

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
Thursday 11 June 2020			
Morning (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.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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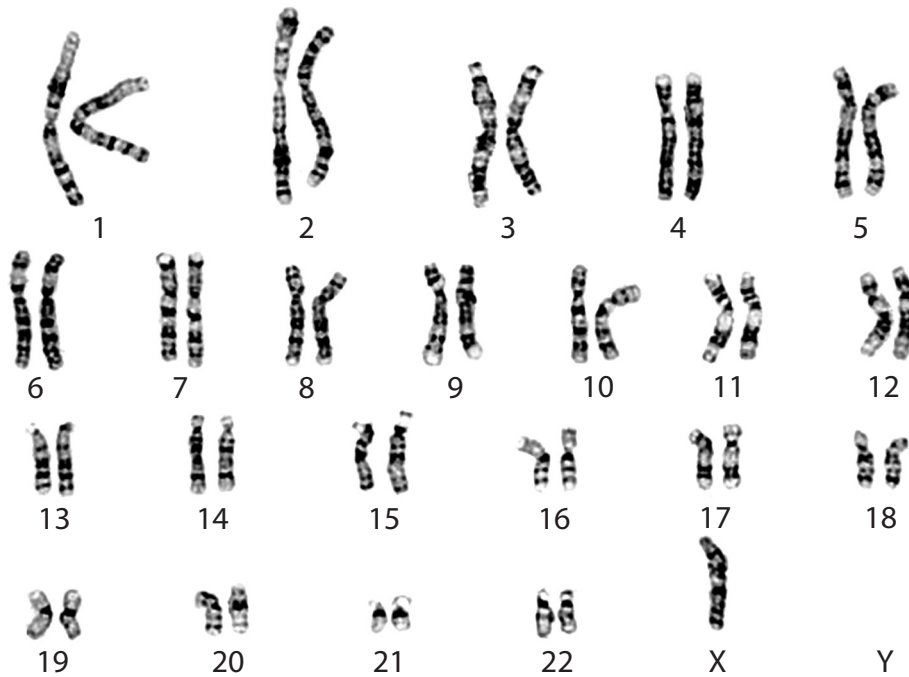
Answer ALL questions.

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 A karyotype shows the chromosomes found in the cells of an individual.

The photograph shows a karyotype from a child with a genetic condition.



(Source: © Dept. of Clinical Cytogenetics, Addenbrookes Hospital / Science Photo Library)

- (a) (i) Which of the following identifies the genetic condition shown in the photograph? (1)

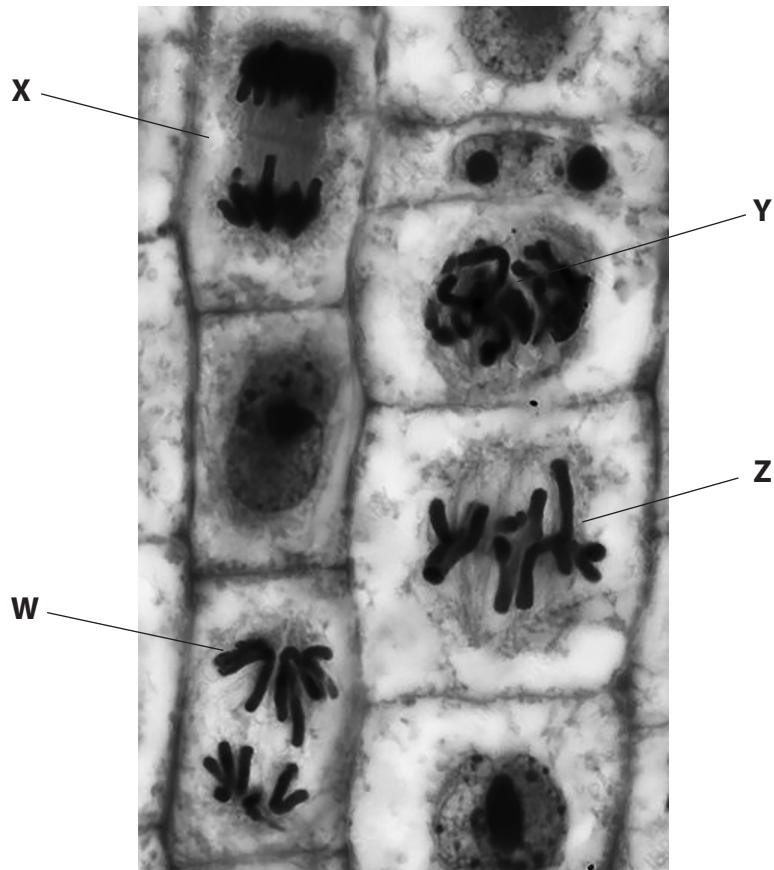
- ☐ A Down's syndrome due to monosomy
- ☐ B Down's syndrome due to polysomy
- ☒ C Turner's syndrome due to monosomy
- ☐ D Turner's syndrome due to polysomy

- (ii) Which process would have caused the genetic condition shown by this karyotype? (1)

- ☐ A base insertion
- ☐ B base substitution
- ☒ C non-disjunction
- ☐ D translocation



(b) The photograph shows cells in different stages of mitosis.



(Source: © STEVE GSCHMEISSNER / Science Photo Library)

(i) Which of the following correctly identifies the stages shown in the photograph?

(1)

	W	X	Y	Z
☒ A	anaphase	telophase	prophase	metaphase
☐ B	anaphase	prophase	telophase	metaphase
☐ C	prophase	anaphase	metaphase	telophase
☐ D	telophase	metaphase	anaphase	prophase



P 6 2 1 3 3 A 0 3 3 6

(ii) Colchicine is a chemical that inhibits mitosis.

A student investigated the effect of colchicine on mitosis.

Two sets of genetically identical cells were grown in culture. Colchicine was added to one culture of cells but not to the other culture of cells.

Six hours after treatment, the mean percentages of cells in each stage of mitosis were determined.

The results are shown in the table.

Mitosis stage	Mean percentage of cells in stage $\pm$ Standard Deviation	
	cells cultured without colchicine	cells cultured with colchicine
interphase	84.8 $\pm$ 4.2	82.8 $\pm$ 3.2
prophase	10.2 $\pm$ 2.2	16.3 $\pm$ 3.1
metaphase	1.8 $\pm$ 0.4	0.8 $\pm$ 0.2
anaphase	1.8 $\pm$ 0.2	0.7 $\pm$ 0.1
telophase	1.4 $\pm$ 0.3	0.4 $\pm$ 0.1

Analyse the data to comment on how colchicine affects mitosis.

(4)

Colchicine has no effect on the percentage of cells in interphase (84.8 and 82.8), as the standard deviations overlap, so the difference is not significant.

With colchicine more cells are in prophase (16.3% compared with 10.2%), so colchicine arrests cells at prophase.

Fewer cells reach metaphase, anaphase and telophase with colchicine (e.g. 0.8% compared with 1.8% in metaphase), and the standard deviations do not overlap, so these differences are significant.

This suggests colchicine inhibits spindle formation, so chromosomes cannot attach to the spindle and line up at the equator, and mitosis stops at prophase.

(Total for Question 1 = 7 marks)



2 Acetylcholine is a neurotransmitter produced by the parasympathetic nervous system.

(a) Describe the process by which acetylcholine is released from a synapse.

(4)

An action potential (impulse) arrives at the presynaptic membrane of the synaptic knob.

This depolarisation causes voltage gated calcium channels to open, and calcium ions diffuse into the neurone.

Calcium ions cause vesicles containing acetylcholine to move towards the presynaptic membrane.

The vesicles fuse with the presynaptic membrane and acetylcholine is released into the synaptic cleft by exocytosis.

(b) Some chemical pesticides, such as diisopropyl fluorophosphate (DFP), affect the activity of synapses.

This pesticide acts by binding irreversibly to the R group of an amino acid in the active site of acetylcholinesterase.

(i) Explain why DFP inhibits the activity of acetylcholinesterase.

(2)

DFP binding to the R group changes the shape (and charge) of the active site of acetylcholinesterase,

so acetylcholine can no longer bind to the active site and no enzyme substrate complexes form.



(ii) Explain why a person poisoned with DFP has a slower heart rate.

(3)

Acetylcholine released by the parasympathetic (vagus) neurone is not broken down, so it builds up in the synaptic cleft,

so it continues to bind to acetylcholine receptors in the SA node, which reduces the frequency of depolarisations, so fewer impulses are sent from the SA node.

Noradrenaline from the sympathetic neurones has less effect, so the heart rate is slower.

(Total for Question 2 = 9 marks)

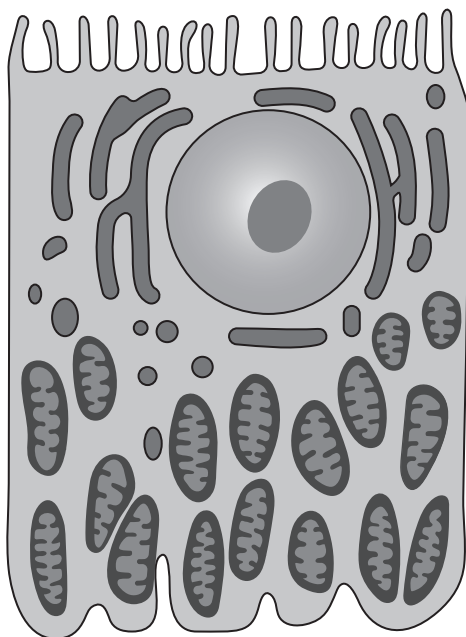
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- 3 (a) The diagram shows a cell from the proximal convoluted tubule of the nephron.



Explain how the features shown in the diagram enable this cell to carry out its function. (4)

The cell has a large number of mitochondria, which carry out aerobic respiration to provide ATP for the active uptake (selective reabsorption) of glucose, amino acids and salts such as sodium ions.

The microvilli provide a large surface area for reabsorption, with many carrier proteins in the membrane for the uptake of glucose, amino acids and salts (e.g. sodium ion cotransporter proteins), so substances are reabsorbed quickly from the filtrate into the blood.

(b) (i) Which of the following statements about facilitated diffusion are correct?

(1)

1. substances move through membrane proteins
2. substances move against a concentration gradient
3. substances move down a concentration gradient
4. substances move between phospholipids

- ☐ **A** 1 and 2
- ☒ **B** 1 and 3
- ☐ **C** 2 and 3
- ☐ **D** 2 and 4

(ii) The collecting duct is also part of the nephron.

Which of the following are the effects of increased release of antidiuretic hormone (ADH)?

(1)

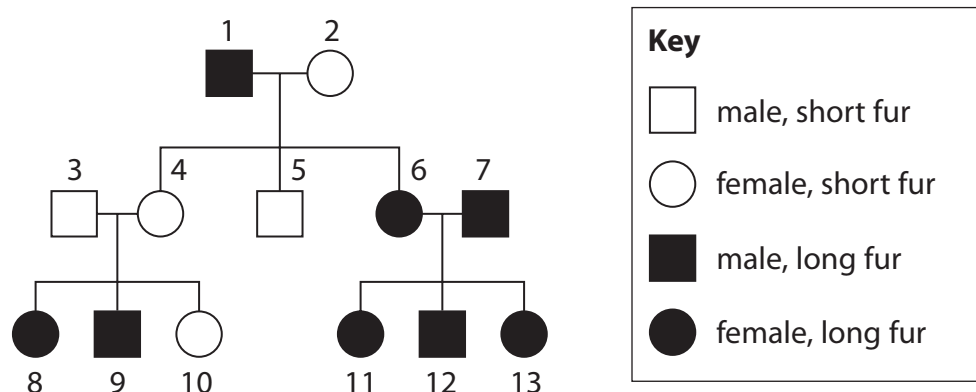
- ☐ **A** decreased permeability of the collecting duct to water, producing more concentrated urine
- ☐ **B** decreased permeability of the collecting duct to water, producing more dilute urine
- ☒ **C** increased permeability of the collecting duct to water, producing more concentrated urine
- ☐ **D** increased permeability of the collecting duct to water, producing more dilute urine

(Total for Question 3 = 6 marks)



- 4 In cats, the gene for fur length is not located on the X chromosome. The allele for short fur (F) is dominant to the allele for long fur (f).

The pedigree diagram shows the inheritance of fur length in a family of cats.



- (a) Explain how one piece of evidence from the diagram shows that the allele for short fur is dominant to the allele for long fur.

(2)

Cats 3 and 4 both have short fur but produce offspring with long fur (cats 8 and 9), so cats 3 and 4 must both be heterozygous (carriers, Ff): the long fur allele is hidden by the short fur allele, so short fur is dominant.

- (b) A gene for fur colour in cats is located on the X chromosome.

The alleles for black fur (X^B) and orange fur (X^O) are codominant.

Tortoiseshell cats have areas of black and orange fur.

- (i) Give all the possible genotypes of a male, black cat with short fur.

(1)

$X^B Y FF$ and $X^B Y Ff$



(ii) Explain why all tortoiseshell cats are female.

(2)

Male cats have only one X chromosome (XY), so they can only carry one fur colour allele, X^B or X^o .

Female cats have two X chromosomes, so they can have both alleles, X^B and X^o ; as these are codominant both are expressed, giving tortoiseshell fur.

(iii) In a genetic cross, a tortoiseshell cat with long fur was mated with an orange male cat, heterozygous for fur length.

Deduce the probability of producing a tortoiseshell cat with long fur from this cross.

Use a genetic diagram to support your answer.

(4)

Parent phenotypes: tortoiseshell, long fur $\times$ orange, short fur

Parent genotypes: $X^B X^o ff$ $\times$ $X^o Y Ff$

Gametes: $X^B f$ $X^o f$ $\times$ $X^o F$ $X^o f$ YF Yf

	$X^o F$	$X^o f$	YF	Yf
$X^B f$	$X^B X^o Ff$	$X^B X^o ff$	$X^B YFf$	$X^B Yff$
$X^o f$	$X^o X^o Ff$	$X^o X^o ff$	$X^o YFf$	$X^o Yff$

Tortoiseshell with long fur = $X^B X^o ff$ = 1 out of 8 offspring

Probability = $1/8 = 0.125$ (12.5%)

(Total for Question 4 = 9 marks)



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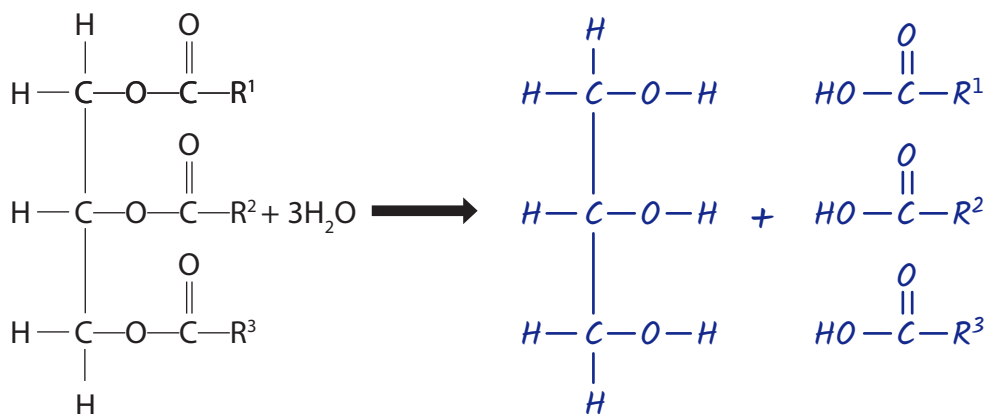


5 Palm plants and cocoa plants are used to produce lipids for the food industry.

Palm oil is produced from palm plants. Cocoa butter is produced from cocoa plants.

(a) Palm oil and cocoa butter are made of triglycerides composed of different fatty acids.

The diagram shows a triglyceride.



Complete the diagram to show the products of hydrolysis of this triglyceride.

(2)

(b) The fatty acid compositions of palm oil and cocoa butter are shown in the table.

Fatty acid	Chemical formula of fatty acid	Percentage of fatty acid found in palm oil and cocoa butter (%)	
		Palm oil	Cocoa butter
palmitic acid	$\text{C}_{16}\text{H}_{32}\text{O}_2$	45	27
oleic acid	$\text{C}_{18}\text{H}_{34}\text{O}_2$	40	31
linoleic acid	$\text{C}_{18}\text{H}_{32}\text{O}_2$	10	3
myristic acid	$\text{C}_{14}\text{H}_{28}\text{O}_2$	1	1
stearic acid	$\text{C}_{18}\text{H}_{36}\text{O}_2$	4	38

(i) How many of the named fatty acids shown in the table are saturated?

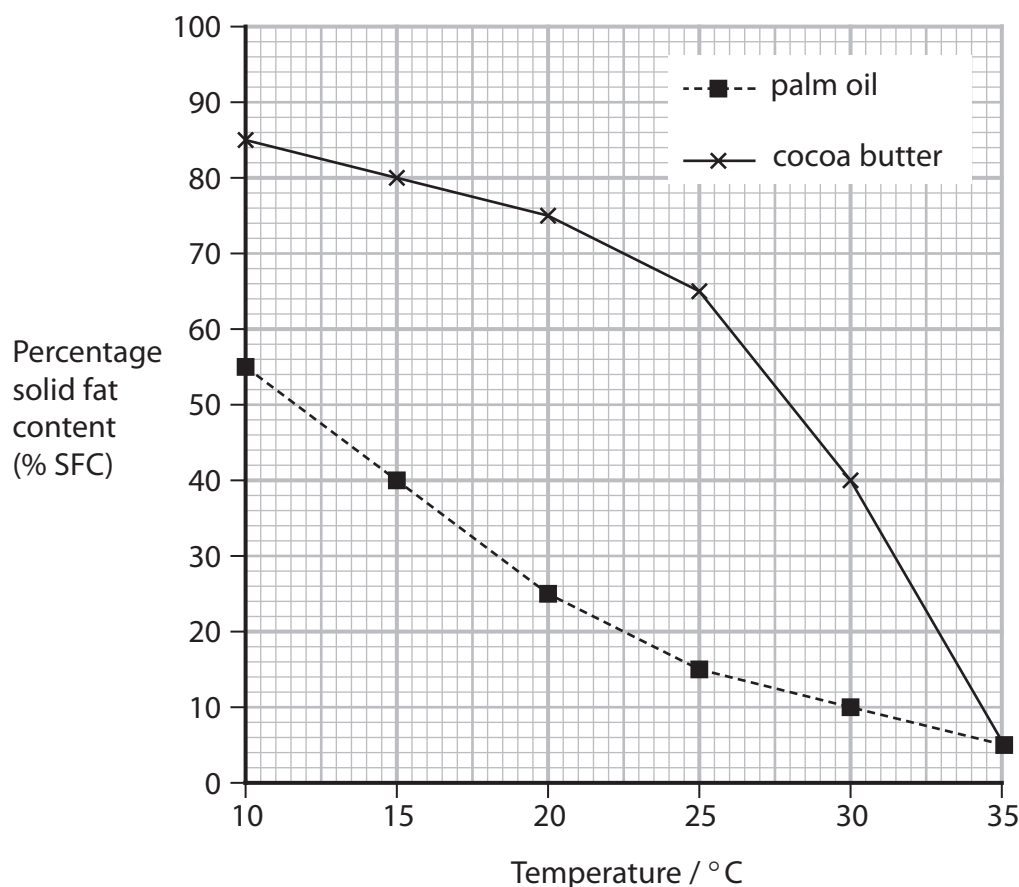
(1)

- ☐ A 1
☐ B 2
☒ C 3
☐ D 4



- (ii) The percentage solid fat content (% SFC) is a measure of how much of a lipid is solid at different temperatures.

The graph shows the effect of temperature on the % SFC for palm oil and for cocoa butter.



Comment on the effect of temperature on the % SFC of palm oil and of cocoa butter.

(4)

The % SFC of both palm oil and cocoa butter decreases as temperature increases, and both have 5% SFC at 35 °C.

The % SFC of cocoa butter is higher at all temperatures below 35 °C, e.g. 85% compared with 55% at 10 °C.

The % SFC of cocoa butter decreases more steeply above 25 °C (65% to 5%).

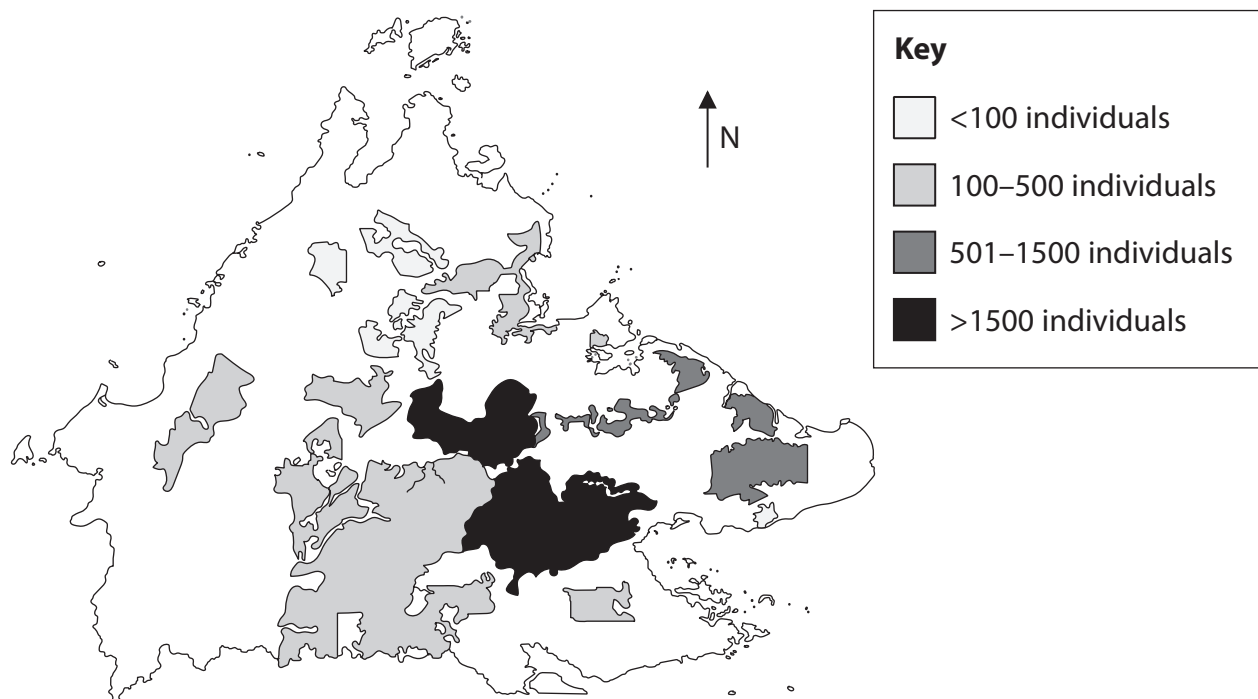
This is because cocoa butter has a higher percentage of saturated fatty acids (stearic acid 38%) with straight chains, so the chains pack more tightly and associate more easily, staying solid at higher temperatures.



- (c) Some forests in Borneo have been cleared to grow these plants.

Orangutans used to live in forests throughout this island but now they are found in small areas of forest.

The map shows the distribution of orangutans in parts of Borneo.



- (i) Explain why in areas with low populations of orangutans, many of the orangutans have deformities and health problems.

(2)

A genetic bottleneck has occurred, so each small population has a smaller gene pool with lower genetic diversity.

So inbreeding occurs and the probability of offspring receiving two recessive (harmful) alleles is higher.



- (ii) The Malaysian government is paying local people to create and maintain 'land-bridges' of forest to link areas of forest together.

Explain why these payments will help to develop palm oil production and support conservation of orangutans.

(3)

The land-bridges let orangutans from different populations move across from forest to forest, so there is more outbreeding,

which increases genetic diversity and widens the gene pool, reducing inbreeding.

The payments balance the needs of local people with conservation, as people keep their jobs and income, so the rest of the land can still be used for palm oil plantations.

Because they are paid, local people are more likely to maintain the bridges.

- (iii) State how treaties such as CITES help conserve orangutans.

(1)

Countries sign the treaty, banning trade (export and import) of orangutans, preventing poaching and illegal trapping.

(Total for Question 5 = 13 marks)



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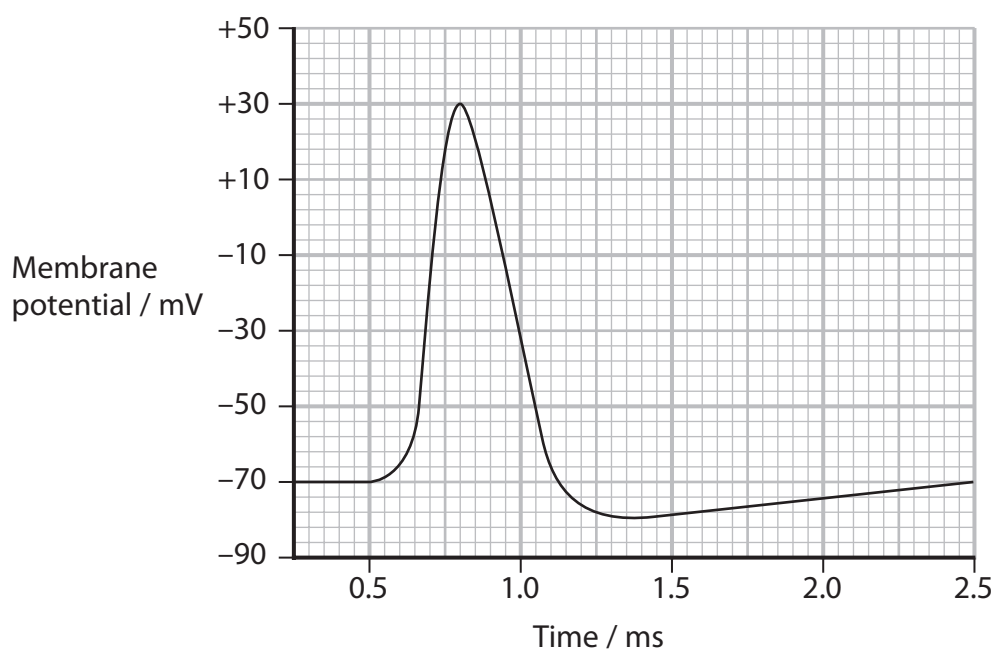
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- 6 The speed of a nerve impulse along a neurone depends on the diameter and the presence or absence of myelin.

(a) The graph shows an action potential in a neurone.



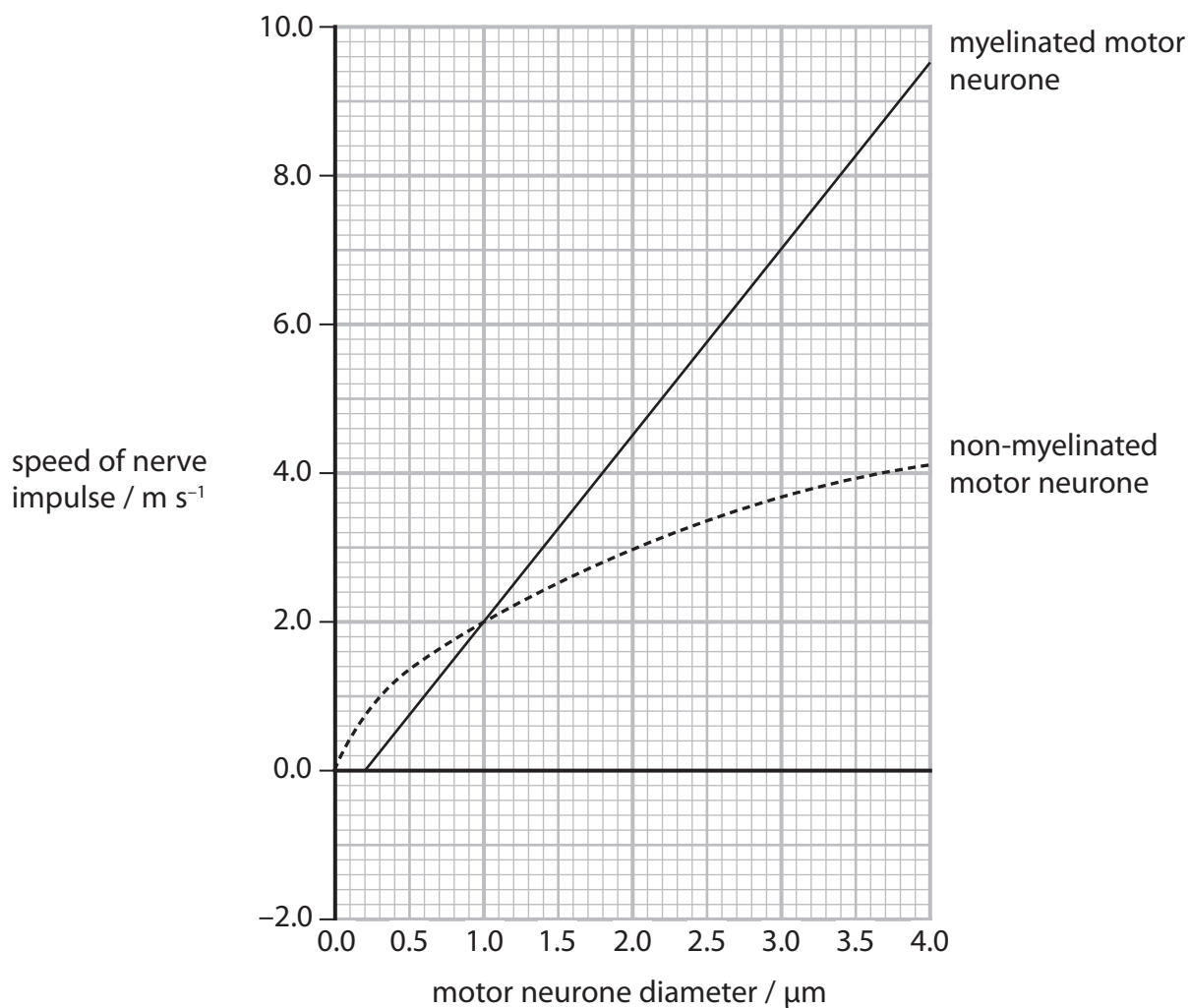
When are voltage-gated sodium channels open?

(1)

- ☐ A 0.25 ms
- ☒ B 0.75 ms
- ☐ C 1.00 ms
- ☐ D 1.25 ms



- (b) The graph shows the relationship between the diameter of the neurone and the speed of nerve impulses along myelinated and non-myelinated motor neurones.



- (i) Compare and contrast the effect of diameter on the speed of an impulse in myelinated and non-myelinated motor neurones.

(4)

Similarity: in both types of neurone the speed of the impulse increases as the diameter increases, and both have the same speed (about 2.0 m s^{-1}) at $1 \mu\text{m}$.

Differences: for diameters above $1 \mu\text{m}$ myelinated neurones are faster, e.g. at $4 \mu\text{m}$ about 9.5 m s^{-1} compared with about 4.1 m s^{-1} .

Below $1 \mu\text{m}$ myelinated neurones are slower than non-myelinated neurones.

Myelinated neurones show a steeper (greater) increase in speed, and a linear (proportional) relationship, whereas the increase for non-myelinated neurones levels off.

- (ii) Determine the speed of a nerve impulse along a myelinated motor neurone with a diameter of $5 \mu\text{m}$.

The equation for a linear relationship is $y = mx + c$

(3)

$$c = y \text{ intercept (extrapolated)} = -0.5 \text{ m s}^{-1}$$

$$\text{gradient } m = 2.0 \div 0.8 = 2.5$$

$$y = 2.5x - 0.5$$

$$y = (2.5 \times 5) - 0.5 = 12.5 - 0.5 = 12$$

Answer 12 m s^{-1}



- (iii) Multiple sclerosis (MS) is a disease that results in the loss of myelin around motor neurones.

Explain why the speed of nerve impulses along axons is slower in people with MS. (3)

In MS there is less myelin, so there are fewer or no nodes of Ranvier, so saltatory conduction does not occur and the impulse cannot jump between nodes. Instead sodium channels have to open in every part of the membrane, so depolarisation has to occur along the whole length of the axon by local currents, which takes longer.

(Total for Question 6 = 11 marks)



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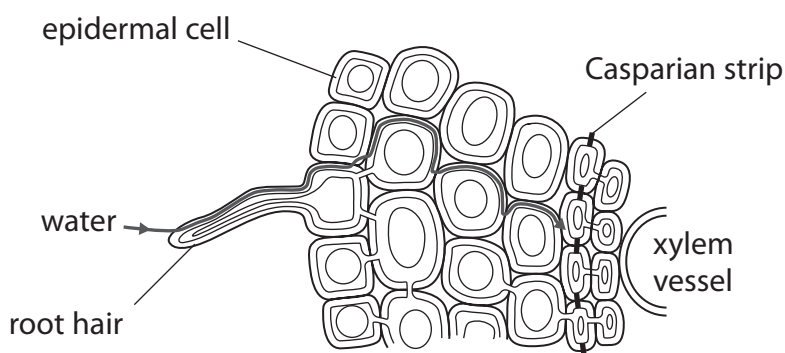
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- 7 The primary productivity of plants depends on their ability to synthesise carbohydrates and transport solutes to cells.

(a) The diagram shows the movement of water across a root.



What is the name of the water movement pathway shown in the diagram?

(1)

- ☒ A apoplastic pathway
☐ B diffusion pathway
☐ C osmotic pathway
☐ D symplastic pathway

(b) Explain how the mass-flow hypothesis accounts for the movement of sugars from leaves to roots.

(4)

Sugars (sucrose) are actively loaded (pumped) into the phloem sieve tubes in the leaf

(the source),

lowering the water potential, so water enters the phloem from the xylem by osmosis,

so the hydrostatic pressure in the phloem increases, and the sap moves by mass flow

towards the roots (the sink), where the pressure is lower.

In the root cells sugars are used in respiration or converted to (insoluble) starch, so

there is a low sugar concentration in root cells and sugars are unloaded from the

phloem,

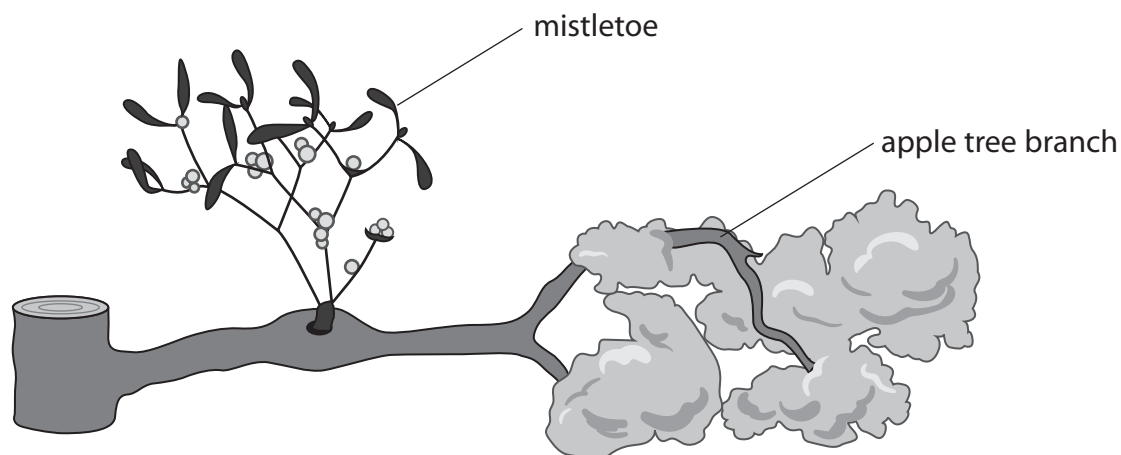
increasing the water potential in the phloem, so water moves out into the xylem.



*(c) Mistletoe is a plant that is a parasite on trees.

Mistletoe has green leaves. Mistletoe also has a modified root that grows into the xylem of a tree.

The diagram shows mistletoe growing on an apple tree branch.



The effect of mistletoe on the growth of apple trees was investigated.

Every year for 20 years, scientists selected apple trees infected with mistletoe and measured the:

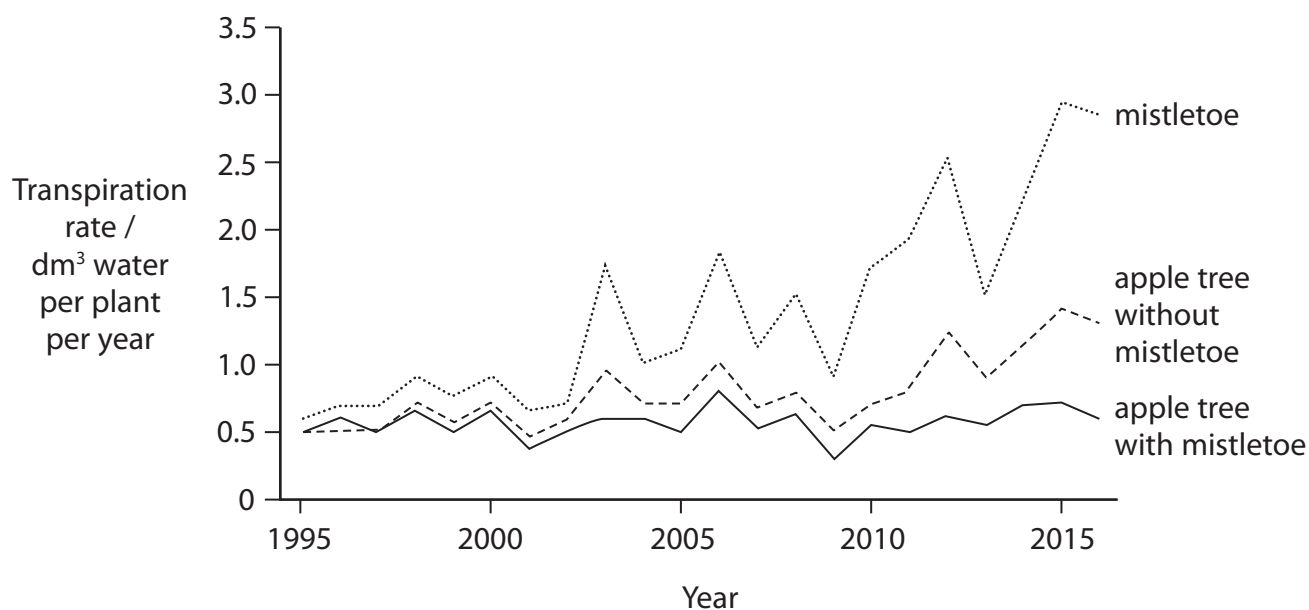
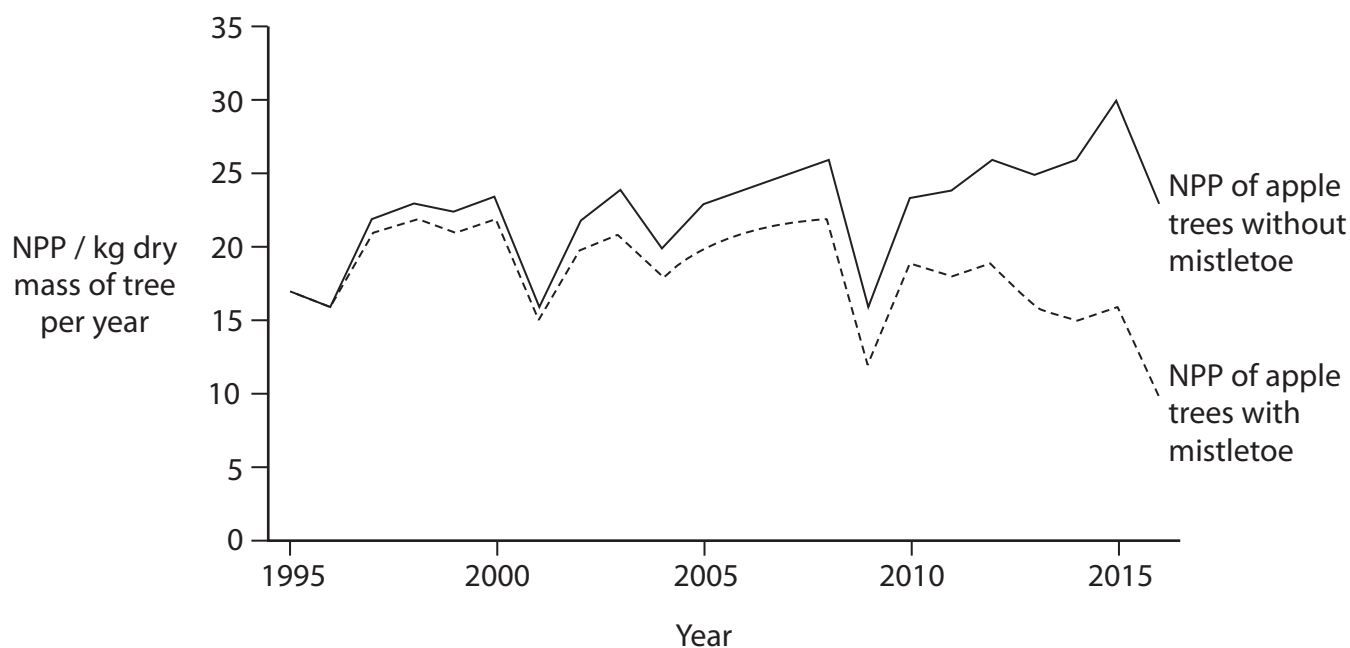
- mean net primary productivity (NPP) of the apple trees
- transpiration rate of the apple trees
- transpiration rate of the mistletoe branches on the apple trees

They also determined the mineral content of the apple tree leaves after 20 years.

A control group of apple trees not infected with mistletoe was included in this investigation.



The graphs and table show the results of the investigation.



Apple tree leaves from	Nitrogen content / mg per g of leaf	Calcium content / mg per g of leaf
trees infected with mistletoe	8.50	6.45
trees not infected with mistletoe	10.60	8.90

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Analyse the data to explain the effect of mistletoe on the NPP of apple trees.

(6)

Mistletoe lowers the NPP of apple trees over time. The NPP of trees without mistletoe shows an upward trend over the 20 years, from about 17 to 30 kg per year, whereas the NPP of trees with mistletoe shows a downward trend after about 2007, falling to about 15 kg per year by 2015, about half that of uninfected trees.

Mistletoe has a higher transpiration rate than the apple tree, rising to about 2.9 dm^3 per year, and the transpiration rate of infected apple trees is lower (about 0.7 compared with 1.4 dm^3 per year in uninfected trees).

So the mistletoe root diverts the transpiration stream from the xylem to the mistletoe, taking water from the apple tree. Less water is available for photosynthesis, and fewer minerals reach the apple tree leaves.

The nitrogen content of infected leaves is lower (8.50 compared with 10.60 mg per g). Less nitrogen means less amino acid and protein synthesis, so fewer enzymes (e.g. rubisco) are made, and less chlorophyll and nucleic acid synthesis occurs, so less photosynthesis and less growth.

The calcium content is also lower (6.45 compared with 8.90 mg per g), so less calcium pectate is made for cell walls (middle lamella), so fewer new cells are produced.

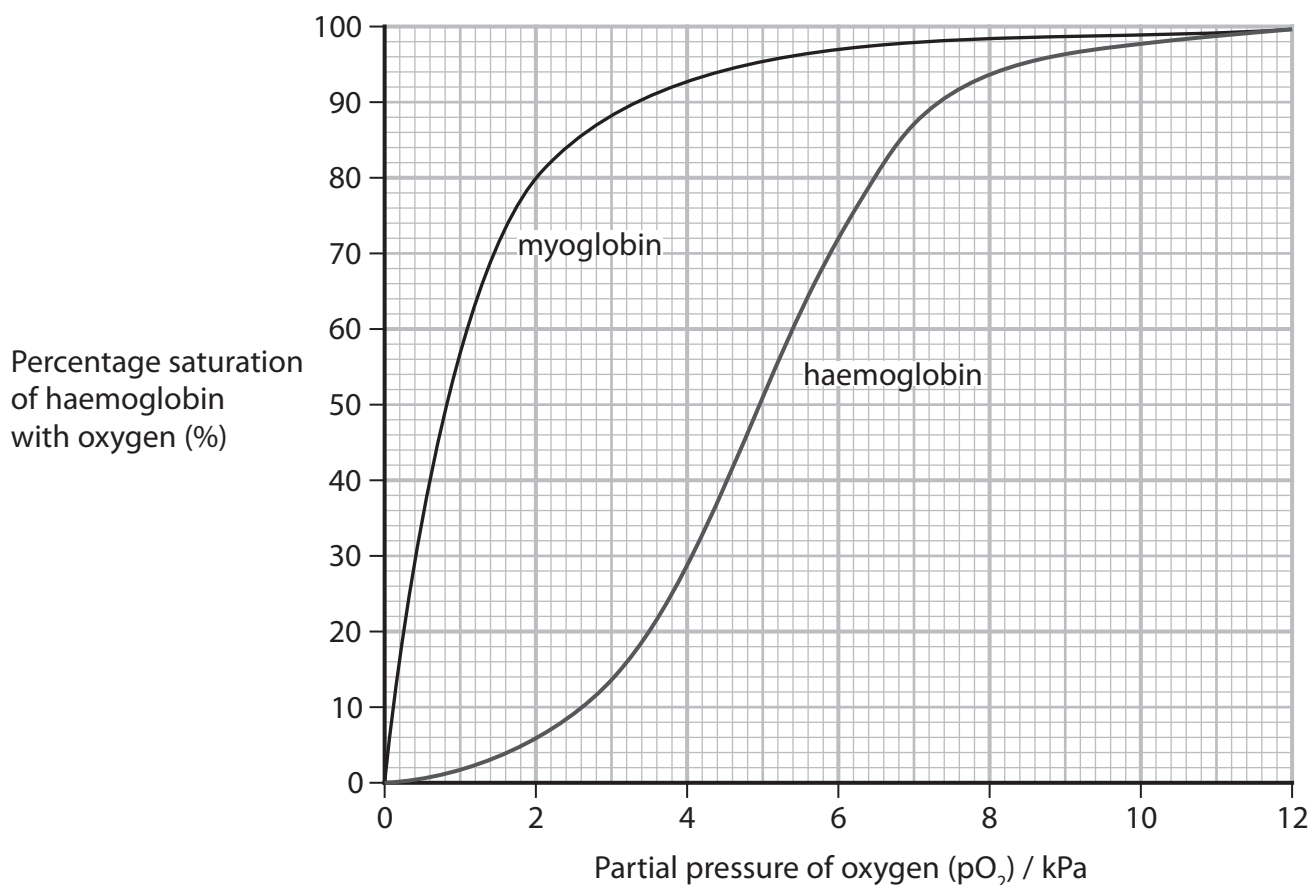
Less photosynthesis means less GPP and so lower NPP, so the apple trees produce less biomass.

(Total for Question 7 = 11 marks)



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- 8 The graph shows the oxygen dissociation curves of human haemoglobin and human myoglobin.



- (a) (i) Calculate the volume of oxygen bound to haemoglobin at a partial pressure of oxygen of 6 kPa in 100 cm^3 blood.

The concentration of haemoglobin is 15 g per dm^3 blood.

When fully saturated, there is 1.36 cm^3 oxygen per g of haemoglobin.

(3)

at 6 kPa, saturation of haemoglobin = 72%

Hb in 100 cm^3 blood = $15 \div 10 = 1.5\text{ g}$

O_2 per g Hb = $72/100 \times 1.36 = 0.9792\text{ cm}^3$

O_2 in 100 cm^3 blood = $0.9792 \times 1.5 = 1.47\text{ cm}^3$

Answer 1.47 cm^3

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- (ii) Explain why the oxygen dissociation curves for haemoglobin and myoglobin are different.

(4)

Myoglobin has a higher affinity for oxygen than haemoglobin, so it binds more tightly to oxygen and its curve is further to the left.

Therefore myoglobin acts as an oxygen store in muscle, only releasing oxygen when the partial pressure of oxygen is very low.

The haemoglobin curve is sigmoidal (S shaped) but the myoglobin curve is not, because haemoglobin has four haem groups and oxygen binds cooperatively: once the first oxygen binds, the shape changes so the affinity varies depending on how much oxygen is already bound.

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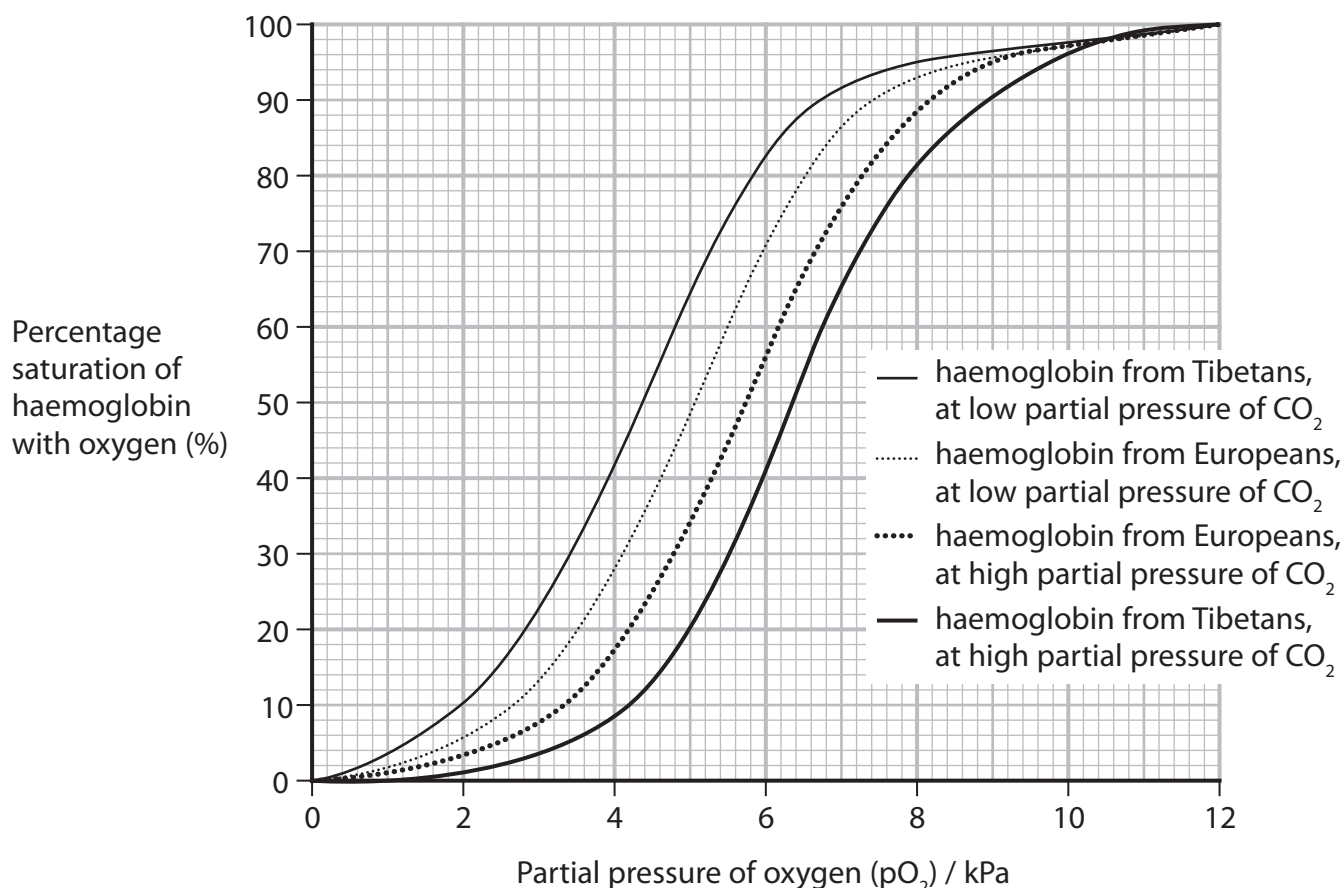
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(b) In an investigation, the oxygen dissociation of haemoglobin from Tibetan people and European people was compared.

The Tibetan people were living at high altitude.

The European people were living at low altitude.

The graph shows the results of this investigation.



Comment on the oxygen dissociation curves of the Tibetan people.

(4)

At low partial pressure of CO_2 Tibetan haemoglobin has a higher affinity for oxygen than European haemoglobin (curve further to the left), so it is more saturated at low partial pressures of oxygen, which helps them load oxygen at high altitude.

At high partial pressure of CO_2 Tibetan haemoglobin has a lower affinity for oxygen than European haemoglobin, because it has a bigger Bohr shift (shift to the right), so it releases oxygen more easily to respiring tissues.



- (c) Tibetan populations have a recessive allele that helps them to survive at high altitude.

In a village in Tibet, 1950 people out of a population of 2500 people carry two copies of this allele.

- (i) Calculate the number of heterozygous people in the village.

Use the Hardy-Weinberg equation

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

(3)

$$q^2 = 1950 \div 2500 = 0.78$$

$$q = \sqrt{0.78} = 0.8832$$

$$p = 1 - 0.8832 = 0.1168$$

$$2pq = 2 \times 0.1168 \times 0.8832 = 0.2063$$

$$\text{heterozygotes} = 0.2063 \times 2500 = 515.8 = 516$$

Answer 516.....



- (ii) This allele is currently found only in human populations in Tibet.

The allele has also been found in the fossil bones of an extinct form of modern humans called the Denisovans.

Fossils of Denisovans have been found in Tibet.

Explain why scientists think that the Denisovans belonged to the same species as modern humans.

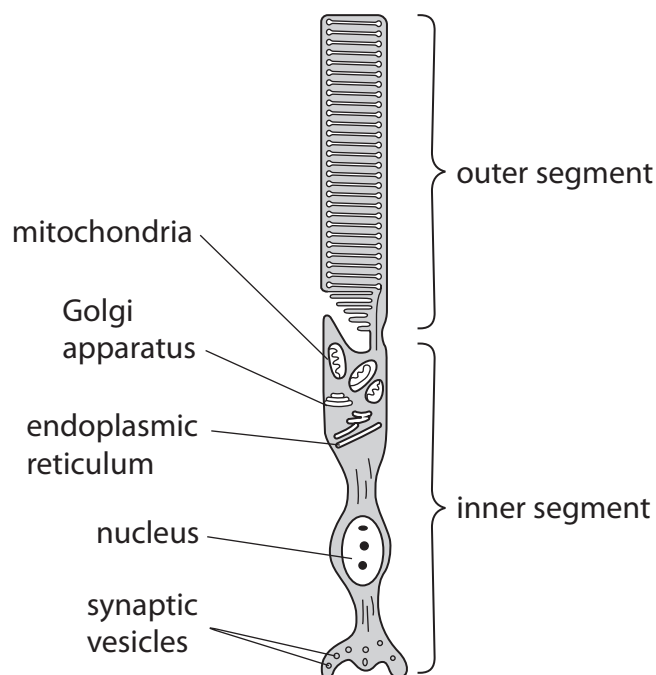
(2)

Only Tibetans and Denisovans have this allele, which suggests that Denisovans and modern humans (Tibetans) must have interbred and produced fertile offspring that passed the allele on, so they belong to the same species.

(Total for Question 8 = 16 marks)



9 The diagram shows the structure of a rod cell.



(a) (i) How many of the labelled organelles have a double membrane?

(1)

- ☐ A 0
- ☐ B 1
- ☒ C 2
- ☐ D 3

(ii) Which of the following statements about the effect of light on rod cells are correct?

(1)

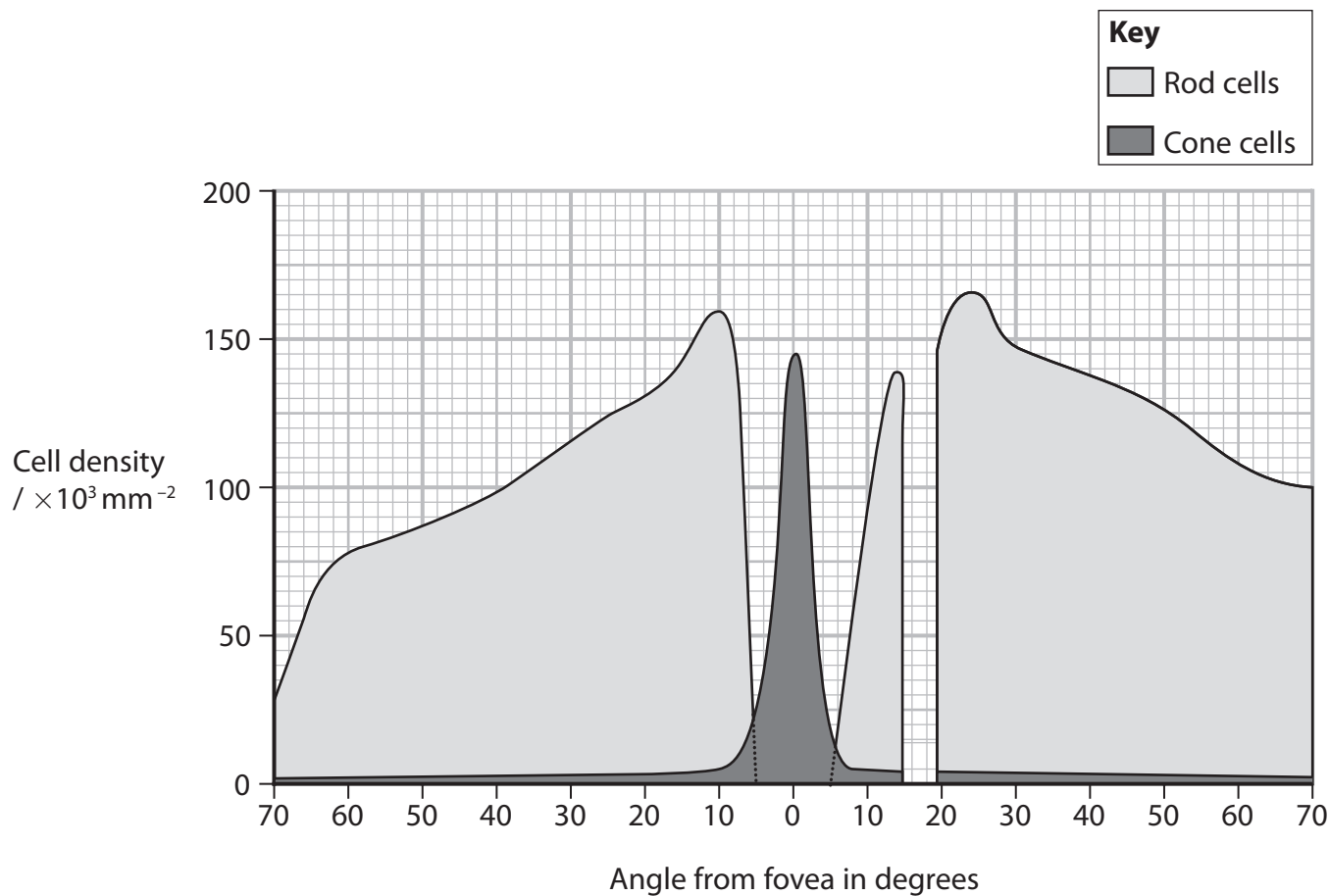
1. rhodopsin breaks down into opsin and trans-retinal
2. voltage-gated sodium channels open in the membrane
3. more neurotransmitter is released from the presynaptic terminal

- ☒ A 1 only
- ☐ B 1 and 2
- ☐ C 1 and 3
- ☐ D 2 and 3

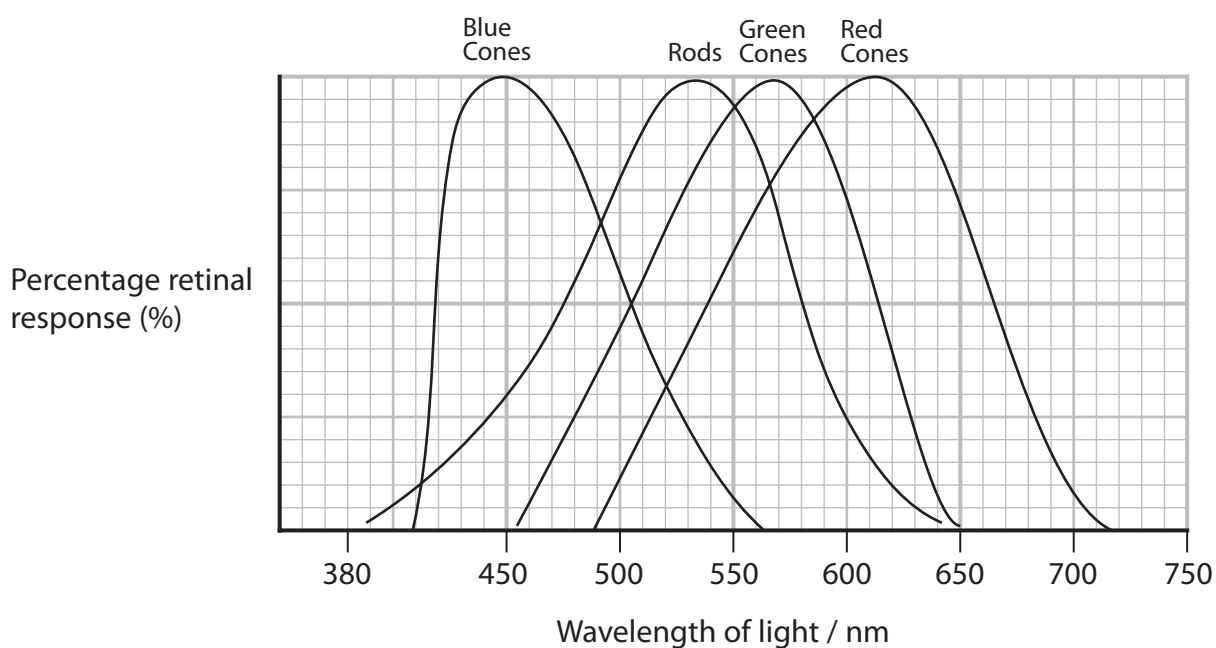


*(b) Graph 1 shows the distribution of photoreceptors across the retina.

Graph 2 shows the sensitivity of rod cells and cone cells to light of different wavelengths.



Graph 1



Graph 2



Students investigated the ability to detect beams of light of different colours and intensities.

A student covered one eye and a bright red light (wavelength 670 nm) was placed at different angles in the field of vision of the other eye. The student stated if they could detect the red light.

This was repeated with a dim red light.

This was then repeated with a bright green light and a dim green light (wavelength 525 nm).

The table shows the results of this investigation.

Angle from fovea in degrees	Light detected (Yes/No)			
	Bright light Red	Dim light Red	Bright light Green	Dim light Green
60	N	N	Y	Y
30	N	N	Y	Y
15	N	N	Y	Y
10	N	N	Y	Y
5	Y	N	Y	N
0	Y	N	Y	N
5	Y	N	Y	N
10	N	N	Y	Y
15	N	N	N	N
30	N	N	Y	Y
60	N	N	Y	Y

Analyse the data to explain the results of this investigation.

(6)

No light is seen at 15° on one side because this is the blind spot, where there are no rods or cones.

Graph 1 shows cones are only found in the fovea (within 5° either side of 0°), and rods are found everywhere except the fovea. Graph 2 shows rods are stimulated by green light (525 nm) but not by red light (670 nm).

Cones are less sensitive than rods and can only detect bright light, because there is no spatial summation (each cone has its own bipolar cell), whereas several rods share one



bipolar neurone, so rods have spatial summation.

Dim red light is not seen at any angle because rod cells are not sensitive to red light (670 nm) and cone cells are not sensitive enough to detect dim light.

Bright red light is only seen when it falls on the fovea (0° and 5° either side), because red cones are only found in the fovea, and rod cells cannot detect red light.

Bright green light is seen everywhere apart from the blind spot; green cones detect it in the fovea and rod cells detect green light away from the fovea.

Dim green light is only seen at angles of 10° or more, because rod cells are sensitive to dim green light, but there are no rods in the fovea and cones cannot detect dim light, so it is not seen at 0° and 5° .

(Total for Question 9 = 8 marks)

TOTAL FOR PAPER = 90 MARKS



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