IB · DP · Biology

🕐 3 hours   ❓ 12 questions
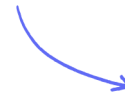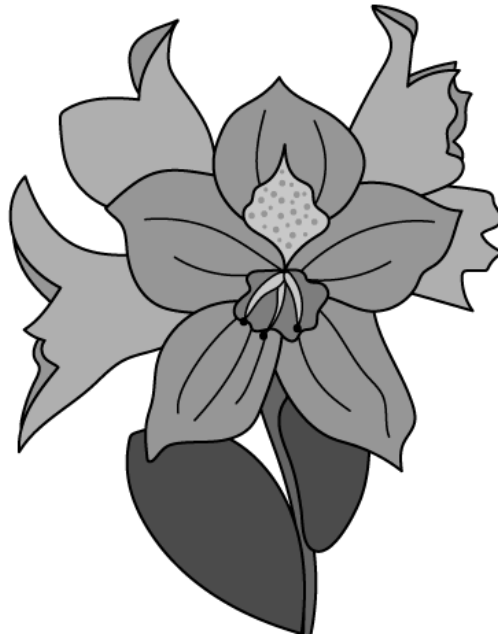
Structured Questions: Paper 2

7.1 Data Questions

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Total Marks	/157

1 (a) *Rhododendron ponticum* (pictured below) is a fast-growing, non-native, invasive species currently threatening biodiversity in the UK.


Rhododendron ponticum

Originally introduced from Spain as a decorative plant for gardens, *R. ponticum* forms large thickets and outcompetes native plants such as bryophytes, other woody plants and wildflowers. Particularly severely affected are Atlantic oak woodland areas of coastal land in the western United Kingdom. Clearance programmes to remove *R. ponticum* have been in place for approximately 30 years in that region. Data was gathered on how the removal of *R. ponitcum* allows for affected sites to recover and for native species to be restored.

A quadrat study was carried out at three sites:

- An area of dense *Rhododendron ponticum* thickets
- An area of intermediate *ponticum* coverage
- An area of uninvaded land as a control

In each study, the number of species in each area's understorey was counted, as well as the % vegetation cover. This data is shown on the graphs below, which have been plotted with a line of best fit.
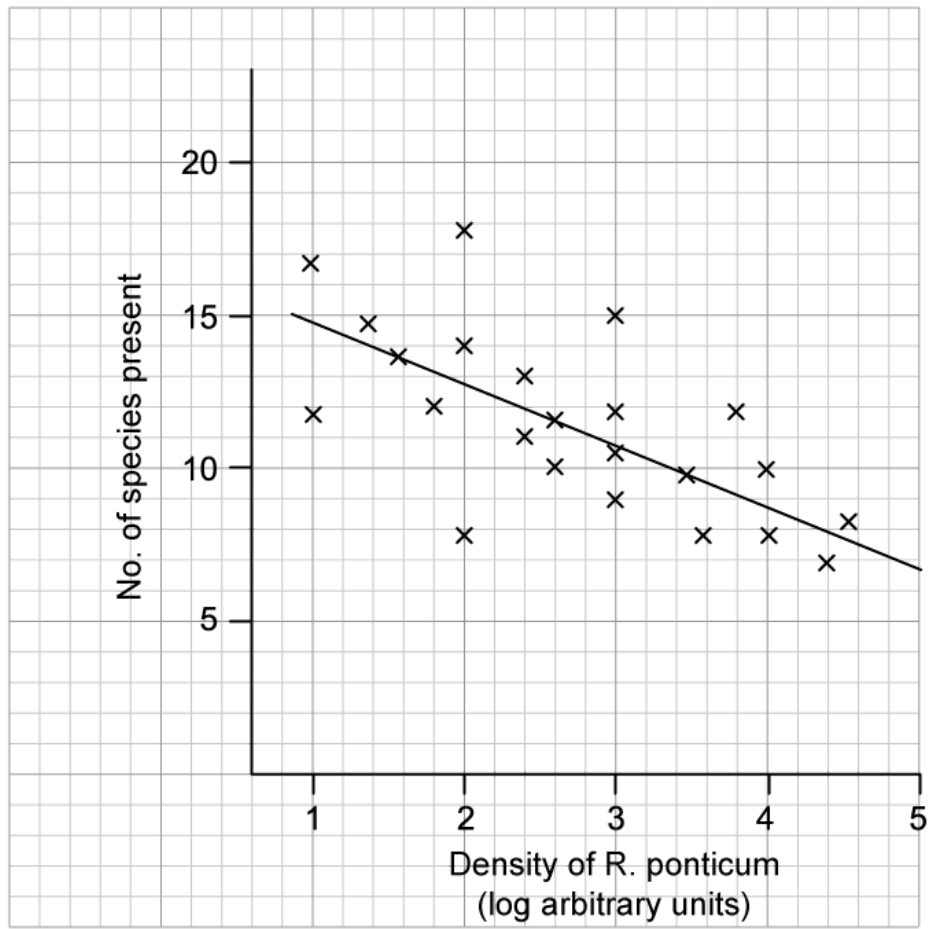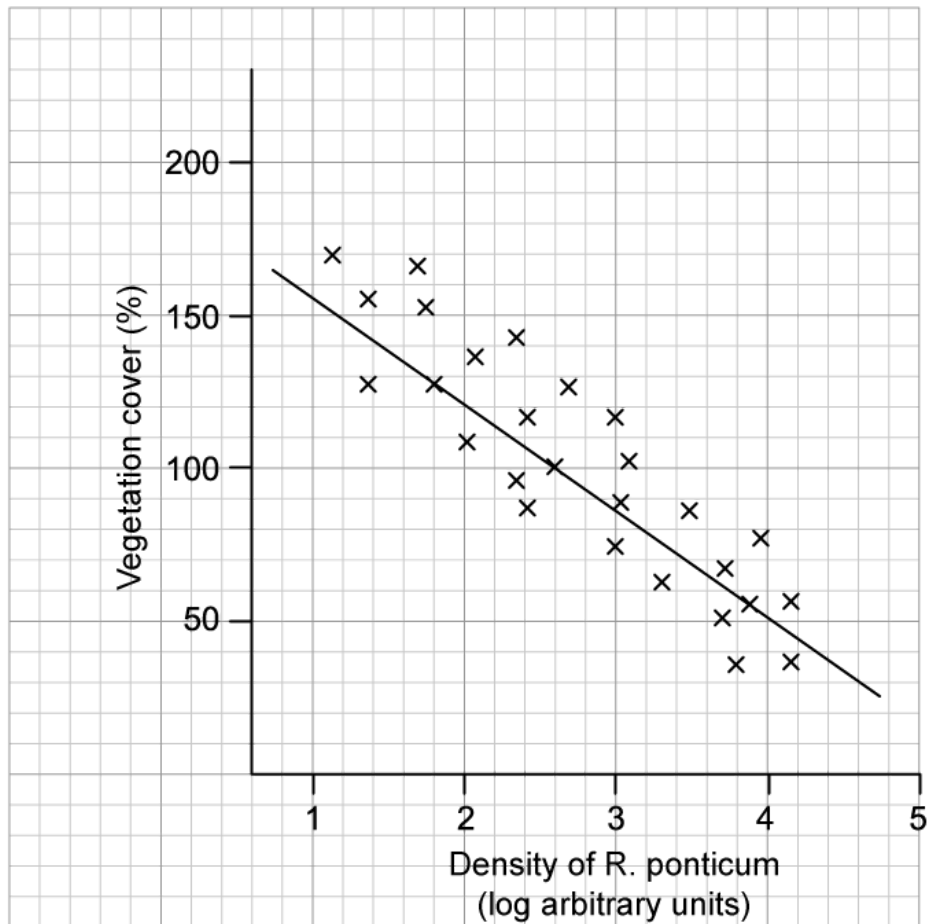
Calculate the range of species found at a *R. ponticum* density of 2 log arbitrary units.

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(1 mark)

(b) State how the % vegetation cover can exceed 100% in a given area.

....

(1 mark)

(c) Suggest why a log scale is used to show the density of *R. ponticum* in the graphs.

....

(1 mark)

(d) Explain the decline in the number of species found as the density of *R. ponticum* increases, as found in this study.

(e) Suggest **two** ways in which *R. ponticum* could affect competition.

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(f) In an extension of this study, the spread of epiphytes (plants that grow on other plants, but not parasitically) was examined as a function of the time elapsed since the human clearance of *R. ponticum* from an area of ancient woodland. Typical taxa of epiphytes include mosses and liverworts. This was done to estimate how well a woodland habitat could recover from an invasion by *R. ponticum*. One theory is that *R. ponticum* can affect successive species long after all its biomass has been cleared away from a site. The results are shown in the diagram below.
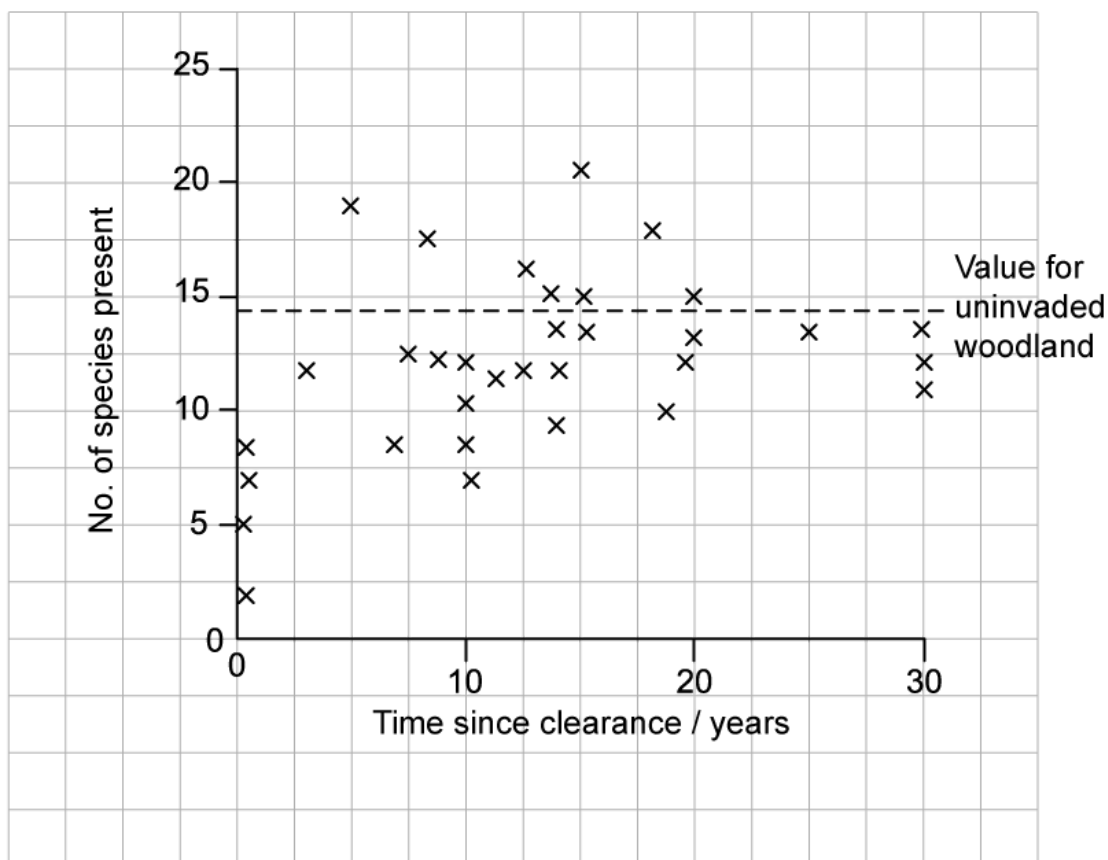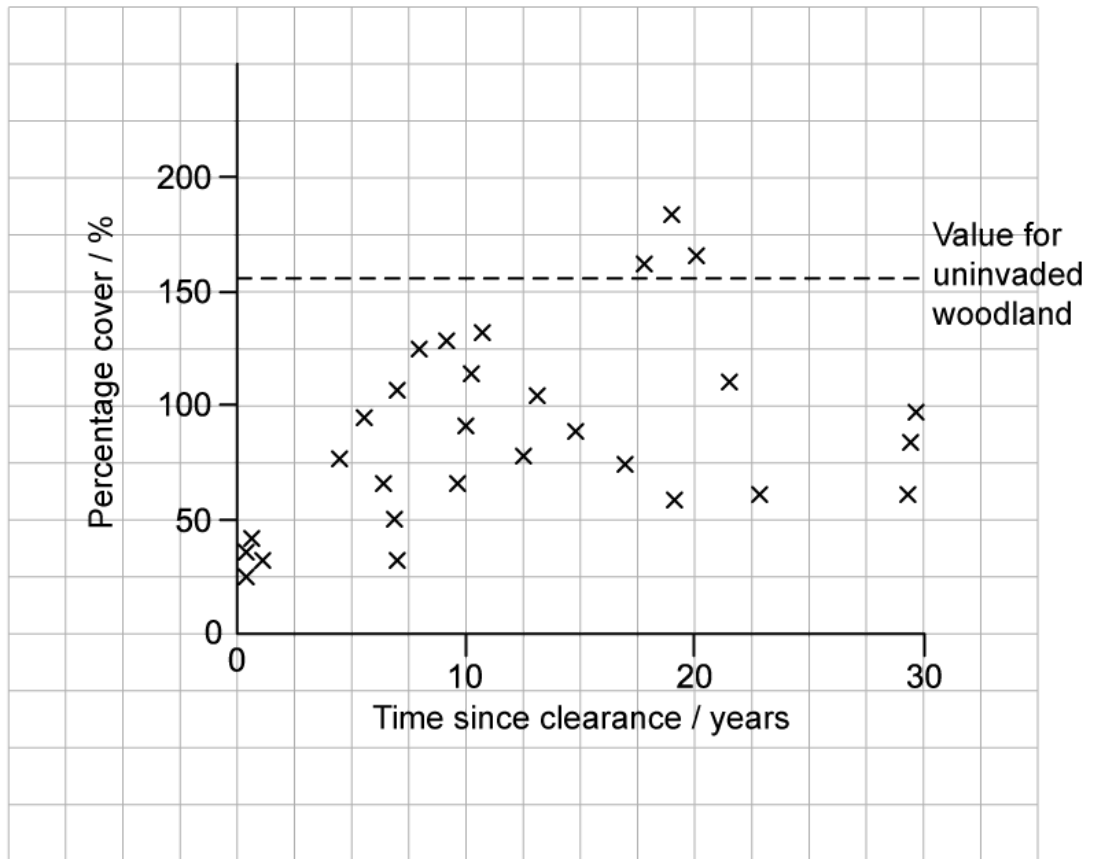
Estimate the number of years before the number of species found on cleared land first exceeded the number of species found in uninvaded woodland.

....

(1 mark)

(g) (i) Discuss whether the clearance of a *R. ponticum* invasion has an impact on the recovery of the woodland habitat.

[2]

(ii) Suggest a reason for any impact observed.

[1]

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(3 marks)

(h) In a further study, a series of measured soil core samples were taken from thirty sites within the Atlantic woodland

- 10 sites uninvaded by R. *ponticum*
- 10 sites cleared of *R. ponticum* more than 10 years previously
- 10 sites of dense R. *ponticum* coverage

The seeds contained within those samples were germinated in a laboratory greenhouse to display which species were present as ungerminated seeds in the soils. The study ran for 20 weeks. Control trays containing sterile compost showed negligible seedling growth.

The table below shows a summary of the results obtained.

Species		No of seedlings emerging in greenhouse trial	Number of sites where ungerminated seeds were found		
			Uninvaded	Cleared	Dense *R. ponticum* growth
European Poplar	*Populus tremula*	2 959	10	10	10
Rushes sp.	*Juncus sp.*	624	10	7	8
R. ponticum	*Rhododendron ponticum*	302	0	10	5
Broadleaf carpet grass	*Axonopus compressus*	402	10	2	3
Small cow wheat	*Melampyrum sylvaticum*	333	4	2	2
Others		2 566	125	51	42
		7 186	**159**	**82**	**70**

(i) Identify the species that was sampled on the fewest sites when the *R. ponticum* growth was densest.

[1]

(ii) Explain what this data shows for the prospects of growth of broadleaf carpet grass (*Axonopus compressus*) on cleared land following an *R. ponticum* invasion.

[2]

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(3 marks)

(i) Using the data in part (h), identify, with a reason, the species that benefited most from the clearance of *R. ponticum* from Atlantic coastal woodland.

....

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(2 marks)

2 (a) Agriculturalists in Mozambique investigated the optimum planting conditions for sweet potato plants. Sweet potato (*Ipomoea batatas*) is a popular root crop, with increasing use as a staple vegetable. Variables under investigation were the spacing of seed sowing and the optimum use of fertilisers to achieve a maximum yield.

Plant spacing (16, 20 and 25 cm between plants) was combined with three nitrogen addition rates of 30, 35 and 40 grams per square metre (gm^{-2}) in separate test plots of area $1.5m^2$. The source of nitrogen used in the study was urea (CH_4N_2O). Other growing conditions were kept constant, to determine the optimal combination of spacing and nitrogen addition.

The study ran for 175 days after planting individual *I. batatas* seeds in the respective conditions. The results of the study are summarised in the table below.

Spacing distance / cm	Urea level added / g per m^2	Mean underground dry mass / g per plant	Mean Crop Yield / tonnes per hectare*
	30	30	12.9
16	35	54	21.4
	40	58	19.8
	30	17	7.6
20	35	148	40.3
	40	141	35.6
	30	42	10.8
25	35	187	12.8
	40	15	8.4

* 1 hectare = 10 000m^2

Identify the growth conditions that gave the most favourable yield of sweet potatoes in this study.

....

(1 mark)

(b) Describe the relationship between the mean underground dry mass of the crop and the mean crop yield of sweet potatoes in this study.

....

(1 mark)

(c) Suggest, with a reason, why underground dry mass is used as an indicator of crop yield in this study.

....

(1 mark)

(d) Compare and contrast the effects of increasing spacing and increasing urea addition, in terms of underground dry mass and crop yields.

....

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(3 marks)

(e) Suggest, with a reason, why the choice of units of crop yield quoted in this study (tonnes per hectare) was not an appropriate one.

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(2 marks)

(f) In another part of this investigation, the mass of plant matter above ground (both fresh mass and dry mass) was measured against leaf length and crop yield for the three levels of urea concentration previously tested. All these data were gathered from sweet potato plants spaced at 20cm distance. The results are shown in the graph below.
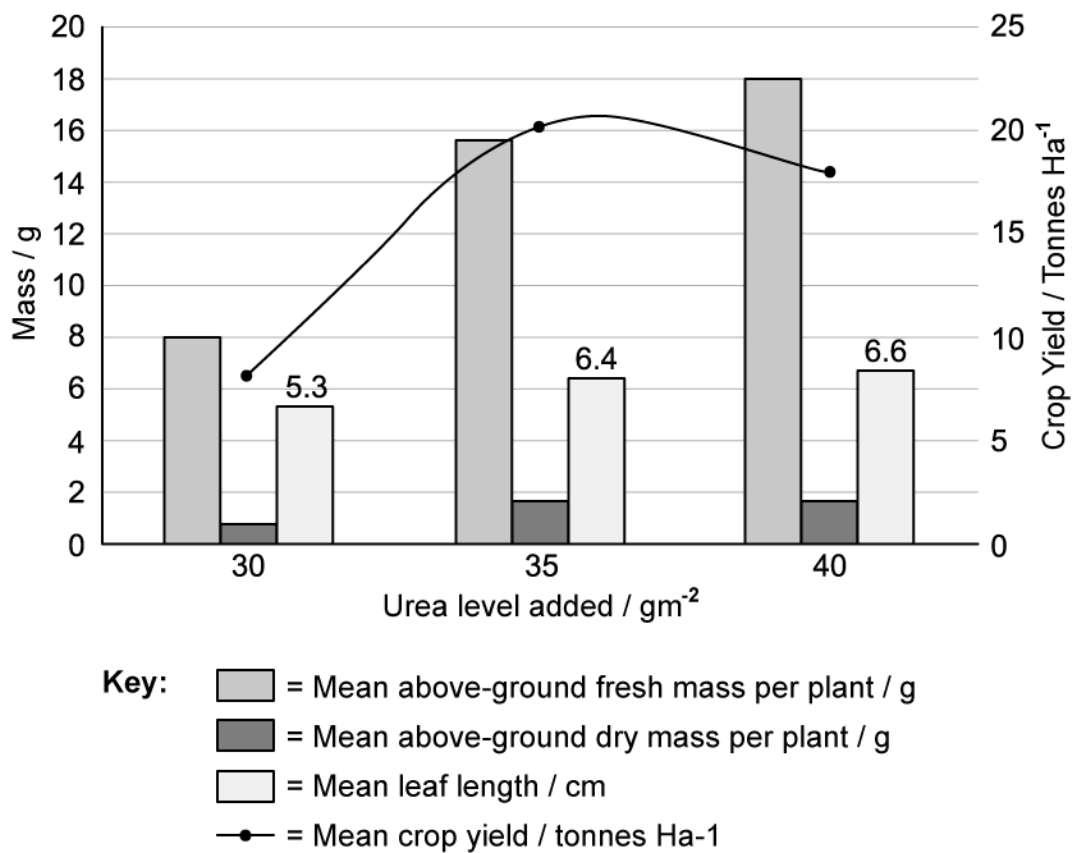
The scientists concluded that a planting regime of plants spaced 20cm apart with an addition of urea more than 35 gm^{-2} should be recommended to farmers. Evaluate the scientists' conclusion, using the data above and from part a).

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(4 marks)

3 (a) EDTA is a compound that reacts with metal ions to form a stable harmless compound. It is commonly used to reduce levels of calcium in many medical procedures including dental work. EDTA has also been shown to have antimicrobial properties effective in the treatment of *Staphylococcus aureus* bacteria.

Scientists wanted to establish how effective EDTA could be in the treatment of infections from *Escherichia coli* bacteria. The growth of *E.coli* bacteria was monitored in response to treatment with EDTA over a period of 5 days. The chart below shows the results.
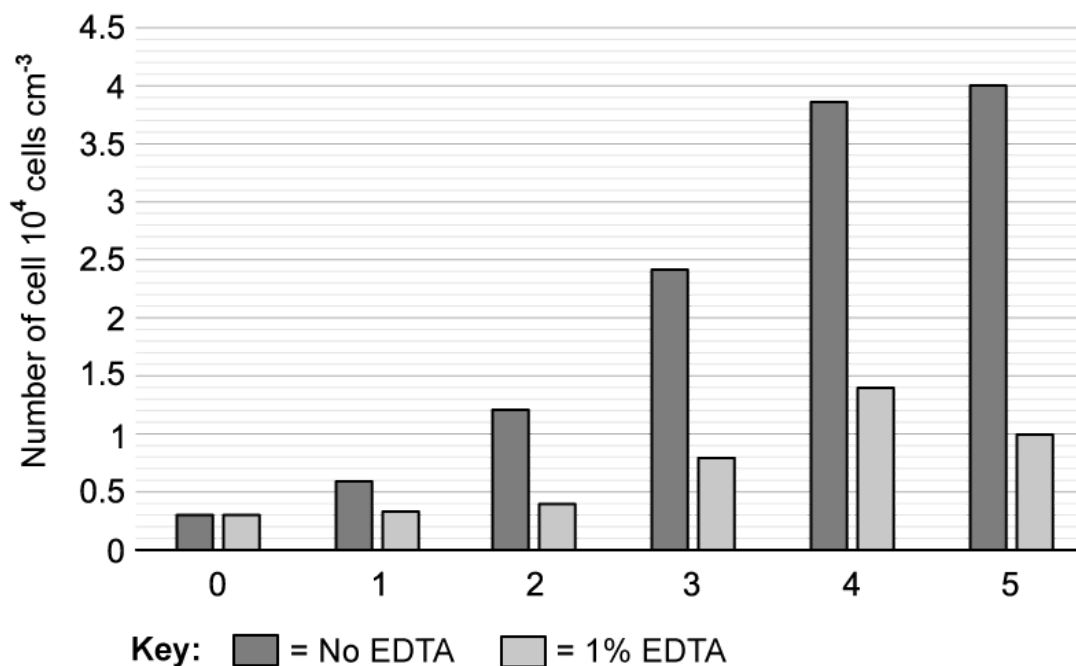
State the reason for the group treated with no EDTA.

....

(1 mark)

(b) Calculate the percentage difference between the number of bacteria in the sample treated with EDTA and the number of bacteria in the untreated sample after 5 days.

....

(1 mark)

(c) Outline the effect of EDTA on the growth of bacteria.

....

(d) The presence of antibiotic resistance within *E.coli* populations was studied and presented in the graph below.

Key: ——— = Amoxicillin   – – – = Tetracycline
         ——— = EDTA   ------ = Pivmecillinam hydrochloride
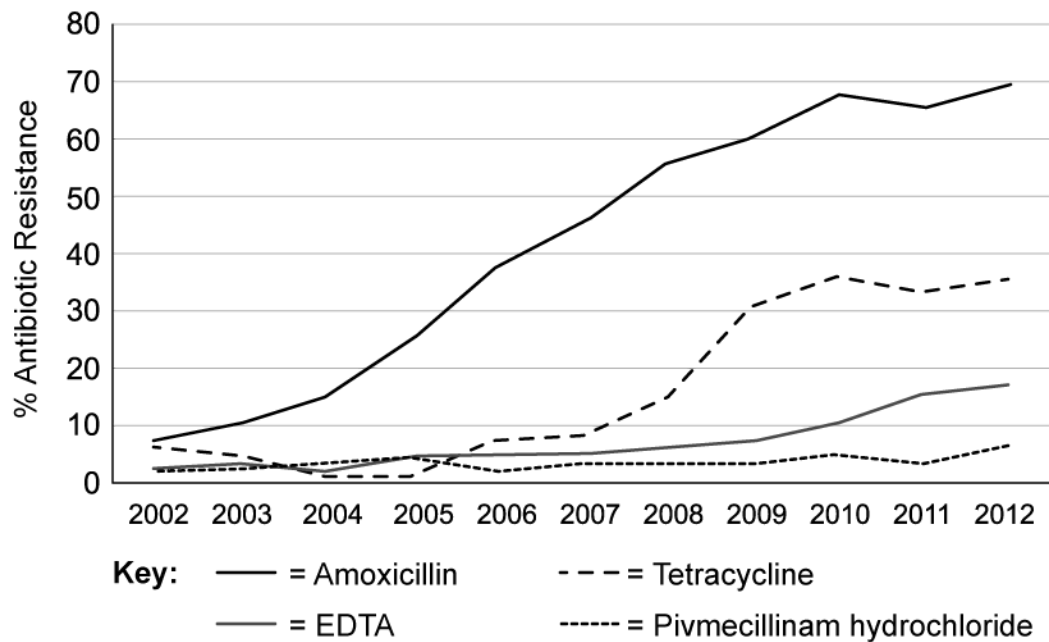
Identify which antibiotic has been shown to be the least effective against *E.coli.*

(1 mark)

(e) Compare the levels of antibiotic resistance shown in *E.coli* to the antibiotics studied.

(2 marks)

(f) The table below shows some of the side effects associated with the antibiotics studied.

Antibiotic	Side effects
EDTA	Abdominal cramps, nausea, vomiting, diarrhoea, headache, low blood pressure, skin problems and fever.
Amoxicillin	Abdominal cramps, back and leg pains, bloating, blood in urine, chest pains
Tetracycline	Nausea, vomiting, diarrhoea, loss of appetite, mouth sores, black hairy tongue, sore throat, headache
Pivmecillinam hydrochloride	Diarrhoea, feeling sick, thrush

Using all the information provided, evaluate whether EDTA is the best candidate antibiotic to treat *E.coli*.

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(3 marks)

(g) Suggest **two** different methods that could be used to help reduce the development of antibiotic resistance.

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(2 marks)

4 (a) In trained athletes, the metabolism of lactate can occur at a fast enough rate to reduce the build-up of lactic acid. As a result, trained athletes are able to maintain a lower lactate level even during periods when their heart rate is very high, compared to an untrained individual. A study was done to compare the blood lactate levels to the heart rate of 5 individuals during exercise.

Individual	Blood Lactate / mol per L	Average V_E / L per min	Heart Rate / min^{-1}
1	1.8	60.1	156
2	2.8	83.1	163
3	4.9	79.8	148
4	5.0	88.9	152
5	9.5	148.0	184

If training allows an individual to maintain a low blood lactate level compared to heart rate, identify which is the most highly trained individual from the study.

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(1 mark)

(b) Maximum minute ventilation (V_E) is a measure of the maximum total volume of gas inhaled or exhaled per minute (measured in L/min). During exercise, V_E changes to accommodate changes in metabolic requirements, this variability around V_E is called V_E variability and is measured in mL/min. Both V_E and V_E variability can be used as indicators of fitness

The graphs below show the differences in V_E variability and maximum V_E from a study of trained and untrained individuals.

Maximum V_E
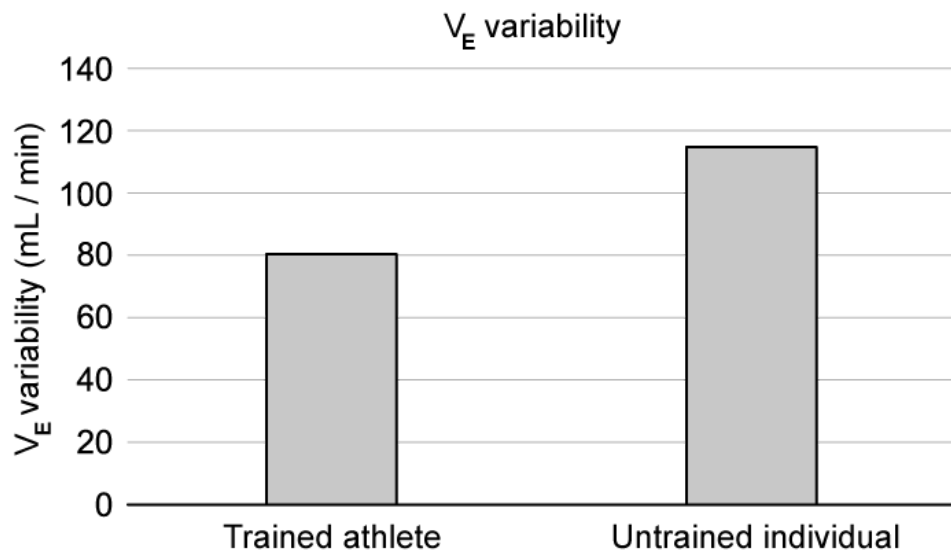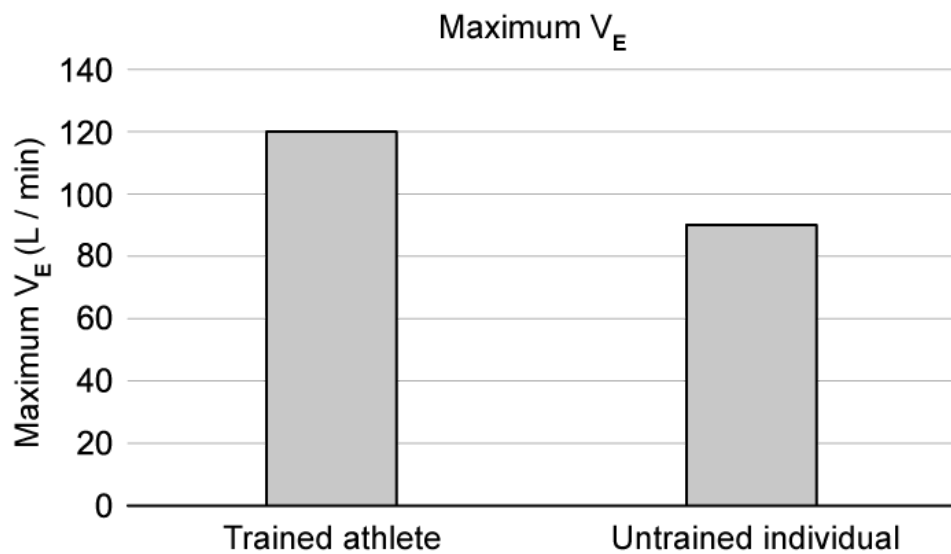
V_E variability

Describe the relationship between training, maximum V_E and V_E variability.

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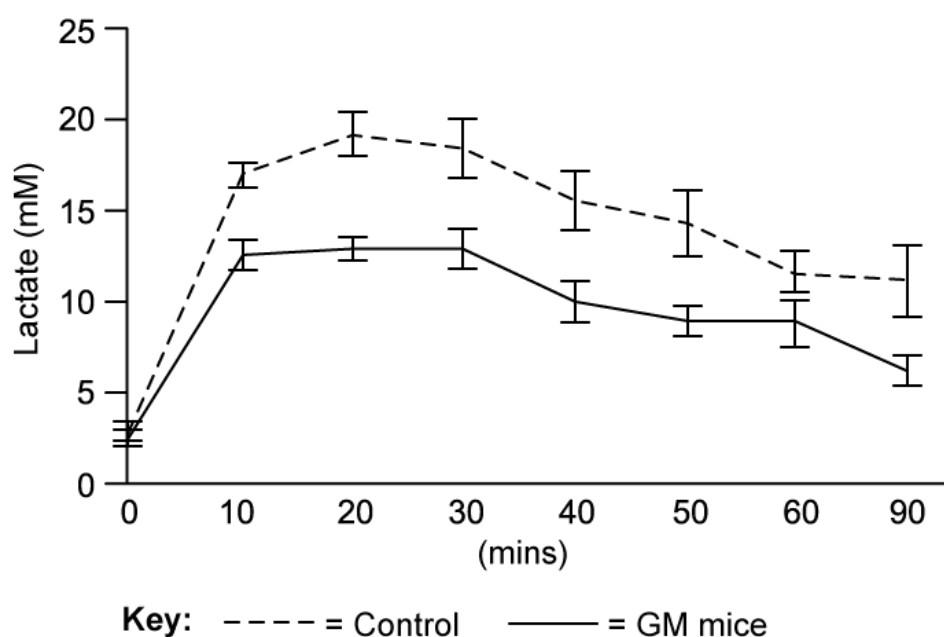
(2 marks)

(c) Using the information provided, discuss the statement that individual **3** and individual **4** are both equally as fit.

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....

....

(3 marks)

(d) A study was done to show how the expression of a gene associated with lactate metabolism would influence exercise performance. Mice were genetically modified (GM) by inserting a gene responsible for the synthesis of a protein involved in lactate metabolism, protein X.

Lactate levels in the two groups of mice were monitored throughout a period of exercise.

Compare the lactate levels of the control group to the GM group.

....

....

(2 marks)

(e) High levels of lactic acid is a characteristic symptom in individuals suffering from diabetes. It can lead to more serious and potentially life-threatening issues such as lactic acidosis. Scientists suggested that protein X could be used as a treatment for high lactate levels in diabetics.

Using the information provided, evaluate whether there is enough evidence to support the use of protein X in the treatment of diabetes.

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(3 marks)

(f) During exercise, V_E increases as a mechanism to reduce the risk of lactic acidosis (high levels of lactic acid).

Suggest how this increase in V_E may prevent lactic acidosis.

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(2 marks)

5 (a) Net primary productivity (NPP) is a measure of the amount of carbon stored as biomass by primary producers. NPP is calculated using the total amount of carbon that the plant fixes during photosynthesis, minus the total amount of carbon lost during respiration. Different ecosystems have different levels of productivity based on abiotic and biotic factors of the environment. The cycling of nutrients in the ecosystem determines the nutrients available to the plants for growth and therefore has a direct impact on the NPP of that ecosystem.

The table below shows the differences in decomposition cycles for six vital nutrients across three different biomes. A calculation has also been done to show the NPP of each biome.

	Time needed for 1 cycle of decomposition / years						
	Carbon (C)	Phosphorus (P)	Nitrogen (N)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	NPP / $g\ C\ m^{-2}\ yr^{-1}$
Boreal Forest	146.0	143.0	100.5	37.5	56.0	197.0	140.0
Mediterranean Forest	3.5	4.7	4.9	1.4	2.5	3.7	600.0
Tropical Forest	0.3	2.1	1.8	0.9	1.1	0.9	2200.0

Identify which biome shows the slowest rate of decomposition for the nutrients.

....

(1 mark)

(b) Suggest a biotic factor which may impact the decomposition rates generated in an ecosystem.

....

(1 mark)

(c) List **two** carbon-containing compounds found in plants.

....

(1 mark)

**(d)** With reference to the data in part (a), outline the differences between the rates of nitrogen cycling in all three forests.

....

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(2 marks)

(e) Describe the relationship between net primary productivity (NPP) and decomposition
rate for the three biomes.

....

....

(2 marks)

(f) A study was conducted to establish the relationship between different abiotic factors and
the rate of decomposition in a Mediterranean forest ecosystem. The data can be seen in
the graph below.
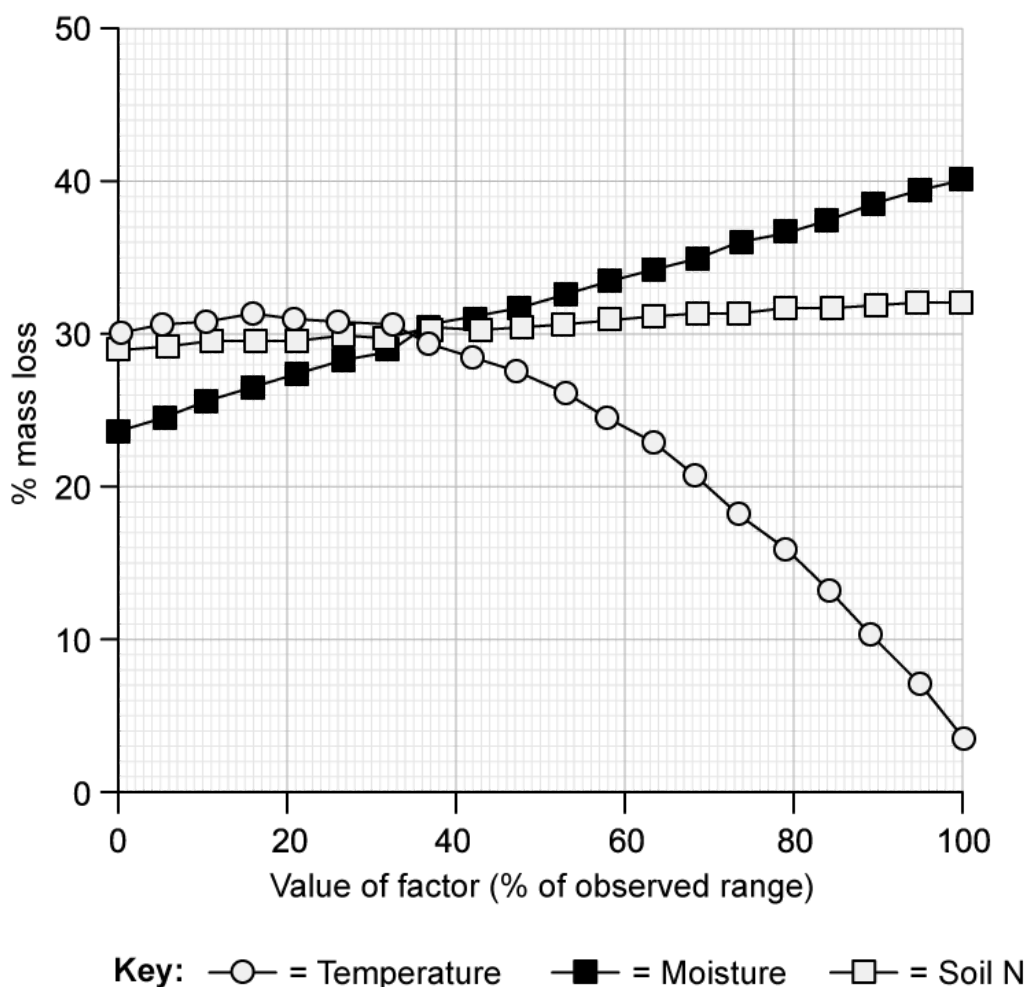
Identify which abiotic factor produced the biggest change in the rate of decomposition.

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(1 mark)

(g) Using the data given in part (f), compare the effects of the different abiotic factors on decomposition.

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(3 marks)

(h) Suggest the reason for the trend shown in decomposition as a result of temperature change.

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(2 marks)

(i) Using the data provided, deduce why tropical rainforests have the highest rate of productivity of the three biomes studied.

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(2 marks)

6 (a) Grey seals (*Halichoerus grypus*) are found in coastal waters around northern Europe and North America. Their diet consists of a variety of fish species, crustaceans, and molluscs, and they are known to dive for periods of up to 45 minutes while searching for food.

The graph below shows the blood flow to various organs in the body of a grey seal while they are either searching for food at the water's surface (i.e. not during a dive), or actively chasing prey, also at the water's surface.
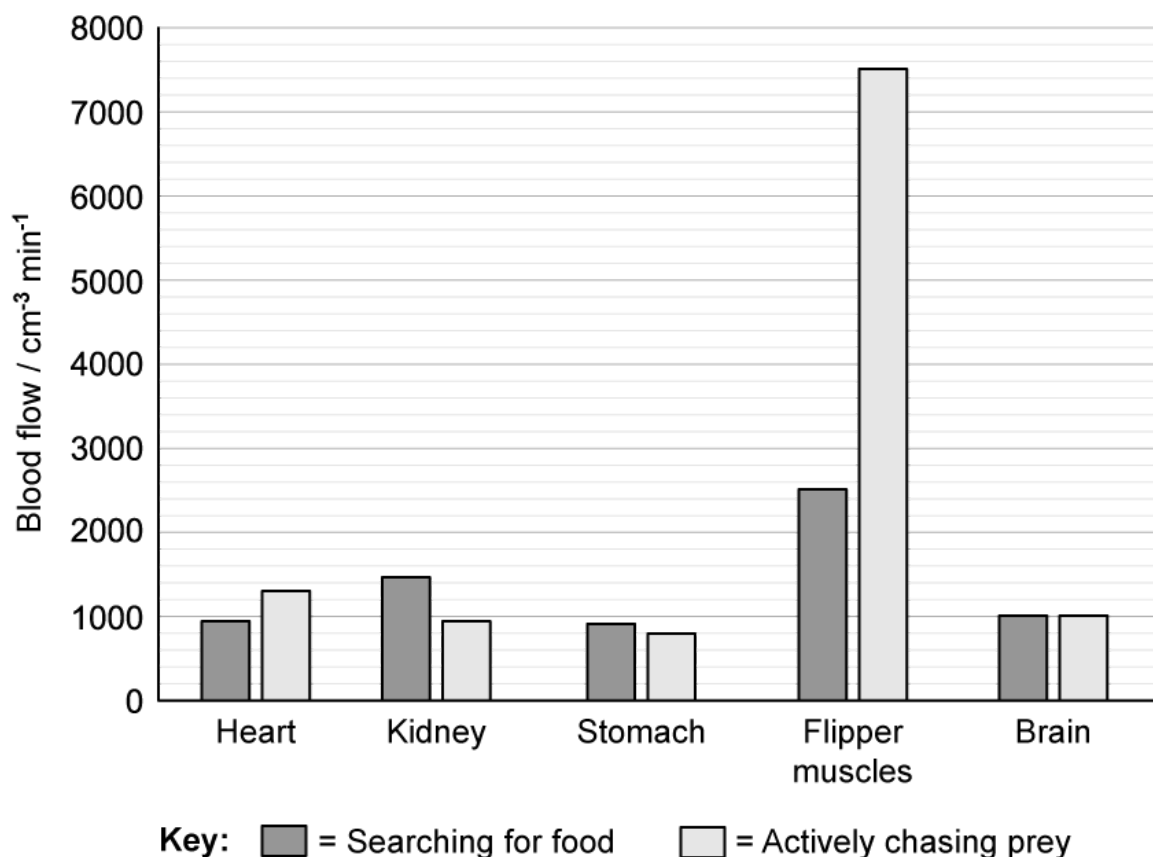
Estimate the difference in blood flow to the heart when the seal is searching for food compared to when it is actively chasing prey.

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(1 mark)

(b) Using the graph in part (a), distinguish between the blood flow when the seal is searching for food and when it is actively chasing prey between the kidneys, flipper muscles, and brain.

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(2 marks)

(c) Suggest why blood flow to the seal's organs is different when the seal is searching for food compared to when it is actively chasing prey.
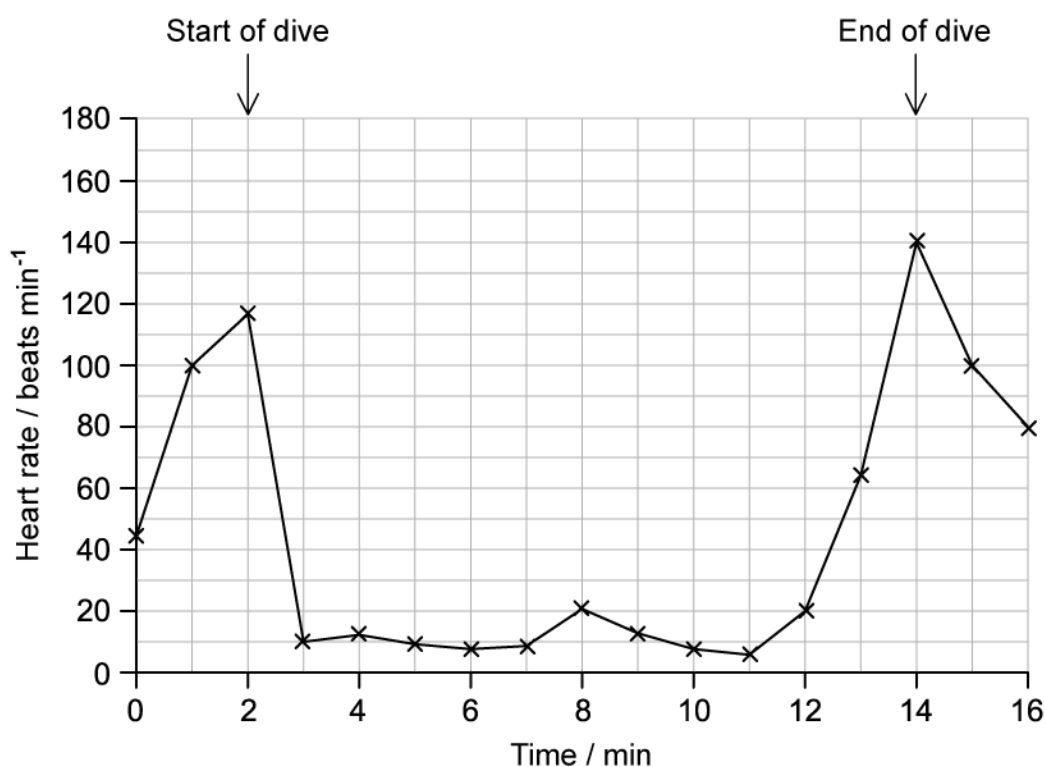
....

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....

(3 marks)

(d) State the property of arterioles that enables blood flow to the organs to be regulated.

....

(1 mark)

(e) Another grey seal's heart rate was measured before, during, and after a feeding dive.

The results are shown in the graph below.

Calculate the difference between the seal's minimum and maximum heart rate throughout the monitoring period.

....

(1 mark)

(f) Describe the changes in heart rate throughout the monitoring period shown in part (e).

....

....

(2 marks)

(g) Suggest how the heart rate changes shown in part (e) might affect the seal's body during a dive.

....

....

(2 marks)

**(h)** Deduce, with reference to both graphs, what would happen to the volume of blood passing through the flippers during a dive.

....

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(2 marks)

7 (a) Disease X is a potentially fatal disease found in sea urchins, with symptoms such as body deflation, body lesions, and discoloration. The cause of disease X has yet to be determined, and several hypotheses have been tested.

One such study investigated the possible connection between the presence of viruses known as densoviruses and disease X in several species of sea urchin.

Some of the results of the study are shown in the graph below.
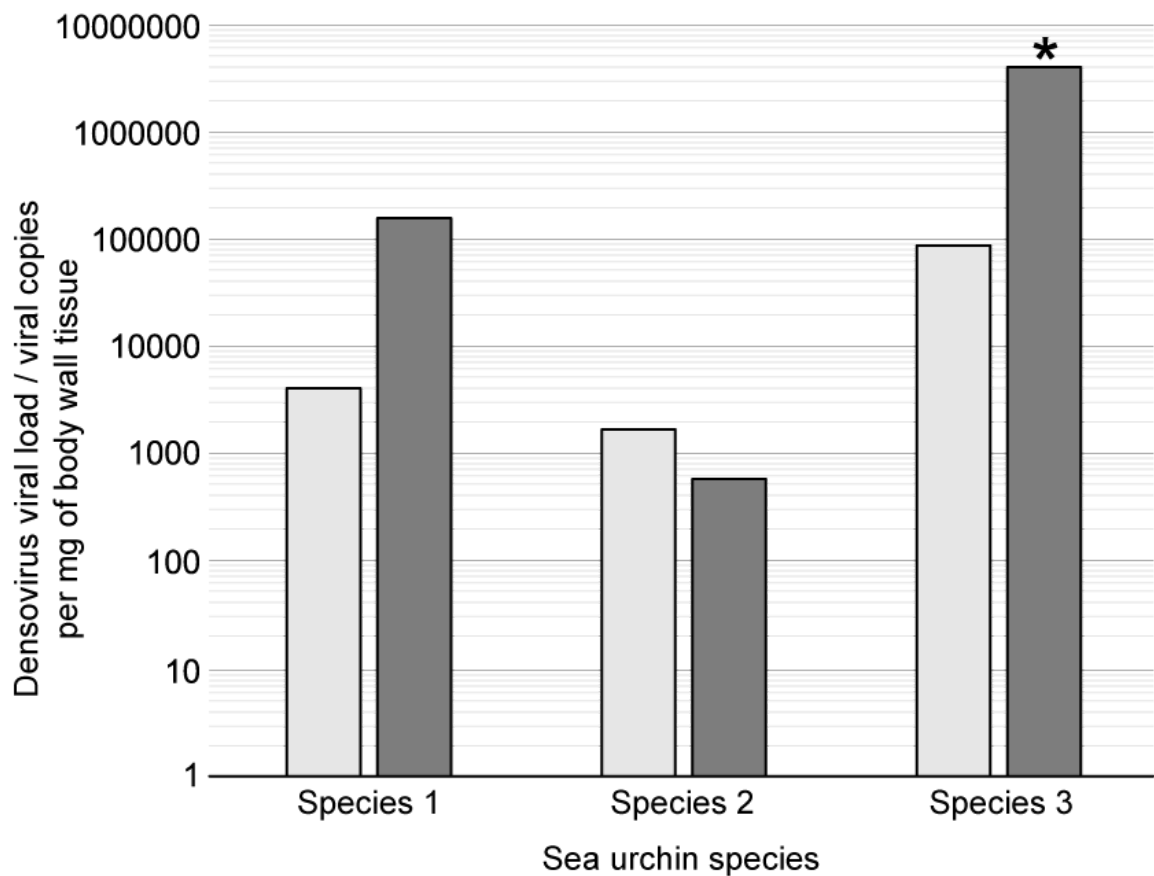
State the viral load of species 1 when symptoms are **not** present.

....

(1 mark)

(b) Compare and contrast the relationship between viral load and disease X symptoms in the different species studied.

....

....

(2 marks)

(c) Use the graph in part (a) to deduce the impact of densoviruses on disease X.

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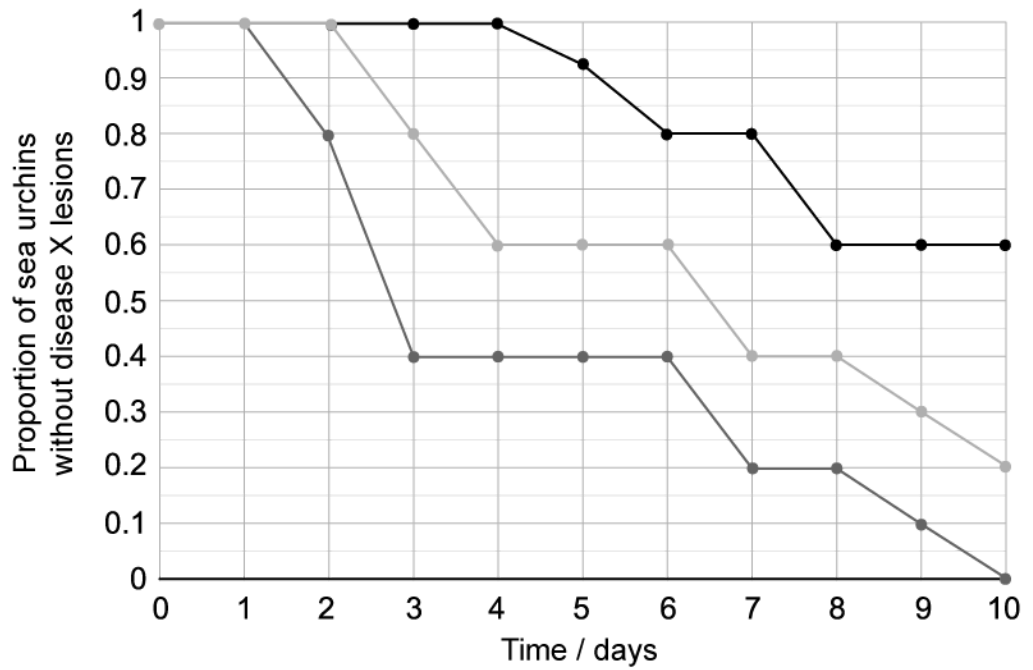
(2 marks)

(d) Aquatic organisms have a thin layer of water surrounding their bodies known as the diffusive boundary layer (DBL). Organisms exchange substances with their environment via this layer, and its composition is different to that of the surrounding seawater.

Another study looked at the impact of the composition of the DBL on the development of disease X. Two types of organic matter were added to the water surrounding sea urchins of species 2:

- Organic matter in the form of lab-grown algae.
- Seawater containing normal levels of organic matter.

The sea urchins were assessed over 10 days for signs of disease X lesions and the water in the DBL was tested for bacteria. Note that the control contained no additional organic matter.
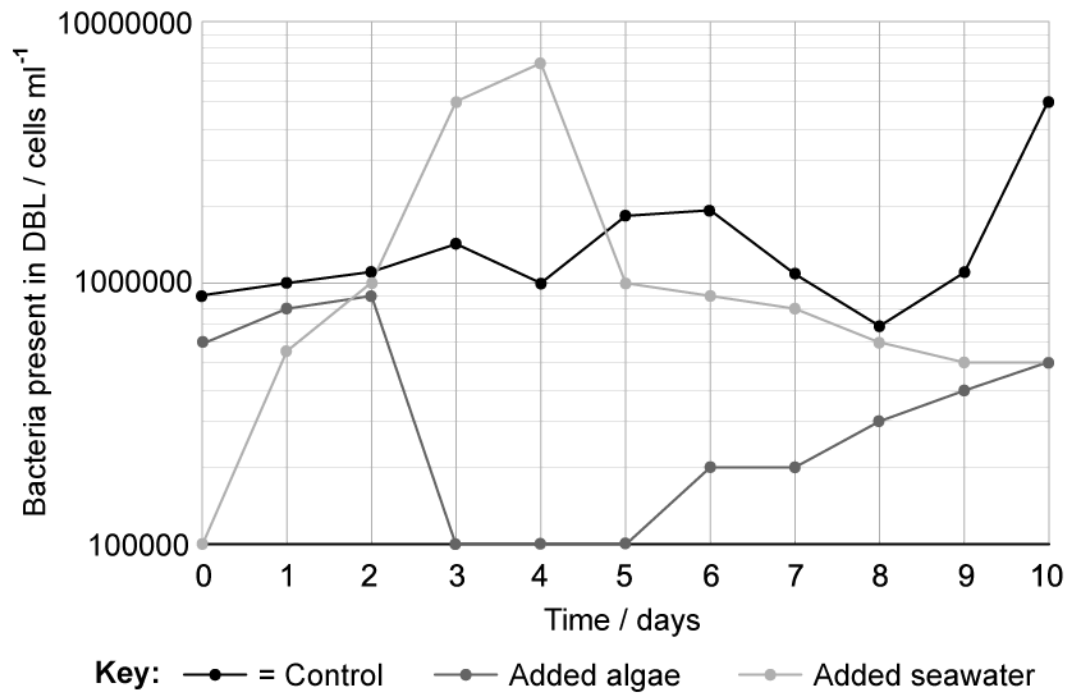
Describe the formation of disease X lesions over the testing period.

....

....

(2 marks)

(e) Discuss any observations on the growth of disease X lesions and the abundance of bacteria in the DBL shown in part (d).

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....

(2 marks)

(f) As part of the same study, the researchers looked at the impact of reduced oxygen levels in the DBL on lesion growth in a fourth species of sea urchin.

Their results are shown in the graph below.

Key: —•— = Control   —•— Depleted oxygen
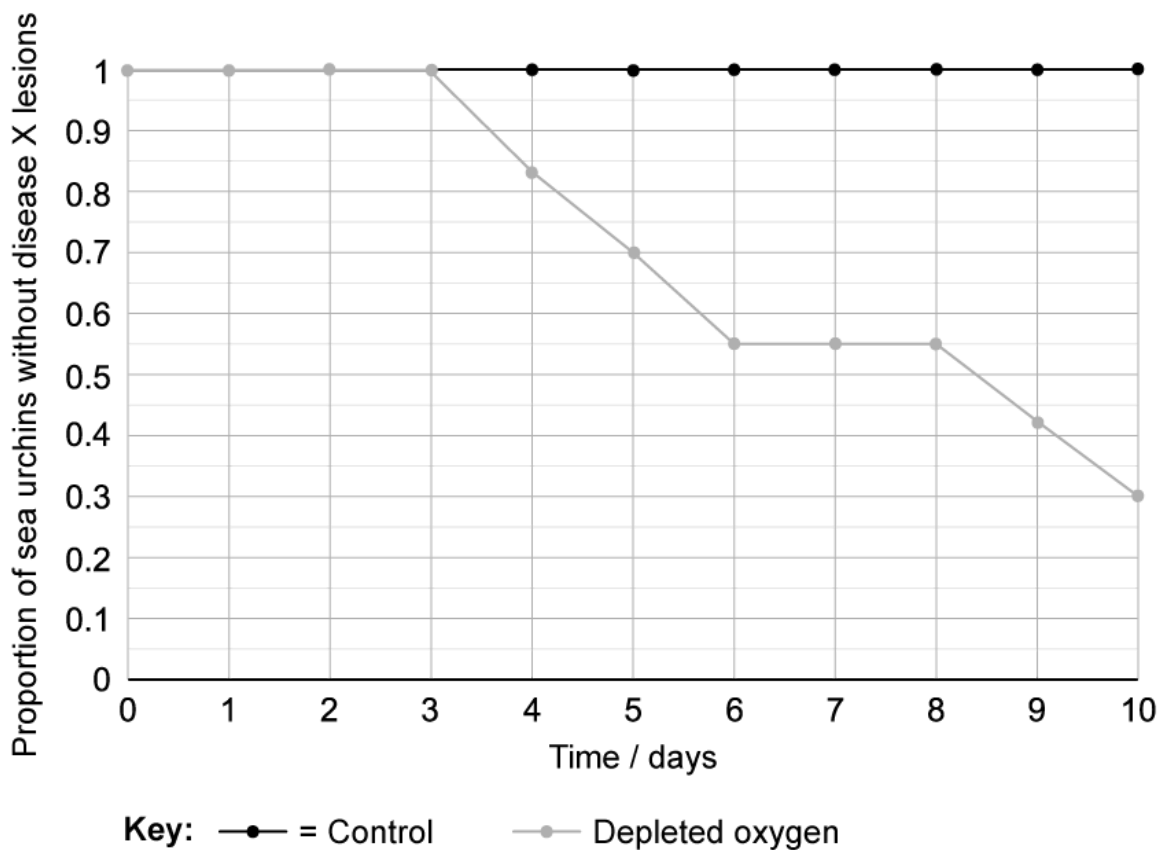
Calculate the number of individuals that **would have lesions** after 10 days with depleted oxygen levels in a population of 23.

....

(1 mark)

(g) Suggest how depleted oxygen might lead to the increase in growth of disease X lesions shown in part (f).

....

....

(2 marks)

(h) A student read the results described in parts (d) and (f) and concluded that disease X is caused by an increase in organic matter and a decrease in oxygen levels in the DBL of sea urchins.

Evaluate the student's conclusion.

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(3 marks)

8 (a) Plant species living in dry climates need to preserve water and often have adaptations that helps them to do this.

Scientists are interested in discovering crop varieties that have water-saving adaptations; one study looked at the effect of dry conditions on several varieties of wheat.

The researchers measured the water content of four varieties of wheat (v1, v2, v3, and v4) at the end of a 10 day period without water; their results are shown in the graph below.
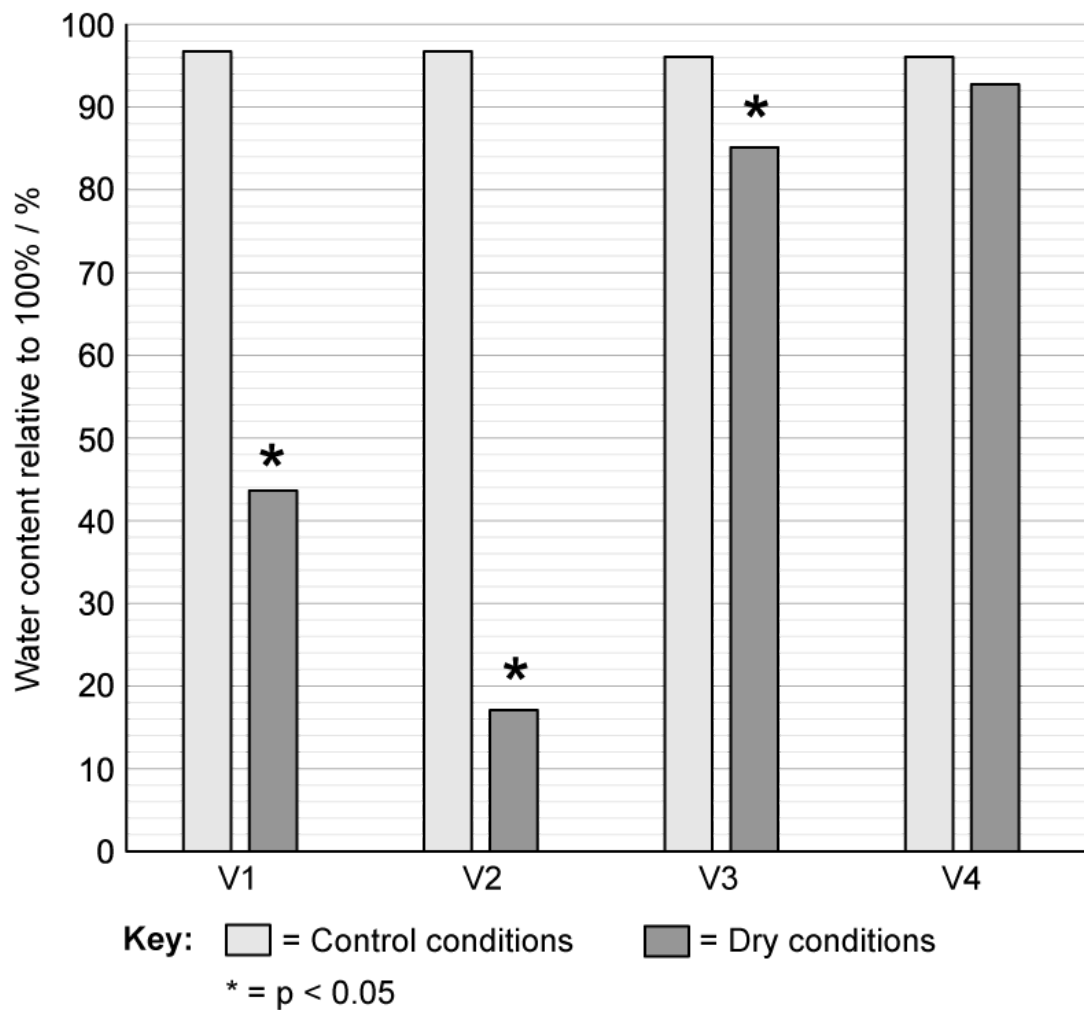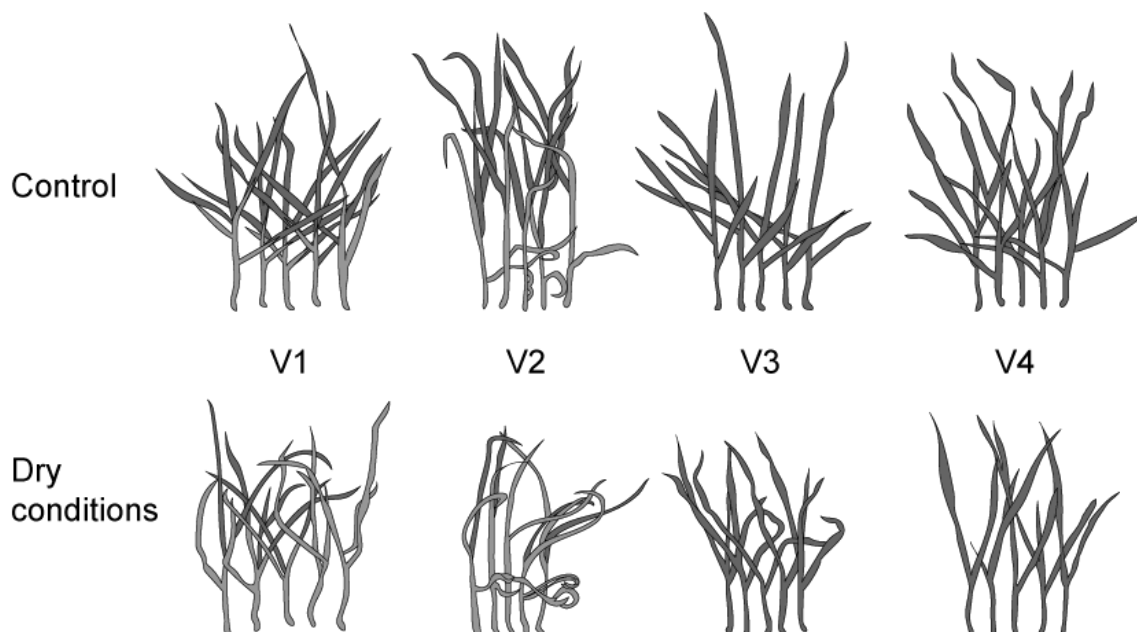

Calculate the difference in water content between the control and dry conditions for variety 2.

....

(1 mark)

(b) Compare and contrast the water content in control and dry conditions for the different varieties of wheat shown in part (a).

....

....

(2 marks)

(c) The image below shows the effect of 10 days without water on the four varieties of wheat.

Outline the effect of 10 days without water on wheat varieties 1-4.

....

....

(2 marks)

(d) Suggest why dry conditions lead to the impacts seen in part (c).

....

(1 mark)

(e) The scientists also analysed the potassium ion (K^+) content of the tissues of each variety after the 10 day experiment period. The results of this analysis are shown in the graph below.
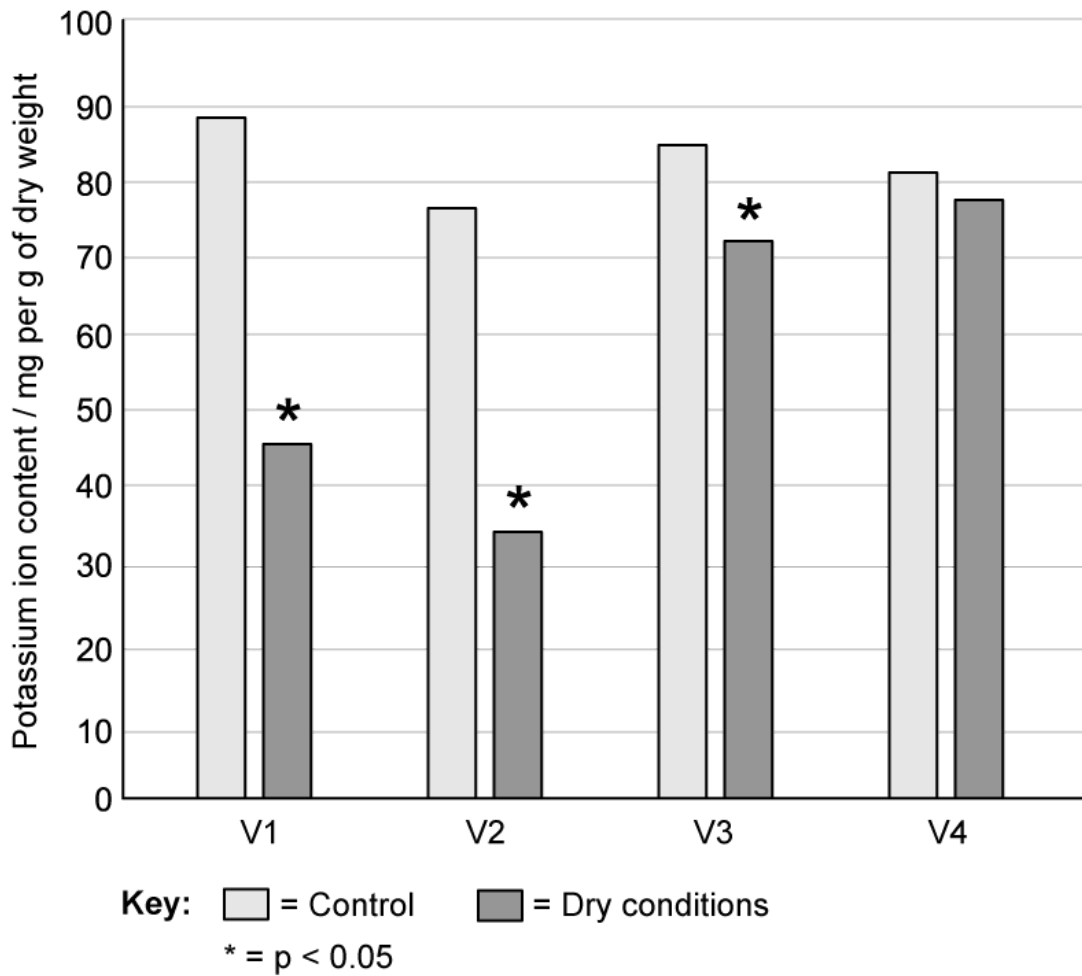
Describe the impact of dry conditions on the potassium ion content of the different varieties.

....

....

(2 marks)

(f) With reference to the results shown in parts (a), (c), and (e):

(i)   Deduce the effect of potassium ion content on the response of wheat to dry conditions.

[1]

(ii)   Suggest how some wheat varieties are able to minimise the impact of dry conditions.

[2]

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(3 marks)

(g) After reading the results shown in parts (a), (c), and (e), a farming organisation recommended that variety 4 should be planted by farmers in parts of the world where drought is common. Evaluate this recommendation.

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(3 marks)

9 (a) Bananas with less starch and more sugar are sweeter. This is advantageous in several ways, including the taste of the bananas and the time taken for them to ripen.

In a particular strain of bacteria, scientists found an enzyme that decreases the production of starch. The gene for this enzyme was transferred to bananas using genetic engineering to decrease the banana's starch content, resulting in transgenic bananas. The gene was transferred to three banana varieties to create three transgenic lines. The table shows the mean amount of starch and sugar contained in three lines of normal bananas (control) and three lines of transgenic bananas.

		Carbohydrate / % of fresh weight	
Banana	**Line**	**Starch**	**Sugar**
Control	1	7.21	1.34
	2	6.48	3.54
	3	8.33	2.87
	Mean	7.34	2.58
Transgenic	1	1.45	3.65
	2	2.76	5.78
	3	2.94	4.22
	Mean	2.38	4.55

(i) Identify which line of transgenic bananas has the greatest amount of sugar.

[1]

(ii) Calculate the difference in the mean percentage of starch in control and transgenic bananas.

[1]

(1 mark)

(b) (i)   Compare the levels of carbohydrate between the transgenic lines of bananas and the control lines of bananas.

[2]

(ii)   Suggest reasons for these differences.

[2]

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(4 marks)

(c) Bananas were harvested from trees and stored. Sample bananas were removed from storage after 2, 4, 6 or 8 days. The colour of the bananas was then measured and value reported using a 0-8 rating (pale yellow through to dark green), where a score of 4 or lower indicates acceptable ripeness for selling. The results are shown in the bar chart.

Key:
- ■ = Transgenic 3
- ■ = Transgenic 2
- ▨ = Transgenic 1
- ▨ = Control 3
- □ = Control 2
- ▨ = Control 1
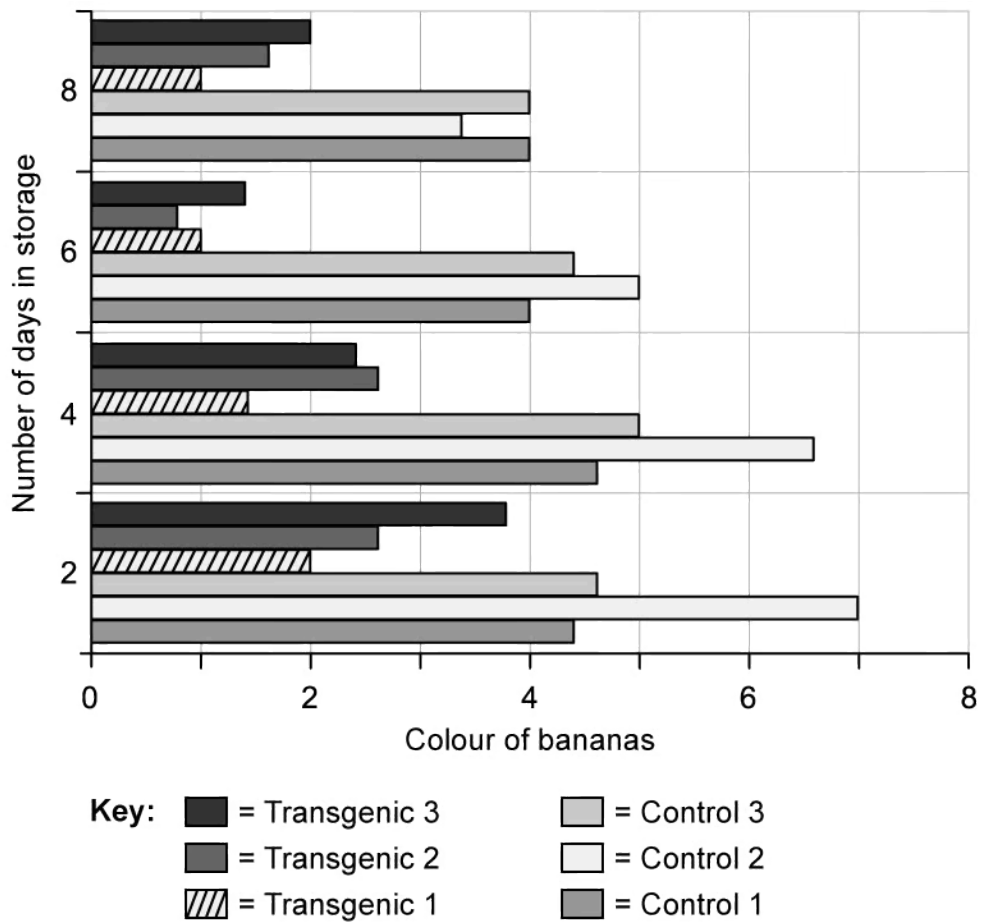
Describe the effect of transferring the bacterial gene on the suitability of the transgenic bananas for selling, compared to control bananas.

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(2 marks)

(d) An important part of storage management is to delay the formation of brown or black spots on the skin of bananas. A second sample of bananas was harvested and stored. Bananas were removed from storage on day 8. They were then examined and the number of brown or black spots present was recorded. The mean number of spots is indicated in the graph for control lines (C1, C2 and C3) and transgenic lines (T1, T2 and T3) of bananas.
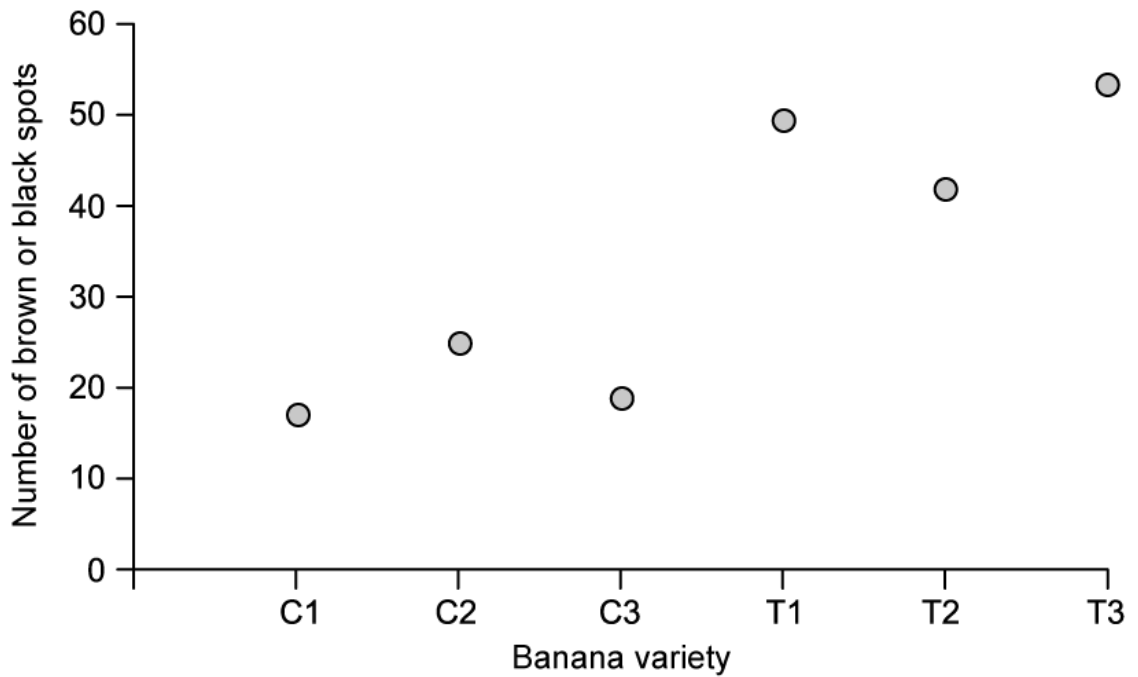
Deduce how the bacterial gene affects the storage of bananas.

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(2 marks)

(e) Some people argue that these genetically modified bananas could have harmful effects. Discuss two possible harmful effects of GM crops.

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(2 marks)

10 (a) Artificial floating islands are man-made rafts or platforms that can be introduced to bodies of water to increase existing habitat for a variety of organisms, including invertebrates, amphibians and birds.

As artificial floating islands have been increasingly introduced to ponds and lakes in parks in London, ecologists have studied how many rafts there are available and how many of these are actually being used as nesting sites by birds. In particular, they have monitored the proportion of rafts that are being used by common moorhens (*Gallinula chloropus*). Data was collected halfway through each year.

Key:
◆——◆ = Rafts available
●——● = Rafts being used
■——■ = Proportion of rafts used by *Gallinula chloropus*
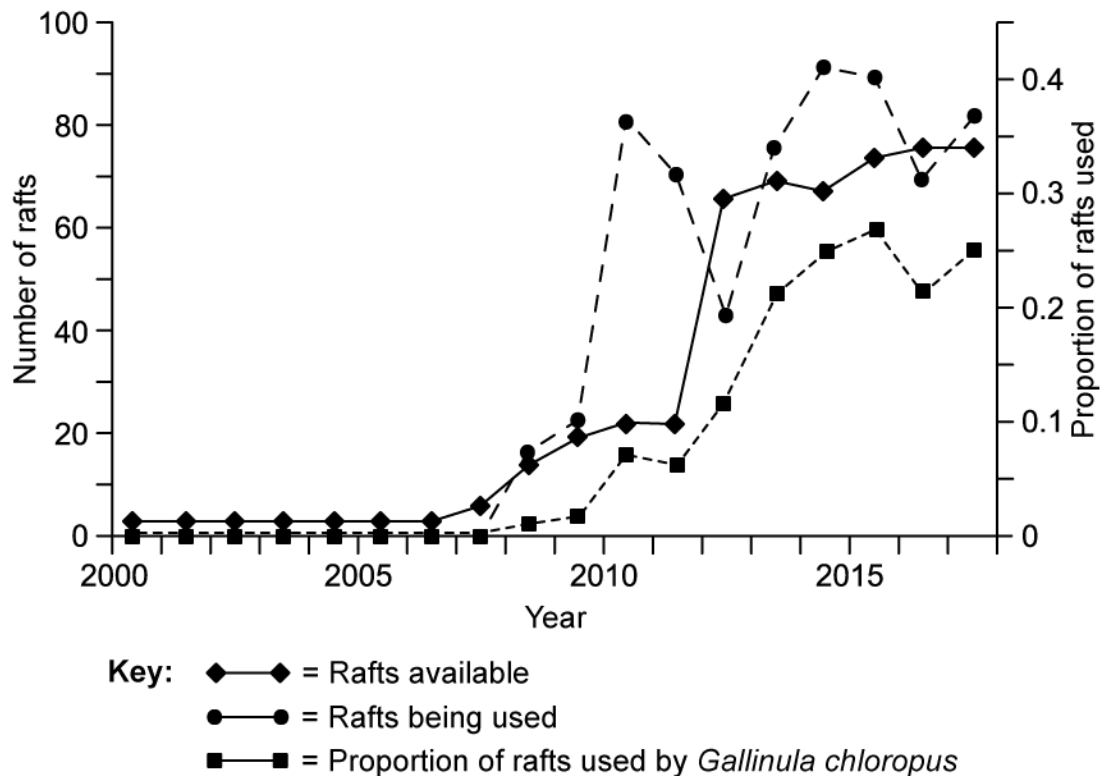
The number of rafts used by *Gallinula chloropus* changes each year. State the year in which the proportion of available rafts being used by *G.chloropus* was greatest.

....

(1 mark)

(b) Calculate how many rafts were introduced to ponds and lakes from mid-2011 to mid-2012.

....

(c) Describe the relationship between the number of rafts available and the number of rafts being used.

....

....

(2 marks)

(d) Foxes, badgers and cats are all known to predate on *G.chloropus* chicks. An ecologist conducted an investigation to see if using ultrasonic repellers (usually used to deter and repel cats) could reduce the numbers of these predators visiting a pond where *G.chloropus* were known to be nesting.
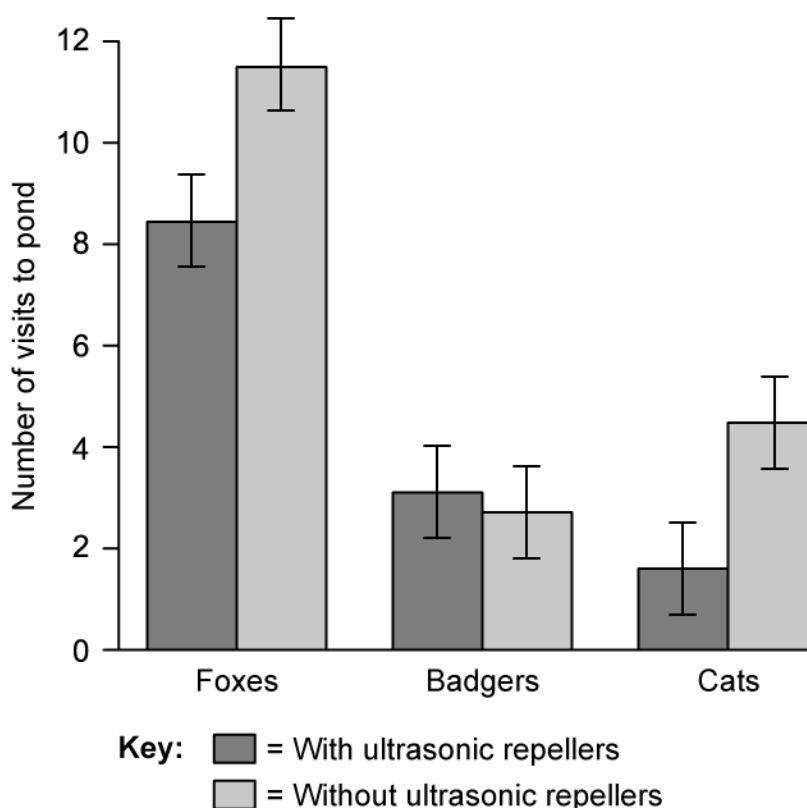
Contrast the number of visits to the pond with and without ultrasonic repellers, for the three different predators.

....

....

....

(3 marks)

(e) Over the same time period and for the same ponds and lakes in London that were studied in part (a), the ecologists monitored *G.chloropus* nests located on the banks of the ponds and lakes and on floating rafts in the centre of those ponds or lakes. Many of the ponds and lakes had ultrasonic repellers placed on their banks over the study period. Every two years, the ecologists measured the average number of chick that survived per nest.
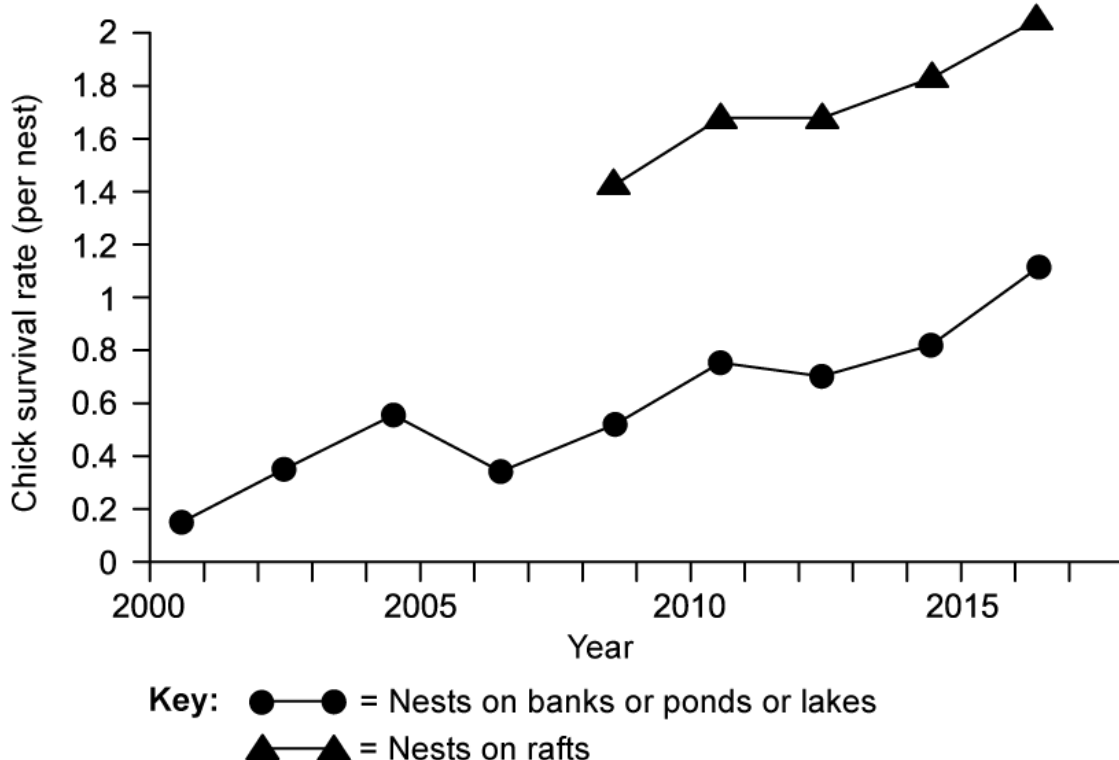
Suggest why data on chick survival rates for nests on rafts were only collected from 2008 onwards.

....

(1 mark)

(f) Compare and contrast chick survival rates for nests on banks of ponds or lakes with chick survival rates for nests on rafts.

....

(g) For the ponds and lakes in question (e), deduce how nest location affects chick survival.

(2 marks)

11 (a) Goat (*Capra hircus*) livestock are the main animal grazed in northern Africa. An increase in demand for meat has resulted in more intensive farming which has increased the degradation of rangelands. To reduce the impact of grazing, farmers have been supplementing the grazing with additional feed resources, however these have proved costly and are difficult to source.

A study was conducted to determine whether the additional feed resources affected the ability of the goats to digest their feed. The feed resources chosen - olive cake and cactus cladodes were cheaper to source and enabled a broader diet for the goats.

For three months 44 goat kids were fed one of the following diets twice a day:

- Control - C (oat, barley - an energy source and faba bean - a nitrogen source)
- Olive Cake - OC (oat, pressed olive concentrate and faba bean)
- Cactus Cladodes - CC (oat, ground cactus stem concentrate and faba bean)
- Olive cake + Cactus cladodes - OC+CC (oat, olive concentrate, cactus concentrate and faba bean)

Table 1.0 Diet and chemical composition of the goat kids' diet

		Diet			
		Control (C)	Olive Cake (OC)	Cactus Cladodes (CC)	Olive Cake + Cactus Cladodes (OC + CC)
Diet ingredients (g/kg)	Oat hay	508	427	466	456
	Barley	390	0	0	0
	Olive cake	0	350	0	150
	Cactus cladodes	0	0	300	150
	Faba bean	590	630	680	680

Percentage of diet ingredients for each diet fed to the goats

Control

☐ = Faba bean
  40.0%

☐ = Oat
  34.0%
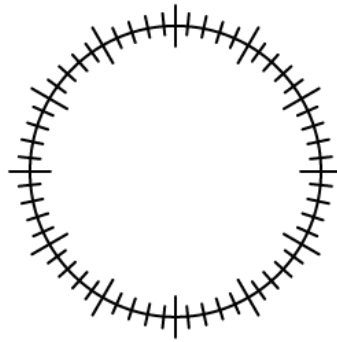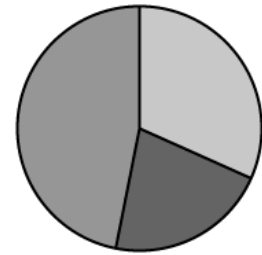
■ = Barley
  26.0%
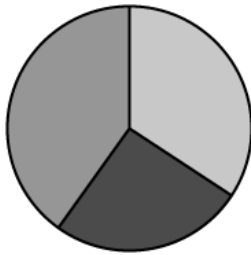
OC

☐ = Faba bean
  45.0%

☐ = Oat
  30.0%

■ = Olive cake
  25.0%

CC

☐ = Faba bean
  47.0%

☐ = Oat
  32.0%

■ = Cactus cladodes
  21.0%

Olive cake + Cactus cladodes

(i)   Calculate the percentage for each diet ingredient in the Olive Cake + Cactus Cladodes diet and complete the above chart.
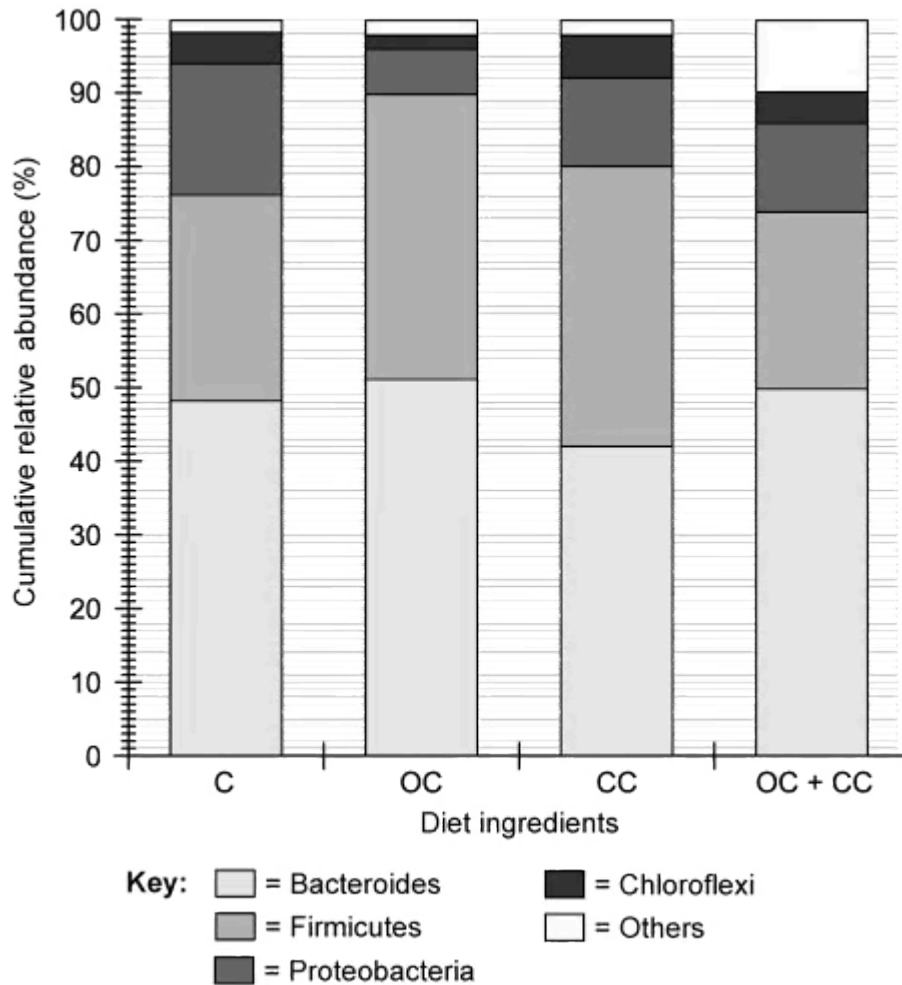
[2]

(ii)   Identify which diet/s contain the highest source of nitrogen.

[1]

(3 marks)

(b) At the end of three months rumen (digestive system) juices and muscle samples were taken. DNA was extracted from the rumen to establish the abundance of the key digestive microbial phyla for each diet.

Key: ☐ = Bacteroides ■ = Chloroflexi
     ▨ = Firmicutes ☐ = Others
     ▩ = Proteobacteria

(i) Determine which diet has the lowest relative abundance of the *Proteobacteria phyla.*

[1]

(ii) Analyse the effect of diet on the abundance of the key microbial phyla.

[2}

....

....

....

(3 marks)

(c) The pH was also measured for each feed.

(Diets with * are significantly different)
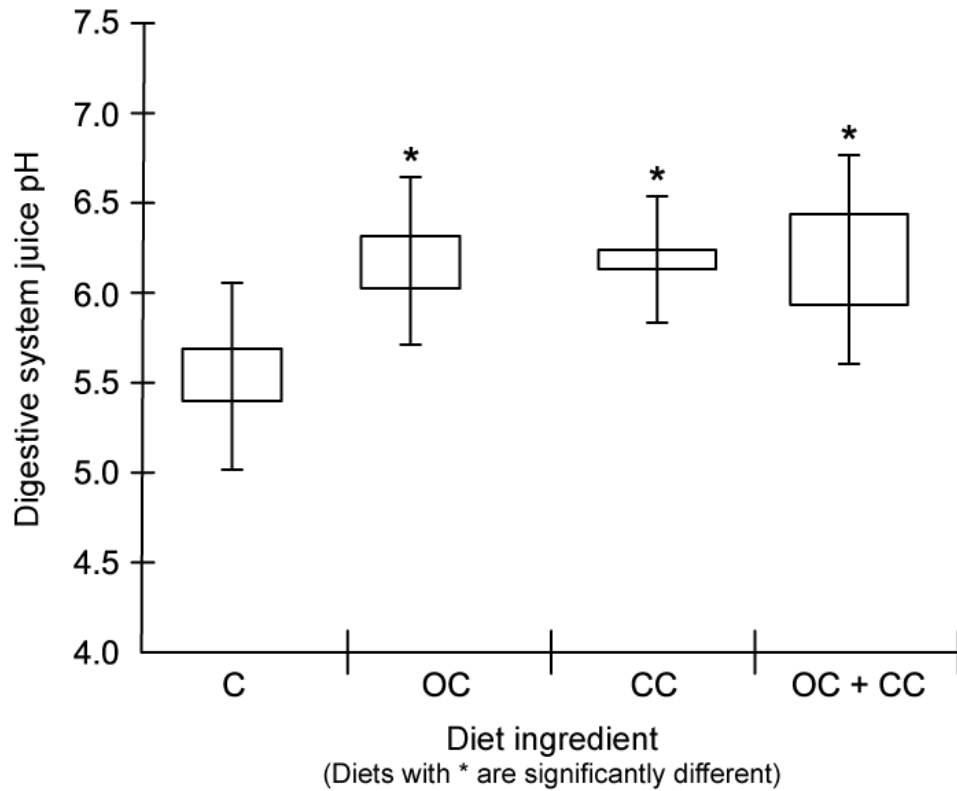
(i) State the significance of the statement: * are significantly different at p < 0.05.

[1]

(ii) Compare the effect of the different diets on the digestive system pH.

[2]

_____

_____

_____

(3 marks)

(d) Suggest how the pH could affect the digestion of the different diets.

_____

_____

(2 marks)

(e) Evaluate the hypothesis, using the data, that the microbial ecosystem digestibility is not increased by the additional feeding resources.

....

....

(2 marks)

12 (a) The *Helicoverpa punctigera* (native budworm) caterpillar is a major insect pest for *Cicer arietinum* (chickpeas). Reduction to crop yield and seed quality occurs when the larvae density reaches 10 to 20 per m². The larvae primarily cause damage to the leaf surface area, flower buds and fruiting bodies and are classified into 4 instars (sizes); very small (VS) - 1 to 2 mm, small (S) - 4 to 7 mm, medium large (ML) - 8 to 23 mm and large (L) - 24 to 30+ mm. The smaller instars prefer foliage, however it is the larger instars (greater than 8 mm), who prefer the pods, that cause the most economical damage. Farmers regularly monitor their *arietinum* crop to determine when insecticides are required to control the *H.punctigera*.

The monitoring involves beating the plants to determine the mean number of larvae per metre row and making observations of the type of damage.
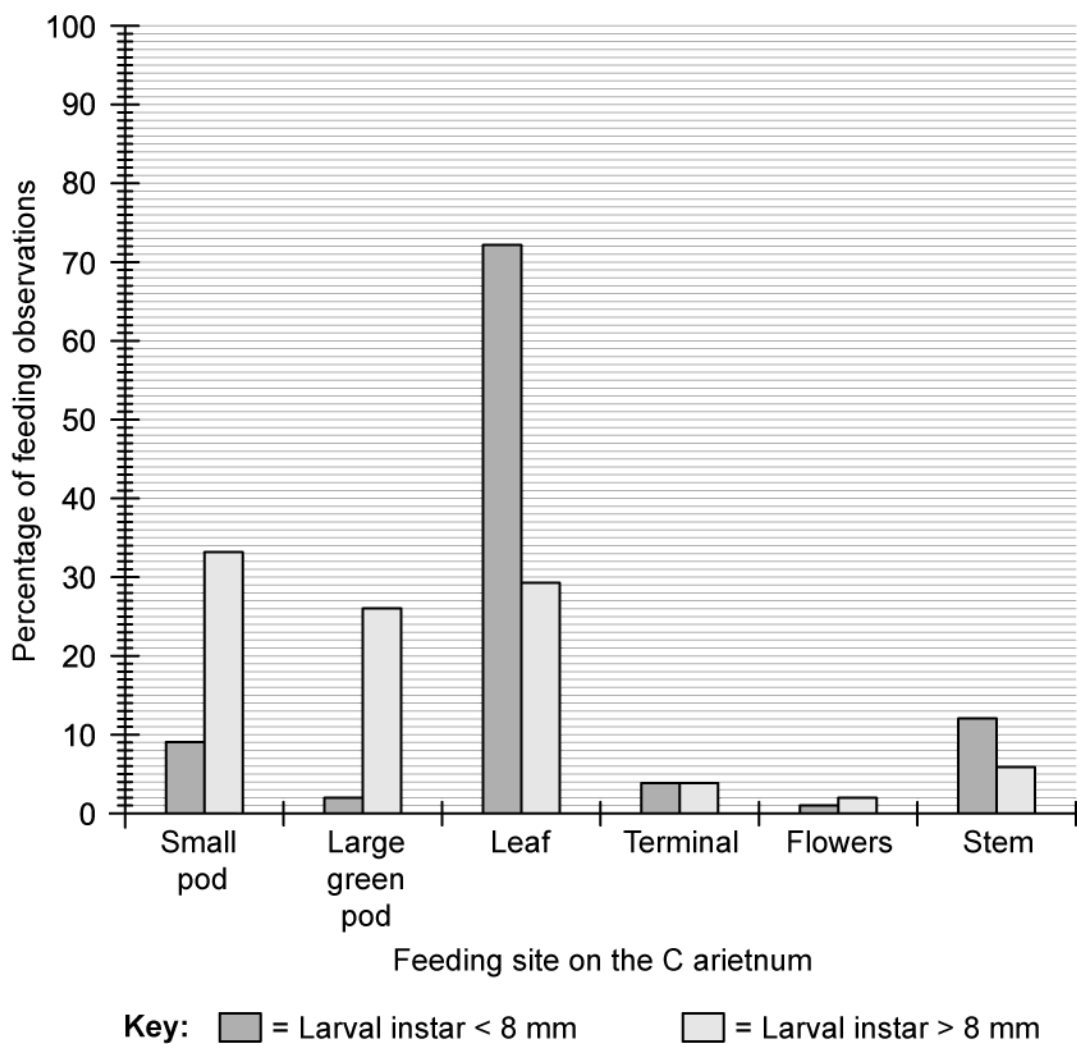
Identify the feeding site on the *C.arietinum* that has the least percentage of feeding by larvae smaller than 8 mm.

....

(b) Calculate the difference between the percentage of feeding by larvae less than and greater than 8 mm, on *C.arietinum* leaves.

....

(1 mark)

(c) Suggest a reason for the preference of the small larvae feeding on the leaves.

....

(1 mark)

(d) Pest management is economically and environmentally important to farmers. Insecticides can be costly, insect resistance can develop and broad-spectrum insecticides can cause beneficial insects (e.g. pollinators) to be killed when applied. Scientists have been researching the most appropriate method to manage pests of chickpea crops. They have genetically engineered *C.arietinum* plants with the bacterium *Bacillus thuringiensis* (Bt), which results in the plants releasing a toxin that kills insects that ingest it. Scientists have also been developing synthetic pyrethroids (e.g. -Cypermethrin) that *H.punctigera* currently have a low resistance to.

In this study, scientists explored four different pest management methods over one growing season. The graphs below represent data from the experiments undertaken.
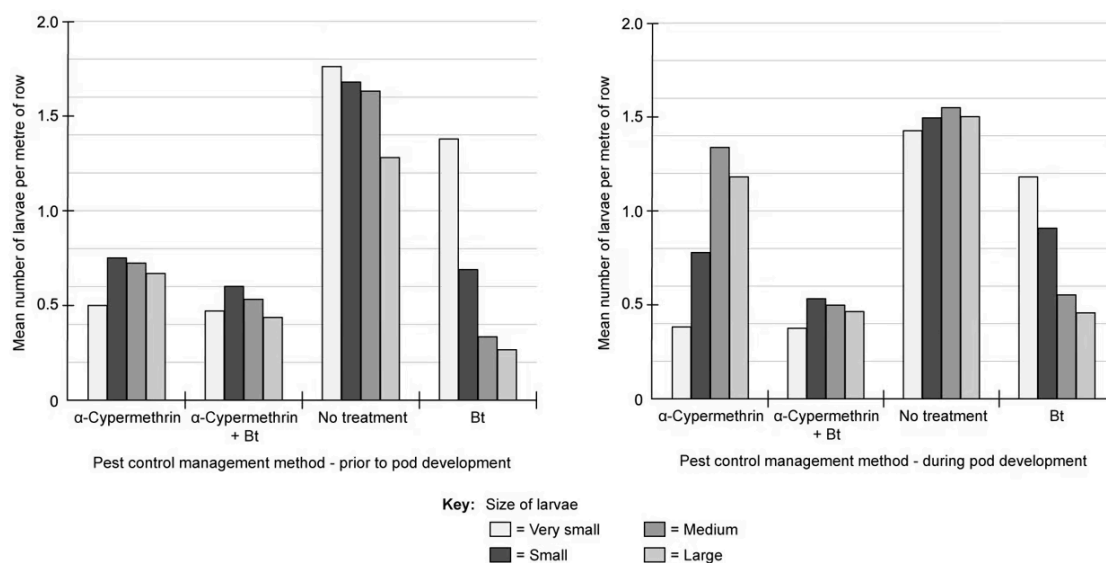
State which pest control management method was most successful in controlling larvae less than 8 mm prior to pod development.

....

(1 mark)

(e) Suggest why Bt *C.arietinum* appear to be more effective at controlling the larger larvae of *H.punctigera*.

....

(1 mark)

(f) Compare the effectiveness of the three methods used in limiting the damage caused by *H.punctigera,* prior to pod development and during pod development.

....

....

....

(3 marks)

(g) Using all the data provided, evaluate the hypothesis that the most sound pest management method is a combination of using a synthetic pyrethroid (-Cypermethrin) on a genetically engineered (Bt) chickpea crop.

....

....

....

(3 marks)