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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.

INTERNATIONAL A-LEVEL BIOLOGY (9610)

Unit 4 Control

Tuesday 6 June 2023

07:00 GMT

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- 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).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 75.

For Examiner's Use

Question	Mark
1	
2	
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TOTAL	



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Answer **all** questions in the spaces provided.

0 1

Neurones are specialised cells adapted to conduct nerve impulses.

0 1 . 1

Complete **Table 1** by naming the part of the neurone that carries out the function described.

Table 1

Function	Part of neurone
Conducts nerve impulses towards the cell body	<i>Dendrons / dendrites</i>
Provides electrical insulation	<i>Myelin sheath (Schwann cells)</i>

[2 marks]

Question 1 continues on the next page

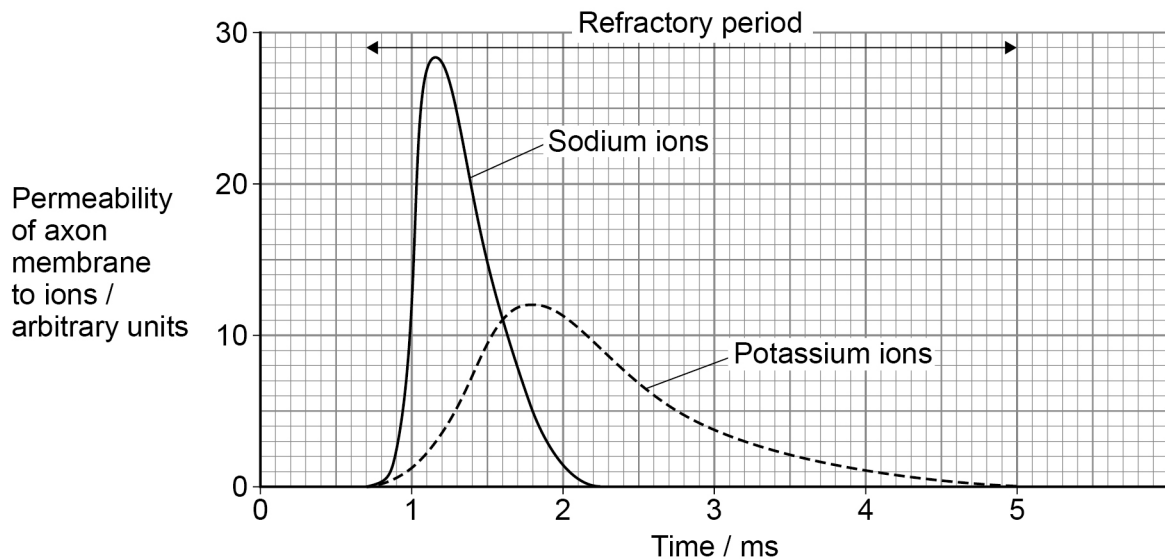
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During an action potential, the permeability of the axon membrane to sodium ions and potassium ions changes.

Figure 1 shows how membrane permeability changes during the action potential.

Figure 1



During an action potential, the membrane potential rises to +40 mV and then falls.

0 1 2

Explain the rise and fall in membrane potential during an action potential.

[4 marks]

Rise: the membrane becomes more permeable to sodium ions because sodium ion channels (gates) open,

so sodium ions diffuse in, causing depolarisation: the inside of the neurone becomes less negative and then positive (up to +40 mV).

Fall: the membrane becomes less permeable to sodium ions and more permeable to potassium ions, as the sodium ion channels close and the potassium ion channels (gates) open,

so potassium ions diffuse out, causing repolarisation: the inside of the neurone becomes less positive and then more negative (hyperpolarisation).



0 1 . 3

Calculate the maximum number of action potentials per second along this axon.

Give your answer to the nearest whole number.

Use data from **Figure 1**.

[2 marks]

$$\text{Refractory period} = 5.0 - 0.7 = 4.3 \text{ ms} = 0.0043 \text{ s}$$

$$\text{Maximum frequency} = 1 \div 0.0043 \text{ s} = 232.6 \text{ per second}$$

Answer = 233 action potentials s^{-1}

0 1 . 4

The refractory period causes action potentials to move in one direction only.

Explain why.

[2 marks]

An action potential can only pass to the next region of the axon that is polarised (at resting potential), i.e. from an active region to a resting region.

It cannot pass backwards because the region behind is in its refractory period: the membrane is not permeable to sodium ions as the sodium ion channels are closed (unresponsive to another stimulus).

10

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0 2

Scientists have discovered a bacterium that produces an enzyme called PETase. This enzyme can break down a plastic called PET.

Using genetic engineering techniques, scientists used plasmids as a vector to transform yeast cells. The transformed yeast cells now produce the PETase enzyme.

0 2 . 1

Describe how vectors transform the yeast cells.

[1 mark]

The vector (plasmid) carries (transfers) the PETase gene from one organism, the bacterium, into the yeast cells.

0 2 . 2

Describe the role of restriction endonuclease **and** DNA ligase enzymes in the process of inserting the PETase gene into a plasmid.

[4 marks]

Restriction endonuclease *Cuts the (bacterial) chromosome (DNA) at a specific recognition sequence to remove the PETase gene.*

The PETase gene and the plasmid are cut with the same restriction endonuclease, creating complementary sticky ends (overhanging ends with complementary single strands).

DNA ligase *DNA ligase joins (anneals) the PETase gene into the plasmid by forming phosphodiester bonds between the plasmid and the gene.*

0 2 . 3

Suggest **one** possible advantage of transforming yeast with the PETase gene for reducing plastic pollution.

[1 mark]

The yeast could produce more PETase, so there is faster (more) breakdown of plastic waste, so less plastic in landfill.



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0 3

Scientists investigate the effect of two different chemicals on the behaviour of a species of beetle (*Tribolium confusum*). This beetle is a pest that feeds on stored cereal products such as wheat flour.

The scientists:

1. divide a choice chamber (a clear plastic container) into two sections as shown in **Figure 2** (on page 9)
2. add a chemical called anethole to one section of the choice chamber and distilled water to the other section (control)
3. put the choice chamber into a temperature-controlled and light-controlled room
4. put one beetle into the choice chamber and wait five minutes
5. observe the behaviour of the beetle for 10 minutes and record the time that the beetle spends in each of the two sections
6. repeat steps 1 to 5 to collect results for a total of 30 individual beetles.

To complete the investigation, the scientists repeat steps 1 to 6, but in step 2 add a chemical called caryophyllene instead of anethole.

0 3 . 1

Name **one** factor, other than temperature or light, that the scientists should control.

[1 mark]

Concentration (volume) of anethole / caryophyllene solution.

0 3 . 2

Give **one** reason why the beetles are left for five minutes before their movement is recorded.

[1 mark]

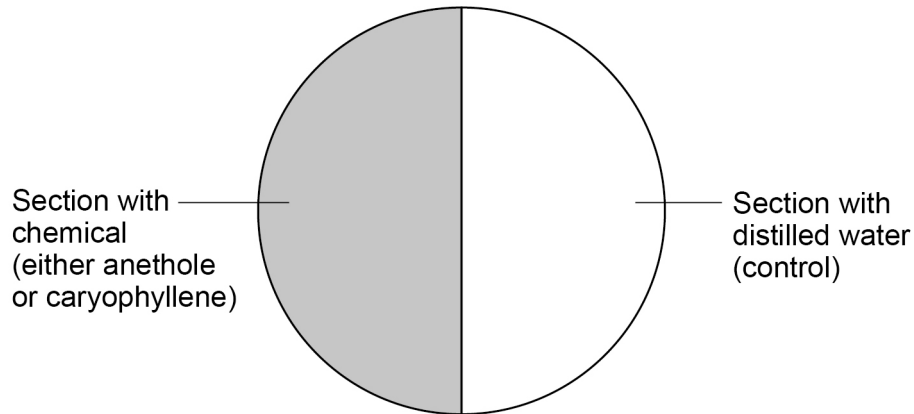
So the beetle is no longer affected by handling, so its behaviour is typical of that condition.



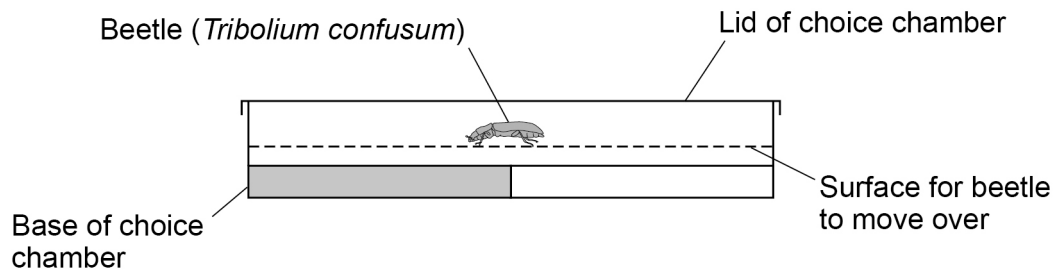
Figure 2 shows the choice chamber that the scientists use.

Figure 2

Top view



Side view



0 3 . 3

Each beetle usually spends more time in the control area.
The scientists conclude that the beetles are showing a kinesis response.

Describe what observations of the beetle's movements would support this conclusion.
[2 marks]

The beetles move more slowly in the control area (faster in the area with the chemical),

and they turn less frequently in the control area (more frequently in the area with the chemical).

Question 3 continues on the next page

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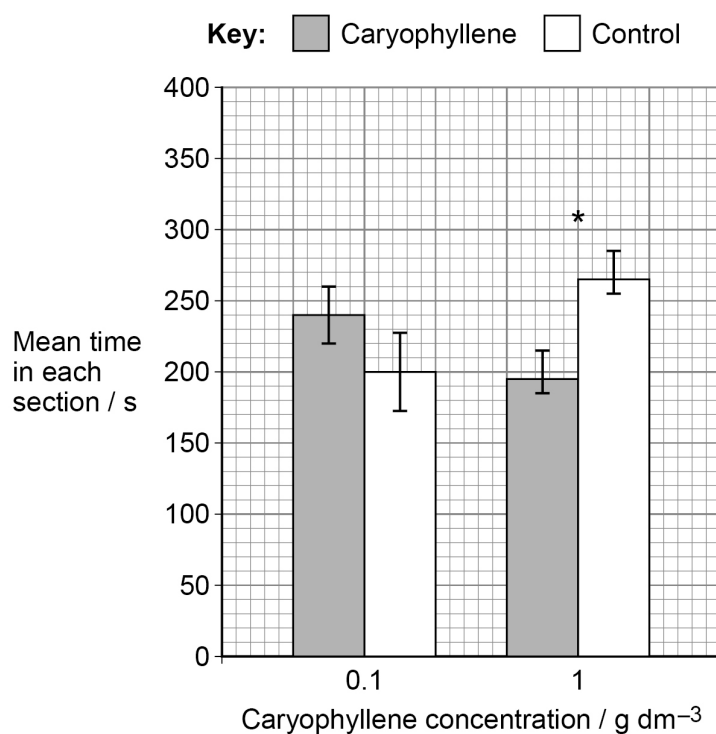
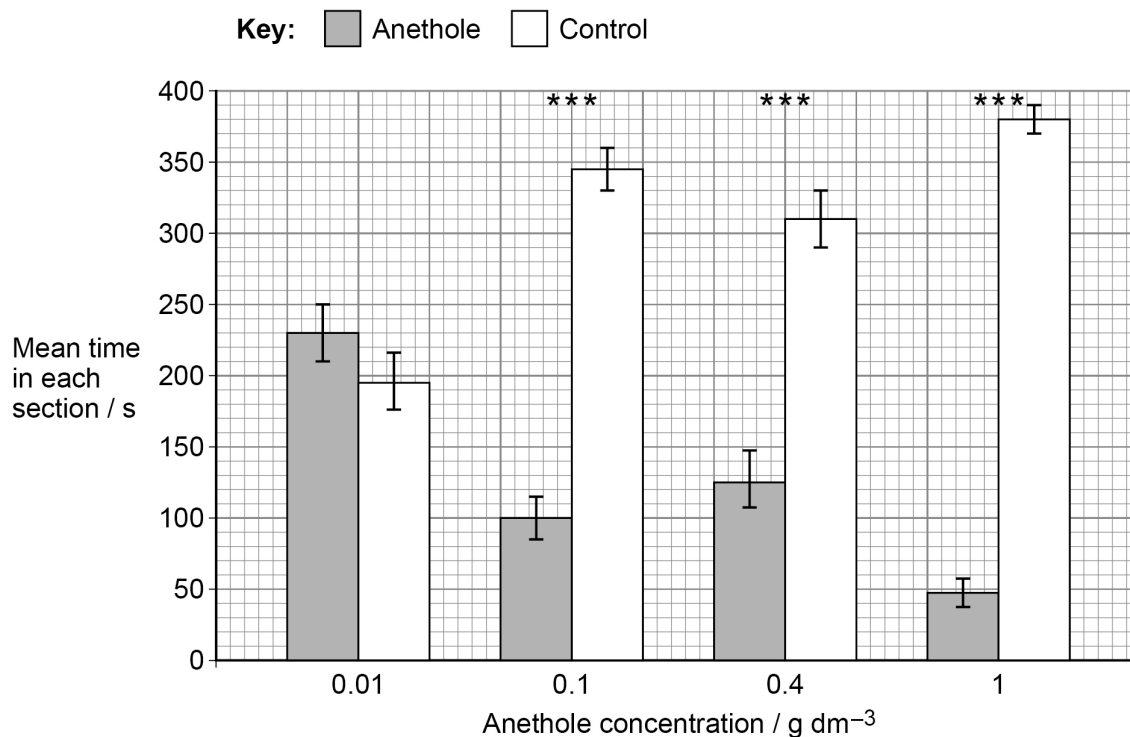
Figure 3 shows the mean time the beetles are in each section when different concentrations of anethole and caryophyllene are used.

Error bars show ± 2 standard deviations.

* shows significance at $P < 0.05$

*** shows significance at $P < 0.001$

Figure 3



0 3 . 4

The scientists make two conclusions.

1. Anethole is more effective than caryophyllene at repelling the beetles.
2. Anethole could be used for protecting stored cereal products from insect pests such as *Tribolium confusum*.

Use the information in **Figure 3** to evaluate the scientists' conclusions.

[5 marks]

For conclusion 1: the mean time in the anethole section is significantly lower than in the control for concentrations above 0.01 g dm^{-3} (e.g. 48 s compared with 380 s at 1 g dm^{-3}),

whereas for caryophyllene the mean time is only significantly lower than the control at 1 g dm^{-3} , with no significant difference at 0.1 g dm^{-3} .

The probability that the difference between anethole and the control is due to chance is less than 0.001 (0.1%), and the error bars for anethole and the control do not overlap above 0.01 g dm^{-3} .

At equal concentrations anethole gives a lower mean time than caryophyllene, e.g. 100 s compared with 240 s at 0.1 g dm^{-3} and 48 s compared with 195 s at 1 g dm^{-3} .

Against: only tested under experimental conditions in a choice chamber in the laboratory, and only observed for a short period of time (10 minutes);

only 30 insects were used, a small sample size; only one species was investigated, so other insect pests might respond differently;

anethole could have a possible effect on the food, e.g. its taste or toxicity, and there is no information about the cost of either chemical.

9

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0 4

Students investigate the effects of indoleacetic acid (IAA) on the growth of *Arabidopsis thaliana* seedlings.

The students:

- remove 2 mm from the shoot tips of 30 seedlings of the same age
- cut the next 15 mm lengths from the shoots
- put 5 of the 15 mm lengths of shoot into each of 6 Petri dishes
- add 50 cm³ of a different concentration of IAA solution to each Petri dish
- cover the Petri dishes in plastic film
- measure the length of each shoot after 4 days and calculate the mean change in the shoot length at each of the IAA concentrations.

0 4 . 1

The students grow the seedlings at the same temperature and light intensity before the start of the investigation.

Give **two** other environmental variables that the students should control.

[2 marks]

1 *Wavelength (duration) of light*

2 *Volume of water given (and concentration of mineral ions)*

0 4 . 2

Explain why the students remove the shoot tips from each of the seedlings.

[2 marks]

IAA is produced (released) in the shoot tip,

so if the tips were not removed, existing IAA would affect the IAA

concentration, so the change in length would not only be affected by

the added IAA solutions.

0 4 . 3

Explain why the students covered each Petri dish in plastic film.

[2 marks]

To prevent (reduce) evaporation of water from the IAA solution,

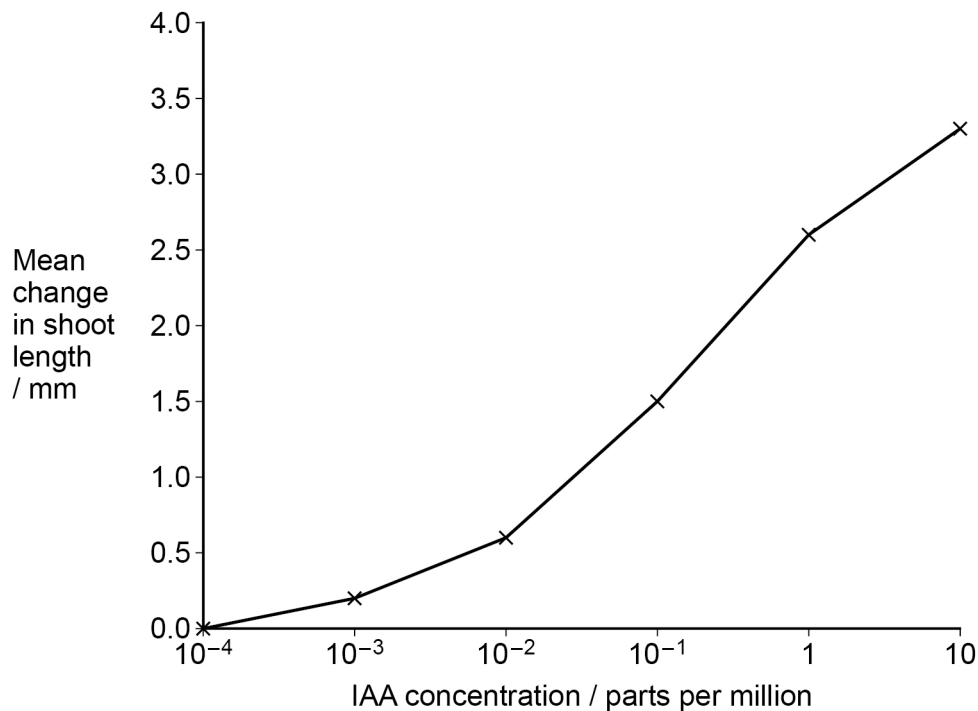
so the concentration (water potential) of the IAA solution is not

changed.



Figure 4 shows the students' results.

Figure 4



0 4 . 4 Give the reason why the students use a logarithmic scale for the IAA concentration.

[1 mark]

The IAA concentrations used are over a large range (so all the data fit on a single graph).

0 4 . 5 Explain the effect of IAA on shoot growth shown in Figure 4.

[2 marks]

*As the IAA concentration increases, the mean change in shoot length is greater (increases),
because IAA stimulates (causes) elongation of the shoot cells.*

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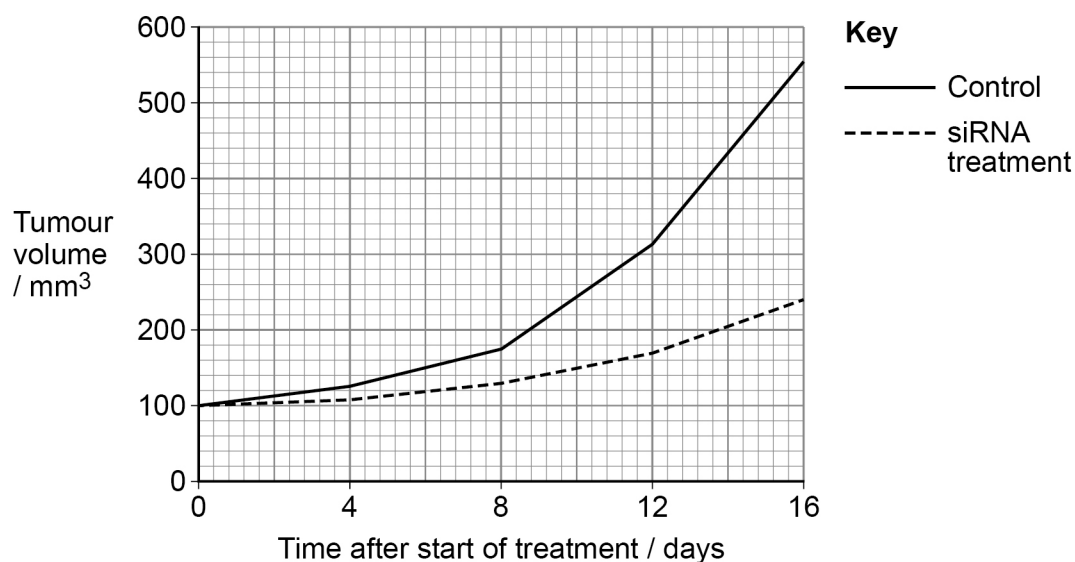


0 5

Small interfering RNA (siRNA) can be used for treating tumours. Scientists investigate the effect of siRNA on the growth of tumours.

Figure 5 shows the scientists' results.

Figure 5



0 5

1

Calculate the difference in rate of tumour growth between the control and siRNA treatment over the 16 days.

[2 marks]

$$\text{Control rate} = (555 - 100) \div 16 = 28.44 \text{ mm}^3 \text{ day}^{-1}$$

$$\text{siRNA rate} = (240 - 100) \div 16 = 8.75 \text{ mm}^3 \text{ day}^{-1}$$

$$\text{Difference} = 28.44 - 8.75 = 19.69$$

Difference in rate = 19.7 mm³ day⁻¹



0 5 . 2

One type of tumour cell that the scientists used divides every 8 hours.

Calculate the number of tumour cells that would be produced from a single tumour cell after 16 days.

Give your answer in standard form to 3 significant figures.

[2 marks]

$$16 \text{ days} = 16 \times 24 = 384 \text{ hours}; \quad 384 \div 8 = 48 \text{ divisions}$$

$$\text{Number of cells} = 2^{48} = 2.8147 \times 10^{14}$$

$$\text{Number of tumour cells} = \underline{2.81 \times 10^{14}}$$

In similar investigations, scientists have measured the area of a tumour as an indicator of tumour size.

0 5 . 3

Give **one** reason why measuring the volume of the tumour gives a better indication of tumour size.

[1 mark]

Tumours are 3D, so measuring volume takes into account tumours of different depths (area does not consider depth).

Question 5 continues on the next page

Turn over ►



The siRNA used in the investigation inhibits the expression of a gene that blocks cell death (apoptosis).

0 5 . 4

Explain how this siRNA could inhibit the expression of the gene and how this could slow the onset of cancer.

Use the information given and the results in **Figure 5** (on page 14).

[3 marks]

The siRNA binds to the (complementary) mRNA produced from the target gene,

so the mRNA is broken down into fragments and the protein that blocks apoptosis is not produced (the gene is not expressed).

This leads to increased cell death (apoptosis) of tumour cells, so it reduces the growth of the tumour: Figure 5 shows a smaller tumour volume than the control (240 compared with 555 mm³ at 16 days).

Another cause of tumour development is abnormal methylation of DNA in tumour suppressor genes.

0 5 . 5

Explain how abnormal methylation of a tumour suppressor gene could cause the development of a tumour.

[3 marks]

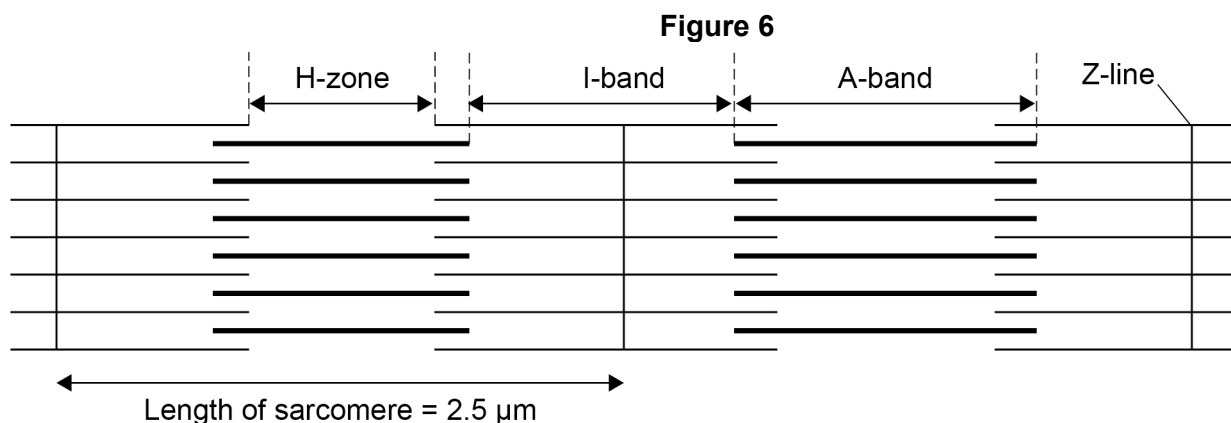
Increased methylation (hypermethylation) of the tumour suppressor gene: methyl groups are added to the DNA of the gene.

This inhibits transcription of the tumour suppressor gene, as transcription factors are unable to bind to the promoter region of the gene, so the protein that slows cell division is not made, which leads to uncontrolled cell division (and a tumour).



0 6

Figure 6 shows part of a myofibril from a section of skeletal muscle. The sarcomeres are relaxed.



0 6 . 1

Figure 6 shows that the length of each sarcomere is 2.5 μm

Use this information to calculate the magnification of the diagram.

[2 marks]

Measured length of sarcomere = 74 mm = 74 000 μm

Magnification = 74 000 $\div$ 2.5 = 29 600

Magnification = × 29 600

0 6 . 2

Describe **two** ways the appearance of the sarcomeres would change when the muscle fibre contracts.

[2 marks]

1 The length of the sarcomere decreases (Z-lines move closer together).

2 The length of the H-zone decreases and the length of the I-band decreases.

Question 6 continues on the next page

Turn over ►



0 6 . 3

When a muscle sarcomere contracts, a single actin filament moves $0.64\ \mu\text{m}$

This movement requires energy from the hydrolysis of 16 ATP molecules.

Calculate the distance that an actin filament would move with the energy from the hydrolysis of only one ATP molecule.

Give your answer in nm

[1 mark]

$$0.64\ \mu\text{m} \div 16 = 0.04\ \mu\text{m} = 0.04 \times 1000\ \text{nm}$$

Distance = 40 nm

0 6 . 4

Describe the role of phosphocreatine during muscle contraction.

[2 marks]

*Phosphocreatine donates a phosphate (P_i) to ADP, phosphorylating ADP,
which produces ATP (anaerobically) for muscle contraction.*



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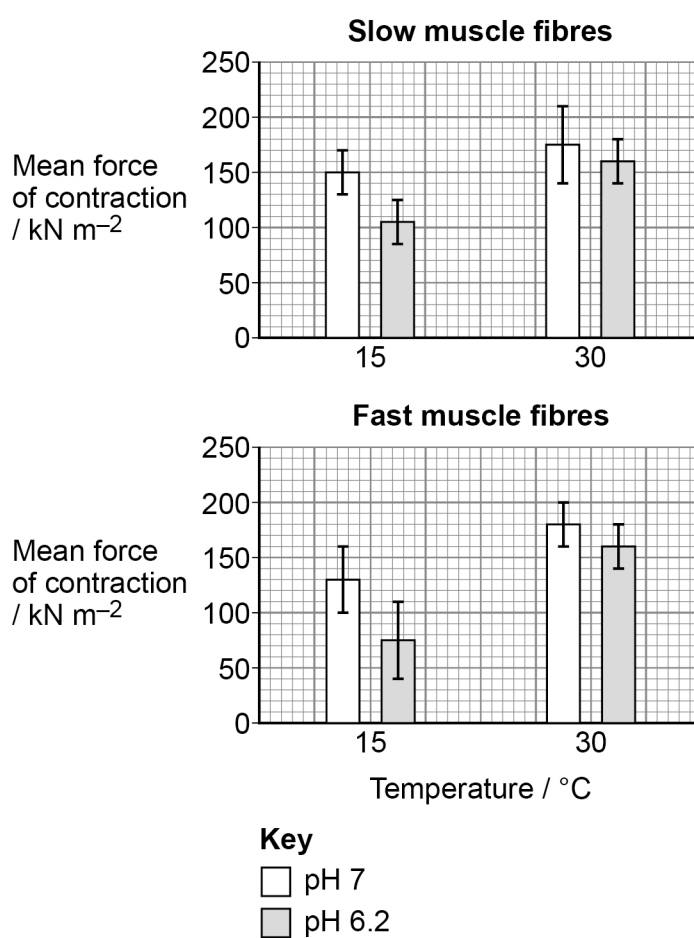
Scientists investigate the effect of pH and temperature on the force of skeletal muscle contraction.

The scientists:

- isolate fast and slow skeletal muscle fibres from the bodies of four rats
- put the isolated fast and slow muscle fibres into two different solutions:
 - pH 7 (typical pH of rat muscle tissue)
 - pH 6.2
- measure the force of muscle contraction of both fast and slow muscle fibres at 15 °C and 30 °C

Figure 7 shows the scientists' results. Error bars show ± 2 standard deviations.

Figure 7



0 6 . 5

A student concludes that a decrease in pH always causes a decrease in the force of muscle contraction.

Use information from **Figure 7** to evaluate this conclusion.

[5 marks]

For: at pH 6.2 the mean force of contraction is lower than at pH 7 for both fast and slow fibres at both 15 °C and 30 °C.

For slow fibres at 15 °C the ± 2 SD bars for pH 7 and pH 6.2 do not overlap, so the difference is likely to be significant.

Against: for slow fibres at 30 °C, and for fast fibres at 15 °C and 30 °C, the SD bars overlap, so the difference is not likely to be significant.

Only four rats were used, a small sample size, and only one investigation; only (muscle tissue from) rats was used, so it may not apply to other animals.

Only two pH values (pH 7 and pH 6.2) and only two temperatures (15 °C and 30 °C) were investigated, so 'always' cannot be concluded.

Only isolated skeletal muscle tissue was used (not in the body), and no statistical test was done to check whether the differences are significant.

Question 6 continues on the next page

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0 6 . 6

The scientists suggest that the decrease in the force of muscle contraction is due to a reduction in the effect of calcium ions.

Explain how a reduction in the effect of calcium ions might lower the force of contraction.

Use your knowledge of muscle contraction.

[3 marks]

Fewer calcium ions bind to troponin, so less tropomyosin moves away from (changes shape to expose) the binding sites on actin, which stay blocked.

So fewer actinomyosin cross bridges form between the myosin heads and actin.

There is less activation of ATPase, so less ATP is hydrolysed and there is less movement of actin over myosin, so less force.

15



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07

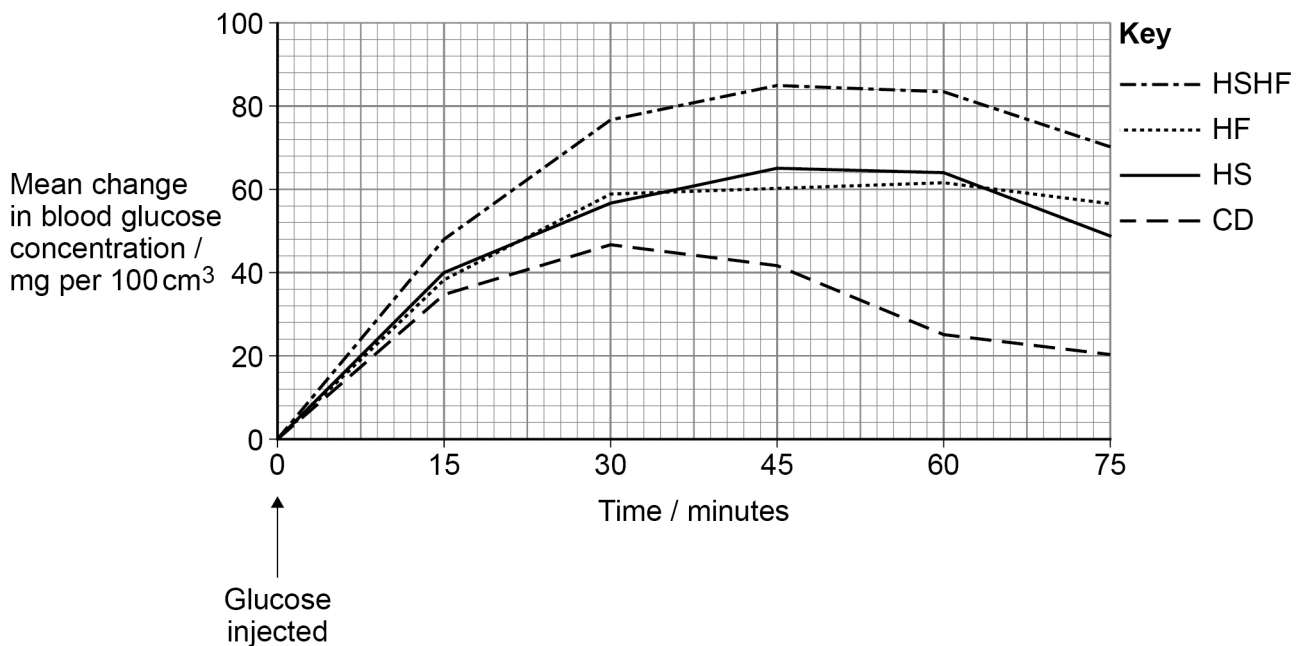
Scientists investigate the effect of diet on the blood glucose concentration of mice.

The scientists:

- put 24 mice into four groups of 6 mice
- feed each group of mice a different diet for eight weeks as follows:
 - high sugar and high fat diet (HSHF)
 - high fat diet (HF)
 - high sugar diet (HS)
 - control diet (CD)
- stop feeding the mice six hours before the start of the experiment
- inject each of the mice with a glucose solution
- measure the blood glucose concentration of the mice in each group at 15-minute intervals.

Figure 8 shows the scientists' results.

Figure 8



07.1

Suggest why the scientists stop feeding the mice six hours before the start of the experiment.

[1 mark]

So that measurements are not affected by any food recently eaten:

blood glucose (and insulin) concentration will be low (similar) for all

mice at the start.



0 7 . 2

Describe what **Figure 8** shows about the effect of diet on blood glucose concentration.

[3 marks]

The CD group peaks at the lowest concentration (47 mg per 100 cm³), has the lowest concentration throughout and the slowest increase.

In the CD group the decrease in concentration started sooner (after 30 minutes) and it decreases the most, whereas the other groups decrease later (e.g. HSHF from 45 minutes).

The HSHF group peaks at the highest concentration (85 mg per 100 cm³) with the fastest increase; the HS and HF groups have a similar pattern throughout.

0 7 . 3

Explain the change in blood glucose concentration in the control mice after 30 minutes.

[4 marks]

The rise in blood glucose is detected and insulin is secreted into the blood by the beta cells of the islets of Langerhans in the pancreas.

Insulin binds to (specific) receptors on the cell surface membranes of target cells (liver and muscle cells).

This causes an increase in the number of (opens) glucose channel (carrier) proteins in the cell surface membrane, so there is increased glucose uptake into the cells.

Enzymes are activated that convert glucose to glycogen (glycogenesis) and to fat in liver and muscle cells, and the respiratory rate of cells increases, so blood glucose falls (from 47 to 20 mg per 100 cm³).

Question 7 continues on the next page

Turn over ►



Another group of scientists report the effect of a chemical called Cpd 1 on the action of glucagon. The structure of Cpd 1 allows it to bind to the same receptors as glucagon on the surface of liver cells.

The scientists:

1. isolate the livers from mice and put the livers into dilute salt solution
2. measure the glycogen content of the livers
3. add glucagon to one of the livers and measure the amount of glycogen in the liver at 10-minute intervals for 40 minutes
4. repeat step 3 by adding different concentrations of Cpd 1 in addition to glucagon to each of the other livers
5. calculate the amount of glycogen remaining in the livers as a percentage of the maximum content.

Figure 9 shows the scientists' results.

Figure 9

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07.4

Describe the scientists' results.

Use data from **Figure 9** in your answer.**[3 marks]**

Glucagon alone caused the fastest and greatest decrease in glycogen remaining, a 75% decrease (to 25% of the maximum).

Increasing the concentration of Cpd 1 gave a higher percentage of glycogen remaining (a lower percentage decrease); with 50 μM Cpd 1 the glycogen remaining stayed around 100% throughout.

After 20 minutes the rate of decrease in glycogen slows for all 4 groups.

Question 7 continues on the next page

Turn over ►



People with diabetes can have high levels of glucagon linked to a high blood glucose concentration.

The scientists conclude that Cpd 1 is effective in blocking glucagon receptors on liver cells and could prevent high blood glucose in people with diabetes.

0 7 . 5

Explain the effects of Cpd 1 shown in **Figure 9** (on page 26).

Use your knowledge of the mechanism of glucagon action.

[4 marks]

Cpd 1 binds to the same receptors as glucagon on the liver cell surface

membrane, so less glucagon attaches to the receptors.

So less adenyl cyclase is activated (via the G protein) to convert ATP to cAMP (the second messenger).

With less cAMP, less protein kinase (A) is activated,

so less phosphorylase is activated and there is less hydrolysis of glycogen to glucose (less glycogenolysis), so more glycogen remains, especially at higher concentrations of Cpd 1.

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