Year 13 Biology Day 1-10 packs

Complete the following tasks:

Day 1: Watch Videos attached to Google Classroom and create AO1 paragraphs for your essays *Max 90mins*

Day 2: Uplearn – watch any video you have not watched and complete all recall questions for topics 5-8. Achieve 250XP. ***Max 90mins***

Day 3: Watch the Math skills videos. Create flash cards with key information on each component. ***Max 90mins***

Day 4: Work through exam style questions on Topic 5. ***Max 90mins***

Day 5: Work through exam style questions on Topic 6. ***Max 90mins***

Day 6: Work through exam style questions on Topic 7. ***Max 90mins***

Day 7: Work through exam style questions on Topic 8. ***Max 90mins***

Day 8: Work through Math skills exam questions. ***Max 90mins***

Day 9: Uplearn attempt a Paper 2 or 3

Day 10: Review your booklet. Identify any weaknesses using the Checklists on Google classroom Create a revision timetable for the weeks leading up to the first exam. Submit this onto google Classroom

1. (a) In the following passage the numbered spaces can be filled with biological terms.

During photosynthesis, plants produce __(1)__ compounds which contain carbon, such as carbohydrates, lipids and proteins. Most of the sugars synthesised by plants are used by the plant in __(2)__. The rest are used to make other groups of biological molecules. These biological molecules form the biomass of the plants. Biomass can be measured in terms of mass of __(3)__ per given area per given time. The chemical energy store in dry biomass can be estimated using __(4)__.

Write the correct biological term beside each number below, that matches the space in the passage.

(1) _____

(2) _____

(3) _____

(4) _____

(2)

(b) Describe the **light-independent** reaction of photosynthesis.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 8 marks)

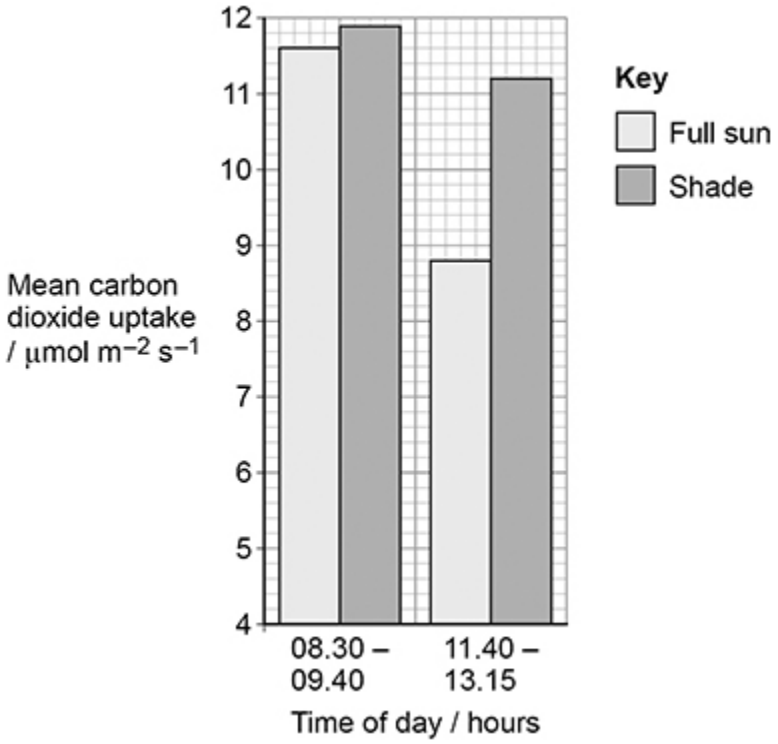
2. Scientists investigated the effect of full sun and shade on the rate of photosynthesis in a species of shade-tolerant tree.

To estimate the rate of photosynthesis, the scientists measured uptake of carbon dioxide by trees in a forest. They measured uptake of carbon dioxide during two parts of the day:

- 08.30 – 09.40 hours
- 11.40 – 13.15 hours.

Figure 1 shows the scientists' results.

Figure 1



(a) Calculate the total uptake of carbon dioxide between 11.40 and 13.15 hours in trees exposed to full sun in a forest that is 12 000 m^2 in area.

Give your answer in standard form. Show your working.

Answer _____ µmol

(3)

(b) **Figure 1** shows there is a small difference in the mean uptake of carbon dioxide between 08.30 and 09.40 hours by trees in full sun and by trees in the shade. When the scientists performed a statistical test on these data, they calculated $P > 0.5$

State what this P value tells you about this difference.

Explain your answer using the words **probability** and **chance**.

(2)

(c) In this species of tree, very high light intensities can inhibit the release of electrons from chlorophyll.

Suggest how this could explain the results shown in **Figure 1** for 11.40 to 13.15 hours.

(4)

Tomato plants grow best in high light intensities. To increase the yield of tomato plants, a farmer uses LED lightbulbs to provide additional light.

The increase in dry mass (D) produced when using additional light can be calculated using this equation.

$$D = \frac{L}{0.4F}$$

Where
L = light used in photosynthesis
F = GPP to NPP conversion factor for tomato plants

The table below shows some of these values for LED lightbulbs.

L / MJ m^{-2} h^{-1}	**F / MJ kg^{-1}**
2.87×10^{-2}	20

(d) Use the equation and the table to calculate the increase in dry mass produced when using LED lightbulbs.

Give your answer in standard form **and** give the units.

Answer _____ Units _____

(2)

(e) Mature leaves from slow-growing, shade-tolerant plants produce poisonous chemicals that are a defence against being eaten by herbivores.

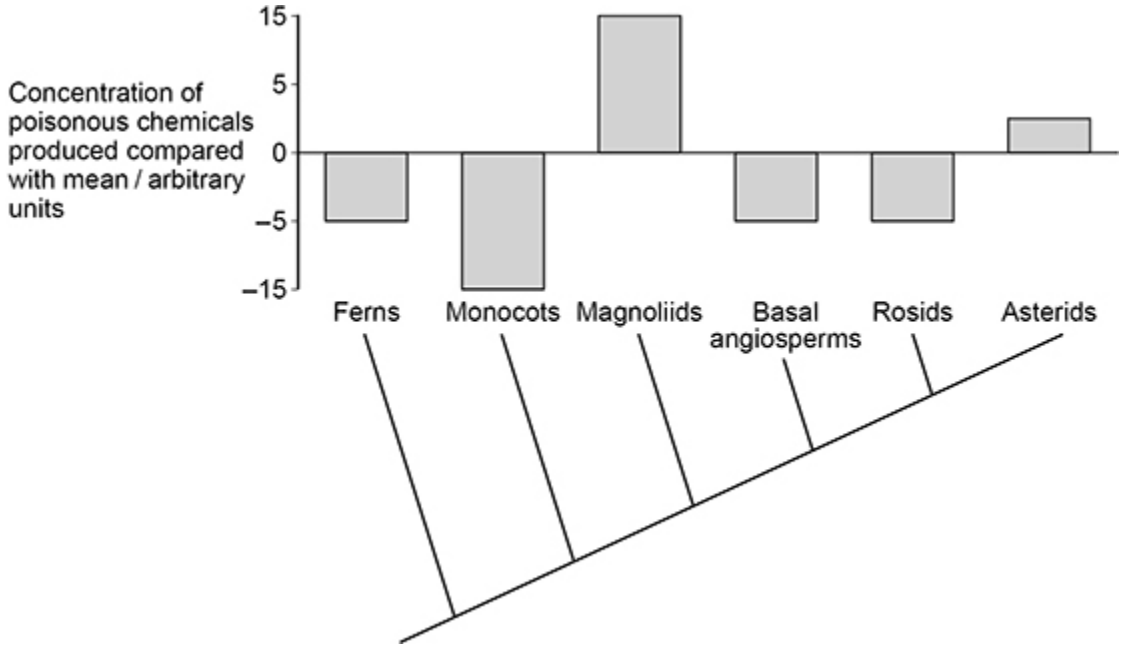
Suggest how this benefits slow-growing, shade-tolerant plants.

(2)

Scientists measured the concentration of poisonous chemicals produced by shade-tolerant plant species in six taxa. They compared this with the mean concentration of poisonous chemicals produced by all plants and the phylogenetic relationships between the six taxa.

Figure 2 shows the scientists' results.

Figure 2



(f) A journalist published the following summary of these results.

'The more recently a shade-tolerant plant species evolved, the greater the concentration of poisonous chemicals it produces.'

Do the data in **Figure 2** support this summary? Justify your answer.

(2)

(Total 15 marks)

3. Heat stress is a condition that often occurs in plants exposed to high temperatures for a prolonged period of time. Heat stress is a major factor in limiting the rate of photosynthesis.

(a) Heat stress decreases the light-dependent reaction of photosynthesis.

Explain why this leads to a decrease in the **light-independent reaction**.

(2)

(b) Another effect of heat stress is a decrease in the activity of the enzyme rubisco. A decrease in the activity of an enzyme means that the rate of the reaction it catalyses becomes slower.

A decrease in the activity of the enzyme rubisco would limit the rate of photosynthesis.

Explain why.

_____

_____

_____

_____

_____

(2)

(c) Where precisely is rubisco found in a cell?

_____

_____

(1)

Scientists investigated the effect of temperature on the activity of two enzymes isolated from the leaf cells of cotton plants.

- Rubisco
- Rubisco activase – an enzyme that activates rubisco

Figure 1 and **Figure 2** show their results.

Figure 1

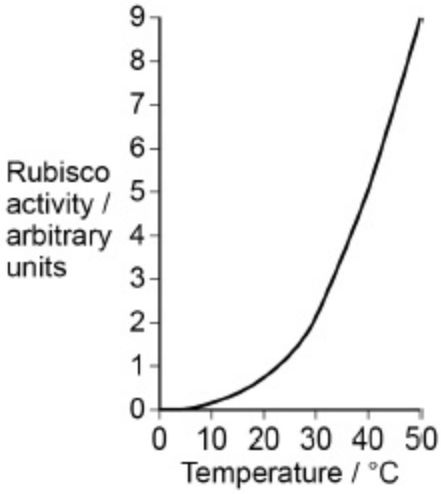
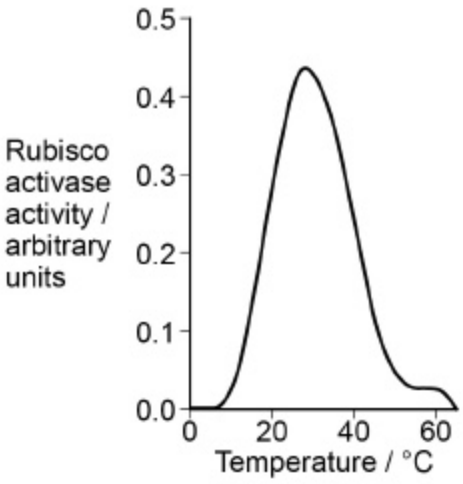


Figure 2



(d) The scientists concluded that heat stress reduces the activity of rubisco in plant leaves by affecting rubisco activase.

Use all the information to evaluate their conclusion.

(4)

(Total 9 marks)

4. (a) In photosynthesis, which chemicals are needed for the light-dependent reaction?
Tick (✓) **one** box.

- Reduced NADP, ADP, Pi, water and oxygen. ☐
- NADP, ATP and water. ☐
- Reduced NADP, ATP, water and carbon dioxide. ☐
- NADP, ADP, Pi and water. ☐

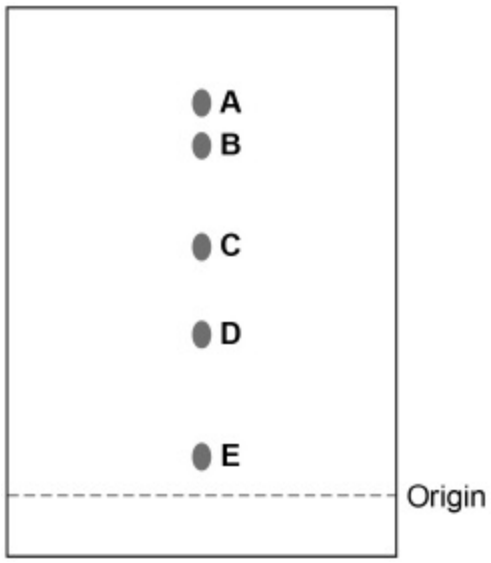
(1)

(b) Describe what happens during photoionisation in the light-dependent reaction.

(2)

A student obtained a solution of pigments from the leaves of a plant. Then the student used paper chromatography to separate the pigments.

The diagram shows the chromatogram produced.



(c) Explain why the student marked the origin using a pencil rather than using ink.

(1)

(d) Describe the method the student used to separate the pigments after the solution of pigments had been applied to the origin.

_____

_____

_____

_____

_____

_____

(2)

(e) Calculating the R_f values of the pigments can help to identify each pigment. An R_f value compares the distance the pigment has moved from the origin with the distance the solvent front has moved from the origin.

$$R_f = \frac{\text{distance pigment has moved from the origin}}{\text{distance solvent front has moved from the origin}}$$

The distance each pigment has moved is measured from the middle of each spot.

Pigment **A** has an R_f value of 0.95

Use the diagram above to calculate the R_f value of pigment **C**.

R_f value of pigment **C** = _____

(1)

(f) The pigments in leaves are different colours. Suggest and explain the advantage of having different coloured pigments in leaves.

_____

_____

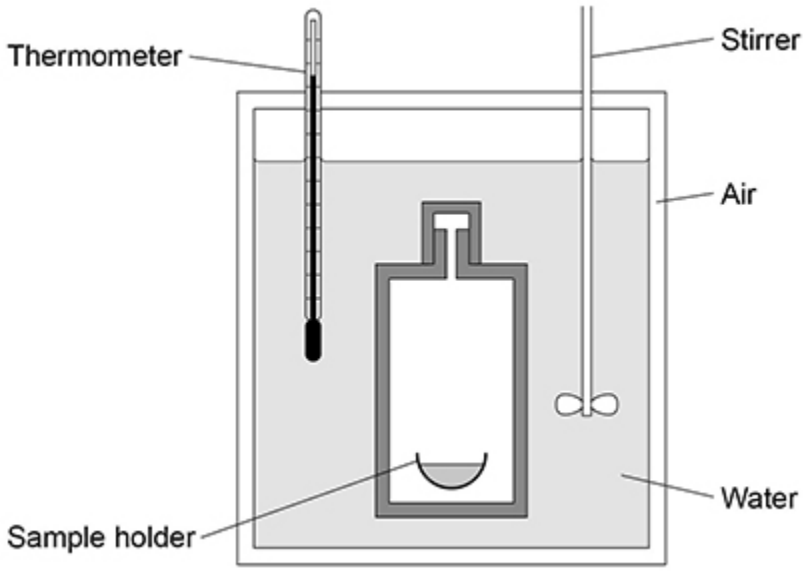
_____

_____

(1)

(Total 8 marks)

5. The diagram below shows one type of calorimeter.



A calorimeter can be used to determine the chemical energy store of biomass. A known mass of biomass is fully combusted in a calorimeter. The heat energy released from this combustion increases the temperature of the water in the calorimeter. The increase in the temperature of a known volume of water is recorded.

(a) Other than the thermometer, explain how **two** features of the calorimeter shown in the diagram above would enable a valid measurement of the total heat energy released.

1 _____

_____

_____

2 _____

_____

_____

(2)

(b) A 2 g sample of biomass was fully combusted in a calorimeter.

The volume of water in the calorimeter was 100 cm^3

The increase in temperature recorded was 15.7 °C

4.18 J of energy are needed to increase the temperature of 1 cm^3 of water by 1 °C

Use this information to calculate the heat energy released in kJ per g of biomass.

Show your working.

Answer _____ kJ g^{-1}

(2)

Plants and algae produce fuels called biofuels. Scientists have used *Chlorella* to produce biofuel. *Chlorella* is a genus of single-celled photosynthetic alga. *Chlorella* can be grown in open ponds and fermenters.

(c) In natural ecosystems, most of the light falling on producers is **not** used in photosynthesis.

Suggest **two** reasons why.

1 _____

_____

_____

2 _____

_____

_____

(2)

(d) The light absorbed by chlorophyll is used in the light-dependent reaction.

Name the **two** products of the light-dependent reaction that are required for the light-independent reaction.

1 _____

2 _____

(2)

(e) *Chlorella* cells can divide rapidly. A culture of 2000 *Chlorella* cells was set up in a fermenter. The cells divided every 90 minutes.

You can assume that there were no limiting factors and that no cells died during the 24 hours.

Calculate the number of cells in the culture after 24 hours.

Give your answer in standard form.

Show your working.

Answer _____

(2)

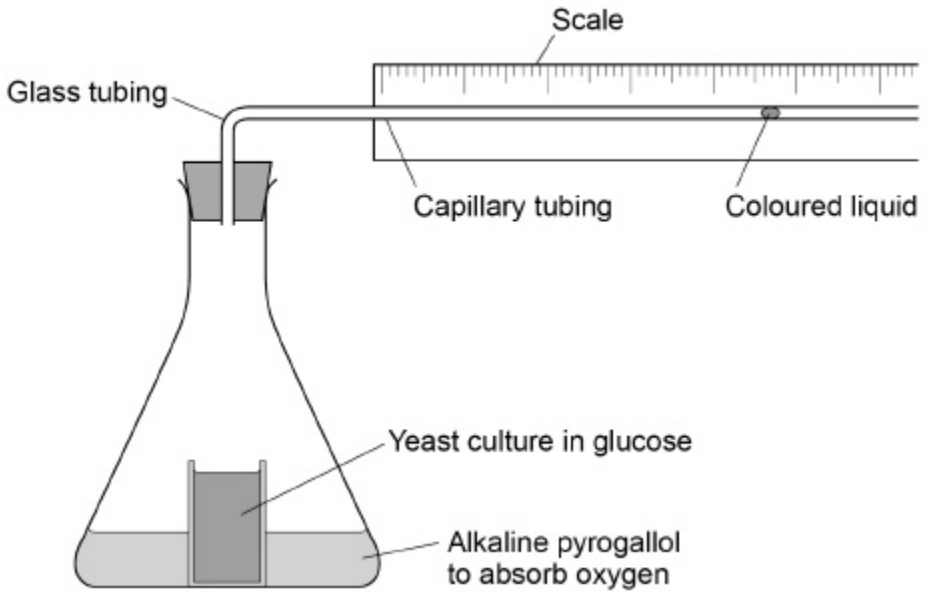
(Total 10 marks)

6. Yeast cells can respire aerobically or anaerobically. A student used the apparatus shown in **Figure 1** to measure the rate of respiration in yeast.

She:

- positioned the flask in a water bath so that the yeast culture reached a constant temperature
- then left the apparatus for one hour before starting her investigation.

Figure 1



(a) Suggest **one** reason why it was important that the student left the apparatus for one hour after the yeast culture reached a constant temperature.

_____

_____

(1)

(b) During her investigation, the coloured liquid moved to the right.

Explain why it moved to the right.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(c) The student found that the coloured liquid moved 1.5 cm in 24 hours. The diameter of the lumen (hole) of the capillary tubing was 1 mm.

The volume of a capillary tubing is given by $\pi r^2 l$, where π is 3.14 and l = length.

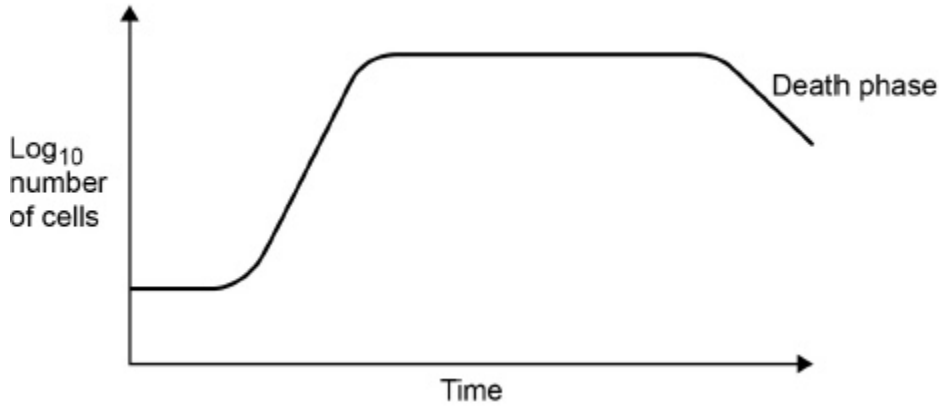
Calculate the volume of gas produced in $cm^3\ hour^{-1}$.
Show your working.

Answer = _____ $cm^3\ hour^{-1}$

(2)

Figure 2 shows a typical population growth curve for yeast under laboratory conditions.

Figure 2



(d) Explain why a log scale is used to record the number of cells.

_____

_____

_____

(1)

(e) Many yeast cells die during the death phase.

Suggest **one** reason why.

_____

_____

_____

_____

(1)

(f) The following equation can be used to make predictions of the growth in the population of yeast cells under ideal laboratory conditions.

$$X_t = X_0 e^{rt}$$

X_t = the population after a certain time
X_0 = the population at the start
e = 2.72 (base of natural logarithm)
r = growth rate
t = time period in hours over which r applies

A population of 2000 yeast cells was left for 10 hours.
The value for the growth rate was 0.5

Assuming no yeast cells died, calculate the predicted size of the population after 10 hours.
Show your working.

Answer = _____

(2)

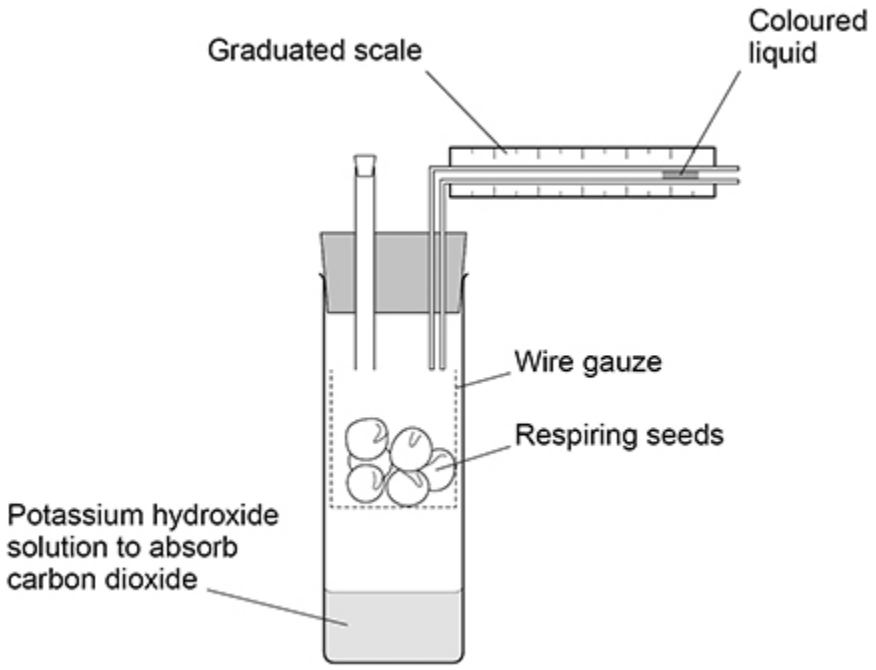
(Total 9 marks)

7. (a) Put a Tick (✓) in the box next to the process that occurs in anaerobic respiration but does **not** occur in aerobic respiration.

Phosphorylation of glucose	☐
Reduction of NAD	☐
Reduction of pyruvate	☐
Substrate-level phosphorylation	☐

(1)

A student used the apparatus shown in the diagram below to measure the rate of aerobic respiration of seeds for 48 hours.



(b) During the 48 hours, the coloured liquid moved to the left.

Explain why.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(c) Apart from time, give **two** measurements the student would have to make to determine the rate of aerobic respiration of these seeds in cm^3 $hour^{-1}$

1 _____

_____

2 _____

_____

(2)

(d) The student used the same apparatus to determine the volume of carbon dioxide the seeds produced during 48 hours.

Give the change the student would need to make to the contents of the apparatus **and** describe how he could calculate the volume of carbon dioxide produced.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(e) The student calculated that during the 48 hours, 6.2×10^{-4} cm^3 of oxygen was absorbed by 40 g of seeds.

Calculate the oxygen uptake in $cm^3\ g^{-1}\ hour^{-1}$

Answer _____ $cm^3\ g^{-1}\ hour^{-1}$

(1)

(Total 10 marks)

8. (a) Describe the role of saprobionts in the nitrogen cycle.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(b) One environmental issue arising from the use of fertilisers is eutrophication. Eutrophication can cause water to become cloudy.

You are given samples of water from three different rivers.

Describe how you would obtain a quantitative measurement of their cloudiness.

(3)

(Total 5 marks)

9. (a) Describe the process of glycolysis.

(4)

(b) Malonate inhibits a reaction in the Krebs cycle.

Explain why malonate would decrease the uptake of oxygen in a respiring cell.

(2)

(Total 6 marks)

10. (a) Put a Tick (✓) in the box next to the equation that shows how the net production of consumers, *N*, can be calculated where
I represents the chemical energy store in ingested food
F represents the chemical energy lost to the environment in faeces and urine
R represents the respiratory losses to the environment.

$N = (I - F) + R$ ☐

$N = I - (F + R)$ ☐

$N = I + (F + R)$ ☐

$N = I - (F - R)$ ☐

(1)

In the UK, some female cattle are only used for breeding. This female breeding herd has dairy cows and beef cows.

The table below shows data on dairy cows and beef cows in the UK female breeding herd in December 2013 and December 2017.

Date	**Total number in female breeding herd / millions**	**Percentage of total female breeding herd**	
		Dairy cows	**Beef cows**
December 2013	3.35	54	46
December 2017	3.45	55	45

(b) In December 2017, the female breeding herd was 48% of all female cattle in the UK.
Use the table above to calculate the percentage of all female cattle that were beef cows in the UK in December 2017.

Answer _____ %

(1)

(c) Use the table above to calculate the increase in the number of dairy cows in the UK female breeding herd between December 2013 and December 2017.

Show your working.

Increase in number _____

(2)

(d) Farming cattle for humans to eat is less efficient than farming crops because of energy transfer.
Explain why.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(Total 6 marks)

11. Freshwater marshes have one of the highest rates of gross primary production (*GPP*) and net primary production (*NPP*) of all ecosystems.

Carbon use efficiency (*CUE*) is the ratio of *NPP:GPP*. Freshwater marshes have a high *CUE*.

(a) Use your knowledge of *NPP* to explain why freshwater marshes have a high *CUE* **and** the advantage of this.

Do **not** refer to abiotic factors in your answer.

Explanation _____

Advantage _____

_____

(2)

(b) Freshwater marsh soils are normally waterlogged. This creates anaerobic conditions.

Use your knowledge of the nitrogen cycle to suggest why these soils contain relatively high concentrations of ammonium compounds and low concentrations of nitrite ions and nitrate ions.

(2)

A student investigated the growth rate of a freshwater marsh plant.

The growth rate (R) of a plant can be determined using this equation.

$$R = \frac{(\ln W_2 - \ln W_1)}{t}$$

Where
ln = natural logarithm
t = duration of the investigation in days
W_1 = plant biomass at the start of the investigation
W_2 = plant biomass at the end of the investigation

The student used the equation above; however, she substituted height for biomass. This was because she did not want to destroy the plants to measure their biomass.

(c) State the assumption the student has made **and** suggest why this assumption might **not** be valid.

(2)

(d) At the end of the investigation, the student noted the freshwater marsh plant had grown 268 mm in height, and now measured 387 mm. She calculated the rate of growth *(R)* to be 0.097 mm m^{-1} day^{-1}

Use this information and, **substituting height for biomass**, use the equation to calculate the duration of the student's investigation.

Give your answer to the nearest full day. Show your working.

_____ days

(2)

(Total 8 marks)

12. Nitrogen-fixing bacteria such as *Azotobacter chroococcum* use the enzyme nitrogenase to produce ammonia from nitrogen gas in the air. *A. chroococcum* can use ammonium chloride as a direct source of ammonia. When a source of ammonia is not available this bacterium uses nitrogen fixation.

A scientist investigated the effect of an increase in the concentration of ammonium chloride on the activity of nitrogenase in this bacterium. He prepared several liquid medium cultures of the bacterium. Each liquid culture had the same volume. He grew each culture in a different concentration of ammonium chloride.

In each culture:

- he recorded the nitrogenase activity in arbitrary units
- he removed the bacteria and then recorded the concentration of ammonium chloride remaining in each liquid medium.

The table below shows the scientist's results.

Concentration of ammonium chloride / µg cm^{-3}	**Nitrogenase activity / arbitrary units**	**Concentration of ammonium chloride remaining in liquid medium / µg cm^{-3}**
0	45	0
20	30	0
40	17	0
60	7	0
80	0	6
100	0	14
120	0	20

(a) Apart from temperature and pH, give **two** variables the scientist would have controlled when **preparing** the liquid medium cultures.

1 _____

_____

_____

_____

2 _____

_____

_____

_____

(2)

(b) A student concluded that this investigation showed that ammonia inhibits nitrogenase activity in nitrogen-fixing bacteria. Use all the information to evaluate the student's conclusion.

(3)

(c) Nitrogenase catalyses the reduction of nitrogen during nitrogen fixation. The reaction requires 16 molecules of ATP for each molecule of nitrogen that is reduced.
When ammonia inhibits nitrogenase activity, nitrogen-fixing bacteria may benefit.
Explain how.

(2)

(Total 7 marks)

13. Write an essay on **one** of the topics below.

The importance of cycles in biology.

(Total 25 marks)

Mark schemes

1.

(a) 1. Organic

2. Respiration

Ignore aerobic/anaerobic

3. Carbon

Accept cells/tissue(s)/plant(s)/animal(s)/organism(s)/ NPP/ living material/biological molecules.

Ignore biomass/biological materials/organic matter and reference to 'dry'.

4. Calorimetry;;

Accept calorimeter but reject colorimeter.

Accept phonetic spellings.

4 correct = ***2 marks***

2–3 correct = ***1 mark***

0–1correct = ***0 marks***

2

(b) 1. Carbon dioxide combines/reacts with ribulose bisphosphate/RuBP;

Accept idea of fixation for 'reacts'.

2. Produces two glycerate (3-)phosphate/GP using (enzyme) Rubisco;

Accept: any answer which indicates that 2 × as much GP produced from one RuBP catalysed by Rubisco.

Reject GP once if incorrectly named e.g., glucose 3- phosphate.

3. GP reduced to triose phosphate;

Reject GP once if incorrectly named e.g., glucose 3- phosphate.

Must have idea of reduction. This may be conveyed by stating mp4.

Only accept TP if triose phosphate is also in the answer. However only penalise once.

4. Using reduced NADP;

Accept NADPH or $NADPH_2$ or NADPH + H for reduced NADP.

Reject: Any reference to reduced NAD for mp4 but allow reference to reduction for mp3.

Must be in context of GP to triose phosphate.

5. Using <u>energy</u> from ATP;

Must be in context of GP to triose phosphate.

6. Triose phosphate converted to glucose/hexose/RuBP/ribulose bisphosphate/named organic substance;

Only accept TP if triose phosphate is also in the answer. However only penalise once.

Accept marks in suitable diagram.

6

[8]

2. (a) Correct answer of 6.0×10^8/6.02×10^8/6.0192×10^8 = **3 marks**;;;

601920000 = **2 marks**;;

8.8 × any **two** of 12000 **OR** 95 **OR** 60 = **1 mark**

1.0032×10^7 / 6.336×10^6 / 5.0160×10^4 = **1 mark**

*Correct answer but not in correct standard form = **2 marks**, eg 60.192×10^7*

Accept 10032000 / 6336000 / 50160 for 1 mark

3

(b) 1. (This difference) is **not** significant;

2. There is greater than a 0.5 probability that this difference is due to chance
OR
There is greater than a 0.05 probability that this difference is due to chance

Accept 50%/1 in 2 for 0.5

Accept 5%/1 in 20 for 0.05

Reject 'results' for 'difference' once

2

(c) 1. Less ATP **and** reduced NADP produced;

Accept NADPH/$NADPH_2$ for reduced NADP

Reject less reduced NAD/NADH for reduced NADP

2. Less GP/glycerate 3-phosphate reduced/converted to triose phosphate;

*If triose phosphate is not mentioned, **reject TP once***

3. Less triose phosphate to regenerate/make RuBP
OR
Less RuBP is regenerated/made;

*If triose phosphate is not mentioned, **reject TP once***

4. Less RuBP to react with carbon dioxide

Need idea of less at least once

*Reject **no** once*

*If mark points 2, 3 and 4 are not present, allow 1 mark for less light independent reactions **OR** fewer Calvin cycles.*

4

(d) 1. 3.5875×10^{-3};

Accept any correct rounding eg 4×10^{-3}

2. kg m^{-2} h^{-1};

*Accept per m^2 **and/or** per hour*

Accept kg/m^2/h

Accept kg h^{-1} m^{-2}

Reject kg^{-1}

*Reject m^{-2} h^{-1} kg **OR** h^{-1} m^{-2} kg*

2

(e) 1. (In the shade, so) **less/slower rate of** photosynthesis;

Accept any named aspect of photosynthesis that uses light, eg LDR, photoionisation

2. (Slow-growing, so) would take a long time to replace (mature leaves)
OR
Leaves more likely to reach maturity
OR
Leaves take a long time to mature;

Accept would take a long time to make cellulose or any other correct named compound

3. Plants can maintain (a large enough) surface area for photosynthesis
OR
Plants can absorb enough light;

2 max

(f) Yes (no mark)

1. The most recently evolved species/asterids produce more than the mean concentration;

2. The least recently evolved species/ferns produce less than the mean concentration;

No (no mark)

3. The highest concentration was **not** in the most recently evolved species/asterids
OR
The highest concentration was in magnoliids
OR
Magnoliids produce more than more recently evolved species/basal angiosperms/rosids/ asterids;

4. The lowest concentration was **not** in the least recently evolved species/ferns
OR
The lowest concentration was in monocots
OR
Monocots evolved more recently but produce a lower concentration than ferns;

5. The least recently evolved species/ferns have the same concentration as more recently evolved species/basal angiosperms/rosids;

6. Basal angiosperms and rosids have the same concentration but evolved at different times;

Ignore answers relating to no statistical testing
Accept 'newest species' for most recently evolved species/asterids
Accept 'oldest species' for least recently evolved species/ferns

2 max

[15]

3.

(a) 1. (Less/no) ATP;

2. (Less/no) reduced NADP;

Accept NADPH, NADPH + H, $NADPH_2$ NADPH + H^+
Reject reduced NAD, NADH etc,

2

(b) 1. (Less/no) carbon dioxide (reacts) with RuBP;

2. (Less/no) GP;

2

(c) 1. Stroma (of/in chloroplast);

Reject: stoma

Reject stroma of cytoplasm/chlorophyll

Reject stroma of mitochondrion

Ignore references to Calvin cycle or the light-independent reaction

1

(d) 1. Rubisco activity increases with temperature
OR
Rubisco optimum temperature is above (**rubisco activase**);

2. (Rubisco) **activase** activity decreases at high temperatures (allow any temperature above 25 ºC.)
OR
(Rubisco) **activase** optimum (allow in range) 25 to 30 ºC.;

Accept denatures at high temperature (allow any temperature above 25 ºC)

3. (Results/graphs suggest) **activase** cannot/does not affect activity of rubisco;

4. (Results are) only for cotton;

Accept may not be the same in other species/types of plant

Ignore: only one study

5. (Results are) for isolated enzymes;

6. No stats test;

4 max

[9]

4. (a) ☑ NADP, ADP, Pi and water;

1

(b) 1. <u>Chlorophyll absorbs</u> light
OR
<u>Light</u> excites/moves electrons in <u>chlorophyll</u>;

Ignore photosystems.

2. Electron/s are lost
OR
(Chlorophyll) becomes positively charged;

Ignore site/molecule from where electrons are lost.

Accept electrons go to electron transport/carrier chain for 'electrons lost'.

2

(c) Ink and (leaf) pigments would mix
OR
(With ink) origin/line in different position
OR
(With pencil) origin/line in same position
OR
(With pencil) origin/line still visible;

1

(d) 1. Level of solvent below origin/line;

Reject water or any named aqueous solution.

Accept named organic solvent.

2. Remove/stop before (solvent) reaches top/end;

2

(e) Accept any answer in range of 0.58 to 0.62;

Accept 0.58 or 0.62.

Ignore any numbers which follow numbers in range.

1

(f) (Absorb) different/more wavelengths (of light) for photosynthesis;

Accept wider/larger range of wavelengths.

Accept frequency for wavelength.

Accept light-dependent reaction /photophosphorylation /photoionisation for photosynthesis.

1

[8]

5. (a) 1. Stirrer distributes heat (energy);

Accept stirrer ensures equal/even temperature or prevents build up of 'hot spots'.

2. Insulation/space/air reduces loss/gain of heat

OR

Insulation/space/air reduces conduction/convection;

Reject vacuum.

3. Water has high (specific) heat capacity;

2 max

(b) 3.28 / 3.3 (kJ g^{-1}) **= 2 marks;;**

Incorrect answer but shows 328 / 33 (ignore any subsequent numbers and decimal point) **= 1 mark**

OR

Incorrect answer of 6.56 / 6.6 (kJ g^{-1}) (ignore any subsequent numbers) **= 1 mark;**

2

(c) 1. (Light is) reflected;

Light is not absorbed on its own is not enough.

2. (Light is) wrong wavelength;

Accept frequency for wavelength.

Accept reference to absorbing specified wavelengths/frequencies.

3. (Light) misses chlorophyll/ chloroplasts/photosynthetic tissue;

4. CO_2 concentration or temperature is a limiting factor.

2 max

(d) 1. ATP;

2. Reduced NADP;

Accept 1 and 2 in either order.

Reject Reduced NAD.

Accept NADPH/NADPH$_2$.

2

(e) Correct answer of 1.31/1.3 × 10^8 (ignoring any subsequent numbers after 1.31) = **2 marks**;;

Incorrect answer but shows 2^{16} = **1 mark**

OR

65536 in any correct numerical form = **1 mark OR**

Incorrect answer but shows 131 ignoring any subsequent numbers and ignoring any decimal point = **1 mark**;

2

[10]

6. (a) (So the) oxygen is used/absorbed/respired;

1

(b) 1. Anaerobic respiration produces carbon dioxide;

2. Increase in pressure/volume (of gas);

Reference to either volume or pressure required for the mark

2

(c) 1. Correct answer in range of
4.9×10^{-4} to 4.91×10^{-4} = **2 marks**;;

Accept any equivalent mathematical representation of this answer

2. Incorrect answer buts shows division by 24 = **1 mark**
OR
Incorrect answer but shows a number from 1175 to 1178 (ignore position of decimal point, standard form and any numbers that follow) = **1 mark**;
OR
Incorrect answer but show the number 49 (ignore position of decimal point, standard form and any numbers after 49) = **1 mark**;

2

(d) Large range/difference/increase in numbers;

Accept reference to exponential (increase)

Ignore if the answer only refers to numbers being high

Ignore to 'fit on the scale'

1

(e) Decrease/no glucose/substrate
OR
Increase in ethanol/carbon dioxide/acidity;

*Accept decrease/no oxygen as **Figure 2** is not linked to **Figure 1**.*

Accept competition for glucose/oxygen.

Accept any named sugar

Accept decrease in pH

Accept increase in toxins

Ignore food/nutrients

1

(f) 1. Correct answer of 298000 or 297766 or 297765.59 or 296826 = **2 marks**;;

Accept: any equivalent answer with appropriate rounding

e.g. 2.98×10^5,

29.78×10^4 *etc.*

2. Incorrect answer but working shows 2000 × 2.72 = **1 mark**;
OR
Incorrect answer but working shows $2.72^{0.5 \times 10}$ / 2.72^5 / $e^{0.5 \times 10}$ / = **1 mark**

2

[9]

7. (a) Automarked question − ☑ Reduction of pyruvate
(Box 3)

1

(b) 1. Oxygen/O_2 taken up/used (by seeds);

2. Carbon dioxide/CO_2 (given out) is absorbed by solution/potassium hydroxide/KOH;

3. Decrease in pressure/volume (of air inside);

Ignore 'negative pressure' but reject reference to vacuum.

Accept 'air pressure higher than inside'.

3

(c) 1. Distance (drop/liquid moves);

Accept description of distance, e.g. 'start and end position'.

2. Diameter/radius/bore of tubing/lumen

Accept (cross-sectional) area of tubing/lumen.

Ignore time.

2

(d) 1. Remove potassium hydroxide/KOH

OR

Remove solution which removes carbon dioxide.

OR

Replace potassium hydroxide/KOH with water;

Reject if seeds removed or another organism used.

2. Record distance liquid moves (without potassium hydroxide);

Reject moves to the right.

Accept 'liquid would not move'.

3. Use difference in distance liquid moves (with potassium hydroxide and without potassium hydroxide)

OR

Use difference in (calculated) volumes (with potassium hydroxide and without potassium hydroxide);

Accept 'if liquid does not move (volume of) carbon dioxide produced is the same as (volume of) oxygen used'.

Answers which add/use a syringe, reject mp2 ***and*** *mp3.*

3

(e) Answer in the range 3×10^{-7} to 3.33×10^{-7};

Accept equivalent answers in this range which are not in standard form.

Accept 3.0×10^{-7}

Ignore any numbers after 3.33.

1

[10]

8.

(a) 1. (They use enzymes to) decompose proteins/DNA/RNA/urea;

Accept any named molecule containing nitrogen eg enzymes, NAD, ATP, amino acids

Accept digest/breakdown/hydrolyse for decompose

Ignore 'nitrogen -containing compounds' unqualified

2. Producing/releasing ammonia/ammonium compounds/ammonium ions;

Accept (they) perform ammonification

Accept named ammonium compound

2

(b)

Principle is

1. *Named apparatus*
2. *What is measured*
3. *Standardisation of method*

Accept **any** valid method, for example

1. Use of colorimeter;

Reject calorimeter

2. Measure the absorbance/transmission (of light);

Reject if samples are filtered unless filtering to remove debris

Accept descriptions

3. Example of how method can be standardised eg same volume of water, zeroing colorimeter, same wavelength of light, shaking the sample;

Ignore references to calibration curves

3

[5]

9.

(a) 1. Phosphorylation of glucose using ATP;

2. Oxidation of triose phosphate to pyruvate;

Accept removal of hydrogen from triose phosphate for oxidation.

3. Net gain of ATP;

Accept any description that indicates a net gain e.g., 4 produced, 2 used.

4. NAD reduced;

Accept NADH/$NADH_2$/NADH + H^+ produced.

Accept all mark points in diagrams.

4 max

(b) 1. Less/no reduced NAD/coenzymes

OR

Fewer/no hydrogens/electrons removed (and passed to electron transfer chain);

Accept less/no FAD reduced.

2. Oxygen is the final/terminal (electron) acceptor;

2

[6]

10. (a) Automarked question − ☑ *N = I − (F + R)*;
(Box 2)

1

(b) 21.6
OR
22;

1

(c) Correct answer of 88500/89000 = **2 marks**;;

Incorrect but shows 1.8975/1.898/1.9/1.90 (million) /1897500 = **1 mark**
OR
Incorrect but shows 1.809/1.81/1.8/1.80 (million) / 1809000 = **1 mark**
OR
Incorrect but shows 885/89/90 with incorrect position of decimal point = **1 mark**

*Accept 90000 for **2 marks**.*

Accept any of the answers in any correct mathematical form e.g., shows 1.8 (million) as 1800000.

2

(d) 1. Energy lost between/at trophic/feeding levels;

Accept description of trophic levels e.g., food chain.

2. Energy lost via respiration/excretion/faeces;

Accept energy lost via heat/metabolism/food not eaten/digested /muscle contraction/movement/maintaining temperature.

Reject energy used in respiration.

Reject energy produced/generated.

2

[6]

11. (a) 1. Low respiration;

Accept less energy lost in respiration

2. More growth/biomass/colonisation;

Allow examples of more carbon-containing molecules eg glucose

2

(b) 1. Less nitrification

OR

Fewer/less active nitrifying bacteria;

OR

Nitrification/nitrifying bacteria require oxygen/aerobic conditions;

2. (Less) oxidation/conversion of ammonium (ions) to nitrite (ions) and to nitrate (ions);

Order must be nitrite then nitrate

Accept ammonia for ammonium ions

Accept correct chemical formulae for ions, eg there will be little oxidation/conversion of $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$

Ignore 'breakdown' for oxidation/conversion

3. More denitrification

OR

More/more active denitrifying bacteria

OR

Denitrification/denitrifying bacteria do not require oxygen

OR

Denitrification/denitrifying bacteria require anaerobic conditions;

4. (So more) nitrate (ions) reduced/converted to nitrogen (gas);

Accept correct chemical formulae eg So more NO_3*-reduced/converted to* N_2*;*

2 max

(c) 1. Assumed that height is (directly) proportional to biomass;

Accept descriptions of 'is proportional to', eg correlates to, is equivalent to

2. (Plants may put biomass into) other named aspect of growth (other than height)

OR

Height does not include the roots

OR

Some increase in height results from water gain;

Examples of other named aspects of growth could include root growth, flower/seed/fruit formation, lateral growth, wider leaves

2

(d) 1. Answer of 12 days = **2 marks**;;

2. 12.16 (12.15774433) **= 1 mark**

OR

4 days (used 387 and 268, ie not calculated starting length) **= 1 mark;**

2

[8]

12. (a) 1. Volume of (stock) bacteria (culture);

If not credited accept number/mass of bacteria for 1 mark.

Ignore volume/concentration of liquid culture.

Ignore amount.

2. Concentration of (stock) bacteria (culture);

If not credited accept number/mass of bacteria for 1 mark.

Ignore volume/concentration of liquid culture.

Ignore amount.

3. Concentration of glucose

OR

Concentration of (respiratory) substrate;

Accept concentration of ion/named ion but ignore ammonium chloride.

Ignore 'same bacteria/species/type'.

Ignore 'sugar'.

Ignore amount.

Ignore nutrients.

4. Volume of ammonium chloride;

Ignore amount.

Ignore nutrients.

5. Time (bacteria/culture left to divide);

6. Concentration/volume of oxygen;

Ignore amount.

Ignore availability/access/exposure.

7. Concentration/volume of nitrogen;

Ignore amount.

Ignore availability/access/exposure.

Accept vol. for volume and conc. for concentration.

2 max

(b) **(For)**

1. Nitrogenase activity decreases with increase in ammonium chloride (concentration);

Accept ammonia for ammonium chloride.

Accept negative correlation between nitrogenase activity and ammonium chloride (concentration).

2. Nitrogenase activity zero with high (concentration of) ammonium chloride
OR
Ammonium chloride remains (in medium) when nitrogenase activity zero;

Accept ammonia for ammonium chloride.

Accept nitrogenase activity zero at 80/100/120/above 60 (µg cm^3 of ammonium chloride).

Accept 'stops' for zero.

(Against)

3. Only used one species;

Accept only Azotobacter/A. chroococcum/ chroococcum/one nitrogen-fixing bacterium/one type/strain used.

4. (Inhibition/results) may be due to chloride (ions)
OR
(Investigation) uses ammonium chloride not ammonia;

Reject 'chlorine'.

Ignore reference to statistical tests.

3 max

(c) 1. Less/no ATP/energy required/used

OR

More ATP/energy available;

2. ATP/energy can be used for growth/synthesis/replication

OR

Lower (rate of) respiration required

OR

ATP for phosphorylation;

Accept ATP can be used for 'other reactions', 'movement', 'active transport' or correctly named reaction.

Ignore 'aerobic', 'anaerobic' in context of respiration.

Reject ATP/energy used for/in respiration.

Reject mitosis.

2

[7]

13.

21-25	Extended Abstract Generalised beyond specific context	Response shows holistic approach to the question with a fully integrated answer which makes clear links between several different topics and the theme of the question. Biology is detailed and comprehensive A-level content, uses appropriate terminology, and is very well written and always clearly explained. No significant errors or irrelevant material. For top marks in the band, the answer shows evidence of reading beyond specification requirements.
16-20	Relational Integrated into a whole	Response links several topics to the main theme of the question, to form a series of interrelated points which are clearly explained. Biology is fundamentally correct A-level content and contains some points which are detailed, though there may be some which are less well developed, with appropriate use of terminology. Perhaps one significant error and, or, one irrelevant topic which detracts from the overall quality of the answer.
11-15	Multistructural Several aspects covered but they are unrelated	Response mostly deals with suitable topics but they are not interrelated and links are not made to the theme of the question. Biology is usually correct A-level content, though it lacks detail. It is usually clearly explained and generally uses appropriate terminology. Some significant errors and, or, more than one irrelevant topic.
6-10	Unistructural Only one or few aspects covered	Response predominantly deals with only one or two topics that relate to the question. Biology presented shows some superficial A-level content that may be poorly explained, lacking in detail, or show limited use of appropriate terminology. May contain a number of significant errors and, or, irrelevant topics.
1-5	Unfocused	Response only indirectly addresses the theme of the question and merely presents a series of biological facts which are usually descriptive in nature or poorly explained and at times may be factually incorrect. Content and terminology is generally below A-level. May contain a large number of errors and, or, irrelevant topics.
0		Nothing of relevance or no response.

Commentary on terms and statements in the levels mark scheme

The levels mark scheme for the essay contains a number of words and statements that are open to different interpretations. This commentary defines the meanings of these words and statements in the context of marking the essay. Many words and statements are used in the descriptions of more than one level of response. The definitions of these remain the same throughout.

Levels mark scheme word/statement	Definition
Holistic	Synoptic, drawing from different topics (usually sections of the specification)
A fully integrated answer which makes clear links between several different topics and the theme of the question.	All topics relate to the title and theme of the essay; for example, explaining the biological importance of a process. When considering, for example, the importance of a process, the explanation must be at A-level standard. 'Several' here is defined as at least four topic areas from the specification covered. This means some sentences, not just a word or two. It does not mean using many examples from one topic area.
Biology is detailed and comprehensive A-level content, uses appropriate terminology, and is very well written and always clearly explained.	Detailed and comprehensive A-level content is the specification content. Terminology is that used in the specification. Well written and clearly explained refers mainly to biological content and use of terminology. Prose, handwriting and spelling are secondary considerations. Phonetic spelling is accepted, unless examiners are instructed not to do so for particular words; for example, glucagon, glucose and glycogen.
No significant errors or irrelevant material.	A significant error is one which significantly detracts from the biological accuracy or correctness of a described example. This will usually involve more than one word. Irrelevant material is several lines (or more) that clearly fails to address the title, or the theme of the title.
For top marks in the band, the answer shows evidence of reading beyond specification requirements.	An example that is relevant to the title and is not required in the specification content. The example must be used at A-level standard.
Response mostly deals with suitable topics but they are not interrelated and links are not made to the theme of the question.	Not addressing the biological theme of the essay (eg importance) at A-level standard.

The importance of cycles in biology

- 3.1.1 Monomers and polymers
- 3.1.4.2 Many proteins are enzymes
- 3.1.5.2 DNA replication
- 3.1.6 ATP
- 3.2.2 All cells arise from other cells
- 3.3.2 Gas exchange – mechanism of breathing
- 3.3.4.1 Cardiac cycle and blood circulation and 3.6.1.3 Control of heart rate
- 3.4.3 Meiosis
- 3.5.1 Photosynthesis – light independent reaction
- 3.5.2 Respiration – Krebs cycle and electron transport chain
- 3.5.4 Nutrient cycles
- 3.6.2.1 Nerve impulses
- 3.6.2.2 Synaptic transmission
- 3.6.3 Muscle contraction
- 3.6.4.1 Negative feedback
- 3.6.4.2 Control of blood glucose concentration
- 3.6.4.3 Control of blood water potential
- 3.7.4 Populations in ecosystems – predation
- 3.8.4.1 Recombinant DNA technology – PCR

In order to fully address the question and reach the highest mark bands students must also include at least four topics in their answer, to demonstrate a synoptic approach to the essay.

Students may be able to show the relevance of other topics from the specification.

Note, other topics from beyond the specification can be used, providing they relate to the title and contain factually correct material of at least an A-level standard. Credit should not be given for topics beyond the specification which are below A-level standard.

[25]

Examiner reports

1.

(a) Despite being a very good discriminator, it was disappointing to find that only one in four students obtained both marks for this question. Almost 56% of students obtained one mark, usually by correctly referring to two of the following: ‘organic,’ ‘respiration’ and ‘calorimetry’. Some students referred to ‘photosynthesis’ rather than ‘respiration’. A far less frequent error was to refer to ‘colorimetry’ rather than ‘calorimetry’. Although many alternatives were accepted for ‘carbon’, this was often the incorrect biological term of the four required.

(b) This question proved to be an excellent discriminator. However, it was disappointing that 27% of students failed to obtain a mark. On some scripts, this was due to describing the light-dependent reaction rather than the light-independent reaction. More frequently, there was lack of detail in the responses, incorrectly named compounds or reactions, and/or confusion with the Krebs cycle. Fewer than one in ten students obtained maximum marks.

However, 26% obtained at least five of the six marks available. Most of these students did not refer to the release of energy from ATP.

The most accessible marking points (MP) were carbon dioxide reacting with RuBP and the conversion of triose phosphate into a named organic compound. MP 3 and MP 4 referred to triose phosphate and students who only provided the abbreviation TP were penalised one of these marks. As GP *is* abbreviated in the specification, reference to GP was accepted as part of MP 2. However, some students incorrectly named GP as glucose phosphate and so failed to gain this mark. Other common errors included reference to reduced NAD rather than reduced NADP and stating that triose phosphate is oxidised rather than reduced. Less frequently, the enzyme rubisco was linked to an incorrect reaction.

2.

With **(a)**, a third of students were able to score all 3 marks. Those who failed to score full marks either failed to convert their answer into standard form, or failed to multiply by either 95 (the number of minutes between 11.40 and 13.15) or 60 (to convert seconds into minutes). Those who failed to score any marks mostly read incorrectly from the graph.

(b) discriminated well; however, only 22.75% of students scored 2 marks. P > 0.5 seemed to cause a lot of confusion with P > 0.05 or 5%. The students who scored 1 mark often only referred to 'the results' rather than the 'difference in results.' Those who failed to score mostly did so for not knowing the symbol > meant 'more than' and read it as 'less than', failed to use the words probability and chance as instructed, or provided very confused language. For example, 'there is not a greater than 95% probability that the results are not due to chance.'

(c) also discriminated well, but students found it hard to score higher marks, with only 1.68% scoring all 4 marks, and 4.89% scoring 3 marks. There were many cases of students only describing the results, or not explaining the result in Figure 8, i.e. not explaining the low carbon dioxide uptake, and focusing their answer solely on Photoionization. There were also many cases where students failed to gain a mark for using the abbreviation 'TP' for triose phosphate, which is not an abbreviation recognised in the specification. Some students failed to score MP1 for only stating either less ATP or less reduced NADP, but not both. Students also failed to score MP1 if they stated no ATP and reduced NADP was produced, but since the graph shows carbon dioxide is taken up, this would not be true.

With **(d)**, the majority of students (60%) were able to score 1 mark for correctly substituting values into the equation. However, students struggled more with stating the correct units, with only 23% scoring both marks. These students understood that dry mass needed to be expressed as mass, per unit area, per unit time. There were some interesting rearrangements of these units, including those that didn't start with kg for what is essentially a measurement of mass.

(e) did clue students into how to address their responses by stating 'Suggest how this benefits slow-growing, shade-tolerant plants.' However, many responses focused on them not being eaten and therefore surviving, so just repeating the first line of the stem, rather than addressing the slow-growing and shade-tolerant aspects. Many answers centred around herbivores likely being in the shade, or herbivores having easy access to the plants as they will be low down. Herbivores were also often referred to as 'predators' of the plants. As a result, only 3.5% scored 2 marks, and 74.5% scored 0 marks.

With **(f)**, 16% of students scored both marks, and mostly scored MP3 and MP5. A further 45% scored 1 mark, mostly for MP3. There were many students who gave all three alternatives for MP3 as their answer. Students who failed to score often read the phylogenetic tree the wrong way round, so had ferns as the most recently evolved species. As the question asked students to justify whether data supported a summary, there were rote-learned answers evident such as 'no stats test,' 'we can't tell,' and 'no sample size stated.' Other responses that were stated, but did not score were 'don't know how old the plants are,' and 'don't know how many species there are.'

3.

(a) Approximately 41% of students obtained both marks by referring to the reduction in ATP and reduced NADP. Students who gained a single mark usually did so by stating that there was less ATP rather than less reduced NADP. Many of these students incorrectly stated that less NADP or less reduced NAD was produced. Some students suggested that heat stress caused stomata to close and this limited carbon dioxide uptake and photosynthesis. Many students used additional pages for this question due to initially describing denaturation of rubisco or ATP synthase before realising that they needed to name specific products of the light-dependent reaction. It was disappointing to note that nearly a third of students scored zero.

(b) Again, approximately 41% of students obtained both marks by explaining the role of rubisco in photosynthesis. Students gaining a single mark often failed to mention both RuBP and carbon dioxide, or simply referred to a six-carbon product with no mention of GP being formed. A minority of students incorrectly referred to GP as glucose phosphate. One in four students scored zero. Most of these responses were limited to describing how denaturation of rubisco would occur. Some students confused the Calvin cycle with the Krebs cycle.

(c) Almost two-thirds of students correctly named the stroma as the location of rubisco. The thylakoids, crista and matrix were common incorrect responses.

(d) The majority of students (56%) obtained two marks, invariably for describing the effects of an increase in temperature on the activity of rubisco and rubisco activase. However, many students then failed to use all the information successfully to evaluate the scientists' conclusion. Only 25% of students obtained more than two of the four marks available. Relatively few students clearly stated that the results indicate that rubisco activase does not activate rubisco. Similarly, very few students stated that these results were only for cotton plants and were for isolated enzymes. Equally surprising was the scarcity of responses which referred to the lack of a statistical test. Consequently, this question did not discriminate as effectively as had been expected.

4.

(a) Almost 70% of students correctly identified the chemicals needed for the light-dependent reaction.

(b) Photoionisation in the light-dependent reaction was clearly described by many students, with 44% obtaining both marks and approximately 77% obtaining at least one mark. Some students limited their description to photolysis and gained no marks. Many students referred to chlorophyll absorbing light and/or light exciting the electrons in chlorophyll. Some answers referring only to chloroplasts or photosystems did not obtain this mark point. Many students referred to electrons being lost or being passed to the electron transport chain. Few students referred to chlorophyll molecules becoming positively charged.

(c) This question was not well answered and was a poor discriminator. Slightly more than 20% of students obtained the mark. Only the minority of students could clearly explain that pencil was used to mark the origin so that the origin/line was still visible after running the chromatogram. The problem of ink dissolving in the solvent was appreciated by many but the consequences of this were not explained; the mixing of the ink and leaf pigments was not appreciated by most students. Answers often only referred to the ink running/smudging /dissolving in the solvent and affecting results. It was not always clear whether students were writing about pencil or ink.

(d) Considering this required straightforward recall of required practical activity 7, the responses were often quite poor. Approximately 12% of students obtained both marks and around 45% obtained at least one mark. Many answers only mentioned placing the chromatogram in a solvent, adding a lid and running the chromatogram for a set time or until the pigments had separated. More students obtained a mark for the level of the solvent being below the origin than for marking the solvent front or for removing the chromatogram before it reached the top/end. Some students explained the principle of chromatography rather than providing details on the method. A range of inappropriate solvents were referred to including water, glucose and hydrochloric acid.

(e) Approximately 66% of students used the given formula and correctly calculated the R_f value of pigment **C**.

(f) Approximately 46% of students obtained this mark, explaining that different wavelengths/frequencies of light could be absorbed for photosynthesis. Students failing to gain credit often omitted to mention photosynthesis or did not refer to wavelength or frequency of light. A few students suggested the different colours of pigments enabled them to be identified during chromatography.

5.

(a) Responses to this question were disappointing with almost 60% of students failing to gain a mark. Most students identified the stirrer and air space as important features in enabling a valid measurement of the total heat energy released. However, the explanations provided were often either incorrect or lacked detail. Common errors were to refer to the air space as a vacuum or to omit any reference to heat. A significant minority of students incorrectly referred to the oxygen concentration inside the calorimeter as a feature. Water was mentioned in a variety of contexts, but only infrequently in terms of high (specific) heat capacity.

(b) Over a third of students failed to gain at least one mark for this calculation. Students who failed to realise that the sample of biomass was 2g rather than 1g were able to gain one of the two marks available. Similarly students who were able to perform the calculation but did not provide their answer in kilojoules gained a mark. 42% of students successfully completed the calculation to obtain both marks.

(c) It was surprising to find that almost 40% of students failed to gain a mark on what was considered to be a relatively accessible question. Again, lack of sufficient detail prevented a significant number of students from obtaining a mark. These students often limited their responses to ‘light not being absorbed’ or to ‘chlorophyll not using all the light’. Despite the question being in the context of ‘light falling on producers’, a considerable number of answers stated that light ‘misses the producers’. Students who obtained one mark frequently stated that light missed the chloroplasts/chlorophyll. The 31% of students who gained a second mark often referred to light being reflected or that it was the wrong wavelength. A minority of students gained credit for stating temperature could be a limiting factor. Students who mentioned carbon dioxide rarely specified its concentration and so failed to gain credit.

(d) Almost 91% of students gained at least one mark, often by naming ATP as a product of the light-dependent reaction required for the light-independent reaction. Almost 30% of students failed to name reduced NADP as the second product. The most frequent incorrect responses were reduced NAD, NAD and NADP. Water, carbon dioxide, oxygen, RuBP and triose phosphate were also incorrectly suggested by a minority of students.

(e) This proved to be a difficult calculation for the 50% of students who scored zero. Although many students appreciated that 16 cell divisions had taken place, a common error was to calculate 2000^{16} rather than 2000×2^{16}. Some students arrived at the correct number of 131072000 but then failed to give their answer in standard form. Almost 37% of students provided the correct answer, however.

6.

(a) Less than 17% of students realised that the apparatus was left for an hour so that the oxygen was absorbed or respired. Frequent responses which were not credited included “to reach equilibrium”, “to reach a constant/stable/maximum rate of respiration”, “to activate enzymes” and “to allow pressure to stabilise”.

(b) Approximately 70% of students obtained at least one mark, usually for stating that an increase in the volume/pressure of gas in the flask caused the coloured liquid to move to the right. Although many students did appreciate that the gas evolved in this investigation was carbon dioxide, most referred only to respiration rather than anaerobic respiration. A minority mentioned both aerobic and anaerobic respiration. Some students suggested that ethanol produced by anaerobic respiration increased the pressure in the flask.

(c) This question clearly demonstrated the benefit of following the instruction to 'show your working', with over 52% of students obtaining one mark for an incorrect answer with some valid working. Often this was awarded for showing division by 24. Less than a third of students gained both marks. A common incorrect answer was 0.049; this was awarded one mark as this was indicative of some correct methodology.

(d) Approximately 31% of students gained this mark, often by referring to the large range in numbers, the rapid increase in numbers or to an exponential increase. Common responses not credited included "to fit on the scale", "numbers are large", "is more accurate" and "is more comparable".

(e) Surprisingly, only 53% of students obtained this mark. Many failed to do so due to vague terminology such as 'lack of food' or 'lack of resources'. Others showed lack of knowledge, for example "killed by lactate". The most common correct responses mentioned a decrease in glucose or oxygen, or an increase in ethanol.

(f) This proved relatively straightforward for most students with over 75% obtaining both marks. Very few students (3%) failed to gain any credit, as the majority could provide at least one of the steps required in the calculation. This was often for 2000 x e/2.72 or e/2.72 raised to the correct power.

7.

(a) Approximately 68% of students correctly identified the reduction of pyruvate as the process that occurs in anaerobic respiration but does occur in aerobic respiration. The most frequent incorrect response was substrate-level phosphorylation.

(b) This question was generally well answered and was an excellent discriminator. Almost 88% of students obtained at least one mark and 70% at least two marks. Usually, these were the first two MPs, i.e. the uptake/use of oxygen and the absorption of carbon dioxide by the potassium hydroxide solution. As in previous years, there was some confusion over the changes in pressure/volume within the apparatus. Approximately 45% of students obtained maximum marks. These students correctly referred to a decrease in pressure and/or volume in the respirometer. A significant number of students suggested an increase in volume and/or pressure, or suggested a vacuum was produced, which was rejected.

(c) Although this question was another very effective two-mark discriminator, it was disappointing that only 67% of students gained at least one mark and 22% both marks. Usually, students who obtained a single mark referred to the distance moved by the liquid. Several students stated the 'volume of the tubing' or 'time' as required measurements despite the latter being excluded in the question. Other frequent incorrect responses included, mass/number of seeds, temperature, volume of oxygen uptake, volume of carbon dioxide produced and the volume/mass of potassium hydroxide.

(d) In terms of obtaining maximum marks, this proved to be the most difficult question on the paper. Approximately 2% of students obtained maximum marks and only 15% more than one mark out of the three available. The question was also a poor discriminator. There were several reasons for the poor performance of students on this question. The most common was students suggesting that a syringe should be added to the apparatus. The question clearly states that the same apparatus was used and that a change to the 'contents' of the apparatus would be required. Students who suggested the addition of a syringe could only access MP 1, i.e. removal of the potassium hydroxide solution or its replacement with water. Approximately 64% of students gained at least one mark and invariably this was the mark they obtained.

Unfortunately, a significant number of students suggested replacing the potassium hydroxide with a solution that absorbed oxygen. Other incorrect responses included filling the apparatus with water and counting the bubbles of carbon dioxide released, adding limewater, or covering the seeds/KOH with a layer of oil. Several students failed to gain MP 2 as they suggested that the liquid would move to the right which would only occur if anaerobic respiration was taking place. The question states that the student used the apparatus to measure aerobic respiration.

Other incorrect responses included measuring a change in the mass of the seeds or a change in the mass/volume of the KOH. Due to the errors included in many responses, MP 3 was inaccessible to the vast majority of students. Even students who did follow the correct procedure had difficulty clearly expressing how they would use their results to calculate the volume of carbon dioxide produced.

(e) Approximately 70% of students obtained the correct answer in this calculation. For a single mark calculation, this question was a very effective discriminator. The most frequent correct answers were 3.23×10^{-7} and 3.2×10^{-7}. Most correct answers gave the number in standard form. Some responses included e.g. 3.2 but omitted 10^{-7} or gave the wrong power. Other incorrect responses included
1.55×10^{-5} when students divided 6.2×10^{-4} by 40 (g) and not 48 (hours) or
1.29×10^{-5} when students divided 6.2×10^{-4} by 48 (hours) and not 40 (g) or
5.17×10^{-4} when students multiplied by 40 and divided by 48.

8. In question (a), students either failed to include the necessary detail, or failed to select the correct part of the nitrogen cycle, with some describing the whole thing, seemingly expecting the examiner to choose the correct part. For MP1, very few actually named a nitrogen-containing compound, or confused ammonification with nitrogen fixation. MP2 was more commonly awarded. Two-thirds of students scored at least one mark, and this question discriminated well.

Students found question (b) to be more accessible, with only about 15% failing to score any marks. Students generally had the right idea, but there were an alarming number of calorimeters in use. For MP2, those who failed to score generally gave answers such as 'read the colorimeter' and did not state what to measure. There were many references to the production of calibration curves, which would not be necessary in this case, i.e. students did not consider the context, and gave a role-learnt response. This was evidenced even further by several responses adding Benedict's solution to each sample.

9. It was disappointing to find that a third of students did not obtain a mark for part (a). A number of these students attempted to describe glycogenesis, glycogenolysis or gluconeogenesis. Some responses included a mixture of reactions from respiration and photosynthesis and referred to reduced NADP, RuBP and GP. Nevertheless, almost 50% of students obtained at least two marks, often by referring to the phosphorylation of glucose using ATP and to the production of reduced NAD. Although ATP production was mentioned in many responses, the idea of a net gain of ATP was not always clear. The most inaccessible mark point was the oxidation of triose phosphate to pyruvate. Most students who included this reaction in their answer simply referred to 'conversion' or 'breakdown' of triose phosphate to pyruvate. Consequently, fewer than 10% of students gained full marks.

Part (b) proved to be a very good discriminator. Approximately 46% of students obtained at least one mark, usually for referring to oxygen as the final electron acceptor (in the electron transfer chain). 22% of students obtained a second mark by explaining that malonate would decrease the production of reduced coenzymes/NAD/FAD or that fewer hydrogens would be removed during the Krebs cycle. Some students suggested that oxidative phosphorylation would not occur but provided no further details, or that no NAD or FAD would be produced. Others suggested that a lack of ATP caused a reduction in oxygen uptake. A common uncredited response was that only anaerobic respiration would occur, so less oxygen would be required. A few answers referred to photosynthesis and included references to NADPH and RuBP.

10. (a) Over 92% of students could correctly identify the equation for identifying how the net production of consumers can be calculated.

(b) Approximately one in two students successfully completed this calculation for one mark. A few students incorrectly rounded their calculated answer and failed to obtain the mark.

(c) Almost 78% of students gained at least one mark for this calculation and 62% obtained both marks. Correct answers were usually expressed as 88500, less often as 0.0885 million. Sometimes, the same total number in the female breeding herd was used for both 2017 and 2013. One mark was often gained for 1.8975, the number of dairy cows in 2017, while errors were more common when calculating the number in 2013. An extra 0 was added to the figure(s) calculated for 2017 or 2013. Some students correctly calculated both values but then expressed their answer as a 4.89/4.9 percent increase. Unfortunately, 88500 was erroneously transferred to the answer line as 85500 by a surprising number of students. Incorrect calculations included just finding the difference between the total number in the female breeding herd in 2017 and 2013, i.e. 3.45 million minus 3.35 million.

(d) It was disappointing to find that only 22% of students obtained both marks for this question. The majority of students, 78%, did gain at least one mark for providing a suitable example of how energy is lost, e.g. during respiration/movement, via faeces or as heat. A significant number of students did not obtain this mark as they suggested that energy is 'used in respiration' or that 'energy is produced'. Most students failed to gain both marks as they did not mention energy being lost between trophic/feeding levels.

11. Both parts (a) and (b) discriminated well. With (a), there was a fundamental lack of understanding of the relationship between *GPP* and *NPP*, and that it relates to plants, not animals. There was also a large number of responses stating that carbon dioxide is required for respiration. With (a), students seemed to want to make their incorrect knowledge of the nitrogen cycle fit the question, rather than use the correct part of their knowledge, for example, stating that saprobionts are anaerobic and that nitrates are denitrified into ammonia. That said, 25.26% of students were able to score both marks. With (c), students were asked to state the assumption that the students in the question had made, and many failed to do so, possibly as they did not know what an assumption is. There was also a lot of confusion as to what biomass actually is, with many stating that biomass is dry mass. Part (d) was a better answered maths question, with 35.05% scoring 2 marks, and most correctly obeying the command to give their answer to the nearest full day. Those who scored 1 mark mostly failed to calculate the starting length.

12. (a) Overall, responses to this question were disappointing, with 42% of students failing to gain a mark and only 14% obtaining both marks. Despite the wording of the question excluding temperature and pH as control variables, a few students still included them in their responses. However, the most frequent errors were concentration/volume of nitrogenase and volume of liquid culture, despite the stem of the question stating that each liquid culture had the same volume. Another common error was to suggest concentration of ammonium chloride as a control variable even though this was the independent variable. Other incorrect responses included humidity, water potential and light intensity.

The use of imprecise terminology also contributed to students failing to gain credit. A significant number of students referred to ‘amount’ rather than concentration or volume. The most frequent correct responses referred to volume of ammonium chloride, time (the bacteria were allowed to divide), concentration/volume of nitrogen and the volume or concentration of bacteria.

(b) The vast majority of students, 92%, obtained at least one mark, almost invariably for stating that nitrogenase activity decreases with increase in ammonium chloride concentration. Many students, approximately 51%, obtained a second mark usually for indicating that nitrogenase activity was zero at high concentrations of ammonium chloride. Only 8% of students gained maximum marks for also indicating that only one species was investigated or that chloride (ions) may be causing the inhibition rather than ammonia. Students differed in their understanding of the word ‘inhibits’; it was thought to mean both a reduction in activity and zero activity by certain students.

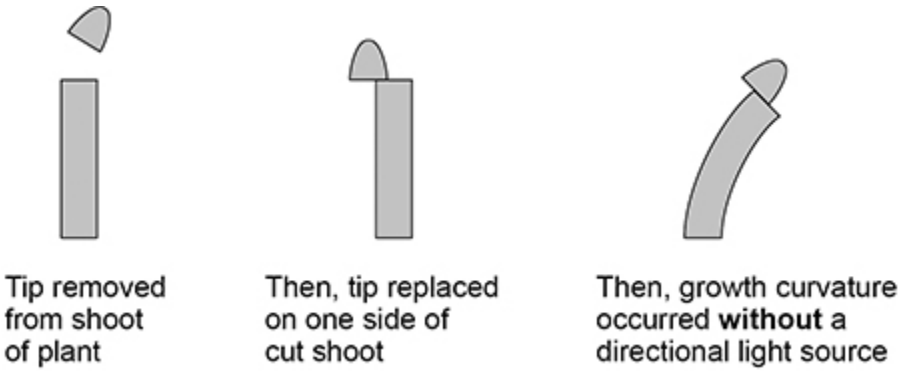
Several responses mentioned the lack of a statistical test to determine if the differences in nitrogenase activity were significant. However, this was not credited as the differences in nitrogenase activity are very considerable in the data and a statistical test would not be required. Similarly, ‘correlation does not mean causation’ was not credited. Students were expected to ‘use all the information’ to provide a higher-level response, such as the effect on nitrogenase activity may not have been due to ammonia as ammonium chloride was used in the investigation.

(c) For a two-mark question, this was a very effective discriminator, even though 32% of students scored zero. Most students gained a mark for realising that more ATP/energy would be available if less ATP was being used in the reduction of nitrogen. However, only 28% of students also suggested that the ATP could be used for other reactions or that the rate of respiration could be lowered. As in question 02.4, the misconception that energy is used in respiration was penalised. However, a few students specifically referred to ATP being required for (the beginning of) glycolysis and were awarded this mark. The most frequent correct answers were for growth, protein synthesis, active transport, and movement. A few students mentioned the use of ATP for phosphorylation or for binary fission.

13. There were a number of excellent descriptions of the Calvin Cycle, the nitrogen cycle, PCR, and negative feedback in either the context of the control of blood glucose or blood water potential. Areas of variable quality included the Krebs cycle, synaptic transmission, the cell cycle, and the cardiac cycle. With the latter, students often failed to mention contraction of the atria or ventricles increases blood pressure, linking pressure change only to the filling of the chambers with blood. There were occasions where students outlined the whole of photosynthesis or respiration, and not just the cyclic elements of both, and therefore included irrelevant material. There was some confusion with regards to how hexose sugars are made as a result of the Calvin cycle. Interphase was often stated as being part of mitosis. This was not given as a significant error, however students should know that it is a stage of the cell cycle and not a stage of mitosis. There was a number of students who failed to actually make the topic areas they were discussing into a cycle, for example not outlining how ribulose bisphosphate is regenerated to complete the cycle. There was evidence of students thinking certain cycles not detailed on the specification would count as material beyond it, however, these were not at the correct depth. For example, the menstrual cycle and the carbon cycle being outlined at GCSE level at best, and the water cycle being outlined at key stage 2 geography depth. This essay rarely had ‘the importance of’ addressed at A-level depth, with many AO2 responses solely given as ‘without respiration we would die,’ ‘without muscle contraction we couldn’t run away from predators,’ and ‘glucose is needed for respiration.’

1. **Figure 1** shows an investigation into growth factors in plants.

Figure 1



(a) Use your knowledge of indoleacetic acid (IAA) to explain the growth curvature shown in **Figure 1**.

(3)

A bioassay is a method to determine the concentration of a substance by its effect on living tissues.

Figure 2 shows the practical procedure used in a growth curvature bioassay to determine the concentration of IAA in shoot tips.

Figure 2

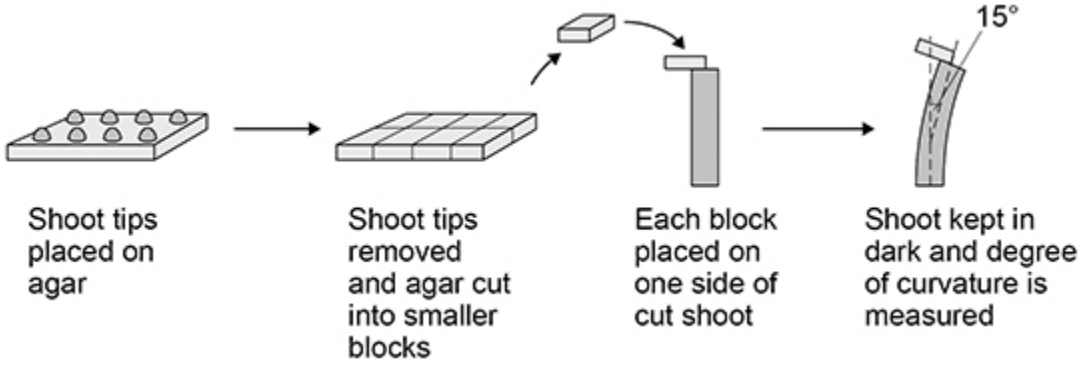
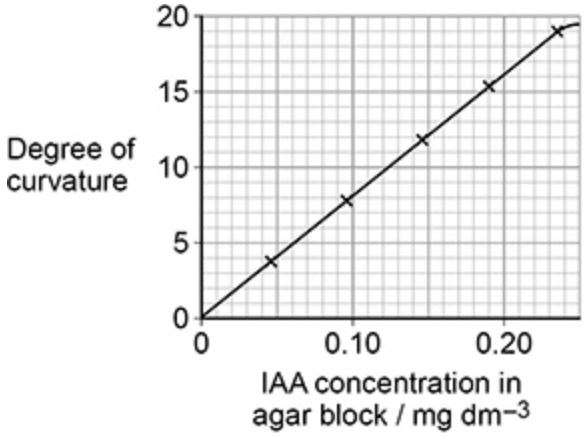


Figure 3 shows the calibration curve for this growth curvature bioassay.

Figure 3


Degree of curvature
20
15
10
5
0
0
0.10
0.20
IAA concentration in agar block / mg dm−3

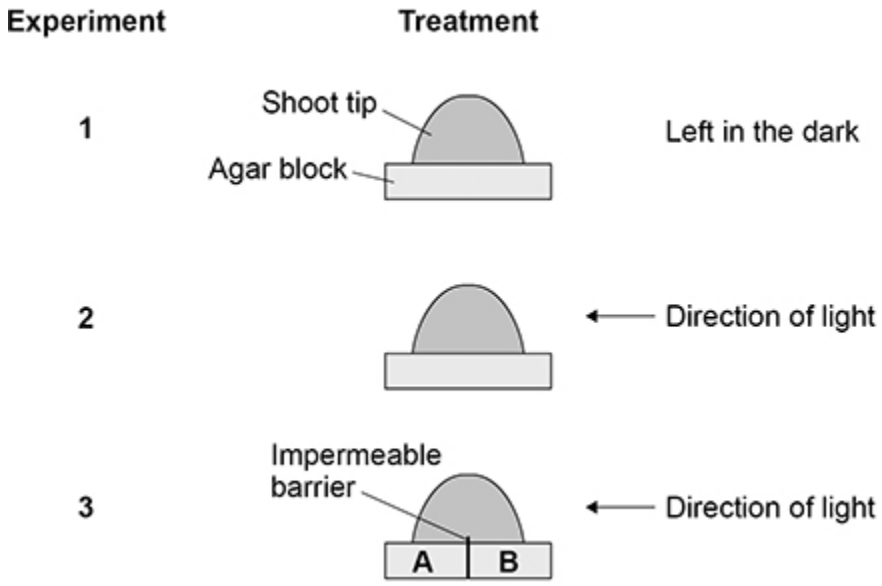
(b) Using the procedure in **Figure 2** and the calibration curve in **Figure 3**, describe how you could compare the IAA concentration in shoot tips from two different plant species.

In your answer you should refer to all the variables that should be controlled to produce a valid comparison.

(5)

A scientist investigated the effect of a directional light stimulus on the distribution of IAA in shoot tips. The scientist set up three experiments as shown in **Figure 4**. All variables were controlled apart from exposure to light.

Figure 4



She then used the growth curvature bioassay to compare the IAA concentrations in the agar

blocks from:

- experiment **1**
- experiment **2**
- experiment **3** section **A**
- experiment **3** section **B**.

The table below shows the scientist's results.

Experiment	Degree of curvature in Bioassay / degrees
1	17.69
2	17.61
3A	11.22
3B	6.50

(c) State **two** conclusions about IAA that you can make from the results shown in the table above.

1 _____

_____

2 _____

_____

(2)

(Total 10 marks)

2. The crown-of-thorns starfish (COTS) is one of the main causes of the decline of the world's coral reefs.

Marine biologists used a choice chamber to investigate the effects of flashing and constant light on the behaviour of COTS.

Table 1 shows their results as they presented them. The P values show results from a statistical test.

Table 1

Behaviour of COTS	**Type of light used in choice chamber**	
	Flashing	**Constant**
COTS moving towards the stimulus	22	12
COTS moving away from the stimulus	28	38
P value	0.69	0.02

(a) State a null hypothesis the marine biologists tested in this investigation.

_____

_____

_____

_____

(1)

(b) The natural habitat of COTS is coral reefs of tropical oceans.

Suggest **two** factors that should be kept constant in the choice chambers so that COTS display normal behaviour.

1 _____

2 _____

(1)

(c) A journalist studying **Table 1** suggested that either type of light could be used to cause COTS to move away from coral reefs.

Evaluate the journalist's suggestion.

(3)

(d) One of the reasons COTS can destroy coral reefs in a short time is because COTS move quickly, allowing them to move from one reef to another.

Table 2 shows the maximum speeds recorded of COTS in constant light.

Table 2

Response to light	**Maximum speed / mm min^{-1}**
COTS moving towards constant light	259
COTS moving away from constant light	264

Calculate the shortest time one COTS would take to move up a coral reef from 66 m under water to 18 m under water in hours of daylight.

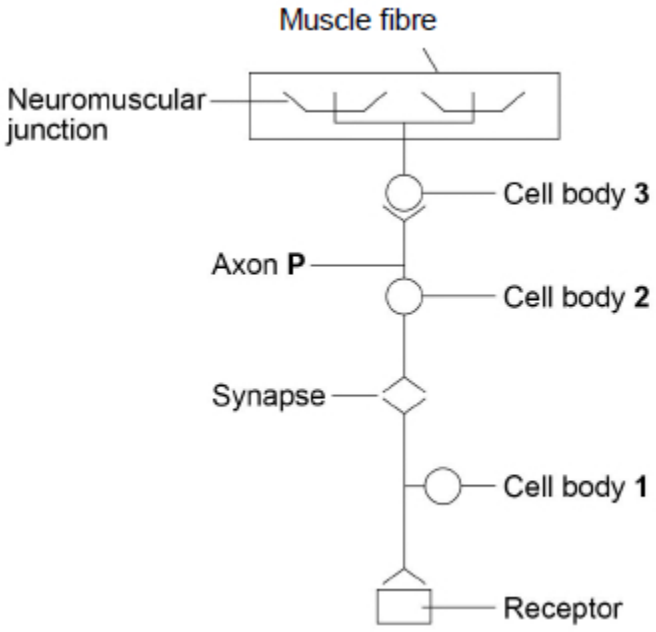
Give your answer to the nearest hour.

Answer = _____ hours

(2)

(Total 7 marks)

3. The diagram below shows a nerve pathway in an animal.



(a) The nerve pathway shown in the diagram may be regarded as a simple reflex arc.

Use the diagram to explain why.

_____

_____

_____

(1)

(b) Suggest **two** advantages of simple reflexes.

1. _____

_____

_____

2. _____

_____

_____

(2)

(c) In the nerve pathway in the diagram, synapses ensure that nerve impulses only travel towards the muscle fibre.

Explain how.

_____

_____

_____

_____

_____

(2)

(d) Axon **P** was found to conduct impulses much faster than other axons in the nerve pathway shown in the diagram.

Describe and explain **one** feature of axon **P** that might cause this difference.

_____

_____

_____

_____

_____

_____

(2)

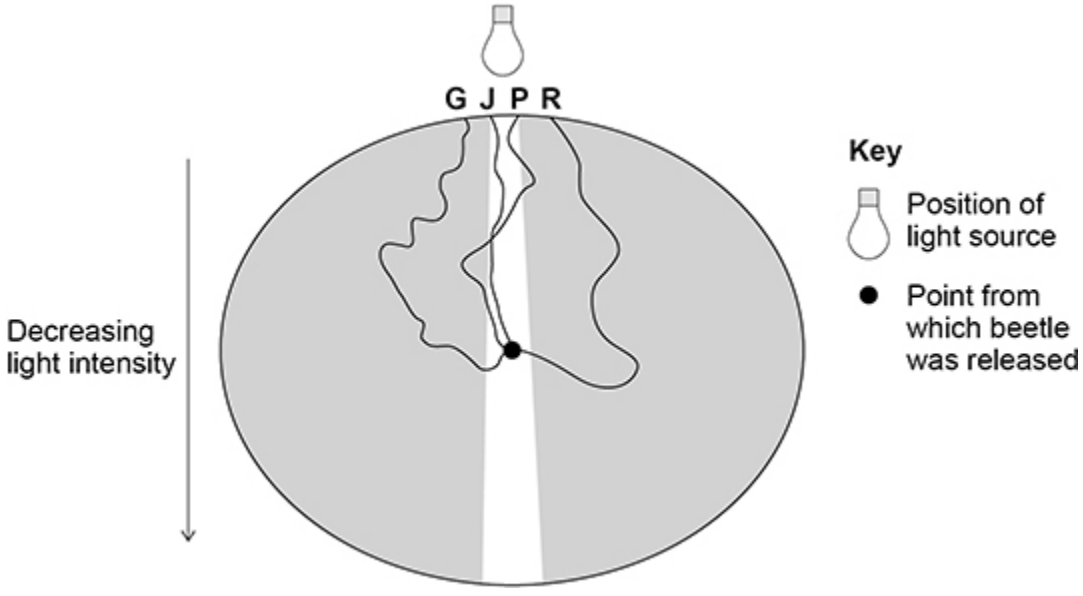
(Total 7 marks)

4. Scientists investigated movement in adult pine beetles. Adult beetles emerge from cracks in tree bark.

The scientists released a newly emerged adult beetle, **G**, from the centre of a sample area that had a single light source coming from one direction. They made a drawing of the beetle's path of walking. They repeated this with three more beetles, **J**, **P** and **R**.

Figure 1 shows the scientists' results.

Figure 1



(a) Name the type of behaviour shown by beetles **G**, **J**, **P** and **R**, and suggest **one** advantage to adult beetles of the type of behaviour shown.

Behaviour _____

Advantage _____

_____

_____

(2)

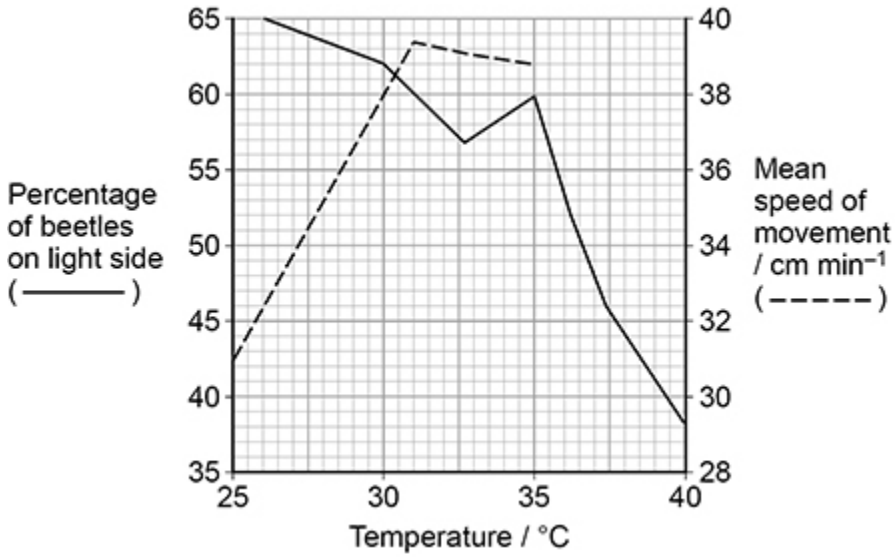
At higher temperatures and higher light intensities, adult pine beetles normally

- move more
- fly rather than walk.

When preparing to fly, these adult beetles walk slowly. The scientists investigated the movement of adult beetles at different temperatures, and in the light and the dark. They created a box that was half in the light and half in the dark. They released an adult beetle at the midpoint of the central dividing line between light and dark areas. They recorded the path of the beetle's movement and its location after 5 minutes. From this, they calculated the mean speed of movement. They repeated the experiment with many beetles and at several temperatures.

Figure 2 shows the scientists' results.

Figure 2



(b) After studying these experiments, a student concluded:

- there is a significant change in movement between 35 °C and 37.5 °C
- between 35 °C and 37.5 °C, more beetles move away from the light
- between 35 °C and 37.5 °C, more beetles have a slower walking speed.

Suggest reasons why these conclusions might **not** be valid.

(3)

(Total 5 marks)

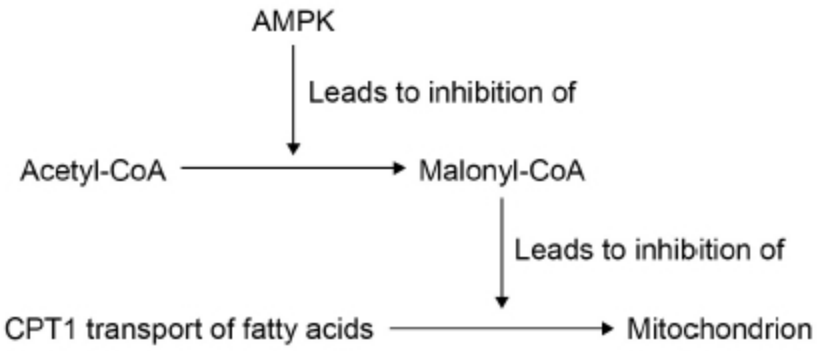
5. (a) Exercise causes an increase in heart rate.

Describe the role of receptors and of the nervous system in this process.

(4)

(b) AMP-activated protein kinase (AMPK) is an enzyme that regulates a number of cellular processes. Exercise leads to activation of AMPK.

The diagram shows one effect of activation of AMPK during exercise.



CPT1 is a channel protein that transports fatty acids into mitochondria.

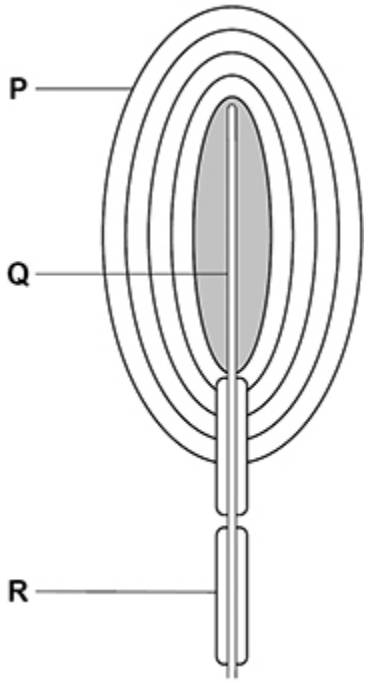
Using the diagram above, explain the benefit of activation of AMPK during exercise.

(3)

(Total 7 marks)

6. **Figure 1** shows a diagram of a Pacinian corpuscle.

Figure 1



(a) Name the structures labelled **P**, **Q** and **R** shown in **Figure 1**.

P _____

Q _____

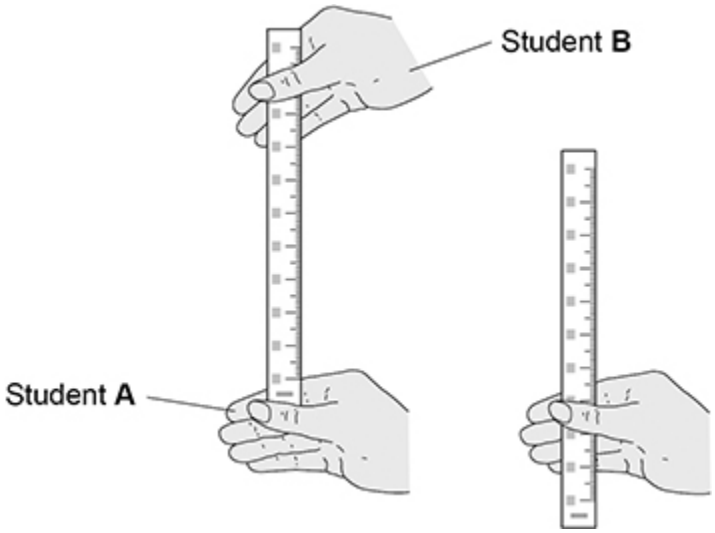
R _____

(2)

Two students (**A** and **B**) investigated reaction time in response to touch.

- Student **A** sat with her eyes shut and her forearm resting on a worktop so that her hand was over the edge.
- Student **B** held a ruler vertically between student **A**'s thumb and first finger, with the ruler at 0 mm lightly touching student **A**'s first finger.
- Student **B** released the ruler.
- As soon as student **A** felt the ruler fall, she closed her thumb and first finger to catch the ruler as shown in **Figure 2**.
- Student **B** measured the distance the ruler had fallen to the nearest mm

Figure 2



The test was repeated three more times using the same hand to catch the ruler. **Table 1** shows student **A**'s results.

Table 1

Trial	Distance the ruler has fallen / mm
1	79
2	97
3	10
4	94

The student was able to convert these distances into reaction times using **Table 2**.

Table 2

Distance the ruler fell / mm	Reaction time / ms
10	45
20	64
30	78
40	90
50	101
60	111
70	120
80	128
90	136

(b) Calculate the percentage uncertainty in the measurement of **Trial 1** in **Table 1**.

Put a Tick (✓) in the correct box below.

0.633% ☐

1.27% ☐

2.53% ☐

12.6% ☐

(1)

(c) In this investigation, it is not possible for a student to react in less than 45 ms

Suggest **one** explanation for the value recorded in **Trial 3** in **Table 1**.

_____

_____

_____

(1)

(d) Student **A** estimated that the length of the nerve pathway involved was 175 cm

Use **Table 1** and **Table 2** to calculate the mean speed of nerve impulse transmission.

Do **not** use the value for **Trial 3** in your calculation.

Answer _____ m s^{-1}

(2)

(e) In response to touch, nerve impulses can be transmitted at speeds of 76.2 m s^{-1}

Suggest **three** reasons why, in this investigation, the estimated speed of student **A**'s impulse transmission was less than 76.2 m s^{-1}

1 _____

_____

_____

2 _____

_____

_____

3 _____

_____

_____

(3)

(Total 9 marks)

7. (a) Describe how ultrafiltration occurs in a glomerulus.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(b) Glucose and water are reabsorbed by the proximal convoluted tubule of a nephron.

Put a tick (✓) in the box next to the correct ways in which glucose and water are reabsorbed.

Glucose by active transport and water against a water potential gradient	☐
Glucose by diffusion and water down a water potential gradient	☐
Glucose by facilitated diffusion and active transport and water against a water potential gradient	☐
Glucose by facilitated diffusion and active transport and water down a water potential gradient	☐

(1)

(c) The equation shows the relationship between urine concentration in arbitrary units (y) and mean length of the loop of Henle in mm (x).

$$y = 0.72x + 4$$

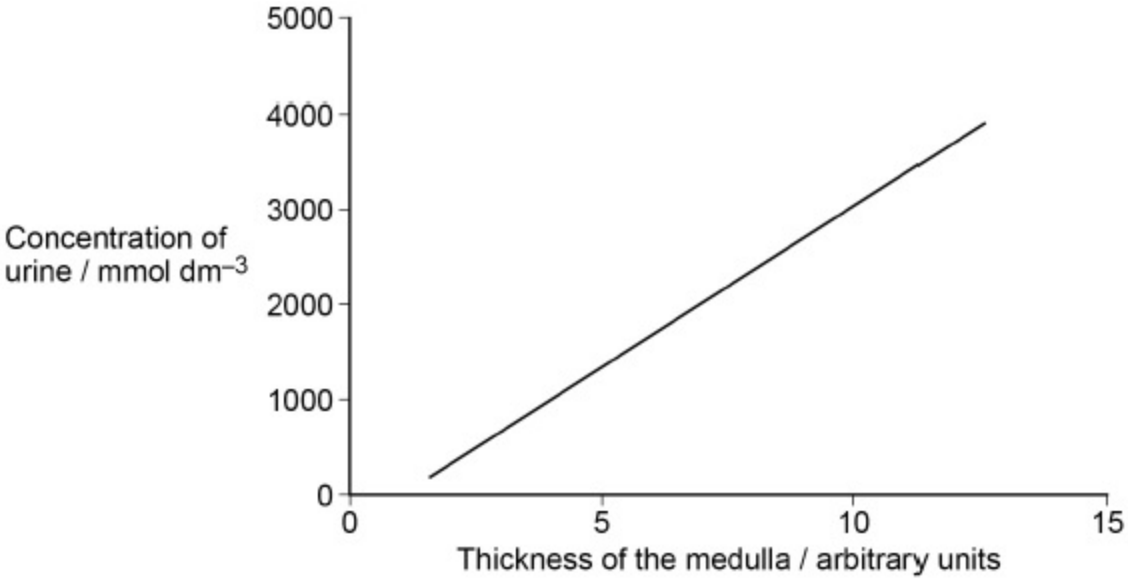
Calculate the mean length of the loop of Henle in an organism that produces urine with a concentration of 16.56 arbitrary units.

Answer = _____ mm

(1)

(d) Scientists investigated the relationship between the thickness of the kidney medulla of different species of mammals and the concentration of their urine.

The graph shows their results.



Explain the pattern shown by the results in the graph above.

(3)

(Total 8 marks)

8. Read the following passage.

North American black bears can hibernate for up to 7 months without food or water. The bears survive using the fat stores in their bodies. The bears build up the fat stores during the summer. During hibernation, the heart rate of black bears decreases from a summer mean of 55 beats per minute to 14 beats per minute. Their metabolic rate falls by 75%.

In many mammals, 'uncoupling proteins' help to maintain a constant body temperature during hibernation. Uncoupling proteins are found in the inner mitochondrial membrane and act as proton channels during chemiosmosis. However, these proton channels do not generate ATP.

In the mountains of North America, when winter changes into spring, the coat colour of snowshoe hares changes from white to brown. Climatic changes have caused the snow to melt earlier. This has reduced the survival rate of snowshoe hares in these habitats. The change in coat colour occurs when new fur replaces old fur. This is called moulting. Recent research has shown that snowshoe hares within a population moult at different times. Moulting at different times could be a major factor in ensuring the survival of snowshoe hare populations.

Use the information in the passage and your own knowledge to answer the following questions.

(a) Black bears can hibernate for up to 7 months without food or water (lines 1−2).

Suggest and explain how.

(3)

(b) During hibernation, the heart rate and the metabolic rate of black bears decrease (lines 3−5).

Use your knowledge of the nervous control of heart rate to describe how these are linked.

(4)

(c) In many mammals, ‘uncoupling proteins’ help to maintain a constant body temperature during hibernation (lines 6−7).

Suggest and explain how.

(2)

(d) Climatic change has reduced the survival rate of snowshoe hares in mountain habitats (lines 11−13).

Suggest and explain how.

(2)

(e) Snowshoe hares within a population moult at different times (line 15).

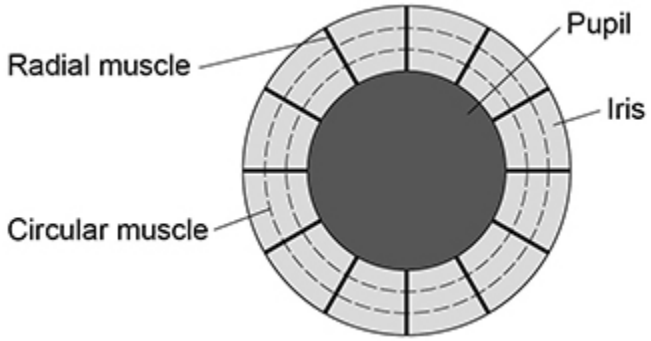
Explain how this could ensure the survival of snowshoe hare populations in these mountain habitats.

(4)

(Total 15 marks)

9. The iris in the human eye is a muscular structure. The iris changes the size of the pupil.

The diagram below shows the muscles in the iris.



(a) Suggest and explain how the interaction between the muscles labelled in the diagram above could cause the pupil to constrict (narrow).

_____

_____

_____

_____

_____

_____

(2)

(b) The fovea of the eye of an eagle has a high density of cones. An eagle focuses the image of its prey onto the fovea.

Explain how the fovea enables an eagle to see its prey in detail.

Do **not** refer to colour vision in your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(c) The retina of the human eye has an area of approximately 1.094×10^3 mm^2

The circular fovea in a human eye has a diameter of $3 \times 10^3 \mu m$

Calculate the area of the fovea as a percentage of the area of the retina.

The area of a circle is πr^2. Use $\pi = 3.14$ in your calculation.

Show your working.

Answer _____ %

(2)

(d) The retina of an owl has a high density of rod cells.

Explain how this enables an owl to hunt its prey at night.

Do **not** refer to rhodopsin in your answer.

(3)

(Total 10 marks)

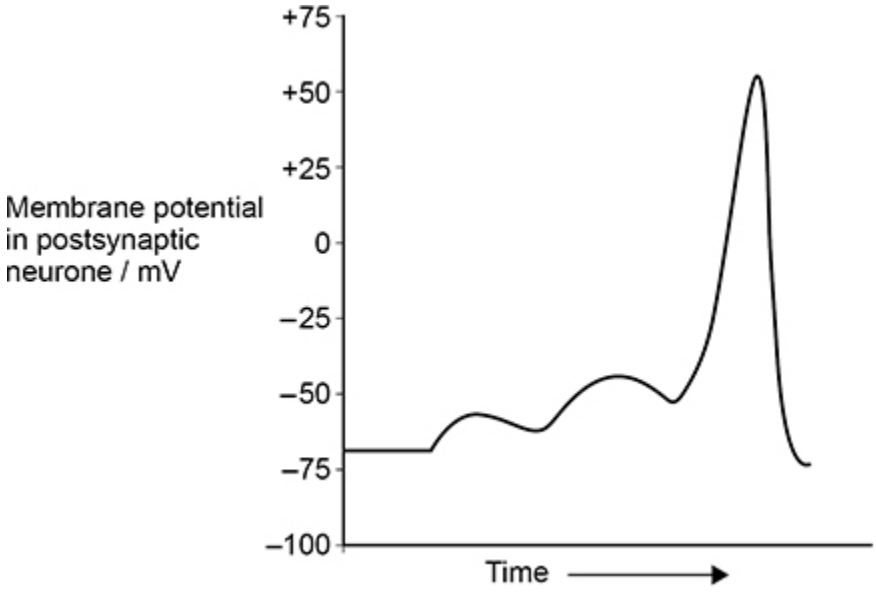
10. (a) Give **two** reasons why transmission across a cholinergic synapse is unidirectional.

1 _____

2 _____

(2)

The graph below shows the changes in membrane potential in a postsynaptic neurone after repeated stimulation from a single presynaptic neurone.



(b) Name and explain the type of summation shown in the graph above.

Type of summation _____

Explanation _____

_____

_____

(2)

Myasthenia gravis (MG) is an autoimmune disease caused when antibodies bind to the sarcolemma (postsynaptic membrane) of neuromuscular junctions. This can weaken contraction of muscles.

Mestinon is a drug that inhibits the enzyme acetylcholinesterase. Mestinon can help in the treatment of MG.

(c) Suggest and explain how MG can weaken contraction of muscles.

Do **not** include details of myofibril or muscle contraction in your answer.

_____

_____

_____

_____

_____

_____

(2)

(d) Mestinon can help in the treatment of MG. Explain how.

(3)

(Total 9 marks)

11. (a) Explain how a resting potential is maintained across the axon membrane in a neurone.

(3)

(b) Explain why the speed of transmission of impulses is faster along a myelinated axon than along a non-myelinated axon.

(3)

(c) A scientist investigated the effect of inhibitors on neurones. She added a respiratory inhibitor to a neurone. The resting potential of the neurone changed from –70 mV to 0 mV.

Explain why.

(3)

(Total 9 marks)

Mark schemes

1.

(a) 1. Tip produces IAA;

Accept source/release for produces but ignore contains/stores IAA.

2. IAA diffuses (into shoot);

Accept auxin for IAA.

Accept IAA diffuses down.

3. (More) elongation of cells on one side (than other);

Accept (more) elongation of cells on left side.

Reject any reference to shaded/dark side or away from light.

3

(b) 1. Size of shoot/tip;

2. Number of shoot tips;

3. Size/type of agar (block);

Accept 'amount of agar'.

4. (Shoots) at same stage of growth/development;

Accept (Shoots/plants) are same age.

5. Time (period) tips kept on agar

OR

Time (period) agar/block kept on (cut shoot)

OR

Time (period shoots) kept in dark;

6. Temperature;

Mark points 1 to 6 = max 3.

Ignore pH, species, carbon dioxide, humidity, nutrients, water and light.

7. (Repeat several times and) calculate a mean;

8. Compare/read degree of curvature (on calibration curve) to determine (IAA) concentration

OR

Higher the degree of curvature the higher the IAA concentration;

5 max

(c) 1. (IAA) is not broken down by light

OR

(IAA) is produced in the dark **OR**

Light/dark does not affect (IAA) production;

2. (IAA) moves away from light

OR

(IAA) moves to shaded side;

IAA accumulates on shaded side is not enough on its own, idea of movement is required.

2

[10]

2. (a) Accept suitable null hypothesis that **includes type of light and behaviour**, eg

The type of light has no effect on the behaviour/movement of COTS
OR
There is no difference in behaviour/movement with constant/flashing light;

Ignore general null hypotheses, or example 'there is no difference between observed and expected'

1

(b) Accept any **two** factors for **one** mark from the list below;

Salinity / salt concentration of the water

Temperature (of the water)

Amount / distribution of food

pH (of the water)

Oxygen/carbon dioxide concentration

Intensity/wavelength of (constant and flashing) light

List rule applies
Ignore humidity
Ignore type of coral
Ignore depth of water

1 max

(c) Yes (no mark)

1. Movement is away from either type/both types of light
OR
Negative (photo) taxis to both types/either types of light;

2. Significant movement away from constant light **as** p = 0.02 / < 0.05 / = 2% / < 5%
OR
Movement away from constant light is not due to chance **as** p = 0.02 / 0.05 / = 2% / < 5%;

*Ignore '**results**' in the context of significance or chance*

No (no mark)

3. Movement away from flashing light is not significant **as** p = 0.69 / > 0.05 / = 69% / > 5%
OR
Movement away from flashing light is due to chance **as** p = 0.69 / > 0.05 / = 69%/> 5%;

*Ignore '**results**' in the context of significance or chance*

3

(d) Correct answer of 3 hours = 2 marks;;

Allow 1 mark for distance of 48 000 mm in working

1 max for answer of 185 minutes/3 hours and 5 minutes/3.09 hours

1 max for answer of 1 hour (ie answers that use 564 in their calculation);

2 max

[7]

3. (a) Only 3 neurones / nerve cells (in reflex arc)

1

(b) 1. Rapid;

2. Protect against damage to body tissues;

3. Do not have to be learnt;

4. Help escape from predators;

5. Enable homeostatic control.

2 max

(c) 1. Neurotransmitter only made in / stored in / released from pre-synaptic neurone;

2. (Neuro)receptors only on the post-synaptic membrane;

2

(d) 1. Axon **P** is myelinated;

2. So shows saltatory conduction / impulses jump between nodes of Ranvier

OR

3. Axon **P** has a larger diameter;

4. So less resistance to flow of ions.

*Mark as 1 & 2 **OR** 3 & 4*

2

[7]

4.

(a) Behaviour

1. (Positive photo) taxis;

Reject negative (photo) taxis

Advantage

2. Accept any suitable suggestion, eg to avoid competition, to find a mate, increase dispersal, to avoid predators;

Neutral – to move into the open or to move out of the tree bark

2

(b) 1. No stats test, so do not know if change (in movement away from light) is significant;

2. Between 35 °C and 36.5 °C more than half of beetles are still found on the light side;

3. (At higher temperatures/above 35 °C) beetles might be flying (not walking)

OR

(Y-axis) states speed of movement, might not just be walking speed;

4. Slowing of movement happens before 35 °C;

5. Slowing of movement could be due to beetles preparing to fly (and not temperature);

6. Speed (of movement) not recorded above 35 °C/ between 35 and 37.5 °C/between 35 and 40 °C;

OR

Speed (of movement) not recorded at 37.5 °C

7. (Mean speed could mean) some might walk very quickly **and** others stay still/not move;

3 max

[5]

5.

(a) 1. Chemoreceptors detect rise in CO_2 / H_+ / acidity / carbonic acid / fall in pH

OR

Baro / pressure receptors detect rise in blood pressure;

2. Send impulses to cardiac centre / medulla;
3. More impulses to SAN;
4. By sympathetic (nervous system for chemoreceptors / CO_2)

OR

By parasympathetic (nervous system for baro / pressure receptors / blood pressure);

1. Ignore: location of receptors.

1. Ignore: chemoreceptors detect oxygen.

2 and 3. Accept: action potentials.

2. Reject: 'messages', 'signals', 'an impulse' or an 'action potential'.

3. Ignore: messages', 'signals', 'an impulse' or an 'action potential' as emphasis here is on increase in frequency.

4

(b) 1. Less / no malonyl-CoA;
2. (More) fatty acids transported / moved into mitochondria;
3. Respiration / oxidation of fatty acids provides <u>ATP;</u>

1. 'Inhibition of malonyl-CoA' on its own is not enough but accept production of malonyl-CoA is inhibited.

2. Accept: 'transport of fatty acids into mitochondria is not inhibited'.

2. Ignore: method of entry.

3. Accept: for respiration any stage of aerobic respiration e.g. Krebs (cycle), link (reaction) etc.

*3. Reject: production of energy, **but** accept production of energy in the form of <u>ATP</u>.*

3. Accept: acetyl CoA can enter Krebs cycle / mitochondria to provide ATP.

3

[7]

6.

(a) **Two** marks for **three** correct structures,

one mark for **two** correct structures;;

P = capsule/lamella(e)

Accept connective tissue

Q = Axon (membrane)

Accept (sensory) neurone

Accept nerve cell

Ignore nerve

R = Schwann cell(s)
OR
R = Myelin (sheath)

2

(b) 1.27% (second box) ticked;

1

(c) 1. The student started to move/close her hand before the ruler was released;

Accept any descriptions of a pre-emptive strike

2. The ruler did not fall vertically/was not placed vertically;

3. The ruler stuck to her skin;

4. (Student **B**) held the ruler too high/higher;

*Ignore answers related to student **A** having their eyes open*

*Ignore student **B** misread the ruler*

1 max

(d) Correct answer of 12.9/13 (m s^{-1}) = **2 marks**;;

Use of reaction time of 136 (ms)/0.136 (s) in answer = **1 mark**

OR

$14.58\dot{3}$ (answer including Trial 3) = **1 mark**

OR

1.29 = **1 mark**

*For **2 marks** accept any correct rounding of 12.8676471*

2

(e) 1. Synaptic transmission
OR
Transmission at neuromuscular junction;
Accept (involves) synapses

2. Time for muscle contraction;

3. Time taken for (stretch-mediated) sodium ion channels to open (in the Pacinian corpuscle);

4. Student may have been distracted/not concentrating;

5. Time taken for coordination/comprehension (by the brain);

Ignore answers relating to the estimate of the length of the nerve pathway involved
For 1 mark, accept correct reference to student conditions/medication eg tiredness, antidepressants

3 max

[9]

7. (a)

Ignore references to podocytes

1. High blood/hydrostatic pressure;
Ignore references to afferent and efferent arterioles
Ignore 'increasing/high er blood pressure' as does not necessarily mean high

2. **Two named** small substances pass out eg water, glucose, ions, urea;
Accept correct named ions
Accept mineral ions/minerals
Accept amino acids/small proteins
*Ignore references to molecules **not** filtered*

3. (Through small) gaps/pores/fenestrations in (capillary) endothelium;
Accept epithelium for endothelium

4. (And) through (capillary) basement membrane;

3 max

(b) ☑ Glucose by facilitated diffusion and active transport and water down a water potential gradient

1

(c) 17.4;
Accept any number of fours after the decimal point.

1

(d) 1. Thicker medulla means a longer loop (of Henle);

2. (The longer the loop of Henle means) **increase** in sodium ion concentration (in medulla)
OR
(The longer the loop of Henle means) sodium ion gradient maintained for **longer** (in medulla)
OR
(The longer the loop of Henle means) **more** sodium ions are moved out (into medulla);

Must have idea of increase/longer/more

3. (Therefore) water potential gradient maintained (for longer), **so** more water (re)absorbed (from loop and collecting duct);
OR
More water is (re)absorbed **from** the loop (of Henle) / collecting duct **by** osmosis;

*Reject water being reabsorbed **into** the loop of Henle*

Direction is important

Accept Ψ for water potential

3

[8]

8. (a) 1. Fat (store) used in respiration/metabolism;

Mark points 1 to 4 = 2 max.

Mark points 5 to 8 = 2 max.

2. Less energy/food (store) is required due to low respiration/metabolism

OR

Less energy/food (store) is required due less movement;

Reject respiration 'uses energy' or 'produces energy'.

3. Gluconeogenesis;

Accept description in terms of using glycerol, fatty acids or amino acids.

4. Low surface area to volume reduces heat loss

OR

Fat (layer/insulation) reduces heat loss;

5. Long loop of Henle so less water lost;

Accept thick medulla (in kidney) for long loop of Henle.

6. Water provided from respiration;

7. Reduced/no urination;

8. Less evaporation;

Accept less sweating.

3 max

(b) 1. (Lower metabolism so) less/low CO_2 (in blood);

If neither mark point 1 or 2 credited = 3 max.

Accept increase in pH or decrease in H ions/acidity for less CO_2.

Ignore baroreceptors.

2. (Detected by) chemoreceptors;

Ignore detects oxygen, (concentration).

3. (Chemoreceptors) located in aorta/medulla

OR

(Chemoreceptors) located in carotid artery;

Accept carotid body or aortic body.

4. Fewer impulses to cardiac centre;

OR

Fewer impulses to medulla (oblongata);

5. (More) impulses along parasympathetic/vagus pathway/neurones/nerve

OR

Fewer impulses along sympathetic pathway/neurones/nerve;

Reject (once only) reference to 'an/one impulse'.

Reject 'signals', 'messages' (once only) for 'impulses'

Accept 'action potential/s' for impulses.

6. (To) SAN;

4 max

(c) 1. Allow passage of protons/H^+;

Ignore direction of movement/diffusion/active transport.

2. (Energy) released as heat;

Accept 'produces heat' but reject 'produces 'heat energy'.

2

(d) 1. Less snow **so** less camouflage;

Accept 'snow melts'

Accept description of less camouflage, e.g. more hares seen.

2. More hares seen/eaten/killed by predators;

Accept description of predation.

2

(e) 1. Hares which moult earlier (more likely to) survive;

Accept less likely to be killed for 'survive'.

Accept description of survival e.g. not killed/eaten.

Accept moult quicker/faster for earlier.

Answers must be in the context of moulting earlier/quicker/faster.

Accept rabbits for hares.

2. Hares which moult earlier (more likely to) reproduce;

Answers must be in the context of moulting earlier/quicker/faster.

Accept rabbits for hares.

Accept 'pass on allele to offspring' or 'to next generation' = 2 marks.

3. Pass on (advantageous) allele;

Accept 'pass on alle to offspring' or 'to next generation' = 2 marks.

4. Frequency of allele increases (in future populations);

'More alleles' is not enough for a mark.

4

[15]

9. (a) 1. Circular muscle contracts;

2. Radial muscle relaxes;

Accept, for one mark 'both muscles contract' or 'both muscles relax' as names of muscles are in the diagram.

Reject muscles constrict.

2

(b) 1. High (visual) acuity;

2. (Each) cone is connected to a single neurone;

Accept no retinal convergence.

Accept 'bipolar/nerve cell' for neurone.

3. (Cones send) separate (sets of) impulses to brain;

Accept 'optic nerve' for brain.

Reject 'signals', 'messages' for 'impulses'.

Accept 'action potential'.

3

(c) 1. Correct answer of 0.6 (%) = **2 marks**;;

Ignore any numbers after 0.6, 2.58, 2.6 and after 0.43.

2. Incorrect answer but shows number sequence 7065 / 7068 / 7069 / (ignore position of decimal point) = **1 mark**

OR

Final answer number sequence has 64 / 65 (ignore preceding zeros, numbers that follow and position of decimal point) **= 1 mark**

OR

Final answer is 2.58 / 2.6 (%) = **1 mark**

OR

Final answer of 0.43 (%) = **1 mark**;

2

(d) 1. High (visual) sensitivity;

Accept retinal convergence.

2. Several rods connected to a single neurone;

Accept 'bipolar/nerve cell' for neurone

Accept 2, 'many' or

3. Enough (neuro)transmitter to reach/overcome threshold

OR

Spatial summation to reach/overcome threshold; more for 'several'

Reject 'signals', 'messages' for 'impulses'.

Accept named neurotransmitter.

Accept depolarisation, 'action potential' or 'generator potential' for 'to reach threshold'.

Generator potentials combine to reach threshold/ depolarisation/action potential/generator potential.

3

[10]

10. (a) 1. (Only) the presynaptic neurone/knob/membrane releases/has neurotransmitter/acetylcholine;

Accept abbreviations for acetylcholine e.g. ACh, Ach, AChol.

Ignore has/releases 'transmitter'.

2. (Only) the postsynaptic neurone/membrane has receptors
OR
No receptors in the presynaptic neurone/membrane;

2

(b) 1. Temporal

2. (Several/repeated impulses in short time) provide (enough) neurotransmitter/acetylcholine to reach threshold
OR
(Several/repeated impulses in short time) so (enough) sodium ions enter to reach threshold
OR
(Several/repeated impulses in short time) increases membrane potential to reach threshold;

Accept abbreviations for acetylcholine e.g. ACh, Ach, AChol.

Accept 'to cause depolarisation' or 'to produce action/generator potential' for 'to reach threshold'.

Accept Na^+ for sodium ions.

2

(c) 1. Less/no acetylcholine/neurotransmitter binds to receptor/s;

Accept abbreviations for acetylcholine e.g. ACh, Ach, AChol

Ignore competitive inhibition but reject 'active site'.

2. Less/no depolarisation
OR
Fewer/no action potential(s)
OR
Fewer/no sodium ions enter to reach threshold;

Accept 'takes longer for depolarisation or action/generator potential to be produced'.

Ignore 'weaker action potential/depolarisation'.

Accept Na^+ for sodium ions.

2

(d) 1. Less/no acetylcholine/neurotransmitter broken down;

Accept (more) acetylcholine/neurotransmitter present/remains.

Accept acetylcholine/neurotransmitter remains attached to receptors (for longer) = 2 marks.

Accept ACh or other abbreviations e.g. AChol for acetylcholine.

2. (More) acetylcholine attaches to <u>receptors;</u>

Accept acetylcholine/neurotransmitter remains attached to receptors (for longer) = 2 marks.

Accept ACh or other abbreviations e.g. AChol for acetylcholine.

3. Depolarisation (of sarcolemma) occurs
OR
Action potential(s) produced
OR
(Enough) sodium <u>ions</u> enter to reach threshold
OR
Fewer/no antibodies attach;

Accept Na^+ for sodium ions.

3

[9]

11. (a) 1. Higher concentration of potassium ions inside **and** higher concentration of sodium ions outside (the neurone)

OR

potassium ions <u>diffuse</u> out

OR

sodium ions <u>diffuse</u> in;

Accept 'more' for 'higher concentration'.

Accept 'sodium ions can't diffuse in (due to alternative explanation).

2. (Membrane) more permeable to potassium ions (leaving than sodium ions entering)

OR

(Membrane) less permeable to sodium ions (entering than potassium ions leaving);

Accept for 'less permeable to sodium ions' is 'impermeable to sodium ions' or 'sodium gates/channels are closed' (alternative explanation).

3. Sodium ions (actively) transported out and potassium ions in;

reference to <u>ions</u> or Na^+ and K^+ is required. If mentioned once allow for all mark points.

*If an answer provides two or three of these mark points **without** any reference to <u>ions</u> – award **one** maximum mark.*

Accept 3 Na^+ out and 2 K^+ in but reject if numbers used are incorrect.

3

(b) 1. Myelination provides (electrical) insulation;

Reject thermal insulation.

Accept description of (electrical) insulation.

2. (In myelinated) saltatory (conduction)

OR

(In myelinated) depolarisation at nodes (of Ranvier);

3. In non-myelinated depolarisation occurs along whole/length (of axon);

Accept action potentials for depolarisation.

'Messages' or 'signals' disqualifies first of these marks credited.

3

(c) 1. No/less ATP produced;

2. No/less <u>active</u> transport

OR

Sodium/potassium pump inhibited;

*Accept Na^+ not/fewer moved out **and** K^+ not/fewer moved in.*

3. Electrochemical gradient not maintained

OR

(Facilitated) diffusion of ions causes change to 0 mV

OR

(Results in) same concentration of (sodium and potassium) ions (either side of membrane)

OR

No net movement of (sodium and potassium) ions;

Accept reaches electrical equilibrium/balance.

Accept concentration gradient of sodium and potassium ions not maintained.

3

[9]

Examiner reports

1. 57% of students obtained at least one mark for (a). The most frequently awarded mark was for reference to the production of IAA in the shoot tip. A significant number of students simply stated that the tip contained IAA. Despite **Figure 1** indicating that there wasn't a directional light source, many students described phototropism or in some instances geotropism. This misinterpretation was further demonstrated by references to the 'shaded side' or 'the tip providing shade'. Mark point 2, relating to the diffusion of IAA, was rarely credited. Consequently, only 7% of students obtained maximum marks. Approximately 27% of students obtained at least two marks. These students explained that (more) cell elongation would occur on one side of the shoot. Responses such as 'more growth' or 'more elongation' were not credited.

Considering (b) was a five-mark question and assessed evaluation skills, it was not a very effective discriminator. Approximately 91% of students obtained at least one mark and 50% at least three marks. Most students were able to refer to variables which should be controlled to provide a valid conclusion. The mark scheme credited a maximum of three variables from a list of six. Apart from mark point 4, 'shoots at same stage of growth/development', all the listed variables were frequently credited. Almost 21% of students obtained at least one mark in addition to providing three correct variables. Usually, this was mark point 8, describing how the calibration curve could be used to compare IAA concentrations. Very few students suggested repeats and the calculation of a mean. Consequently, only 3% of students obtained maximum marks. Common errors in weaker responses included adding known IAA concentrations to the agar blocks, plotting calibration curves for the two plant species being investigated and not realising that the shoots were kept in the dark to determine the degree of curvature.

Part (c) was not well answered and proved to be a very poor discriminator. Only 1% of students obtained both marks and 23% obtained one mark. Most students did not provide conclusions but simply described the results shown in the table. Students who did obtain a mark usually concluded that IAA had moved to the shaded side or had moved away from light. Very few students concluded that IAA was not broken down by light or was still produced in the dark. Many incorrect answers referred to the effects of IAA in terms of bending or phototropism rather than its movement or production.

2. Question (a) was well answered, with about 70% scoring the mark. Those who failed to score mostly either gave a hypothesis rather than a null hypothesis, or gave a generalised null hypothesis, such as 'there is no significant difference between observed and expected'.

Question (b) was correctly answered by just over half of students. It required students to identify two factors that **can be controlled** in a choice chamber used by scientists during an investigation in a laboratory. Many failed to read the stem of the question and recognise this context; the scientists were not attempting to recreate or mimic the dynamic environment of the reef itself. Those students who correctly identified two factors selected accepted abiotic factors, usually pH, temperature and the salinity of the water that could reasonably influence the behaviour of the COTS. Unfortunately, some students made references to biotic factors in the natural marine environment, such as the need for 'a reef' to be present or the 'type of coral' or to 'maintain the natural environment of the ocean', that are impossible to control. Those students who were only able to identify one factor did not gain credit. Very few gave more than two answers so were not in jeopardy of having marks cancelled through the list principle.

Question (c) saw students failing to evaluate once more, with only about 6% scoring all three marks; there was also a lack of understanding of how to analyse the statistical data in **Table 1**, and confusion with p values and critical values, with comments such as 'no critical values are given, so no conclusion can be drawn'. Many students could identify that both light regimes caused movement away, showing evidence of reading and interpreting the question accurately. Invalid comments such as 'results are significant' were once again evident.

Question (d) is a relatively straightforward calculation, however only just over a third of students scored two marks. Successful students appreciated that the COTS were moving towards constant light, were able to calculate the distance travelled as 48000 mm, divide this figure by the speed of 259 mm min^{-1} and convert 185 minutes into hours, to achieve two marks. Answers that scored one mark were a mix of the distance travelled correctly shown as 48000 mm, or the answer not being rounded to the nearest hour as requested. A large number of students who scored zero could not convert metres into millimetres, calculating the distance to be 4800 mm.

4. Part (a) showed a lack of understanding of terminology, with only 18.56% scoring 2 marks. Incorrect responses included 'tropism' and 'kinesis' for MP1, and for MP2 there were many vague answers of '*to survive*' and many students stating that the beetles moved away from the light, which is the opposite to what is shown in **Figure 2**. There were also multiple incidences of beetles needing to move towards the light for photosynthesis. With (b), the majority could score at least 1 mark, but only 4.47% scored 2 marks. The question asked why the conclusions might **not** be valid, but several students answered why they were valid. Once again, students gave rote-learned responses, including '*small sample size'* (despite the stem stating, '*They repeated the experiment with many beetles…*') and '*there may be other factors*'.

5. (a) Considering that this question required mainly straightforward recall, it was disappointing to note that over 25% of students did not obtain a mark and that only 10% obtained full marks. One of the main reasons for this was the use of poor terminology, particularly when describing nerve impulses as 'messages' or 'signals'. Most responses did refer to chemoreceptors but there was some confusion concerning their role. A minority of students mentioned baroreceptors, often in addition to chemoreceptors. The role of the sympathetic nervous system in increasing the heart rate was the most frequently credited mark point. However, the increase in frequency of impulses from the medulla was only described in the best answers. Interestingly, this question proved to be one of the best discriminators on the paper.

(b) This question also proved challenging with over a third of students scoring zero. Nevertheless, most students gained credit for describing the action of AMPK in inhibiting the conversion of acetyl-CoA to malonyl-CoA. However, the idea that this would lead to more fatty acids being transported into mitochondria was often misunderstood with many students incorrectly suggesting that transport of fatty acids would be reduced. A common misconception was that glucose would be used as an alternative respiratory substrate to fatty acids. Better answers did refer to increased ATP production from the use of either fatty acids or acetyl-CoA as respiratory substrates.

6.

(a) represents the first time that the structure of a Pacinian corpuscle has been assessed. 21% of students were able to correctly name the three structures, with a further 47% being able to name two of the structures. P was often incorrectly named as 'stretch-mediated sodium ion channel.' Q was often just named as a nerve, which is insufficient detail for A-level. R was incorrectly named as a node of Ranvier.

The answer to **(b)** was correctly calculated by 44% of students; of the remaining 56%, most did not know how to calculate percentage uncertainty.

(c) proved harder than expected for students. Only 42% were able to suggest an explanation. Incorrect responses mentioned eyes being open or the ruler being caught before it was dropped (not true, as it did move). Surprisingly, there were many responses referring to student B not starting or stopping the stop clock accurately, however no stop clock was involved in the students' investigation. Most correct responses were based around marking point (MP) 1.

(d) was correctly answered for 2 marks by only 16% of students. Many students did not seem to know that speed equals distance divided by time, and students struggled to convert units from milliseconds to seconds.

(e) proved very difficult for students, with only 0.2% scoring all 3 marks, and 2% scoring 2 marks. Students seemed to repeat answers given for **(c)**. There were many responses that stated the length of the nerve pathway was underestimated; however, to get a speed of 76.2 m s^{-1}, the student's nerve pathway would have to be 10.36 m long to glean a reaction time of 136 ms. There were many answers that failed to consider the context of the question, and put 'low temperature', 'small axon diameter' and 'less myelination.' There was also confusion with reaction time in ms and speed of impulse transmission in m s^{-1}, with lots of responses discussing a faster reaction speed and the effects of caffeine.

7.

Question (a) tested AO1 skills and was aimed to be a simple start to the exam. However, it proved rather difficult for students, with only about 10% scoring three marks, and nearly a third scoring zero marks. It did discriminate well. Most students set the context of the blood arriving in the afferent arteriole and leaving via the efferent arteriole; a pity, as neither forms part of the glomerulus. Many used this to justify an increase in pressure, but failed to state that the pressure was high, and also failed to mention that it was blood or hydrostatic pressure. Those who omitted the arterioles often went straight for high blood/hydrostatic pressure (thus avoiding the pitfalls of a comparative answer).

Most students made reference to the 'small molecules'; the less successful students left it at that while the more able students included lists, most of which were correct; the most common were water and glucose. These two marking points were the most commonly awarded. A small number of students mentioned the epithelium or endothelium, but omitted to make reference to the gaps, and had molecules crossing the cells. Occasionally answers suggested there were holes in the actual cells. The basement membrane was noted on occasion, but not frequently, and it was sometimes endowed with holes. Some students moved from the glomerulus/Bowman's capsule to various parts of the loop of Henle. A small number of students listed blood proteins as not forming part of the filtrate.

Question (b) was generally well answered, with over three-quarters scoring the mark.

Question (c) was generally well answered, with around 80% scoring the mark. Those who failed to score did so by either incorrect rounding or not obeying the rules for rearranging equations (i.e. divided first, then subtracted and arrived at an answer of 19).

Question (d) also discriminated well, but the majority of students failed to make the necessary link of understanding that the loop of Henle is in the medulla of the kidney for MP1. Only about 2% of students scored all three marks. There were many descriptions of the data in the graph, but few explanations. Many students saw the term 'thickness' on the graph, ignored the rest of the question and based their response on a long diffusion pathway. For MP2, the mark scheme was made very accessible by accepting 'increase in sodium ion concentration'; however, many students only mentioned ions, and not sodium ions specifically. There was also a fundamental lack of understanding that the filtrate in the loop of Henle will eventually form urine, and so answers seemed to discuss water moving into the loop rather than out of the loop for MP3. Again, the mark scheme for MP3 was made more accessible by allowing 'more water is absorbed from the loop / collecting duct by osmosis'; however, most failed to give the mechanism, i.e. did not write *by osmosis*.

8.

(a) Although only 4% of students gained all three marks and 67% gained at least one mark, this question was an effective discriminator. The most frequently credited marking points were the use of (stored) fat in respiration/metabolism and less (stored) food being required due to reduced respiration/metabolism during hibernation. A significant number of students attempted to describe gluconeogenesis, but very few did this successfully. Most confused this process with glycogenolysis. Several other features of hibernating bears were mentioned including reduced movement, fat insulation and their reduced surface area to volume ratio, but the significance of these features were rarely explained. References to water were less frequent. However, reduced urination, reduced sweating and particularly the production of water from respiration were all credited at some point. Some students incorrectly suggested that water could be provided by hydrolysis.

(b) This question was the second most effective discriminator on this exam paper. This was surprising considering that 36% of students scored zero. Approximately 25% of students obtained at least three marks and 14% obtained the maximum four marks. The best answers displayed a full understanding of the role of chemoreceptors and the autonomic nervous system in reducing the heart rate in response to a decrease in the metabolic rate. Some of the students who scored zero failed to mention the nervous system and based their response on the reduced heart rate reducing the supply of oxygen to tissues, this resulting in a reduced metabolic rate. Other students could not accurately recall any details of the nervous control of the heart rate or described how contraction of the heart is coordinated. Frequently, students who gained a single mark did so for stating that impulses were sent to the SAN. The role of chemoreceptors was appreciated in better responses. However, a significant minority of students suggested that they only respond to the concentration of oxygen in the blood. Rarely did students refer to the frequency of impulses in terms of more or fewer, but this did not prevent maximum marks being achieved. However, poor use of terminology was again a feature with 'messages' and 'signals' particularly apparent on low scoring responses.

(c) Very few students could apply their knowledge and understanding of chemiosmosis to uncoupling proteins. Consequently, only 7% of students obtained both marks and 29% one mark. 10% of students did not attempt this question. Many students simply repeated the information on uncoupling proteins in the passage or completely ignored this and described the production of ATP via chemiosmosis. Some students suggested that these uncoupling proteins released another form of energy without being specific. A significant number of students incorrectly referred to the 'production of energy'. Students who gained a single mark usually gained credit for mentioning the release of heat energy rather than the passage of protons through the uncoupling proteins. Despite the problems students encountered with this question, it proved to be an effective discriminator.

(d) This question caused few problems for most students, with 79% obtaining at least one mark and 59% both marks. However, it proved to be a poor discriminator. Most students appreciated that the snow melting earlier, when the snowshoe hares still had their white coats, meant they were no longer camouflaged and therefore more easily spotted and killed by predators. Occasionally, the snow melting earlier was omitted from the answer. A more frequent occurrence was to suggest that the snowshoe hares were camouflaged from their prey which was not credited. Some students confused the use of the terms predator and prey. A significant minority of students attempted to explain the reduced survival rate of the hares in terms of temperature control, failing to appreciate that new fur replaces old fur. Some responses were vague, only referring to mutations and a lack of beneficial alleles.

(e) This question proved more difficult for students than (d) and was a far more effective discriminator. Only 11% of students gained the maximum four marks and 58% at least one mark. The best responses were often clear and concise explanations of how early moulting enabled the survival of snowshoe hares in their mountain habitats and included the use of appropriate scientific terminology. Weaker responses referred to genes rather than alleles and to 'more alleles' rather than to an increase in their frequency. Students who did not explain the survival of snowshoe hare populations in terms of 'earlier moulting' were unable to obtain more than two marks. Similarly to question (d), weaker answers attempted to explain survival in terms of maintaining a constant body temperature or confused the terms predator and prey.

9.

(a) It was disappointing to find that only one in four students obtained both marks for this question by correctly referring to the contraction of circular muscles and the relaxation of radial muscles. Almost 40% of students scored zero, often by writing the converse or by not naming the muscles involved. Other incorrect responses used terms such as constrict, expand, widen, lengthen, and shorten rather than contract or relax to describe muscle action. A number of students gained one mark by suggesting that both circular and radial muscles were contracting or relaxing. Weaker responses suggested that the iris contains rods or cones to trigger the response.

(b) This question proved to be a very effective discriminator. Most students, 74%, gained at least one mark, usually for stating that each cone is connected to a single neurone. Many of these students also realised that cones provide high visual acuity. Far fewer students, 14%, gained maximum marks as most students did not refer to cone cells sending separate (sets of) impulses to the brain. In some instances, the use of poor terminology, e.g. 'messages' or 'signals', prevented students accessing this mark. Despite being advised not to do so, some students provided details of colour vision.

(c) It was pleasing to find that approximately 45% of students obtained both marks in this calculation and that 37% gained one mark. Students in this latter group were able to calculate the area of the fovea, but not as a percentage of the area of the retina. Errors relating to the conversion of μm to mm were common. Students who used the value of π from their calculator rather than using 3.14 (as stated in the question) were not penalised.

(d) As with part (b), this question assessed an understanding of photoreceptors and similarly proved to be a very effective discriminator. However, only 65% of students gained at least one mark and only 10% gained maximum marks. One mark was most often gained for the knowledge that several rods are connected to a single bipolar neurone. A good proportion of these students then referred to rods providing high visual sensitivity for a second mark point. However, once more, the use of poor or incorrect terminology hindered many students. References to 'weak impulses' and 'stimuli combining' were common when students tried to explain how a threshold could be reached in a neurone. Better responses often referred to, or explained, spatial summation.

10. (a) Surprisingly, only 66% of students obtained at least one mark on this relatively straightforward recall question, which proved to be an excellent discriminator. Almost 41% of students obtained both marks. A significant number of students who scored zero referred to the refractory period, concentration/diffusion gradients, sodium ions and calcium ions in their responses, or referred to vesicles without any reference to acetylcholine/neurotransmitter. A common misconception among weaker responses was that sodium ion channels are only present in postsynaptic neurones.

(b) Again, it was surprising that only 63% of students gained at least one mark on this question. The expectation was that far more students would access MP 1, i.e. naming the type of summation as 'temporal'. There were numerous incorrect alternatives to temporal including spatial, multiple, excitatory, all-or-nothing and saltatory. The explanations provided for MP 2 often lacked detail, with many students simply stating that many impulses or action potentials are required to reach a threshold. Better responses included detail on how sufficient neurotransmitter, entry of sodium ions or increase in membrane potential was required to reach a threshold. Consequently, this question proved to be a very effective discriminator. Approximately 20% of students obtained both marks.

(c) Interestingly, there was almost an even split between students obtaining two, one or zero marks on this question. It also proved to be a very good discriminator. Although many students realised that antibodies prevented the binding of acetylcholine to the sarcolemma, far fewer referred to receptor/s to obtain MP 1. It was pleasing to note that, compared with responses on previous exam papers, fewer students used the term 'active site' to describe the receptor. Some students suggested that the antibodies block the sodium ion channels. The idea that less/no depolarisation or fewer/no action potentials would be produced was a far more accessible mark point. However, a significant number of students referred to weaker action potentials being generated, which was not credited.

(d) This question proved to be one of the most effective discriminators on the exam paper. Approximately 31% of students obtained maximum marks and approximately 57% at least two marks. As in question 07.3, many students did not mention receptor/s to access MP 2. Students often appreciated that the drug Mestinon would result in either less/no acetylcholine being broken down or that more acetylcholine would remain to gain MP 1. Many of these students also realised that this would lead to depolarisation or action potentials, to obtain MP 3. One in four students scored zero. Many of these responses thought that MG (Myasthenia gravis) were antibodies or other molecules, or that MG attached to antibodies.

11. It was surprising that only 13% of students obtained all three marks on part (a). Nevertheless, it proved to be an excellent discriminator. Approximately 59% of students obtained at least one mark, usually mark point 3, by referring to the (active) transport of sodium ions out of and (active) transport of potassium ions into the axon. However, a significant number of students incorrectly described the direction of transport of these ions or suggested that 2 sodium ions are transported out for every 3 potassium ions transported in. Another frequent misconception was to suggest that the sodium/potassium pump involved diffusion rather than active transport. The mark scheme enabled students to obtain full marks whether they based their explanations on the axon membrane being 'impermeable' or 'less permeable' to sodium ions (compared with potassium ions) in terms of diffusion. However, only a third of students obtained at least two marks as there was considerable confusion concerning the diffusion of ions through the axon membrane. It was not uncommon to find responses with ions diffusing in the wrong direction or contradictory statements within the same answer. Some students suggested that the axon membrane was impermeable to sodium and potassium ions.

Part (b) also had a very high discrimination index despite only 8% of students obtaining maximum marks. Relatively few students mentioned mark point 1, i.e. myelination provides (electrical) insulation. Several students, who did refer to insulation, suggested that myelin provided thermal insulation. Some of these students then suggested that the resulting higher temperature caused faster transmission of impulses in myelinated neurones. The most frequently credited mark related to using the term saltatory (conduction) to explain faster transmission in myelinated neurones. Students who attempted to explain this process often referred to 'impulses jumping from node to node' which was not credited. Better responses used the term depolarisation. Similarly, students who did not refer to depolarisation or action potential could not access mark point 3 when explaining slower transmission of impulses along a non-myelinated neurone. Nevertheless, this part of the question was an excellent discriminator and 73% obtained at least one mark and 36% two or more marks.

Part (c) was also a very good discriminator but not as effective as parts (a) and (b) on the same topic. Only 47% of students obtained at least one mark on part (c). There was considerable variation in the responses which were not awarded marks. Some students simply ignored the respiratory inhibitor and explained how depolarisation occurs or explained how an action potential is produced. A significant number of students suggested that the inhibitor would block or change the shape of channel/carrier proteins in the membrane. A few students explained how neurotransmitters could be inhibited in synapses. Students obtaining a single mark often did so by explaining that the inhibitor would reduce production of ATP. Unfortunately, weaker responses suggested that 'energy could not be produced'. Most students who mentioned the decrease in ATP gained another mark by explaining that this would affect the sodium/potassium pump. However, as with part (a), there was a significant number of students who incorrectly described the function of the pump. Only 8% of students obtained maximum marks by fully explaining how a resting potential of 0 mV is eventually produced. Very few students came close to accessing mark point 3. Students who did obtain this mark often referred to the same concentration of ions either side of the membrane or to no net movement of these ions.

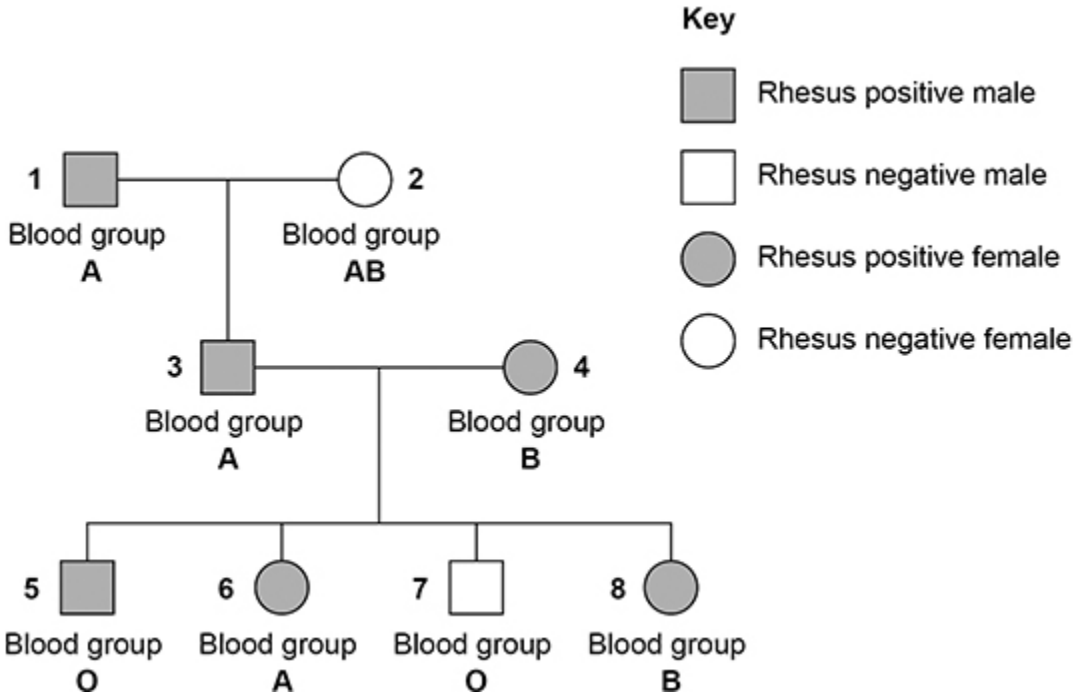
1. In humans, the ABO blood groups and Rhesus blood groups are under genetic control. The inheritance of the ABO blood groups is controlled by three alleles of a single gene, I^A, I^B and I^O. The alleles I^A and I^B are codominant, and the allele I^O is recessive to I^A and recessive to I^B.

There are four ABO phenotypes, **A**, **B**, **AB** and **O**.

The gene for the Rhesus blood groups has two alleles. The allele for Rhesus positive, **R**, is dominant to the allele for Rhesus negative, **r**.

The genes for the ABO and Rhesus blood groups are **not** sex-linked and are **not** on the same chromosome.

The diagram below shows the phenotypes in a family tree for the ABO and Rhesus blood groups.



(a) Give the genotypes of the ABO blood groups for individuals **1** and **2**.

Do **not** include the genotypes for the Rhesus blood groups in your answer.

1 _____

2 _____

(1)

(b) Explain **one** piece of evidence from the figure above that the allele for Rhesus positive is dominant.

_____

_____

_____

_____

_____

_____

(2)

(c) Calculate the probability of individuals **1** and **2** producing a Rhesus positive son with blood group **A** (individual **3**). You can assume that individual **1** is heterozygous for the Rhesus blood group.

Show your working.

Probability _____

(2)

Scientists determined the frequencies of the ABO alleles and ABO phenotypes in a large population. They then used a statistical test to determine if the frequencies of the four phenotypes differed significantly from the frequencies expected according to the Hardy–Weinberg equation.

(d) The frequencies of the I^A and I^O alleles were 0.15 and 0.65. What is the frequency of the I^B allele?

Frequency of I^B allele _____

(1)

(e) Name the statistical test you should use to determine if the observed frequencies of the four phenotypes differed significantly from the frequencies expected according to the Hardy–Weinberg equation.

State how many degrees of freedom should apply.

Statistical test _____

Number of degrees of freedom _____

(2)

(f) The scientists concluded that the observed frequencies of the four phenotypes differed significantly from the expected frequencies. Use your knowledge of the Hardy–Weinberg principle to suggest **two** reasons why.

1 _____

_____

_____

2 _____

_____

_____

(2)

(Total 10 marks)

2. Ecologists studied a stream community before and after a flood. The flood reduced animal populations in the stream by 98%.

The table shows how the populations of six animal species found in the stream changed following the flooding.

Animal species	**Number of days after flooding**						
	1	**5**	**13**	**22**	**35**	**49**	**63**
	Mean number of organisms / thousands m^{-3}						
Baetis quilleri	0.03	0.85	2.6	9.3	6.4	0.9	0.3
Leptohyphes packeri	0.0	0.0	0.25	2.5	17.3	18.0	29.5
Helicopsyche mexicana	0.0	0.02	0.2	0.1	0.07	0.03	0.01
Cryptolabis paradoxa	0.0	13.3	21.3	55.8	62.9	168.7	182.6
Pentaneurini guttipennis	0.1	0.5	0.6	1.8	1.0	0.6	0.25
Micropsectra klinki	0.0	0.0	0.0	0.0	0.0	0.2	5.6

(a) Explain how the data in the table provides evidence of succession.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(b) The populations of *Cryptolabis paradoxa* and *Leptohyphes packeri* both increased between days 13 and 63.

Calculate how many times the population growth per day of *Cryptolabis paradoxa* is greater than that of *Leptohyphes packeri* between these days.

Answer = _____

(2)

(c) The stream eventually recovered to reach a climax community.

Give **two** features of a climax community.

1. _____

_____

2. _____

_____

(2)

(Total 9 marks)

3. (a) On islands in the Caribbean, there are almost 150 species of lizards belonging to the genus *Anolis*. Scientists believe that these species evolved from two species found on mainland USA. Explain how the Caribbean species could have evolved.

(6)

(b) *Anolis sagrei* is a species of lizard that is found on some of the smallest Caribbean islands. Describe how you could use the mark-release-recapture method to estimate the number of *Anolis sagrei* on one of these islands.

(4)

(c) Large areas of tropical forest are still found on some Caribbean islands. The concentration of carbon dioxide in the air of these forests changes over a period of 24 hours and at different heights above ground.

Use your knowledge of photosynthesis and respiration to describe and explain how the concentration of carbon dioxide in the air changes:

- over a period of 24 hours
- at different heights above ground.

(5)

(Total 15 marks)

4. There are nine subspecies of giraffe. These subspecies evolved when populations of giraffe were separated for long time periods. Each subspecies has distinct coloured skin markings. Some biologists have suggested that up to six of these subspecies should be classified as different species.

(a) Explain how different subspecies of giraffe may have evolved from a common ancestor. Use information from the passage in your answer.

(5)

(b) Biologists compared the mitochondrial DNA of the different subspecies of giraffe. They used the results from comparing this DNA to conclude that six of the nine subspecies are separate species.

Suggest how they came to this conclusion.

(2)

(Total 7 marks)

5. (a) What term is used to describe populations of different species living in the same habitat?

(1)

(b) Different species occupy different ecological niches.

Explain the advantage of species occupying different niches.

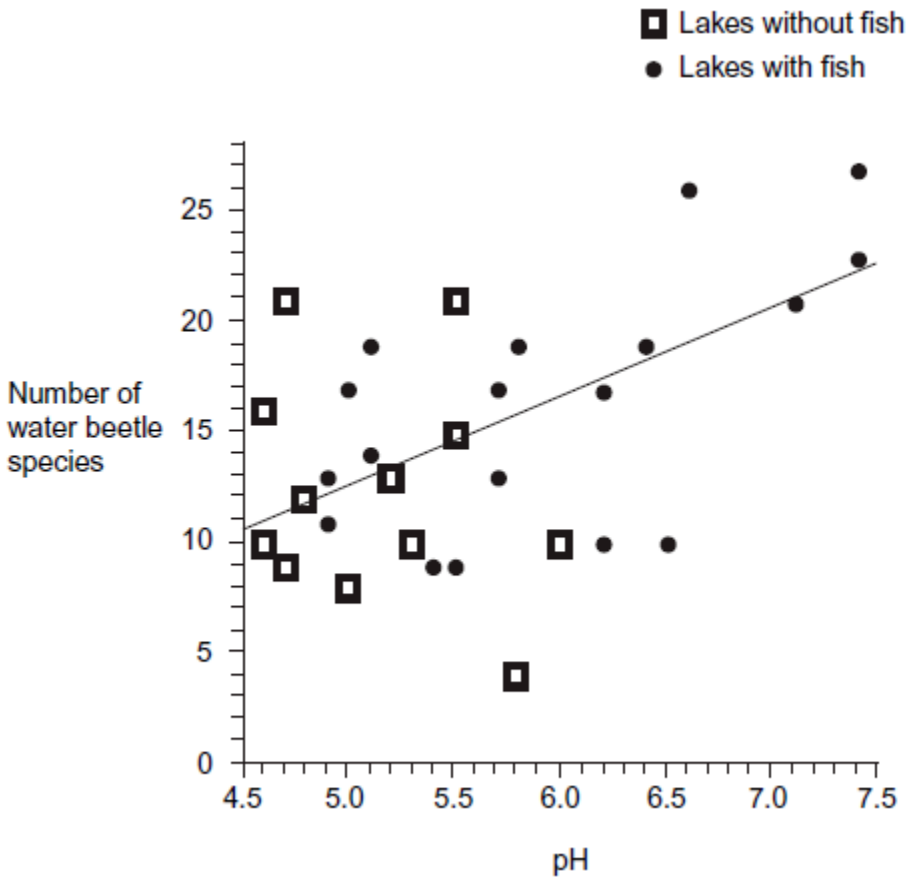
_____

_____

(1)

Scientists recorded the number of water beetle species in 30 lakes. In each lake, they measured the pH of the water and recorded whether there were any fish present.

The graph shows their results.



(c) A student concluded that a decrease in acidity caused an increase in the number of water beetle species.

Evaluate this conclusion.

(3)

(d) Explain how the presence of fish in a lake could cause an increase in the number of water beetle species.

(1)

(Total 6 marks)

6. In fruit flies, males have the sex chromosomes XY and the females have XX. In fruit flies, a gene for eye colour is carried on the X chromosome. The allele for red eyes, **R**, is dominant to the allele for white eyes, **r**.

(a) Male fruit flies are more likely than female fruit flies to have white eyes.

Explain why.

(2)

(b) A female fruit fly with white eyes was crossed with a male fruit fly with red eyes to produce a large number of offspring.

Tick (✓) **one** box next to the statement which correctly describes the phenotypes produced from this cross.

All offspring red-eyed ☐

All females red-eyed, all males white-eyed ☐

All males red-eyed, all females white-eyed ☐

All males white-eyed, females red-eyed and females white-eyed ☐

(1)

In fruit flies, the genes for body colour and for wing development are **not** on the sex chromosomes. The allele for grey body colour, **G**, is dominant to the allele for black body colour, **g**. The allele for long wings, **L**, is dominant to the allele for short wings, **l**.

A geneticist carried out a cross between fruit flies with grey bodies and long wings (heterozygous for both genes) and fruit flies with black bodies and short wings.

The table below shows the results of this cross.

Phenotype of offspring	**Number of offspring**
Grey body **and** long wings	223
Black body **and** short wings	218

(c) Explain the results in the table above.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(d) The **first** generation of a population of fruit flies had 50 females.

Calculate how many female fruit flies would be produced from this population in the **fifth** generation.

You can assume:

- each female produces 400 offspring each generation
- half the offspring produced each generation are female
- there is no immigration or emigration
- no flies die before reproducing.

Show your working.

Give your answer in standard form.

Answer _____

(3)

(Total 9 marks)

7. (a) In fruit flies, the genes for body colour and wing length are linked. Explain what this means.

_____

_____

(1)

A scientist investigated linkage between the genes for body colour and wing length.
He carried out crosses between fruit flies with grey bodies and long wings and fruit flies with black bodies and short wings.

Figure 1 shows his crosses and the results.

- **G** represents the dominant allele for grey body and **g** represents the recessive allele for black body.
- **N** represents the dominant allele for long wings and **n** represents the recessive allele for short wings.

Figure 1

Phenotype of parents	grey body, long wings	×	black body, short wings
Genotype of parents	**GGNN**		**ggnn**
Genotype of offspring	**GgNn**		
Phenotype of offspring	all grey body, long wings		

These offspring were crossed with flies homozygous for black body and short wings.

The scientist's results are shown in **Figure 2**.

Figure 2

GgNn crossed with **ggnn**

	Grey body, long wings	**Black body, short wings**	**Grey body, short wings**	**Black body, long wings**
Number of offspring	975	963	186	194

(b) Use your knowledge of gene linkage to explain these results.

(4)

(c) If these genes were **not** linked, what ratio of phenotypes would the scientist have expected to obtain in the offspring?

(1)

(d) Which statistical test could the scientist use to determine whether his observed results were significantly different from the expected results?

Give the reason for your choice of statistical test.

(2)

(Total 8 marks)

8. Read the following passage.

Lake Malawi in East Africa has more species of fish than any other lake in the world. Many of these species have evolved from a common ancestor. Lake Malawi is one of the largest lakes in the world and was formed several million years ago. Since then, the water level has fluctuated greatly. As a result, what is now a large lake was at one time many smaller, separate lakes.

The country of Malawi has a total area of 118 000 km^2. The actual land area is only 94 080 km^2, because approximately one-fifth of the country is Lake Malawi.

In December 1990, forests covered 41.4% of the actual land area of Malawi.
In December 2016, forests covered 26.4% of the actual land area of Malawi.

Deforestation and farming along the shores of Lake Malawi have caused increased soil erosion and loss of nutrients into the lake. This has resulted in a decrease in some fish populations. The mark-release-recapture method can be used to estimate the size of a fish population. However, this method can produce unreliable results in very large lakes.

Use the information in the passage and your own knowledge to answer the following questions.

(a) Lake Malawi in East Africa has more species of fish than any other lake in the world (line 1).

Suggest and explain how this speciation may have occurred.

(4)

(b) The percentage of forest cover in Malawi decreased between December 1990 and December 2016 (lines 9–10).

Calculate the mean loss of forest cover in km^2 per week during this time period.

Answer _____ km^2 per week

(2)

(c) Loss of nutrients **into** Lake Malawi has resulted in a decrease in some fish populations (lines 12–13).

Explain why.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(d) The mark-release-recapture method can be used to estimate the size of a fish population (lines 13–14).

Explain how.

(4)

(e) Suggest why the mark-release-recapture method can produce unreliable results in very large lakes (lines 14–15).

(1)

(Total 15 marks)

9. (a) Mutation is one cause of genetic variation in organisms.

Give **two** other causes of genetic variation.

1 _____

_____

2 _____

_____

(2)

In a species of flowering plant, the **T** allele for tallness is dominant to the **t** allele for dwarfness. In the same species, two alleles $\mathbf{C^R}$ (red) and $\mathbf{C^W}$ (white) code for the colour of flowers. When homozygous red-flowered plants were crossed with homozygous white-flowered plants, all the offspring had pink flowers.

(b) Name the relationship between the two alleles that code for flower colour.

_____

(1)

(c) A dwarf, pink-flowered plant was crossed with a heterozygous tall, white-flowered plant.

Complete the genetic diagram to show all the possible genotypes and the ratio of phenotypes expected in the offspring of this cross.

Phenotypes of parents:	Dwarf, pink-flowered	×	Tall, white-flowered
Genotypes of parents:	_____		_____

Genotypes of offspring: _____

Phenotypes of offspring: _____

_____

Ratio of phenotypes: _____

(3)

(d) A population of this species of plant contained 9% of red-flowered plants.

Use the Hardy–Weinberg equation to calculate the percentage of pink-flowered plants in this population.

Show your working.

Answer _____ %

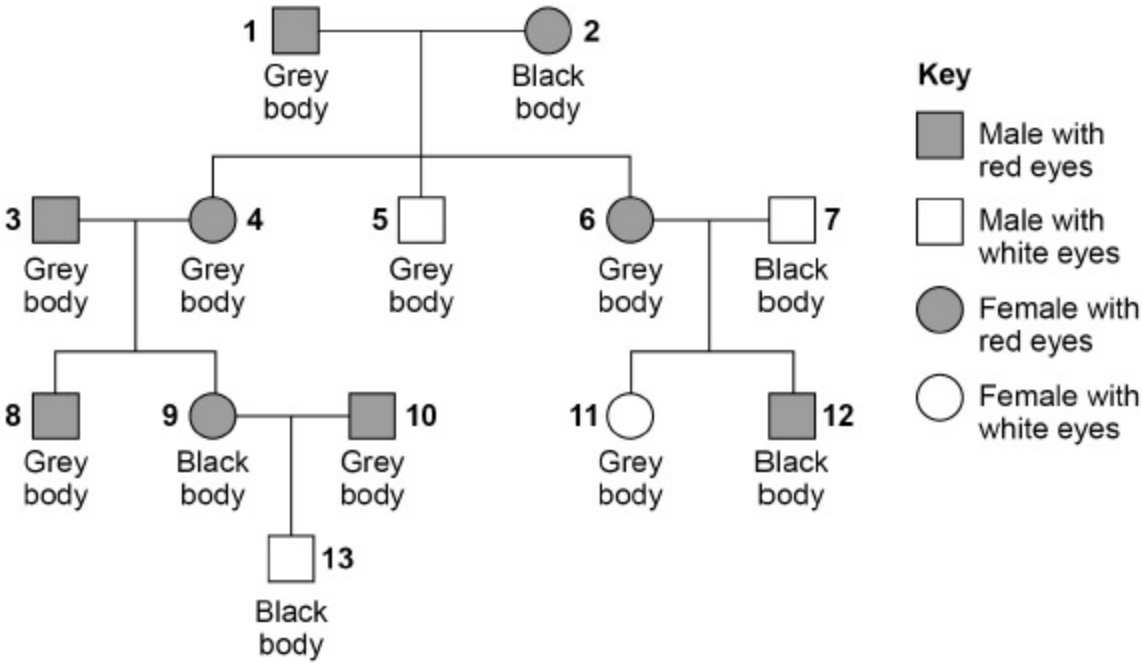
(2)

(Total 8 marks)

10. In fruit flies, a gene for body colour has a dominant allele for grey body, **G**, and a recessive allele for black body, **g**.

A gene for eye colour has a dominant allele for red eyes, **R**, and a recessive allele for white eyes, **r**, and is located on the **X chromosome**.

The diagram shows the phenotypes of fruit flies over four generations.



(a) Give the full genotype of the fly numbered **6** in the diagram.

Genotype = _____

(1)

(b) Give **one** piece of evidence from the diagram above to show that the allele for grey body colour is dominant.

_____

_____

_____

_____

(1)

(c) Explain one piece of evidence from the diagram above to show that the gene for body colour is **not** on the **X chromosome**.

_____

_____

_____

_____

_____

_____

(2)

(d) A heterozygous grey-bodied, white-eyed female fly was crossed with a black-bodied, red-eyed male fly.

Complete the genetic diagram below to show all the possible genotypes and the ratio of phenotypes expected in the offspring from this cross.

Phenotypes of parents: Grey-bodied, white-eyed female × Black-bodied, red-eyed male

Genotypes of parents: _____ × _____

Genotypes of offspring _____

Phenotypes of offspring _____

_____

_____

Ratio of phenotypes _____

(3)

(e) A population of fruit flies contained 64% grey-bodied flies. Use the Hardy–Weinberg equation to calculate the percentage of flies heterozygous for gene **G**.

Answer = _____%

(2)

(Total 9 marks)

11. (a) What is meant by the term phenotype?

_____

_____

_____

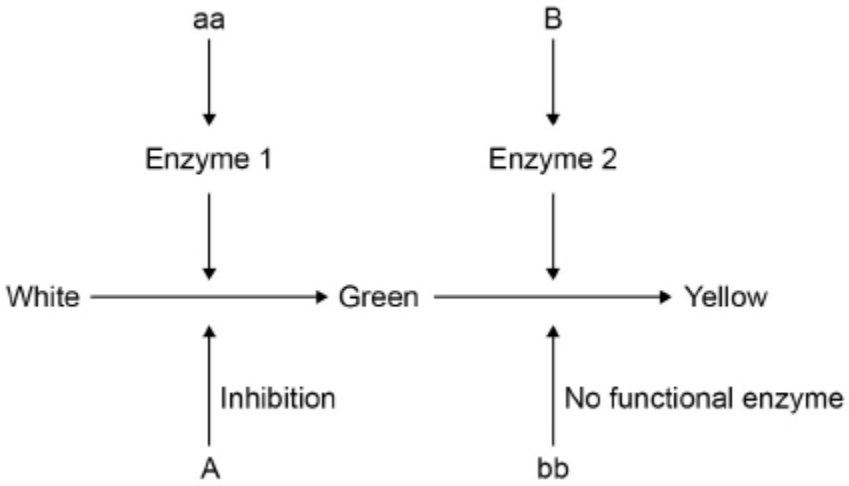
_____

_____

(2)

(b) The inheritance of fruit colour in summer squash plants is controlled by two genes, **A** and **B**. Each gene has two alleles.

The diagram shows the interaction of these two genes in controlling fruit colour in summer squash plants.



Name the type of gene interaction shown in the diagram above.

_____

(1)

(c) What fruit colour would you expect the following genotypes to have?

AAbb _____

aaBB _____

(1)

(d) Genes **A** and **B** are not linked.

Complete the genetic diagram to show all the possible genotypes and the ratio of phenotypes expected in the offspring of this cross.

Genotypes of parents **aabb** × **AaBb**

Genotypes of offspring _____

Phenotypes of offspring _____

Ratio of phenotypes _____

(3)

(e) A population of summer squash plants produced only green and yellow fruit. The percentage of plants producing yellow fruit in this population was 36%.

Use the Hardy−Weinberg equation to calculate the percentage of plants that were heterozygous for gene **B**.

Answer = _____ %

(2)

(Total 9 marks)

1.

(a) (1) I^AI^O **and** (2) I^AI^B;

*Accept I^OI^A for (1) **and** I^BI^A for (2).*

*Accept AO or OA for (1) **and** AB or BA for (2).*

Accept lower case for A, B and O.

1

(b) 1. Rhesus positive parents produce 7/Rhesus negative child

OR

3 and 4 produce 7/Rhesus negative child

OR

Two Rhesus positive produce 7/Rhesus negative child;;

Reject if incorrect evidence and correct evidence provided.

Accept Rhesus positive parents produce Rhesus positive and Rhesus negative child.

Accept 'affected' for Rhesus positive and 'unaffected' for Rhesus negative.

2. Both Rhesus positive/3 and 4 carry recessive <u>allele</u>

OR

Both Rhesus positive/3 and 4 are heterozygous/carriers

OR

If Rhesus positive was recessive, all children (of 3 and 4) would be Rhesus positive / have recessive (phenotype);

Reject if incorrect explanation and correct explanation provided.

Accept 'affected' for Rhesus positive and 'unaffected' for Rhesus negative.

2

(c) Correct answer of 0.125 / $^1/_8$ / 12.5% = **2 marks**;;

Incorrect answer of 0.25 / $^1/_4$ / 25% = **1 mark**;

Accept 1 in 8 for 2 marks or accept 1 in 4 for 1 mark.

Accept equivalent raw fractions e.g., $^2/_{16}$ for 2 marks or $^4/_{16}$ for 1 mark.

Accept 12.5 for 1 mark.

2

(d) 0.2

OR

0.20;

1

(e) 1. Chi-squared;

2. 3;

Accept χ^2 or Chi^2

2

(f) 1. Selection (against/for a blood group/phenotype/allele);

2. (High rate of) mutation;

3. Immigration/emigration;

Accept 'migration' or population is not isolated.

4. No random mating.

Ignore no 'random fertilisation'.

Reject converse statements as context would be incorrect

Ignore births/deaths.

2 max

[10]

2. (a) 1. (Overall, data show an) increase in species richness / increase in species diversity / increase in total number of living organisms;

2. *Baetis quilleri* and / or *Pentaneurini guttipennis* are pioneers;

3. (Pioneers cause) named change of environment e.g. provide food for other species;

4. New species / example from data colonise once there is a change;

5. *Baetis quilleri* / *Pentaneurini guttipennis* / *Helicopsyche mexicana* decline / outcompeted / eaten as succession continues.

5

(b) Correct answer 5.5 = 2 marks;

Allow 1 mark for correct calculation of mean population growth rate per day for each species, i.e:

Cryptolabis paradoxa = 3.226

Leptohyphes packeri = 0.585

2

(c) 1. Same species present (over long time) / stable community (over long time);

2. Abiotic factors (more or less) constant (over time)

3. Populations stable (around carrying capacity)

2 max

[9]

3.

(a) 1. Geographic(al) isolation;

2. Separate gene pools / no interbreeding / gene flow (between populations);

Accept: reproductive isolation

This mark should only be awarded in context of during the process of speciation. Do not credit if context is after speciation has occurred.

3. Variation due to mutation;
4. Different selection pressures / different abiotic / biotic conditions / environments / habitats;

Neutral: different conditions / climates if not qualified

Accept: named abiotic / biotic conditions

5. Different(ial) reproductive success / selected organisms (survive and) reproduce;

Accept: pass on alleles / genes to next generation as equivalent to reproduce

6. Leads to change / increase in allele frequency.

Accept: increase in proportion / percentage as equivalent to frequency

6

(b) 1. Capture / collect sample, mark and release;
2. Method of marking does not harm lizard / make it more visible to predators;
3. Leave sufficient time for lizards to (randomly) distribute (on island) before collecting a second sample;
4. (Population =) number in first sample × number in second sample divided by number of marked lizards in second sample / number recaptured.

4

(c) 1. High concentration of / increase in carbon dioxide linked with respiration at night / in darkness;
2. No photosynthesis in dark / night / photosynthesis only in light / day;

Neutral: less photosynthesis

3. In light net uptake of carbon dioxide / use more carbon dioxide than produced / (rate of) photosynthesis greater than rate of respiration;
4. Decrease in carbon dioxide concentration with height;

More carbon dioxide absorbed higher up

Accept: less carbon dioxide higher up / more carbon dioxide lower down

5. (At ground level)
less photosynthesis / less photosynthesising tissue / more respiration / more micro-organisms / micro-organisms produce carbon dioxide.

Neutral: less leaves unqualified or reference to animals

5

[15]

4.

(a) 1. No interbreeding / gene pools are separate / geographic(al) isolation;

Accept: reproductive isolation as an alternative to no interbreeding.

2. Mutation linked to (different) markings/colours;
3. Selection/survival linked to (different) markings/colours;
4. Adapted organisms breed / differential reproductive success;

Note: 'passed on to offspring' on its own is not sufficient for reproduction.

5. Change/increase in allele frequency/frequencies;

5

(b) 1. (Compare DNA) base sequence / base pairing / (DNA) hybridisation;

Ignore: compare chromosomes / 'genetic make-up'.

Accept: (compare) genes / introns / exons.

*Note: reference to **only** comparing alleles is 1 max.*

2. Different in six (species) /different in different species / similar in three (subspecies) /similar in same species/subspecies;

Ignore: compare chromosomes / 'genetic make-up'.

Reject: '<u>same</u> alleles/ <u>same</u> DNA bases in three species/subspecies'.

Note: mark point 2 can be awarded without mark point 1.

2

[7]

5.

(a) Community;

1

(b) (Less) competition for food/resource;

Ignore: competition for niche/habitat.

Accept: space/named resource.

Reject: intraspecific competition.

1

(c) 1. <u>Correlation</u> **but** does not mean a causal effect;

Ignore: positive/ negative (correlation).

2. Other abiotic/biotic/named factor involved;

Accept: due to presence/absence of fish.

Reject: 'other factors' unless further qualified.

3. Variation in numbers of beetles species at same/similar particular pH;

Accept: same number of beetles at different pHs.

Accept: 'scattered results' / 'anomalies' / 'spread of results'.

4. Large sample;

Max 3

(d) Fish feed on predator/consumer of water beetle;

Accept: beetles feed on fish/faeces.

1

[6]

6.

(a) 1. Males have one allele;

Accept males only need one allele.

2. Females need two recessive alleles

OR

Females must be homozygous recessive

OR

Females could have dominant and recessive alleles

OR

Females could be heterozygous/carriers;

Ignore references to X and Y chromosomes.

Accept r as recessive allele and R as dominant allele.

*If no reference to allele, accept for **one mark** male needs one recessive gene whereas females need two recessive genes.*

2

(b) 1. Box 2.

All females red-eyed, all males white-eyed.

Reject if more than one box with tick. Ignore crossed-out ticks.

1

(c) 1. The (two) genes are linked

OR

Autosomal linkage;

Accept that the genes are on the same chromosome.

Accept 'Alleles are linked' (accept symbols for alleles) but reject if context suggests alleles of the 'same gene'.

2. No crossing over (occurs)

OR

(Linked) genes are close together;

Accept crossing over less likely to occur.

3. No Gl and no gL (gametes produced)

OR

No Ggll and no ggLl (offspring produced)

OR

Only GL and gl (gametes produced);

Ignore reference to independent assortment.

3

(d) 1. Correct answer of 8×10^{10} **= 3 marks**;;;

2. Correct answer **not** in standard form = **2 marks**

OR

1.6×10^{13} = **2 mark**

OR

1.6×10^{11} = **2 mark**

OR

6.4×10^{11} = **2 mark**

OR

Shows 8×10^{10} in the working **= 2 marks;;**

3. 1.28×10^{12} = **1mark**

OR

3.2×10^{11} = **1 mark**

OR

8×10^{11} = 1 **mark**

OR

8×10^{9} = 1 **mark**

OR

Shows 1.6×10^{11} in the working = **1 mark**

OR

Shows 200^4 in the working = **1 mark**;

*If no other mark is credited accept for **one mark** working which shows multiplication by 200 for 4 generations. This could be shown in a variety of ways e.g. multiplied by 400 divided by 2 for 4 generations.*

3

[9]

7. (a) (Genes / loci) on same chromosome.

1

(b) 1. GN and gn linked;
2. GgNn individual produces mainly GN and gn gametes;
3. Crossing over produces some / few Gn and gN gametes;
4. So few(er) Ggnn and ggNn individuals.

4

(c) (Grey long:grey short:black long:black short) =1:1:1:1

1

(d) 1. Chi squared test;
2. Categorical data.

2

[8]

8.

(a) 1. Variation/differences due to mutation/s;

2. (Reference to) allopatric (speciation);
Ignore sympatric speciation.

3. Smaller/different lakes have different environmental conditions

OR

Smaller/different lakes have different selection pressures;
Accept different populations for different lakes.

4. Reproductive separation/isolation

OR

No gene flow

OR

Gene pools remain separate;

5. Different alleles passed on/selected

OR

Change in frequency of allele/s;

6. Eventually different species/populations cannot breed to produce fertile offspring;

4 max

(b) 1. Correct answer of 10/10.4 **= 2 marks**;;
Ignore any numbers after 10.4

2. Working shows 14,112 = **1 mark**

OR

13.09/13.1 = **1 mark**;

2

(c) 1. (Growth/increase of) algae/surface plants/algal bloom blocks light;

2. Reduced/no photosynthesis so (submerged) plants die;

3. Saprobiotic (microorganisms) aerobically respire

OR

Saprobiotic (microorganisms) use oxygen in respiration;

Accept: Saprobiont/saprophyte/ saprotroph

Neutral: decomposer

4. Less oxygen for fish to respire;

4

(d) 1. Capture/collect sample, mark and release;

2. Ensure marking is not harmful (to fish)

OR

Ensure marking does not affect survival (of fish);

Accept examples e.g., marking should not be toxic.

3. Allow (time for) fish to (randomly) distribute before collecting a second sample;

4. (Population =) number in first sample × number in second sample divided by number of marked fish in second sample/number recaptured;

4

(e) 1. Less chance of recapturing fish

OR

Unlikely fish distribute randomly/evenly;

Accept 'harder to capture marked fish' (recaptured fish) but ignore 'harder to capture fish'.

Accept that fish may remain in one area.

Accept fish may congregate.

1

[15]

9.

(a) 1. Crossing over;

2. Independent segregation/assortment (of homologous chromosomes);

Accept independent assortment of alleles.

Accept meiosis as an alternative for 1 or 2 if neither of these marks is awarded.

3. Random fusion of gametes

OR

Random fertilisation;

Accept random mating.

2 max

(b) Codominance;

Accept incomplete dominance

1

(c) 1. ttC^RC^W **and** TtC^WC^W;

2. TtC^RC^W, TtC^WC^W, ttC^RC^W **and** ttC^WC^W ;

3. Tall pink, tall white, dwarf pink, dwarf white, **and** ratio 1 : 1 : 1 : 1;

Accept: any order of genotypes and phenotypes and ignore if on incorrect answer lines.

Accept: sequence of phenotypes does not need to mirror genotypes but must be correct.

Accept equivalent ratios e.g. 4:4:4:4.

Allow equivalent of mark points 2 and 3 for cross using homozygous tall parent i.e. TTC^WC^W.

*Allow **one mark** for correct dihybrid genotypes of offspring from incorrect parental genotypes.*

3

(d) 1. Correct answer of 42% = **2 marks**;;

Accept: 0.42 for 1 mark.

2. Incorrect answer but shows understanding that 2pq = pink/heterozygous/carriers = **1 mark**

OR

Answer = 0.42 = **1 mark OR**

Answer = 16.38 / 16.4 = **1 mark**;

Accept $1 – (p^2 + q^2)$ for 2pq or equivalent using numbers.

Accept: understanding of 2pq by using a calculation involving 2 × two different numbers.

2

[8]

10. (a) GgX^RX^r ;

Accept alleles in any order.

Accept GgRr with alleles in any order.

1

(b) If it were recessive all flies of 3 and 4 would be grey
OR
3 and 4 produce 9/black (fly)
OR
Grey parents produce black (fly);

1

(c)

***Mark in pairs** 1 and 2 or 3 and 4.*

1. (Fly) 3 (and 4) produce 9/black (fly)
OR
(Fly) 9 would not be black
OR
(Fly) 9 would be grey
OR
Grey parents/male produce black female (fly);

2. (Fly) 3 would pass dominant allele to 9;

Accept allele for grey colour would be passed on by 3.

3. (Fly) 2 (and 1) produce 5/grey (fly)
OR
Black **female** produces grey **male**
OR
(Fly) 5 could not be grey
OR
(Fly) 5 would be black;

4.(Fly) 5 would receive recessive allele from 2;

Accept allele for black colour would be passed on by 2.

2 max

(d) 1. GgX^rX^r **and** ggX^RY;

Accept the following alternative notations for sex-linked crosses e.g. for mp 1

Ggrr and ggRY or

Ggrr and gg R- or

Ggrr and ggR

i.e. space for Y chromosome.

2. GgX^RX^r, ggX^RX^r, GgX^rY **and** ggX^rY;

Accept any order of genotypes and phenotypes.

Accept the following alternative notations for sex-linked crosses e.g. for mp 1

Ggrr and ggRY or

Ggrr and gg R- or

Ggrr and ggR

i.e. space for Y chromosome.

3. Grey-bodied red-eyed female, black-bodied

red-eyed female, grey-bodied white-eyed

male, black-bodied white-eyed male **and** ratio

1 : 1 : 1 : 1;

Accept any order of genotypes and phenotypes.

Accept sequence of phenotypes does not need to mirror genotypes but must be correct.

Accept alternative ratios in correct proportions e.g. 4:4:4:4

If 1, 2 and 3 incorrect **allow one mark** for correct gametes from incorrect dihybrid parental genotypes.

3

(e) 1. Correct answer of 48% = **2 marks**;;

Accept 0.48 for 1 mark.

2. Incorrect answer but shows understanding that

2pq = heterozygous/carriers = **1 mark**
OR
Incorrect answer but shows understanding that

$1 – (p^2 + q^2)$ = heterozygous/carriers = **1 mark**;

Accept understanding of 2pq by using a calculation involving 2 x two different numbers.

2

[9]

11.

(a) 1. (Expression / appearance / characteristic due to) genetic constitution / genotype / allele(s);

2. (Expression / appearance / characteristic due to) environment;

1. Accept: named characteristic.

1. Accept: homozygous / heterozygous / genes / DNA.

1. Ignore: chromosomes.

2

(b) Epistasis

OR

Epistatic (interaction / control);

Accept: phonetic spellings.

Ignore: preceding word e.g. (recessive / dominant) epistasis.

1

(c) **AAbb** – white

aaBB – yellow;

Both correct for one mark.

1

(d) 1. AaBb, Aabb, aaBb, aabb;

2. White, (white), yellow, green;

3. 2 : 1 : 1;

Note: If genotypes are incorrect = zero marks.

1. Accept: equivalent genotypes e.g. ABab for AaBb.

Accept: sequence of phenotypes does not need to mirror genotypes but must be correct.

*3. Accept: ratios of 2:1:1 or 1:2:1 or 1:1:2 even if sequence of phenotypes do not match if mark points 1 **and** 2 have been awarded.*

3. Accept: alternative ratios in correct proportions e.g. 4:2:2

3. Ignore: percentages / fractions.

3

(e) 1. Correct answer of 32% = **2 marks**;

2. Incorrect answer but shows understanding that 2pq = heterozygous / carriers = 1 mark;

Accept: understanding of 2pq by using a calculation involving 2 × two different numbers.

2

[9]

Examiner reports

1.

(a) Approximately 54% of students gave the correct genotypes of the ABO blood groups for individuals 1 and 2. The most common error was to show the genotype of individual 1 as I^AI^A or to show this genotype and the correct genotype. Despite information to the contrary in the stem of the question, some students showed the alleles on the sex chromosomes. A few students included the genotypes for the Rhesus blood groups in their answer, which was ignored.

(b) Despite 62% of students failing to obtain at least one of the two marks available, this question was a reasonably good discriminator. Students failing to gain credit often used individuals 1, 2 and 3 as their source of evidence. These students also displayed a lack of understanding of a pedigree diagram by suggesting that individuals 3 and 4 were offspring from individuals 1 and 2. Students obtaining a single mark usually correctly referred to individuals 3, 4 and 7 as their source of evidence, but then suggested that only one of 3 and 4 was heterozygous. Approximately one in four students obtained both marks. Most of these students obtained their second mark by stating that both 3 and 4 would be heterozygous or would have the recessive allele. Very few students provided the alternative response that all the children of 3 and 4 would be Rhesus positive if the Rhesus positive allele was recessive.

(c) Again, despite 39% of students failing to obtain a mark, this question was a reasonably good discriminator. Almost 23% of students gained two marks, usually by expressing the probability value as 0.125 or 12.5%. The 38% of students who obtained one mark, often for expressing the probability as 25%, had not included the probability of a male offspring being produced. The most frequent incorrect answer gaining no marks was 50%. This was usually due to students only calculating the probability of individuals 1 and 2 producing a child with blood group A.

(d) Approximately 82% of students correctly determined the frequency of the I^B allele to be 0.2. The most frequent incorrect response was 0.02.

(e) Approximately 88% of students obtained at least one mark, invariably by correctly naming the chi-squared test. Nevertheless, this two-mark question proved to be a reasonably good discriminator. Incorrectly named statistical tests included the Student's t-test, Spearman rank, Mann-Whitney and Wilcoxon. There was considerable variation in the range of responses for the number of degrees of freedom. The most frequent incorrect answers were 2, 4, 5 and 0.05. Approximately 44% of students obtained both marks.

(f) In terms of accessibility, this question caused problems for many students. Almost 12% of students did not provide a response, the highest percentage on this paper. Only 9% of students obtained both marks and almost four out of five students scored zero. The most common incorrect responses included crossing over, linked genes, codominance, independent segregation/assortment, and random fertilisation/fusion of gametes. A significant number of students suggested that the population was small even though it was stated in the stem of the question that the population was large. Some students provided the converse of the points in the mark scheme which meant their responses were in the incorrect context. Correct responses usually referred to one or more of the following taking place: mutation, immigration/emigration and, to a lesser extent, selection. The idea of no random mating occurring was rarely seen.

3.

(a) This question proved to be a very effective discriminator despite similar questions on speciation occurring previously in this component. The vast majority of students obtained the mark for geographical isolation / separation. However, many students only referred to the lack of interbreeding after the new species had been formed rather than during the process of speciation. These responses did not obtain the equivalent mark point. Variation and mutation were not always linked or one of these was omitted. Mutations were occasionally caused by the environment or by variation. Different selection pressures were well known although sometimes there were vague references to 'different conditions' or 'different climates'. Most students understood that differential reproductive success resulted in a change in allele frequency although weaker students referred to 'alleles reproducing'. Less than five percent of students managed to miss every marking point, sometimes after writing a whole page in response. These answers often described succession or directional selection.

(b) As expected this question was very well answered with over seventy percent of students obtaining three out of the four marks available and just over a third obtaining maximum marks. Although there was some variation in which marking points were omitted, a significant number of students did not mention leaving time for lizards to distribute randomly in the population before obtaining a second sample. Other common errors included omitting any reference to releasing the lizards after they were initially captured and / or providing an incorrect equation for calculating the final population. Most students appreciated that the method of marking the lizards should not cause harm or make them conspicuous to predators.

(c) This was another question which proved to be a good discriminator and provided a good spread of marks. There were some excellent answers with these students providing a detailed account of the relative effects of photosynthesis and respiration on the concentration of carbon dioxide in a forest over a period of 24 hours and at different heights above the ground. These answers included reference to the greater rate of photosynthesis than respiration during the day, a concept that was not found in the vast majority of scripts. At the other end of the range ability, students often only gained credit for linking an increase in concentration of carbon dioxide at night to respiration. Better answers did refer to 'no photosynthesis' at night for a second mark but a surprising number of students referred to 'less photosynthesis' at night, suggesting that it was still occurring. The information about heights above ground tended to be less clear and often failed to include more or less (respiration or photosynthesis). A surprising number of students suggested there was a greater carbon dioxide concentration higher up linked with more photosynthesis, despite previously giving correct descriptions of carbon dioxide uptake for photosynthesis and its release from respiration and gaining some of the earlier marking points. References to microorganisms were rare. A minority of answers described and explained changes in oxygen levels. Some students believed that the light-independent reaction could occur at night. A few responses described carbon dioxide levels in the upper layers of the atmosphere (troposphere, stratosphere).

4.

(a) This question proved to be a very effective discriminator. 60% of students were able to obtain at least three marks often by reciting the basic principles of speciation. The marks most frequently credited referred to geographical isolation, differential reproductive success and change in allele frequency. Many of these students failed to gain further credit as they did not use the specific information provided on the coloured skin markings. Better answers applied this information, outlining that mutations could result in particular skin colourations and selection for these giraffes could eventually lead to speciation. Consequently, only 10% of students achieved maximum marks.

(b) One in every three students obtained both marks. These students provided clear explanations on how the mitochondrial DNA of different giraffes could be compared to determine if they were the same species. The most frequently used method was to compare DNA base sequences. Students obtaining a single mark often failed to outline specifically how they would compare mitochondrial DNA. However, these students gained credit for stating that the DNA of different species of giraffes would have more differences than would subspecies.

5.

(a) Almost 95% of students gave community as the correct answer. Ecosystem was the most common incorrect response.

(b) The vast majority of students appreciated that competition would be reduced. However, only 60% referred to competition for a resource or named resource. A minority of students incorrectly referred to intraspecific competition.

(c) Surprisingly, almost 25% of students did not obtain a mark on this question and less than 10% obtained maximum marks. Many students gained one mark for stating that correlation does not mean causation. Students often realised that another factor was involved, but did not always specify a factor. When factors were identified, temperature, fish or food sources were frequent responses. A significant number of students referred to the wide spread of results at the same pH. Fewer students referred to the sample size and when they did, the sample size of 30 was often considered to be too small.

(d) Almost 60% of students provided a correct answer, most frequently in relation to fish feeding on the predators of water beetles. Beetles feeding on fish or on their faeces was also frequently awarded as was fish eating competitors of the water beetles. The most common misconception related to fish respiring and adding carbon dioxide to the water and benefiting water beetle species.

6.

52% of students obtained both marks for (a), often providing very clear and concise explanations in terms of males requiring only one recessive allele whereas females needed two. Almost 23% of students obtained one mark. These students often explained why males were likely to have white eyes but did not provide enough detail concerning females. One mark was also awarded to students who used the term gene rather than allele but provided a full explanation for males and females. Students failing to gain credit often omitted any reference to allele or gene and limited their explanation to the sex chromosomes. A number of responses referred to an X allele rather than an X chromosome or suggested that the allele was on the Y chromosome.

Approximately 73% of students obtained the mark for (b) by correctly identifying the results of a sex-linked cross.

Despite only 26% of students obtaining at least one mark and only 1% all three marks, (c) proved to be an effective discriminator. As with previous questions involving linkage, most students had difficulty explaining the results in the table. Many students simply explained the results in terms of a dihybrid cross involving dominant and recessive alleles, omitting to explain why a 1:1 ratio rather than a 1:1:1:1 ratio was produced. Some students suggested epistasis was involved or provided a list of possible reasons including independent segregation, mutation and linkage. Some students, who did attempt to explain why particular phenotypes did not appear in the results, suggested lethal combinations, differential reproduction, adaptation to the environment and random fertilisation. Only 9% of the students who obtained a mark for referring to linkage then obtained a mark for suggesting that no crossing over had occurred. Students who could then outline which gametes/genotypes were or were not produced for a third marking point were a rarity.

46% of students provided a correct answer in (d) to obtain all three marks. Approximately one in four students obtained two marks and 80% of students obtained at least one mark. Common errors preventing students obtaining all three marks included using five generations or including males and females in the answer or the calculation. There was no evidence of students providing a correct answer which was not in standard form.

8.

Part (a) was also an excellent discriminator even though almost a third of students failed to obtain a mark. Despite part (a) asking about speciation, a significant number of these students attempted to answer in terms of succession. Students who used the information in the passage often stated that populations of fish would become geographically isolated but did not necessarily mention allopatric speciation, mark point 2. However, most of these students obtained mark point 4, stating that reproductive isolation would occur. Many of these students also obtained mark point 6, i.e. different species cannot breed to produce fertile offspring. Weaker responses often omitted ‘fertile offspring’. The 31% of students who obtained three or four marks did so in a variety of ways. Many did refer to a change in the frequency of alleles and to variation caused by mutations. However, it was not uncommon for students to refer to mutation without mentioning variation or to refer to genes rather than alleles. Similarly, a significant number of students mentioned different selection pressures or environmental conditions but not in the context of smaller/different lakes. It was evident that these students had not used the information in the passage and simply provided an explanation of speciation. This also led to several accounts of sympatric speciation. These students limited their explanations to speciation in a large lake. Although reference to the term ‘sympatric’ was not credited, these explanations could access most of the marking points and obtain maximum marks. Almost 12% of students obtained maximum marks on this part.

45% of students obtained both marks and 22% one mark for (b). A variety of successful methods were used to obtain two marks. Some immediately determined 15% of land area, while others approached it by determining 41.4% and 26.4% of land area and then obtaining the difference. Most students obtaining a single mark did so by showing 11 412 in their working. However, some students gained a single mark for performing a correct calculation using the total area of the country of Malawi (118 000 km^2) rather than the actual land area (94 080 km^2). Examiners were surprised to find responses in which the number of weeks in a year was shown as 48, 54 and even 60!

The main reasons for a low mean mark on part (c) were due to misinterpretation of the wording and failure to follow the rubric. Examiners commented that 50% of students explained how a loss of nutrients in Lake Malawi resulted in a decrease in some fish populations and consequently did not obtain any marks. Part (c) asked students about the loss of nutrients **into** Lake Malawi. The word into was emboldened in this part of the question to emphasise what was required. If these students had followed the rubric, i.e. 'Use information in the passage….' they would have understood that soil erosion had caused an increase in nutrients in Lake Malawi. Consequently, this part (c) did not discriminate very effectively, and many students failed to gain credit. Students who misinterpreted part(c) often described competition between fish populations for the limited food available due to loss of nutrients. Students who did interpret part (c) correctly often gained mark point 1, i.e. increase in algae causing less light to enter the lake. Many of these students went on to obtain a second mark by explaining that submerged plants would die due to the inability to photosynthesise. Weaker responses often omitted any reference to photosynthesis. Only 17% of students obtained three or more marks. Students gaining three marks often did so by linking the death of fish to the inability to respire due to lack of oxygen. Students who did not obtain this mark point frequently failed to mention respiration. 6% of students gained maximum marks by including the role of saprobionts in using oxygen in respiration during decomposition. Unfortunately, some students only referred to bacteria or decomposers. Some students believed that decomposition released toxic products which resulted in the death of fish or that the nutrients were toxic. Other students considered the nutrients to be pesticides, both insecticides and herbicides, and developed arguments to suit. These invariably related to food chains and reduced availability of food for fish.

Part (d) proved to be an excellent discriminator, with the second highest discrimination index on the paper. Four out of five students obtained at least one of the four marks available and 15% obtained maximum marks. Most students obtained mark point 1, the capture, marking and release of fish. Students who didn't often failed to mention the release of fish, presumably in their haste to answer this part of the question. Ensuring that the marking of fish did not affect their survival was also frequently credited, enabling almost 60% of students to obtain at least two marks. Almost 40% of students obtained at least three marks, most of these students mentioning that sufficient time should be provided to allow fish to distribute before collecting a second sample. The failure of better responses to obtain maximum marks mainly involved errors in providing the equation used to estimate the fish population. There was a range of errors. Some students provided the correct equation but then multiplied by 100. More frequently, students added or subtracted, rather than multiplied the two sample numbers and/or divided by the total number of fish in the second sample.

Part (e) was not well answered and was a very poor discriminator. Approximately one in four students obtained the mark, usually for stating that it would be difficult to recapture fish in large lakes. Relatively few students gained credit for the alternative response that it is unlikely that fish would distribute randomly in large lakes. A significant number of students ignored the context of 'large lakes' and commented on possible errors in the procedure, such as 'the marking washing off' or fish 'not surviving'. Other common incorrect responses referred to births, deaths, immigration, emigration and migration.

9.

(a) Although 50% of students obtained both marks, this question was a good discriminator. Crossing over and independent segregation/assortment (of homologous chromosomes) were frequent correct responses. Slightly fewer students referred to random fusion of gametes. Almost 27% of students failed to obtain a mark. There were numerous incorrect responses, including allopatric/sympatric speciation, natural/directional/stabilising selection, epistasis, mutation, epigenetics, linkage, genetic bottleneck, genetic drift, gene flow, founder effect, and geographical isolation.

(b) Approximately 77% of students correctly named the relationship between the alleles as codominance. Incorrect responses included epistasis, heterozygous, dihybrid, dominant, recessive and linkage.

(c) Despite almost 59% of students obtaining all 3 marks, this question proved to be a very good discriminator. When the parental genotypes were correctly given, the correct offspring genotypes, phenotypes and ratios usually followed to gain maximum marks. There was almost an equal split of students who achieved, two, one or zero marks. A frequent error was to show the parental tall genotype as homozygous rather than heterozygous. The mark scheme enabled these students to achieve two marks if they then successfully completed the resulting dihybrid cross with the corresponding phenotypes and ratio. Most students achieving two marks did so via this pathway. However, some students provided the correct parental phenotypes and dihybrid cross but then made an error when showing the phenotypes of the offspring produced. A significant minority of students showed a 9:3:3:1 ratio despite completing all other parts correctly! Students achieving one mark often provided the correct parental genotypes but could not produce a correct dihybrid cross. The mark scheme also allowed one mark for correct dihybrid genotypes of offspring from incorrect parental genotypes.

(d) This question was an excellent discriminator, especially for a two-mark question. Approximately 38% of students were able to correctly calculate the percentage of pink-flowered plants in the population. Approximately 23% obtained one mark, often for showing that 2pq represented the percentage of heterozygous/pink-flowered plants. A frequent error was to use 0.09 = q and 0.91 = p, giving 2pq = 16.38, which gained one mark. Some students either correctly or incorrectly calculated 2pq but then divided by 2 to give pq as the final answer which resulted in zero marks.

10.

(a) Surprisingly, this question and question (b) were poor discriminators. The genotype GgRr (alleles in any order) was credited, in addition to the conventionally recognised genotype of GgX^RX^r (alleles in any order). Despite this, only 57% of students provided a correct genotype. Incorrect responses included genotypes with one allele of each gene, genotypes with a Y chromosome and incorrect dihybrid genotypes.

(b) The fact that only 18% of students obtained this mark was extremely disappointing. Most students incorrectly suggested that the fact that individuals 1 and 2 produced all grey-bodied offspring was evidence that the allele for grey colour is dominant. The greater numbers of grey-bodied offspring compared with black was also often incorrectly given as evidence.

(c) Although it was thought that this question would prove challenging, the overall performance of students was well below expectations. Only 5% of students obtained both marks and around 24% gained one mark. A common error was to suggest that the presence of more grey-bodied flies than black-bodied flies indicates that the gene is on the X chromosome. Many other students used incorrect pairs of flies as evidence. More effective responses recognised that the evidence involved: fly 3 (and fly 4) producing a black-bodied female, 9; or fly 2 (and fly 1) producing a grey-bodied male, 5. However, as outlined, only about 5% of students gained a second mark as the vast majority did not refer to allele(s) in their explanations.

(d) This question and part (e) were effective discriminators. There were some very clear, correct genetic diagrams for this sex-linked, dihybrid cross which enabled around 28% of students to gain all three marks. Relatively few students, around 8%, scored two marks. These students provided correct genotypes for the parents and offspring and then made an error with the phenotypes of the offspring. Usually, these errors involved omitting the gender of the offspring or providing an incorrect phenotype for a male offspring. Almost a third of students obtained a single mark, often for providing correct gametes from incorrect dihybrid genotypes. Fewer students obtained a single mark by providing correct genotypes and then incorrectly completing the dihybrid cross.

(e) Approximately 27% of students obtained both marks using the Hardy-Weinberg equation to calculate the percentage of flies heterozygous for gene **G** as 48%. Approximately 41% of students gained one mark for an incorrect answer but showed an understanding that 2pq represented the frequency of the heterozygous genotype. A significant number of students scored zero as they calculated pq rather than 2pq.

11. (a) The definition of phenotype was generally well known with over 90% of students obtaining at least one mark. Students scoring zero usually provided a GCSE standard answer in terms of the phenotype representing an observable feature. Responses awarded a single mark usually described the genetic influence on the phenotype. Better answers also included the effect of the environment, to gain both marks.

(b) Almost 60% of students correctly named the type of gene interaction shown in the diagram as epistasis. Common incorrect responses included dihybrid and codominance.

(c) Almost 85% of students correctly identified the genotypes provided as phenotypically white and yellow respectively.

(d) Over 55% of students obtained all three marks in this question which proved to be a very effective discriminator. However, it was surprising to note that over 25% of students scored zero marks on what was considered to be a relatively straightforward genetic cross. It was difficult to give any credit to students who started their answer by providing incorrect genotypes of the offspring. A number of students were unable to determine the correct phenotypes despite having provided the correct genotypes. A few gave the correct genotypes and phenotypes, writing white, white, yellow, green but then gave a 1:1:1:1 ratio. The ratio was also sometimes given as 9:3:3:1 even though the genotypes and phenotypes were correct.

(e) Approximately one in six students obtained both marks for this question. This low success rate was not due to a lack of mathematical ability, but due to misinterpreting the information provided. Most students mistakenly thought that 36% represented the homozygous recessive genotype and obtained the incorrect answer of 48%. These students often obtained one mark as they showed that 2pq represented the frequency of the heterozygous genotype. Students who realised that that 64% represented the homozygous recessive genotype generally obtained both marks, although occasionally an answer of 0.32 was given which was awarded one mark.

1. Read the following passage.

BRCA1 and *BRCA2* are human genes that code for tumour suppressor proteins. Mutations in *BRCA1* and *BRCA2* can cause cancer. Specific inherited mutations in these genes increase the risk of female breast cancers and ovarian cancers and have been associated with increased risks of several other types of cancer. Genetic testing, using DNA from saliva, can screen for all known harmful mutations in both genes.

ER-positive breast cancers have receptors for the hormone oestrogen. These cancers develop as a result of increased oestrogen concentrations in the blood. Effective treatment of ER-positive breast cancers often involves the use of drugs which have a similar structure to oestrogen.

Blood tests can be used to test for cancers. Men with prostate cancer have a high concentration of prostate-specific antigen (PSA) in their blood. Urinary infections and a naturally enlarged prostate can also increase concentrations of PSA.

Recent research has indicated that several cancers result from epigenetic abnormalities. Treatment with drugs might be able to reverse the epigenetic changes that cause cancers.

Use the information in the passage and your own knowledge to answer the following questions.

(a) *BRCA1* and *BRCA2* are human genes that code for tumour suppressor proteins. Mutations in *BRCA1* and *BRCA2* can cause cancer (lines 1–2). Explain how.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(b) Genetic testing, using DNA from saliva, can screen for all known harmful mutations in both genes (lines 5–6). Describe how this DNA could be screened for all known harmful mutations in both genes.

(4)

(c) Effective treatment of ER-positive breast cancers often involves the use of drugs which have a similar structure to oestrogen (lines 9–10).

Suggest and explain how these drugs are an effective treatment of ER-positive breast cancers.

(3)

(d) Blood tests can be used to test for cancers (line 11). However, the results of blood tests may **not** be conclusive when testing for prostate cancer. Explain why.

(2)

(e) Treatment with drugs might be able to reverse the epigenetic changes that cause cancers (lines 16–17). Suggest and explain how.

(3)

(Total 15 marks)

2. (a) Complete the following definitions.

The genome is _____

The proteome is _____

(2)

Recombinant DNA technology can involve the transfer of fragments of human DNA into bacteria. The bacteria are then used to produce human proteins.

(b) Give **two** reasons why bacteria are able to use human DNA to produce human proteins.

1 _____

_____

_____

2 _____

_____

_____

(2)

(c) Suggest and explain **one** reason why bacteria might **not** be able to produce every human protein.

_____

_____

_____

_____

_____

_____

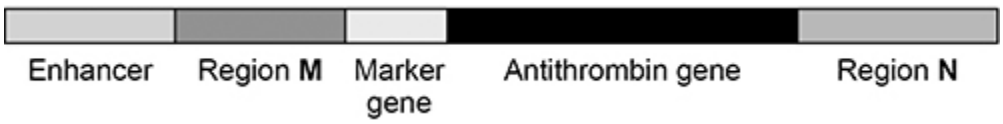
(1)

Antithrombin is a protein. Antithrombin prevents blood from clotting too much.

Some people have a deficiency of antithrombin in their blood, so they need to inject the protein.

Genetically modified goats are used to produce this protein. The human antithrombin gene is transferred into goat embryos. The adult goats then make human antithrombin protein.

The diagram below shows an example of a DNA fragment that can be transferred into the cells of goats.



(d) The enhancer stimulates region **M**.

Name regions **M** and **N** shown in above diagram.

Region **M** _____

Region **N** _____

(2)

(e) Explain the purpose of the marker gene.

_____

_____

(1)

(f) The enhancer only stimulates region **M** in the milk-producing glands of a goat.

Suggest **two** explanations for the importance of the enhancer being included in the DNA fragment transferred.

1 _____

_____

_____

_____

2 _____

_____

_____

_____

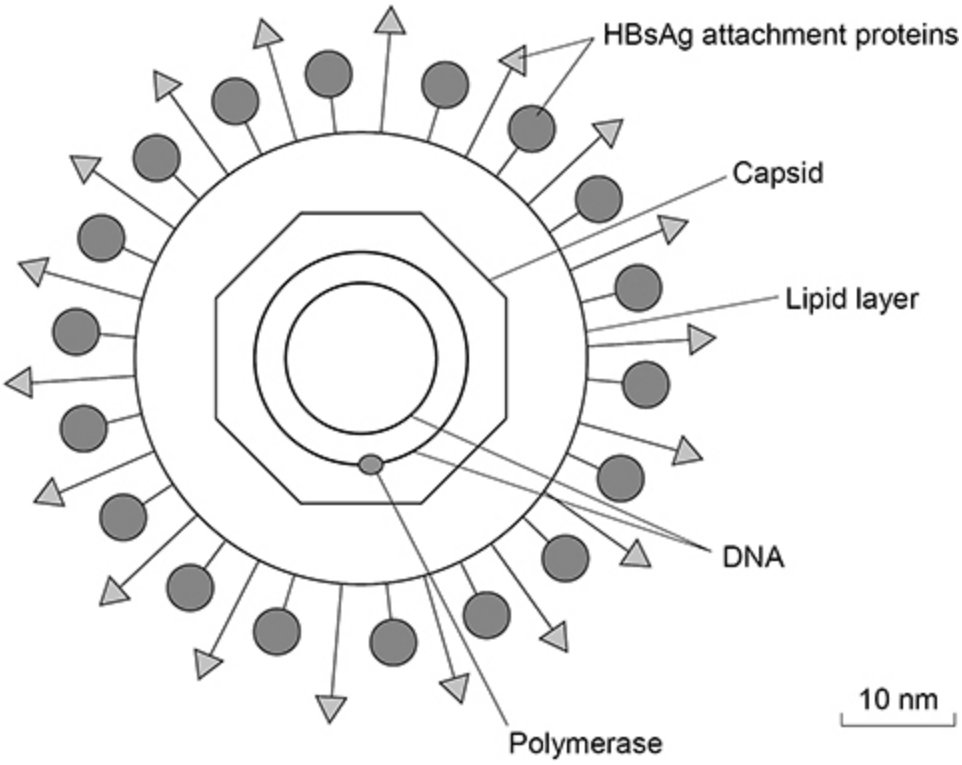
(2)

(Total 10 marks)

3. Hepatitis B is a life-threatening liver infection caused by the hepatitis B virus (HBV).

Figure 1 shows the structure of HBV.

Figure 1



(a) HBV infects a liver cell. The liver cell is 25 μm in diameter.

Use **Figure 1** to calculate how many times larger in diameter this cell is than HBV. You should use the lipid layer to measure the diameter of HBV.

Answer _____ times larger

(2)

Scientists investigated the effectiveness of two types of RNA interference (RNAi) molecules on reducing HBV replication. These molecules were:

- short hairpin RNA (shRNA)
- long hairpin RNA (lhRNA).

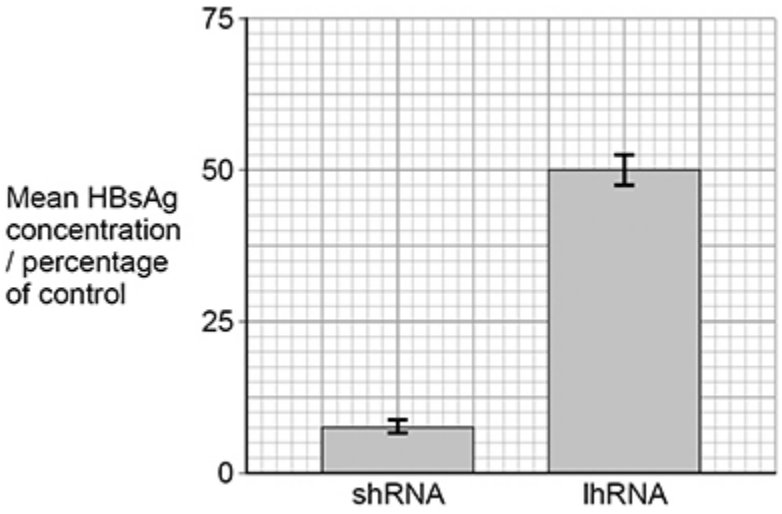
The scientists infected mouse liver cells with HBV and transferred either shRNA or lhRNA into these cells. Then they determined the concentration of the attachment proteins, HBsAg, in these cells.

The concentration of HBsAg is a measure of HBV replication.

Figure2 shows the scientists' results.

The error bars represent ±2 standard deviations from the mean, which includes over 95% of the data.

Figure 2



(b) One method of transferring RNAi molecules into cells involves combining these molecules with a lipid. Suggest why this increases uptake of RNAi molecules into cells.

(1)

(c) Using all the information provided, evaluate the use of the two types of RNAi in treating hepatitis B in humans.

Do **not** refer in your answer to how RNAi reduces HBV replication.

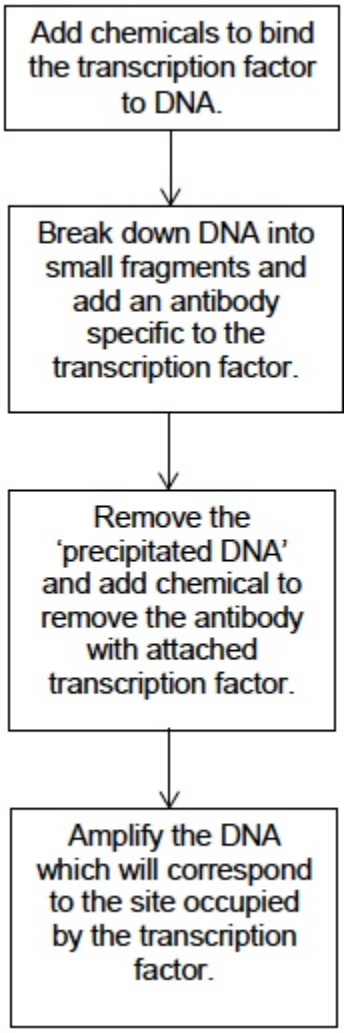
(5)

(Total 8 marks)

4. (a) What is meant by a genome?

(1)

Chromatin immunoprecipitation is one method to determine where a transcription factor binds to DNA. The principle behind this procedure is shown in the chart.



(b) Explain why the antibody binds to the transcription factor.

(2)

(c) Use the chart to explain what 'precipitated DNA' consists of.

(1)

Soybeans are used in a number of processed foods. However, soybeans contain a protein known as P34 that causes an allergic response in some people. Scientists have created transgenic soybeans that produce single-stranded cDNA, which prevents transcription of the *P34* gene. They used recombinant plasmids as vectors to transform soybean cells. After they had screened these cells for production of the P34 protein, they cultured the transformed cells to form soybean plants.

(d) Suggest how single-stranded cDNA could prevent transcription of the *P34* gene.

_____

_____

_____

_____

(1)

(e) Describe the roles of **two** named types of enzymes used to insert DNA fragments into plasmids.

Type of enzyme _____

Role _____

_____

_____

_____

Type of enzyme _____

Role _____

_____

_____

_____

(2)

(f) The soybean cells were screened for the presence of the P34 protein. This process involved the use of gel electrophoresis to separate proteins extracted from soybean cells.

Suggest **two** features of the structure of different proteins that enable them to be separated by gel electrophoresis.

1. _____

_____

_____

2. _____

_____

_____

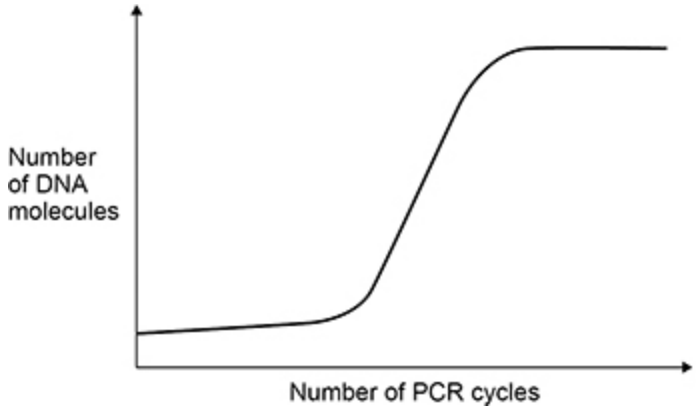
(2)

(Total 9 marks)

5. (a) Describe and explain how the polymerase chain reaction (PCR) is used to amplify a DNA fragment.

(4)

The figure below shows the number of DNA molecules produced using a PCR.



(b) Explain the shape of the curve in the figure above.

(2)

(Total 6 marks)

6.

(a) In the UK in 2016, there were 525 048 deaths. Cancer caused 30.4% of all deaths. Throat cancer caused 5% of all deaths from cancer.

Calculate the mean number of people who died of throat cancer per month in 2016.

Show your working.

Answer _____ people per month

(2)

Increased methylation of the promoter region of a tumour suppressor gene causes one type of human throat cancer.

In this type of throat cancer, cancer cells are able to pass on the increased methylation to daughter cells. The methylation is caused by an enzyme called DNMT.

Scientists have found that a chemical in green tea, called EGCG, is a competitive inhibitor of DNMT. EGCG enables daughter cells to produce messenger RNA (mRNA) from the tumour suppressor gene.

(b) Suggest how EGCG allows the production of mRNA in daughter cells.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 5 marks)

7. Plants transport sucrose from leaves to other tissues for growth and storage. SUT1 is a sucrose co-transporter protein.

Scientists investigated whether the cells of tobacco plant leaves used SUT1 to transport sucrose to other tissues.

(a) The scientists used a radioactively labelled DNA probe to show that the cells of tobacco plant leaves contained the *SUT1* gene.

Describe how they would do this.

Do **not** include PCR in your answer.

(4)

(b) To study the role of SUT1 in tobacco plants, scientists reduced the expression of the *SUT1* gene.

When the *SUT1* gene is transcribed, the SUT1 mRNA produced is called 'sense' SUT1 mRNA. The scientists genetically modified plants by inserting an **extra** gene so that this **also** allowed the production of 'antisense' SUT1 mRNA.

The scientists had two types of tobacco plants:

- type **A** – plants that were genetically modified
- type **B** – plants that were **not** genetically modified.

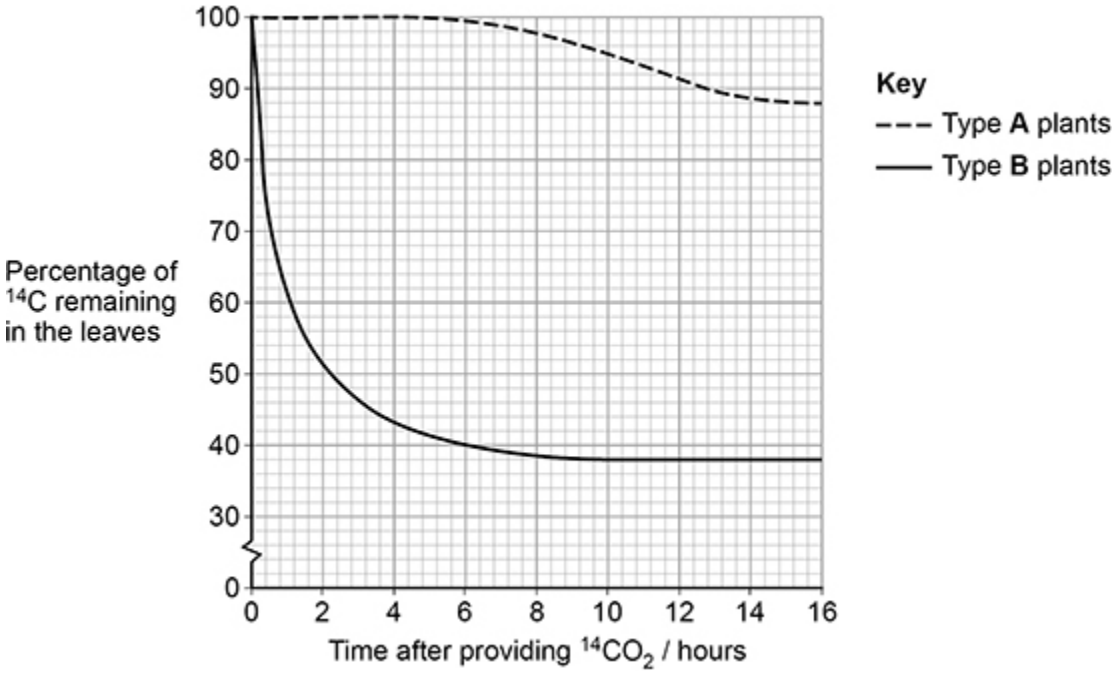
Suggest how the production of 'antisense' SUT1 mRNA in type **A** plants would reduce the expression of the *SUT1* gene.

(4)

(c) The scientists hypothesised that lower rates of sucrose transport from leaves would cause reduced growth.

To test this hypothesis, the scientists provided leaves of type **A** and type **B** plants with labelled carbon dioxide ($^{14}CO_2$). To estimate sucrose transport out of leaves, they measured the percentage of ^{14}C remaining in the leaves for 16 hours.

The figure below shows their results.



Calculate the ratio of percentage of ^{14}C remaining in leaves of type **B** to type **A** plants 16 hours after providing $^{14}CO_2$

Answer _____

(1)

(d) In type **B** plants, the percentage of ^{14}C remaining in the leaves does not reach zero per cent, as shown in the figure above.

Suggest **two** reasons why.

1 _____

_____

2 _____

_____

(2)

The scientists measured physiological differences between type **A** plants and type **B** plants.

The table below shows the scientists' results as they presented them.

Physiological factor	**Type of tobacco plant**	
	Type A	**Type B**
Rate of sucrose transport from leaf cells / µmol m^{-2} s^{-1}	0.1	3.7
Leaf sucrose concentration / mmol m^{-2}	22	4
Ratio of shoot:root dry mass	6:1	2:1
Rate of photosynthesis / µmol glucose m^{-2} s^{-1}	4	14

Sucrose is able to inhibit the production and activity of rubisco in leaves of a plant. Type **A** plants have decreased dry mass compared with type **B** plants.

(e) Use all the information to suggest **and** explain how the physiological factors in the table above would contribute to the decreased dry mass observed in type **A** plants.

(4)

(Total 15 marks)

Mark schemes

1.

(a) 1. Change in DNA base sequence/triplet;

2. Change in (sequence of) amino acids
OR
Change in primary/tertiary/3^0 structure;

Ignore reference to protein not being formed.

Reject (different) amino acids formed.

Ignore 3D structure.

3. (Results in) rapid/uncontrollable cell division;

Accept cell division cannot be regulated.

Ignore growth.

Accept cell replication but ignore cell reproduction.

3

(b) 1. Use of PCR to amplify (DNA sample);

Accept description of amplification.

2. Cut (DNA) using restriction endonuclease/enzymes;

3. Separate (DNA fragments) using electrophoresis;

Accept use of microarray for electrophoresis.

4. Addition of (labelled) DNA probes **and** binding (by DNA hybridisation);

Ignore primers.

Reference to probe being complementary is insufficient.

5. (Mutations) identified by fluorescence/radioactivity
OR
Compare positions/bands (to known) DNA sample with (all harmful) mutations;

Accept identification using X-ray/photographic/film/autoradiography or UV light.

***Note if only DNA sequencing** is used award **max 3 marks** for the following.*

1 Use of PCR to amplify (DNA/sample);

2. Sequence the DNA sample;

3. Compare DNA sequence with known DNA sequence of mutation;

4 max

(c) 1. (Drug) binds to (oestrogen/ER) receptor;

Accept (inactive) transcription factor for receptor.

2. Prevents binding of oestrogen/hormone;

Reject active site/enzyme-substrate complex once only.

3. No/fewer transcription factor(s) bind to promoter
OR
RNA polymerase not stimulated/activated;

3

(d) 1. High/increased (concentration of) PSA not always linked to (prostate) cancer
OR
High/increased (concentration of) PSA could be a false positive;

2. 2.(Could be) due to urinary infection
OR
(Could be) due to enlarged prostate;

Accept 'urine infection'.

2

(e) 1. (Drugs could) increase methylation of oncogene(s);

2. (Drugs could) decrease methylation of tumour suppressor gene(s);

3. (Increased) methylation of DNA/gene(s) inhibits transcription/expression (of genes)
OR
Decreased methylation of DNA/gene(s) stimulates transcription/expression (of genes);

Accept promoter (region) for DNA/gene

4. Decreased acetylation of histones inhibits transcription/expression (of genes)
OR
(Increased) acetylation of histones stimulates transcription/expression (of genes);

Ignore 'switching on' and 'switching off' genes once but accept as alternative(s) for 1 mark if used correctly in context of transcription/ expression for both points 3 and 4.

Ignore methylation of histones and acetylation of DNA/genes.

Ignore proto-oncogenes.

3 max

[15]

2. (a) **Genome**

1. (The) complete set of genes in a cell/organism
OR
(All) the DNA in a cell/organism;

Accept (all) the genes/alleles/genetic material/genetic code in a cell/organism

Accept the total number of DNA bases in a cell/organism

Reject all the DNA/genes within a species/population

Proteome

2. Range of proteins that a cell/organism **can produce**
OR
Range of proteins the genome/DNA **can code for**;

Do not accept number of proteins unqualified

Ignore range of proteins that a species/population can produce

2

(b) 1. (The) genetic/DNA code is universal
OR
The same triplets/codons code for the same amino acids (in all species);

Do not accept 'DNA is universal' unqualified

Reject the genetic code is degenerate

Ignore anything after 'genetic/DNA code is universal' unless incorrect

2. (The mechanism of) transcription is universal;

3. (The mechanism of) translation is universal;

2 and 3 Accept descriptions of universal, eg transcription/translation are the same in humans and bacteria

2 and 3 If neither is stated, accept '(the mechanism of) protein synthesis is universal' for 1 mark

Accept bacteria have ribosomes, and so could translate (human mRNA)

2 max

(c) Cannot splice (pre-mRNA), **so** cannot remove introns

OR

Do not have Golgi (apparatus), **so** cannot process/modify (proteins);

OR

Do not have transcriptional factors (required), **so** cannot carry out transcription/produce mRNA;

Accept do not have spliceosomes/spliceozyme for cannot splice

Accept 'rough endoplasmic reticulum' for 'Golgi'

Accept (human protein) is too complex and bacteria do not have Golgi (apparatus)

1

(d) 1. (Region **M**) promoter;

2. (Region **N**) terminator;

Accept phonetic spellings

2

(e) Shows that the (antithrombin) gene has been taken up (by cells/embryos/goats)

OR

Shows transgenic/transformed goat cells/goat embryos/goats

OR

Allows detection of genetically modified cells/organisms/mammals/goats;

Accept 'GM' for 'genetically modified'

1

(f) 1. Milk/protein/antithrombin is easy to extract from a goat
OR
Extracting milk/protein/antithrombin from a goat does it no harm;

2. If (antithrombin was produced) in their blood, could prevent/affect clotting
OR
(Antithrombin) could damage other cells;

2

[10]

3.

(a) 1. Correct answer of 625 = **2 marks**;;

2. Shows 625 but decimal point incorrect = **1 mark**

OR

Working shows 40 = **1 mark**

OR

1600/1.6 = **1 mark**

OR

667/666.6 = **1 mark**;

2

(b) (Cell/membrane has a) phospholipid bilayer

OR

No channel/carrier protein (for uptake)

OR

No need for channel/carrier protein (for uptake);

1

(c) 1. Both are more effective than the control;

Mark points 4 to 10 = 4 max.

Accept both (results) are below the control.

2. Differences in the means not (likely to be) due to chance

OR

Significant difference (in effectiveness between both types);

Reject 'results are significant'.

Accept significantly higher or significantly lower in correct context.

3. (As) SDs do not overlap;

Accept error bars do not overlap.

4. HBsAg (reduced), not zero

OR

Replication (reduced), not zero;

5. Not (investigated in) humans

OR

(Investigated in) mice;

6. shRNA (more effective as) 7.5% (of control) compared with 50% for lhRNA;

Accept 42.5% difference.

Accept (mean) concentration for %.

7. No indication of sample size/number;

8. Long term effects not known

OR

Side effects not known;

Accept 'could be toxic' for side effects not known.

9. No statistical test to determine significance;

10. (Investigated) in vitro

OR

Not (investigated) in vivo;

Accept not done inside an organism or not done in liver (organ) but 'only tested in liver cells' is insufficient unless qualified.

Ignore only 'one study' or 'no repeats'.

5 max

[8]

4. (a) (All) the DNA in a cell/organism;

Accept

'(all) the 'genes'/alleles' 'genetic material/code' in a cell/organism/ person'

'the total number of DNA bases in a cell/organism'

Reject all the DNA/ genes within a <u>species</u>

1

(b) 1. (Transcriptional factor/antibody) has a specific/tertiary structure/shape;

Accept (antibody) has a specific variable region

Accept (transcription factor/antibody) has a specific binding site

Reject active site but only once.

2. Complementary (shape/structure);

Reject active site but only once.

2

(c) DNA, transcription factor and antibody;

Accept Nucleotides for DNA

Ignore 'reference to chemicals'

1

(d) Binds to P34 gene/DNA/mRNA
OR
Binds to transcription factor gene/DNA
OR
Binds to promoter;

Reject binds to transcription factor

1

(e) 1. Restriction (endonuclease/enzyme) to cut plasmid/vector;

2. Ligase joins gene/DNA to plasmid/vector;

2

(f) 1. Mass/number of amino acids/polypeptides;

Accept weight for mass

Ignore density/size

Accept length of polypeptide/amino acid chain

Accept primary structure /sequence of amino acids.

Accept tertiary structure

2. Charge;

3. R groups (differ);

2 max

[9]

5.

(a) 1. (Requires DNA fragment) DNA polymerase, (DNA) nucleotides and primers;

2. Heat to 95 °C to break hydrogen bonds (and separate strands);

Accept temperature in range 90 to 95 °C.

3. Reduce temperature so primers bind to DNA/strands;

Accept temperature in range 40 to 65 °C.

4. Increase temperature, DNA polymerase joins nucleotides (and repeat method);

Accept Taq polymerase for DNA polymerase.

Accept temperature in range 70 to 75 °C.

4

(b) 1. (Initially) number (of molecules) doubling is low

OR

Doubles each cycle to produce exponential increase;

First alternative relates to idea of low numbers i.e., 2, 4, 8, 16, 32 etc.

2. Plateaus as no more nucleotides/primers;

Accept 'levels out' or 'flattens' for plateaus.

Accept enzyme/polymerase (eventually) denatures.

2

[6]

6.

(a) 665 (people per month);;

Allow one mark for 7980/7981 in working (number of deaths from throat cancer per year)

Accept answers not rounded

2

(b) 1. (EGCG) binds to <u>active site</u> of DNMT;

Ignore active site changes shape

Ignore 'forms enzyme-substrate' complex

2. (DNMT) cannot methylate (promoter region of tumour suppressor gene);

3. Transcription(al) factor(s) can bind (to promoter region);

4. RNA polymerase (stimulated/activated);

Accept less methylation (of promoter region/tumour suppressor gene)

3 max

[5]

7.

(a) 1. Extract DNA and add restriction endonucleases/restriction enzymes;

2. Separate fragments using electrophoresis;

3. (Treat DNA to) form single strands

OR

(Treat DNA to) expose bases;

Ignore method used to separate strands

4. The probe will bind to/hybridise/base pair with the *SUT1*/gene;

5. Use autoradiography (to show the bound probe);

Accept use photographic or X ray film (to show the bound probe)

X rays alone is not sufficient

4 max

(b) 1. Antisense mRNA is complementary to 'sense' mRNA;

2. Antisense mRNA would bind/base pair to (sense) mRNA;

OR

Double stranded (m)RNA forms;

3. Ribosomes would not be able to bind;

4. Preventing/less translation (of mRNA)

OR

Preventing/less production of SUT1 (protein);

Accept descriptions of translation

4

(c) $0.4\ (3\dot{1}\dot{8})$:1;

Accept any suitable rounding

1

(d) 1. Some ($^{14}CO_2$) used to make cellulose/cell walls;

Accept some becomes lipids/ proteins/DNA/RNA/ nucleotides

2. Some ($^{14}CO_2$) converted into starch (which remains in the leaf);

Accept some ($^{14}CO_2$) converted into glucose

3. Not all ($^{14}CO_2$) fixed/used in photosynthesis;

OR

Not enough RuBP (to combine with all of the $^{14}CO_2$);

Accept descriptions of this

4. Some used to reform RuBP

OR

Some (is still) in glycerate 3-phosphate/GP/triose phosphate/in the Calvin cycle;

2 max

(e) 1. Reduced *SUT1* expression/less SUT 1 (protein) means less sucrose exported (so concentration increases in leaves);

2. (Increased sucrose in leaves) inhibits rubisco, so less $^{14}CO_2$ fixed into GP;

OR

(Increased sucrose in leaves) inhibits rubisco, so less $^{14}CO_2$ combines with RuBP;

OR

(Increased sucrose in leaves) inhibits rubisco, so less Calvin cycle/light independent reaction/s;

Accept less rubisco or less active rubisco for 'inhibits rubisco'

3. Less sucrose transported to roots, so roots do not develop/grow (as shown by larger shoot to root dry mass ratio);

4. Roots less developed so fewer minerals available for growth

Accept: roots less developed so less water available for photosynthesis

5. Less growth means less dry mass;

Accept: less photosynthesis/light independent reaction/s means less dry mass;

4 max

[15]

Examiner reports

1.

(a) Although only 6% of students gained all three marks and 28% at least two marks, this question was a very good discriminator. Almost 80% of students gained at least one mark, invariably MP 3, by referring to rapid/uncontrollable cell division (of cancer cells). Students who did not obtain this mark often referred to the growth of cells rather than cell division. Very few students obtained MP 1 for explaining what a mutation is. Some students only referred to a change in the base sequence without mentioning DNA. Other students referred to the 'RNA base sequence of a gene' or more frequently 'the amino acid sequence of a gene'. A surprisingly large number of students confused mutation with methylation of DNA. Students were more successful in accessing MP 2, i.e. describing the effect of a mutation on the primary or tertiary structure (of a protein). Most correct responses referred to a change in (the sequence of) amino acids. Answers which only stated that a protein would not be formed were not credited.

(b) The standard of the answers provided to this question was very disappointing. Only 5% of students obtained the maximum four marks and almost 47% of students scored zero. This includes the 9% of students who made no attempt to answer the question. Nevertheless, this question proved to be an excellent discriminator.

Approximately 21% of students obtained a single mark on this question. This mark was often obtained for including the use of PCR to amplify the DNA sample or by outlining how mutations could be identified, e.g. by fluorescence/radioactivity, etc. The use of restriction endonucleases/enzymes was often omitted, or their role was incorrectly described. Some students named other enzymes, helicase and reverse transcriptase being the most common. Although the term electrophoresis appeared on a regular basis in responses, many students did not describe its role in separating the DNA fragments. Some students were able to obtain the alternative option to this mark point by including the use of a microarray.

There was considerable confusion between DNA probes, primers, and marker genes. Even when DNA probes were used in the correct context, a significant number of students did not refer to binding. Fortunately, the mark scheme did not insist on 'DNA hybridisation', the terminology included on the specification. This would have further reduced the accessibility of this mark point.

Weaker responses included the use of a gene machine, an electron microscope, electrolysis, plasmids, recombinant DNA technology, and the ELISA test. A few students attempted to describe DNA sequencing as a method to screen the DNA for all the mutations. These attempts were generally unsuccessful. Some students obtained a mark for comparing the DNA sequence with known DNA sequences of the mutations. However, there were several references to the 'amino acid sequence of genes' which invalidated this mark. 32% of students obtained at least two marks on this question and 15% obtained at least three out of the four maximum marks available.

(c) As with most of the comprehension questions, this was another very effective discriminator, despite only 7% of students obtaining all three marks. Most students, 75%, obtained at least one mark, usually for MP 2, i.e. drugs preventing the binding of oestrogen (to the receptor). Many of these students also referred to the drugs binding to the (oestrogen/ER) receptor or transcription factor to gain MP 1. However, some students simply stated that the drugs acted as competitive inhibitors without any reference to binding, or they omitted 'receptor' or 'transcription factor'. A few responses suggested that the drugs bind to oestrogen. There were also some references to 'active site' and enzyme-substrate complexes, which were rejected. Nevertheless, 48% of students obtained at least two marks. Rarely was the third mark point credited without maximum marks being achieved. Only the best responses included any reference to the promoter or to RNA polymerase. These students displayed an excellent understanding of how the drugs are effective in the treatment of ER-positive breast cancers.

(d) 49% of students used the information in the passage to obtain both marks. These students appreciated that the high/increased (concentration of) PSA could be due to an enlarged prostate and/or urinary infections. Only 15% of students obtained a single mark. These students often did not refer to a high/increased PSA (concentration) for MP 1 or only referred to 'infections', which was insufficient for MP 2. 36% of students failed to obtain a mark. Many of these students suggested reasons why PSA would not be present, or present in low concentrations in blood. A number of these responses suggested that the prostate does not receive a blood supply.

(e) This question proved far more difficult for students than 10.4 and was a far more effective discriminator. Only 5% of students gained the maximum three marks and 37% at least one mark. Almost 10% of students did not provide a response, but there was no evidence to suggest that this was due to lack of time. Many responses provided general facts concerning epigenetics without answering the question. Although several students knew that methylation and acetylation may be involved, they did not provide sufficient detail to access any of the mark points.

Students who did gain credit often did so by describing the effects of methylation. Responses gaining two marks often suggested that drugs could decrease methylation of tumour suppressor genes, inhibiting transcription of these genes. There were far fewer references to oncogenes despite the specification referring to 'abnormal methylation of tumour suppressor genes and oncogenes'. Perhaps not surprisingly, MP 4, relating to acetylation was awarded less frequently. The use of imprecise terminology, e.g. genes being 'switched on or off' rather than referring to the transcription/expression of genes prevented some students from obtaining an additional mark. There was considerable confusion between oncogenes and proto-oncogenes (not on the specification). As in part (a), a surprising number of students suggested that epigenetic changes cause mutations.

2.

(a) discriminated well and 41% of students provided two correct definitions. Those who failed to get the definition of genome correct often confused it with the definition of genotype and mentioned all the genes in a species or population. Proteome was harder for students to define and there was confusion with the definition of phenotype and a lack of qualification, i.e. students failing to state 'can produce' or 'can code for.'

(b) also discriminated well, but only 13.5% scored both marks and 55% score 0 marks. There was a lot of discussion of 'sticky ends', plasmids, restriction enzymes and reverse transcriptase in responses that failed to score. There were many vague, unqualified responses, for example 'DNA is universal', and also many students who disqualified themselves from MP1 by stating 'The genetic code is universal because is it degenerate.'

Students found **(c)** difficult, with only 10% able to score a mark. Many students incorrectly thought that bacteria only have uracil and not thymine, that bacteria do not have the amino acids required to make a protein, that the human gene would be too long or too big (bacteria can make the largest human protein titin) and that bacteria would not be able to make haemoglobin as they lack prosthetic groups (haemoglobins are widespread in bacteria). Those students who came close to scoring the mark often suggested or explained, but did not do both; for example, just stated that 'bacteria cannot splice' or 'bacteria to not have introns.'

(d) discriminated well and 40% scored both marks. Those who failed suggested that regions M and N are start and stop codons, introns and exons and VNTRs was also suggested for both. More than 5% of students did not even attempt this question.

(e) was correctly answered by 43.5% of students. Those who failed to score gave vague responses, for example 'to see the gene.'

With **(f)**, only 6% of students scored both marks. There were students who did not understand what the question was asking, seemingly having ignored the first sentence. They confused the enhancer for a promoter. There were many repeats/paraphrases of the stem, i.e. 'so only produced in milk.' Some students thought the only way to extract a product from a goat, if not in the milk, is to kill it, and a large number of students thought if the protein was produced in the milk, goats could pass it on to their offspring. This question had the highest number of non-attempts at nearly 8%.

3.

Approximately 40% correctly performed the calculation in (a) for two marks. Approximately 24% of students obtained one mark, usually for showing '40' in the working. However, a significant number of students gained a mark for a final answer showing 625 but with the decimal point in the incorrect place, e.g. 6.25, 62.5, 6250. These students had often made an error when converting units of measurement. Common incorrect answers were 2400 (60 000 divided by 25), 240 and 2.4.

Approximately 39% of students obtained the mark for (b), almost invariably by referring to the phospholipid bilayer. Only a handful of students gained the mark for suggesting that no carrier/channel proteins would be available for uptake of the RNAi molecules. Many of the responses which were not credited lacked sufficient detail, for example by stating that the cell-surface membrane has 'phospholipids', 'a lipid bilayer' or 'a lipid layer', or that the molecule was now 'lipid soluble'. More fanciful explanations involved the lipids acting as receptors and carrying the RNAi across the membrane. Others suggested that the RNAi had lipid receptors to which the lipid could bind.

(c) was an excellent discriminator, the most effective on the paper. Approximately 80% of students gained at least one mark, and almost 14% obtained the maximum five marks. Although mark points 1, 4 and 10 were rarely awarded, all the points on the mark scheme were credited at some stage of marking. The most frequent mark awarded related to the investigation being on mice rather than on humans. Students who gained a mark by referring to the overlap in standard deviations often obtained another mark by stating that there was a significant difference in the effectiveness of the two types of RNAi. It was pleasing to note that few students referred to the 'results being significant'. However, a substantial number of students omitted any reference to the overlap in standard deviations but instead compared the spread of this data around the mean in terms of reliability of the results. Almost 47% of students gained at least three marks. There was some variation in how higher marks were achieved. The most frequent additional points related to long-term or side-effects not being known and the fact that sample size was unknown. However, a significant number of students did use the data in **Figure 2** to compare the effectiveness of the types of RNA. Less frequent were responses which referred to the lack of a statistical test to determine significance or references to the investigation being *in vitro* rather than *in vivo*.

4.

(a) The mark scheme for this question reflected the considerable variation in acceptable definitions for the term genome. Despite this, nearly 40% of students did not obtain the mark. There some very detailed definitions which often included the DNA in mitochondria and chloroplasts. The most common incorrect responses referred to "all the genes in a chromosome" or "all the genes in a species".

(b) Almost 80% of students obtained at least one mark for this question, often for referring to complementary structures. Almost half of these students gained a second mark by referring to a specific tertiary structure, shape or binding site. Weaker responses suggested that the term complementary is equivalent to 'similar' or referred to 'active site' rather than binding site.

(c) This proved more difficult than expected with only 26% of students obtaining the mark. Incorrect responses included (unbound) DNA fragments, nucleotides, exons, introns, DNA without an antibody or transcription factor bound to it, and any combination of two of the three parts required to gain the mark. The constituent parts of a DNA molecule were also listed.

(d) Again, relatively few students (30%) obtained the mark for this question. The most frequent correct responses referred to cDNA binding to the *P34* gene, preventing its transcription, or binding to mRNA, preventing its translation. The binding of the cDNA to mRNA, resulting in the destruction of mRNA, was also described. Binding to the promoter region was less frequently awarded. A significant minority of students mentioned that cDNA prevented RNA polymerase binding to the *P34* gene or just prevented its transcription, but with no suggestion of how. Incorrect responses often referred to cDNA increasing/decreasing methylation of the *P34* gene or simply that cDNA could not be transcribed into mRNA and translated to form the *P34* protein.

(e) Considering that this question was relatively straightforward, it proved to be a very effective discriminator. Surprisingly, many students could not name both enzymes correctly. Consequently, only 35% of students obtained both marks for this question and 28% obtained a single mark. DNA helicase, reverse transcriptase and DNA polymerase were frequent incorrect responses. Even when the correct enzymes were named, students did not always describe the precise roles of the enzymes in the formation of recombinant plasmids. These descriptions were often too vague, e.g. “produces sticky ends” or “joins DNA together”, without any mention of the plasmid/vector. A significant minority referred to incorrect types of bonds when outlining the role of correctly named enzymes.

(f) A significant number of students had difficulty applying their knowledge of electrophoresis to separating proteins. Only 14% of students gained both marks for this question, however 50% did at least obtain a single mark. Many students simply reverted to discussing DNA, especially VNTRs, or referred to DNA and protein, often suggesting that proteins consist of bases. Common responses which were not credited often referred to ‘size’ and ‘mass’, with no reference to the structure of proteins. However, better answers did obtain a mark when mass/size was linked to the number of amino acids or polypeptides. Difference in charge was the most frequently awarded marking point. Far fewer students mentioned different ‘R groups’ or ‘variable groups’.

5. Considering that part (a) assessed knowledge and understanding, it was surprising and very disappointing that almost 20% of students did not attempt it. However, despite this and the fact that only 41% of students gained at least one mark, it proved to be an excellent discriminator. The most frequently credited response was reference to the breaking of hydrogen bonds by heating DNA at a high temperature (90° to 95°C). Students obtaining two or more marks often mentioned reducing the temperature enabling the binding of primers to the DNA. A common error among students who gained a maximum of two marks was to omit any reference to nucleotides, making marking points 1 and 4 inaccessible, or to omit one of the temperature changes required. Weaker responses included a variety of incorrect enzymes, most frequently RNA polymerase, but also reverse transcriptase, restriction endonuclease and ligase. References to just ‘polymerase’ were also common. Approximately 22% of students obtained at least three marks. One reason for students not gaining maximum marks was to incorrectly outline the role of DNA polymerase. Consequently, only 10% of students obtained all 4 marks.

Only 5% of students obtained both marks for part (b). Considering the difficulties most students had in describing and explaining the polymerase chain reaction in (a), this was not surprising. Most students simply described the shape of the curve in the figure rather than explaining it. The 22% of students who gained one mark for this question invariably obtained mark point 2. Most of these students explained the plateau in terms of lack of nucleotides or primers. Few responses referred to the eventual denaturation of DNA polymerase. Weaker responses frequently suggested that the number of DNA fragments was the limiting factor or that DNA polymerase had been ‘used up’. Students gaining both marks often included an explanation of the exponential increase due to doubling of the number of DNA molecules.

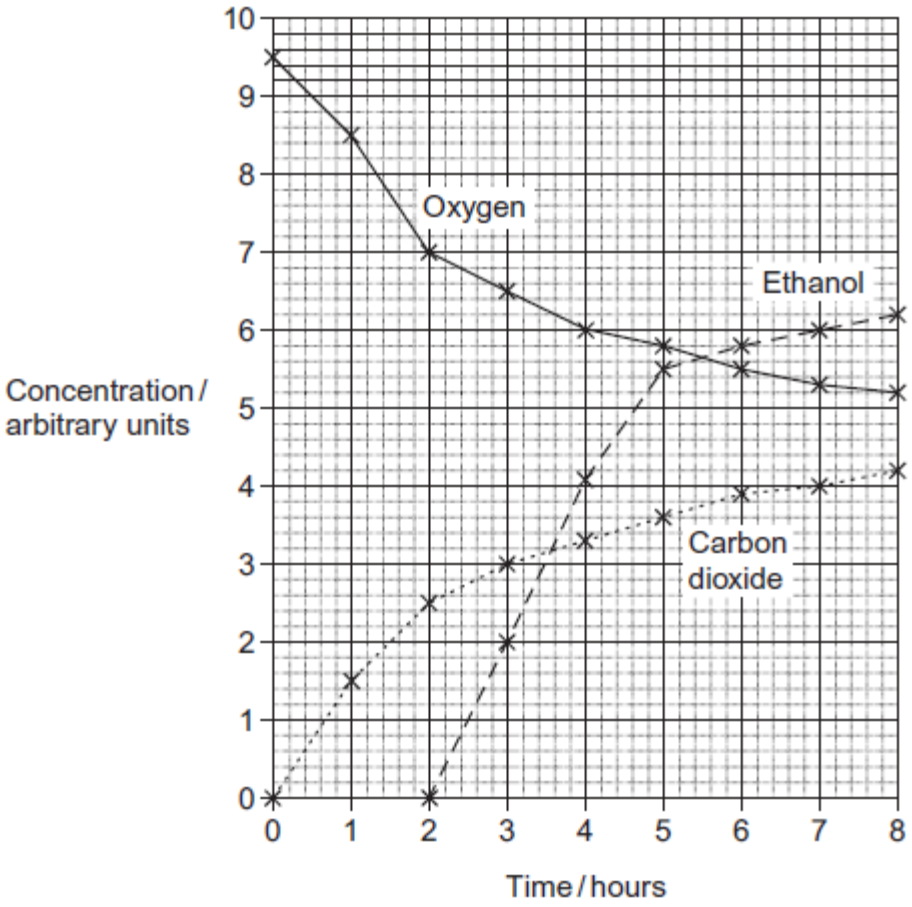
6. (a) tested similar maths skills to (c) and nearly 72% of students scored both marks.

(b) discriminated well, however only 14% scored 3 marks. There was confusion about what is the enzyme and what is the substrate. Students stated that EGCG binds to the promotor region instead of DNMT and also that ECGC and DNMT have similar shapes so bind to the same thing, despite being told that ECGC is a competitive inhibitor.

7.

Parts (a) and (b) discriminated well; however, on both over 17% of students failed to even attempt the question. With (a), only 1.20% scored full marks, and there was confusion between a DNA probe and a marker gene, with several answers describing *in vivo* cloning, others describing a tracer experiment, and several incidences of microarrays being used, the latter not being on the specification. There were also many incidences of students changing the radioactively labelled DNA probe into a fluorescent probe. With (a), it seems that students failed to understand what the stem was outlining, and, as such, examiners found a lot of misinterpretation in responses, with students stating that the antisense mRNA binds to the *SUT1* gene or the antisense mRNA makes the wrong protein. There were also several incidences of a fundamental biology mistake by stating '*translation of the SUT1 gene is prevented*'. Only 2.05% scored full marks, and 56.87% scored zero marks. With (c), students failed to understand that, in biology, ratios are expressed as 'something to one'; as a result, only 7.04% answered the question correctly. Students displayed poor knowledge of photosynthesis in part (d), and many students failed to grasp that the question stated ^{14}C and not $^{14}CO_2$. Incorrect responses included '*CO_2 is still produced in photosynthesis', '$^{14}CO_2$ is still taken in', 'CO $_2$ is used for growth', 'plants need CO_2' and 'some still remains'* . Over 10% failed to attempt part (e), and only 0.34% scored full marks. Students were able to access MP1, MP2 and MP6, but rarely did they link MP3 and MP4 to the development or growth of the roots. Those who did often referred to '*nutrients'* for MP4 rather than minerals.

1. A scientist investigated the use of a new source of carbohydrate in the production of ethanol for biofuel. He wanted to find the optimum time to leave a mixture of yeast and this carbohydrate to produce ethanol. The scientist set up an airtight container containing yeast and this carbohydrate. He then measured the oxygen, carbon dioxide and ethanol concentrations over 8 hours.
The results of his investigation are shown in the graph below.



(a) The scientist used a container that was airtight.
Give **two** explanations why the container had to be airtight.

1. _____

_____

_____

_____

2. _____

_____

_____

_____

(4)

(b) Explain the relationship between the concentration of oxygen and the concentration of carbon dioxide between 0 and 3 hours.

_____

_____

_____

_____

_____

_____

(2)

(c) The scientist concluded that yeast starts to respire anaerobically when the oxygen concentration falls below a certain concentration. What is the oxygen concentration when the yeast starts to respire anaerobically? Explain your answer.

_____

_____

_____

_____

_____

(2)

(d) (i) The scientist worked for a biofuel company. Give **two** suggestions for further work he should do to make sure that the results he presented to the company were reliable. Explain how each of your suggestions would make the results more reliable.

Suggestion_____

_____

Explanation _____

_____

Suggestion_____

_____

Explanation _____

_____

(4)

(ii) The scientist recommended that when the ethanol is produced commercially as biofuel the reaction should be stopped at 6 hours. Use the graph to suggest why.

_____

_____

_____

_____

_____

(2)

(iii) The scientist's work was funded by a biofuel company. Explain why the source of funding can cause problems with scientific work.

_____

_____

_____

_____

_____

(2)

(Total 16 marks)

2. Gangliosides are lipids found in the cell surface membranes of nerve cells. Hexosaminidase is an enzyme present in blood that breaks down gangliosides. If gangliosides are not broken down, they damage nerve cells.

(a) Hexosaminidase only breaks down gangliosides. It does not break down other lipids.

Explain why this enzyme only breaks down gangliosides.

_____

_____

_____

_____

_____

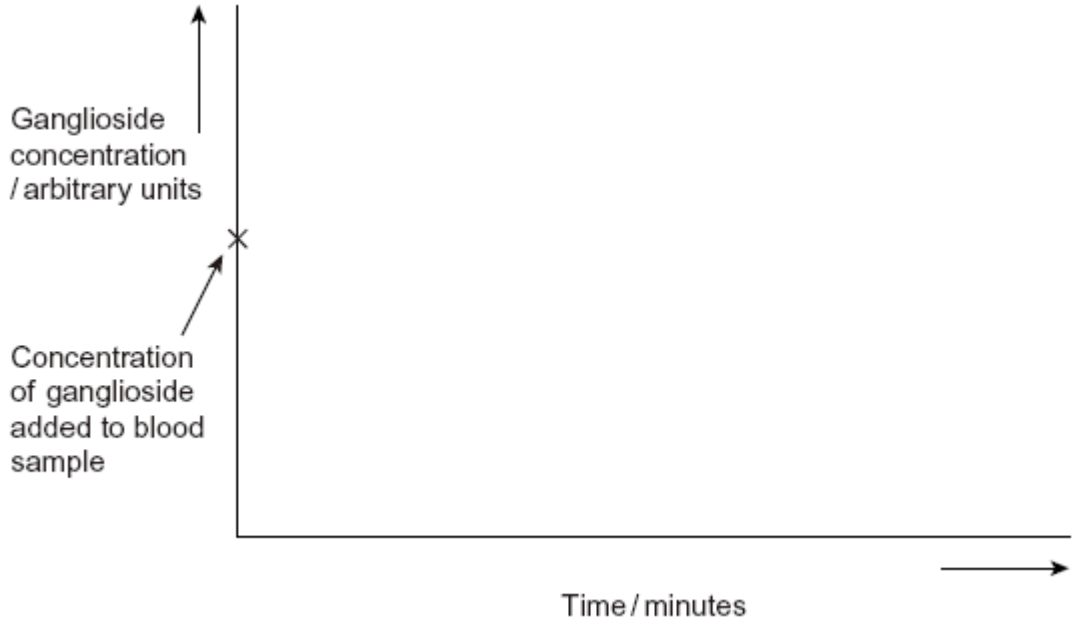
_____

(3)

(b) Hexosaminidase is found in the blood of healthy people. People with Tay Sachs disease do not have this enzyme in their blood.

Doctors confirm Tay Sachs disease by using a blood test. The technician carrying out the test adds a solution containing a high concentration of gangliosides to a sample of blood from the person being tested. The technician then measures the concentration of gangliosides in the person's blood at regular intervals.

(i) Complete the graph below by sketching a curve to show the results you would expect for a person with Tay Sachs disease. Label this curve **T**.



(1)

(ii) Sketch a curve on the same graph to show the results you would expect for a healthy person who does **not** have Tay Sachs disease. Label this curve **H**.

(1)

(c) Scientists are trying to find a way to give the missing enzyme to people with Tay Sachs disease. Suggest why they cannot give the enzyme as a tablet that is swallowed.

_____

_____

_____

_____

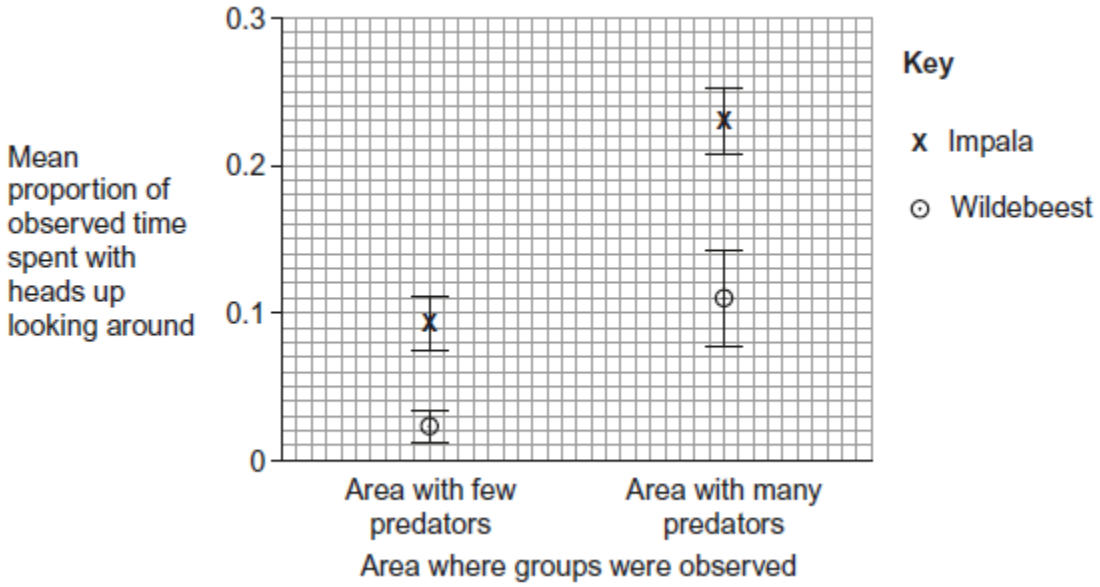
(2)

(Total 7 marks)

3. Impala and wildebeest are species of herbivore that live in large groups. They spend most of their time feeding with their heads near the ground.

Scientists investigated the relationship between the number of predators in an area and the mean proportion of time these herbivores spent with their heads up, looking around rather than feeding. They obtained data from groups of impala and wildebeest in two areas. In one area there were few predators and in the other area there were many predators.

The graph shows their results. The bars show standard deviations.



(a) The scientists observed both groups of animals for 75 hours.

Use data from the graph to calculate the difference in the mean number of hours spent by each species looking around in the area where there were **many** predators.

Show your working.

Difference _____ hours

(2)

(b) The scientists concluded that these herbivores spend more time looking for predators in areas where there are many predators.

Do these data support this conclusion? Give reasons for your answer.

(4)

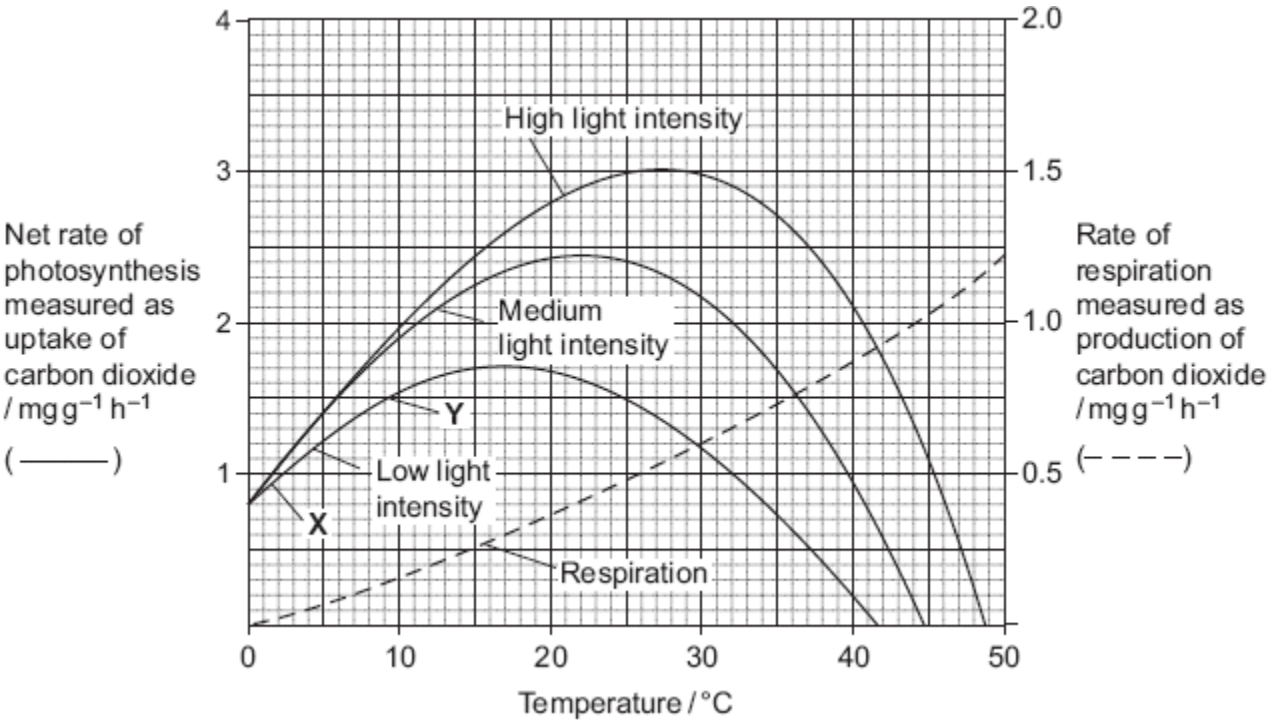
(c) The behaviour of the herbivores in having their heads up has a benefit but it also has costs. The benefit is being able to see, and escape from, predators.

Suggest and explain **one** cost to the herbivores of this behaviour.

(2)

(Total 8 marks)

4. Scientists investigated the effects of temperature and light intensity on the rate of photosynthesis in creeping azalea. They investigated the effect of temperature on the net rate of photosynthesis at three different light intensities. They also investigated the effect of temperature on the rate of respiration. The graph shows the results.



(a) (i) Name the factors that limited the rate of photosynthesis between **X** and **Y**.

_____

(1)

(ii) Use information from the graph to explain your answer.

_____

_____

_____

_____

_____

(2)

(b) Use information from the graph to find the gross rate of photosynthesis at 20°C and medium light intensity.

Answer _____

(1)

(c) Creeping azalea is a plant which grows on mountains. Scientists predict that in the area where this plant grows the mean summer temperature is likely to rise from 20 °C to 23 °C. It is also likely to become much cloudier. Describe and explain how these changes are likely to affect the growth of creeping azalea.

_____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

5. (a) Describe the mass flow hypothesis for the mechanism of translocation in plants.

_____

_____

_____

_____

_____

_____

_____

_____

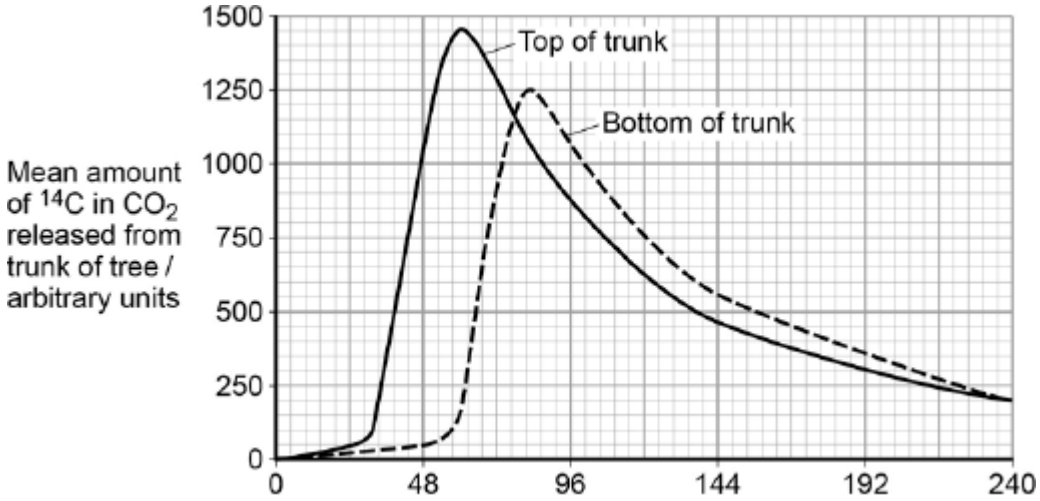
(4)

Scientists measured translocation in the phloem of trees. They used carbon dioxide labelled with radioactive ^{14}C.

They put a large, clear plastic bag over the leaves and branches of each tree and added $^{14}CO_2$. The main trunk of the tree was not in the plastic bag.

At regular intervals after adding the $^{14}CO_2$ to the bag, the scientists measured the amount of $^{14}CO_2$ released from the top and bottom of the main trunk of the tree. On the surface of the trunk of these trees, there are pores for gas exchange.

The following figure shows the scientists' results.



(b) Name the process that produced the $^{14}CO_2$ released from the trunk.

_____

(1)

(c) How long did it take the ^{14}C label to get from the top of the trunk to the bottom of the trunk? Explain how you reached your answer.

_____

_____

_____

_____

(2)

(d) What other information is required in order to calculate the mean rate of movement of the ^{14}C down the trunk?

_____

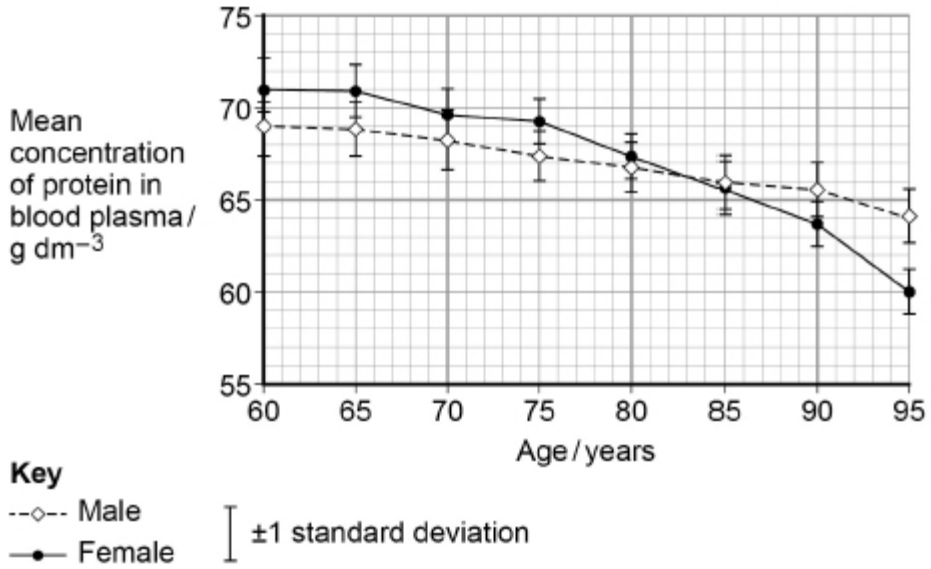
_____

(1)

(Total 8 marks)

6. Scientists investigated how the concentration of protein in blood plasma changes in people between the ages of 60 and 95.

The graph shows the scientists' results. The bars show ±1 standard deviation.



(a) What is the difference between males and females in the fall in mean concentration of protein in blood plasma between 60 and 95 years?

Answer = _____ g dm^{-3}

(1)

(b) Use the graph above to calculate the rate of change of the mean concentration of protein in the blood plasma of males between the ages of 60 and 95.

Show your working.

Answer = _____ g dm^{-3} $year^{-1}$

(2)

(c) What can you conclude from the graph above about the effect of ageing on the mean concentration of protein in the blood plasma in males and females?

(2)

(d) The scientists measured the absorption of each sample of blood plasma using a colorimeter. They used a calibration curve to find the concentration of protein in samples of blood plasma.

Describe how the scientists could obtain data to produce a calibration curve and how they would use the calibration curve to find the concentration of protein in a sample of blood plasma.

(3)

(e) Older people are more likely to suffer from infectious diseases.

Suggest how this may be linked to the decrease in the mean concentration of protein in the blood as people get older.

(1)

(Total 9 marks)

7. Species richness and an index of diversity can be used to measure biodiversity within a community.

(a) What is the difference between these two measures of biodiversity?

_____

_____

(1)

Scientists investigated the biodiversity of butterflies in a rainforest. Their investigation lasted several months.

The scientists set one canopy trap and one understorey trap at five sites.

- The canopy traps were set among the leaves of the trees 16–27 m above ground level.
- The understorey traps were set under trees at 1.0–1.5 m above ground level.

The scientists recorded the number of each species of butterfly caught in the traps. The table below summarises their results.

Species of butterfly	**Mean number of butterflies**		**P value**
	In canopy	**In understorey**	
Prepona laertes	15	0	< 0.001
Archaeoprepona demophon	14	37	< 0.001
Zaretis itys	25	11	> 0.05
Memphis arachne	89	23	< 0.001
Memphis offa	21	3	< 0.001
Memphis xenocles	32	8	< 0.001

(b) The traps in the canopy were set at 16–27 m above ground level. Suggest why there was such great variation in the height of the traps.

_____

_____

(1)

(c) By how many times is the species diversity in the canopy greater than in the understorey? Show your working.

Use the following formula to calculate species diversity.

$$d = \frac{N(N-1)}{\sum n\,(n-1)}$$

where N is the total number of organisms of all species and n is the total number of organisms of each species.

Answer = _____

(3)

(d) The scientists carried out a statistical test to see if the difference in the distribution of each species between the canopy and understorey was due to chance. The P values obtained are shown in the table.

Explain what the results of these statistical tests show.

_____

_____

_____

_____

_____

(3)

(Total 8 marks)

8. Scientists investigated the effect of different types of animal farming on the diversity and number of dung beetles. They determined the number of dung beetle species and their total number on intensive (**I**), rough grazing (**R**) and organic (**O**) farms.

Figure 1 and **Figure 2** show some of their results.

Figure 1

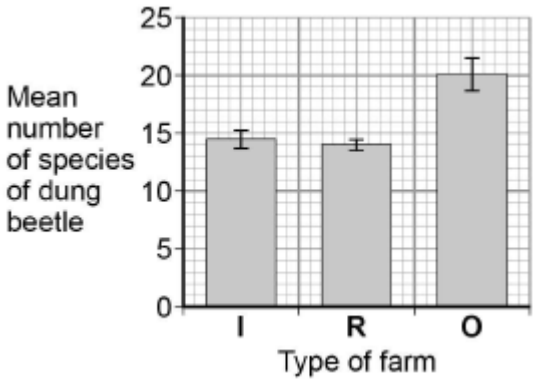
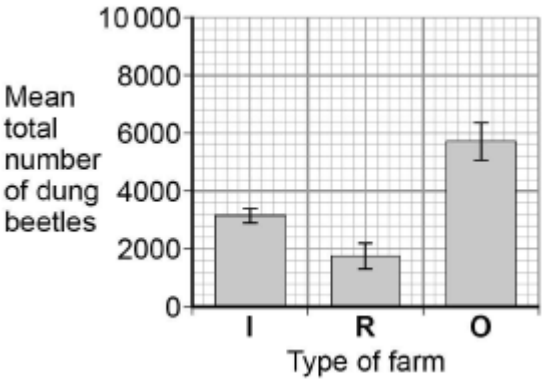


Figure 2



Key: I Standard deviation

(a) What is the mean species richness for dung beetles on the rough grazing farms?

_____

(1)

(b) In addition to the information provided in **Figures 1** and **2**, what other measurement is required to calculate an index of diversity for dung beetles?

_____

_____

(1)

(c) Explain what the standard deviations suggest about the difference in mean total number of dung beetles between the different types of farm.

_____

_____

_____

_____

_____

(2)

(d) The scientists placed traps to collect the dung beetles at sites chosen at random.

Explain the importance of the sites being chosen at random.

(1)

(e) On the intensive farms, the farmers had removed hedges to increase land for grazing. This resulted in a decrease in the diversity of birds on these farms.

Explain why the removal of hedges caused a decrease in the diversity of birds.

(3)

(Total 8 marks)

Mark schemes

1.

(a) 1. No oxygen can enter;

2. Ethanol produced during anaerobic respiration;

OR

3. No ethanol / carbon dioxide can escape;

4. Allows accuracy of measuring;

OR

5. To prevent entry of / contamination with microorganisms;

6. Prevent competition with yeast;

Any two pairs of answers

Second mark of each pair must be related to the first point of the pair.

4 max

(b) 1. Yeast respiring aerobically;

2. Oxygen used equal to carbon dioxide produced;

2

(c) 1. 7.0 / 7;

2. Ethanol production starts;

2

(d) (i) 1. Repeat;

2. Identify anomalies / see if results are similar / enough results for statistical test / give more reliable mean;

3. Carry out statistical test / statistical analysis;

4. Ensure results are significant / find probability of results being due to chance;

5. Peer review;

6. Allows procedure to be checked / see if other scientists get similar results;

Two pairs of linked points, each pair a suggestion and an explanation. The explanation must relate to the suggestion to gain the second point of the pair.

4

(ii) 1. Curve levelling off / rate of increase is decreasing / very little extra ethanol produced;

2. Becomes less cost effective / less profit;

2. Accept a description of cost effectiveness

2

(iii) 1. (Funding agency) might want particular results;

2. Results may be withheld / results may not be published / results may be confidential;

2 max

[16]

2. (a) Active site (complementary / specific) structure / shape;
(Only) fits / binds to gangliosides;
Forms enzyme-substrate complexes;

OR

Active site (complementary / specific) structure / shape;
(Does not) fit / bind with other lipids;
Does not form enzyme-substrate complexes;

Note: 'active site has a specific shape' = 2 marks;
Reject: same shape

Second mark for either route can refer to the enzyme or the substrate

Accept: converse of second mark point and (different) structure / shape if referring to other lipids

3 max

(b) (i) No change / substrate remains high / horizontal line;

Curve should be labelled
*If curve **H** correctly labelled then assume other is curve **T***

Reject: obvious rise or fall / rise then plateau

1

(ii) Curve decreases rapidly at first then more slowly;

Curve should be labelled

*If curve **T** correctly labelled then assume other is curve **H***

Reject: falling at a slower rate initially

1

(c) (Enzymes are) proteins;
Digested / broken down / destroyed (by enzymes / acid);

OR

(Enzymes are) too large;
To cross cell membranes / be absorbed / enter the bloodstream;

Accept: denatured (by acid)

Neutral: digested by saliva

Reject: digested by amylase

Neutral: will not reach the bloodstream

2

[7]

3. (a) 9 (hours);;

If multiply 75 by 0.11 and 0.23 but wrong answer, then 1 mark

*Accept for **one** mark if multiply 75 by two wrong proportions near to 0.11 ± 0.01 and 0.23 ± 0.01 or multiply by the difference between the two (wrong) proportions*

2

(b) (Yes because)

1. Both/Each species (mean) time spent looking around greater where many predators;
2. Differences (appear to be) significant because SDs do not overlap;

(No because)

3. Wildebeest spend same (mean) time looking around where many predators as impalas where few predators;
4. Don't know what they are looking for (when heads up);
5. Habitats might be different in different areas (which could affect the behaviour);

Accept 'mean proportion' means 'time'

1. Require idea of both, not just quoting numbers

2. This point must be in the context of point 1

2. Do not accept results significant

2. Accept 'because bars do not overlap'

2. Do not accept SE for SD

3. Accept overlap in SD as equivalent to same time

5. Ignore 'other factors' unqualified and discussions of experimental variables

4 max

(c) 1. Less time spent feeding

OR

More energy lifting head/looking round;

2. (So) less food/biomass for respiration

OR

less energy for growth/reproduction/care of young;

OR

3. Raising head makes them more visible to predators;

4. So more likely to be attacked/eaten/killed;

2. Accept any appropriate suggestion of less energy for something to do with life of the herbivore

2. Allow less food/biomass for growth/reproduction

2. Ignore references to energy for respiration

2

[8]

4.

(a) (i) Temperature and light;

1

(ii) Increase in temperature causes increase in rate of photosynthesis / uptake of carbon dioxide;

Increase in light / more / medium / high light (intensity) causes increase in rate of photosynthesis / uptake of carbon dioxide;

2

(b) 2.75 – 2.81 (mg g^{-1} hr^{-1})

Accept answers in range 2.75 – 2.81

1

(c) 1. Growth will decrease (at higher temperature);

2. Rate of respiration will increase at higher temperature;

3. Photosynthesis decreases as limited by light / as there is less light;

Ignore references to effect of temperature on rate of photosynthesis

3

[7]

5.

(a) 1. In source / leaf sugars actively transported into phloem;

2. By companion cells;

3. Lowers water potential of sieve cell / tube and water enters by osmosis;

4. Increase in pressure causes mass movement (towards sink / root);

5. Sugars used / converted in root for respiration for storage.

Accept starch

4 max

(b) Respiration.

1

(c) 1. (About) 30 hours;

2. Time between peak ^{14}C at top of trunk and bottom.

2

(d) Length of trunk (between top and bottom).

1

[8]

6. (a) 6 (g dm^{-3});

1

(b) Correct answer of (−)0.14;
1 mark for correct difference in concentration (5) divided by 35 / (69 − 64) ÷ 35 / 1 ÷ 7

Ignore +/- sign

Ignore additional d.p.

Accept 0.31(4) for 1 mark if female data used

2

(c) 1. Protein content decreases with age and decreases more in females;
2. Difference (between sexes) only significant at 95 years because SDs do not overlap;
OR
Differences not significant because 2 × SD would overlap;

2

(d) 1. Produce known concentrations of protein;
2. Measure absorbance of each concentration
OR
Measure each concentration with colorimeter;
3. Plot a graph of absorbance on y-axis against concentration (on x-axis) and draw curve;
4. Use absorbance of sample to find protein concentration from curve;

1. Idea of known concentrations required.

Accept % transmission / absorption for absorbance

3 max

(e) 1. (Lower plasma protein concentration suggests) fewer antibodies;

Ignore ref. to other proteins.

Reject answers which refer to white blood cells as proteins.

1

[9]

7. (a) Species richness measures only number of (different) species / does not measure number of individuals.

1

(b) Trees vary in height.

1

(c) 1. Index for canopy is 3.73;
2. Index for understorey is 3.30;
3. Index in canopy is 1.13 times bigger;

If either or both indices incorrect, allow correct calculation from student's values.

3

(d) 1. For *Zaretis itys*, difference in distribution is probably due to chance / probability of being due to chance is more than 5%;
2. For all species other than *Zaretis itys*, difference in distribution is (highly) unlikely to be due to chance;
3. Because P < 0.001 which is highly significant / is much lower than 5%.

3

[8]

8.

(a) 14;

1

(b) Number (of individuals) in each species (of dung beetle);

Accept: population of each species.

1

(c) 1. No overlap in standard deviations;

Accept: no overlap in error bars.

2. (Difference in mean total) significant/is not due to chance/is real;

2

(d) No bias;

Ignore: 'representative sample'.

1

(e) 1. Removes species/types of plant/insect;

Accept: decrease in plant/insect diversity.

2. Fewer food sources;

Ignore: less food.

Accept: less variety of food.

Accept: removes a food source.

3. Fewer habitats/niches;

Accept: loss/removal/destruction/ of a habitat.

Accept: no habitat.

Ignore: homes/shelters.

3

[8]