

Please check the examination details below before entering your candidate information

Candidate surname <i>StemUp Model Solution</i>		Other names	
Pearson Edexcel Level 3 GCE		Centre Number 	Candidate Number
Time 1 hour 45 minutes		Paper reference	9BI0/02
Biology B Advanced PAPER 2: Advanced Physiology, Evolution and Ecology			
You must have: Calculator, HB 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.*
- You may use a scientific calculator.

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- 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.
- Good luck with your examination.

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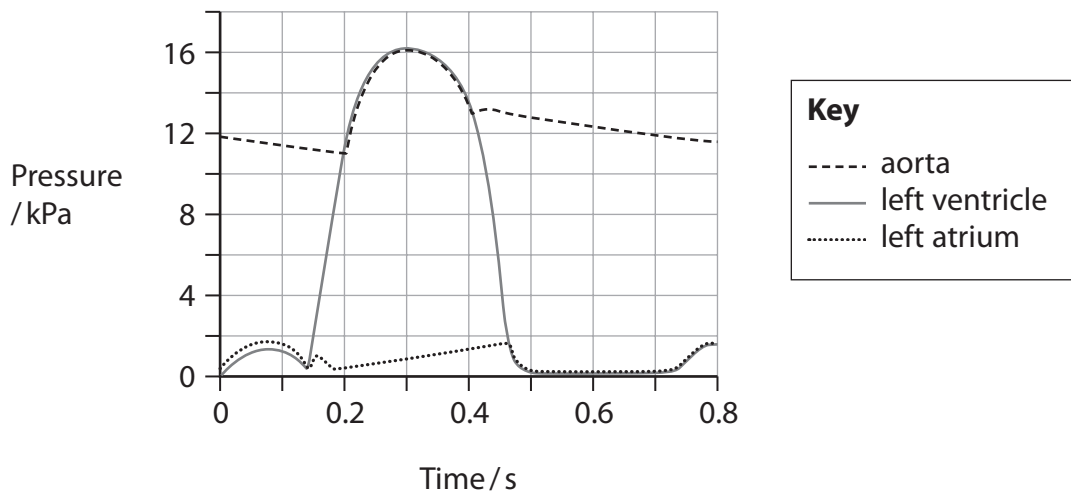


Answer ALL questions.

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 (a) The graph shows the pressure changes in the left side of the heart during one contraction.



- (i) At what time does the atrioventricular (bicuspid) valve close?

(1)

- ☒ **A** 0.14 s
- ☐ **B** 0.20 s
- ☐ **C** 0.45 s
- ☐ **D** 0.40 s

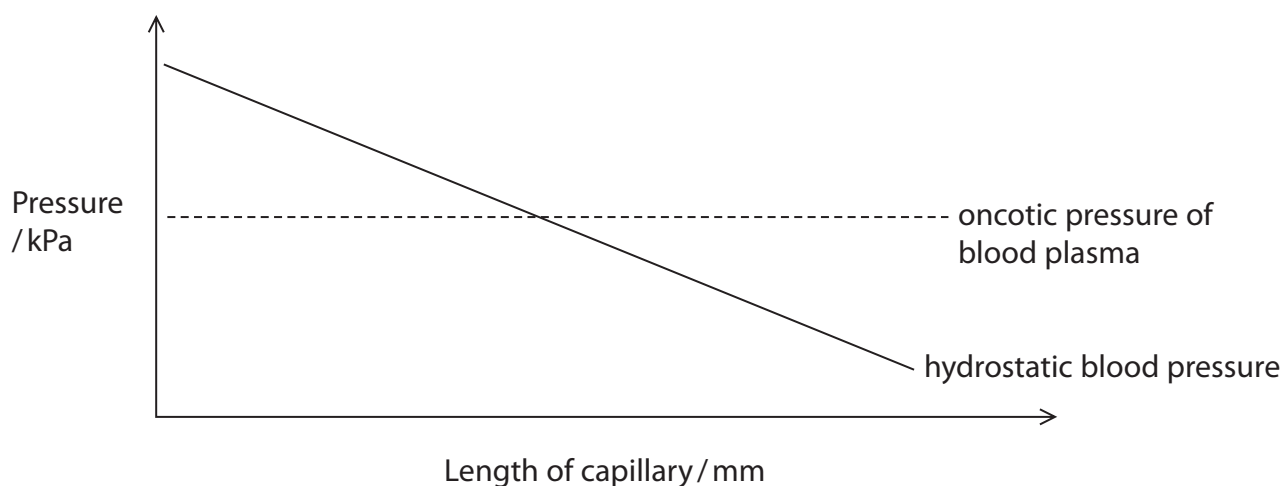
- (ii) Which is the sequence of structures that an impulse passes through during one heart contraction?

(1)

- ☐ **A** atrioventricular node, bundle of His, sinoatrial node
- ☐ **B** atrioventricular node, sinoatrial node, bundle of His
- ☐ **C** sinoatrial node, bundle of His, atrioventricular node
- ☒ **D** sinoatrial node, atrioventricular node, bundle of His



- (b) The graph shows the hydrostatic pressure and oncotic pressure of the blood along a capillary.



- (i) Explain how tissue fluid is formed by the capillary. Use the information in the graph to help your answer.

(3)

At the arterial end of the capillary the hydrostatic blood pressure is greater than the oncotic pressure of the blood plasma.

So fluid (water and small solutes such as glucose and ions) is forced out of the capillary through the pores (gaps between the endothelial cells) to form tissue fluid.

Plasma proteins are too large to leave the capillary, so there is more protein in the blood plasma than in the tissue fluid; this protein causes the oncotic pressure.



- (ii) Kwashiorkor is a condition caused by a lack of dietary protein. One symptom is accumulation of tissue fluid.

Explain why children suffering from kwashiorkor often suffer from an excess of tissue fluid. Use the graph to support your answer.

(2)

With little dietary protein there is less protein in the blood plasma, so the oncotic pressure is lower.

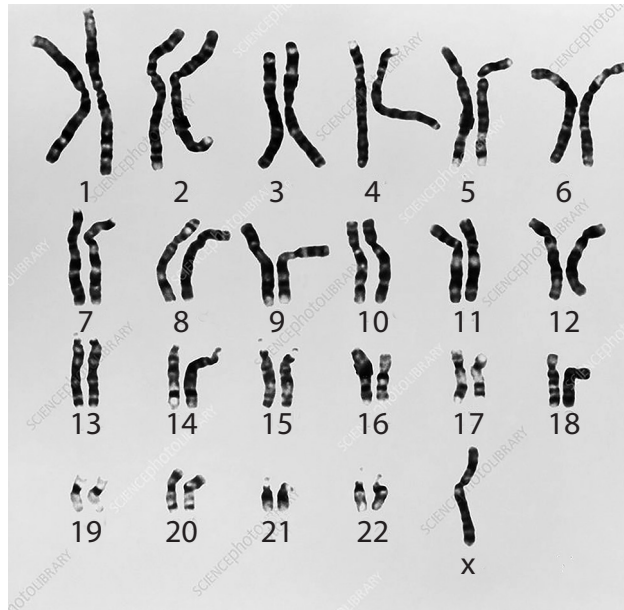
So there is less capillary length where the oncotic pressure is greater than the hydrostatic pressure, so less tissue fluid (water) returns to the blood at the venous end; more fluid leaves than enters.

(Total for Question 1 = 7 marks)



P 6 5 4 5 7 A 0 5 4 0

2 (a) The diagram shows a human karyotype.



(Source: © DEPT. OF CLINICAL CYTOGENETICS, ADDENBROOKES HOSPITAL/SCIENCE PHOTO LIBRARY)

(i) Which of the following identifies the human with this karyotype?

(1)

- ☐ A female with Down's syndrome
- ☒ B female with Turner's syndrome
- ☐ C male with Down's syndrome
- ☐ D male with Turner's syndrome

(ii) Which of the following would cause the karyotype in the diagram?

(1)

- ☒ A non-disjunction producing a monosomy
- ☐ B non-disjunction producing a polysomy
- ☐ C translocation producing a monosomy
- ☐ D translocation producing a polysomy



- (b) (i) The table shows the chromosome number and chromatid number of some of the cells formed during oogenesis in humans.

Cell type	Chromosome number	Chromatid number
ovum	23	23
primary oocyte	46	92
secondary oocyte	23	46

Which of the cells are haploid?

(1)

- ☐ A ovum and primary oocyte
- ☒ B ovum and secondary oocyte
- ☐ C primary oocyte and secondary oocyte
- ☐ D ovum alone

- (ii) Explain how meiosis produces new combinations of alleles in gametes.

(4)

In prophase I, homologous chromosomes pair up and crossing over occurs: chiasmata form between non-sister chromatids.

Sections of DNA are swapped between the homologous chromosomes, so alleles (genes) are exchanged, giving new combinations of alleles on each chromatid.

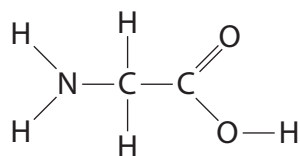
In metaphase I there is independent (random) assortment: homologous pairs line up randomly on the equator.

So the maternal and paternal chromosomes of each pair move randomly to the poles, giving many different combinations of chromosomes, and therefore alleles, in the gametes.

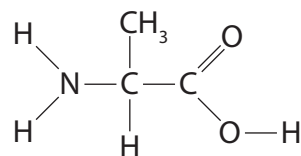
(Total for Question 2 = 7 marks)



3 The diagram shows two amino acids found in the primary sequence of collagen.



glycine



alanine

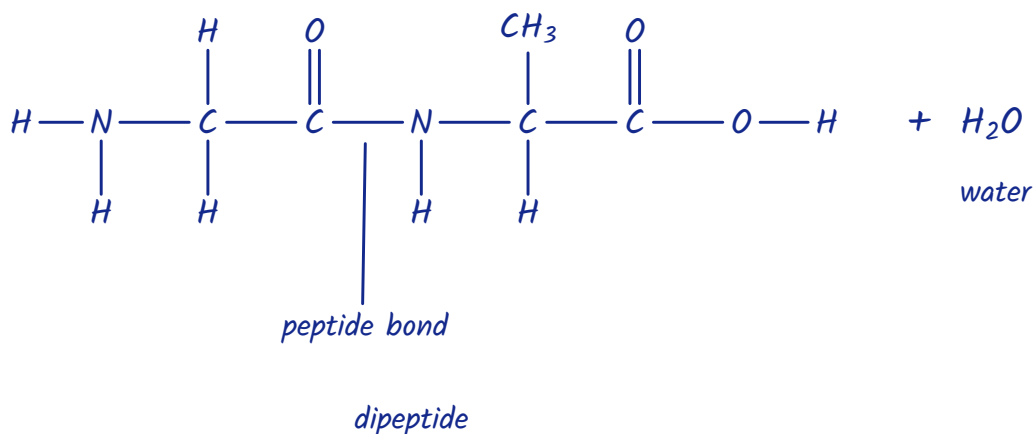
(a) (i) Which is the R-group for alanine?

(1)

- ☒ **A** CH₃
☐ **B** COOH
☐ **C** H
☐ **D** NH₂

(ii) Draw the products of a condensation reaction between glycine and alanine.

(2)



(iii) Describe the structure of collagen.

(3)

Collagen is a fibrous protein made of three polypeptide chains; every third amino acid is glycine and there is a lot of proline.

Each polypeptide chain is a (left-handed) helix, and the three chains are wound together to form a triple helix (tropocollagen).

The chains are held together by many hydrogen bonds (and some covalent cross-links).

Many tropocollagen molecules (triple helices) are joined together by covalent cross-links, staggered to form fibrils and fibres.

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- (b) Ehlers-Danlos syndrome is a human condition caused by a mutation in a collagen gene.

This causes changes to the elasticity and strength of arteries.

Mice were genetically modified to have this mutation.

The elastic constant and force required to break arteries from genetically modified mice and unmodified mice were measured.

The elastic constant is calculated by using the formula:

$$\text{elastic constant} = \frac{\text{force applied}}{\text{increase in length of artery}}$$

The results are shown in the table.

Artery	Elastic constant / N mm ⁻¹	Force required to break artery / N
unmodified mice	0.26	2.0
genetically modified mice	0.12	1.6



- (i) Calculate the force required to produce an increase in length of 0.5 cm for an artery taken from an unmodified mouse.

(1)

$$0.5 \text{ cm} = 5 \text{ mm}$$

$$\text{force} = \text{elastic constant} \times \text{increase in length}$$

$$= 0.26 \times 5 = 1.3 \text{ N}$$

Answer... 1.3 N

- (ii) People with Ehlers-Danlos syndrome are at risk of developing aneurysms.

An aneurysm is an area of artery wall that weakens and can burst.

Explain why people with Ehlers-Danlos syndrome have a high risk of aneurysms.

(3)

The mutated collagen is weaker, so the artery wall has less elasticity and stretches more: a smaller force produces a longer extension.

This is shown by the lower elastic constant (0.12 N mm^{-1} compared with 0.26 N mm^{-1}).

Blood in arteries is at high (hydrostatic) pressure, so the wall bulges and weakens.

Also less force is required to break the artery (1.6 N compared with 2.0 N), so the weakened wall can burst.

(Total for Question 3 = 10 marks)



- 4 The photograph shows an insect fossilised in amber resin.



(Source: Bjoern Wylezich. 123rf.com/PAL)

Scientists have classified another fossilised insect found in amber resin as a new species of mosquito, *Priscoculex burmanicus*.

This mosquito is anatomically very similar to modern species of mosquito.

- (a) (i) Which of these processes produces new species without geographically separating populations?

(1)

- ☐ A allopatric speciation
- ☐ B genetic speciation
- ☐ C stabilising speciation
- ☒ D sympatric speciation

- (ii) *Priscoculex burmanicus* became extinct about 100 million years ago.

State why it was difficult for scientists to decide if this insect belonged to a different species from modern mosquitoes.

(1)

They could not test whether it could interbreed with modern mosquitoes to produce fertile offspring.



(iii) State how scientists would have reached agreement on classifying this mosquito.

(1)

Their findings were peer reviewed, published in scientific journals and discussed at conferences.

(iv) Complete the classification table for *Priscoculex burmanicus*.

(2)

Taxon	Name
Domain	Eukarya
Kingdom	Animalia
<i>Phylum</i>	Arthropoda
<i>Class</i>	Diptera
Order	Culicidae
Family	Anophelinae
Genus	<i>Priscoculex</i>
Species	<i>burmanicus</i>



- (b) Mosquito populations are often controlled using pesticides that inhibit the enzyme acetylcholinesterase.

Long-term use of pesticides often leads to the development of resistance in these mosquitoes.

The ace-1 gene codes for the enzyme acetylcholinesterase.

The ace-1^r allele is a recessive form of this gene that gives resistance to pesticides.

The changes in the numbers of resistant and non-resistant mosquitoes in an area of farmland where pesticides were used in 2007 was investigated.

The use of the pesticides was stopped in 2016.

The table shows the results of this investigation.

Mosquito type	Number of mosquitoes		
	2005	2015	2018
resistant	125	5250	4120
non-resistant	8755	1250	3950

- (i) Calculate the number of heterozygous mosquitoes in 2015.

Use the Hardy-Weinberg equation

$$p^2 + 2pq + q^2 = 1$$

(3)

$$q^2 = 5250 \div (5250 + 1250) = 5250 \div 6500 = 0.8077$$

$$q = \sqrt{0.8077} = 0.8987$$

$$p = 1 - 0.8987 = 0.1013$$

$$2pq = 2 \times 0.1013 \times 0.8987 = 0.1821$$

$$\text{heterozygotes} = 0.1821 \times 6500 = 1183$$

Answer 1183



- (ii) Explain why the changes in the numbers of the resistant and non-resistant mosquitoes, from 2005 to 2018, are related to the function of the ace-1 gene.

(4)

After pesticide use began in 2007, the number of resistant mosquitoes rose from 125 to 5250 in 2015 and non-resistant fell from 8755 to 1250, so the frequency of the ace-1^r allele increased.

This is because the acetylcholinesterase coded for by the ace-1^r allele is not affected (inhibited) by the pesticide, so the enzyme still works.

So acetylcholine is still broken down in the synapses, and the mosquitoes are not killed.

The resistant mosquitoes have a selective advantage, so they survive, breed and pass on the resistance allele.

After pesticide use stopped in 2016, resistant mosquitoes fell to 4120 and non-resistant rose to 3950: there is no selection pressure to retain the allele and it carries a cost, so non-resistant mosquitoes out-compete resistant ones.

(Total for Question 4 = 12 marks)



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5 (a) (i) Which bonds join the nucleotides in a single strand of DNA?

(1)

- ☐ A peptide
- ☐ B disulfide
- ☐ C glycosidic
- ☒ D phosphodiester

(ii) Describe how the process of DNA replication produces two identical DNA molecules.

(4)

DNA helicase breaks the hydrogen bonds between the complementary bases, unzipping the two strands; each strand acts as a template.

Free DNA nucleotides line up by complementary base pairing with the exposed bases on each template strand.

Hydrogen bonds only form between adenine and thymine and between cytosine and guanine, so the new strand is complementary to its template.

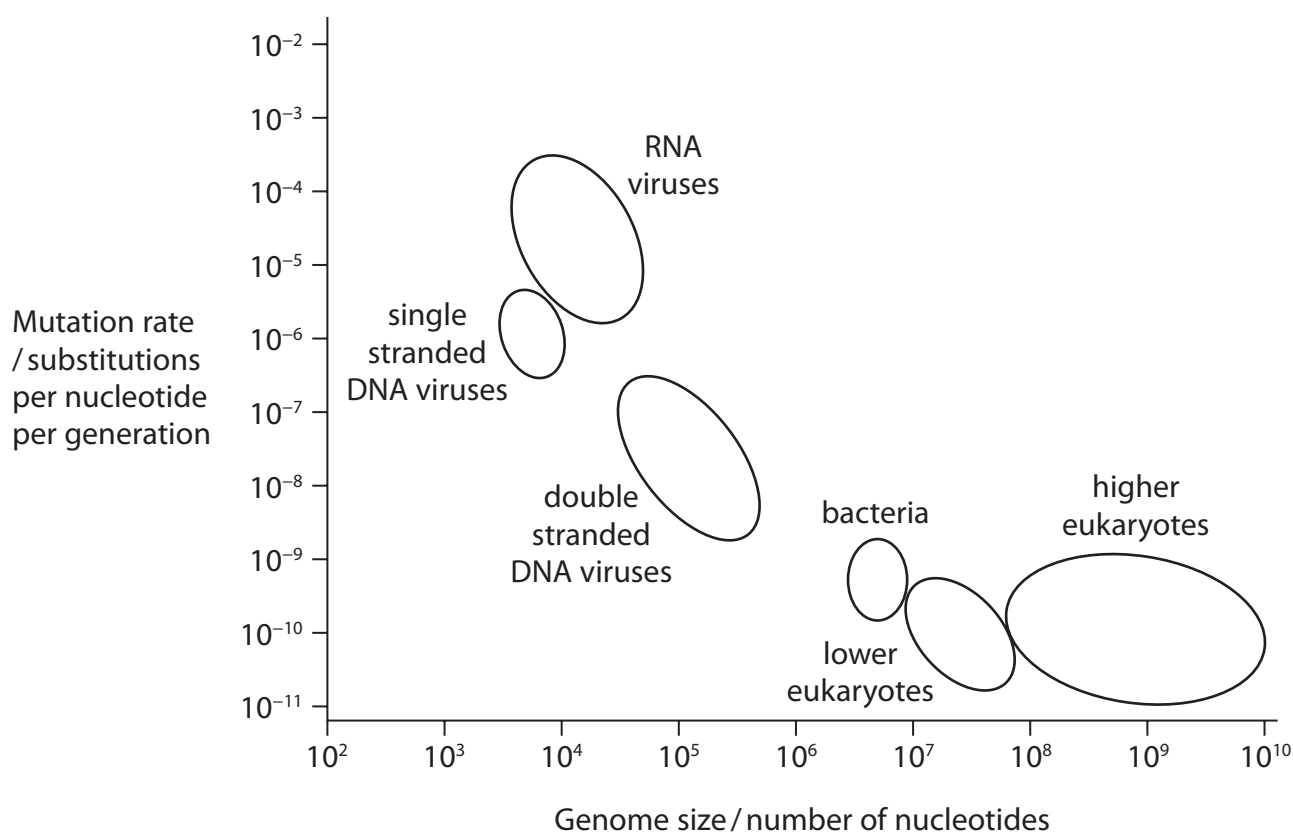
DNA polymerase forms phosphodiester bonds between adjacent nucleotides of the new strand.

The leading strand is made continuously, but the lagging strand is made in fragments which are joined by DNA ligase.

This is semi-conservative replication: each new molecule has one original strand and one new strand, so the two molecules are identical.



- (b) The graph shows the relationship between genome size and mutation rates of organisms.



- (i) Analyse the graph to determine the approximate mutation rate for tobacco mosaic virus (TMV).

(2)

TMV is an RNA virus, genome about 6×10^3 nucleotides

reading the RNA virus area: about 10^{-4}

= 1×10^{-4} substitutions per nucleotide per generation

Answer 1×10^{-4}



- (ii) Comment on the relationship between genome size and mutation rate of the organisms shown in the graph.

(3)

As genome size increases, the mutation rate decreases (negative correlation).

RNA viruses have the highest mutation rates (about 10^{-5} to 10^{-3}), and single-stranded nucleic acids (RNA and single-stranded DNA viruses) have higher mutation rates than double-stranded DNA.

This is because a single-stranded template has no complementary strand to check against, so errors are not corrected, and it is less stable.

Viruses have higher mutation rates than bacteria, and eukaryotes have the lowest mutation rates and the largest genomes.

(Total for Question 5 = 10 marks)



P 6 5 4 5 7 A 0 1 9 4 0

6 Acetylcholine is a neurotransmitter released by neurones in the autonomic nervous system.

(a) (i) Which of the following substances bind to acetylcholine receptors?

(1)

1. cobra venom
2. nicotine
3. lidocaine

- ☒ **A** 1 and 2
- ☐ **B** 1 and 3
- ☐ **C** 1, 2 and 3
- ☐ **D** 2 and 3

(ii) Which row is correct for acetylcholine?

(1)

	Type of neurone that releases acetylcholine	Effect of acetylcholine
☐ A	parasympathetic neurone	increases heart rate
☒ B	parasympathetic neurone	decreases heart rate
☐ C	sympathetic neurone	increases heart rate
☐ D	sympathetic neurone	decreases heart rate



(iii) Describe the events that lead to the release of acetylcholine at a synapse.

(3)

An action potential (impulse) arrives at the presynaptic terminal (knob) and depolarises the presynaptic membrane.

Voltage-gated calcium ion channels open and calcium ions (Ca^{2+}) diffuse into the presynaptic knob.

This causes vesicles containing acetylcholine to move to the presynaptic membrane.

The vesicles fuse with the membrane and release acetylcholine into the synaptic cleft by exocytosis.

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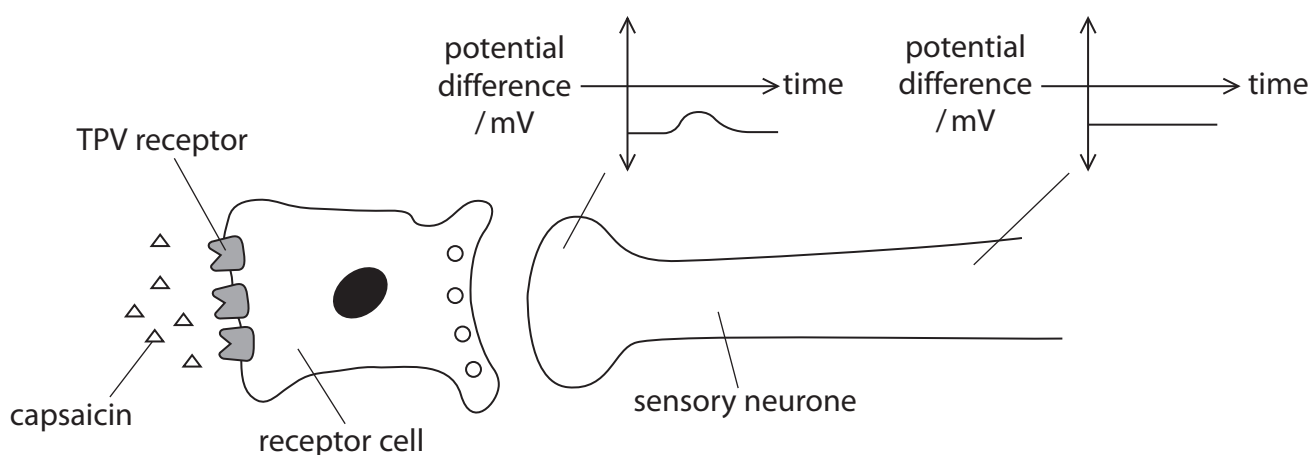
(b) Capsaicin is a substance found in chilli plants that makes them taste 'hot.'

Capsaicin binds to temperature receptor proteins called TPV receptors. This stimulates impulses along sensory neurones that send impulses to the brain.

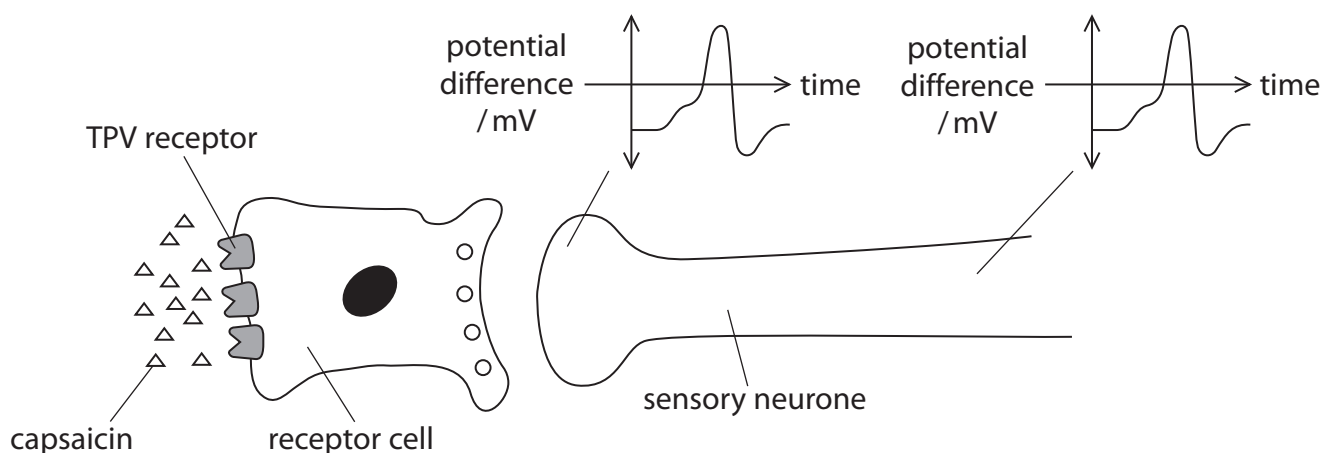
The effect of capsaicin on the depolarisation of the membrane of a sensory neurone was investigated. The potential difference across the membrane was measured at two places on the sensory neurone after adding capsaicin.

The results for a high concentration and a low concentration of capsaicin are shown in the diagram.

Low concentration of capsaicin



High concentration of capsaicin



(i) Explain the effect of capsaicin on the depolarisation of the sensory neurone.

(3)

Capsaicin binds to the TPV receptors in the membrane of the receptor cell.

This causes neurotransmitter to be released from the receptor cell onto the sensory neurone, opening sodium ion channels so sodium ions flow in, generating an EPSP (generator potential).

At a low concentration the depolarisation is small and does not reach the threshold, so no action potential forms.

At a high concentration the depolarisation overcomes the threshold, voltage-gated sodium channels open and an action potential is produced, which moves along the neurone (seen at the second electrode).



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- *(ii) Capsaicin affects sweat production. It has been suggested that capsaicin could be used to lower the temperature of people with fevers.

The effect of three different doses of capsaicin on sweat production was investigated.

Five students took one 10 mg tablet of capsaicin each day, for one week.

The mass of sweat produced from a 10 cm^2 area of skin was measured one hour after taking each tablet of capsaicin.

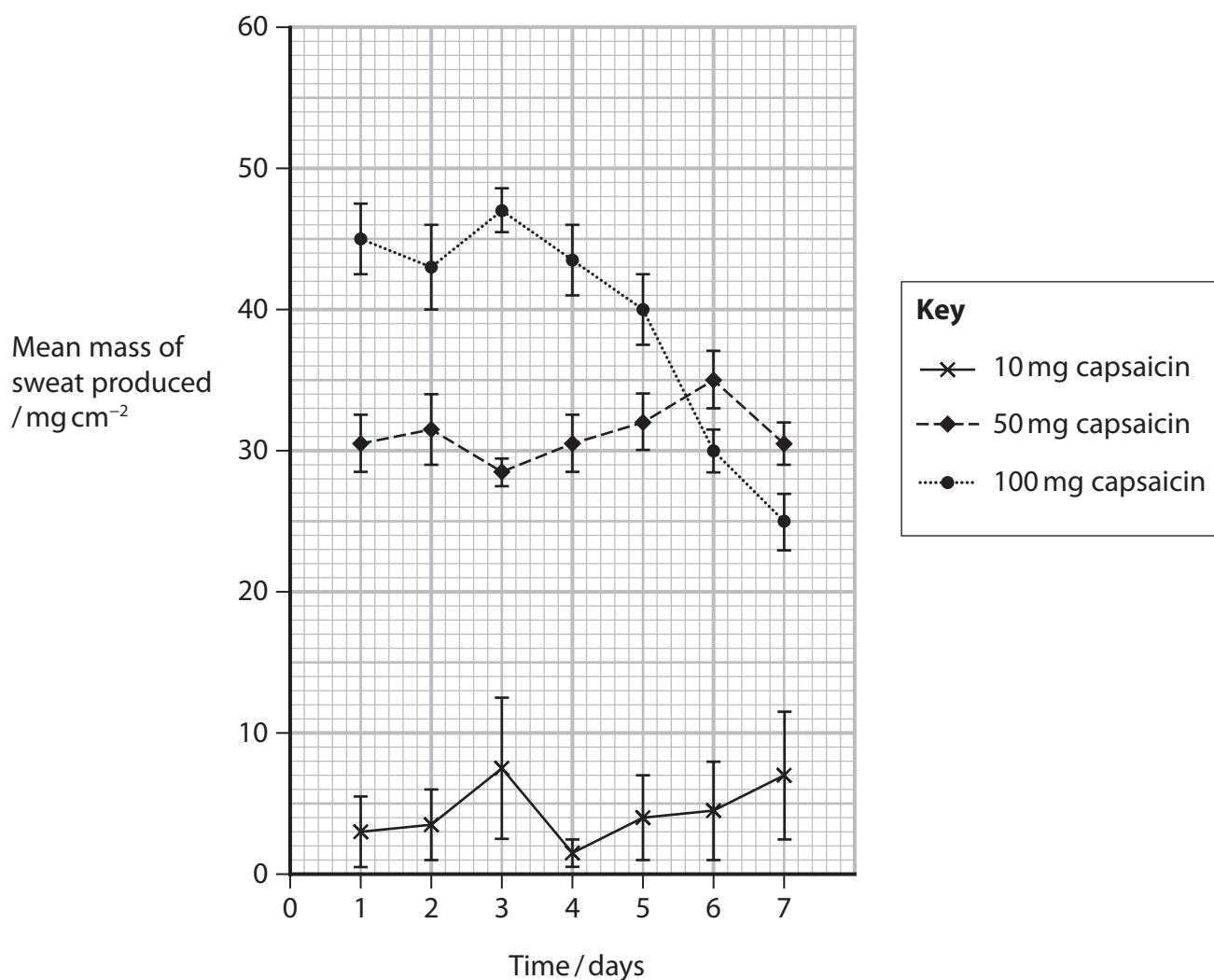
The mean mass of sweat per square centimetre of skin for the group of students was calculated for each day.

This was repeated with different groups of students taking 50 mg of capsaicin and taking 100 mg of capsaicin.

Most of the students who were given 100 mg of capsaicin reported a burning sensation and redness of the skin.

The results are shown in the graph.

Error bars represent standard deviations.



Analyse the data to discuss the use of capsaicin to lower the temperature of people with fevers.

(6)

Higher doses increase the mass of sweat: 100 mg gives about 45 mg cm^{-2} and 50 mg about 30 mg cm^{-2} ; 10 mg has much less effect (below 8 mg cm^{-2}).

10 mg and 50 mg have roughly the same effect over all seven days, but the effect of 100 mg decreases after day 3, and by days 6 to 7 it produces less sweat than 50 mg (25 compared with 31 mg cm^{-2}).

Evaporation of water from sweat requires heat energy; water has a high latent heat of vaporisation, so more sweating removes a lot of heat and could lower the temperature.

So 50 mg seems to be the optimal dose, because 100 mg begins to lose its effect after 3 to 5 days and causes side effects such as a burning sensation and red skin.

Validity: for 50 mg the error bars (standard deviations) all overlap, so sweat production is consistent; the 50 mg and 100 mg means are significantly higher than 10 mg as their standard deviations do not overlap. 10 mg has large standard deviations, showing high variation between volunteers.

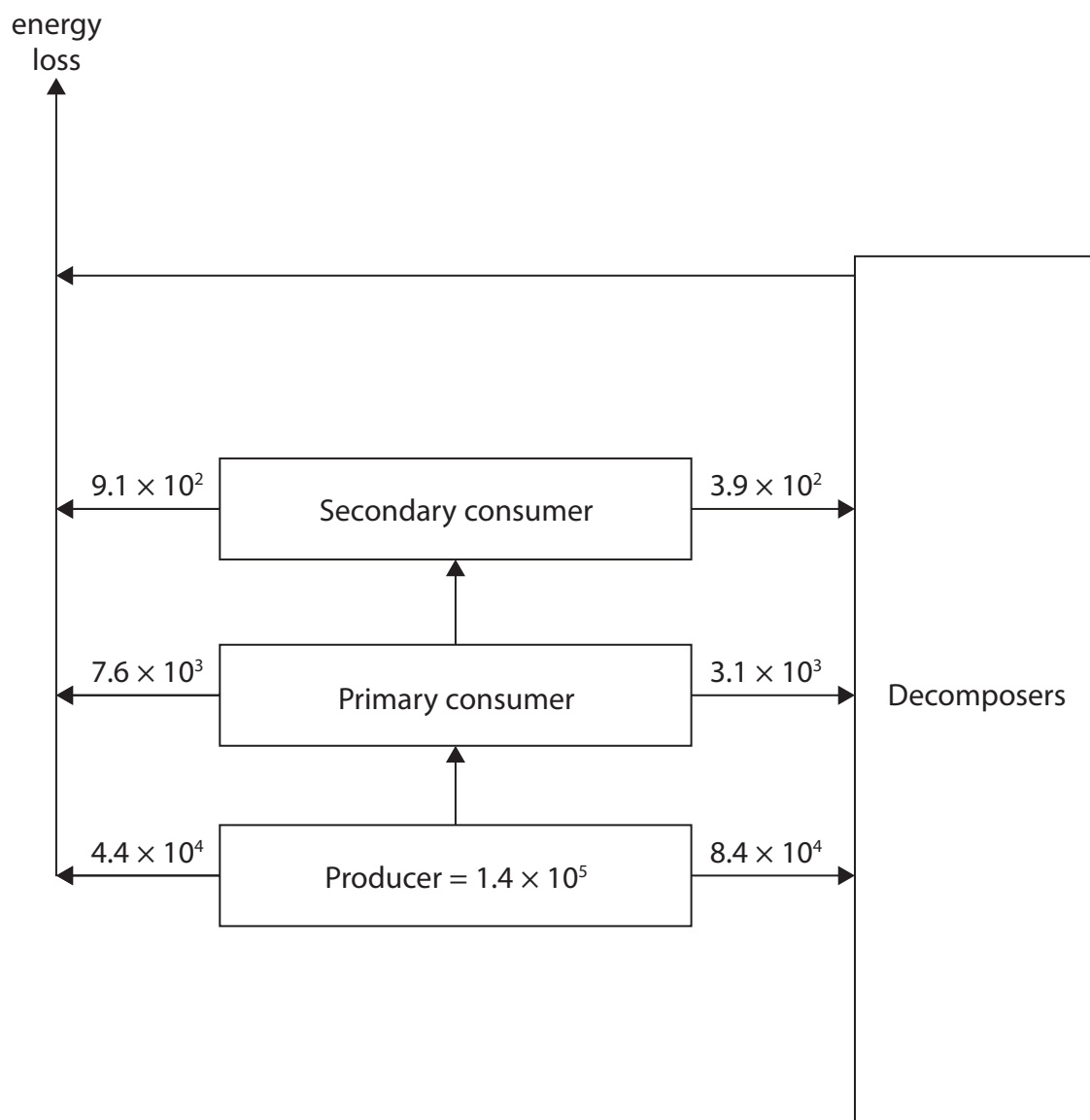
However, there is no control, the sample size is small (five per dose) and the students did not have fevers; capsaicin may make illness worse or interfere with other medicines.

(Total for Question 6 = 14 marks)



- 7 (a) (i) The diagram shows the transfer of energy through a grassland food chain.

All values are given in $\text{kJ m}^{-2} \text{yr}^{-1}$.



Calculate the percentage efficiency of the energy transfer from the producer to the primary consumer.

(2)

$$\text{energy in primary consumers} = 7.6 \times 10^3 + 3.1 \times 10^3$$

$$+ 9.1 \times 10^2 + 3.9 \times 10^2 = 1.2 \times 10^4 \text{ kJ m}^{-2} \text{ yr}^{-1}$$

$$\text{efficiency} = (1.2 \times 10^4 \div 1.4 \times 10^5) \times 100$$

$$= 8.57 \%$$

Answer 8.6 %



- (ii) Explain the differences in the efficiency of energy transfer between the trophic levels in a food chain.

(3)

Much of the energy in producers is not transferred to primary consumers because producers have more indigestible or inedible parts (e.g. cellulose, lignin, roots), which are not eaten or are lost in faeces.

Animals (primary and secondary consumers) have higher respiration rates than producers, so more energy is lost as heat and used in movement and maintaining body temperature.

Animals also lose more energy in excretion (urea) than producers; different organisms have different amounts of indigestible parts and respiration rates, so efficiency differs between levels.

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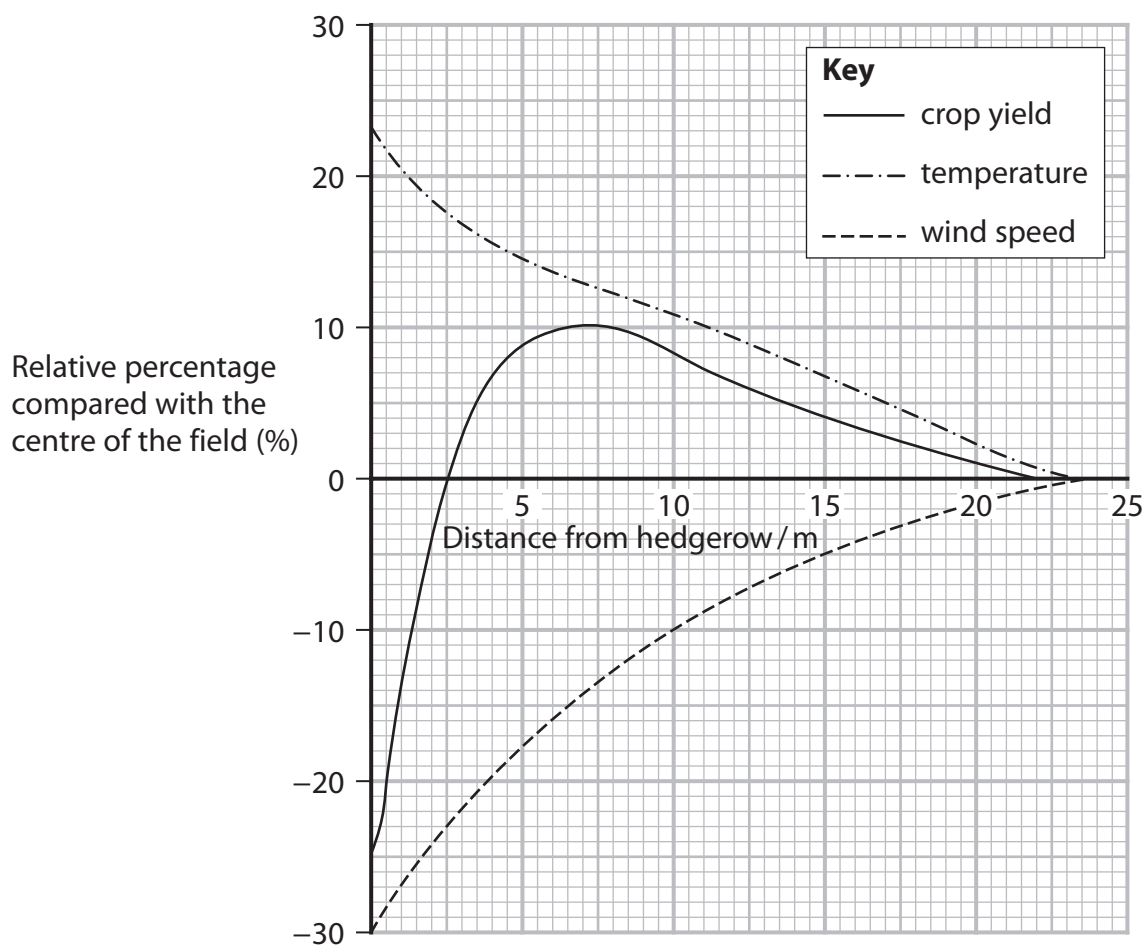
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- *(b) For many years, hedgerows have been removed to increase field sizes to grow crop plants.

Hedgerows provide a habitat for many species of plants and animals.

Some animals that live in hedgerows eat pests of crops and some pollinate crop plants.

The crop yield, temperature and wind speed were measured across the field starting at the hedge. These factors and the crop yield are shown as a relative percentage compared with the centre of the field in the graph.



Analyse the information to comment on the value of conserving hedges around fields used for growing crops.

(6)

Crop yield is lowest right next to the hedgerow (about -25% at 0 m , lower than the centre of the field up to about 2.5 m), then increases to a maximum of about $+10\%$ between 5 m and 10 m , and then decreases towards the centre.

Wind speed is lowest by the hedge (about -30%) and increases with distance, and temperature is highest by the hedgerow (about $+23\%$) and falls with distance.

The hedgerow acts as a windbreak; reduced wind speed increases the temperature and humidity near the hedge, so transpiration and evaporation (water loss) from the crop are lower.

Between 5 m and 15 m the higher temperature is closer to the optimum temperature for enzymes, so the rate of photosynthesis increases, increasing yield. Less wind also reduces damage to crops.

Within about 2 m of the hedge yield is lower because of shading, reducing photosynthesis, and competition with hedge plants for water, nutrients and light.

Biotic factors: hedges are a habitat for pollinators, which are essential for seeded crops, and for predators which eat the herbivores (pests), so less pesticide is needed and productivity increases.

So conserving hedges can increase crop yield and biodiversity, but hedges take up land that could grow crops, so fields need to be smaller; on balance hedges are of value, as yield is above that of the centre for much of the 25 m .

(Total for Question 7 = 11 marks)

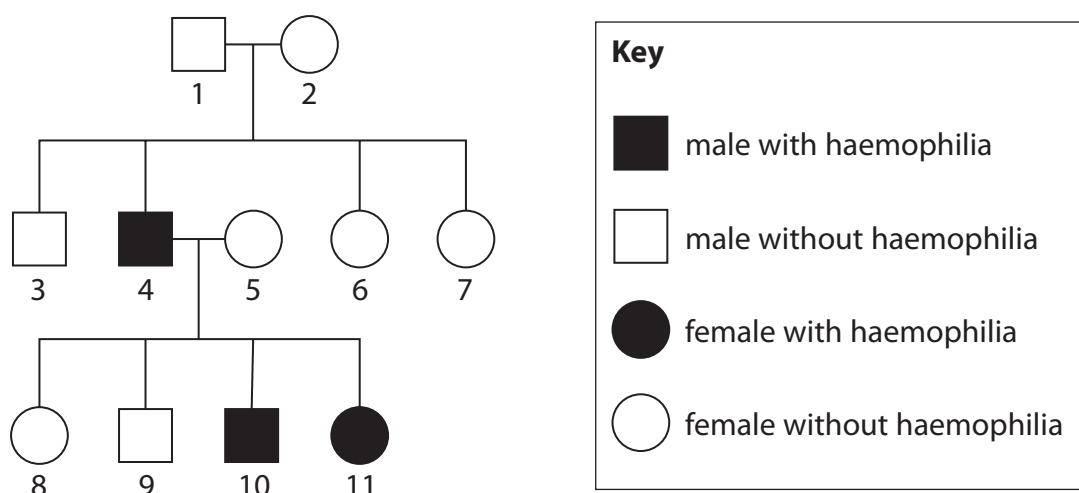


- 8 (a) Haemophilia is a sex linked, genetic condition that prevents blood clotting.

X^H is the allele for blood clotting

X^h is the allele for haemophilia

The pedigree diagram shows a family that has individuals who have haemophilia.



- (i) What are the genotypes of individuals 1 and 2?

(1)

- ☐ **A** X^HY and X^HX^H
- ☐ **B** X^hY and X^HX^h
- ☐ **C** X^hY and X^HX^H
- ☒ **D** X^HY and X^HX^h



- (ii) Use a genetic diagram to determine the probability that the next child of individuals 4 and 5 will be a boy without haemophilia.

(3)

parents: 4 = X^hY × 5 = X^HX^h

(5 is a carrier, as daughter 11 has haemophilia)

gametes: X^h , Y X^H , X^h

	X^H	X^h
X^h	X^HX^h	X^hX^h
Y	X^HY	X^hY

boy without haemophilia = X^HY = 1 out of 4

Answer... 0.25 (25%)



- (b) Kidney dialysis machines are used to remove urea from the blood of patients who are suffering from kidney disease.

Anti-clotting drugs are given to patients to reduce the risk of blood clot formation whilst undergoing kidney dialysis.

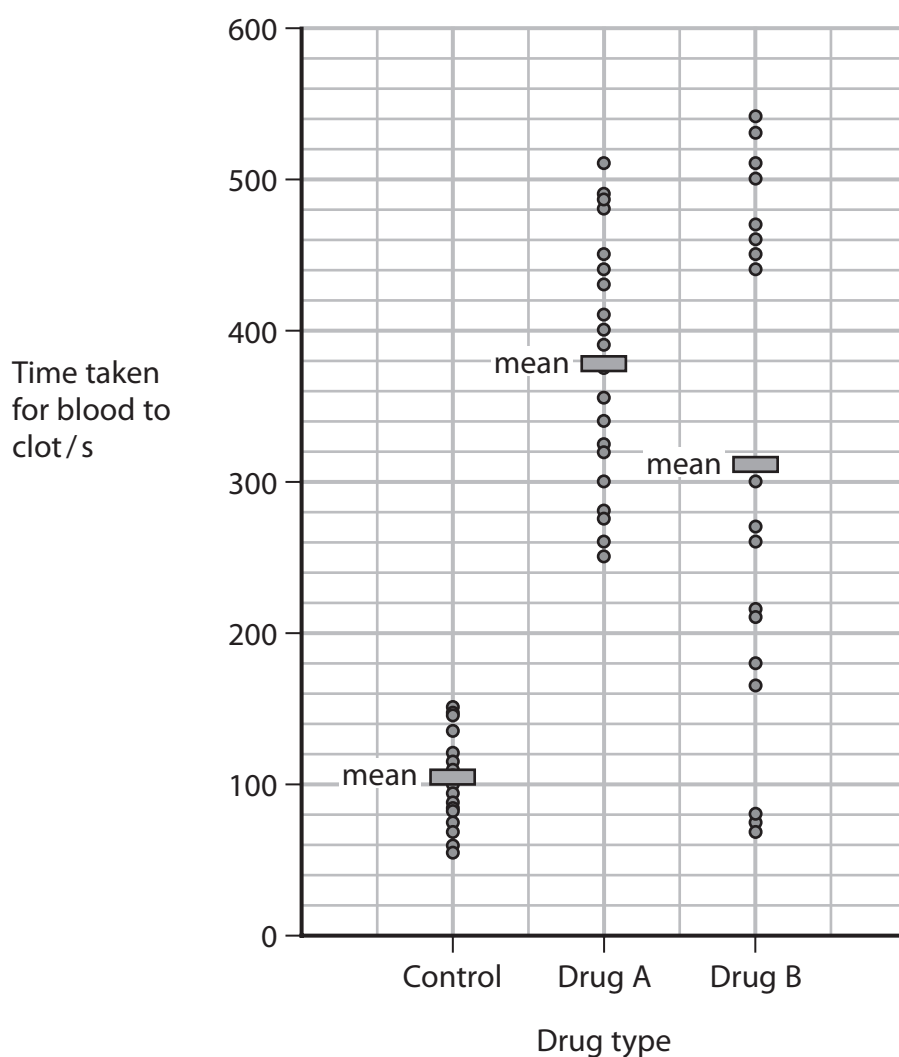
The potential use of two anti-clotting drugs, Drug A and Drug B, was investigated.

Blood samples were taken from 20 healthy adults and placed into test tubes.

The times taken for the blood samples to clot after addition of 2 mg dm^{-3} of Drug A were recorded.

This was repeated with Drug B and again with a control.

The results are shown in the graph.



It takes 40 minutes for Drug A to become inactive in a person and 110 minutes for Drug B to become inactive.

Analyse the data to discuss the use of Drug A and Drug B to prevent the formation of blood clots.

(5)

Both drugs increase the mean clotting time compared with the control (about 100 s):

Drug A to about 380 s and Drug B to about 310 s.

There is little variation in the control group (about 60 to 150 s), but Drug B has the highest variation (range about 70 to 540 s), more spread than Drug A (about 250 to 510 s).

Drug B does not increase clotting time for some blood samples, as some of its values overlap with the control group, whereas Drug A increased the clotting time for all samples, with no overlap with the control.

Drug B takes 110 minutes to become inactive, so it has a slower clearance time and patients would be at risk of bleeding after dialysis.

So Drug A would be better, as it works for all samples and is cleared from the body faster (40 minutes), allowing the blood to clot sooner after dialysis. However, only 20 healthy adults were tested, not dialysis patients.

(Total for Question 8 = 9 marks)



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9 Auxins and cytokinins are plant growth regulators that control apical dominance and cell elongation.

(a) Explain how auxins and cytokinins control the growth of lateral buds.

(3)

Auxin is produced and released by the terminal (apical) bud and diffuses down the stem.

Auxin inhibits the action of cytokinin and so inhibits lateral bud (shoot) growth, causing apical dominance.

Cytokinin is produced at the base of the shoot (in the roots) and stimulates lateral bud growth; the two act antagonistically, so if the apex is removed the lateral buds grow.

(b) Auxin is an uncharged molecule when it diffuses through the cell surface membrane. When inside the cytoplasm, auxin develops a negative charge. Auxin leaves cells by facilitated diffusion.

Explain how the structure of the cell membrane affects the transport of auxin.

(2)

Uncharged auxin can diffuse through the phospholipid bilayer, between the non-polar (hydrophobic) fatty acid tails.

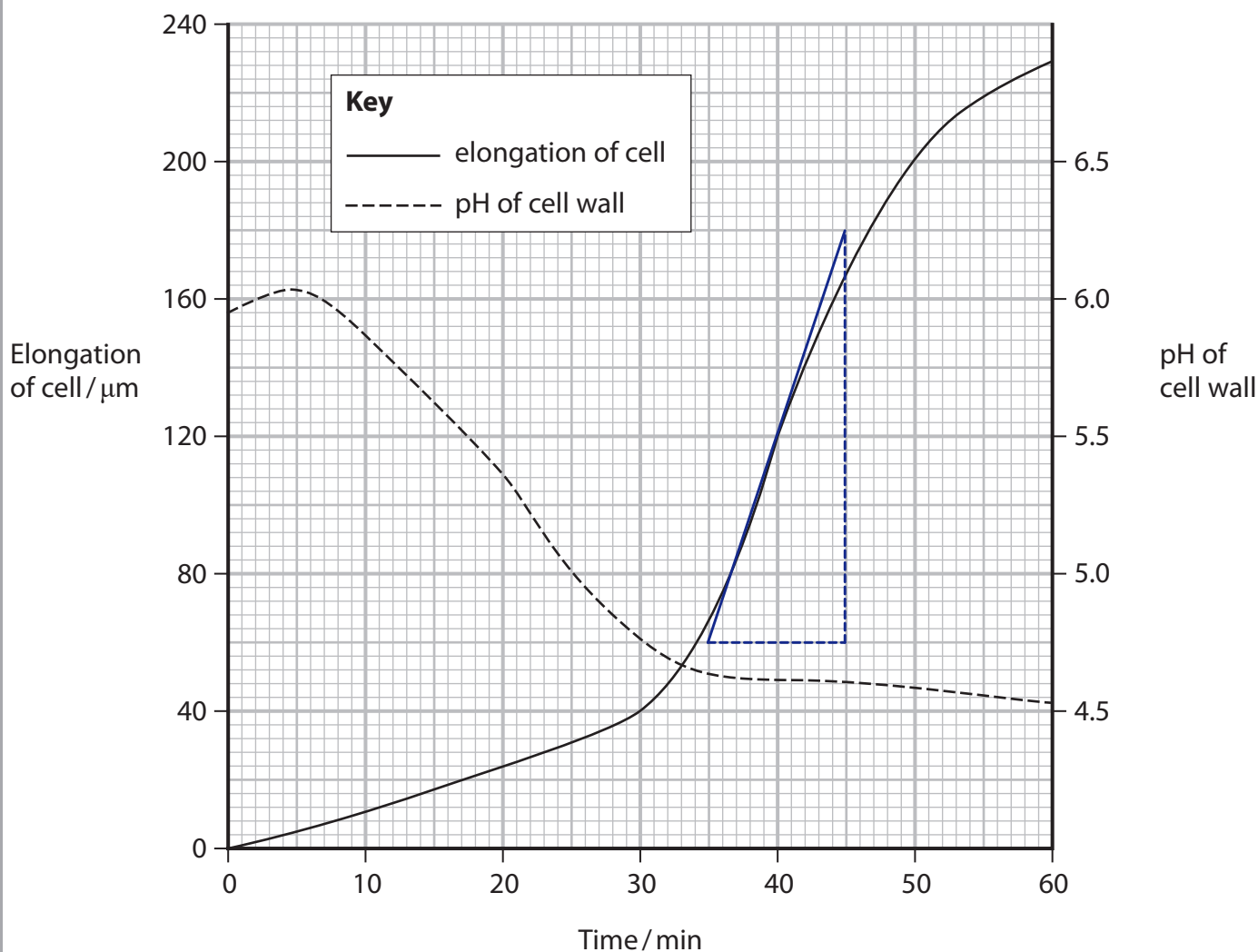
Negatively charged auxin cannot pass through the hydrophobic tails, so it has to leave through protein channels or carrier proteins.



- (c) When auxin enters a cell, it causes hydrogen ions to be pumped out of the cell into the cell wall.

The effect of auxin on the pH of the cell wall and cell elongation was investigated. Auxin was added to plant cells. The pH of the cell wall and cell elongation were measured over a period of 60 minutes.

The results are shown in the graph.



- (i) Calculate the maximum rate of elongation of the cell.

(2)

tangent at steepest part (about 40 min):

$$\text{rate} = (180 - 60) \div (45 - 35) = 120 \div 10$$

$$= 12 \mu\text{m min}^{-1}$$

Answer 12 $\mu\text{m min}^{-1}$



(ii) Expansin is a protein located in cell walls.

Expansin disrupts hydrogen bonds and ionic bonds of molecules in the cell wall.

Deduce a mechanism by which auxin and expansin cause cells to elongate.

(3)

Auxin causes hydrogen ions to be pumped into the cell wall, so the pH of the cell wall

falls (from about 6.0 to 4.6), and as the pH falls the elongation of the cell increases.

The low pH (hydrogen ions) activates expansin, changing its shape so that it can act on the cell wall.

Expansin breaks the hydrogen bonds and ionic bonds between cellulose microfibrils, hemicelluloses and calcium pectate, weakening (loosening) the cell wall.

The cell takes in water by osmosis, and the turgor pressure stretches the loosened wall, so the cell expands and elongates.

(Total for Question 9 = 10 marks)

TOTAL FOR PAPER = 90 MARKS



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