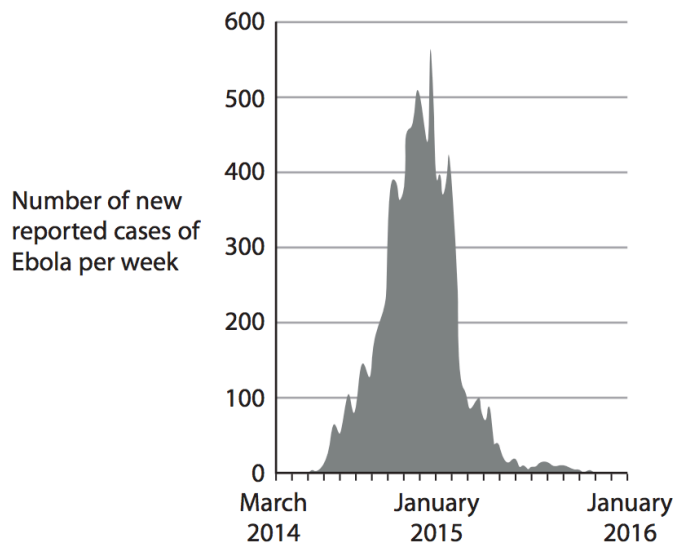
....

....

....

....

.... [2]

[Total: 11]

Handling 6 Marks Question

12

Ebola is a disease that has a high mortality rate. In 2014, there was an outbreak of Ebola in West Africa resulting in the deaths of over 11 000 people. The graph shows the number of reported cases in Sierra Leone from March 2014 to January 2016.

The maps show the number of reported cases in districts of Sierra Leone, Guinea and Liberia in four months recorded during the outbreak. The capital cities of these three countries are also shown.
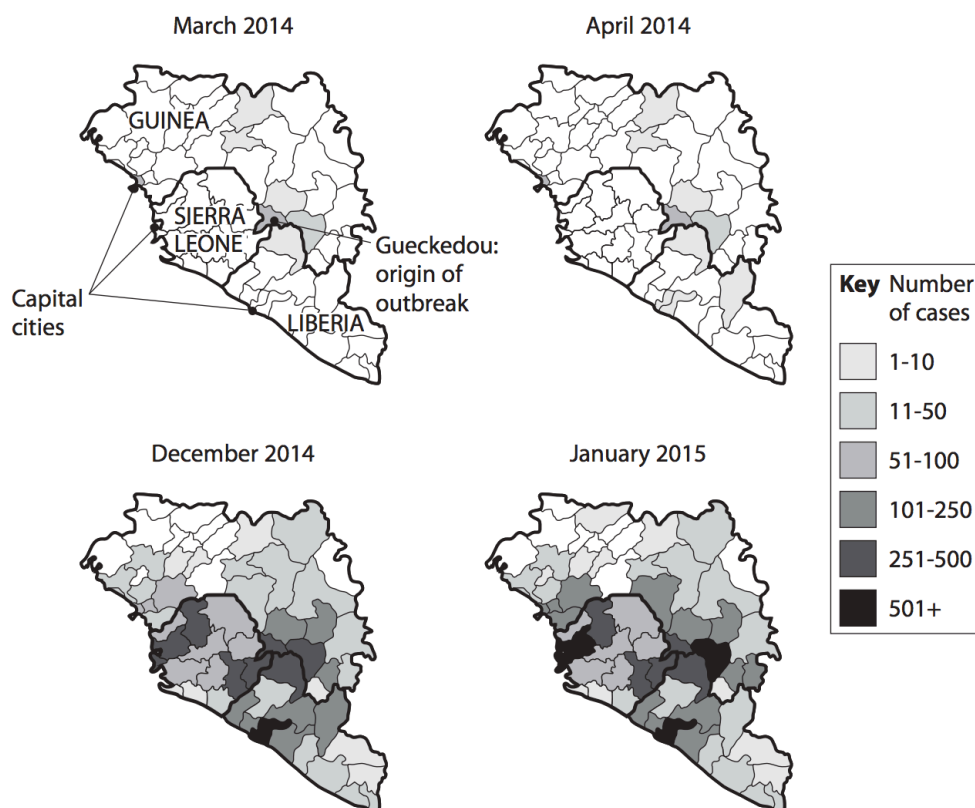
*(i) Analyse the information in the graph and maps to comment on the spread of Ebola in West Africa. (6)