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Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level BIOLOGY

Paper 3

Time allowed: 2 hours

Materials

For this paper you must have:

- a ruler with millimetre measurements
- a scientific calculator.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in **Section A**.
- Answer **one** question from **Section B**.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for the questions are shown in brackets.
- The maximum mark for this paper is 78.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
TOTAL	



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ANSWER IN THE SPACES PROVIDED**

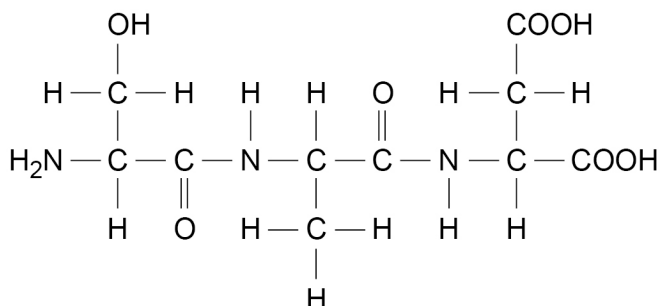


Section AAnswer **all** questions in this section.

You are advised to spend no more than 1 hour and 15 minutes on this section.

0 1Amino acids are used to make proteins. **Table 1** shows the R groups of six different amino acids.**Table 1**

Amino acid	R group	Amino acid	R group
Alanine	CH ₃	Glutamic acid	CH ₂ CH ₂ COOH
Asparagine	CH ₂ CONH ₂	Glycine	H
Aspartic acid	CH ₂ COOH	Serine	CH ₂ OH

0 1 . 1Use **Table 1** to identify the **three** different amino acids used to make the polypeptide shown in **Figure 1**.**[2 marks]****Figure 1**Left amino acid SerineMiddle amino acid AlanineRight amino acid Aspartic acid**Question 1 continues on the next page****Turn over ►**

0 1 2

Table 2 shows three statements and names of four biological molecules.

Put a tick (✓) in each box where the statement is true for the biological molecule.

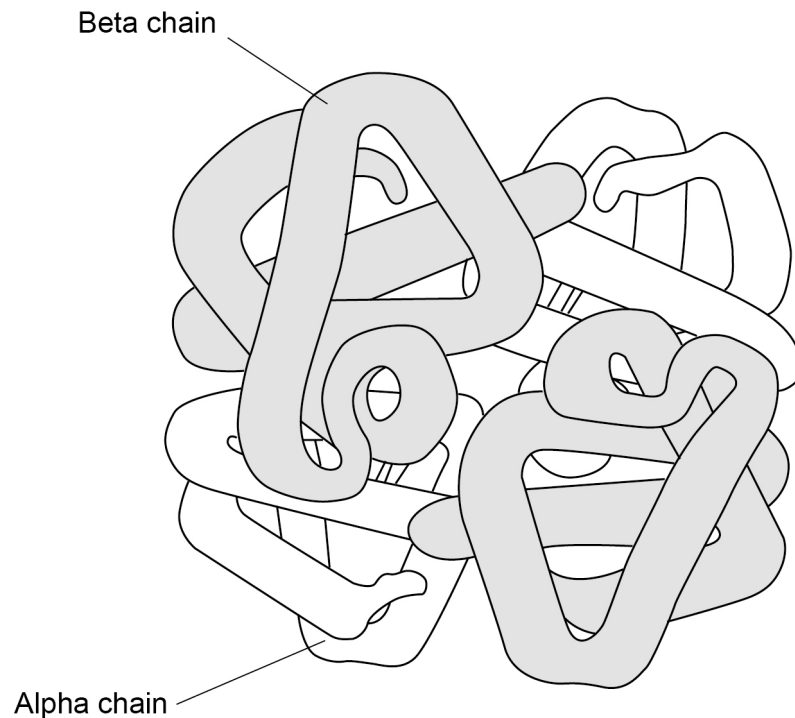
[3 marks]

Table 2

Statement	DNA	ATP	Reverse transcriptase	Phospholipid
Contains peptide bonds			✓	
Is formed using a condensation reaction	✓	✓	✓	✓
Is a polymer	✓		✓	

Figure 2 represents the structure of adult human haemoglobin.

Figure 2



0 1 . 3

The number of amino acids in the beta chains in **Figure 2** is 3.546% greater than in the alpha chains. Each alpha chain contains 141 amino acids.

Calculate how many amino acids there are in total in the haemoglobin molecule shown in **Figure 2**. Give your answer to the nearest whole number.

[2 marks]

$$\text{Beta chain} = 141 \times 1.03546 = 145.99986 = 146 \text{ amino acids}$$

$$\text{Total} = (2 \times 141) + (2 \times 146) = 282 + 292$$

$$= 573.99936 = 574$$

Answer 574 amino acids

When a substance called BPG binds to haemoglobin, it reduces the affinity of haemoglobin for oxygen.

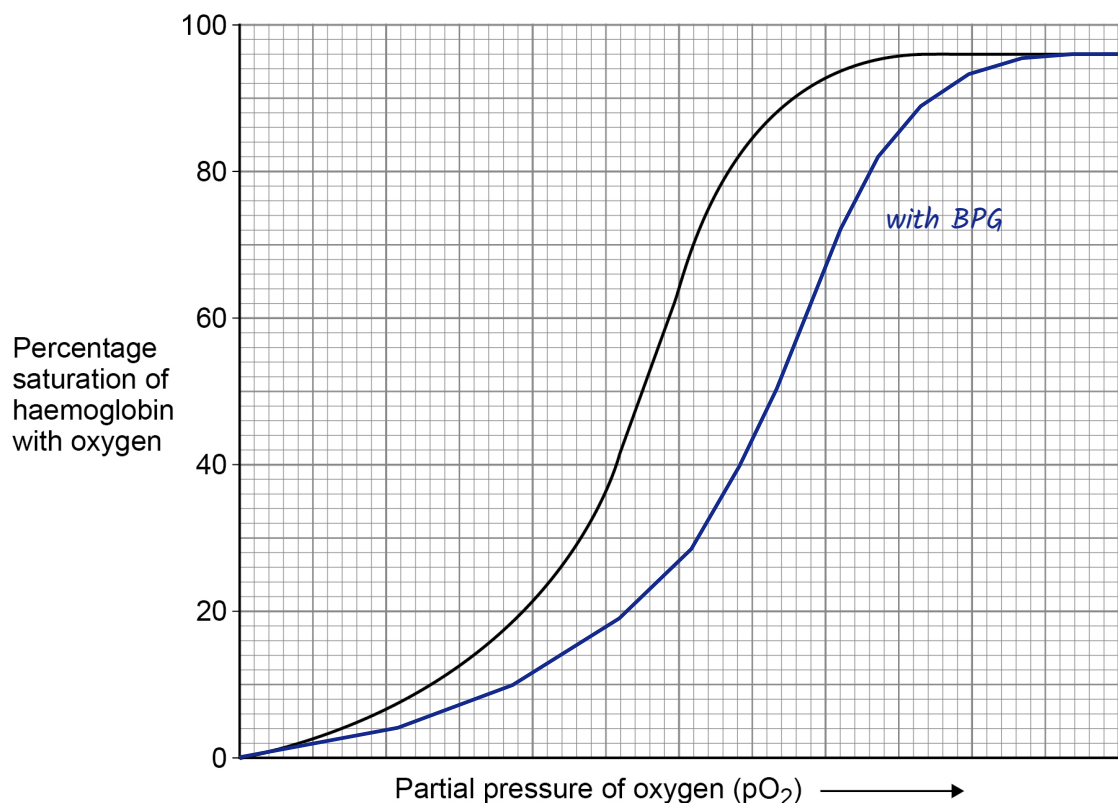
0 1 . 4

Figure 3 shows an oxyhaemoglobin dissociation curve for haemoglobin in normal conditions.

Sketch a curve on **Figure 3** to show the oxyhaemoglobin dissociation curve for haemoglobin when BPG binds to it.

[1 mark]

Figure 3



Question 1 continues on the next page

Turn over ►



0 1 . 5

Suggest and explain when it would be an advantage to a human for BPG to bind to haemoglobin.

[2 marks]

It would be an advantage during exercise (or at high altitude), when the partial pressure of oxygen in the respiring tissues is low.

Because the haemoglobin has a lower affinity for oxygen, oxygen dissociates (unloads) more readily, so more oxygen is delivered to the muscles for aerobic respiration (oxygen is the terminal electron acceptor), delaying anaerobic respiration.

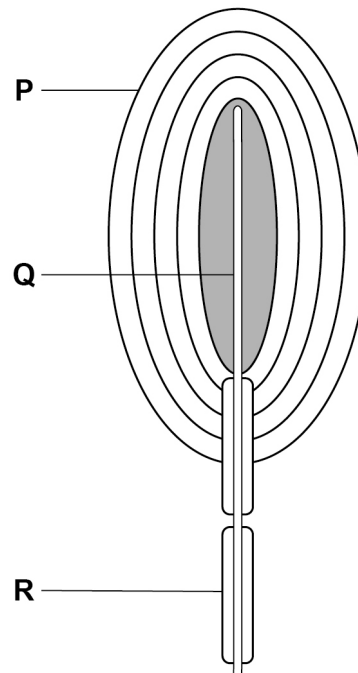
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0 2

Figure 4 shows a diagram of a Pacinian corpuscle.

Figure 4



0 2 . 1

Name the structures labelled **P**, **Q** and **R** shown in **Figure 4**.

[2 marks]

P Capsule / lamellae (layers of connective tissue)

Q Axon (membrane) of the sensory neurone

R Myelin sheath (Schwann cell)

Question 2 continues on the next page

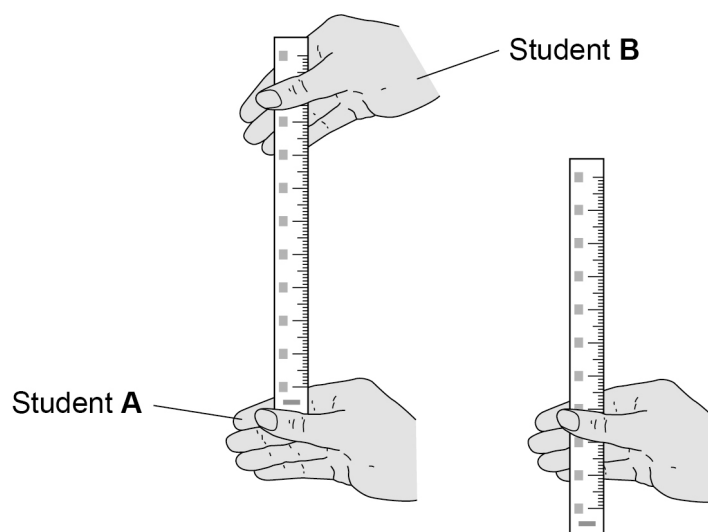
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Two students (**A** and **B**) investigated reaction time in response to touch.

- Student **A** sat with her eyes shut and her forearm resting on a worktop so that her hand was over the edge.
- Student **B** held a ruler vertically between student **A**'s thumb and first finger, with the ruler at 0 mm lightly touching student **A**'s first finger.
- Student **B** released the ruler.
- As soon as student **A** felt the ruler fall, she closed her thumb and first finger to catch the ruler as shown in **Figure 5**.
- Student **B** measured the distance the ruler had fallen to the nearest mm

Figure 5



The test was repeated three more times using the same hand to catch the ruler. **Table 3** shows student **A**'s results.

Table 3

Trial	Distance the ruler has fallen / mm
1	79
2	97
3	10
4	94

The student was able to convert these distances into reaction times using **Table 4**.

Table 4

Distance the ruler fell / mm	Reaction time / ms
10	45
20	64
30	78
40	90
50	101
60	111
70	120
80	128
90	136



0 2 . 2 Calculate the percentage uncertainty in the measurement of **Trial 1** in **Table 3**.

Put a tick (✓) in the correct box below.

[1 mark]

0.633%

☐

1.27%

☒

2.53%

☐

12.6%

☐

0 2 . 3 In this investigation, it is not possible for a student to react in less than 45 ms

Suggest **one** explanation for the value recorded in **Trial 3** in **Table 3**.

[1 mark]

The student anticipated the drop and started to close her thumb and finger before the ruler was actually released, or the ruler did not fall vertically.

0 2 . 4 Student **A** estimated that the length of the nerve pathway involved was 175 cm

Use **Table 3** and **Table 4** to calculate the mean speed of nerve impulse transmission.

Do **not** use the value for **Trial 3** in your calculation.

[2 marks]

$$\text{Mean distance} = (79 + 97 + 94) \div 3 = 90 \text{ mm}$$

$$\text{Reaction time for 90 mm} = 136 \text{ ms} = 0.136 \text{ s}$$

$$\text{Speed} = 1.75 \text{ m} \div 0.136 \text{ s} = 12.87 \text{ m s}^{-1}$$

Answer 12.9 m s⁻¹

Question 2 continues on the next page

Turn over ►



0 2 . 5

In response to touch, nerve impulses can be transmitted at speeds of 76.2 m s^{-1}

Suggest **three** reasons why, in this investigation, the estimated speed of student A's impulse transmission was less than 76.2 m s^{-1}

[3 marks]

- 1 *There are synapses in the pathway and a neuromuscular junction, and synaptic transmission (diffusion of neurotransmitter across the cleft) is slow.*
- 2 *Time is taken for the brain to process the information and coordinate a response, and for the muscles to contract.*
- 3 *Time is taken for the stretch-mediated sodium ion channels in the Pacinian corpuscle to open; also the student may have been tired or not concentrating.*

9



0 3

A student prepared a stained squash of cells from the root tips of garlic to calculate a mitotic index. He:

1. cut the end 5 mm from 10 garlic roots
2. placed the root tips into a Petri dish containing 5 cm³ of hydrochloric acid for 12 minutes
3. rinsed the root tips in distilled water
4. placed one of the root tips on a microscope slide and added toluidine blue stain
5. placed a coverslip onto the microscope slide, and gently pressed the coverslip downwards on the root tip
6. observed the root tip using an optical microscope.

0 3 . 1

Suggest why the student soaked the root tips in hydrochloric acid in step 2.

[2 marks]

To break down (hydrolyse) the links between the cells and their cell

walls, so the cells separate and can be squashed more easily.

This also lets the stain diffuse into the cells, and the acid stops mitosis so the cells are fixed at their stage of division.

0 3 . 2

Pressing the coverslip downwards enabled the student to observe the stages of mitosis clearly.

Explain why.

[2 marks]

Pressing down spreads the cells out into a single, thin layer of cells, so they do not overlap.

This means light can pass through the cells, so the chromosomes in each cell can be seen clearly.

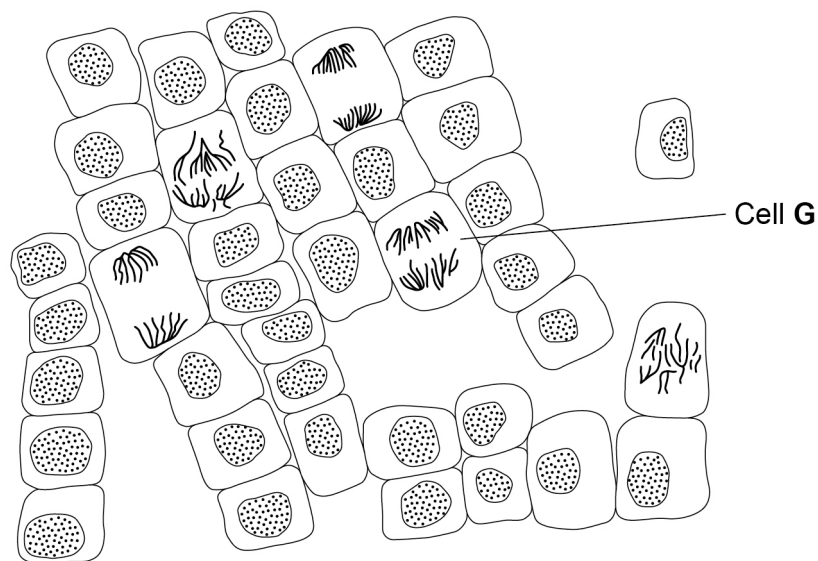
Question 3 continues on the next page

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Figure 6 shows the student's drawing of one field of view.

Figure 6



0 3 . 3

Name the stage of mitosis shown in cell **G**. Explain the appearance of this cell.

[2 marks]

Stage of mitosis Anaphase

Explanation The sister chromatids have separated at the centromere and are being pulled to opposite poles of the cell by the spindle fibres, so they look V-shaped and are at the two ends of the cell.

0 3 . 4

Use **Figure 6** to calculate a mitotic index for the cells in this field of view.

[1 mark]

Cells in mitosis = 5; total cells = 39

Mitotic index = $5 \div 39 = 0.128$

Mitotic index 0.128



0 3 . 5

Other students in the class followed the same method, but calculated different mitotic indices.

Apart from student errors, suggest **two** explanations why.

[2 marks]

- 1 *The roots were of different ages or grown in different conditions (e.g. temperature), or came from different garlic bulbs, so their cells divide at different rates.*
- 2 *A single field of view is not representative of the whole root tip; different fields of view come from different parts of the root tip, which have different rates of mitosis.*

9

Turn over for the next question

Turn over ►



0 4 . 1

Complete the following definitions.

[2 marks]

The genome is the complete set of genes (all the DNA) in a cell or organism.

The proteome is the full range of proteins that a cell or organism is able to produce (that the genome can code for).

Recombinant DNA technology can involve the transfer of fragments of human DNA into bacteria. The bacteria are then used to produce human proteins.

0 4 . 2

Give **two** reasons why bacteria are able to use human DNA to produce human proteins.

[2 marks]

1 The genetic code is universal: the same triplets (codons) code for the same amino acids in humans and bacteria.

2 The mechanisms of transcription and translation are universal; bacteria have ribosomes so they can translate human mRNA.

0 4 . 3

Suggest and explain **one** reason why bacteria might **not** be able to produce every human protein.

[1 mark]

Bacteria do not have a Golgi apparatus (or rough endoplasmic reticulum), so they cannot modify or process some human proteins, for example by adding carbohydrate to make glycoproteins. Also they cannot splice pre-mRNA to remove introns.

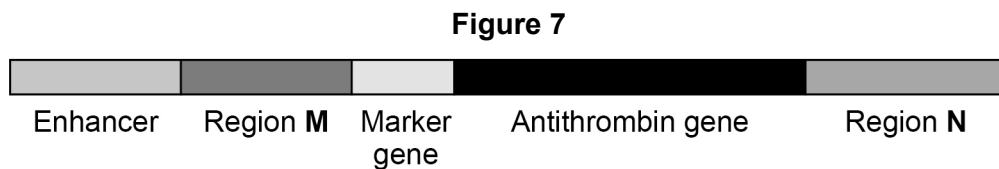


Antithrombin is a protein. Antithrombin prevents blood from clotting too much.

Some people have a deficiency of antithrombin in their blood, so they need to inject the protein.

Genetically modified goats are used to produce this protein. The human antithrombin gene is transferred into goat embryos. The adult goats then make human antithrombin protein.

Figure 7 shows an example of a DNA fragment that can be transferred into the cells of goats.



0 4 . 4 The enhancer stimulates region **M**.

Name regions **M** and **N** shown in **Figure 7**.

[2 marks]

Region **M** Promoter

Region **N** Terminator

0 4 . 5 Explain the purpose of the marker gene.

[1 mark]

It shows which goat cells / embryos have taken up the antithrombin gene, so genetically modified (transgenic) goats can be identified.

0 4 . 6 The enhancer only stimulates region **M** in the milk-producing glands of a goat.

Suggest **two** explanations for the importance of the enhancer being included in the DNA fragment transferred.

[2 marks]

1 The antithrombin is secreted in the milk, which is easy to collect and extract the protein from without harming the goat.

2 If antithrombin was produced in other tissues, e.g. released into the goat's blood, it could prevent the goat's blood clotting properly, or damage other cells.

10

Turn over ►



0 5

Scientists investigated the effect of full sun and shade on the rate of photosynthesis in a species of shade-tolerant tree.

To estimate the rate of photosynthesis, the scientists measured uptake of carbon dioxide by trees in a forest. They measured uptake of carbon dioxide during two parts of the day:

- 08.30 – 09.40 hours
- 11.40 – 13.15 hours.

Figure 8 shows the scientists' results.

Figure 8

Figure 8 not reproduced here due to third-party copyright restrictions

0 5 . 1

Calculate the total uptake of carbon dioxide between 11.40 and 13.15 hours in trees exposed to full sun in a forest that is 12 000 m² in area.

Give your answer in standard form. Show your working.

[3 marks]

$$\text{Time from 11.40 to 13.15} = 95 \text{ min} = 95 \times 60 = 5700 \text{ s}$$

$$\text{Uptake per m}^2 = 8.8 \times 5700 = 50\,160 \text{ } \mu\text{mol}$$

$$\text{Total} = 50\,160 \times 12\,000 = 601\,920\,000 \text{ } \mu\text{mol}$$

Answer 6.02 × 10⁸ μmol



0 5 . 2

Figure 8 shows there is a small difference in the mean uptake of carbon dioxide between 08.30 and 09.40 hours by trees in full sun and by trees in the shade. When the scientists performed a statistical test on these data, they calculated $P > 0.5$

State what this P value tells you about this difference.

Explain your answer using the words **probability** and **chance**.

[2 marks]

The difference is not significant.

The probability that this difference is due to chance is greater than 0.5 (more than 50%), which is much more than 0.05, so we accept the null hypothesis that there is no real difference.

0 5 . 3

In this species of tree, very high light intensities can inhibit the release of electrons from chlorophyll.

Suggest how this could explain the results shown in **Figure 8** for 11.40 to 13.15 hours.

[4 marks]

In full sun at midday the very high light intensity inhibits the release of electrons from chlorophyll (photoionisation), so less electron transfer occurs in the light-dependent reaction.

So less ATP and less reduced NADP are produced.

So less glycerate 3-phosphate (GP) is reduced to triose phosphate in the light-independent reaction (Calvin cycle).

So less triose phosphate is available to regenerate RuBP, and with less RuBP, less carbon dioxide combines with RuBP (via rubisco).

This explains why trees in full sun took up less carbon dioxide than trees in the shade between 11.40 and 13.15.

Question 5 continues on the next page

Turn over ►



Tomato plants grow best in high light intensities. To increase the yield of tomato plants, a farmer uses LED lightbulbs to provide additional light.

The increase in dry mass (D) produced when using additional light can be calculated using this equation.

$$D = \frac{L}{0.4F}$$

Where

L = light used in photosynthesis

F = GPP to NPP conversion factor for tomato plants

Table 5 shows some of these values for LED lightbulbs.

Table 5

L / MJ m ⁻² h ⁻¹	F / MJ kg ⁻¹
2.87 × 10 ⁻²	20

0 5 4

Use the equation and **Table 5** to calculate the increase in dry mass produced when using LED lightbulbs.

Give your answer in standard form **and** give the units.

[2 marks]

$$D = 2.87 \times 10^{-2} \div (0.4 \times 20)$$

$$= 2.87 \times 10^{-2} \div 8 = 0.0035875$$

Answer 3.59 × 10⁻³ Units kg m⁻² h⁻¹



0	5	.	5
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Mature leaves from slow-growing, shade-tolerant plants produce poisonous chemicals that are a defence against being eaten by herbivores.

Suggest how this benefits slow-growing, shade-tolerant plants.

[2 marks]

Shade-tolerant plants receive little light, so they have a slow rate of photosynthesis (light-dependent reaction) and produce sugars slowly.

Because they are slow growing, it would take a long time to replace mature leaves (e.g. to make new cellulose), so the poison means the leaves are not eaten and the leaves reach maturity.

So the plants keep a large enough leaf surface area to absorb enough light for photosynthesis.

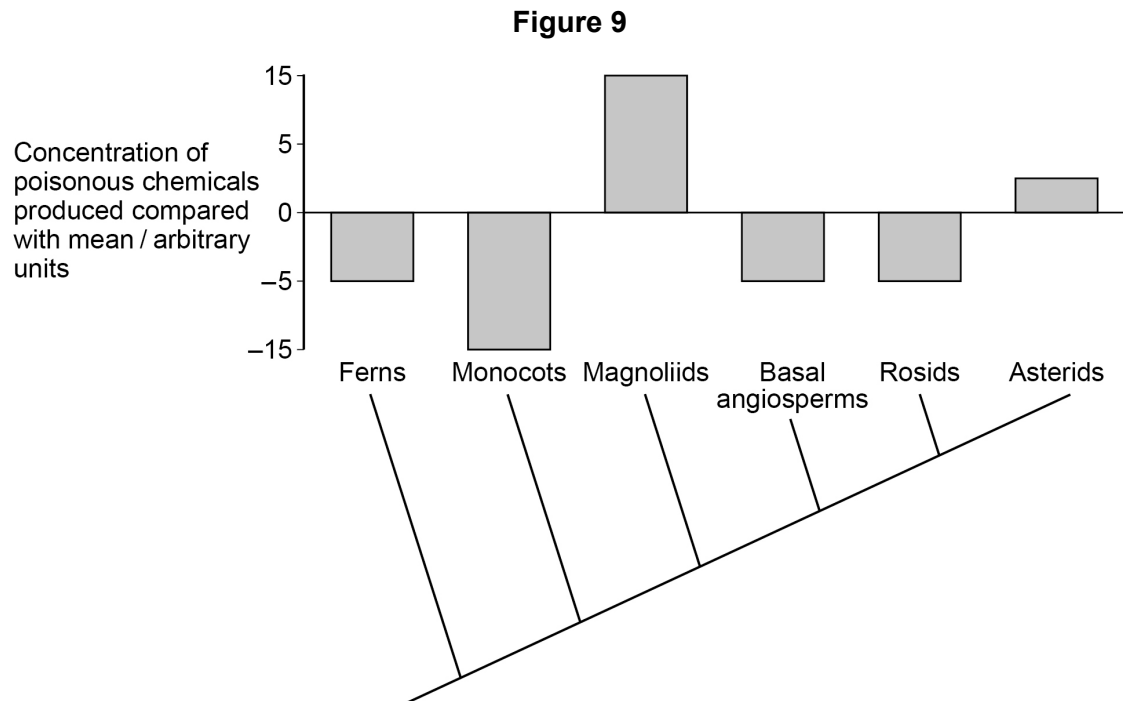
Question 5 continues on the next page

Turn over ►



Scientists measured the concentration of poisonous chemicals produced by shade-tolerant plant species in six taxa. They compared this with the mean concentration of poisonous chemicals produced by all plants and the phylogenetic relationships between the six taxa.

Figure 9 shows the scientists' results.



0 5 . 6

A journalist published the following summary of these results.

'The more recently a shade-tolerant plant species evolved, the greater the concentration of poisonous chemicals it produces.'

Do the data in **Figure 9** support this summary? Justify your answer.

[2 marks]

No, the data do not fully support the summary.

The highest concentration (about +15) is in the magnoliids, not in the most recently evolved asterids, so magnoliids produce more than the more recently evolved basal angiosperms, rosids and asterids.

The lowest concentration (about -15) is in the monocots, which evolved more recently than the ferns. Also ferns, basal angiosperms and rosids all have the same concentration (about -5), even though they evolved at different times.

15



Section BAnswer **one** question.

You are advised to spend no more than 45 minutes on this section.

0 6Write an essay on **one** of the topics below.**Either****0 6 . 1**

The uses and importance of ATP in organisms.

[25 marks]**Or****0 6 . 2**

The importance of cycles in biology.

[25 marks]*06.2 The importance of cycles in biology*

A cycle is a series of events or reactions that repeats, so that the end point regenerates the starting point. Cycles are important in biology because they allow limited resources, molecules and structures to be used again and again, and they allow processes to be repeated and regulated. They occur at every level of organisation, from molecules inside a single cell, to organs, to whole ecosystems.

At the molecular level, one of the most important cycles is the ATP cycle. ATP is hydrolysed by ATP hydrolase into ADP and inorganic phosphate, releasing a small, manageable amount of energy. This energy is used in active transport, muscle contraction, the synthesis of polymers such as proteins and DNA, and to phosphorylate other molecules, making them more reactive. ATP is then resynthesised from ADP and P_i by ATP synthase in a condensation reaction, using energy from respiration or from light in photosynthesis. Because ATP cannot be stored in large amounts, this continuous cycle is essential: a human recycles roughly

Turn over ►

their own body mass of ATP every day, and without it cells would quickly run out of their immediate energy source.

Enzymes also work in a cycle. A substrate with a complementary shape binds to the active site to form an enzyme-substrate complex, the reaction takes place, and the products are released. The enzyme is unchanged, so it is free to bind another substrate molecule. This means that a very small amount of enzyme can catalyse a huge number of reactions, which is important because making proteins uses a lot of energy and amino acids.

The Calvin cycle and the Krebs cycle are central to energy transfer in organisms. In the light-independent reaction of photosynthesis, carbon dioxide combines with ribulose biphosphate (RuBP), catalysed by rubisco, to form two molecules of glycerate 3-phosphate. GP is reduced to triose phosphate using ATP and reduced NADP from the light-dependent reaction. Some triose phosphate is used to make glucose, amino acids and lipids, but five out of every six molecules are used to regenerate RuBP, using ATP. Because RuBP is regenerated, carbon dioxide can be fixed continuously. In aerobic respiration, the Krebs cycle takes place in the matrix of the mitochondria. Acetyl coenzyme A combines with a four-carbon compound (oxaloacetate) to form a six-carbon compound, which is then decarboxylated and dehydrogenated back to the four-carbon compound, producing reduced NAD, reduced FAD, ATP by substrate-level phosphorylation and carbon dioxide. Because oxaloacetate is regenerated, a small amount of it can process a large number of acetyl groups. The reduced coenzymes are then oxidised in the electron transport chain, where the energy released is used to pump protons into the intermembrane space; the protons flow back through ATP synthase



by chemiosmosis, producing most of the cell's ATP. NAD and FAD are themselves recycled, which is why anaerobic respiration must regenerate NAD by reducing pyruvate to lactate or ethanol, so that glycolysis can continue.

The cell cycle is important for growth, repair and asexual reproduction. During interphase the cell grows, organelles are replicated and DNA is copied by semi-conservative replication, using DNA helicase and DNA polymerase. During mitosis the sister chromatids are separated during anaphase, so that two genetically identical daughter cells are produced, followed by cytokinesis. The cycle is controlled at checkpoints, which is important because if control is lost, for example by mutations in tumour suppressor genes or proto-oncogenes, cells divide uncontrollably and form a tumour. Many anti-cancer drugs work by disrupting the cell cycle, for example by preventing spindle formation. Sexual life cycles involve meiosis, which halves the chromosome number so that fertilisation restores the diploid number, and produces genetic variation by crossing over and independent segregation, which is the raw material for natural selection.

Cycles are also vital at the organ level. In the cardiac cycle, the sinoatrial node sends a wave of electrical excitation across the atria, causing atrial systole, which forces blood into the ventricles. The atrioventricular node delays the impulse, then it passes down the bundle of His and Purkyne tissue so that the ventricles contract from the base upwards, forcing blood into the arteries. Pressure changes open and close the atrioventricular and semilunar valves, preventing backflow. The repeated cycle maintains a continuous blood flow, delivering oxygen and glucose to respiring tissues and removing carbon dioxide. The rate of the

Turn over ►



cycle is altered by the medulla in response to chemoreceptors and pressure receptors, so that the heart rate increases during exercise.

Similarly, the ventilation cycle of inspiration and expiration, produced by the contraction and relaxation of the diaphragm and intercostal muscles, maintains a steep concentration gradient of oxygen and carbon dioxide across the alveolar epithelium.

Within the nervous and muscular systems, there are also cycles. At a cholinergic synapse, acetylcholine is hydrolysed by acetylcholinesterase into choline and ethanoic acid, which diffuse back into the presynaptic neurone and are recombined using ATP. This recycling prevents continuous stimulation of the postsynaptic neurone and saves energy. In muscle contraction, the cross-bridge cycle occurs: myosin heads bind to actin, the head moves (the power stroke), pulling the actin filament, then ATP binds, causing the myosin head to detach. Hydrolysis of ATP returns the head to its original position, ready to bind again. Repeating this cycle makes the sarcomere shorten.

Negative feedback loops can also be thought of as cycles that maintain homeostasis. In the control of blood glucose, a rise in glucose concentration is detected by beta cells, which secrete insulin, causing glucose to be taken up by cells and converted to glycogen; the concentration falls, so less insulin is secreted. If the concentration falls too low, alpha cells secrete glucagon, causing glycogenolysis and gluconeogenesis. The same principle controls blood water potential through osmoreceptors in the hypothalamus and ADH. These cycles are important because they keep conditions within narrow limits, so that enzymes work efficiently and cells do not lose or gain too much water by osmosis.

In ecosystems, nutrient cycles allow elements to be reused. In the



nitrogen cycle, saprobionts break down proteins and DNA in dead organisms by extracellular digestion, releasing ammonium ions (ammonification). Nitrifying bacteria oxidise ammonium ions to nitrites and then to nitrates, which plants absorb by active transport to make amino acids, proteins and nucleotides. Nitrogen-fixing bacteria such as *Rhizobium* in root nodules convert nitrogen gas into ammonia, and denitrifying bacteria convert nitrates back to nitrogen gas in anaerobic conditions. In the phosphorus cycle, phosphate ions are released from rocks by weathering and from dead organisms, and are taken up by plants, helped by mycorrhizae, to make ATP, phospholipids and nucleic acids. These cycles are essential because the amount of nitrogen and phosphorus available to organisms is limited; without recycling, plant growth, and therefore all food chains, would stop. Farmers add fertilisers to replace the minerals removed when crops are harvested, but leaching can lead to eutrophication. Predator and prey populations also fluctuate in cycles, which helps to keep population sizes within the carrying capacity of the ecosystem.

Humans also make use of cycles in biotechnology. The polymerase chain reaction is a repeated cycle of heating to 95 °C to separate the DNA strands, cooling to about 55 °C so primers can anneal, and heating to 72 °C so Taq polymerase can add nucleotides. Each cycle doubles the amount of DNA, so after 30 cycles over a billion copies can be made from a tiny sample, which is important in genetic fingerprinting and diagnosing disease.

Beyond the specification, circadian rhythms are an important cycle. In mammals, the suprachiasmatic nucleus in the hypothalamus acts as a master clock. It works through a transcription-translation feedback loop:

Turn over ►



transcription factors called *CLOCK* and *BMAL1* switch on the *PER* and *CRY* genes, and the *PER* and *CRY* proteins build up and then inhibit *CLOCK* and *BMAL1*, so their own transcription falls, giving a cycle of about 24 hours. Light detected by the retina resets the clock each day. This cycle controls the release of melatonin from the pineal gland and cortisol, and so regulates sleep, body temperature and metabolism, which is why shift workers and people with jet lag can suffer health problems when their rhythms are disrupted.

In conclusion, cycles are important because they allow molecules such as ATP, coenzymes, enzymes, RuBP and oxaloacetate, and elements such as nitrogen and phosphorus, to be reused, which conserves resources and energy. They allow processes such as the heartbeat, breathing, cell division and muscle contraction to be repeated continuously, and they allow conditions in the body to be regulated by negative feedback. Without cycles, life as we know it could not be sustained.



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25

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