

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: 1 hour 45 minutes)

Paper reference **9BI0/02**

Biology B

Advanced

PAPER 2: Advanced Physiology, Evolution and Ecology

You must have:
Scientific 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.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

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.

Turn over ►

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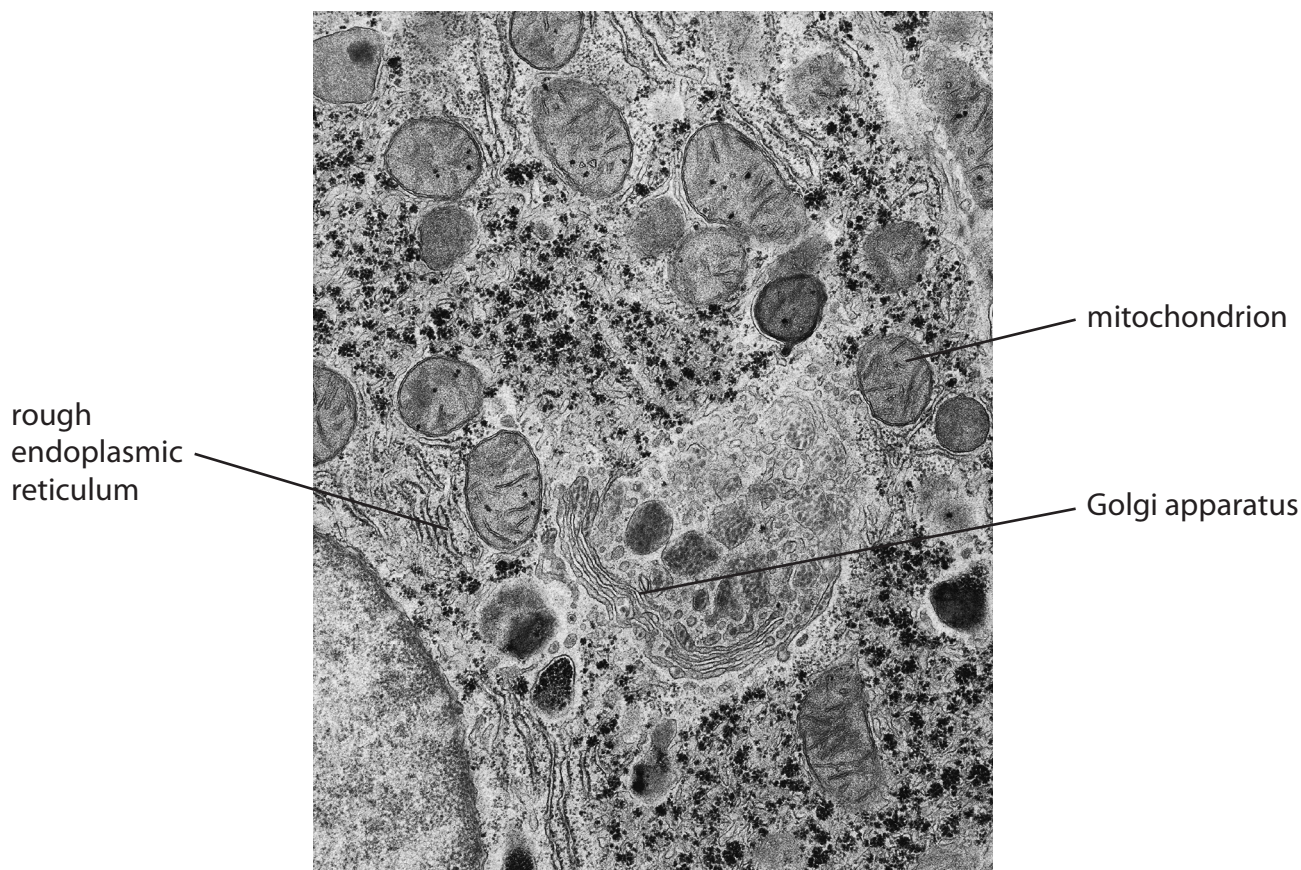



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Answer ALL questions. Write your answers in the spaces provided.

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 photograph shows part of a liver cell, as seen using an electron microscope.



(Source: © Keith R. Porter/SCIENCE PHOTO LIBRARY)

- (a) Describe the roles of the labelled organelles in a liver cell.

(3)

Rough endoplasmic reticulum: the ribosomes on its surface carry out protein synthesis

(translation), forming the polypeptides (primary structure) and folding them into secondary and tertiary structure.

Golgi apparatus: modifies and packages proteins, e.g. glycosylates proteins by adding carbohydrates to them, and produces lysosomes.

Mitochondrion: site of aerobic respiration, which makes ATP for the liver cell.



(b) Hepatitis B is a DNA virus that infects liver cells. The DNA of the virus replicates inside liver cells.

(i) Describe the process of DNA replication.

(3)

DNA helicase breaks the hydrogen bonds between the bases, which unzips the DNA and separates the two strands.

Each strand acts as a template. Free nucleotides pair up with their complementary bases (adenine with thymine, cytosine with guanine).

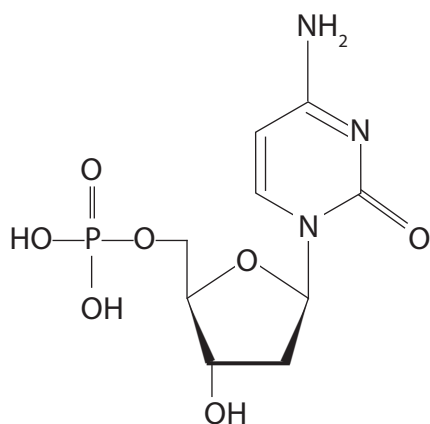
DNA polymerase joins the nucleotides together by forming phosphodiester bonds, making the sugar-phosphate backbone.

DNA ligase joins the Okazaki fragments.

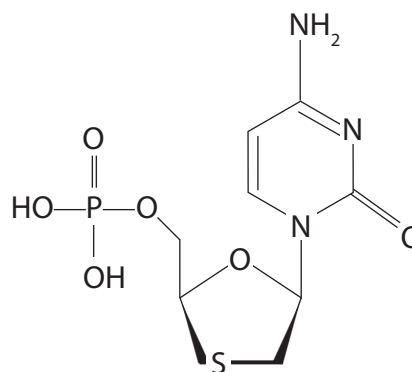


- (ii) The drug lamivudine is used to treat infections by the hepatitis B virus. It causes the production of altered nucleotides containing cytosine.

The diagram shows a normal nucleotide and an altered nucleotide.



normal nucleotide



altered nucleotide

Explain how lamivudine reduces replication of the hepatitis B virus in liver cells.

(2)

The altered nucleotide has a missing OH group on the sugar (it has sulfur instead of carbon in the ring), so a phosphodiester bond cannot form with the next (adjacent) nucleotide.

So the sugar-phosphate backbone cannot form and the viral DNA cannot be replicated.

(Total for Question 1 = 8 marks)



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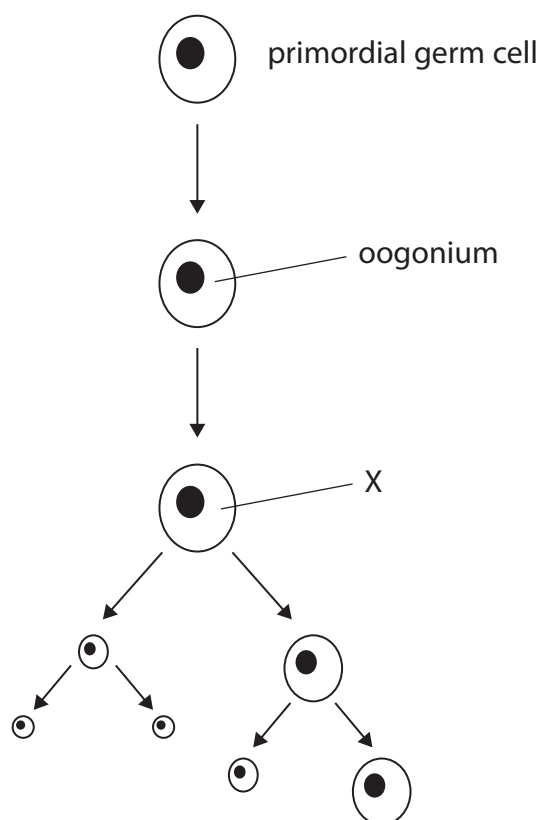
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2 The diagram shows the process of oogenesis.



(a) (i) Which is the name of the cell labelled X?

(1)

- ☐ **A** ovule
- ☐ **B** ovum
- ☒ **C** primary oocyte
- ☐ **D** secondary oocyte

(ii) Meiosis is involved in oogenesis.

Describe the events of prophase I during oogenesis.

(3)

The chromosomes condense (DNA coils around histones) and become visible.

Homologous chromosomes pair up to form bivalents.

Chiasmata form and crossing over occurs between non-sister chromatids of homologous chromosomes.

The nuclear membrane and nucleolus disintegrate, and the centrioles move to the poles to begin forming the spindle.

(iii) Compare and contrast the process of oogenesis with spermatogenesis.

(3)

Similarities: both begin with primordial germ cells (stem cells), and both involve mitosis and meiosis to produce haploid gametes with genetic variation.

Differences: oogenesis produces only one gamete (plus polar bodies) from each primary oocyte, whereas spermatogenesis produces four gametes.

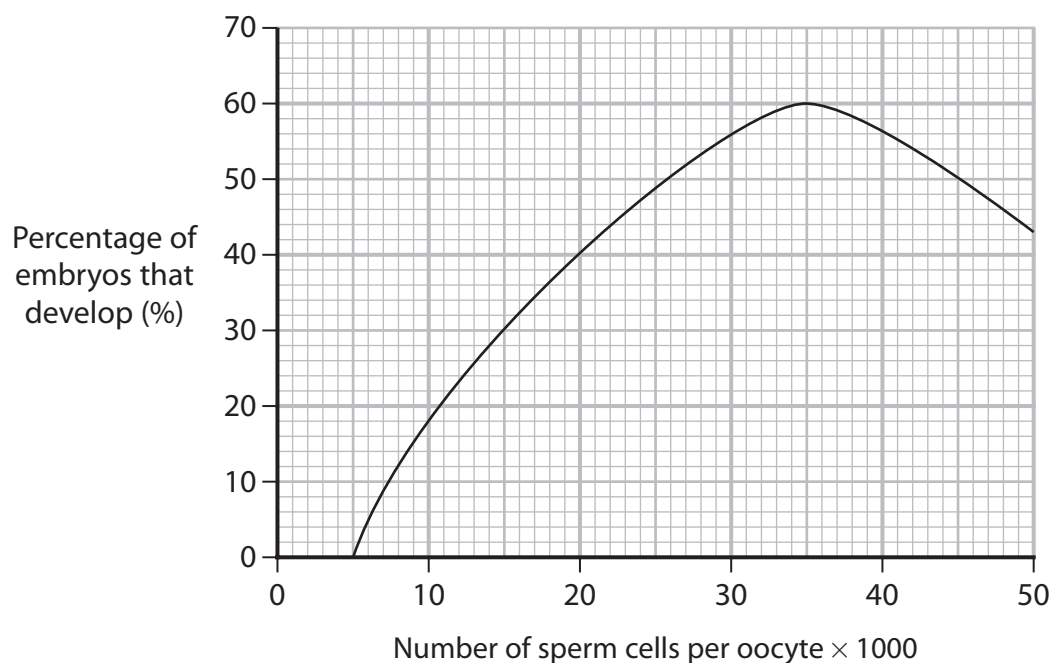
Oogenesis begins before birth, whereas spermatogenesis starts at puberty. Oogenesis pauses (arrests) at prophase I and at metaphase II and is only completed at fertilisation, whereas spermatogenesis is continuous.



- (b) During in vitro fertilisation (IVF), oocytes are fertilised with sperm cells in a culture medium.

If more than one sperm cell fertilises an oocyte, the embryos do not develop.

The graph shows the effect on the production of embryos that develop when different numbers of sperm cells are added to oocytes during IVF.



- (i) Calculate the number of sperm cells that need to be added to four oocytes so that 60% of embryos develop.

(1)

60% of embryos develop at $35 \times 1000 = 35\,000$ sperm per oocyte

$35\,000 \times 4 = 140\,000$

Answer *140 000*



- (ii) Analyse the data to explain the effects of increasing the number of sperm cells per oocyte on the percentage of embryos that develop.

(2)

The percentage of embryos that develop increases up to 35×1000 (35 000) sperm per oocyte, to 60%, and then decreases.

At low numbers there are not enough enzymes from the acrosomes to digest the zona pellucida. At high numbers several sperm fertilise the egg (polyspermy), so the zygote has too many sets of chromosomes (is polyploid).

(Total for Question 2 = 10 marks)

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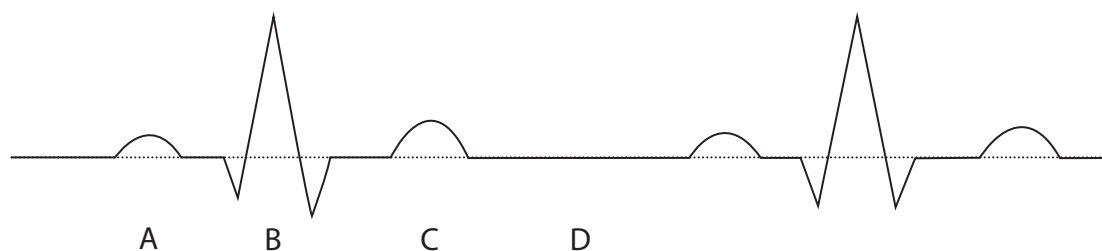
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3 Stress can change the heart rate of a person.

(a) The diagram shows an ECG trace for a student at rest.



(i) Which of the letters on this ECG trace represents the time when ventricular systole occurs?

(1)

- ☐ A
- ☒ B
- ☐ C
- ☐ D

(ii) Describe how myogenic stimulation maintains the heart rate of the student when at rest.

(3)

The sinoatrial node (SAN) initiates a wave of depolarisation (excitation), which spreads across the atria and causes the atria to contract (atrial systole).

The atrioventricular node (AVN) delays the impulse, then transmits the depolarisation down the bundle of His to the Purkinje fibres.

The depolarisation passes from the apex up the ventricle walls, stimulating the ventricles to contract from the apex upwards.

- (b) Scientists investigated the effect of an anti-anxiety drug on the change in heart rate of a student after a sudden fright.

In this investigation:

- The resting heart rate of the student was measured.
- The student was given a sudden, unexpected fright and their heart rate was measured again.
- This was repeated four more times.
- The investigation was then repeated after the student had taken the anti-anxiety drug.

The table shows the results of this investigation.

Fright number	Heart rate / beats per minute			
	without anti-anxiety drug		with anti-anxiety drug	
	resting	after fright	resting	after fright
1	64	135	46	70
2	56	125	54	65
3	55	125	48	70
4	75	110	56	105
5	72	105	48	65

- (i) The mean volume of blood pumped around the body in one minute after a fright without the anti-anxiety drug is 18 dm^3 .

The stroke volume of the student's heart was 150 cm^3 .

Calculate the mean volume of blood pumped around the body in one minute after a fright, when taking the anti-anxiety drug.

Give your answer in dm^3 and to the **nearest whole number**.

(2)

mean heart rate after fright with drug

$$= (70 + 65 + 70 + 105 + 65) \div 5 = 375 \div 5 = 75 \text{ beats per minute}$$

$$\text{volume per minute} = 75 \times 150 \text{ cm}^3 = 11\,250 \text{ cm}^3$$

$$= 75 \times 0.15 \text{ dm}^3 = 11.25 \text{ dm}^3$$

Answer 11..... dm^3



(ii) The anti-anxiety drug has a similar shape to noradrenaline.

Analyse the data to comment on the results of this investigation.

(4)

The drug has a similar shape to noradrenaline, so it binds to the noradrenaline receptors on the heart (SAN) and blocks them, acting as a competitive inhibitor, so noradrenaline (adrenaline) cannot bind.

Heart rate increases after a fright both with and without the drug.

However, heart rate is lower with the drug, and it increases less after a fright with the drug (e.g. 64 to 135 without the drug compared with 46 to 70 with the drug).

Without the drug the increase in heart rate becomes less with repeated frights (71 for fright 1 but only 33 for fright 5).

Fright number 4 with the drug (105) is anomalous, as it does not fit the pattern and is too high compared with the others.

(Total for Question 3 = 10 marks)

- 4 Sickle cell anaemia is a condition caused by a mutation and a change in the structure of haemoglobin.

The diagram shows the changes that occur in the DNA sequence and the amino acid sequence for this condition.

	unaffected				sickle cell anaemia		
DNA:	GGA CCT	CTC GAG	CTC GAG		GGA CCT	CAC GTG	CTC GAG
amino acid sequence:	--	proline	-	glutamate	-	glutamate	--
	--	proline	-	valine	-	glutamate	--

- (a) (i) Which type of bond is used when forming both the secondary structure and tertiary structure of proteins?

(1)

- ☐ A disulfide
- ☒ B hydrogen
- ☐ C ionic
- ☐ D peptide

- (ii) Which type of mutation has occurred to produce the allele for sickle cell anaemia?

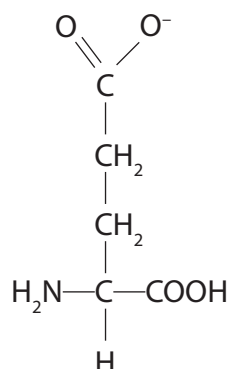
(1)

- ☐ A insertion
- ☐ B deletion
- ☒ C substitution
- ☐ D translocation

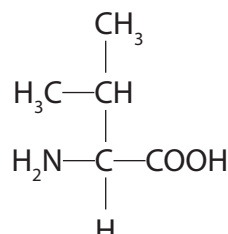


- (iii) Glutamate is a charged, polar amino acid. It is located on the outer surface of unaffected haemoglobin molecules.

The diagram shows the structure of the amino acids glutamate and valine.



glutamate



valine

Explain why the mutation in sickle cell anaemia causes haemoglobin molecules to bind together.

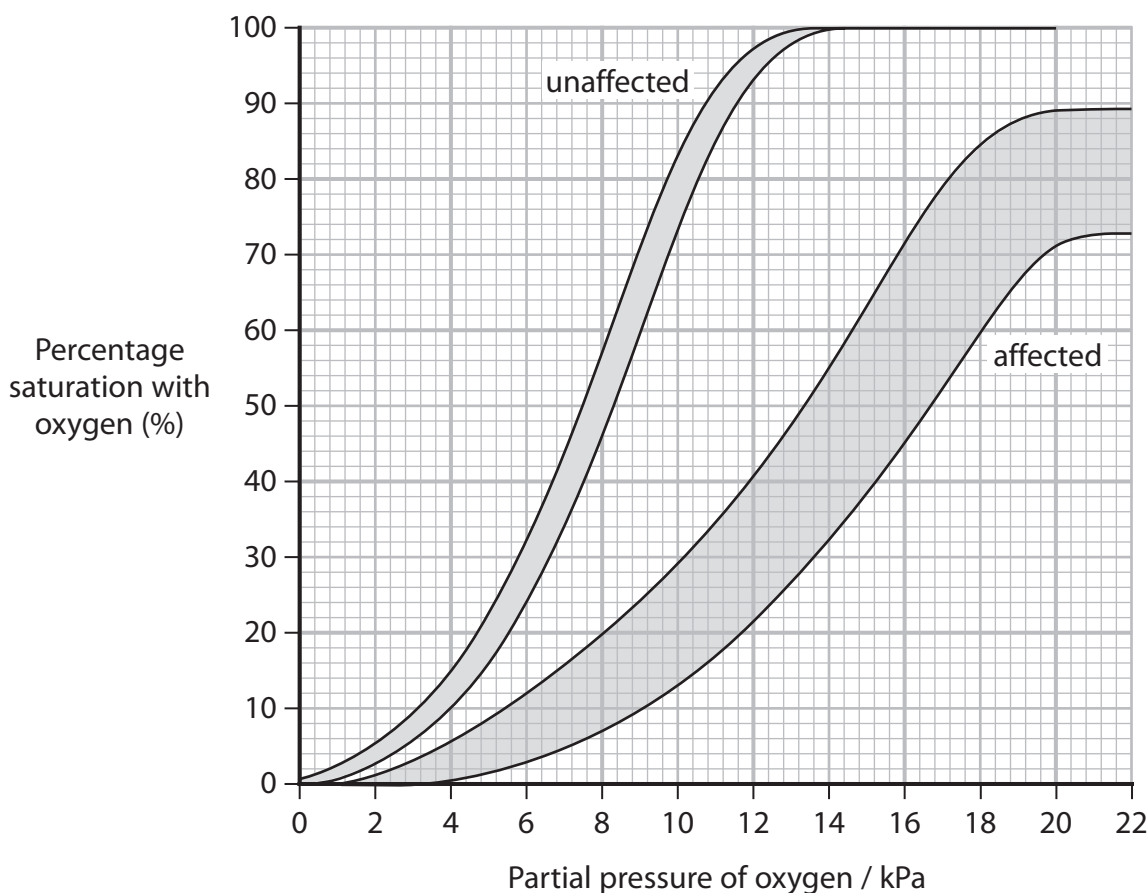
(2)

Valine is non-polar (not charged), so valine is hydrophobic, whereas glutamate is hydrophilic.

So the haemoglobin molecules form fewer hydrogen bonds with water and are less soluble in water, so the hydrophobic regions of the haemoglobin molecules bind together.

- (b) The graph shows the range of oxygen dissociation curves for haemoglobin taken from people who do not have sickle cell anaemia (unaffected) and from people with sickle cell anaemia (affected).

The shaded areas represent the ranges for each blood sample.



- (i) Compare and contrast the properties of haemoglobin from these two groups of people.

(2)

Similarity: both have an S-shaped (sigmoidal) curve, showing cooperative binding.

Differences: affected haemoglobin has a lower affinity for oxygen and never reaches

100% saturation, and there is a wider range (variation) in affinity for haemoglobin from people with sickle cell anaemia.



- (ii) There is only one known allele that causes sickle cell anaemia.

State how the graph suggests that other genes affect the phenotype of people affected by sickle cell anaemia.

(1)

There is a wide variation (range) in the curves for the affected people, even though they all have the same allele.

- (iii) Explain why the oxygen dissociation curve for people with sickle cell anaemia means that they have difficulty exercising.

(3)

Sickle cell haemoglobin has a lower affinity for oxygen, so it never becomes fully saturated and less oxygen loads onto haemoglobin in the lungs (it carries less oxygen). So less oxygen is available for aerobic respiration in the muscles and more anaerobic respiration occurs. So less ATP is produced for muscle contraction and more lactic acid forms in the muscles, causing fatigue.

(Total for Question 4 = 10 marks)



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5 Auxin is a plant growth substance.

(a) Which of the following are functions of auxin?

1. inhibiting lateral shoot growth
2. stimulating the elongation of cells in plant stems
3. stimulating flowering

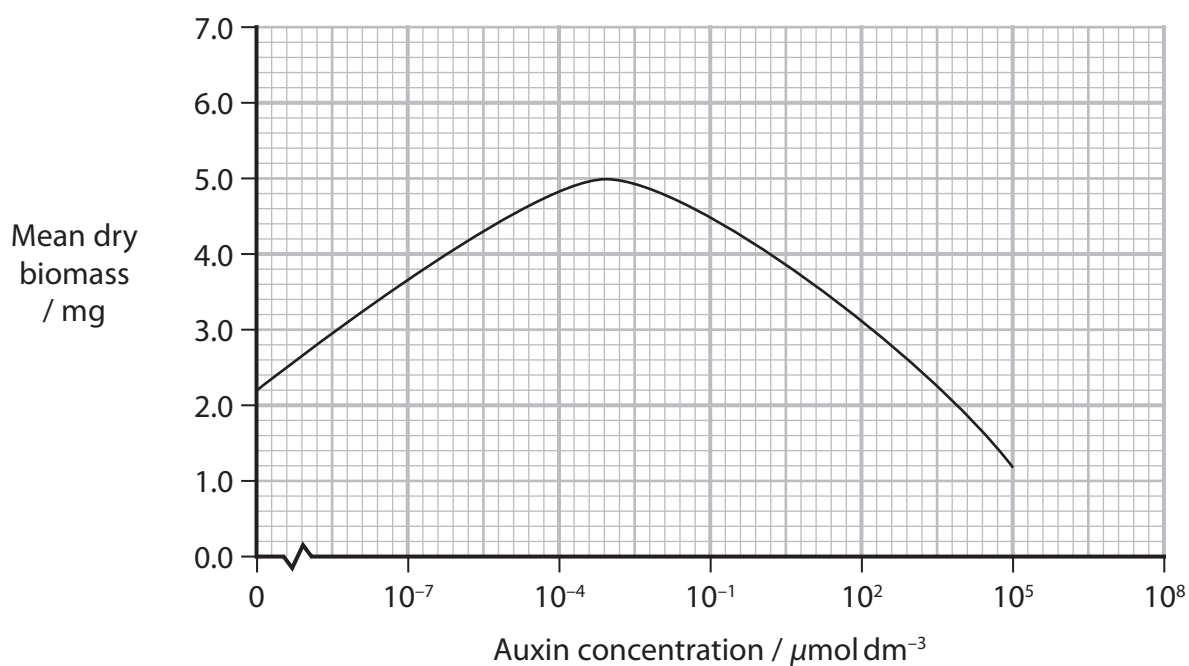
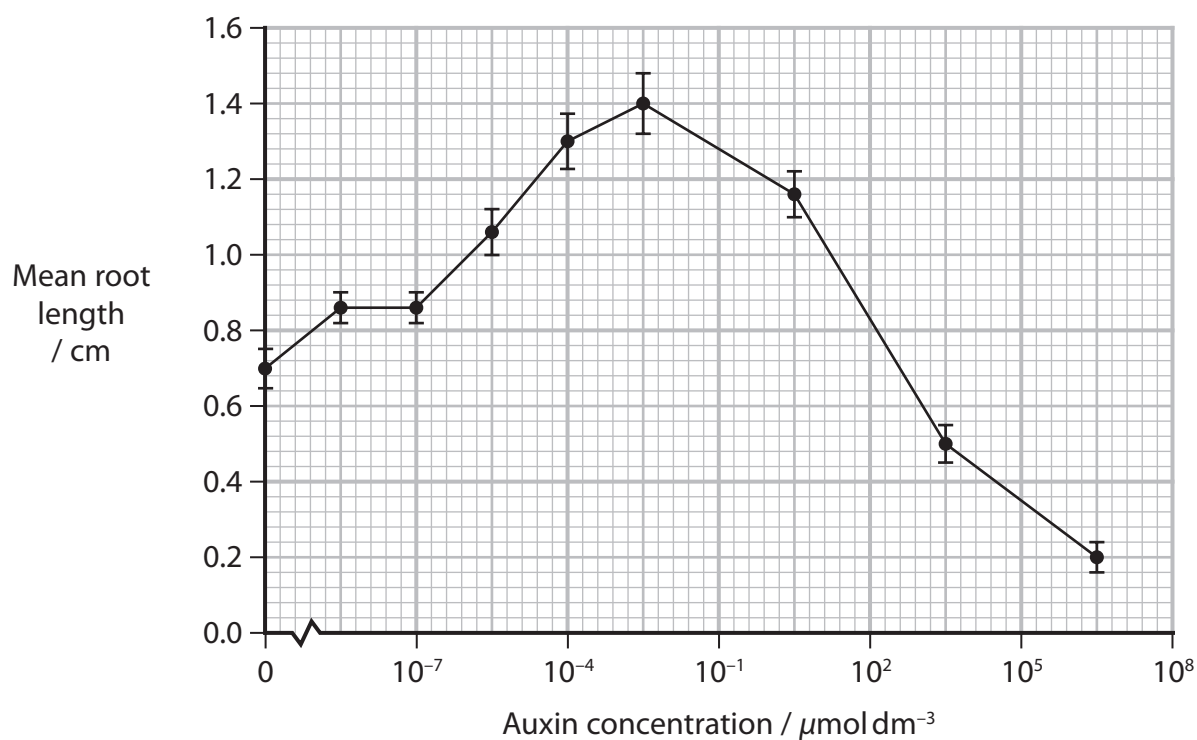
(1)

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

- (b) In an investigation, wheat seedlings were exposed to different concentrations of auxin.

The mean lengths of the roots and the mean dry biomass of the seedlings were calculated.

The graphs show the results of this investigation.



- (i) Calculate the percentage increase in mean root length when given an auxin concentration of $10^{-4} \mu\text{mol dm}^{-3}$ compared with no auxin.

Give your answer to the **nearest whole number**.

(1)

no auxin = 0.7 cm, $10^{-4} \mu\text{mol dm}^{-3} = 1.3 \text{ cm}$

$$(1.3 - 0.7) \div 0.7 \times 100 = 85.7\%$$

Answer 86%

- (ii) Analyse the data to discuss the effects of auxin on the growth of wheat seedlings.

(4)

As auxin concentration increases, root length increases then decreases, and biomass also increases then decreases. The optimum concentration for both is about $10^{-3} \mu\text{mol dm}^{-3}$ (between 10^{-4} and 10^{-1}).

There is a positive correlation between root growth and biomass.

This is because longer roots can obtain more water and minerals: nitrates are used for amino acid (protein) synthesis, magnesium for chlorophyll and phosphate for DNA, RNA and phospholipids, so the seedlings grow more.

The error bars for the two lowest auxin concentrations (both 0.86 cm) overlap, so there may be no significant difference in root growth between them, but the bars for no auxin and 10^{-4} do not overlap, so this difference is significant.

(Total for Question 5 = 6 marks)

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6 The photograph shows a brown rat, *Rattus norvegicus*.



(Source: © DK IMAGES/SCIENCE PHOTO LIBRARY)

(a) The classification hierarchy for the brown rat is:

- Domain: Eukarya
- Kingdom: Animalia
- Phylum: Chordata
- Mammalia
- Rodentia
- Muridae
- Genus: *Rattus*
- Species: *norvegicus*.

(i) Which family, order and class does the brown rat belong to?

(1)

	Family	Order	Class
☐ A	Mammalia	Muridae	Rodentia
☐ B	Mammalia	Rodentia	Muridae
☒ C	Muridae	Rodentia	Mammalia
☐ D	Muridae	Mammalia	Rodentia

(ii) State **one** method that scientists use to determine the evolutionary relationships of the brown rat compared with other species.

(1)

DNA (base) sequencing, comparing the base sequences of the rat with other species.

- (b) Warfarin is a poison that is often used to control brown rat populations.

In areas where large amounts of warfarin have been used, many rats have developed resistance to warfarin.

Three genotypes occur in rat populations:

$W^N W^N$ – rats that are not resistant to warfarin

$W^R W^R$ – rats that are resistant to warfarin but require large amounts of vitamin K in their diet to survive

$W^N W^R$ – rats that are resistant to warfarin and **do not** require large amounts of vitamin K to survive.

After the introduction of warfarin, scientists determined the change in numbers of rats that were resistant to warfarin, and the number that were not resistant to warfarin.

The table shows their results.

Type of rat	Genotypes of rats	Number of rats		
		before warfarin was used	two years after warfarin use started	five years after warfarin use started
Resistant to warfarin	$W^R W^R$ and $W^N W^R$	35	195	180
Not resistant to warfarin	$W^N W^N$	265	105	120

- (i) Calculate the expected number of rats that would be resistant to warfarin but **do not** require large amounts of vitamin K to survive, before warfarin was used.

Use the Hardy-Weinberg equation

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

(3)

$$q^2 = 265 \div 300 = 0.8833$$

$$q = \sqrt{0.8833} = 0.9398 \quad p = 1 - 0.9398 = 0.0602$$

$$2pq = 2 \times 0.0602 \times 0.9398 = 0.1131$$

$$0.1131 \times 300 = 33.9$$

Answer 34



- (ii) Explain why, after two years, there is a change in the number of rats that are resistant to warfarin.

(2)

Warfarin acts as a selection pressure: rats that are resistant survive and breed (produce offspring), while non-resistant rats die and do not breed.

The resistant rats pass on the resistance allele (w^R) to their offspring, so the number of resistant rats increases.

- (iii) Warfarin is highly toxic to rats that have no resistance.

Explain why, after five years, there are still many rats that are not resistant to warfarin.

(2)

Heterozygotes ($w^N w^R$) have an advantage and survive better, as they are resistant and do not need extra vitamin K, while $w^R w^R$ rats die as they need more vitamin K.

The heterozygotes pass on the w^N allele, so they produce $w^N w^N$ offspring.

(Total for Question 6 = 9 marks)

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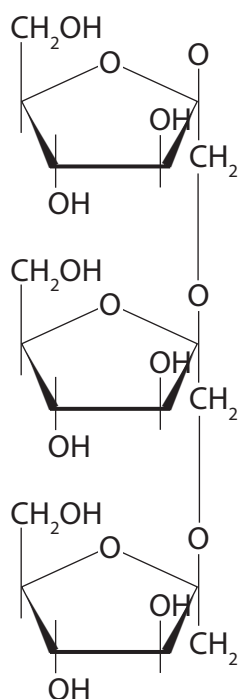
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- 7 Inulin is a polysaccharide made of fructose that is used as a storage molecule by some plant species.

The diagram shows part of a molecule of inulin.



- (a) (i) The inulin molecule in the diagram contains fructose.

Which of these carbohydrates also contain fructose?

(1)

- ☐ A lactose, maltose, and sucrose
- ☐ B lactose and sucrose
- ☐ C maltose and sucrose
- ☒ D sucrose

- (ii) Which is the name of the chemical bond that joins the monosaccharides in inulin?

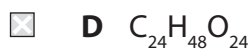
(1)

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

(iii) Fructose has the same molecular formula as glucose.

Which is the molecular formula of a molecule of inulin consisting of four fructose sugars?

(1)



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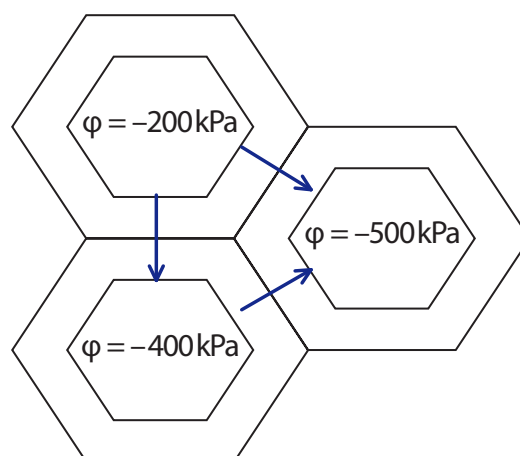
- (b) The number of fructose molecules in inulin can vary from 10 to 70.

Inulin with high numbers of fructose molecules is less soluble in water.

- (i) The diagram shows three plant cells with different water potentials.

Draw arrows on the diagram to show the direction of water movement between the cells.

(1)



- (ii) Explain why some plant species make inulin with fewer fructose molecules in dry weather and inulin with more fructose molecules in wet weather.

(2)

In dry weather inulin with fewer fructose molecules is more soluble (more able to dissolve), so the water potential of the cells becomes lower (more negative), so water moves into the cells and roots by osmosis and water is retained.

In wet weather inulin with more fructose is less soluble, so water potential is higher and less water is absorbed.

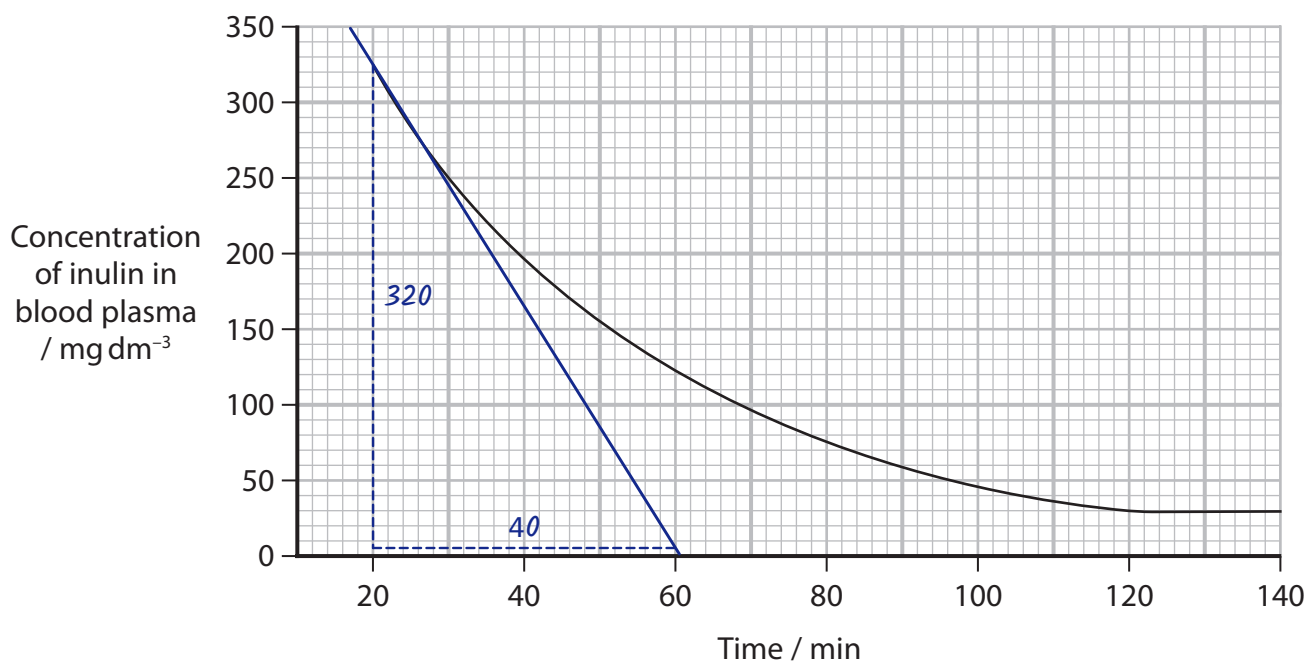
(c) Inulin is used to measure the rate of filtration by the kidneys.

A saline solution containing inulin is injected into the vein of a patient.

The concentration of inulin in the blood plasma is then measured over time.

The rate of filtration is a measure of the maximum rate that inulin is removed from the blood by the kidneys.

The graph shows the concentration of inulin in the blood plasma after an injection of 5 g of inulin.



(i) Calculate the maximum rate that the inulin is removed from the blood.

Give your answer to **two decimal places** with appropriate units.

(2)

tangent drawn at the start of the curve (20 min):

$$\text{gradient} = (325 - 5) \div (60 - 20) = 320 \div 40$$

$$= 8.00 \text{ mg dm}^{-3} \text{ min}^{-1}$$

Answer 8.00 mg dm⁻³ min⁻¹



- (ii) Explain how inulin passes from the blood plasma into the proximal convoluted tubule of a nephron.

(2)

Ultrafiltration: the high hydrostatic pressure in the glomerulus forces inulin out of the blood into the Bowman's capsule.

Inulin is small enough to pass through the pores (fenestrations) and the basement membrane, and through the gaps between the podocytes.

- (iii) Explain why all the inulin is released into the urine.

(2)

Inulin has no function in humans (it is not needed), so it is not reabsorbed back into the blood,

because there are no inulin channels, carriers or pumps in the proximal convoluted tubule.

(Total for Question 7 = 12 marks)



- 8 The photograph shows a grouse on a heather moor. Heather moors are areas of countryside that are dominated by heather plants.



(Source: © Ben Hall/2020VISION/Nature Picture Library/SCIENCE PHOTO LIBRARY)

Heather moors are habitats for a variety of plants and animals. They are also used for sheep farming and as areas to raise grouse.

The net primary productivity (NPP) of a heather moor decreases with the age of the heather plants.

- (a) Which of the following is the correct formula to calculate NPP?

(1)

- ☒ **A** $\text{NPP} = \text{gross primary productivity (GPP)} - \text{respiration}$
- ☐ **B** $\text{NPP} = \text{gross primary productivity (GPP)} + \text{respiration}$
- ☐ **C** $\text{NPP} = \text{gross primary productivity (GPP)} + \text{photosynthesis}$
- ☐ **D** $\text{NPP} = \text{gross primary productivity (GPP)} - \text{photosynthesis}$

- (b) As heather plants age, the ratio of leaf area to area of woody stem changes.

A student investigated the relationship between the age of heather plants and the ratio of leaf area : woody stem area.

The student carried out a Spearman's rank correlation test using the data in the table.



Age of heather plant / years	Rank of age of heather plant	Ratio of leaf area : woody stem area	Rank of leaf area : woody stem area	d	d ²
16	4	0.7	4.5	-0.5	0.25
15	5	0.4	8	-3	9
12	6	0.6	6	0	0
4	9	2.0	1	8	64
7	8	1.1	2.5	5.5	30.25
22	1	0.2	10	-9	81
20	2	0.3	9	-7	49
3	10	1.1	2.5	7.5	56.25
17	3	0.5	7	-4	16
11	7	0.7	4.5	2.5	6.25

- (i) Calculate the missing values to complete the table.
Write your answers in the table.

(2)

- (ii) Calculate the Spearman's rank correlation coefficient for the data in the table.
Use the formula

$$r_s = 1 - \frac{6\sum d^2}{n(n^2 - 1)}$$

(3)

$$\sum d^2 = 0.25 + 9 + 0 + 64 + 30.25 + 81 + 49 + 56.25 + 16 + 6.25 = 312$$

$$6\sum d^2 = 6 \times 312 = 1872$$

$$n(n^2 - 1) = 10 \times (100 - 1) = 990$$

$$r_s = 1 - (1872 \div 990) = 1 - 1.891 = -0.891$$

Answer -0.89

- (iii) The table gives some critical values for the Spearman's rank correlation coefficient.

n	Level of significance	
	$P = 0.05$	$P = 0.01$
5	1.000	–
6	0.886	1.000
7	0.786	0.929
8	0.738	0.881
9	0.700	0.833
10	0.648	0.794
11	0.618	0.755

Comment on the relationship between the age of the heather and the ratio of leaf area to woody stem area.

Use your calculated value of Spearman's rank correlation coefficient and the table.

(3)

There is a significant negative correlation: as the age of the heather increases, the ratio of leaf area to woody stem area significantly decreases.

The calculated value (0.891, ignoring the sign) is greater than the critical value for $n = 10$ of 0.648 at $P = 0.05$ and also greater than 0.794 at $P = 0.01$.

So there is a less than 0.01 (1%) probability that the correlation is due to chance.



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- *(c) Farmers manage heather moors by burning the heather every 10 years. This removes older heather and allows younger plants to grow.

Managing heather moors by burning is controversial.

It has been suggested that instead of burning the heather, the moors should be left to return to nature as part of a rewilding strategy.

Rewilding strategies aim to return areas of farmland to the original ecosystems that existed before the heather moors.

Several factors have to be considered before a decision on rewilding is made.

- The heather moors are areas of peat containing dead organic waste that decomposes very slowly.
- Heather moors are an area of income for farmers.
- Over time, heather becomes very dominant and lies flat over the ground, blocking light.
- A variety of small species of plants live around areas of older heather.
- Heather seeds need to be heated to germinate efficiently.
- Some endangered species consume grouse.
- Grouse are raised by humans for profit.
- Heather moors have been managed for many years and many species that lived in the area are now extinct.



Analyse all the information in the question to discuss the effects of rewilding the moors compared with management by burning.

(6)

Older heather has a low leaf area : woody stem area ratio, so it carries out less photosynthesis compared with respiration, fixes less carbon and has a low NPP, so less energy is available for food chains. Young heather has a high leaf ratio and high NPP. Burning removes the old, unproductive heather, and the heat stimulates heather seeds to germinate, so young heather grows. The ground is no longer shaded, so more light reaches young heather and other plant species. This increases carbon and energy fixation, gives more grouse and sheep, which means more income for farmers and more food for endangered birds of prey that eat grouse.

However, burning is not selective and kills other species as well as heather, and it is not a natural ecosystem. It releases carbon dioxide and causes loss of peat, so less carbon is locked up, adding to global warming and climate change. Smoke causes health issues and fires may get out of control.

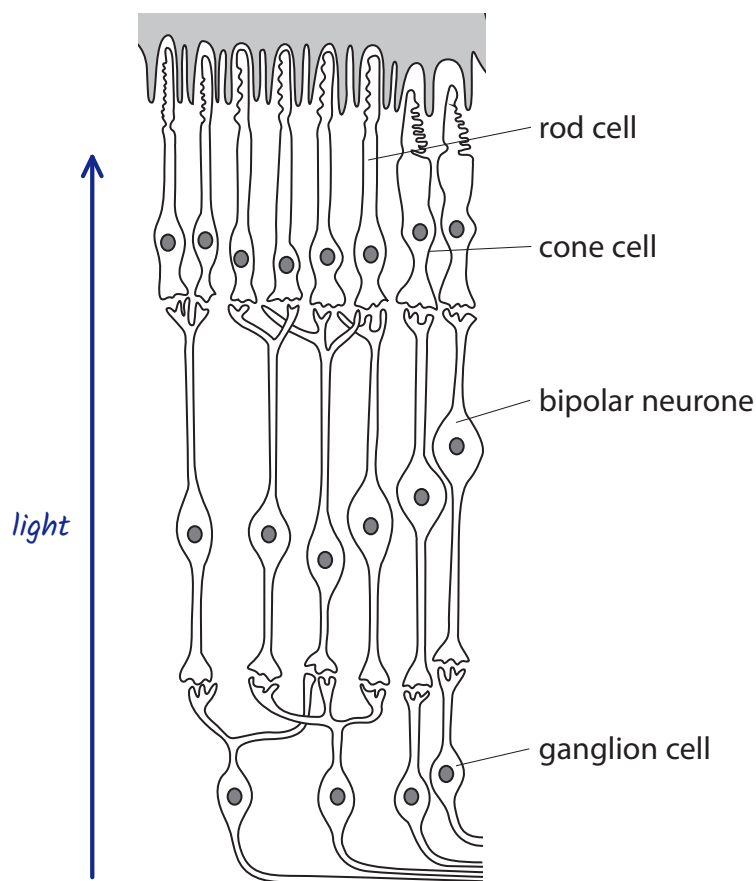
Rewilding would allow secondary succession back towards the original ecosystem, increasing biodiversity as natural species return. The peat decomposes slowly, so carbon stays locked up in the peat, reducing global warming.

However, the old heather would become dominant, lie flat and shade the small plants. Many original species are extinct, so there would be few grazers or predators and some species could dominate and outcompete others. Farmers would lose income.

Overall, rewilding is better for carbon storage, but burning is better for productivity and income.

(Total for Question 8 = 15 marks)

9 The diagram shows a section through the central area of a human retina.



- (a) (i) Draw an arrow on the left of the diagram to show the direction that light travels through the retina.

(1)

- (ii) Describe how light absorbed by rhodopsin in a rod cell leads to a change in release of neurotransmitter from the rod cell.

(3)

Light causes rhodopsin to break down (bleach) into trans-retinal and opsin.

Opsin causes the sodium ion channels to close, so sodium ions do not enter the cell

(the dark current stops), while the sodium-potassium pump continues to pump sodium ions out.

So the membrane becomes hyperpolarised and less glutamate (neurotransmitter) is released from the rod cell.

*(b) A student investigated the retinal structures of different mammals.

The student collected information about:

- the structure of the retina of the cat (a predator that hunts at night)
- the distribution of rods and cones in the retina of humans and cats
- the total number of rods and cones in the retinas of species active in the day and species active at night.

The diagram shows part of the retina of a cat.

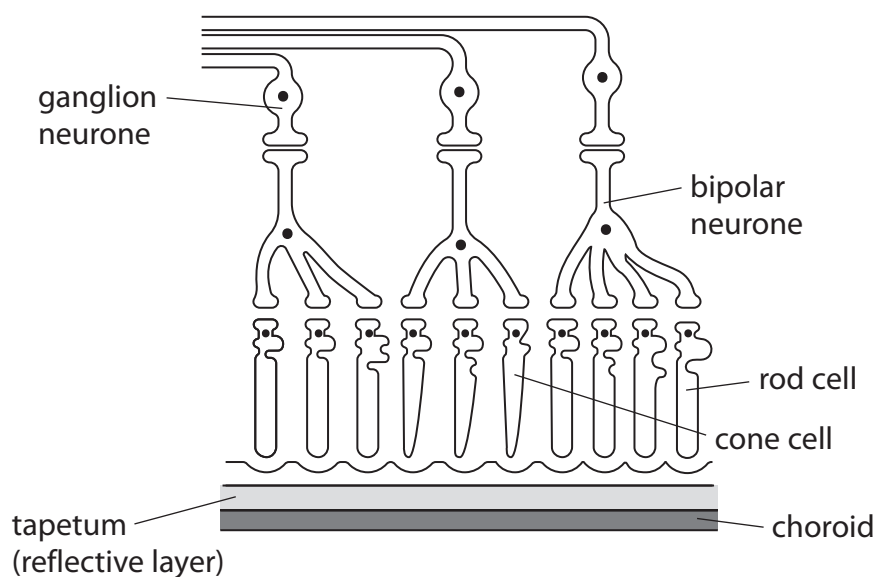


Table 1 and Table 2 show some of the data collected by the student.

Table 1

Distribution of rods and cones	Density of cells in retina / cells per mm ²	
	human	cat
Highest cone density	199 000	27 000
Highest rod density	160 000	460 000
Cone density around edge of retina	5 000	<3 000
Rod density around edge of retina	40 000	250 000

Table 2

Species	When active	Total number of cells $\times 10^6$	
		rod cells	cone cells
Rat	night	30	3
Night monkey	night	150	3
Marmoset monkey	day	6	11
Saimiri monkey	day	30	10

Discuss how the retinas of animals are adapted to their activity at different times of the day.

(6)

In the cat retina several rods (and cones) synapse with one bipolar neurone, so there is spatial summation, which makes the cat retina very sensitive to dim light, and cats have a reflective tapetum that reflects light back through the retina to help them see in the dark at night.

The cat has far more rods than humans (460 000 compared with 160 000 per mm^2 at the highest density), and more rods around the edge of the retina (250 000 compared with 40 000), giving better peripheral vision, but fewer cones (27 000 compared with 199 000).

Rods contain rhodopsin, which is more sensitive than iodopsin, and many rods join one bipolar neurone, so rods are sensitive to low light intensity but have low acuity and give only black and white vision.

So nocturnal animals have more rod cells: the rat and night monkey have many more rods than cones (30 and 150 compared with 3). Animals active in the day have more cones, e.g. the marmoset has more cones than rods (11 compared with 6).

Cones each have their own bipolar neurone, so day-active animals and humans see colour and fine detail (high acuity).



The saimiri monkey is different, as it is active in the day but has more rods than cones, so it may live in shaded areas. The rat is different as it is less related to the monkeys, and only a few animals were surveyed.

(Total for Question 9 = 10 marks)

TOTAL FOR PAPER = 90 MARKS



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