

Write your name here

Surname

StemUp Model Solution

Other names

**Pearson Edexcel
Level 3 GCE**

Centre Number

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Candidate Number

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Biology B

Advanced

Paper 2: Advanced Physiology, Evolution and Ecology

Monday 11 June 2018 – Afternoon

Time: 1 hour 45 minutes

Paper Reference

9BI0/02

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.
- 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.

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.*

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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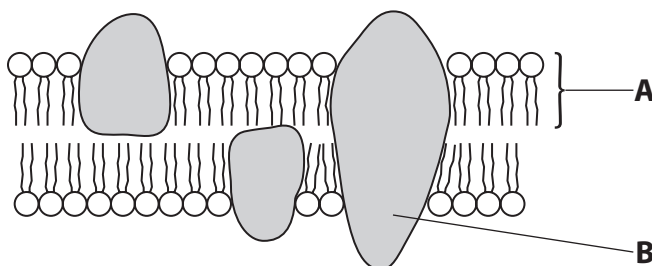


Pearson

Answer ALL questions.

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 diagram shows the structure of a cell membrane.



- (a) Name the parts labelled **A** and **B**.

(1)

A: phospholipid bilayer

B: (channel / carrier) protein

- (b) Explain how the structure of the membrane controls the transport of polar molecules.

(4)

Polar molecules are charged and hydrophilic (water soluble).

The membrane is a phospholipid bilayer: the phosphate heads are hydrophilic and face outwards, while the fatty acid tails are hydrophobic and are on the inside of the membrane.

Therefore polar (charged) substances cannot pass through the hydrophobic centre of the bilayer.

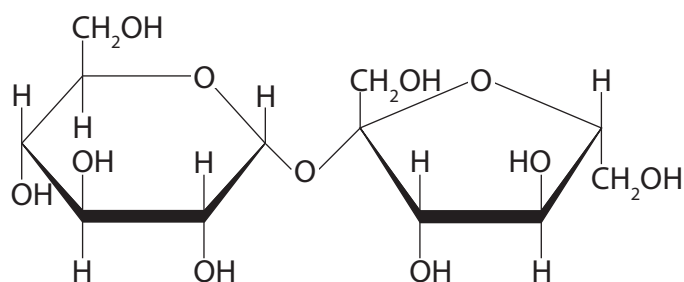
Instead they pass through the membrane via channel proteins or carrier proteins, so these proteins control which polar molecules can cross.

(Total for Question 1 = 5 marks)



2 Enzymes are involved in the breakdown of carbohydrates.

(a) The diagram shows the structure of sucrose.



The enzyme sucrase breaks down sucrose into two monosaccharides.

(i) Which type of reaction does sucrase catalyse?

(1)

- ☐ A condensation
- ☒ B hydrolysis
- ☐ C phosphorylation
- ☐ D translocation

(ii) Name the monosaccharides produced from the breakdown of sucrose.

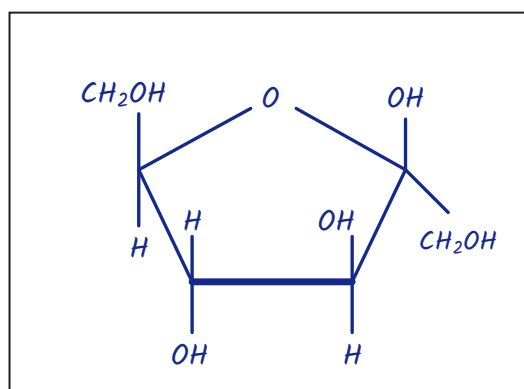
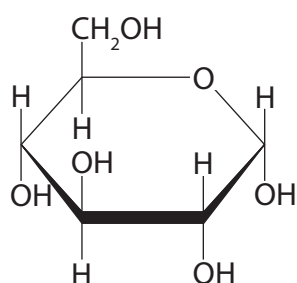
(1)

glucose and fructose

(iii) The diagram shows one of these monosaccharides.

Draw the structure of the other monosaccharide.

(1)



(b) The enzyme amylase breaks down the polysaccharide amylose into maltose.

How many of these statements are true for amylose?

(1)

- It contains 1,6 glycosidic bonds
- It contains 1,4 glycosidic bonds
- It has a helical structure
- It has a branched structure

- ☐ A 1
- ☒ B 2
- ☐ C 3
- ☐ D 4

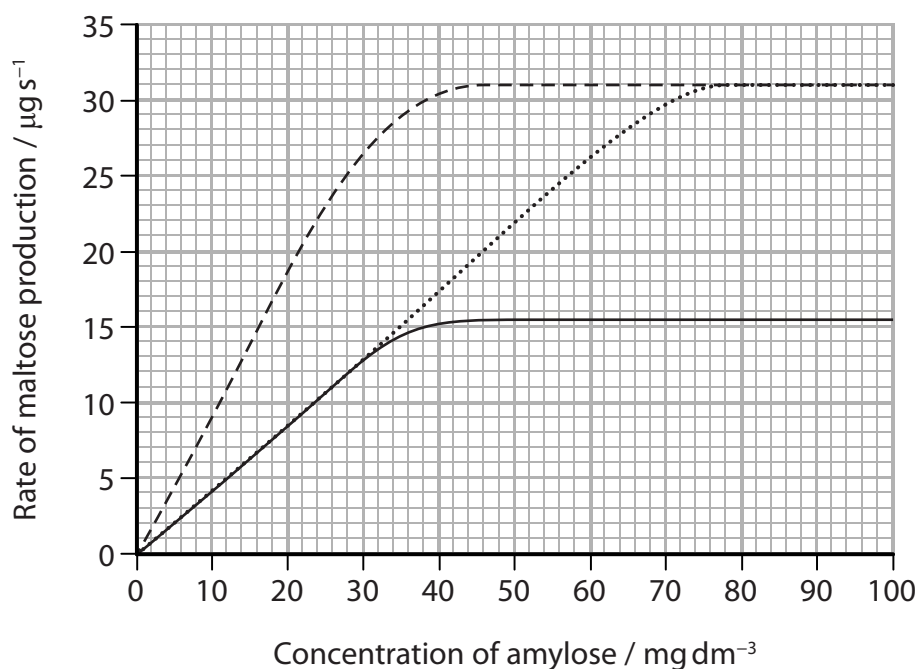
(c) Some plants produce amylase inhibitors.

A student investigated the effects of two inhibitors, A and B, on the activity of amylase.

The same concentration of amylase and the same concentrations of the inhibitors A and B were used.

The rate of maltose production was measured at different concentrations of amylose with each inhibitor and without an inhibitor.

The results are shown in the graph.



Key

- amylase without inhibitor
- amylase + inhibitor A
- amylase + inhibitor B



(i) Compare and contrast the effects of these two inhibitors on amylase activity.

(2)

Both inhibitors reduce the rate by the same amount at low amylose concentrations: the rates with A and B are the same up to about 30 mg dm^{-3} (about $13 \text{ } \mu\text{g s}^{-1}$).

Above this, the rate with inhibitor B stops increasing and levels off at about $15 \text{ } \mu\text{g s}^{-1}$, whereas the rate with inhibitor A continues to increase until it reaches the same maximum as without an inhibitor ($31 \text{ } \mu\text{g s}^{-1}$).

(ii) Explain which of the two inhibitors is non-competitive.

(3)

Inhibitor B is non-competitive, because the rate levels off and never reaches the maximum rate without an inhibitor, even at high amylose concentrations.

This is because inhibitor B binds to the enzyme at an allosteric site (a site other than the active site).

This changes the shape of the active site, so amylose can no longer bind and fewer enzyme-substrate complexes form; adding more substrate cannot overcome this.

Inhibitor A is competitive, as its effect is overcome at high amylose concentrations.

(Total for Question 2 = 9 marks)



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3 The retina contains rod cells and bipolar neurones.

Rod cells contain large numbers of mitochondria.

(a) Explain the role of mitochondria in the functioning of rod cells.

(2)

Mitochondria carry out aerobic respiration, which releases energy to make ATP.

This ATP is needed for the active transport of ions by the $\text{Na}^+\text{-K}^+$ pump, and to regenerate rhodopsin by converting trans retinal back into cis retinal and combining it with opsin.

(b) Rod cells release glutamate, an inhibitory neurotransmitter.

Describe how light causes a change in the release of glutamate from rod cells.

(4)

In the dark, Na^+ ions diffuse into the rod cell through open cation channels, so the cell is depolarised and releases glutamate.

Light is absorbed by the pigment rhodopsin.

Retinal changes from the cis form to the trans form, so rhodopsin breaks down into opsin and retinal.

This causes the Na^+ (cation) channels to close, so Na^+ stops diffusing into the rod cell.

Na^+ is still pumped out of the cell, so the inside of the cell becomes more negative (hyperpolarisation).

As a result, the rod cell stops releasing glutamate onto the bipolar neurone.

(Total for Question 3 = 6 marks)



- 4 The photograph shows part of a bacterial cell surrounded by viruses, as seen using an electron microscope.



- (a) (i) Which of these structures would be present in a bacterial cell but absent in a palisade mesophyll cell?

(1)

- ☐ A cellulose cell wall and nucleoid
☐ B cellulose cell wall and nucleolus
☒ C peptidoglycan cell wall and nucleoid
☐ D peptidoglycan cell wall and nucleolus

- (ii) Which virus contains DNA?

(1)

- ☐ A Ebola
☐ B HIV
☒ C λ (lambda) phage
☐ D tobacco mosaic

- (iii) Explain why an electron microscope, rather than a light microscope, was used to produce this photograph.

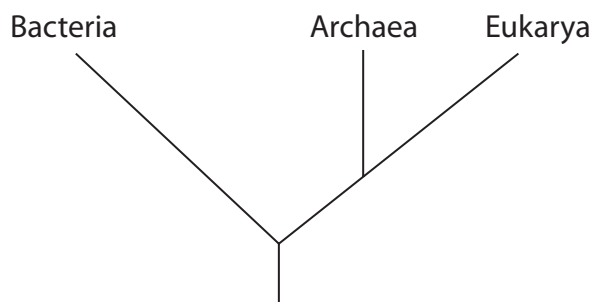
(2)

An electron microscope has a much higher resolution than a light microscope, so the tiny viruses can be seen in detail.

This is because electrons have a much shorter wavelength than light.



(b) The diagram shows the three-domain model of classification as suggested by Carl Woese.



This model was based on the comparison of many different characteristics.

Some of the characteristics used by Woese are shown in the table.

Characteristic	Archaea	Bacteria	Eukarya
Membrane lipids	branched carbon chains attached to glycerol by ether linkage	straight carbon chains attached to glycerol by ester linkage	straight carbon chains attached to glycerol by ester linkage
First amino acid in protein synthesis	methionine	formylmethionine	methionine
Antibiotic sensitivity	no	yes	no
rRNA loop sequence	absent	present	absent
Ribosome size	70 S	70 S	80 S

- (i) Analyse the information to explain the evidence for the three-domain model of classification.

(3)

Each domain has unique characteristics, e.g. only Archaea have branched carbon chains with ether linkages in their membrane lipids, only Bacteria use formylmethionine, are sensitive to antibiotics and have the rRNA loop sequence, and only Eukarya have 80 S ribosomes.

Archaea and Eukarya share three characteristics: methionine as the first amino acid, no antibiotic sensitivity and no rRNA loop sequence.

So Archaea and Eukarya are more closely related to each other than to Bacteria, and have a more recent common ancestor.

The differences in membrane lipids and ribosome size evolved after Archaea and Eukarya split, so there are three separate domains, not two.



(ii) Many scientists agree with this three-domain model.

State how these scientists would have reached agreement about this model.

(1)

They published their findings in scientific journals, where the work was checked by peer review, and discussed it at scientific conferences.

(Total for Question 4 = 8 marks)

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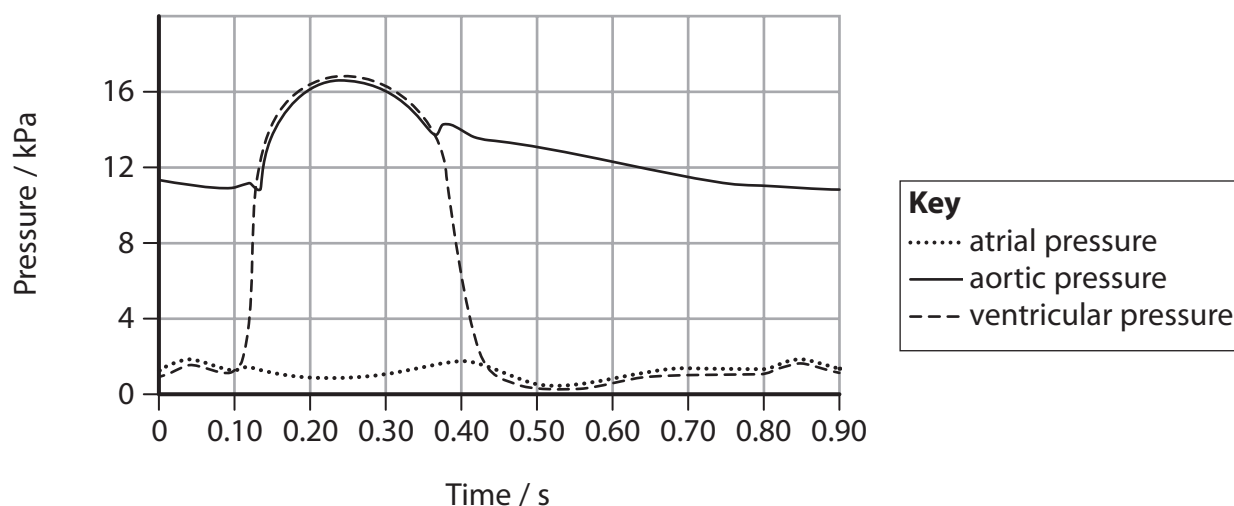
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- 5 The graph shows the pressure changes in the left side of the heart during one cardiac cycle.



- (a) (i) Calculate the heart rate.

(1)

$$\text{length of one cardiac cycle} = 0.80 \text{ s}$$

$$\text{heart rate} = 60 \div 0.80 = 75$$

Answer 75 beats min⁻¹

- (ii) During which time period does blood leave the left ventricle?

(1)

- ☐ A 0.10 s to 0.13 s
- ☐ B 0.10 s to 0.37 s
- ☒ C 0.13 s to 0.37 s
- ☐ D 0.13 s to 0.43 s



(iii) At which time does the valve between the atrium and the ventricle close?

(1)

- ☒ A 0.10 s
- ☐ B 0.13 s
- ☐ C 0.37 s
- ☐ D 0.43 s

(b) Describe how myogenic stimulation brings about contraction of the atria and the ventricles.

(5)

Myogenic means the heart contracts with no external nerve impulses: stimulation is generated within the heart.

Contraction is initiated by the sinoatrial node (SAN) in the wall of the right atrium, which spontaneously generates a wave of excitation (depolarisation).

This wave of excitation spreads across both atria, causing them to contract (atrial systole).

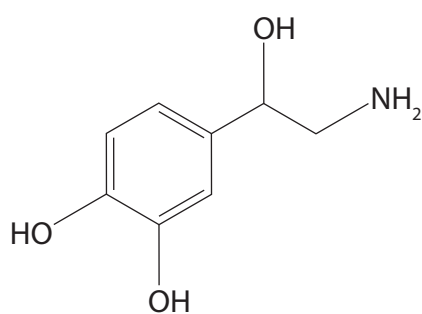
The wave reaches the atrioventricular node (AVN), where there is a short delay, so the atria finish contracting before the ventricles contract.

The depolarisation then passes down the bundle of His in the septum and up through the Purkyne fibres in the ventricle walls.

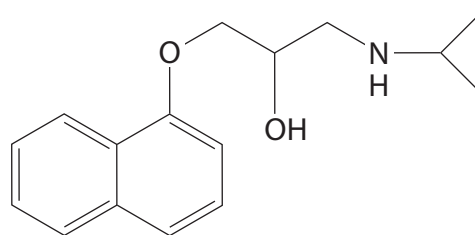
This causes the ventricles to contract from the apex (base) of the heart upwards (ventricular systole).



(c) The diagram shows two chemicals that affect the human heart rate.



Noradrenaline



Beta blocker

Beta blockers are drugs used to regulate the heart rate of some patients.

The effect of beta blockers on the heart rate during exercise was investigated.

The ECG traces show the heart rate of a person exercising before and after taking a beta blocker.

Exercise with no beta blocker



Exercise with a beta blocker



Analyse the information to explain the results of this investigation.

(3)

The heart rate during exercise is slower after taking the beta blocker, as there are fewer heartbeats (QRS peaks) in the same time.

This is because the beta blocker has a similar structure (shape) to noradrenaline, e.g. both have a ring and an OH group and an NH group on the side chain.

So the beta blocker binds to the noradrenaline receptors on the heart (SAN) cells.

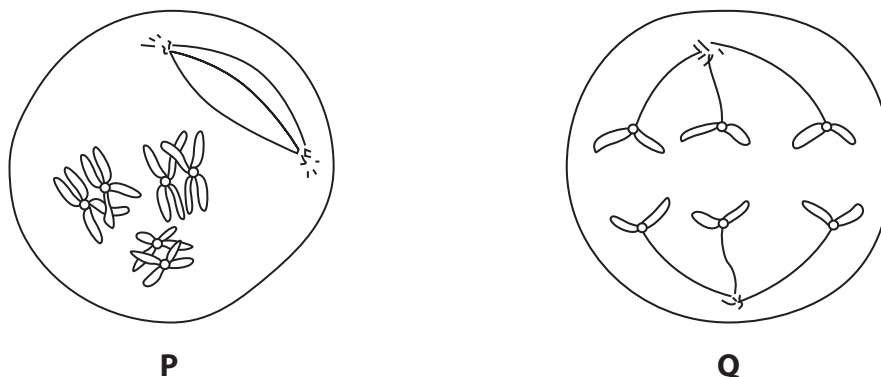
Therefore it blocks the binding of noradrenaline to these receptors, so noradrenaline cannot increase the heart rate.

(Total for Question 5 = 11 marks)



- 6 (a) Mosquitoes have cells with a diploid number ($2n$) of six.

The diagram shows two cells from a male mosquito at different stages of meiosis.



- (i) Which row of the table shows the stages of meiosis of cells P and Q?

(1)

	P	Q
☐ A	anaphase II	anaphase I
☐ B	metaphase I	prophase I
☒ C	prophase I	anaphase II
☐ D	prophase II	metaphase II

- (ii) Non-disjunction occurred during meiosis I.

Which of the following shows the number of chromosomes in each of the four sperm cells produced?

(1)

- ☐ A 4, 3, 3, 2
- ☒ B 4, 4, 2, 2
- ☐ C 6, 6, 7, 5
- ☐ D 7, 7, 5, 5



- (b) Down's syndrome in humans is caused by non-disjunction.

The chance of having a baby with Down's syndrome increases as the age of the mother increases.

At age 40, the probability of having a baby with Down's syndrome is 0.018.

In 2016 the number of women aged 40 in the UK was estimated to be 500 000.

The pregnancy rate for women in the UK aged 40 is 14 pregnancies per 1000 women per year.

Calculate the number of babies with Down's syndrome that were expected in 2016 in the UK.

(2)

$$\text{pregnancies} = (500\,000 \div 1000) \times 14 = 7000$$

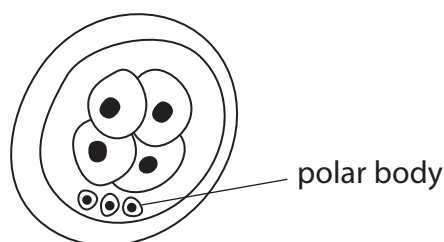
$$\text{babies with Down's syndrome} = 7000 \times 0.018 = 126$$

Answer 126



- (c) *In vitro* fertilisation (IVF) is a technique in which eggs are taken from the ovaries and fertilised with sperm in a laboratory.

The resulting embryos are cultured until the four-cell stage, as shown in the diagram.



Two screening techniques used to identify embryos with chromosomal abnormalities are:

- polar body biopsy in which the polar bodies are removed and the chromosomes analysed
- pre-implantation genetic diagnosis (PGD) in which one cell from the four-cell stage embryo is removed and the chromosomes analysed.

Embryos without chromosome abnormalities are placed into the mother's uterus.

The success rates of both techniques are shown in the table.

Technique	Percentage of embryos that survive screening (%)	Percentage of embryos transferred to the uterus that lead to the birth of baby (%)
Polar body biopsy	87	21
PGD	74	29
Control	IVF with no screening	16



Analyse the data to comment on the effectiveness of the two techniques.

(4)

Both screening techniques are more effective than the control, as a greater percentage of transferred embryos lead to the birth of a baby (21% and 29% compared with 16% with no screening).

More embryos survive screening with polar body biopsy (87%) than with PGD (74%), so polar body biopsy is less damaging to the embryos.

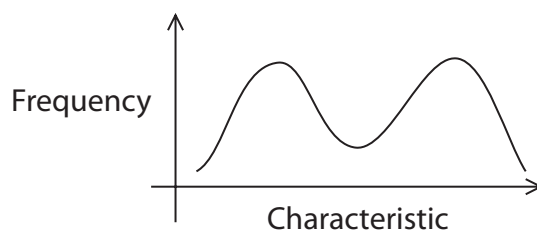
However, PGD is more effective overall, as it produces more births: $0.74 \times 29 = 21\%$ of all screened embryos lead to a birth with PGD, compared with $0.87 \times 21 = 18\%$ with polar body biopsy.

This is because PGD detects abnormalities in both the paternal and maternal chromosomes, whereas polar body biopsy only checks the maternal chromosomes.

(Total for Question 6 = 8 marks)



- 7 (a) The graph shows the frequency of a characteristic found in a population of animals.



Which type of selection would create this pattern?

(1)

- ☐ A allopatric selection
- ☐ B directional selection
- ☒ C disruptive selection
- ☐ D stabilising selection

- (b) The Eurasian lynx is the largest native European cat species.

It was once widespread across Europe but is now restricted to small areas of national parks.



Ex-situ and *in-situ* conservation measures were used in the 1970s to increase biodiversity.

- Lynx were bred in zoos and 10 were reintroduced into an area of protected forest where the lynx had become extinct.
- Existing wild lynx were protected in an area of forest where they had not become extinct.

In 2016 scientists estimated the population sizes and genetic biodiversity of the lynx in these two areas of forest.

They found that the population and genetic biodiversity of the lynx in the area where they had been reintroduced were much lower than in the protected area.



- (i) State what is meant by the term **biodiversity**.

(1)

The variety of living organisms: the number of different species in a habitat, and the genetic variation (different alleles) within a species.

- (ii) Explain why, in 2016, the genetic biodiversity of the lynx population in the area where they had been reintroduced was much lower than in the protected area.

(2)

Only a small number of lynx (10) were reintroduced, so a founder effect (genetic bottleneck) occurred.

This gave a limited gene pool with few different alleles, as the zoo lynx were likely to be inbred and there were no other lynx in the area to provide new alleles.

- (c) Explain the principles and issues associated with ex-situ conservation methods.

(4)

Ex-situ conservation protects species outside their natural habitat, e.g. in zoos, safari parks and seed banks, to prevent the extinction of endangered species.

Captive breeding programmes, controlled feeding, veterinary care and protection from predators and poaching increase population numbers, so animals can be reintroduced.

Zoos also raise money for, and raise awareness of, the importance of conservation.

Issues: captive populations are small, so inbreeding must be avoided by using stud books and exchanging animals or frozen sperm between zoos.

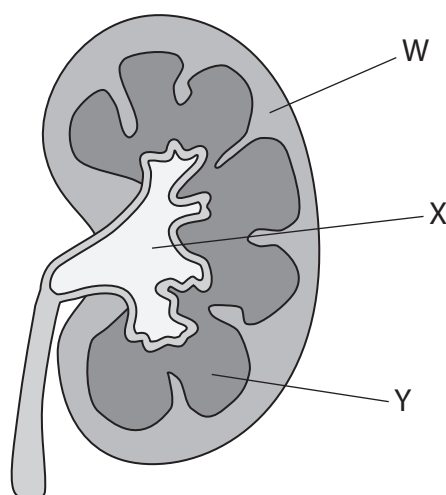
Animals may lose normal behaviours, e.g. they cannot hunt and are reliant on humans.

There are also ethical issues about keeping animals in captivity.

(Total for Question 7 = 8 marks)



- 8 The diagram shows a section through a mammalian kidney.



- (a) Which row of the table names the parts of the kidney labelled in the diagram?

(1)

	W	X	Y
☐ A	cortex	medulla	pelvis
☒ B	cortex	pelvis	medulla
☐ C	medulla	pelvis	cortex
☐ D	medulla	cortex	pelvis

- (b) The table shows information about substances found in the blood and in the filtrate in the renal (Bowman's) capsule.

Substance	Relative molecular mass	Ratio of concentration in the filtrate in the renal (Bowman's) capsule : concentration in blood
sodium ions	23	1.00
water	18	1.00
urea	60	1.00
glucose	180	1.00
myoglobin	17 000	0.75
plasma proteins	69 000	<0.01



Analyse the data to explain the ratios of these substances.

(3)

Substances with a higher relative molecular mass have a lower ratio: sodium ions, water, urea and glucose (mass 180 or less) have a ratio of 1.00, myoglobin (17 000) has 0.75 and plasma proteins (69 000) less than 0.01.

A ratio of 1.00 means all of the substance passes into the filtrate, so smaller substances pass through, while large substances such as plasma proteins do not.

This is because of the size of the pores in the glomerulus capillary wall and the basement membrane, which act as a filter.

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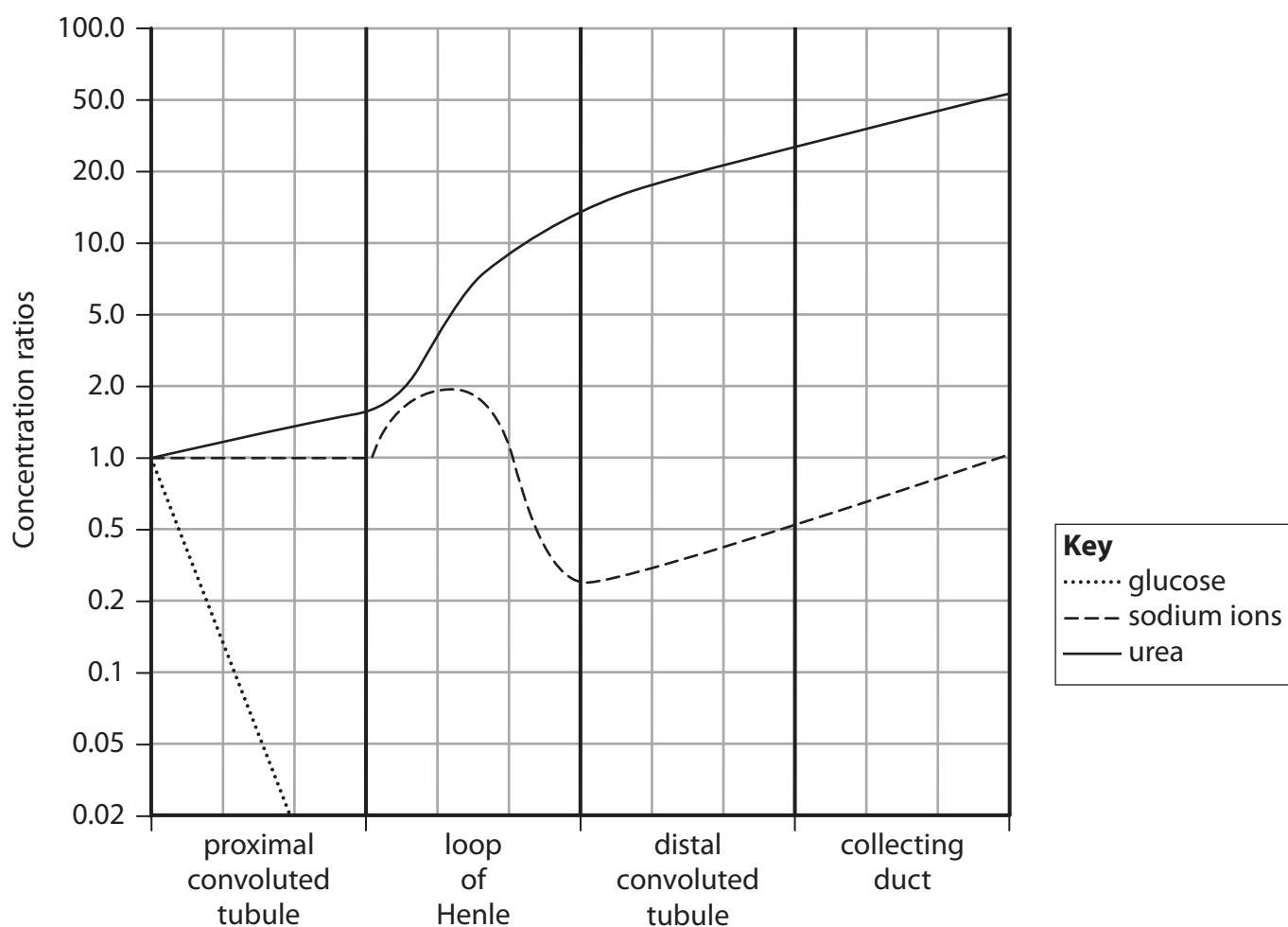
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*(c) The renal (Bowman's) capsule is part of each nephron found in the kidney.

The graph shows the concentration ratios of three solutes in different parts of the nephron compared with their concentrations in the renal capsule.



Explain the changes in the concentration ratios of these solutes in the different parts of the nephron.

(6)

Proximal convoluted tubule: the glucose concentration ratio falls to almost zero because all of the glucose is reabsorbed into the blood by active transport (co-transport with Na^+), using ATP.

Sodium ions are also reabsorbed, so their concentration ratio stays at 1.0 even though water is reabsorbed by osmosis.

The urea concentration ratio rises to about 1.5 because water is reabsorbed but most of the urea stays in the filtrate.

Loop of Henle: in the descending limb, water is reabsorbed by osmosis into the salty medulla, so the sodium ion concentration ratio rises to about 2.0 and the urea ratio rises steeply.

In the ascending limb, sodium ions are actively pumped out and this limb is impermeable to water, so the sodium ion concentration ratio falls to about 0.25.

This creates a low water potential in the medulla, as the loop acts as a countercurrent multiplier.

Distal convoluted tubule and collecting duct: more water is reabsorbed by osmosis, so the concentration ratios of both urea (up to about 50) and sodium ions (up to about 1.0) rise.

ADH increases the permeability of the collecting duct walls to water, so more water is reabsorbed and the urea becomes most concentrated in the collecting duct.

(Total for Question 8 = 10 marks)



P 5 2 2 8 7 R A 0 2 3 3 2

9 The table shows information about one area of the North Atlantic Ocean.

Month	Mean hours of daylight / hr	Mean monthly temperature / °C	Net primary productivity (NPP) / g carbon m ⁻² day ⁻¹
January	9.0	2.8	-1.0
February	10.0	3.1	-1.2
March	11.0	6.7	-0.5
April	13.0	9.4	+3.0
May	14.0	15.5	+4.0
June	15.0	20.6	+8.0
July	14.0	23.9	+7.0
August	13.5	23.3	+7.0
September	12.0	21.1	+5.0
October	11.0	16.1	+4.0
November	10.0	11.1	+3.0
December	9.0	4.0	-1.2

(a) (i) State what is meant by the term **net primary productivity** (NPP).

(1)

NPP is the gross primary productivity minus the energy used in respiration by producers (GPP - R).

(ii) Analyse the data to explain the effect of daylight and temperature on NPP.

(3)

NPP increases as the hours of daylight and the temperature increase, e.g. from -1.0 in January to +8.0 in June.

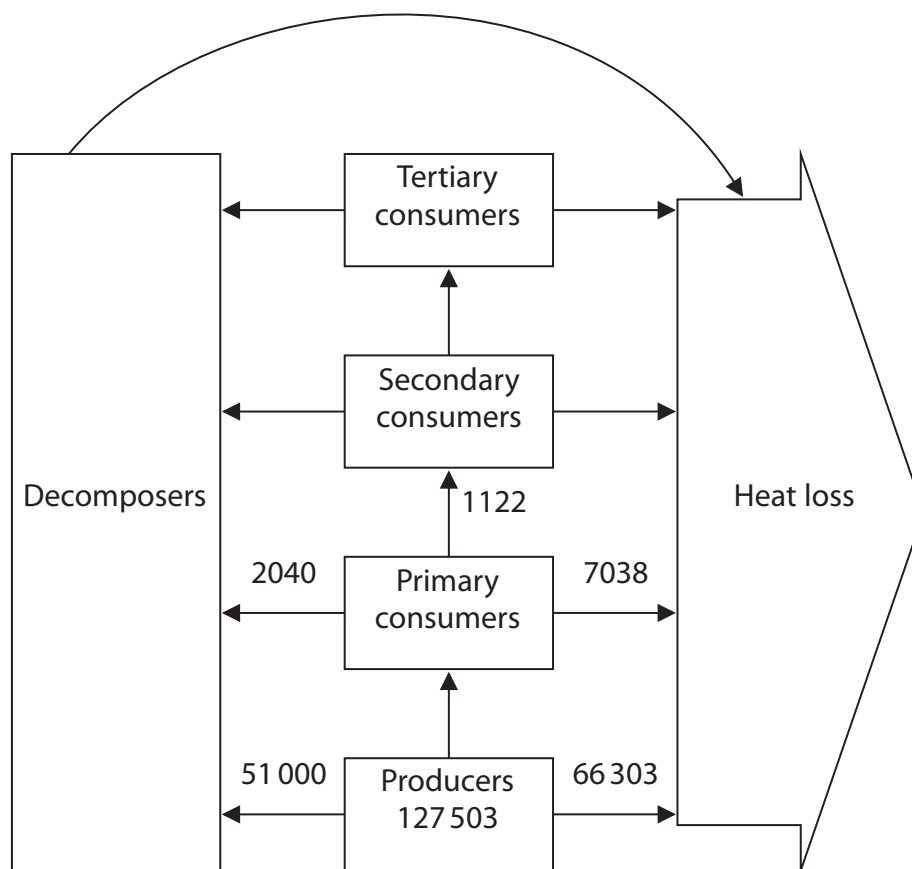
This is because more light and higher temperatures increase the rate of photosynthesis more than the rate of respiration.

Light is the limiting factor between June and July: temperature rises but daylight falls, and NPP falls from +8.0 to +7.0.

NPP is negative (December to March) when respiration is greater than photosynthesis (GPP).



- (b) The diagram shows some of the energy transfers through a food chain from this area.
- The figures show the energy transfer in $\text{kJ m}^{-2} \text{ yr}^{-1}$.



- (i) Calculate the percentage efficiency of energy transfer from the producers to the primary consumers.

(2)

$$\text{energy to primary consumers} = 127\,503 - (51\,000 + 66\,303) = 10\,200$$

$$\text{efficiency} = (10\,200 \div 127\,503) \times 100 = 8.0\%$$

Answer 8%



- (ii) Explain why the efficiency of energy transfer differs between different trophic levels. (3)

Different organisms (trophic levels) use and lose different proportions of the energy.

Some energy is lost as heat from respiration, used for movement and maintaining body temperature.

Some material is not digested and is lost in faeces, some parts are not consumed (e.g. bones, roots), and some is lost in excretion.

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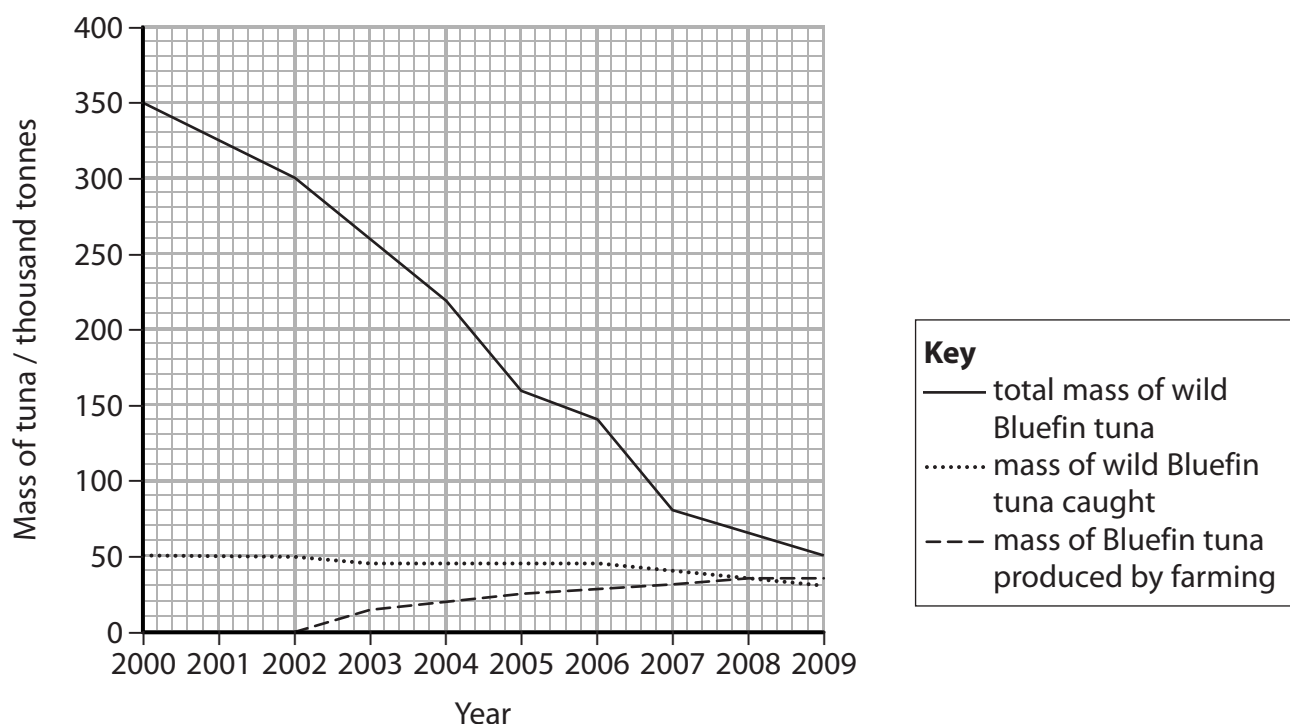
- (c) Bluefin tuna are the top predators in this ocean.

Bluefin tuna are caught by the fishing industry for human consumption. The demand is very high.

One method to help meet the demand for Bluefin tuna is tuna farming.

This method traps young sexually immature fish from the wild. They are placed in submerged cages and fed on a diet of prey species captured from the ocean.

The graph shows the masses of wild Bluefin tuna caught and Bluefin tuna produced by farming. It also shows the total mass of wild Bluefin tuna in an area of the North Atlantic Ocean.



Comment on the impact of Bluefin tuna farming.

(4)

The total mass of wild tuna fell slowly before farming began, but after 2002 it decreased much more steeply, from 300 to only 50 thousand tonnes by 2009.

The mass of wild tuna caught also decreased after 2002, from 50 to about 30 thousand tonnes.

This is because farming takes young, sexually immature fish from the wild before they have reproduced, so breeding of the wild population is reduced.

Farming also reduces the food available for the wild population, as the caged tuna are fed on prey species captured from the ocean.

Farming has not replaced the catch of wild tuna: the total of caught and farmed tuna has increased (to about 65 thousand tonnes), as consumer demand has risen.

(Total for Question 9 = 13 marks)



P 5 2 2 8 7 R A 0 2 7 3 2

- 10 In the fruit fly, *Drosophila*, the allele for normal wings (**N**) is dominant to the allele for vestigial (small) wings (**n**).

The allele for red eyes (**R**) is dominant to the allele for sepia eyes (**r**).

In an investigation, students crossed homozygous parent flies. Flies with normal wings and red eyes were crossed with flies with vestigial wings and sepia eyes.

All the F_1 offspring of this cross had normal wings and red eyes.

Flies from this F_1 generation were crossed and the phenotypes of their offspring (F_2 generation) were counted.

The results for the F_2 generation are shown in the table.

<i>Drosophila</i> phenotype	Number of <i>Drosophila</i> with each phenotype
normal wings and red eyes	885
normal wings and sepia eyes	322
vestigial wings and red eyes	286
vestigial wings and sepia eyes	107

The students thought that the genes for wing length and eye colour were on different chromosomes.

- (a) (i) State a null hypothesis for this investigation.

(1)

There is no difference between the observed and expected numbers of phenotypes.

- (ii) A Chi squared test was carried out to test this hypothesis.

Complete the table.

(1)

Phenotype	Expected ratio	Observed results (O)	Expected results (E)	(O – E)	(O – E) ²	$\frac{(O - E)^2}{E}$
normal wings and red eyes	9	885	900	-15	225	0.25
normal wings and sepia eyes	3	322	300	22	484	1.61
vestigial wings and red eyes	3	286	300	-14	196	0.65
vestigial wings and sepia eyes	1	107	100	7	49	0.49



(iii) Calculate the value of Chi squared using the formula

(1)

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

$$\chi^2 = 0.25 + 1.61 + 0.65 + 0.49$$

Answer 3.00.....

(iv) The table shows some critical values of Chi squared at different degrees of freedom.

Degrees of freedom	p value				
	0.900	0.500	0.100	0.050	0.010
1	0.016	0.455	2.706	3.841	6.635
2	0.211	1.386	4.605	5.991	9.210
3	0.584	2.366	6.251	7.815	11.345
4	1.064	3.357	7.779	9.488	13.277

Use this table to comment on the results of the investigation.

(3)

There are 3 degrees of freedom (4 phenotypes - 1), so the critical value at $p = 0.05$ is 7.815.

The calculated value of 3.00 is less than the critical value, so the null hypothesis is accepted (not rejected).

There is a more than 5% (0.05) probability that the difference is due to chance, so there is no significant difference. This supports the genes being on different chromosomes.



- *(b) In *Drosophila*, the allele for grey bodies (**G**) is dominant to the allele for black bodies (**g**).

In a second investigation, students crossed homozygous parent flies. Flies with normal wings and grey bodies were crossed with flies with vestigial wings and black bodies.

All the F_1 offspring had normal wings and grey bodies.

Flies from this F_1 generation were crossed and the phenotypes of their offspring (F_2 generation) were counted.

The results are shown in the table.

<i>Drosophila</i> phenotype	Number of <i>Drosophila</i> with each phenotype
normal wings and grey body	1105
normal wings and black body	85
vestigial wings and grey body	72
vestigial wings and black body	338

Explain the results of this second investigation.

(6)

The parents are homozygous, $NNGG \times nngg$, so all the F_1 are heterozygous $NnGg$ (normal wings and grey bodies).

If the genes were on different chromosomes, the F_2 would be in a 9:3:3:1 ratio (900 : 300 : 300 : 100 out of 1600), but the results (1105 : 85 : 72 : 338) are not in this ratio.

This is because the genes for wing length and body colour are linked: they are on the same chromosome (autosome).

Each F_1 fly has one chromosome carrying N and G and the homologous chromosome carrying n and g , so most gametes are NG or ng .

F_1 cross $NG/ng \times NG/ng$ therefore gives mostly $NNGG$ and $NnGg$ (normal, grey) and $nngg$ (vestigial, black) offspring, so these phenotypes are more common than expected.

Crossing over occasionally occurs at chiasmata in prophase I of meiosis between the two loci, producing a small number of recombinant gametes, Ng and nG .



So the flies with normal wings and black bodies (e.g. $NnGg$) and vestigial wings and grey bodies (e.g. $nnGg$) are recombinants.

Only 157 of the 1600 flies are recombinants, which suggests the two genes are close together on the chromosome, so crossing over between them is rare.

(Total for Question 10 = 12 marks)

TOTAL FOR PAPER = 90 MARKS



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