

Please check the examination details below before entering your candidate information

Candidate surname <i>StemUp Model Solution</i>		Other names
Centre Number	Candidate Number	

Pearson Edexcel Level 3 GCE

Friday 13 June 2025

Morning (Time: 2 hours)

Paper reference **9BN0/02**

Biology A (Salters Nuffield)

Advanced

PAPER 2: Energy, Exercise and Coordination

You must have:
Scientific calculator, pencil, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Show your working in any calculation questions and include units in your answer where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 100.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- In question(s) marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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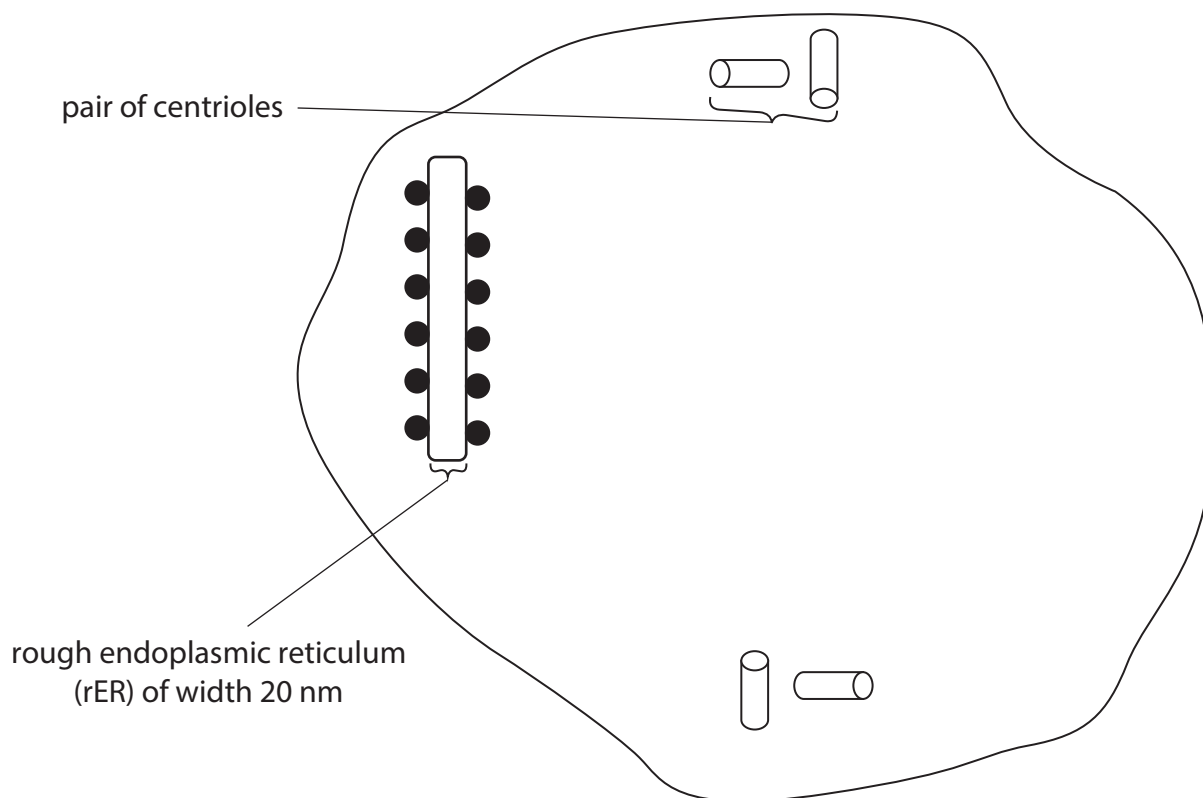
Answer ALL questions. Write your answers in the spaces provided.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

- 1 The pancreas is an organ found in the human body.

The pancreas is made up of a number of different cell types including beta cells and acinar cells.

- (a) The diagram shows a beta cell from a human pancreas.



- (i) Calculate the magnification of this diagram.

(2)

$$\text{Width of rER on diagram} = 5 \text{ mm}$$

$$5 \text{ mm} = 5 \times 10^6 \text{ nm} = 5\,000\,000 \text{ nm}$$

$$\text{magnification} = \text{image size} \div \text{actual size}$$

$$= 5\,000\,000 \div 20 = 250\,000$$

Answer $\times 250\,000$



- (ii) A student viewed the diagram and stated that the cell was undergoing mitosis.

Give **two** reasons why this statement is correct.

(2)

1 *There are two pairs of centrioles, one pair at each pole of the cell.*

2 *No nucleus / nuclear envelope is present, so the nuclear envelope has broken down.*

- (b) Acinar cells produce the digestive enzyme elastase. Elastase is secreted from the acinar cells as a glycoprotein.

The polypeptide chain for elastase is formed on the ribosomes of the rER.

Describe how this polypeptide is processed to form a glycoprotein and then released from the cell.

(4)

The polypeptide is folded into its tertiary structure (3D shape) in the lumen of the rER.

It is then transported from the rER to the Golgi apparatus in vesicles, which fuse with the Golgi apparatus.

In the Golgi apparatus carbohydrate is added to the polypeptide, forming the glycoprotein.

The Golgi apparatus packages the glycoprotein into secretory vesicles, which move to the cell surface membrane and fuse with it, releasing the elastase by exocytosis.

(Total for Question 1 = 8 marks)



2 A spirometer can produce a trace used to study breathing.

- (a) When using a spirometer, the same air is repeatedly inhaled and exhaled. Before the air is inhaled from the spirometer, it passes through soda lime to remove carbon dioxide.

Explain the effect on breathing if the inhaled air is **not** passed through soda lime.

(3)

Carbon dioxide would not be removed, so the concentration of carbon dioxide in the

spirometer air would increase and the person would inhale more carbon dioxide.

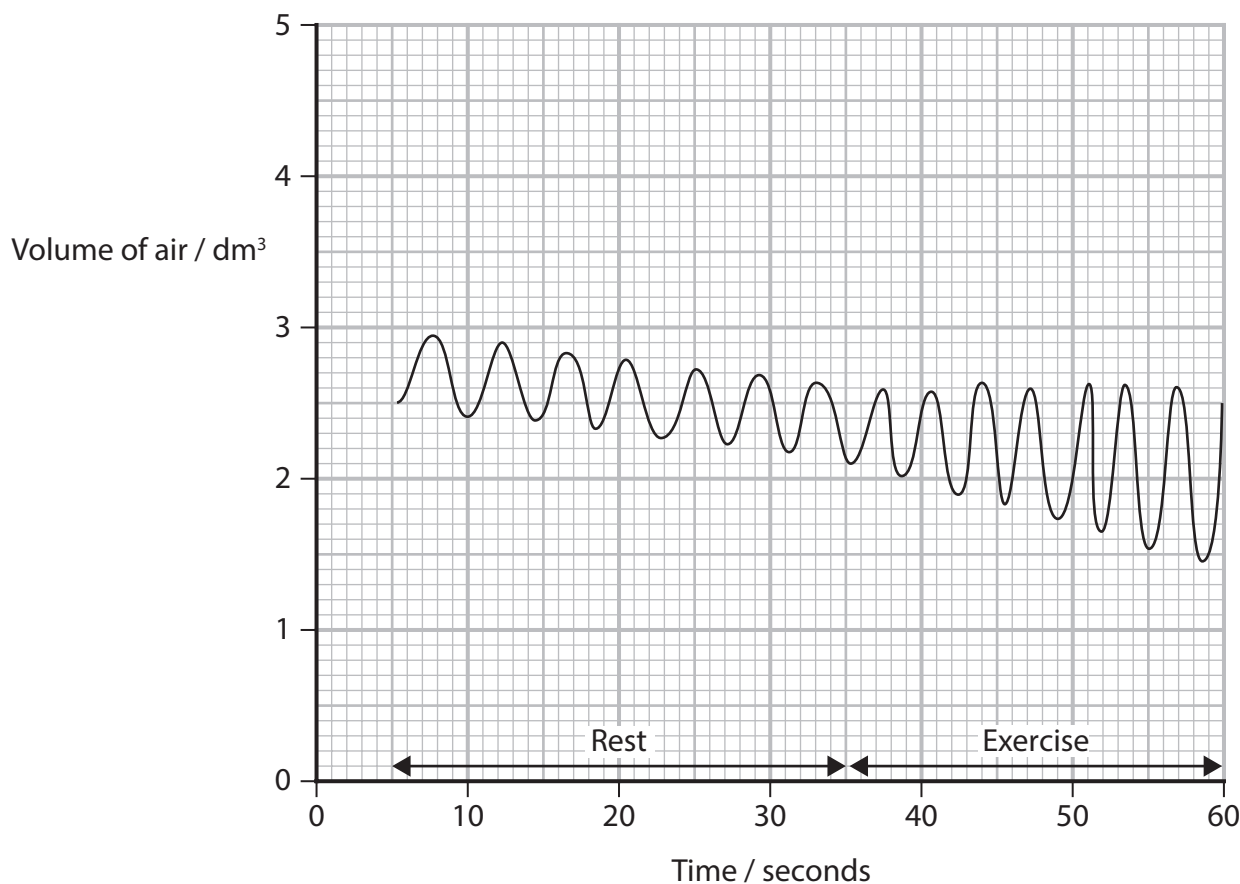
This increases the carbon dioxide concentration in the blood and so lowers the blood pH, which is detected by chemoreceptors.

As a result the breathing rate increases and the depth of breathing (tidal volume) increases.



- (b) A person at rest used a spirometer for 30 seconds. The person then exercised whilst using the same spirometer.

The results are shown in the trace.



- (i) Which is the breathing rate at rest for this person?

(1)

- ☐ A 6 breaths per minute
- ☐ B 7 breaths per minute
- ☒ C 14 breaths per minute
- ☐ D 16 breaths per minute

- (ii) The resting respiratory minute ventilation can be calculated using this trace, and the equation:

Resting respiratory minute volume = resting breathing rate
(in breaths per minute) $\times$ Q

Which is the value of Q?

(1)

- ☒ A 0.5
- ☐ B 1.1
- ☐ C 14
- ☐ D 60



P 7 8 6 5 8 A 0 5 3 2

- (iii) Devise an investigation, using a spirometer, to find the change in the rate of oxygen uptake of a person during exercise compared with at rest.

(3)

Use a spirometer containing soda lime. Record a trace with the person at rest for a set time, e.g. 1 minute, then record a trace while the person exercises for the same time. Repeat the rest and the exercise readings several times so that a mean can be calculated.

From each trace calculate the decrease in volume of air in the spirometer over the time period (line drawn through the troughs), which is the volume of oxygen used.

Divide this by the time to work out the rate of oxygen uptake ($\text{dm}^3 \text{ min}^{-1}$) at rest and during exercise, then calculate the change in the rate of oxygen uptake.

(Total for Question 2 = 8 marks)



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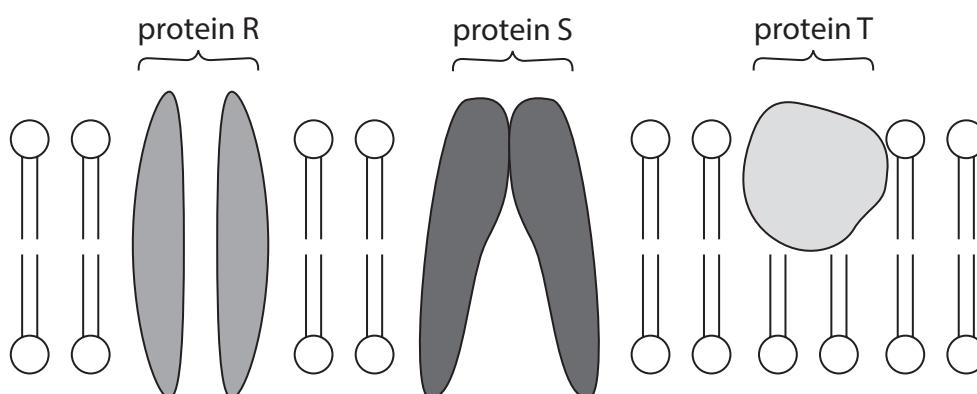
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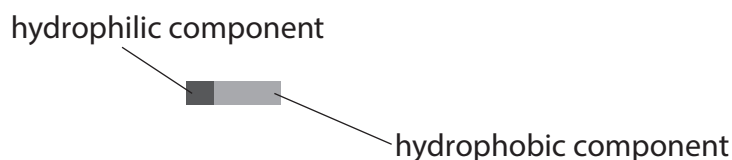
3 All cells have a cell surface membrane that allows some ions to move across.

The diagram shows the fluid mosaic model for the cell surface membrane.



(a) The cell surface membrane also contains cholesterol.

This diagram represents cholesterol.



Describe how the cholesterol is positioned within the phospholipid bilayer.

(2)

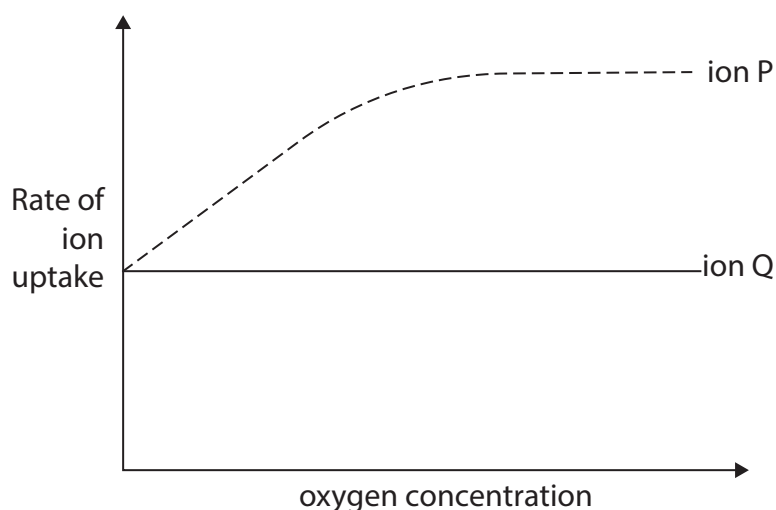
The cholesterol sits between the phospholipid molecules. Its hydrophilic component is next to the phosphate heads, facing the outside of the bilayer.

Its hydrophobic component lies among the fatty acid tails (hydrocarbon chains) in the inside of the bilayer.

- (b) An animal cell, containing proteins R, S and T in its cell surface membrane, was placed in a solution containing two ions, P and Q.

The rate of uptake of both ions was measured as the cell was supplied with an increasing concentration of oxygen.

The results are shown in the graph.



Only one of the proteins labelled R, S and T on the diagram on page 8 allows the uptake of ion P.

This protein changes shape to move ion P.

Explain which protein allows the uptake of ion P.

(4)

Protein S. The rate of uptake of ion P increases as oxygen concentration increases, but uptake of ion Q does not.

As oxygen concentration increases more aerobic respiration occurs, so more ATP is formed.

Protein S is a carrier protein (pump) that uses ATP to change shape, so ion P is moved by active transport. Therefore active transport increases and more of ion P is taken up.

Protein R is a channel protein (no ATP needed) and protein T does not span the membrane.

(Total for Question 3 = 6 marks)

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4 The human eye can detect both images and a change in light intensity.

- (a) Describe the pathway taken by nerve impulses from sensory cells in the eye to the part of the brain that forms the images.

(3)

Light is detected by the rods and cones in the retina.

These synapse with bipolar cells, which pass the nerve impulses to ganglion cells.

The axons of the ganglion cells form the optic nerve, which carries the nerve impulses

from the eye to the visual cortex in the occipital lobe of the brain.

- (b) The fovea is part of the retina.

In one study, the mean density of photosensitive cells in the fovea was found to be $164\,000 \pm 24\,000$ per mm^2 .

The mean radius of the fovea is 0.8 mm.

Calculate the maximum number of photosensitive cells present in the fovea.

Give your answer to 3 significant figures.

(3)

$$\text{maximum density} = 164\,000 + 24\,000 = 188\,000 \text{ per mm}^2$$

$$\text{area of fovea} = \pi \times 0.8^2 = 2.01 \text{ mm}^2$$

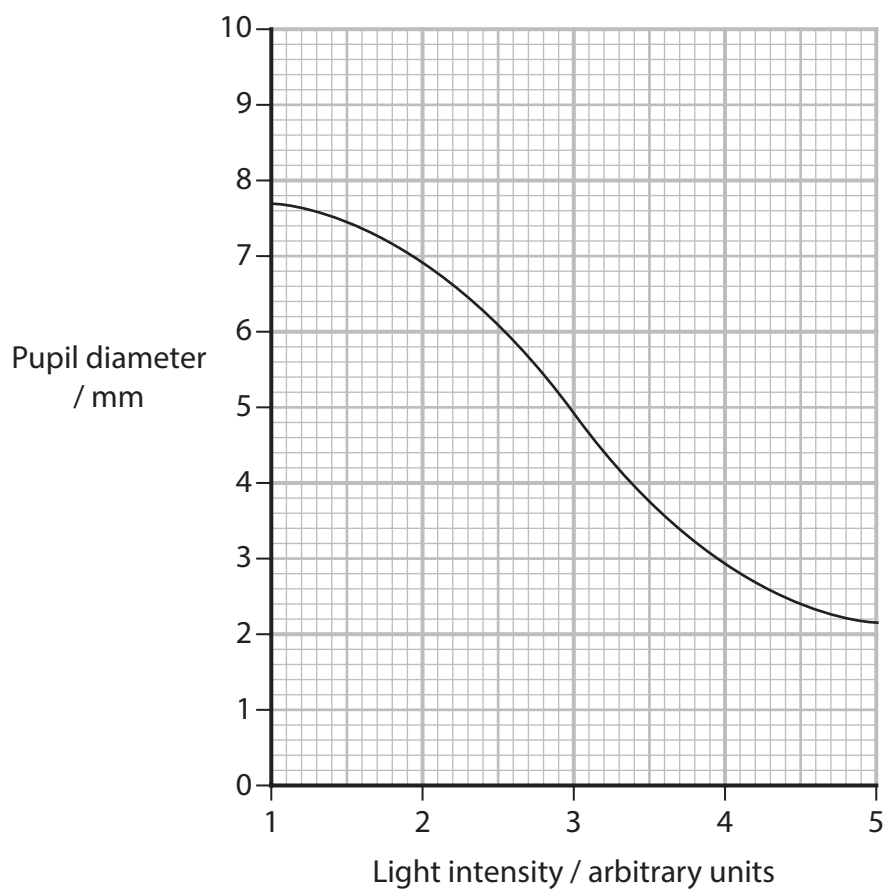
$$\text{number} = 188\,000 \times 2.0106 = 377\,996$$

$$= 378\,000 \text{ (3 s.f.)}$$

Answer 378 000



(c) The graph shows the relationship between light intensity and pupil diameter.



Explain the relationship shown in the graph.

(4)

As light intensity increases, pupil diameter decreases (negative correlation), so the pupil constricts.

This is a reflex. In bright light the circular muscles of the iris contract and the radial muscles relax, which makes the pupil smaller.

This reduces the amount of light entering the eye, reducing the chance of damage to the retina (rods and cones).

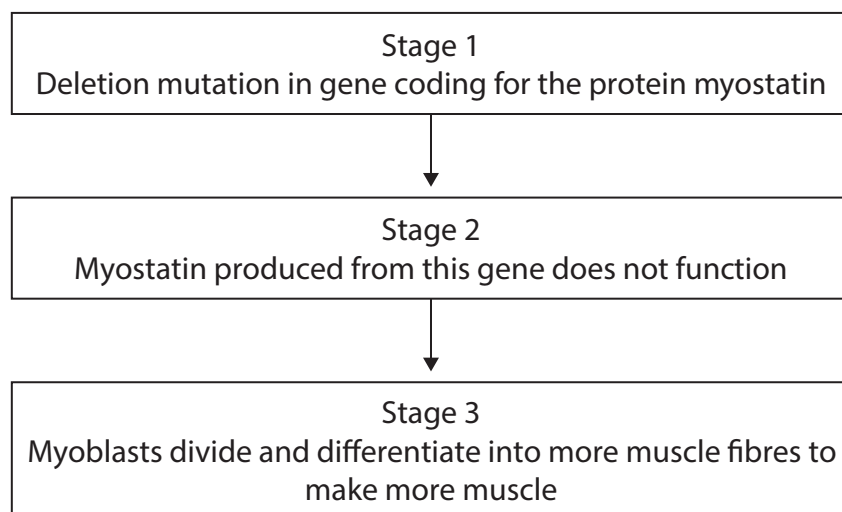
In dim light the radial muscles contract and the circular muscles relax, so the pupil dilates to let more light in.

(Total for Question 4 = 10 marks)



- 5 The Belgian Blue is a breed of cattle that contains a lot of muscle due to a mutation. The mutation affects cells called myoblasts.

The flow diagram shows some stages that lead to the production of excess muscle.



- (a) The base sequence shows 21 bases in one DNA strand of part of the myostatin gene.

T	G	T	G	A	T	G	A	A	C	A	C	T	C	C	A	C	A	G	A	A
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

- (i) Which is the **maximum** number of **different** codons that there would be on the mRNA transcribed from this part of the gene?

(1)

- ☒ **A** 6
- ☐ **B** 7
- ☐ **C** 10
- ☐ **D** 21



(ii) The bases shaded are deleted from one strand in the mutated gene (Stage 1).

T	G	T	G	A	T	G	A	A	C	A	C	T	C	C	A	C	A	G	A	A
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

The two strands of DNA are held together by hydrogen bonds.

There are two hydrogen bonds between adenine (A) and its complementary base and three between the other pair of bases.

Calculate the percentage reduction in the number of hydrogen bonds in this part of the myostatin gene due to the mutation.

Give your answer to one decimal place.

(3)

$$\text{total H bonds} = (12 \times 2) + (9 \times 3) = 24 + 27 = 51$$

$$\text{deleted H bonds} = (6 \times 2) + (5 \times 3) = 12 + 15 = 27$$

$$\% \text{ reduction} = 27 \div 51 \times 100 = 52.94$$

52.9 %

(b) Explain why myostatin produced from the mutated gene does not function (Stage 2).

(3)

Deleting 11 bases causes a frameshift, so the codons after the mutation are changed.

This changes the primary structure (amino acid sequence) of myostatin, with different amino acids and possibly a shorter chain if a stop codon forms.

So the R-groups are different and the bonding between them (hydrogen, ionic and disulfide bonds) changes.

So the tertiary structure / 3D shape (folding) of myostatin changes and it cannot function.

(c) Mitosis is involved in Stage 3.

Mitosis also has a number of other functions.

Which row is correct?

(1)

		Function	
		asexual reproduction	repair of cells
☐	A	✓	✓
☒	B	✓	✗
☐	C	✗	✓
☐	D	✗	✗

Key

✗ = is not a function of mitosis

✓ = is a function of mitosis

(d) Each muscle fibre (Stage 3) is a cell.

Which statement identifies a muscle fibre as a cell?

(1)

- ☒ A it contains cytoplasm in which organelles may be present
- ☐ B it has a cell wall containing actin
- ☐ C it has a nucleus that disappears in interphase
- ☐ D it has genetic material

(Total for Question 5 = 9 marks)



6 Antagonistic muscles interact to control the movement of the legs.

Sprinters need to respond rapidly to the starting signal in a race.

In an investigation, the response time for a group of athletes was studied.

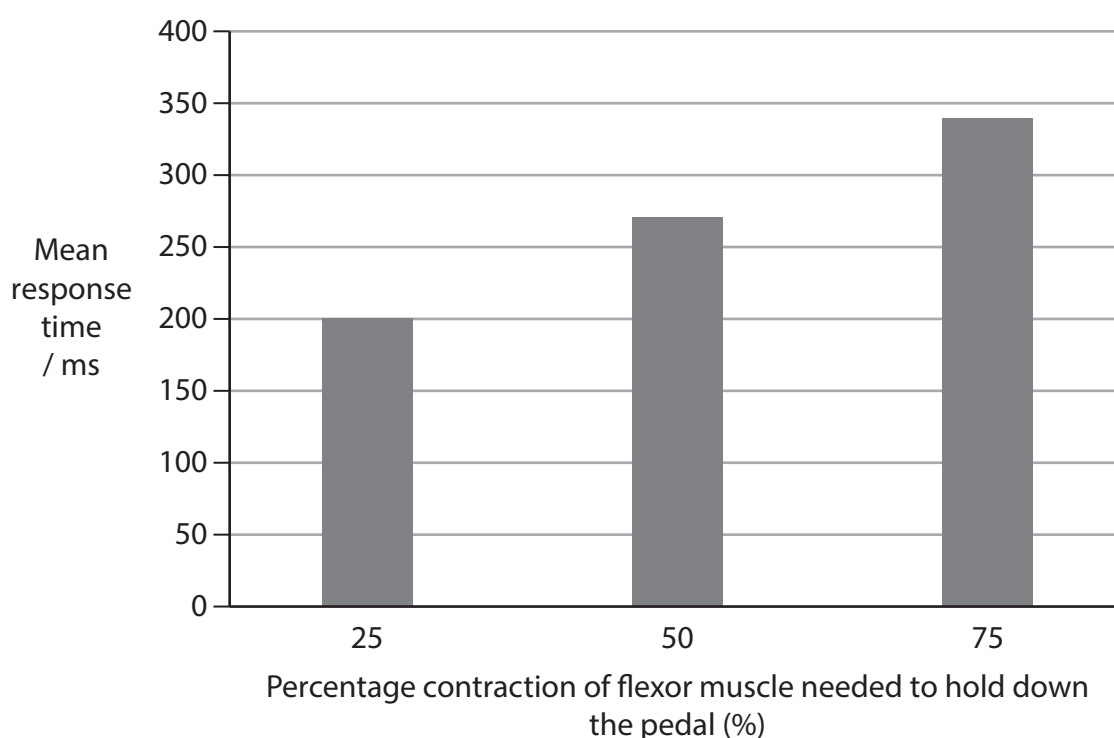
Each athlete contracted a flexor muscle in the leg to hold a pedal down.

When a light was switched off, the athlete released the pedal.

The response time for the flexor muscle to fully relax was recorded.

The investigation was repeated except the percentage muscle contraction needed to hold the pedal down was changed.

The results are shown in the graph.



(a) State the type of muscle that works antagonistically with a flexor muscle.

(1)

Extensor (muscle)

- (b) The difference in the mean response time for the 25% contraction and the 50% contraction was significant at the 0.05 level.

Explain what is meant by this difference being significant at the 0.05 level.

(2)

The p value is less than 0.05 (the calculated value is greater than the critical value), so the null hypothesis of no difference can be rejected.

There is less than a 5% probability that the difference is due to chance, so it is probably not due to chance.

- (c) Which is the relationship between the percentage muscle contraction needed to hold down the pedal and the response time?

(1)

- ☐ A exponential
☒ B linear
☐ C logarithmic
☐ D proportional

- *(d) When the investigation was carried out, it took time between the athlete seeing the light switch off and the flexor muscle being fully relaxed.

Explain why there was a delay between the light being switched off and full relaxation of the flexor muscle in this investigation.

Use the results of the investigation and your own knowledge to answer this question.

(6)

The results show that the greater the percentage contraction of the flexor muscle, the longer it took to relax: the delay rose from about 200 ms at 25% to about 270 ms at 50% and 340 ms at 75%. The delay is the time taken by the eye, the nerve pathway and the muscle.

Eye: the change in light is detected by the rods (and cones) in the retina. Light breaks rhodopsin down into opsin and retinal (cis to trans retinal), and when the light



goes off this changes, altering the membrane potential of the rod cells (hyperpolarised in light) and so whether neurotransmitter is released onto the bipolar neurones. The bipolar neurone then depolarises, and then the ganglion cell depolarises and an action potential is produced.

Nerve pathway: impulses travel along the ganglion cell axons in the optic nerve to the brain, and are processed in the visual cortex in the occipital lobe. The motor cortex then changes the impulses sent along motor neurones: no further impulses are sent to the flexor muscle, so impulses to its neuromuscular junction stop. At every synapse neurotransmitter must be released, diffuse across the synaptic cleft and bind to receptors, which adds to the delay.

Muscle: when impulses stop, calcium ions are taken back up into the sarcoplasmic reticulum by active transport, using energy released from ATP breakdown. Troponin releases calcium and changes shape, so tropomyosin moves back and blocks the binding sites on actin. ATP binds to the myosin heads, so they are released from actin, the myosin heads cannot bind to actin again, and no cross bridges form. The actin slides back over the myosin and the muscle relaxes.

The greater the contraction, the more cross bridges and calcium ions there are to remove, so it takes longer for the muscle to fully relax, which explains the longer response time.

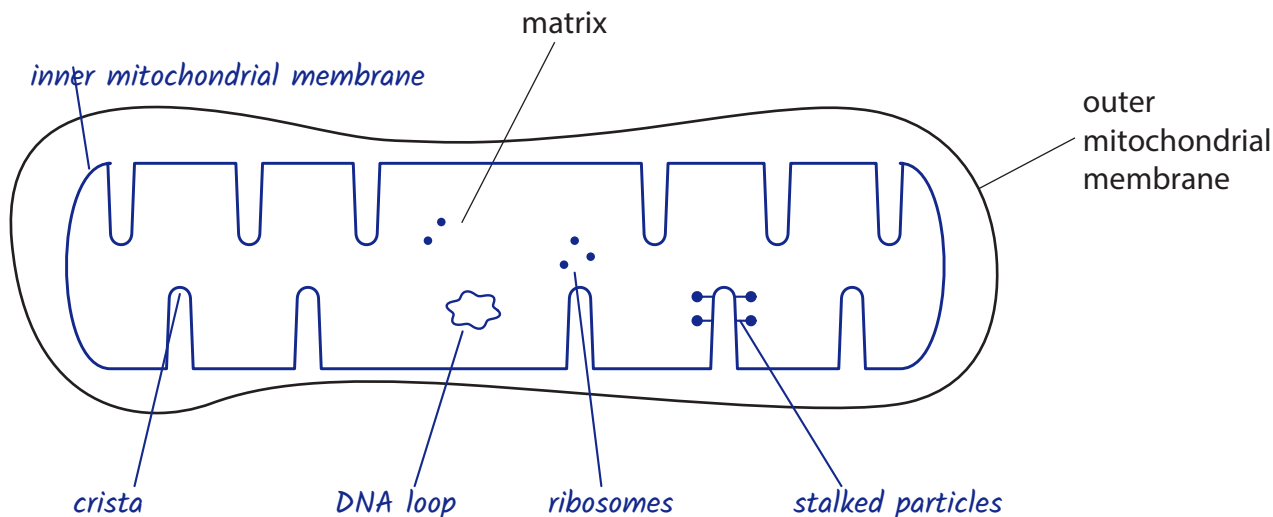
(Total for Question 6 = 10 marks)



7 Aerobic respiration in eukaryotic cells occurs in mitochondria.

- (a) Complete the diagram of a mitochondrion to show the internal structure.
Label each structure that is added.

(3)



- (b) The matrix of a mitochondrion contains a range of enzymes.

Describe the role of enzymes in the link reaction.

(4)

Enzymes catalyse the link reaction by lowering the activation energy.

Pyruvate is decarboxylated: a decarboxylase enzyme removes carbon dioxide.

A dehydrogenase enzyme removes hydrogen, which reduces NAD to reduced NAD.

Coenzyme A (CoA) is then added to the remaining acetyl group to synthesise acetyl CoA.

(c) Proton pumps are found in mitochondria.

Explain the role of proton pumps in aerobic respiration.

(5)

Proton pumps are part of the electron transport chain on the inner mitochondrial membrane (cristae).

Energy released as electrons pass along the chain is used by the proton pumps to move protons (H^+) from the matrix into the inter-membrane space.

This creates an electrochemical (proton) gradient across the inner membrane.

The protons then diffuse down this gradient back into the matrix through the stalked particles (ATP synthase).

This flow of protons is chemiosmosis, and it allows ATP synthase to synthesise ATP from ADP and P_i (oxidative phosphorylation).

(Total for Question 7 = 12 marks)

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8 *Arabidopsis thaliana* is a plant that uses phytochromes and auxin to respond to changes in the environment.

- (a) (i) State **two** ways that the active form of phytochrome (P_{FR}) can be converted to the inactive form (P_R).

(2)

1 Exposing P_{FR} to far red light, which it absorbs.

2 Leaving it in the dark, e.g. during the night, when P_{FR} slowly converts back to P_R .

- (ii) *Arabidopsis* is known as a long-day plant.

Explain why *Arabidopsis* will flower when each day has 16 hours of light.

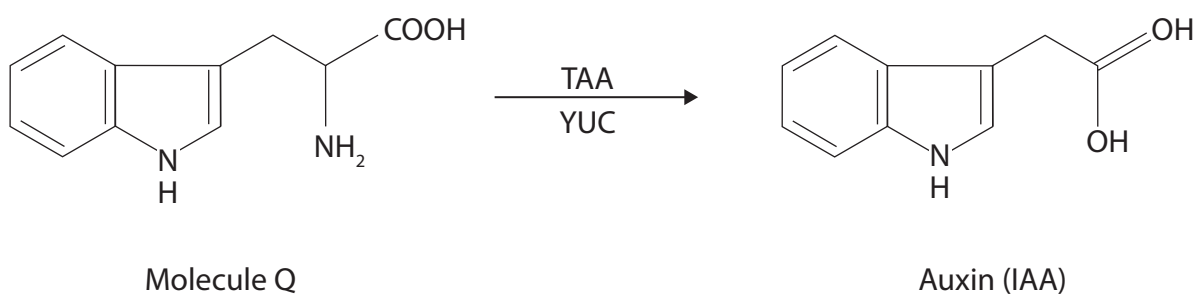
(3)

With 16 hours of light, P_R absorbs red light and is converted to P_{FR} , so P_{FR} accumulates during the long day.

The night is short (8 hours), so there is less time for P_{FR} to be converted back to P_R , and the ratio of P_{FR} to P_R stays high.

P_{FR} stimulates flowering: it activates transcription factors that switch on genes associated with flowering.

- (b) Auxin is made by *Arabidopsis* using molecule Q and the enzymes TAA and YUC, as shown in the diagram.



- (i) Which type of molecule is Q?

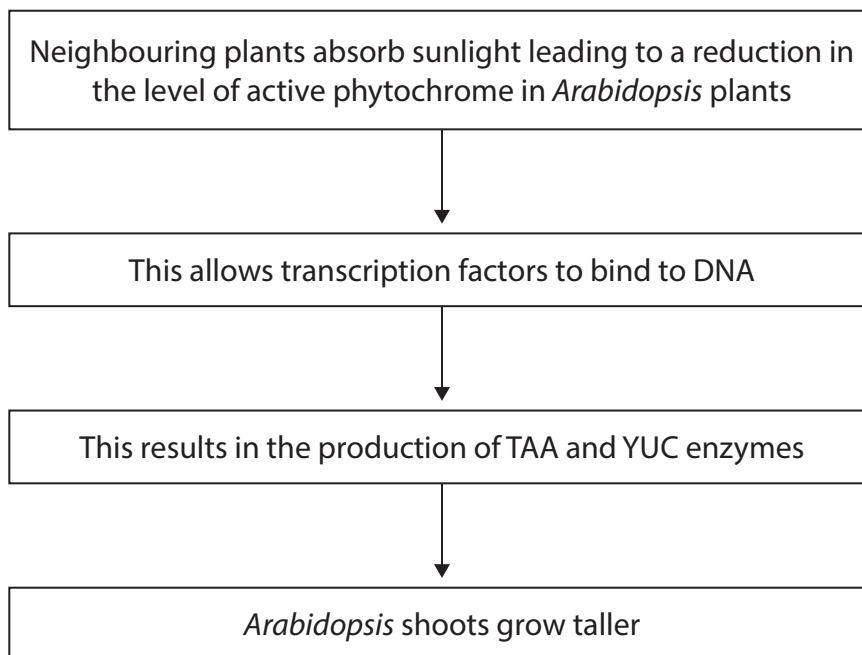
(1)

- ☒ **A** amino acid
- ☐ **B** nucleic acid
- ☐ **C** nucleotide
- ☐ **D** protein

- *(ii) Phytochromes and auxin are involved in the response of *Arabidopsis* plants to the presence of other plants growing nearby.

Arabidopsis plants grow taller if there are many neighbouring plants competing for sunlight.

The diagram shows some of the stages in this response.



Explain how neighbouring plants competing for light result in *Arabidopsis* plants growing taller.

Use the information provided and your own knowledge to answer the question.

(6)

Neighbouring plants absorb the red light, so less red light reaches the *Arabidopsis* plant.

Less P_R is converted to P_{FR} , so the level of active phytochrome (P_{FR}) falls.

P_{FR} normally inhibits the transcription factors, so with less P_{FR} the transcription factors

can bind to the promoter region of the genes for TAA and YUC. This activates the

genes: RNA polymerase binds, the DNA is unzipped and the genes are transcribed into

mRNA.

The mRNA leaves the nucleus through a nuclear pore and attaches to a ribosome. In

translation, tRNA molecules bring specific amino acids, their anticodons pairing with

complementary codons on the mRNA, and peptide bonds form between the amino acids.

So more TAA and YUC enzymes are made.

These enzymes convert molecule Q into auxin (IAA), so more auxin is produced by the

shoot tip. The auxin diffuses down the shoot to the zone of elongation.

There auxin causes H^+ ions to be pumped into the cell walls, which loosens the bonds

between cellulose microfibrils and increases cell wall plasticity. Water enters the cells by

osmosis and forms a large vacuole, so the cells elongate.

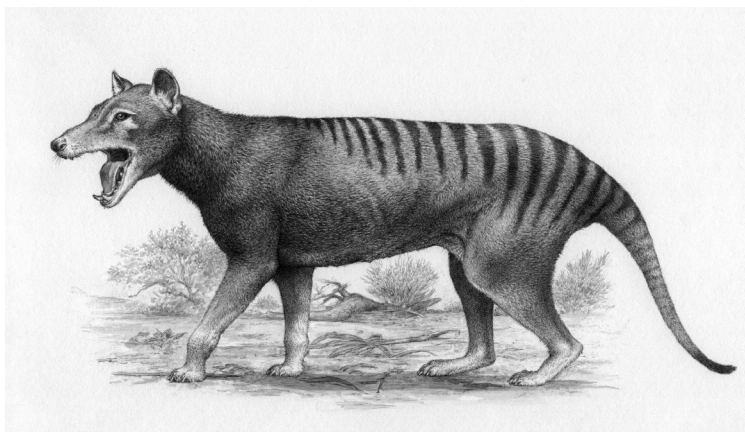
As a result the *Arabidopsis* shoots grow taller, reaching the light above the neighbouring

plants.

(Total for Question 8 = 12 marks)



- 9 The picture shows a thylacine (Tasmanian tiger), a mammal believed to have become extinct during the twentieth century.



(Source: © JOHN SIBBICK/SCIENCE PHOTO LIBRARY)

Some scientists are hoping to produce living thylacines. The scientists are planning to use preserved thylacine DNA, stem cells from closely-related species and gene technology.

- (a) (i) Describe how stem cells can be made to differentiate into different specialised cells.

(4)

Stem cells differentiate by differential gene expression.

A chemical signal (stimulus), e.g. a transcription factor, activates (switches on) specific genes in the stem cell while other genes stay switched off.

The activated genes are transcribed to produce mRNA, and translation of this mRNA produces specific proteins (polypeptides).

These proteins determine the structure and function of the cell, so it becomes a specialised cell.



(ii) Explain why the scientists plan to use stem cells from closely-related species.

(2)

The thylacine is extinct, so no thylacine stem cells are available. Stem cells from closely-related species have many genes in common with the thylacine, so fewer gene edits are needed.

(iii) Explain **one** reason for using stem cells from more than one individual of the same species to produce a population of thylacines that can survive for a long time.

(2)

Stem cells from several individuals give greater genetic diversity (a larger gene pool), so the population is more likely to adapt to a selection pressure and less likely to suffer inbreeding depression.

(b) Gene technology uses restriction enzymes and ligases.

(i) Which type of bond is hydrolysed by a restriction enzyme during gene technology?

(1)

- ☐ A ester
- ☐ B hydrogen
- ☐ C peptide
- ☒ D phosphodiester

- (ii) Determine the number of condensation reactions that occur when ligase joins a single gene to a bacterial plasmid.

(3)

Ligase forms phosphodiester bonds, and each bond is formed by one condensation reaction.

DNA is double-stranded, so at each end of the gene two phosphodiester bonds are needed, one per DNA strand.

The gene joins the plasmid at two ends, so $2 \times 2 = 4$.

Number of condensation reactions = 4

(Total for Question 9 = 12 marks)

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10 Angina is a painful condition caused by a narrowing of the coronary arteries that supply heart muscle with oxygen.

This narrowing can be caused by atheroma partially blocking the artery lumen.

(a) (i) Which structure supplies the coronary artery with oxygenated blood?

(1)

- ☒ **A** aorta
- ☐ **B** left atrium
- ☐ **C** pulmonary artery
- ☐ **D** right ventricle

(ii) Explain why angina is likely to be more painful during exercise than when at rest.

(3)

During exercise the heart rate increases, so the heart muscle respire more and requires more oxygen.

The coronary artery is narrowed (partially blocked) by atheroma, so insufficient oxygenated blood can be supplied to meet the additional demand, although at rest the supply is enough.

So the cardiac muscle starts to carry out anaerobic respiration and lactate is produced, causing more pain.

- (iii) Describe the events that occur in a coronary artery that lead to the formation of an atheroma.

(3)

The endothelium lining the coronary artery is damaged, e.g. by high blood pressure.

This triggers an inflammatory response and white blood cells enter the artery wall.

Cholesterol and fatty deposits build up under the endothelium, calcium salts accumulate (calcification) and fibrous tissue forms, making the atheroma.

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- (b) Angina can lead to a raised heart rate.

A substance found in a plant, Roselle (*Hibiscus sabdariffa*), has been shown to reduce heart rate in humans.

In humans, this substance was effective at a dose of 15 mg kg^{-1} of human body mass.



(Source : © K JAYARAM/SCIENCE PHOTO LIBRARY)

Roselle (*Hibiscus sabdariffa*)

- (i) Why was the substance given at a dose of 15 mg kg^{-1} of human body mass and not just at 15 mg ?

(1)

- ☐ A so each person is given the same mass of substance
- ☐ B so the data is more precise
- ☒ C to allow a valid comparison between humans
- ☐ D to control the dependent variable



- (ii) Devise an investigation to find the mean minimum concentration of this substance that will lower the heart rate in *Daphnia*.

(5)

Measure the mass of each *Daphnia*.

Prepare a range of doses of the substance below 15 mg kg^{-1} of body mass, e.g. 0, 2, 4, 6, 8, 10 and 12 mg kg^{-1} , calculated from the mass of each *Daphnia*.

Place a *Daphnia* in a cavity slide with a small, fixed volume of pond water and view it under a microscope. Count the number of heart beats in a set time, e.g. 20 seconds, before and after adding the substance, leaving the same time for the substance to act.

Control the temperature using a water bath (abiotic variable) and use *Daphnia* of the same species, age and size (biotic variable).

Use several *Daphnia* at each concentration and calculate the mean, then find the lowest concentration that lowers the heart rate to give the mean minimum concentration.

(Total for Question 10 = 13 marks)

TOTAL FOR PAPER = 100 MARKS



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