1(a). Photosynthesis is key to crop production.

The light dependent reactions of photosynthesis depend on pigments such as chlorophyll. The molecular structure of chlorophyll is shown in **Fig. 34.1**.

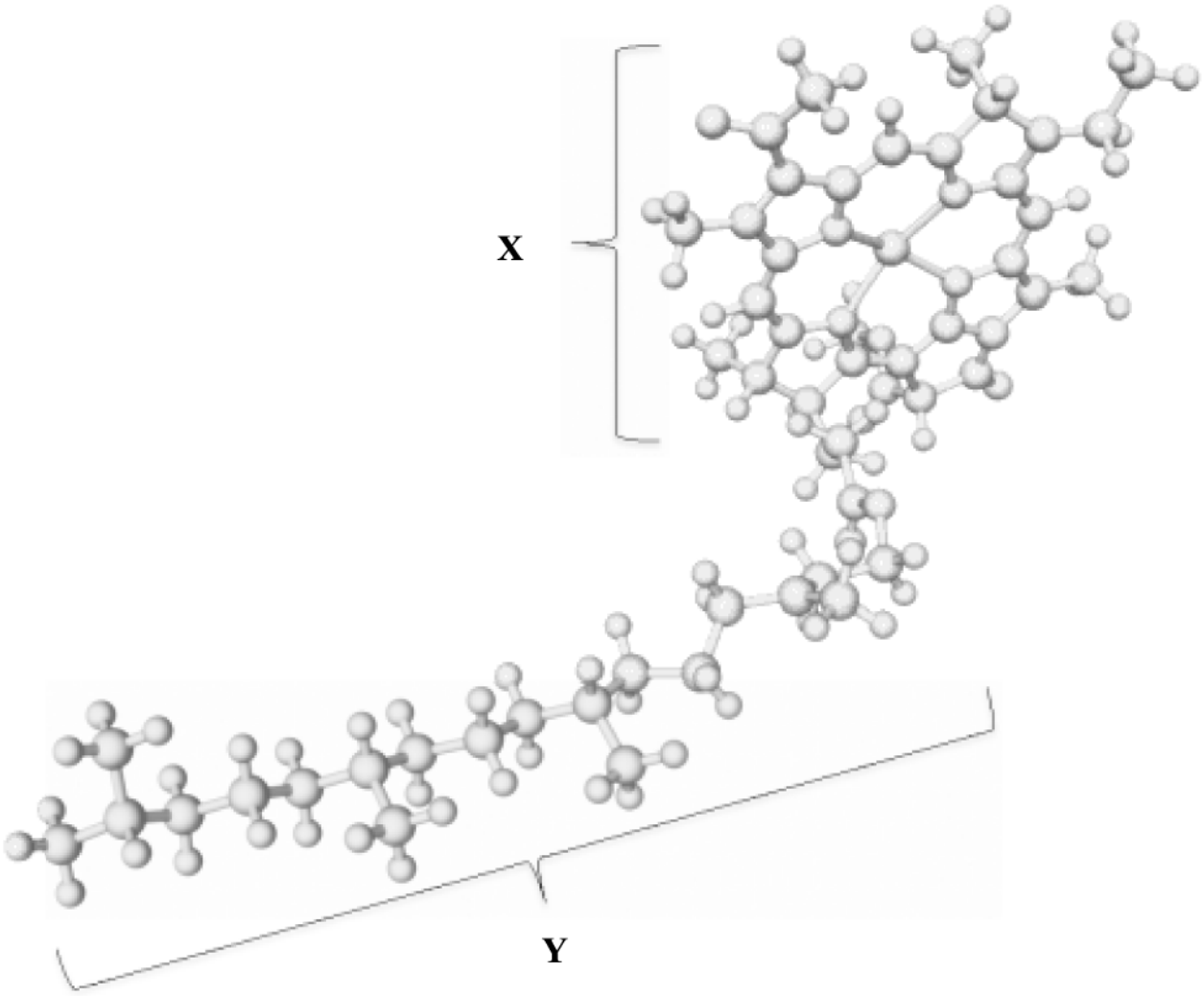


Fig. 34.1

Light energy is absorbed in the 'head' of the molecule labelled **X**. The part labelled **Y** is a long, hydrocarbon chain.

State the location of chlorophyll molecules in chloroplasts **and** suggest the arrangement of parts **X** and **Y** of the molecules.

---

[3]

(b). There are several different photosynthetic pigments present in the leaves of plants. These pigments can be separated out using chromatography. The technique is outlined below:

- pigments are extracted from plant leaves
- leaf extract is loaded onto a strip of chromatography paper
- the strip is placed in a container so that the end of the strip is touching a solvent
- the solvent moves through the paper, separating out the pigments due to differences in their solubility in the solvent.

(i) Outline **one** precaution you would take in order to obtain good separation of photosynthetic pigments.

---

[1]

(ii) In order to identify the pigments that are present in leaves, R_f values can be calculated.

The R_f value compares the distance moved by the solvent with the distance moved by the pigment.

Table 34.1 shows the results of a chromatography experiment on pigments extracted from rye grass.

Pigment	Distance travelled by the pigment (mm)	Distance travelled by the solvent (mm)	R_f value
Chlorophyll A			0.85
Chrorophyll B			0.58
Xanthophyll	100	107	0.93

Table 34.1

Calculate the distances moved by Chlorophyll A and Chlorophyll B.

distance for Chlorophyll A _____ distance for Chlorophyll B _____

[2]

(iii) Use the results in **Table 34.1**, to show what can be concluded about the relative solubility of the three pigments.

---

[2]

(c). Ruminants such as cows are used extensively in food production.

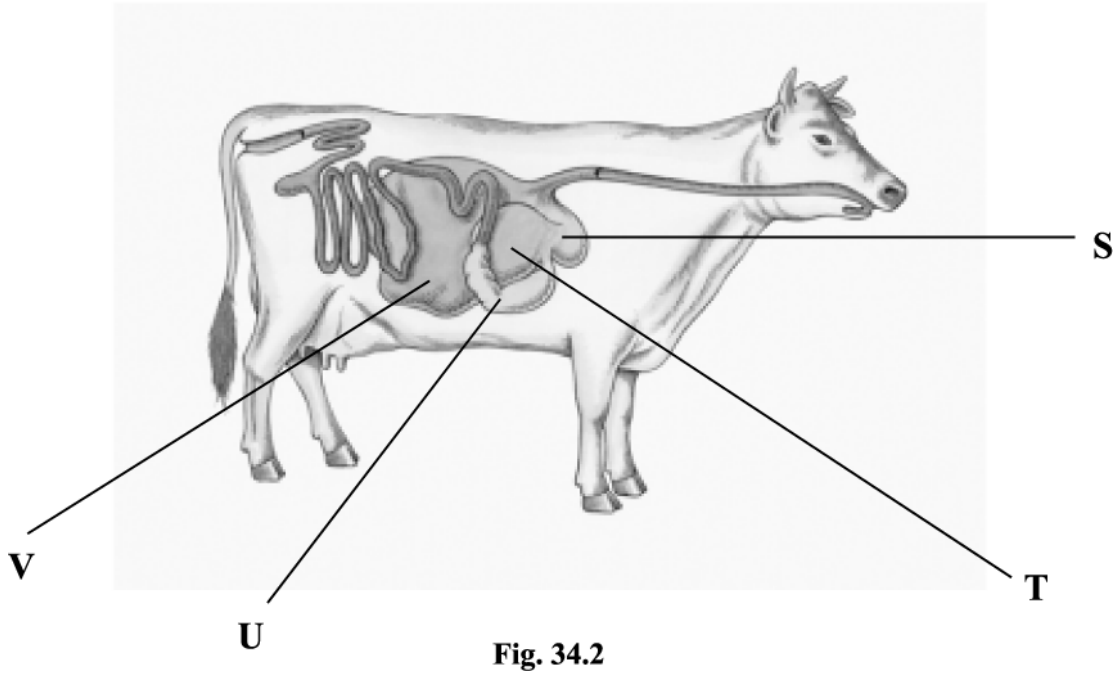


Fig. 34.2

(i) Complete the following table about the parts of the cow's digestive system labelled in **Fig. 34.2**.

Description	Name	Letter
Secretes hydrochloric acid and protease enzymes.		
Allows the cow to regurgitate material back up to the mouth for further chewing.		

[2]

(ii) Both cows and humans need a range of amino acids to make their own proteins.

- Amino acids which have to be present in the diet are called essential amino acids.
- Unlike humans, essential amino acids do **not** need to be present in the diet of cows.

Explain how cows obtain their essential amino acids.

[2]

(iii) Amino acids which have been absorbed but which are **not** required for protein synthesis cannot be stored.

State what happens in liver cells to the amino acids which are not required for protein synthesis.

[1]

2(a). Some bacterial species aid digestion in ruminants.

Describe the role of bacteria in ruminant digestion.

---

[2]

(b). * A student wrote the following statement:

Bacteria can be harmful and cause disease, but some bacteria can play important roles in the environment, for example, recycling nutrients. In recent years, scientists have developed techniques to genetically alter bacteria. These genetically modified bacteria have allowed us to produce useful substances.

Using the ideas in the student's statement, outline the relationship between humans and bacteria.

---

[6]

3(a). Plants experience two compensation points each day, one in the early morning and one in the evening. A compensation point is shown in **Fig. 5.1**, which illustrates the effect of light intensity on the carbon dioxide exchanged by the plant.

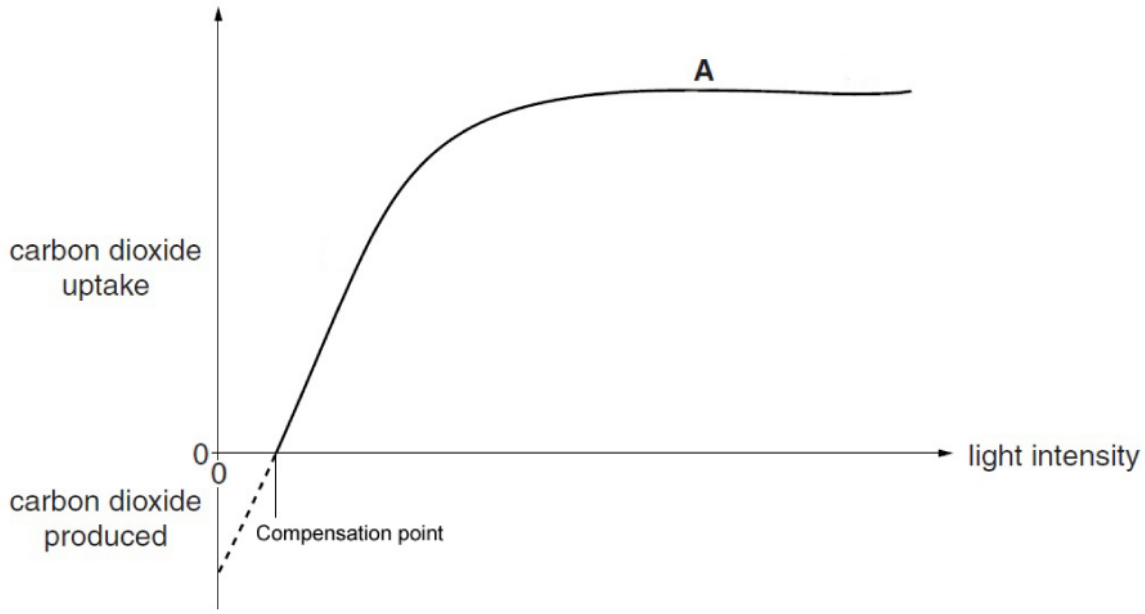


Fig. 5.1

(i) Compare the rates of respiration and photosynthesis between 0 and the compensation point shown in **Fig. 5.1** above.

---

[1]

(ii) Explain why the carbon dioxide uptake forms a plateau at **A** in **Fig. 5.1**.

---

[1]

(b).

(i) A student planned to compare the compensation points of two plant species.

Describe how the student could use hydrogencarbonate indicator solution to investigate the compensation points of the two species.

---

[3]

(ii) The student conducted another experiment using a photosynthometer to investigate the effect of light intensity on the rate of photosynthesis.

When the light source was 0.50 m from the plant, an oxygen bubble 6.00 cm long was collected in the photosynthometer during a 2 minute period.

The diameter of the photosynthometer tube was 0.12 cm.

Calculate the rate of photosynthesis under these conditions.

rate of photosynthesis = _____ $cm^3\ min^{-1}$ **[2]**

(c). The atmospheric carbon dioxide taken up by plants is used as a reactant in the Calvin cycle.

(i) Name **one** product of the light-dependent reactions of photosynthesis that is used as a reactant in the Calvin cycle **and** describe its role in the cycle.

Product

Role

---

[2]

Fig. 5.2 shows the molecular structure of the amino acid cysteine, which can be synthesised from products of the Calvin cycle.

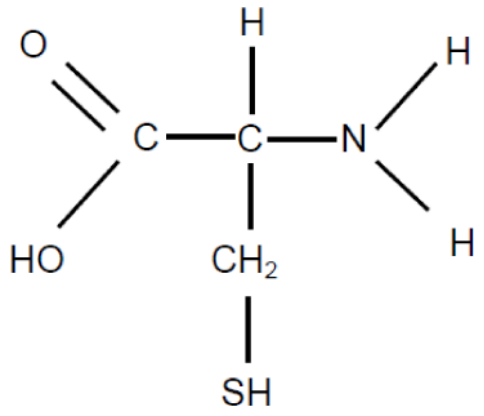


Fig. 5.2

(ii) In addition to the products of the Calvin cycle, suggest **two** mineral ions that plants would need to absorb through their roots in order to synthesise cysteine.

1

2

---

[2]

4. Important crops within the UK include potatoes, sugar beet, oilseed rape, wheat and fresh fruits.

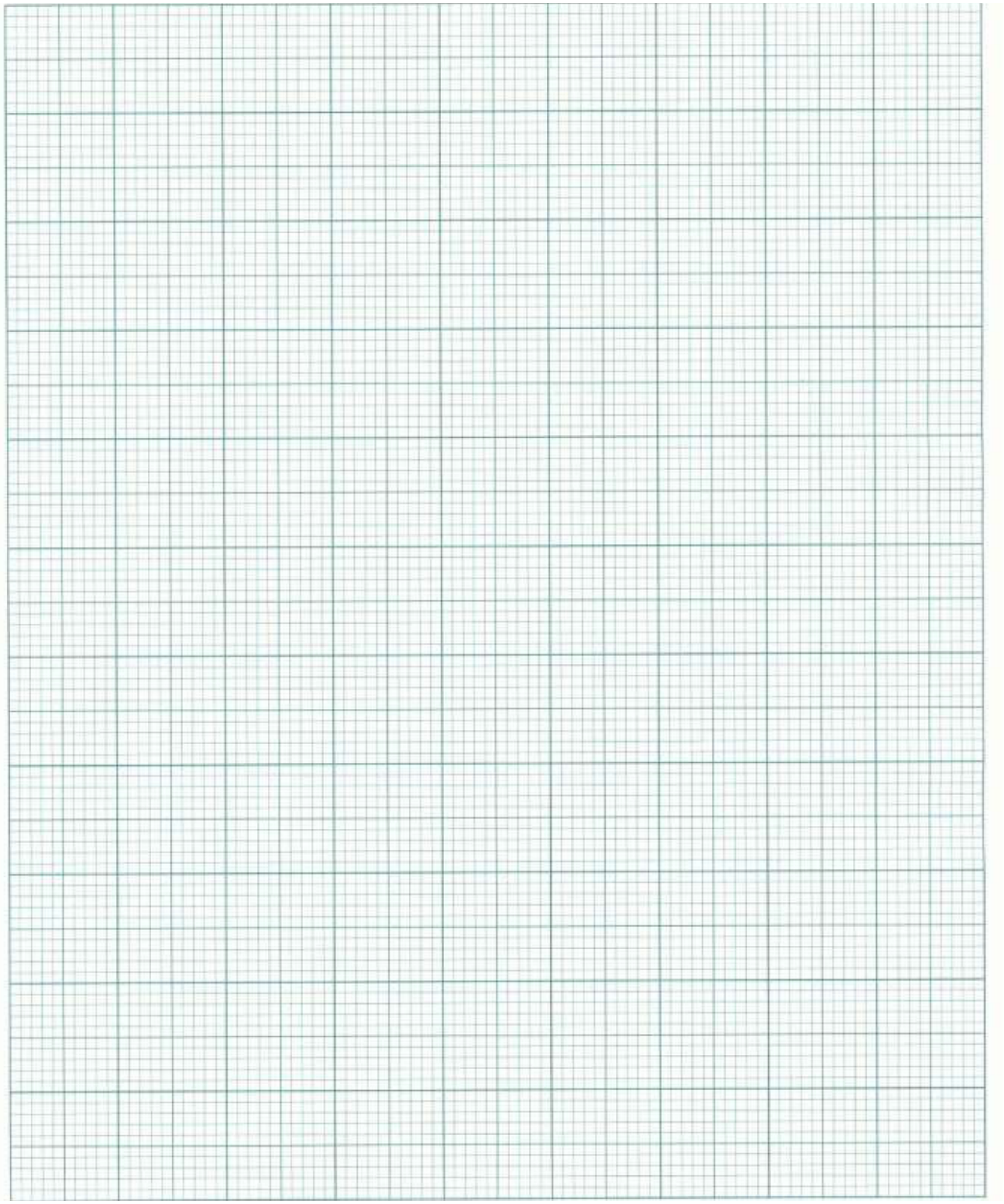
Table 4.1 below shows the UK production in tonnes per hectare for each of these crops in 2012.

Crop	Total production (thousand tonnes per hectare)
Potatoes	4553
Sugar beet	1144
Oilseed rape	2557
Wheat	13261
Fresh fruits	358

Table 4.1

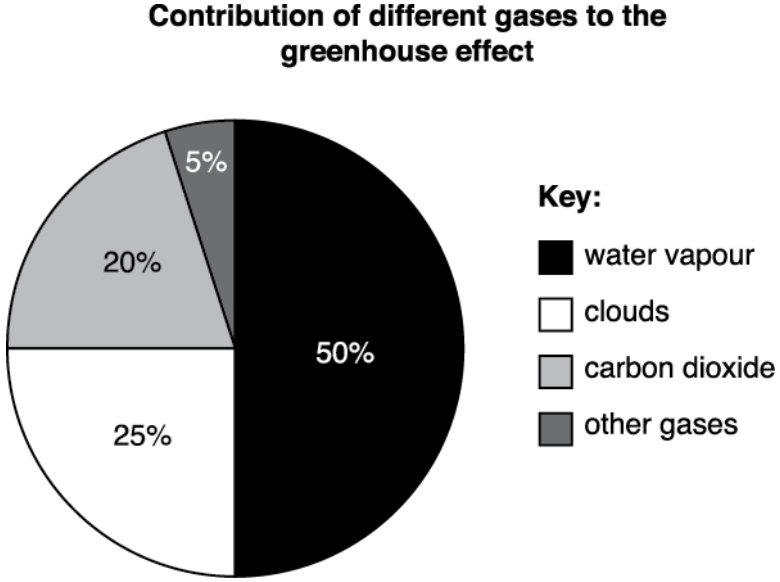
Plot a graph on the grid provided to show this data in the most appropriate way.

[4]



5(a). The greenhouse effect is caused by particular gases in the atmosphere including water vapour.
These gases absorb infrared radiation from the Earth's surface and re-emit it. This process ensures that the surface of the Earth is 20 °C to 30 °C warmer than it would be otherwise.

A simplified summary of the contribution of different gases to the greenhouse effect is shown in the figure.



Suggest why water vapour is **not** considered a cause of global warming.

---

[1]

(b). Greenhouse gases vary in their contribution to global warming. Each greenhouse gas lasts for a different length of time in the atmosphere.

Carbon dioxide equivalents (CO_2e) are used to express the relative global warming potentials of different greenhouse gases.

(i) Suggest the advantage of converting greenhouse gas emissions into carbon dioxide equivalents.

---

[1]

(ii) Carbon dioxide has a global warming potential (GWP) of 1.

Methane has a GWP of 25, meaning that 1 kg of methane emitted is equivalent to 25 kg of carbon dioxide being emitted.

The following table shows the GWP of some greenhouse gases.

Greenhouse gas	GWP
Carbon dioxide	1
Methane	25
Nitrous oxide	298
Hydrofluorocarbon-23	22 800

Using the information in the table, calculate the mass of carbon dioxide that is equivalent to 0.5 kg of nitrous oxide.

Answer =_____ kg **[2]**

(c). Hydrofluorocarbons are used as coolants in refrigeration and air conditioning units.

Hydrofluorocarbons were introduced to replace ozone-destroying chlorofluorocarbons (CFCs).

Explain, using information from The table, why even a small increase in the use of hydrofluorocarbons could act against the benefits gained from the reduction of other greenhouse gases.

---

[2]

6(a). Cereals and legumes are frequently grown in crop rotation.

(i) Explain the advantage to farmers of growing legumes.

[3]

(ii) Explain how nitrogen-containing compounds are returned to the soil.

[3]

(b). The stubble left after harvesting cereal crops provides a habitat during the winter and spring for birds such as Stone curlews and Pink-footed geese.

Changes in farming practices have led to a decline in numbers in both of these species since the end of the nineteenth century.

Discuss briefly the role of cereal crop stubble in the conservation of some bird species.

[2]

7(a). Some of the earliest forms of vegetation to colonise brownfield sites are mosses and lichens. Over time, as these organisms die and decay, the concentration of soil nutrients such as nitrates increases.

Describe how the death and decay of mosses and lichens leads to an increase in the availability of nitrates.

In your answer, you should use the appropriate technical terms spelled correctly.

[4]

(b). In another part of Islington, Caledonian Park, a community orchard has been planted by a group called the London Orchard Project.

The passage below is an extract from their website.

'In an era of climate change and peak oil prices, planting trees, which will provide a large yield year after year for decades to come, is a logical move, helping to build food security.'

Outline how the planting of a community orchard can help to reduce the carbon footprint of communities such as those in Islington.

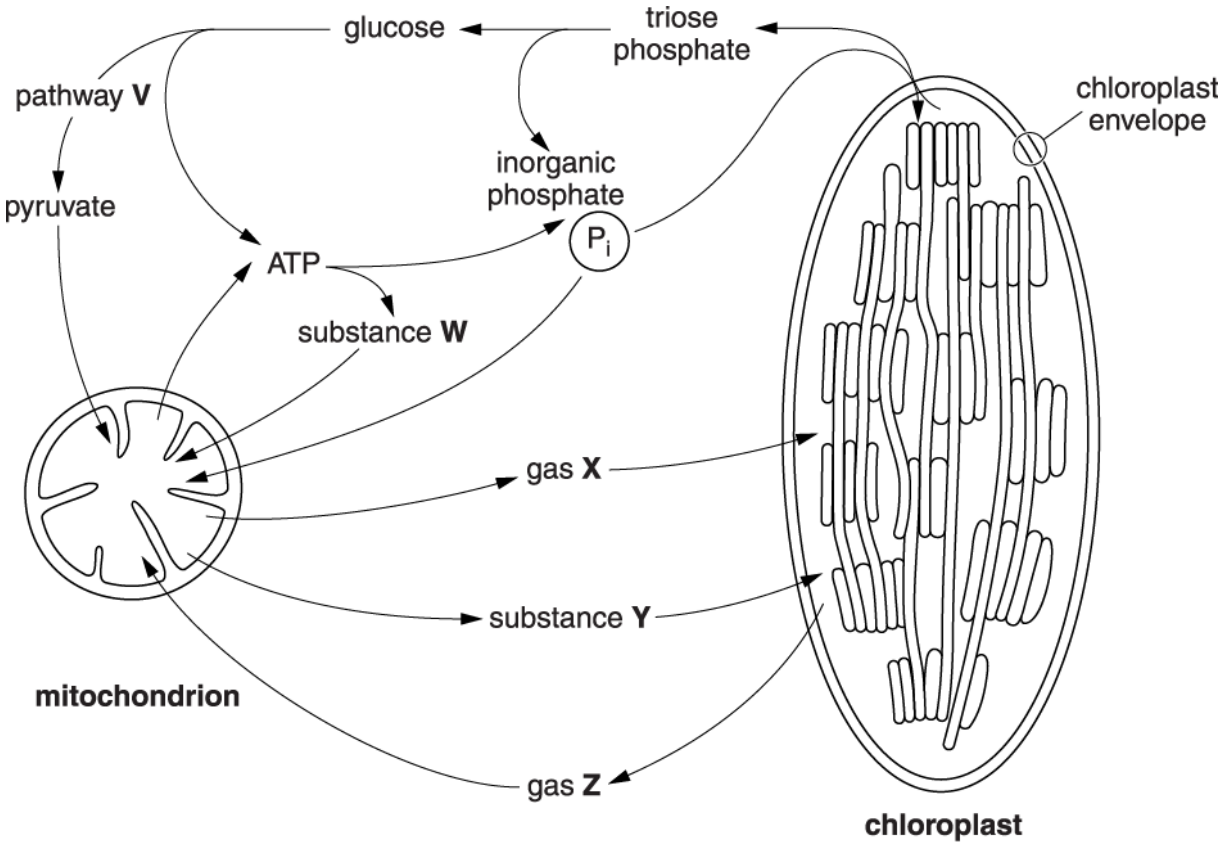
---

[2]

8(a). All living organisms respire in order to produce ATP, which is essential for a variety of biological processes.

Respiration in both plant cells and animal cells depends on the products of photosynthesis.

Fig. 3.1 shows some of the exchanges that take place in plant cells during bright sunlight.



Key

P_i = inorganic phosphate

Fig. 3.1

In which tissue in a plant leaf would a cell containing the organelles shown in Fig. 3.1 be found?

---

[1]

(b). Using Fig. 3.1, **name** the following:

(i) gas **X** _____

gas **Z** _____

[1]

(ii) substance **Y** _____

[1]

(iii) substance **W** _____

[1]

(c). Two groups of enzymes, **carboxylases** and **decarboxylases**, are essential to the exchanges that happen within the plant cell.

On Fig. 3.1, **write the letter C** exactly where a carboxylase is located in the cell and **write the letter D** exactly where a decarboxylase is located.

The answers to this question should be written on Fig. 3.1.

[2]

(d). Identify **one** substance **in addition** to those shown in Fig. 3.1 that is produced in pathway **V**, and which will enter the mitochondrion.

_____

[1]

9(a). *Spirulina* are photosynthetic bacteria belonging to a group known as the Cyanobacteria. Unlike other Cyanobacteria, *Spirulina* do not fix nitrogen.

Name **one** species of bacterium that **can** fix nitrogen.

---

[1]

(b). In *Spirulina*, the light independent stage of photosynthesis is very similar to that in green plants.

Outline how complex organic molecules such as lipids are produced from the light independent stage of photosynthesis.

In your answer, you should use appropriate technical terms, spelled correctly.

---

[5]

(c). Dried *Spirulina* can be eaten directly by humans or fed to cattle.

Fig. 3.3 shows a food chain involving *Spirulina*.

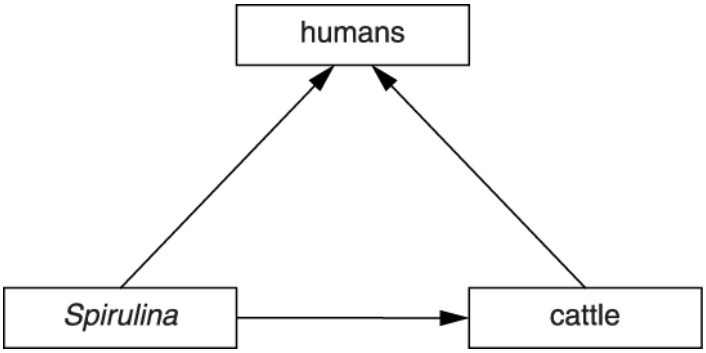


Fig. 3.3

State **and** explain the advantage to human populations of eating dried *Spirulina* directly rather than using it as cattle feed.

---

[2]

10.

(i) In a stream, energy may be transferred between organisms in the following food chain:

aquatic producers → protoctists → shrimps → fish → kingfisher (bird) → hawk

The arrows represent energy transfer.

Name the process that is responsible for the transfer of energy through this food chain.

---

[1]

(ii) Which energy transfer between animals would be the **least** efficient in this food chain?

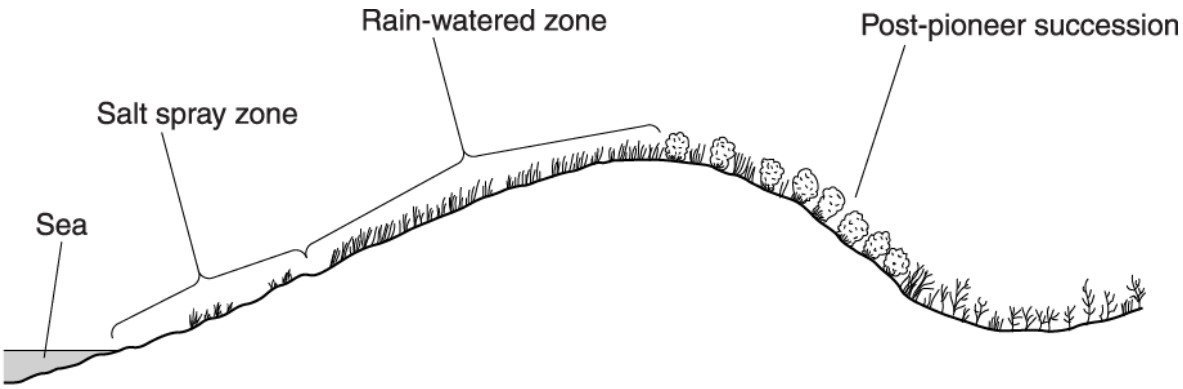
Explain your choice.

---

[2]

11. In the last century, farmers were encouraged to settle on the Galapagos Islands. Some farmers introduced grasses for grazing livestock. These tough grasses spread and competed with native Galapagos species, particularly on sand dunes behind beaches.

The figure shows a typical succession from the beach (where salt spray might give native grasses an advantage), to rain-watered low dunes (where salt is increasingly washed away), and to post-pioneer dunes where grasses are absent.



Researchers could investigate the distribution and abundance of grasses across the salt spray and rain-watered zones.

Choose and describe sampling techniques that would show how the distribution and abundance of native and introduced grasses change across the two zones.

In your answer, you should make clear how the equipment is used.

[7]

12(a). Specialised biotechnology companies have managed to culture some nitrifying bacteria. The bacteria are sold in water-suspension by aquarium suppliers. Aquarium owners use these bacteria to prevent fish death due to toxic levels of ammonia.

(i) With reference to the role of *Rhizobium* in the nitrogen cycle, why would the aquarium suppliers be unlikely to sell *Rhizobium*?

---[1]

(ii) Explain why the use of nitrifying bacteria by aquarium owners is an example of biotechnology.

---[1]

(iii) One of the organisms cultured for sale to aquarium owners is *Nitrosomonas europaea*.
This bacterium is highly sensitive to pH.

With reference to the desired product, explain why biotechnology companies need to control pH when culturing *N. europaea*.

---[3]

(b). Suspensions of nitrifying bacteria could also be used by farmers to improve soil fertility.

Some students at agricultural college experimented with the aquarium cultures of *Nitrosomonas* and *Nitrobacter.* They used cloned maize plantlets on trays of identical sterile sand in a greenhouse. The trays were:

- evenly inoculated with equal volumes of the bacterial suspensions
- watered daily with equal volumes of dilute ammonia solution
- kept close together so that they had the same light intensity and temperature throughout the trial.

On each of ten days, the students uprooted twenty maize plantlets, washed and dried them, and recorded their dry mass. They tabulated their results, as shown in the table.

Day	Dry maize plantlet mass with *Nitrosomonas*	Dry maize plantlet mass with *Nitrobacter*	Dry maize plantlet mass with *Nitrosomonas* and *Nitrobacter*	Control. Dry maize plantlet mass with no bacteria
1	4.0 g	3.7 g	3.7 g	3.9 g
2	4.1 g	3.9 g	3.9 g	4.1 g
3	4.2 g	4.0 g	4.1 g	4.2 g
4	4.3 g	4.1 g	4.2 g	4.3 g
5	4.3 g	4.1 g	4.2 g	4.3 g
6	4.4 g	4.1 g	4.3 g	4.4 g
7	4.5 g	4.2 g	4.5 g	4.4 g
8	4.5 g	4.2 g	4.6 g	4.4 g
9	4.5 g	4.2 g	4.8 g	4.4 g
10	4.5 g	4.2 g	5.1 g	4.4 g

(i) What change should the students make to the way they have presented their results in the table?

---

[1]

(ii) Growing conditions in the greenhouse were kept the same for all trays.

Suggest a variable that has **not** been controlled in the method described.

---

[1]

13(a). This question is based on the Advance Notice article **TURBOCHARGED PHOTOSYNTHESIS?**, which is an insert.

Use Fig. 1 on the insert to help you answer the following questions.

(i) State the precise location of the photosystems involved in the light-dependent reaction of photosynthesis.

---

[1]

(ii) Describe how the structures containing the photosystems are arranged differently in plant cells and cyanobacteria.

---

[2]

(iii) State the precise location of Rubisco in:

unmodified plant cells

---

cyanobacteria

---

[2]

(iv) Explain how cyanobacteria are able to almost eliminate oxygen (O_2) fixation by Rubisco.

---

[3]

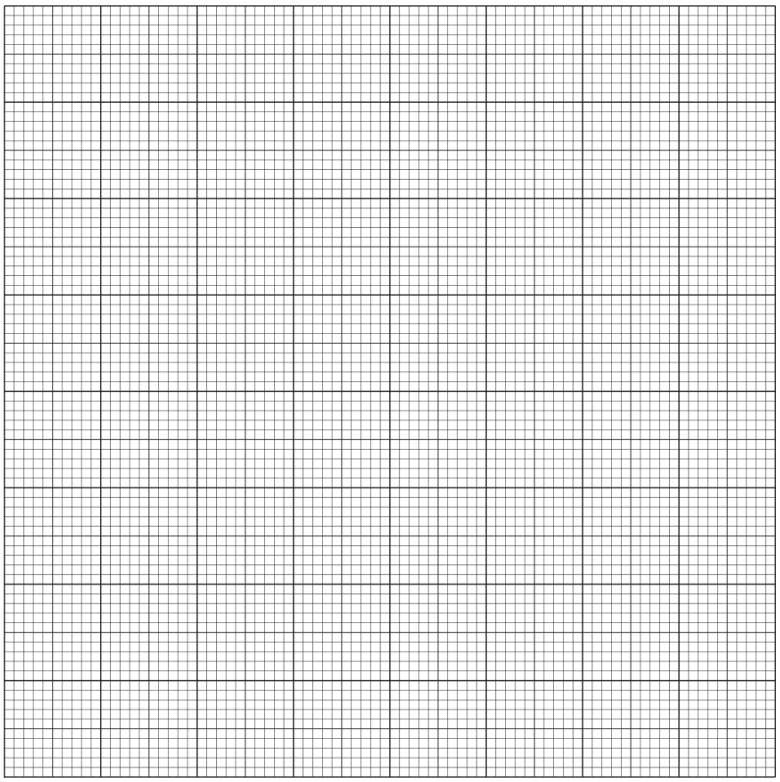
(b). Table 1 on the insert shows the results of experiments to measure carboxylase activity in wild type (WT) tobacco plants and two lines of modified tobacco plant at different concentrations of carbon dioxide (CO_2).

(i) Explain why the units of carboxylase activity are 'mol CO_2 fixed per mol active sites s^{-1}' rather than just 'mol CO_2 fixed s^{-1}'.

---

[1]

(ii) Plot a graph of these results on the grid below. Include error bars showing two standard deviations.



[4]

(iii) Using Table 1 and your graph in **(b)(ii)**, analyse whether the researchers successfully demonstrated that replacing Rubisco in tobacco plants with the cyanobacterial enzyme increased the effectiveness of photosynthesis.

Explain your conclusions.

[3]

(iv) A student made the following statement:

"Photosynthesis is more effective in the M35 strain than the Rbcx strain."

Use Table 1 and your graph in **(b)(ii)** to evaluate the validity of the student's statement.

Explain your conclusions.

[2]

14(a). Farmers rotate different crops on their land to produce higher yields. Crops like beans are used in the rotation to fix atmospheric nitrogen. This reduces the need for synthetic fertilisers.

Name the type of crop, such as beans, that can fix nitrogen.

[1]

(b). The roots of bean plants form nodules due to infection by the nitrogen-fixing bacteria, *Rhizobium*.

Rhizobium can be cultured in a laboratory.

(i) The table shows information for the preparation of agar plates used to culture *Rhizobium*.

Complete the table by suggesting a role for mannitol.

Constituent added to agar	Role of constituent
Mannitol (a carbohydrate)	.....
Yeast extract	source of nitrogenous compounds
Magnesium sulfate	source of essential ions
Dipotassium phosphate and sodium chloride	pH and osmotic buffers

[1]

(ii) * Write a method that could be used to prepare a culture of Rhizobium bacteria in the laboratory.

You are provided with:

- plates with agar containing the constituents listed in the table in part **(i)**
- a bean plant
- school or college resources.

In your answer you should describe how you would minimise potential hazards associated with the preparation.

[6]

(iii) After preparation in the laboratory, *Rhizobium* cultures are usually kept at 30 °C.

Explain why this is a suitable temperature.

[2]

15(a)

. Complete the paragraph below about ecosystems using the most appropriate terms.

Natural change in the community of an ecosystem over time is known as succession.

In this process, biodiversity increases until a …… community is reached. Human activities such as agriculture and forestry can prevent formation of this type of community, instead forming a …….. This process is known as …… succession.

[3]

(b). Pioneer species are the first to colonise an ecosystem.

How do pioneer species promote future biodiversity?

---

[1]

(c). Fig. 33 shows a region of coastal land, stretching from tide to woodland.

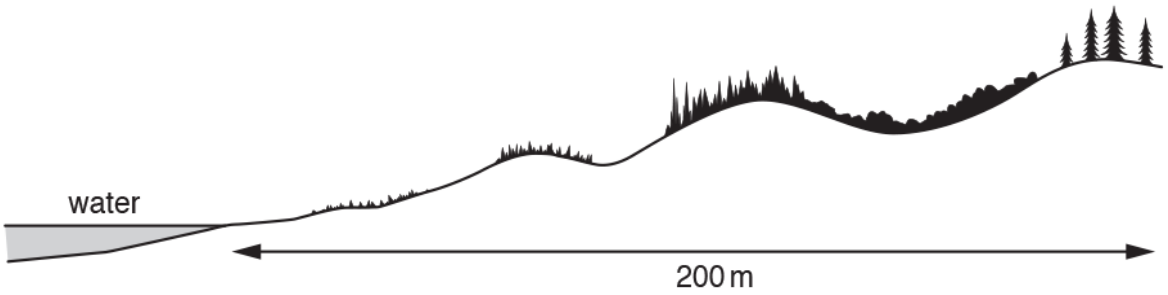


Fig. 33

Outline a sampling method that could be used to investigate succession in this region.

[3]

(d).

(i) Beef cattle that are produced for their meat are fed maize. In a cow, 13 100 MJ of stored biomass energy are produced from 83 000 MJ of maize.

Calculate the efficiency of this energy transfer in the cow.

Answer = ---------- % **[2]**

(ii) In snail farming, snails are fed lettuce leaves.

The efficiency of energy transfer from the lettuce leaves to stored biomass energy in snails is **greater** than that from maize to stored biomass energy in cattle. Suggest why.

---**[1]**

END OF QUESTION PAPER

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td>a</td><td></td><td>(chlorophyll molecules) in thylakoid membrane
Y / hydrocarbon chain, in the (phospholipid) bilayer of thylakoid membranes
X / head, at the surface of the thylakoid membrane</td><td>3</td><td>Thylakoid membrane must be stated in at least one of the mark points but can be implied in the second

ALLOW a description e.g. in the phosphate head region</td></tr>
<tr><td></td><td>b</td><td>i</td><td>Any 1 from:
idea that spot of extract needs to be (very) concentrated / AW
allow one spot to dry before adding another
sufficient length of chromatography paper AVP</td><td>1</td><td>ALLOW a description e.g. ‘put several spots of extract’
ALLOW answers which refer to different apparatus as this may have been Centre dependent
ALLOW values inserted into table</td></tr>
<tr><td></td><td></td><td>ii</td><td>Chlorophyll B = 62 mm

Chlorophyll A = 91 mm</td><td>2</td><td>0.58 × 107 = 62.06 mm

0.85 × 107 = 90.95 mm

Max 1 if units are not given OR figures not given as whole numbers</td></tr>
<tr><td></td><td></td><td>iii</td><td>idea that Chlorophyll A is less soluble than xanthophyll but more soluble than chlorophyll B / AW

Rf data quote in support</td><td>2</td><td>ALLOW answers where comparative statements are made about the three pigments

DO NOT ALLOW if units are given for the Rf value as this is a ratio</td></tr>
<tr><td></td><td>c</td><td>i</td><td><table><tr><th>Description</th><th>Name</th><th>Letter</th></tr><tr><td></td><td>Abomasum</td><td>U</td></tr><tr><td></td><td>Reticulum</td><td>S</td></tr></table></td><td>2</td><td>One mark for each correct row

ALLOW rumen and V</td></tr>
<tr><td></td><td></td><td>ii</td><td>idea that microbes in rumen are a protein source

(microbial protein) hydrolysed into amino acids by protease enzymes</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td>iii</td><td>(amino acids are) deaminated / AW</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>13</td><td></td></tr>
<tr><td>2</td><td>a</td><td></td><td>Any 2 from:
(bacteria) hydrolyse / digest, cellulose
(bacteria have) cellulase
(bacteria found) in rumen ecosystem
symbiosis / symbiotic relationship</td><td>2</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
	b		*** Level 3 (5–6 marks)** Candidate addresses all the ideas in the student's statement making clear connections between humans and bacteria and using examples to illustrate their answers. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated*. **Level 2 (3–4 marks)** Candidate addresses some of the ideas in the student's statement making some connections between humans and bacteria and using at least one example to illustrate their answers. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence*. **Level 1 (1–2 marks)** Simple comments about humans and bacteria made with connections not always made. Little exemplification. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear*. **0 marks** No response or no response worthy of credit.	6	**Examples of relevant scientific points:** **Benefits from the use of bacteria** • nitrogen cycling – including the role of putrefying, denitrifying, nitrogen-fixing and nitrifying bacteria. All benefitting food production • biotechnology – including genetic modification techniques that lead to benefits due to the production of drugs, insulin, the broadening of scientific research. Ideas might include the palindromic nature of recognition sequences for restriction enzymes and the need for reporter genes on plasmids. **Challenges from interactions with bacteria** • communicable diseases – including general mechanisms of pathogenicity of bacteria, causes, transmission, mode of infection, symptoms, treatment e.g. TB • the use of antibiotics and antibiotic resistance, including reference to TB and MRSA. **Examples of technical terms that could be used in answers:** Mycobacterium, communicable disease, prevalence, incidence, denitrification, saprotrophs, nitrification, named bacterial taxa, restriction enzymes, palindromic sequence, plasmid.
			Total	**8**	

Question			Answer/Indicative content	Marks	Guidance
3	a	i	(rate of) respiration, greater than / higher than, (rate of) photosynthesis	1	**ALLOW** reverse argument
		ii	*Idea that* named factor is limiting (rate of) photosynthesis / light intensity is no longer limiting (rate of) photosynthesis	1	**ALLOW** carbon dioxide and temperature as named limiting factors
	b	i	**Any 3 from:** *idea of* varying light intensity named control variable *idea that* hydrogencarbonate changes colour as, pH / CO_2 concentration, changes (hydrogencarbonate indicator is) yellow at, low pH / high CO_2 concentration (hydrogencarbonate indicator is) purple at, high pH / low CO_2 concentration AVP	3	e.g. same temperature / volume of hydrogencarbonate indicator solution / mass of plant e.g. use of colorimeter
		ii	0.03 (cm^3 min^{-1})	2	**ALLOW** correct calculator value or answer rounded correctly to any number of significant figures **AWARD 1 mark** for initial correct calculation ($6 \times (\pi \times 0.06^2)$) if the answer has not been divided by 2 to give a rate per minute.
	c	i	(product) ATP (role) provides / AW, energy **OR** (product) reduced NADP (role) donates hydrogen / provides reducing power / converts GP to TP	2	**DO NOT CREDIT** produces energy **ALLOW** NADPH
		ii	sulphate / SO_4^{2-} nitrate / NO_3^- / ammonium / NH_4^+	2	
			Total	11	

Question			Answer/Indicative content	Marks	Guidance
4			bar chart drawn with equal width size bars, not touching (1) X axis labelled as “Crop” AND Y–axis labelled as “Total production / thousand tonnes per hectare” (1) equidistant vertical scale used so that plot area covers at least 50% of the y axis space (1) all data plotted accurately (1)	4	ALLOW +/– 1 mm
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
5	a		*idea that* (water vapour) does not accumulate / increase over time;	Max 1	**IGNORE** ref. to other greenhouse gases **Examiner's Comments** Apart from relatively few candidates who were aware that water vapour does not accumulate or increase over time, answers were too vague and based loosely on the fact water does not absorb or emit infrared radiation or that it has always been here and is not affected by man's activities.
	b	i	*idea that* it allows comparison between different gases;	1	**CREDIT** CO_2 sets a baseline for comparing other gases **Examiner's Comments** The idea that carbon dioxide equivalents allowed an easy comparison between different gases or that CO2 sets a baseline for comparison was largely appreciated by the majority of candidates and most gained this marking point. Some candidates thought that eCO2 was a real gas, rather than a measurement unit, and wrote about them being used in photosynthesis and being less harmful than other greenhouse gases
		ii	149;;	1	**Max 1** for 298 / 2 **OR** 298 x 0.5 **Examiner's Comments** The majority of candidates correctly calculated the mass of carbon dioxide that is equivalent to 0.5kg of nitrous oxide.

Question			Answer/Indicative content	Marks	Guidance
	c		(hydrofluorocarbons) have very high GWP; *idea that* small quantity of hydrofluorocarbons affect global warming to same degree as large quantity of other greenhouse gases; data quoted correctly in support;	Max 2	IGNORE high / -er / -est / large / -er / -est CREDIT idea that a small quantity of HFC can offset a large reduction in CO_2 production / emissions must be a comparison between GWP values Examiner's Comments There were some very good answers where many candidates had clearly linked the very high GWP value of hydrofluorocarbons to the fact that the release of a small quantity of it would offset a large reduction in CO2 emissions. Although some candidates didn't make clear comparisons, stating that the GWP value of hydrofluorocarbons was higher than the others without emphasising that it had a very high value and simply quoting figures.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
6	a	i	nitrogen-fixing bacteria / Rhizobium (in root nodules); nitrogen required for (synthesis of) nitrogen compounds; *idea of* soil is not depleted of, nitrogen containing compounds / named; *idea of* reduced need for fertiliser;	Max 3	IGNORE Azotobacter CREDIT named nitrogen compound, e.g. amino acids / proteins / RNA / DNA CREDIT increase nitrogen compounds in the soil / maintain a nitrogen rich soil IGNORE provide nitrates to soil CREDIT (legumes) naturally fertilise the soil Examiner's Comments This asked about the advantage of growing legumes to farmers from the point of view of synthesis of nitrogen compounds through nitrogen fixing bacteria in their root nodules, which increased protein synthesis in the plant and therefore its growth and through this increased soil fertility reducing the need for fertilizer. Candidates were then asked to explain how these nitrogen compounds through the mechanisms of decay brought about by bacteria and fungi using extracellular digestion involving deamination, ammonification and nitrification, were returned to the soil. The final part of the question asked candidates to consider the role of cereal crop stubble in the conservation of some bird species. This question tested both AO1 and AO2. The idea that legumes naturally fertilise the soil and of a reduced need for fertilisers was widely appreciated by many candidates in (i), who were also aware of the presence of nitrogen fixing bacteria (Rhizobium) in the root nodules, but most candidates did not link this to the formation of nitrogen containing compounds within the plant such as amino acids proteins,

Question			Answer/Indicative content	Marks	Guidance
					RNA or DNA but to nitrates which they released into the soil. Many candidates failed to make a link to the nitrogen cycle and referred to the increased content in water in the soil or increased biodiversity. The majority of candidates focused on two areas, either the involvement of bacteria or fungi in decomposition of dead plant material, or nitrification through the role of Nitrosomonas in converting nitrites to nitrates and Nitrobacter in converting nitrites to nitrates. Ammonification was also frequently stated. There were few, if any, references made to extracellular enzymes.
		ii	fungi / bacteria; extracellular enzymes; break down of organic material; deamination / ammonification; AVP;	Max 3	DO NOT CREDIT nitrogen fixing / nitrifying, bacteria CREDIT proteins / amino acids / nucleic acids ref. to nitrification

Question			Answer/Indicative content	Marks	Guidance
	b		*idea that* (stubble) provides a food source; *idea that* (stubble) provides, nesting sites / habitat;	Max 2	IGNORE provides shelter Examiner's Comments This asked about the advantage of growing legumes to farmers from the point of view of synthesis of nitrogen compounds through nitrogen fixing bacteria in their root nodules, which increased protein synthesis in the plant and therefore its growth and through this increased soil fertility reducing the need for fertilizer. Candidates were then asked to explain how these nitrogen compounds through the mechanisms of decay brought about by bacteria and fungi using extracellular digestion involving deamination, ammonification and nitrification, were returned to the soil. The final part of the question asked candidates to consider the role of cereal crop stubble in the conservation of some bird species. This question tested both AO1 and AO2. The majority of candidates were fully aware that the stubble provided a habitat or nesting site for the birds as well as providing them with a food source, which enabled them to answer this question with confidence.
			Total	8	

Question			Answer/Indicative content	Marks	Guidance
7	a		1 nitrogen (compounds) / named examples, converted to / AW, **ammonia / ammonium ions** OR **ammonification** of (organic) compounds; 2 (ammonium (ions)) converted to **nitrite**, by *Nitrosomonas*; 3 nitrite converted to nitrate, by *Nitrobacter*; 4 *idea that* **nitrifying bacteria** are responsible for formation of nitrate; **QWC**;	3 1	**Award** if any **3** of the following are used correctly with correct spelling **ammonia / ammonium ions / ammonification** **nitrite** **Nitrosomonas** (**IGNORE** upper or lower case) **Nitrobacter** (**IGNORE** upper or lower case) **nitrifying bacteria** **Examiner's Comments** Many Candidates showed a good knowledge of the bacterial species involved in nitrification and gained two of the four possible marking points. The majority of candidates failed to make the link between the nitrogen compounds within the decaying mosses and lichens and the formation of ammonia. The QWC mark was usually awarded indicating the correct use of technical terms by most candidates.

Question			Answer/Indicative content	Marks	Guidance
	b		*idea that* (trees) photosynthesise, uses / AW, carbon dioxide; (this) can offset carbon (dioxide) production / (trees) act as a carbon sink; idea that less fruit would need to be transported; (this) cuts down fuel use;	2	ACCEPT reduced, net / overall, CO_2 production ACCEPT reduction in food miles Examiner's Comments The idea that trees use up CO_2 was appreciated by most candidates. Although many candidates did not link it to its use in photosynthesis. Offsetting or overall reduction in atmospheric did not seem to be fully understood. Many statements were too vague such as trees 'reducing the CO_2 in the atmosphere'. Answers focusing on reduction in food miles or fuel use appeared less often but although always not precisely stated there was an understanding of the advantages of using local produce.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
8	a		palisade / mesophyll;	1	CREDIT spongy mesophyll DO NOT CREDIT cell (s)) Examiner's Comments This required an understanding of the links between photosynthesis and respiration. Both in terms of both the reactants involved and their locations. The role of ATP in the release of energy for biological processes was also covered. Candidates generally found this question challenging. It tested AO1 throughout. The location of the chloroplast caused a lot of problems. Stroma was a commonly given incorrectly as though the candidate was locating it within the cell rather than the tissue. In many cases where the palisade layer was identified the candidate lost the mark for placing the chloroplast within a cell rather than tissue.
	b	i	X carbon dioxide AND Z oxygen;	1	Both responses correct for 1 mark. ACCEPT CO_2 ACCEPT O_2 IGNOREDo not penalise incorrect formatting (e.g. CO2, O2)
		ii	Y water;	1	ACCEPT H_2O Do not penalise incorrect formatting (H2O)
		iii	W adenosine diphosphate;	1	ACCEPT ADP Examiner's Comments Most candidates knew the gases, and got them the right way round, in part (i), but only the better candidates worked out that the substance was water in part (ii). ADP was answered correctly by almost all candidates.

Question			Answer/Indicative content	Marks	Guidance
	c		letter C within stroma of the chloroplast; letter D within matrix of the mitochondrion;	2	Majority of the letter must be in the correct area **Award** a maximum of 1 mark if **BOTH** letters appear within the correct organelle but not in the correct region **Examiner's Comments** A large number of candidates placed the enzymes outside of both organelles, not appreciating the significance of the enzyme reactions and their locations.
	d		reduced NAD;	1	**CREDIT** NADH / $NADH_2$ / NADH and H^+ / red NAD **Examiner's Comments** The common error was the suggestion of either NADP or NADPH.
			Total	**7**	

Question			Answer/Indicative content	Marks	Guidance
9	a		*Rhizobium* / *Azotobacter*;	1	**Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer = **0 marks** **ACCEPT** phonetic spelling **Examiner's Comments** looked at the nutritional aspects of using Spirulina as a food source for both humans and animals. Candidates were asked to identify a species of bacterium that can fix nitrogen, which Spirulina is unable to do, then from the extract of a leaflet promoting Spirulina, link named substances with their beneficial effects. Candidates were also asked to outline the synthesis of lipids in the light independent reactions of photosynthesis, and finally, consider the advantages of eating Spirulina directly rather than using it as cattle food. The question tested both **AO1** and **AO2**. Rhizobium was correctly identified by many candidates in part (a). Azotobacter, the other correct alternative was rarely given. Nitrobacter and Nitrosomonas were frequently mentioned. In parts **(b)(i) – (iv)** amino acids and antioxidants were often correctly stated but vitamins B3 and B9 were usually incorrectly identified. Overall part **(c)** was answered well with many candidates gaining at least three marks. Early stages of this process, for instance CO_2 combining with RuBP using the enzyme Rubisco were stated by most. The point for the formation of a 6 carbon molecule was made but the link to two three carbon compounds was often not made even though glycerate phosphate was mentioned. Reduction to triose phosphate and its conversion to lipids scored marks for many candidates. Unfortunately many lost the QWC mark through not spelling out the appropriate terms. The quality of some of the answers

Question			Answer/Indicative content	Marks	Guidance
					gave the impression that candidates could easily have spelled out terms such as carbon dioxide, enzymes or triose phosphate. There seems to be confusion in some candidates about RuBP and Rubisco and the number of carbons at different stages in the cycle. Virtually all candidates stated that energy losses would occur if Spirulina was not eaten directly, but very few linked it to the ability to support a larger population by cultivating it for human consumption rather than as cattle feed. Students need to be reminded to read questions carefully and answer the questions asked.
	b		*Up to 3 marks for mark points 1 – 5*	Max 3	
			1 *idea that* **carbon dioxide** / CO_2, is combined with, **ribulose bisphosphate** / RuBP;		1. **ACCEPT** carbon is fixed OR RuBP is carboxylated
			2 by **enzyme ribulose bisphosphate carboxylase** / Rubisco;		
			3 *idea that* two 3 carbon compounds are formed from a, 5+1 / 6, carbon compound;		
			4 **glycerate phosphate** / GP, is converted to **triose phosphate** / TP;		
			5 using, reduced NADP and ATP;		5 **ACCEPT** NADPH / NADPH + H^+ / $NADPH_2$ / red NADP
			6 **triose phosphate** / TP, is converted to lipids;	1	**AWARD** using a **tick** and '**GM**' annotation

Question			Answer/Indicative content	Marks	Guidance
			QWC - use of 3 terms in correct context and with correct spelling;	1	DO NOT CREDIT abbreviations for QWC mark DO NOT CREDIT if terms used in incorrect context Use 3 terms from: carbon dioxide ribulose bisphosphate enzyme ribulose bisphosphate carboxylase glycerate phosphate triose phosphate Use a GREEN DOT to identify where a term has been credited. Insert a tick (✓) against the pencil icon if the QWC is awarded and a cross (x) if not.
	c		*idea that* a larger human population could be supported; *when eating Spirulina directly* *idea of* humans as primary consumers / AW OR energy lost in transfer (from cattle to humans); minerals / vitamins, lost (as retained in parts of cattle not eaten);	2	CREDIT reverse argument for humans eating cattle fed on *Spirulina* IGNORE 'nutrients'
			Total	8	

Question			Answer/Indicative content	Marks	Guidance
10		i	feeding / eating / consuming / ingesting;	1	IGNORE digestion/ heterotrophic nutrition/ predation Examiner's Comments Surprisingly, (c)(i) caused more problems than expected. The most common incorrect answers were ‘digestion’ and ‘predation’. More rarely, there were also incorrect references to productivity and trophic levels.

Question			Answer/Indicative content	Marks	Guidance
		ii	shrimp to fish; (because) more indigestible parts (in shrimp); OR fish to kingfisher; (because) more indigestible parts (in fish); OR kingfisher to hawk; (because) kingfisher, is small / has large SA : Vol ratio / has more indigestible parts;	2	*Marks awarded for* ***link in food chain*** *correctly* ***linked*** *to* ***explanation*** ACCEPT named parts e.g. outer skeleton /shell ACCEPT named parts e.g. scales/ bones ACCEPT more energy lost as heat ACCEPT named parts e.g. bones /feathers/beak Examiner's Comments Most candidates gained one mark for identifying the least efficient energy transfer level (most identifying kingfisher to hawk). A few candidates did not read the question carefully and wrongly suggested the aquatic producers to protoctists transfer,thus gaining no marks, as the answer requires a transfer between *animals*. Such was the challenge of the mark scheme that very few candidates got the second mark. Many candidates discussed losing energy by activity and indigestible parts, however very few identified losing energy as heat or giving the important distinction that they lost *more* energy as heat, or had *more* indigestible parts than other animals. They simply explained that more energy was lost further down the food chain, which did not answer the question.
			Total	3	

Question			Answer/Indicative content	Marks	Guidance
11			T1. lay, tape / string, in a line / across zones; T2. from sea to post-pioneer (boundary) / AW; T3. perform, line / belt, transect; Q4. (frame / open / point) quadrat; Q5. placed systematically / back to back / intervals (along tape); K6. use a key; K7. identify species present; K8. estimate percentage cover / count plants / species frequency / use ACFOR scale; R9. ref. to repeated sampling over time; R10. ref. to repeated sampling in one area;	6 max	Look for wording that indicates up to the end of the pioneers or to first post-pioneers, e.g. top of dune 'lay tape across salt spray and rain - watered zone' = T1 and T2 Q5. DO NOT CREDIT randomly K8. IGNORE percentage abundance

Question			Answer/Indicative content	Marks	Guidance
			QWC – award if TWO items of equipment above is linked to description of correct use;	1	Award if any TWO of the following pairs of marking points have been awarded: T1,T2/ T3 Q4,Q5 K6,K7/ K8 Please insert next to the pencil icon: • You should use the green dot to identify each pair of mps that you are crediting • a tick (?) if QWC has been awarded • or a cross (?) if QWC has not been awarded Examiner's Comments Candidates were requested to describe sampling techniques to investigate the distribution and abundance of grasses in a typical succession from the beach up a dune. Most correctly chose a belt or line transect, laying a tape down across the zones. The use of quadrats was also well known, but the description of how these would be used was frequently spoiled by reference to random sampling techniques. Many accounts included the use of a key to identify the species found, although the term ‘key’ did not always appear to be familiar to candidates. The methods used to assess the distribution and abundance were generally described well, with a reference to percentage cover being most common. Repetition of sampling rarely scored a mark as it was usually only vaguely mentioned: repeats over time or in the same area having been omitted.
			Total	7	

Question			Answer/Indicative content	Marks	Guidance
12	a	i	*idea that Rhizobium* is, involved in nitrogen fixation / not involved in nitrification; (*Rhizobium*) will not reduce / increases levels of, ammonia / ammonium ions;	1 max	IGNORE refs to plant host / symbiosis / legume / nodules / not aquatic / not free living ACCEPT description e.g. *Rhizobium* produces, ammonia / ammonium ions from nitrogen gas ACCEPT NH_3 / NH_4^+ Examiner's Comments This question was well answered by most candidates. The fact that *Rhizobium* was a nitrogen fixer was the commonest correct response. Unsurprisingly there was some confusion between nitrogen fixing/nitrifying and even denitrifying, but this was rare. Some candidates just said that *Rhizobium* is found in roots and would therefore not survive in water, which did not gain credit.
		ii	use of (micro)organisms to, remove / oxidise, ammonia / ammonium ions; use of (micro)organisms for, commercial process / industrial process;	1 max	ACCEPT NH_3 / NH_4^+ IGNORE 'prevents build- up of ammonia' IGNORE refs to products of nitrification / food production / drug production / for human benefit Examiner's Comments This question was not well answered. Many candidates missed getting the mark by giving a generalised and vague definition of biotechnology, e.g. microbes that are used for human benefits, rather than linking it to commercial or industrial processes. Those candidates who chose to discuss this example of biotechnology rarely gained the mark as they wrote about microorganisms being used to keep fish alive, rather than to remove ammonia.

Question			Answer/Indicative content	Marks	Guidance
		iii	*idea that* the desired product is *Nitrosomonas (europaea*) (cells); enzymes / proteins, are denatured (by incorrect pH); enzymes needed for, (named metabolic) processes in growth; (incorrect pH) disruption of, tertiary / 3D,structure / shape; *ref to* effect of hydrogen ions on, H / ionic, bonds;	3 max	ACCEPT increases yield of *N. europaea* IGNORE ref to products of *Nitrosomonas europaea* DO NOT CREDIT nitrogenase is denatured CREDIT enzymes for, respiration / protein synthesis / cell reproduction / DNA replication IGNORE active site Examiner's Comments The vast majority of candidates did not really understand that the desired product was the *Nitrosomonas* bacteria, though plenty still gained the point for saying the bacteria would die. Many gained a mark for denaturation of enzymes, though it was obvious they were talking about enzymes associated with nitrification rather than the enzymes used for processes in growth. Quite a few discussed a change in tertiary structure though many talked about the shape of the active site, which wasn't specific enough to gain that mark. When candidates recognised that hydrogen bonds were broken, many didn't gain the mark as they didn't link this with the effect of hydrogen ions.
	b	i	unit should be in (column) headings;	1	Examiner's Comments The vast majority of candidates gained this mark, though some talked about the need for a column of means, which did not gain credit.

Question			Answer/Indicative content	Marks	Guidance
		ii	number of bacteria (in bacterial suspensions); plantlets not sterilized; (initial) size / mass, of plantlets; concentration of ammonia solution;	1 max	ACCEPT "concentration" of bacteria IGNORE amount of bacteria IGNORE decimal places of grams / duration of trial / age of plantlets / time of day dry mass measured / volume of sand / number of plantlets Examiner's Comments This was a poorly answered question. Most responses were carbon dioxide concentration or even oxygen concentration; pH was another common incorrect response. Those candidates who did gain the mark said concentration of bacteria, concentration of ammonia solution or size / mass of plantlet.
			Total	7	

Question			Answer/Indicative content	Marks	Guidance
13	a	i	(in) thylakoid / grana / lamellae. ✓	1	Examiner's Comments **a)(i)** was well answered: 95% of candidates gave the necessary level of detail required for this answer; a few candidates stated chloroplasts.
		ii	(plant thylakoids in) chloroplast(s) / stacks / grana **ora** ✓ (cyanobacteria thylakoids) near, cell surface membrane / cell wall. ✓	2	**IGNORE** ref to thylakoids attached (to cell surface membrane). Examiner's Comments The majority of candidates structured their answers well with clear references to plant cells and (cyano)bacteria. Most candidates correctly described the thylakoids in plant cells as stacked with only a minority of those adding that they are in chloroplasts which suggests many did not appreciate that thylakoids were held in an organelle in plant cells when compared to the cyanobacteria. Candidates then struggled to describe where the thylakoids were located in cyanobacteria. Many stated they were attached to or on the cell surface membrane and some described them as outside the cell. Candidates should be reminded to read their answers to make sure they make sense.
		iii	stroma (in chloroplast) ✓ carboxysomes (in cytoplasm) ✓	2	Examiner's Comments **(a)(iii)** was generally well answered with a few candidates stating cytoplasm only for mp2 and some confusing stroma with matrix of mitochondria.

Question			Answer/Indicative content	Marks	Guidance
		iv	increased CO_2, around Rubisco / in carboxysomes ✓ (therefore) CO_2, binds to / AW, Rubisco not O_2 ✓ (Membrane-bound) pumps for HCO_3^- (entry into cell)✓ carbonic anhydrase for CO_2 (entry into carboxysome) / conversion of HCQ_3^-✓	3 max	ACCEPT *idea* of CO_2 outcompetes O_2 Examiner's Comments (a)(iv) was also generally well answered and candidates clearly used and understood the literature provided to complement this question. Many candidates wrote about the ancient form of RuBisCO which was not worthy of marks as the question asks for an explanation and this was a direct quote from the literature. Some candidates described the HCO_3^- being pumped into the carboxysome which clearly does not have pumps in the diagram provided. A few candidates described oxygen as being prevented from entering the cell and / or the carboxysome. Generally candidates tended to imply that no oxygen was surrounding RuBisCO. The presence of the pumps obviously led to this misconception. Candidates should be reminded that gases can simply diffuse at a certain rate through all membranes but pumps will increase the rate of movement for other gases as well as allowing passage of charged ions. As a consequence of this, very few candidates mentioned that carbon dioxide would be able to out-compete oxygen for RuBisCO.
	b	i	different <u>concentrations</u> of enzyme (in the different types of tobacco plants).	1	Examiner's Comments Very few candidates achieved the mark for (b)(i). The majority of answers referred to RuBisCO having more than one active site and that's why it needed standardising. There seemed to be little appreciation of the different concentrations of RuBisCO in the different plants. Those candidates that did realise this then referred to the number of enzymes or amount and not concentration.

Question			Answer/Indicative content	Marks	Guidance
		ii	• correct axis labels **AND** both axes scaled appropriately ✓ • three data sets plotted **AND** correctly identified / labelled ✓ • all points correctly plotted to within ± half square **AND** plots joined by straight lines **OR** appropriate line of best fit ✓ • SD / error bars, plotted for all data points ✓	4	i.e. x-axis label: CO_2 concentration / mol dm^{-3} y-axis label: (mean) rate / μmol CO_2 fixed per mol active sites s^{-1} **Examiner's Comments** In answering **(b)(ii)** most candidates labelled their axes correctly with all the units and used clear keys for the different tobacco plants. Approximately 50% of candidates plotted a bar graph as they did not appreciate that the concentration of carbon dioxide would be quantitative data and thus a linear graph. Candidates should be aware that quantitative data can be plotted even if the given values are not equally distributed. Many candidates that plotted line graphs drew lines of best fit that went beyond the data points, particularly converging at zero. Candidates should be aware that a line of best fit can only be used for the data presented and not extrapolated unless specifically requested in the question. Most candidates attempted to plot error bars but some only plotted 2 SD values. They had misinterpreted the question stem 'error bars showing 2 standard deviations' and plotted only 2. Candidates should practice plotting standard deviations as error bars and realise that 'showing 2 standard deviations' would mean double the length of the error bars.

Question			Answer/Indicative content	Marks	Guidance
		iii	*yes because* (carboxylase) activity / rate is, greater in modified tobacco plants (than in wild type) ✓ data quoted to support this conclusion, including correct units used at least **once** ✓ differences (between modified and wild type) are, (statistically) significant / not due to chance ✓ (between modified and wild type) error bars do not overlap / all SDs are small ✓ (between modified and wild type) error bars do not overlap / all SDs are small ✓ *However* only three CO_2 concentrations tested ✓	3 max	ALLOW named modified tobacco plant only if clear comparison with wild type 1 rate for, RbcX / M35, and wildtype **Examiner's Comments** Most candidates recognised the greater rate with modification in **(b)(iii)** although some candidates did not appear to refer back to the graph they had just plotted and use the term 'rate', mainly stating that modified plants were better at fixing carbon dioxide. If candidates had looked at the graph to assist with the answer, it would also have prompted more candidates to achieve mp2 and 4 as very few correctly used units when quoting figures and did not refer to error bars not overlapping. Time and space were used discussing the large SD values of the modified plants which were irrelevant as the comparison was always with the wild type.
		iv	*valid because* M35 has higher rate of, CO_2 fixation / carboxylase activity (at all concentrations) ✓ *not valid because* error bars overlap so, differences due to chance / not statistically significant ✓ large(r) SD so more variation in results ✓	2 max	**Examiner's Comments** For **(b)(iv)**, all candidates appreciated that M35 showed greater rate but as before, did not use the term rate or activity, as prompted in the literature and previous graph. There was a good understanding and description of error bars overlapping or SD values being large but some candidates did not follow through by discussing the consequence of this to the data, merely saying the data is less valid without checking the question stem that validity referred to the student's conclusion, not the data.
			Total	18	

Question			Answer/Indicative content	Marks	Guidance
14	a		legume / leguminous ✓	1	DO NOT ALLOW dicots or dicotyledons IGNORE named examples of crops (as this is not relevant to the question) Examiner's Comments Lower performing candidates did not identify that the question was asking for a type of crop and instead gave examples of crops which was not credited.
	b	i	respiratory substrate ✓	1	ALLOW respiratory carbohydrate/sugar ALLOW energy source DO NOT ALLOW source of energy FOR respiration DO NOT ALLOW source of, carbohydrates /sugars
		ii	*Summary of instructions to markers:* *Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.)* *Using a 'best-fit' approach based on the science content of the answer, first decide which of the level descriptors,* ***Level 1****,* ***Level 2*** *or* ***Level 3****, best describes the overall quality of the answer.* *Then, award the higher or lower mark within the level, according to the* ***Communication Statement*** *(shown in italics):* ◦ award the higher mark where the Communication Statement has been met. ◦ award the lower mark where aspects of the Communication Statement have been missed. • The science content determines the level. • The Communication Statement determines the mark within a level. Level 3 (5–6 marks) Details of method and hazard control with all important steps included.	6	

Question			Answer/Indicative content	Marks	Guidance
			There is a well-developed line of reasoning which is clear and logically structured and uses scientific terminology at an appropriate level. All the information presented is relevant and forms a continuous narrative. Level 2 (3–4 marks) Outline of method and hazard control with some details missing. *There is a line of reasoning presented with some structure and use of appropriate scientific language. The information presented is mostly relevant.* Level 1 (1–2 marks) Correct steps in method or hazard control are described but lack detail. *There is an attempt at a logical structure with a line of reasoning The information is in the most part relevant.* 0 marks No response or no response worthy of credit.		Indicative scientific points could include: AO1.2: examples of knowledge of method • locate a root nodule • use forceps to remove nodule • cut root nodule from plant using a scalpel / razor blade on a tile • wash and sterilise nodule • crush nodule and dilute with distilled water • incubate culture (for 3 days; temperature is given in 1biii and can be ignored). AO2.7 examples of the application of risk assessment/hazard identification: • potential hazards associated with forceps and scalpel & control (e.g. use of tile; blunt forceps) • sterilising the nodule using alcohol/distilled water • use of sterile petri dishes and other equipment (e.g. boiling; use of sodium hypochlorite / hydrogen peroxide solution) • potential microbial hazards (soil-borne microbes) & control (inoculating loop) • safe disposal of equipment <u>Examiner's Comments</u> Candidates who performed well in this question demonstrated that they had either completed this practical in their centre, or observed a demonstration. These candidates gave details such as the identification of healthy nodules by colour (pink) and how to carry out aseptic techniques. Some candidates did not appreciate the bacterium had to be obtained from the root nodules instead using the "whole plant" or inappropriate parts of the plant e.g. stem.

Question			Answer/Indicative content	Marks	Guidance
		iii	optimal temperature for (bacterial) enzymes ✓ allows rapid reproduction rates / AW ✓ prevent growth of <u>pathogenic</u> bacteria / ORA ✓	2 max	ALLOW 'doesn't denature bacteria enzymes' ALLOW faster (rate of) mitosis / quicker reproduction <u>Examiner's Comments</u> Able candidates recognised that incubating bacteria above this temperature could give lead to the culturing of bacteria that could be harmful and pathogenic to humans. Many candidates referred to the optimal temperature for the bacterial enzymes but did not then link this to increased reproduction rates. Exemplar 1 This prevents (or rather minimises) the risk of growing cultures that are harmful to humans as the core body temperature = 37°C (BOD) so bacteria would need to survive at this temperature. Also because this is the temperature at which bacterial enzymes work most efficiently i.e. the optimum. ✓ [2]
			Total	10	

Question			Answer/Indicative content	Marks	Guidance
15	a		climax ✓ plagioclimax ✓ deflected ✓	3	
	b		improves soil quality / provides food / shelter, for future species ✓	1	ALLOW ref to production of humus
	c		any 3 from: use of quadrats ✓ (belt) transect / systematic sampling ✓ record type and abundance of plant species ✓ use of key to identify plant species ✓	max 3	ALLOW regular intervals /example of an interval IGNORE stratified sampling Examiner's Comments Parts 33a-33c were answered well by most candidates but in 33c, a few candidates lost marks by first suggesting that they would use a transect and then contradicting themselves to say they would use random sampling. It is important for candidates to decide on one answer as examiners cannot select a correct answer from a series of answers.
	d	i	16% ✓✓	2	ALLOW 15.8% 15.78% = 1 mark max If answer incorrect, '(13 100/83 000) × 100' = 1 mark
		ii	snails do not lose energy through heat / snails are, ectotherms ✓	1	ORA 'cattle use more energy to maintain temperature/cows are endotherms' IGNORE ref to small size or slow movement of snails Examiner's Comments Examiners were looking for the idea that snails are ectothermic animals, unlike cattle who lose a lot of energy through heat.
			Total	10	