

OCR A-LEVEL BIOLOGY B • H422

BIOLOGY



EXAM QUESTION PACK

4.3.1 PHOTOSYNTHESIS, FOOD PRODUCTION AND MANAGEMENT OF THE ENVIRONMENT

SCORE

/279

PERCENTAGE

%

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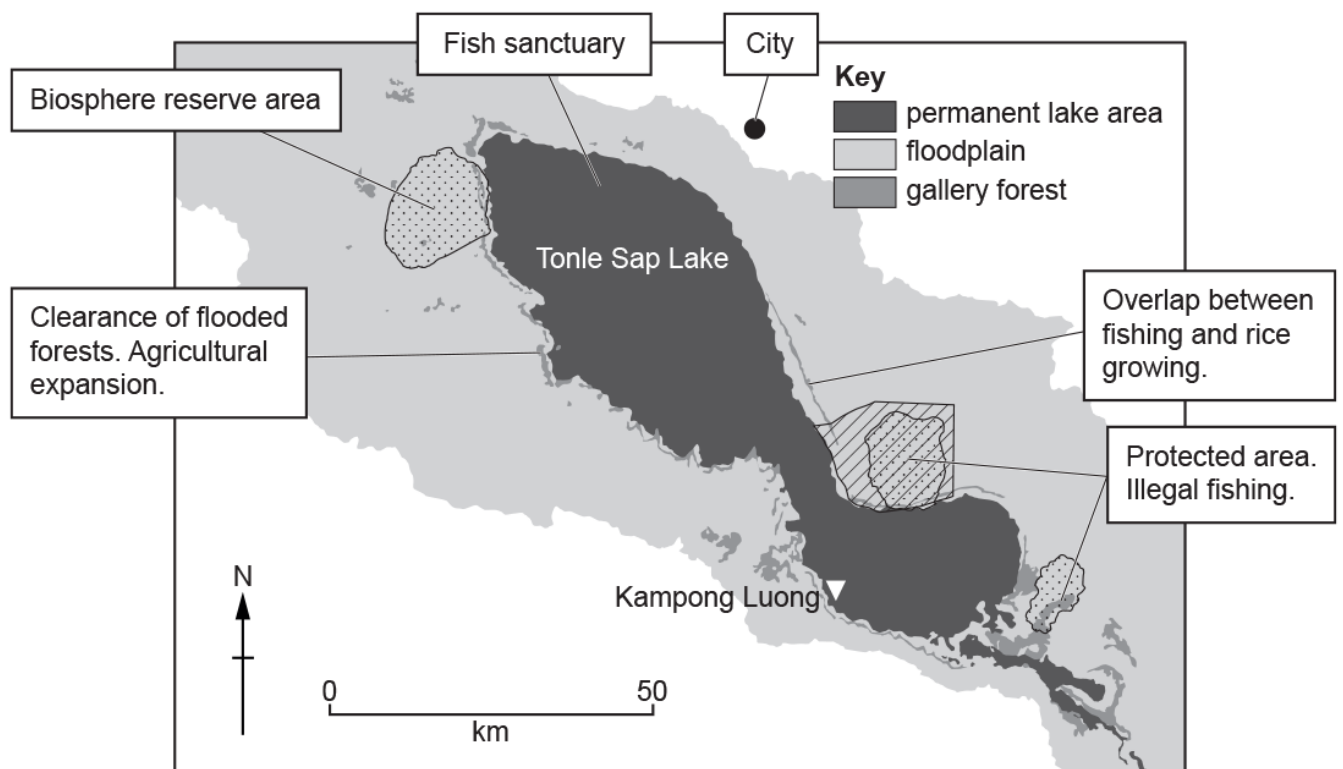
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1 Tonle Sap Lake in Cambodia is one of the world's most productive and biodiverse freshwater ecosystems.

The human population of the Tonle Sap Lake live on floating villages that rise and fall with the water levels and depend on the traditional ways of living from rice farming, fishing and extracting forest resources.

The location map shows the Tonle Sap Lake with some of the human activities that take place.



A team of ecologists recorded the number of animal species living in four different habitats provided by one region of the Tonle Sap Lake.

Their data are shown in the table below.

Habitat	Number of different animal species
Deep water	17
Abandoned rice fields	12
Floodplain shrubland and forest	92
Rice fields	4

(i) Suggest reasons for differences in the number of animal species in these habitats.

[2]

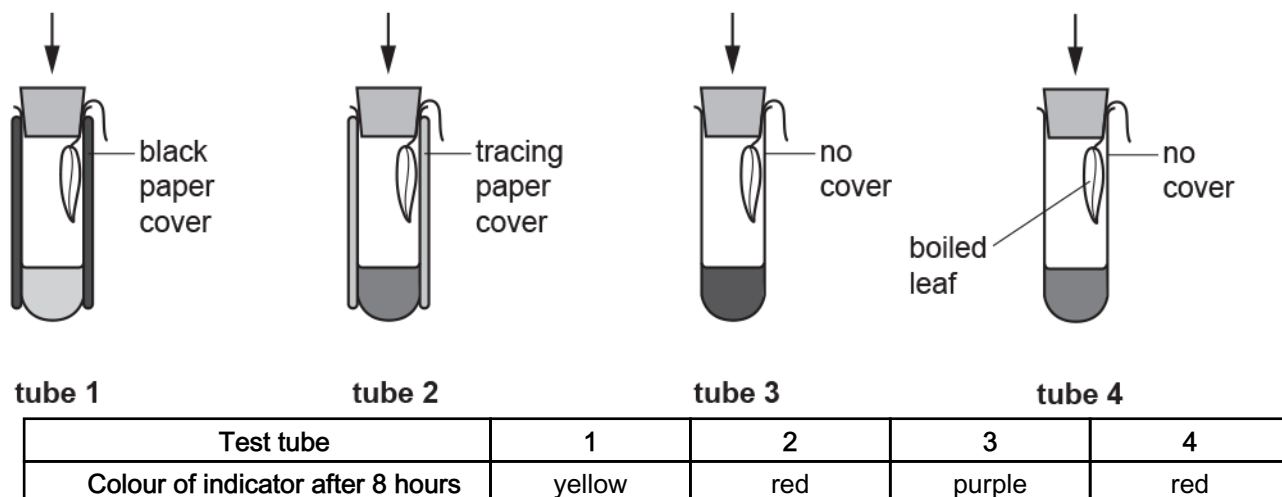
(ii) State how the team of ecologists could calculate the **biodiversity** in each of these habitats **and** what additional data would be needed for the calculation.

[2]

2 Hydrogen carbonate indicator was used to investigate gaseous exchange in plants by measuring the change in pH.

- The indicator ranges from yellow at pH 7.6 to purple at pH 9.2.
- The indicator is red in atmospheric air with normal carbon dioxide concentration.

Four test tubes containing 2 cm³ of hydrogen carbonate indicator and equal-sized leaves from the same plant were prepared as shown in the diagram below. The test tubes were then illuminated under the same light source for 8 hours.



Which of the statements, A to D, about the outcome of the investigation is correct?

- A Both photosynthesis and respiration are taking place in all four test tubes.
- B The rate of photosynthesis is greater than the rate of respiration in test tube 2.
- C The rate of photosynthesis is greater than the rate of respiration in test tube 3.
- D The rate of photosynthesis is equal to the rate of respiration in test tube 3.

Your answer

[1]

3 Which of the structures, A to D, in the ruminant digestive system secretes hydrochloric acid and digestive enzymes?

- A abomasum
- B omasum
- C reticulum
- D rumen

Your answer

[1]

4 Which of the statements, A to D, about why respiration in animals and plants is dependent on photosynthesis is correct?

- A Triose phosphate (TP) can be hydrolysed into glucose.
- B Triose phosphate (TP) can form 6-carbon sugars.
- C Triose phosphate (TP) and glycerate-3-phosphate (GP) can be joined to form sucrose.
- D Triose phosphate (TP) can be converted into fatty acids.

Your answer

[1]

5(a) Plants are usually adapted to living in conditions of different light intensities.

The leaf of a plant that is adapted to living in shade will differ from the leaf of a plant that is adapted to living in sunlight.

A student investigated the correlation between leaf and petiole sizes of two species of ivy plants.
The following procedure was carried out:

- a random sampling technique was used to collect 10 samples of species A and 10 samples of species B
- the variables of leaf width and petiole length, shown in Fig. 2.1, were measured.

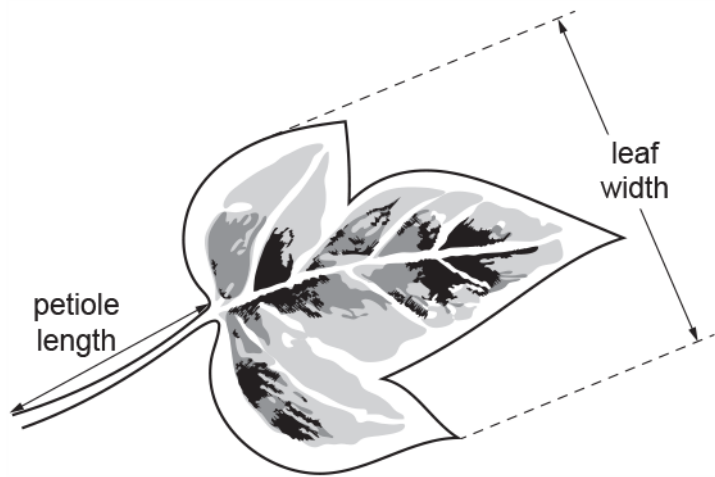


Fig. 2.1

Some of the student’s results are shown in Table 2.1.

Sample	Species A					
	Petiole length (mm)	Rank	Leaf width (mm)	Rank	d	d ²
1	28		52			
2	30		55			
3	17		31			
4	31		52			
5	35		56			
6	45		61			
7	46		62			
8	77		98			
9	33		40			
10	57		69			
					Total	

Table 2.1

(i) Complete the missing values in **Table 2.1** for species A.

[2]

(ii) Calculate Spearman's rank correlation coefficient (r_s).

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

$r_s = \dots\dots\dots$ [2]

(iii) The null hypothesis for this investigation was:

'There is no significant correlation between leaf width and petiole length.'

Write a conclusion for the results.

Your conclusion should explain whether the null hypothesis should be rejected or accepted at the 5% level of probability.

	10%	5%	2%	1%
<i>n</i>				
1	—	—	—	—
2	—	—	—	—
3	—	—	—	—
4	1.0000	—	—	—
5	0.9000	1.0000	1.0000	—
6	0.8286	0.8857	0.9429	1.0000
7	0.7143	0.7857	0.8929	0.9286
8	0.6429	0.7381	0.8333	0.8810
9	0.6000	0.7000	0.7833	0.8333
10	0.5636	0.6485	0.7455	0.7939

-----[2]

- (b) *Metasequoia occidentalis* is an extinct species of redwood tree that grew in forests approximately 39 million years ago.

A group of students wanted to find out if the leaves of *M. occidentalis* were adapted to sun or shade conditions.

They obtained three electron micrographs showing the ultrastructure of chloroplasts that had been extracted from:

- fossilised leaf samples of *M. occidentalis*
- leaf samples of *M. glyptostroboides*, a living *Metasequoia* species that had been growing in sun conditions
- leaf samples of *M. glyptostroboides* that had been growing in shade conditions.

- (i) Suggest **one** reason for using a living species of *Metasequoia* in this investigation.

-----[1]

- (ii) * One of the students made drawings of a chloroplast from each of the three electron micrographs. These are shown in Fig. 2.2a, Fig. 2.2b and Fig. 2.2c.

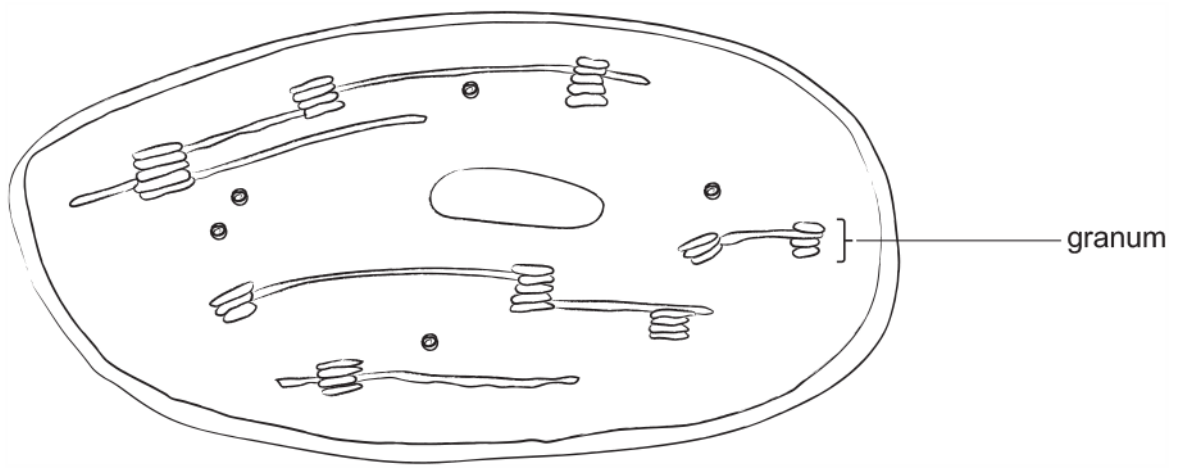


Fig. 2.2a chloroplast from *M. occidentalis*

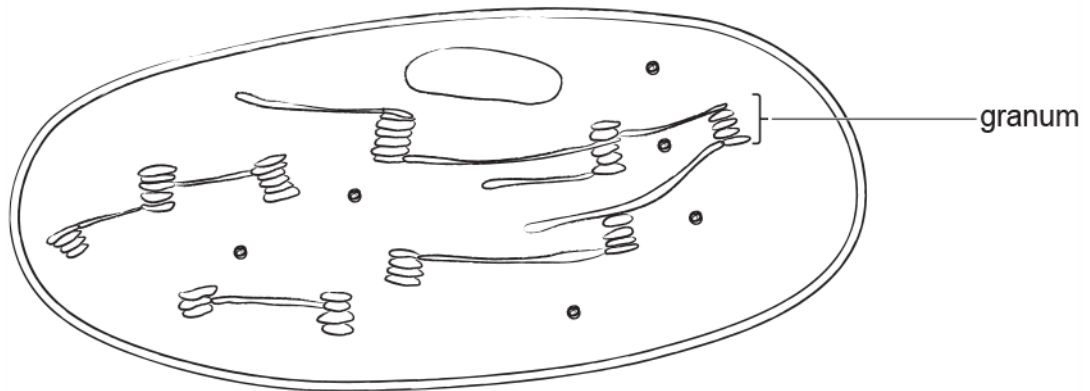


Fig. 2.2b chloroplast from *M. glyptostroboides* in sun conditions

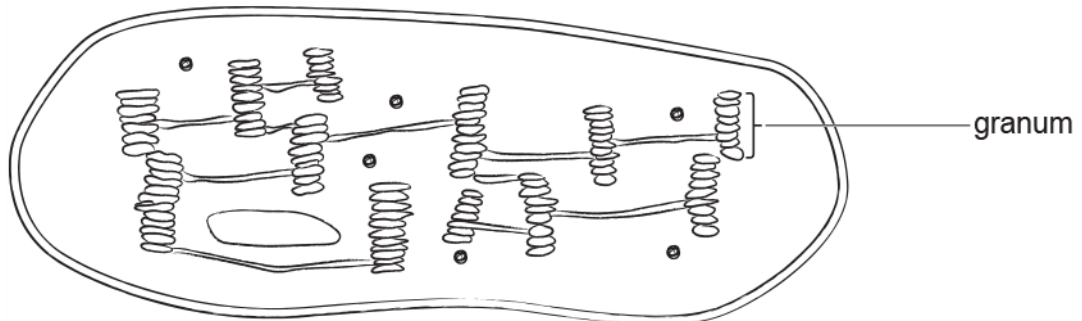


Fig. 2.2c chloroplast from *M. glyptostroboides* in shade conditions

The student concluded that:

M. occidentalis is likely to have grown in sun conditions with high light intensity.

Evaluate this conclusion.

Handwriting practice lines consisting of 20 sets of three horizontal dashed lines.

[6]

6(a) Fig. 3.1 outlines the two stages of photosynthesis.

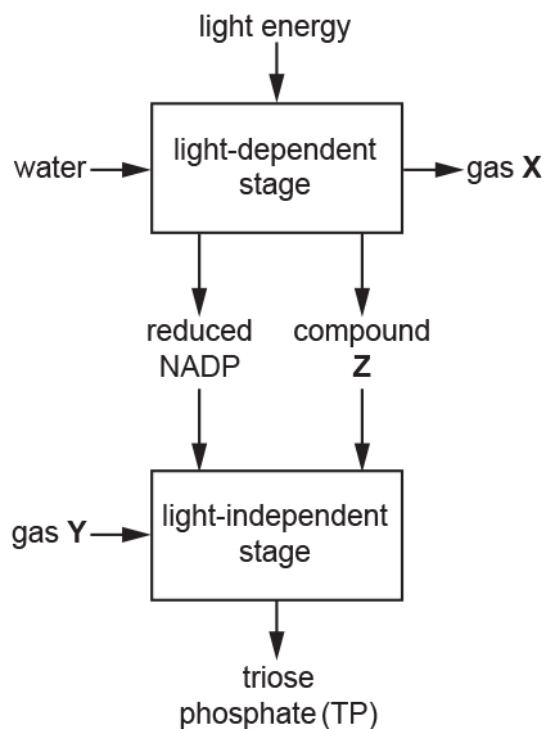


Fig. 3.1

(i) Identify the following from Fig. 3.1:

gas X

gas Y

compound Z

[2]

(ii) Name the structure in the chloroplast in which the light-dependent stage of photosynthesis takes place.

..... [1]

(iii) Describe **two** ways in which the structure you named in (ii) is adapted to its function.

.....

----- [2]

(b) When light energy is absorbed by photosynthetic pigments it causes electrons to be excited to a higher energy level.

(i) Explain how energy from the excited electrons is transferred to ATP.

[4]

(ii) Suggest **two** reasons why the transfer of energy from excited electrons to ATP is not 100% efficient.

1. -----

2. -----

[2]

7 Which of the units, A to D, is suitable in calculating the energy content of areas of tidal mud?

- A megajoules (MJ)
- B MJ m^{-1}
- C MJ m^{-2}
- D $\text{MJ m}^{-2} \text{yr}^{-1}$

Your answer

[1]

8 The table below shows some energy data for a forest ecosystem.

Which of the options, A to D, is the net primary productivity of the ecosystem in $\text{kcal m}^{-2} \text{yr}^{-1}$?

total plant biomass	70 000 kcal m^{-2}
total animal biomass	4 300 kcal m^{-2}
gross primary productivity	18 000 $\text{kcal m}^{-2} \text{yr}^{-1}$
animal respiration	2 900 $\text{kcal m}^{-2} \text{yr}^{-1}$
plant respiration	6 500 $\text{kcal m}^{-2} \text{yr}^{-1}$

- A 11 500
- B 24 500
- C 52 000.
- D 92 300

Your answer

[1]

9(a) In the 1950s, Melvin Calvin studied the series of reactions that we now know as the Calvin Cycle.

Calvin's 'lollipop' experiment was so called because it used a lollipop-shaped glass flask containing single-celled photosynthetic algae growing in culture.

A diagram of the apparatus Calvin used is shown in Fig. 4.1.

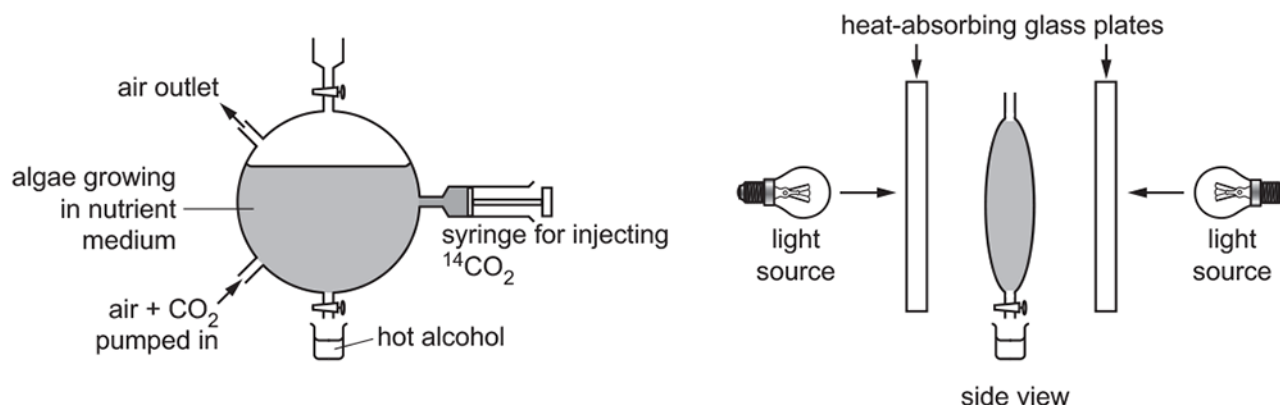


Fig. 4.1

The algae were illuminated for 30 minutes before the start of the experiment. Air and carbon dioxide were pumped into the suspension throughout.

At time zero, a small amount of radioactively-labelled carbon dioxide (¹⁴CO₂) was injected from the syringe.

At intervals after addition of the ¹⁴CO₂, samples of the suspension were run off into hot alcohol before being analysed.

Suggest the reasons for the following steps in the experiment.

1. Illuminating the algae for 30 minutes before the start of the experiment.

2. Placing heat-absorbing glass between the light sources and the flask.

3. Running each sample into hot alcohol before analysis.

[3]

- (b) Calvin measured the relative radioactivity in various compounds at 2 seconds, 10 seconds and 30 seconds after addition of the $^{14}\text{CO}_2$.

The results of the analysis are shown in Table 4. Presence of radioactivity is represented in the table as '+' and no radioactivity as '-'.

Organic compound	Relative radioactivity present at time after addition of $^{14}\text{CO}_2$		
	2 s	10 s	30 s
Amino acids	–	–	+
Glycerate-3-phosphate (GP)	+	+	+
Sucrose	–	–	+
Sugar phosphates	–	–	+
Triose phosphate (TP)	–	+	+

Table 4

- (i) Name the enzyme responsible for the initial incorporation of radioactive CO_2 into organic compounds.

[1]

- (ii) Use the results in Table 4 to explain the order in which the organic compounds are produced during photosynthesis.

----- [3]

- (c) Calvin isolated the compounds formed at the earliest time points and found they contained three carbon atoms.

This led him to conclude that the first reaction in the cycle was between CO_2 and a 2-carbon compound.

Explain why Calvin's conclusion was **incorrect**.

----- [2]

- (d) Fig. 4.2 shows the relationship between the net rate of photosynthesis and light intensity in a plant growing at atmospheric CO_2 concentration (0.04%).

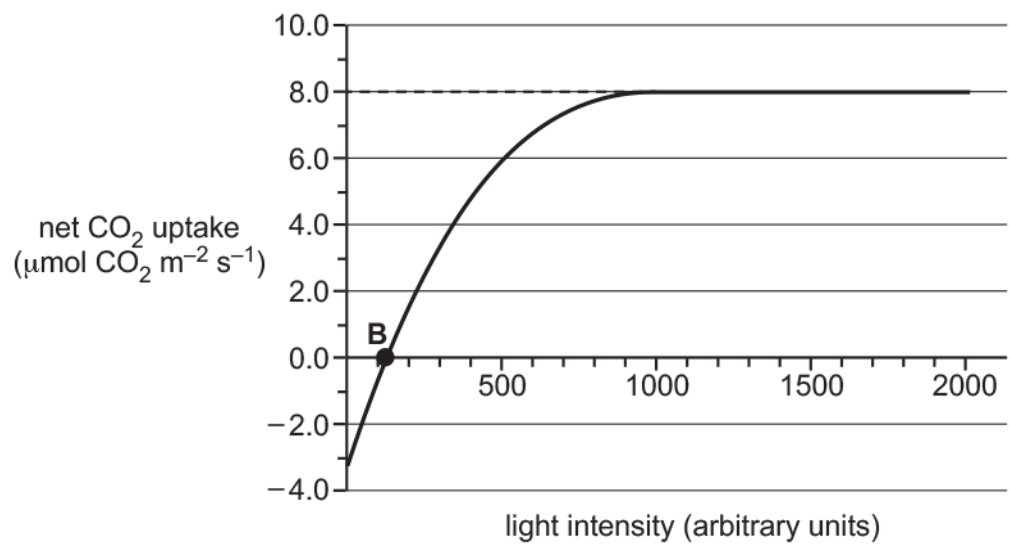


Fig. 4.2

- (i) The plant had a leaf area of 0.97 m².

Calculate the maximum amount of CO₂ that the plant can take up in 1 minute.

maximum amount of CO₂ taken up in 1 minute = ... μmol [2]

- (ii) Explain the significance of the point labelled **B** on Fig. 4.2.

[1]

10(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.

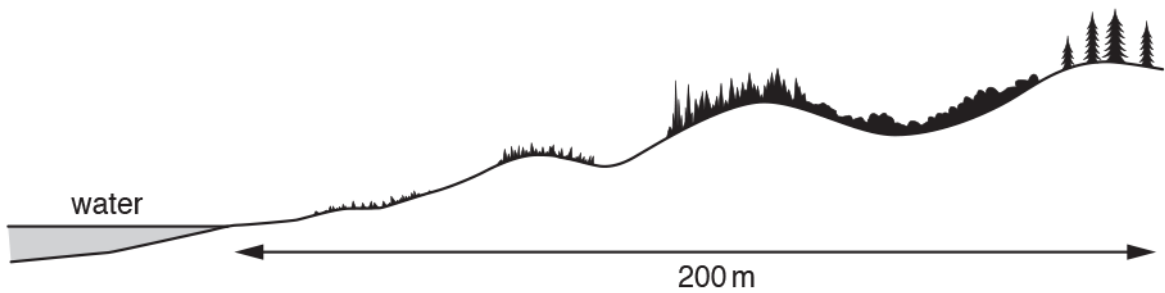


Fig. 33

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]

(e) * Cattle are ruminant animals. The stomach of a ruminant animal contains specialised chambers.

Explain how the ruminant stomach digests food to produce important molecules.

Your answer should refer to **named** chambers of the stomach.

[illegible]

[6]

11 Proton pumps establish electrochemical gradients, which are required for ATP production.

Which of the options, A to D, are regions of a plant cell **into** which protons are pumped?

- A chloroplast stroma and mitochondrial intermembrane space
- B chloroplast stroma and mitochondrial matrix
- C thylakoid space and mitochondrial intermembrane space
- D thylakoid space and mitochondrial matrix

Your answer

[1]

12 DCPIP is a molecule that is used to measure the rate of the Hill reaction in isolated chloroplasts.

Which of the options, A to D, correctly describes DCPIP during the Hill reaction?

- A it becomes oxidised
- B it loses electrons
- C it mimics NADP
- D it turns from colourless to blue

Your answer

[1]

13 Which of the molecules, A to D, is the source of electrons in photosynthesis?

- A ATP
- B CO₂
- C H₂O
- D NADPH

Your answer

[1]

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.

15(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.

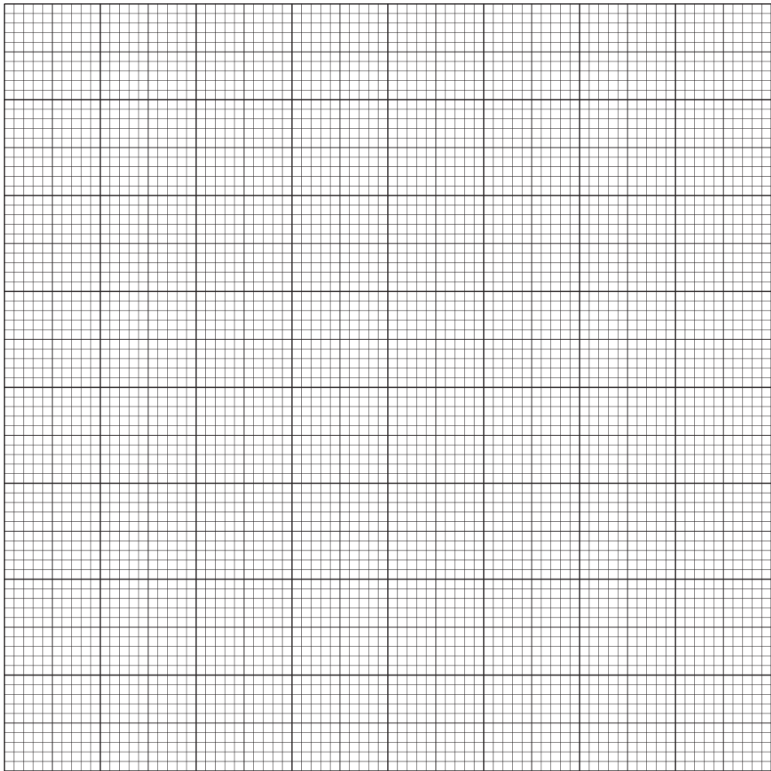
-----[3]

(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 (CO₂).

- (i) Explain why the units of carboxylase activity are 'mol CO₂ fixed per mol active sites s⁻¹' rather than just 'mol CO₂ fixed s⁻¹'.

----- [1]

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



[4]

- Explain your conclusions.

[3]

- “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]



[6]

A potometer was used to investigate the effect of wind speed on the rate of transpiration in a leafy shoot.

The investigation was set up as shown in Fig. 33.

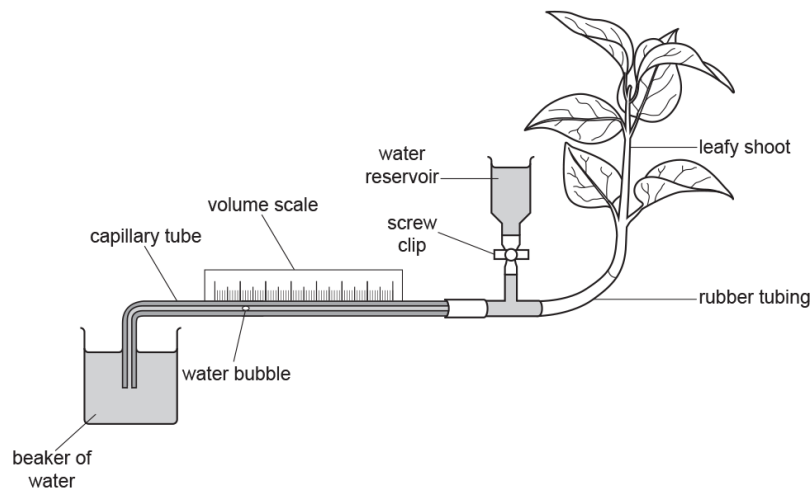


Fig. 33

To vary wind speed, a fan with five different speeds was positioned at a fixed distance from the leafy shoot.

The results of the investigation are shown in Table 33.

	Wind speed (ms ⁻¹)	Rate of water uptake (mm min ⁻¹)				
		Replicate 1	Replicate 2	Replicate 3	Mean	Standard deviation
1	0	0.3	0.3	0.3	0.30	0.00
2	2	2.6	2.5	2.5	2.53	0.06
3	4	5.0	4.8	4.9	4.90	0.10
4	6	7.0	7.0	7.2	7.07	
5	8	9.4	9.5	9.4	9.43	0.06

Table 33

- (i) Give **one** piece of advice when setting up the potometer to ensure a continuous stream of water between the capillary tube and the shoot.

----- [1]

- (ii) Using information in Table 33, calculate the standard deviation for the data from **row 4** (wind speed of 6 ms^{-1}).

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

standard deviation = _____ [2]

- (iii) Describe **and** explain the data trend in Table 33.

----- [3]

- (iv) State **two** environmental variables that should have been controlled during this investigation.

1

2

----- [2]

(v) Explain why the potometer only gives an estimate of the rate of transpiration.

----- [2]

17 The statements below relate to the Calvin cycle.

Which of the following statements is / are correct?

- 1 Molecules of triose phosphate are required for the synthesis of nucleic acids.
 - 2 The production of triose phosphate from glycerate-3-phosphate requires ATP and reduced NAD.
 - 3 Reactions of the Calvin cycle occur at a faster rate when stomata are closed.
- A 1, 2 and 3 are correct
B Only 1 and 2 are correct
C Only 2 and 3 are correct
D Only 1 is correct

Your answer

[1]

18 Photolysis is the process of splitting water using light energy.

Which of the options, **A** to **D**, is the region of the chloroplast in which this process takes place?

- A outer membrane
- B stroma
- C thylakoid lumen
- D thylakoid membrane

Your answer

[1]

19(a) The Succulent Karoo is a biome in southern Africa, which:

- has high levels of biodiversity
- is an arid area receiving very little rainfall per year
- has maximum summer temperatures of 40 °C and winter minima of >4 °C.

Fig. 5.1 shows the results of an experiment conducted on a plant species from the Succulent Karoo. It shows the stomatal conductance of the leaves of the plants over a 24-hour period under conditions as found in the Succulent Karoo. Stomatal conductance is a measure of the rate of movement of carbon dioxide (CO₂) entering, or water vapour exiting a leaf.

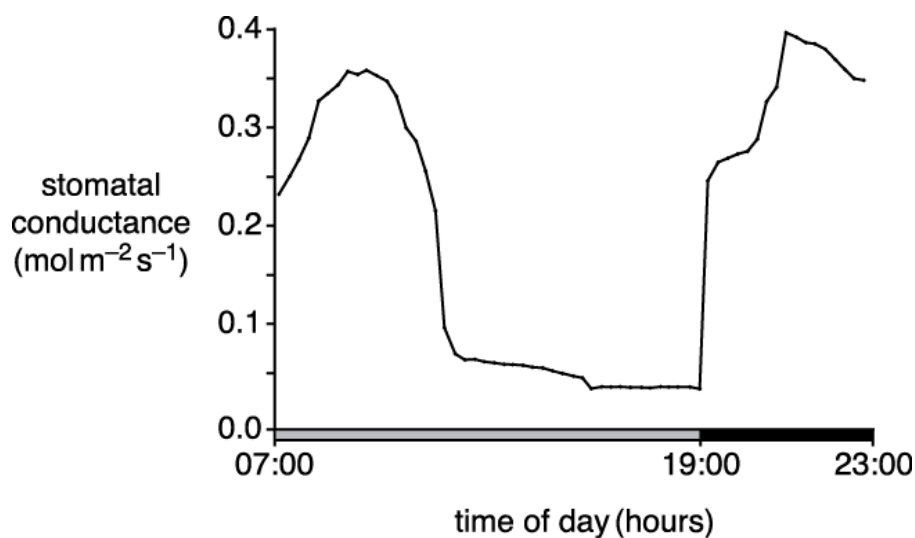


Fig. 5.1

A group of students carried out a survey in the Succulent Karoo. Their hypothesis was:

‘The number of stomata in leaves is affected by the distance from a busy road.’

One student suggested that the survey is done along a line transect. Another student suggested that using a stratified random sampling method would be better.

Evaluate the students' suggestions.

----- [4]

(b) An ecologist collected data on the number of species found in a biome. Table 5.1 shows some of these data.

Species	n	n / N
A	2	0.13
B	6	0.40
C	2	0.13
D	2	0.13
E	3	0.20

Table 5.1

- (i) Using the data in Table 5.1 and the formula for Simpson's diversity index, given below, calculate the biodiversity of this sample.

$$D = 1 - \left(\sum \left(\frac{n}{N} \right)^2 \right)$$

Answer [2]

- (ii) Another survey in a different biome gave a Simpson's diversity index which was half that of the Succulent Karoo.

What does this suggest about the species distribution in this biome compared to the Succulent Karoo?

.....

.....

.....

.....

.....

..... [2]

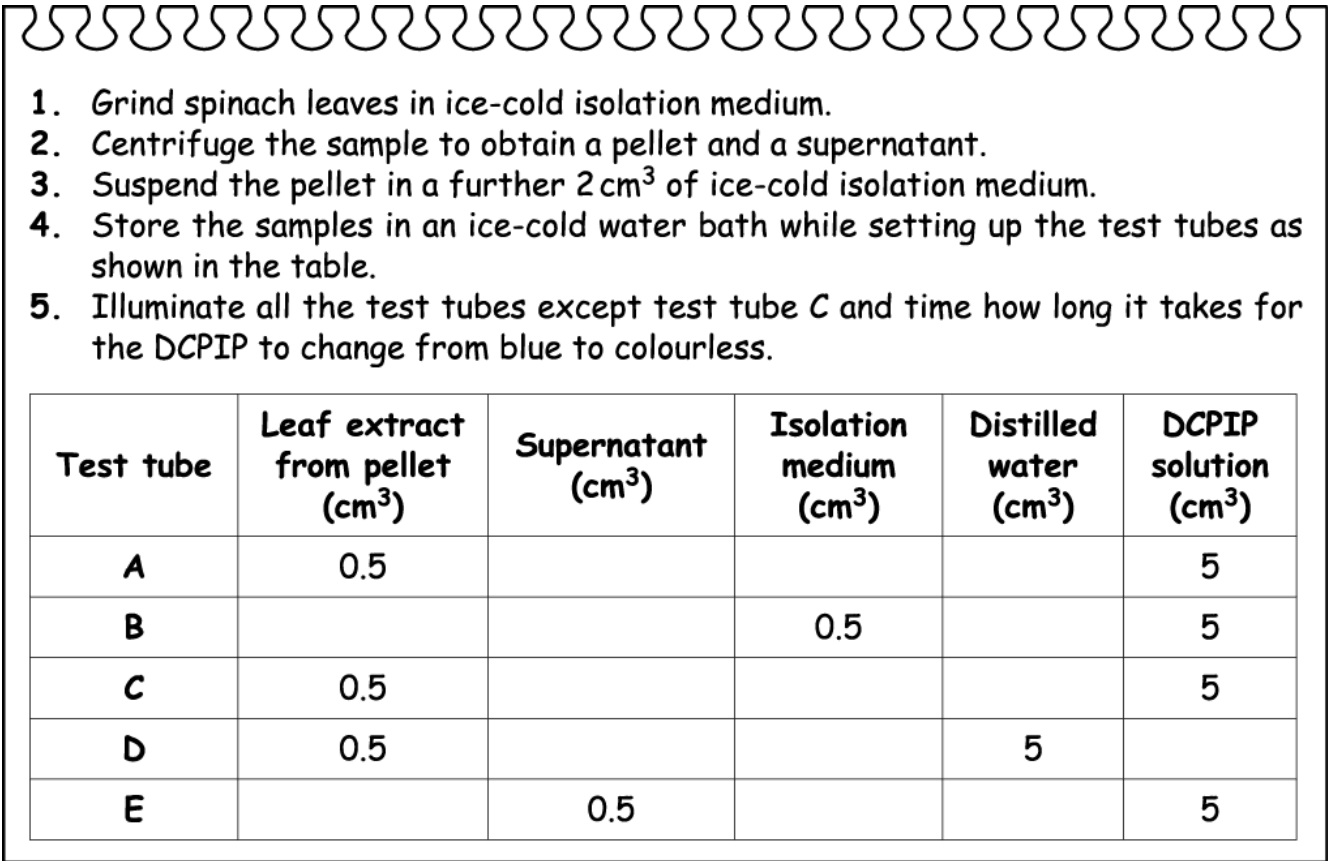


Fig. 3.1

(i) Which stage of photosynthesis was being investigated?

-----[1]

(ii) In this experiment DCPIP was used as an indicator.

What caused the DCPIP to change from blue to colourless?

-----[1]

(iii) The isolation medium used in this investigation was a buffer solution.

Suggest why.

- (b) As an alternative to step 5 in the method described, the colour of the DCPIP was monitored using a colorimeter. Table 3.1 shows some of the readings taken with the colorimeter.

Time from illumination (min)	Absorbance	
	Test tube A	Test tube E
2	5.0	5.0
3	4.6	4.6
4	4.3	4.0
5	4.0	3.7
6	3.8	3.4
7	3.4	3.0
8	3.0	2.7
9	2.6	2.6
10	2.2	2.3
11	1.9	2.0
12	1.4	1.7
13	0.9	1.6
14	0.6	1.3
15	0.5	1.0
16	0.5	0.8
17	0.4	0.5
18	0.5	0.3
19	0.4	0.3
20	0.3	0.3

Table 3.1

- (i) The progress of the reaction was monitored with the use of a colorimeter.

What colour filter should have been used?

(ii) Suggest why no further readings were taken after 20 minutes.

----- [1]

(iii) Both test tubes showed photosynthetic activity and changed the colour of DCPIP equally.

Test tube **A** contained chloroplasts. Test tube **E** contained no chloroplasts.

Suggest how test tube **E** produced the same results as test tube **A**.

----- [2]

21(a) Some plants are classified by their tolerance to shaded conditions:

- plants that can survive in partly shaded conditions are known as shade-tolerant
- plants that require full sunlight to survive are known as shade-intolerant.

Fig. 35 shows the effect of light intensity on net CO₂ uptake in two plants, A and B.

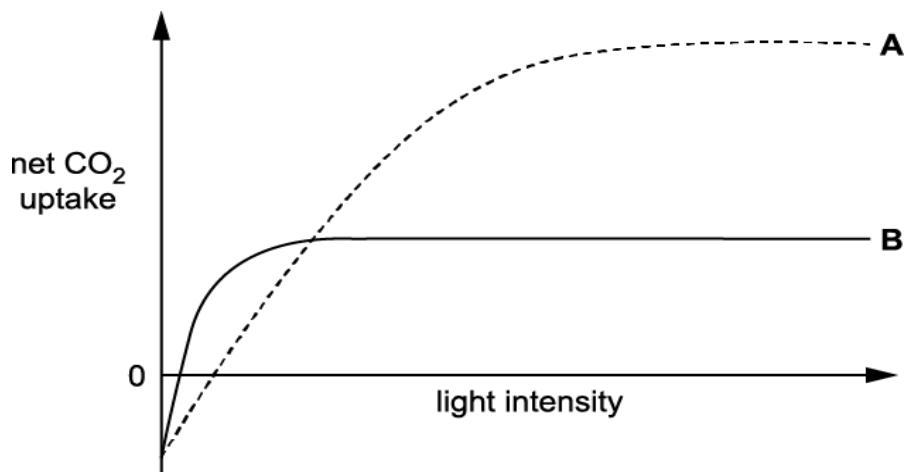


Fig. 35

(i) Define the term *light compensation point*.

----- [1]

(ii) Classify each plant, A and B, in Fig. 35 as either shade-tolerant or shade-intolerant. Give **two** pieces of evidence to support your classification.

----- [3]

23 The stomach of a ruminant animal has four highly-specialised chambers.

Which of the options, **A** to **D**, is a function of the rumen?

- A absorption of essential amino acids
- B digestion of insoluble plant material
- C killing microorganisms
- D passing food to the small intestine

Your answer

[1]

24 A food chain consisting of five organisms is shown below, along with the energy available at each trophic stage.

Organism:	maize	→	locust	→	lizard	→	snake	→	hawk
Energy (kJ m⁻² year⁻¹):	74 011		8075		753		79		8

Which of the options, **A** to **D**, is the percentage energy transfer between the primary consumer and secondary consumer?

- A 9.3
- B 10.3
- C 10.9
- D 12.2

Your answer

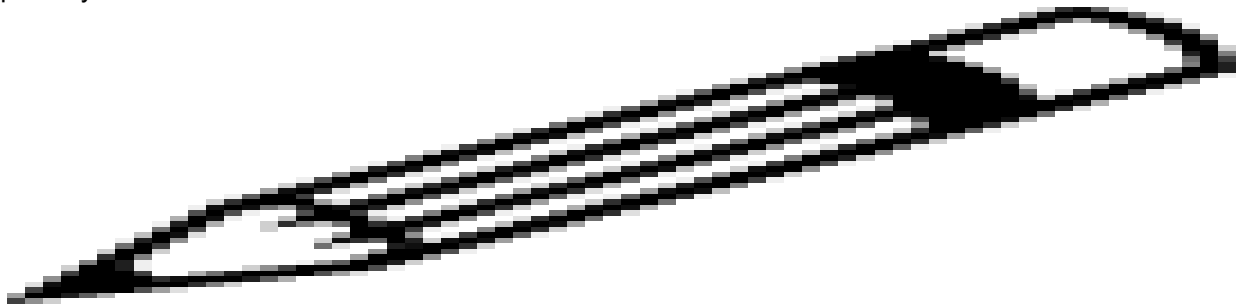
[1]

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*.

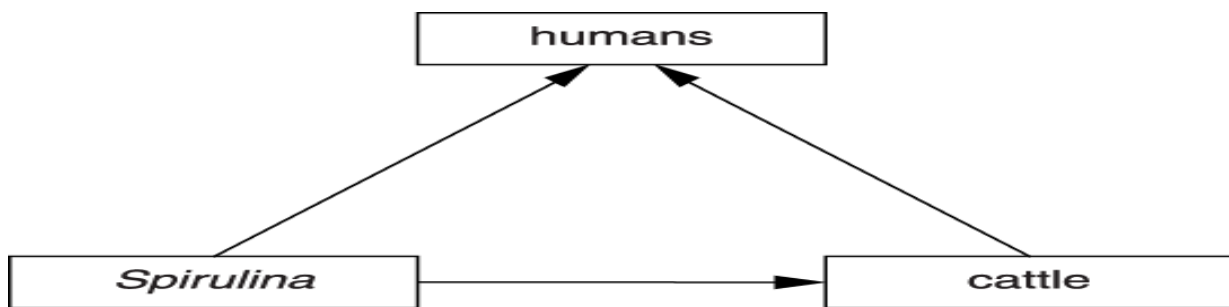


Fig. 3.3

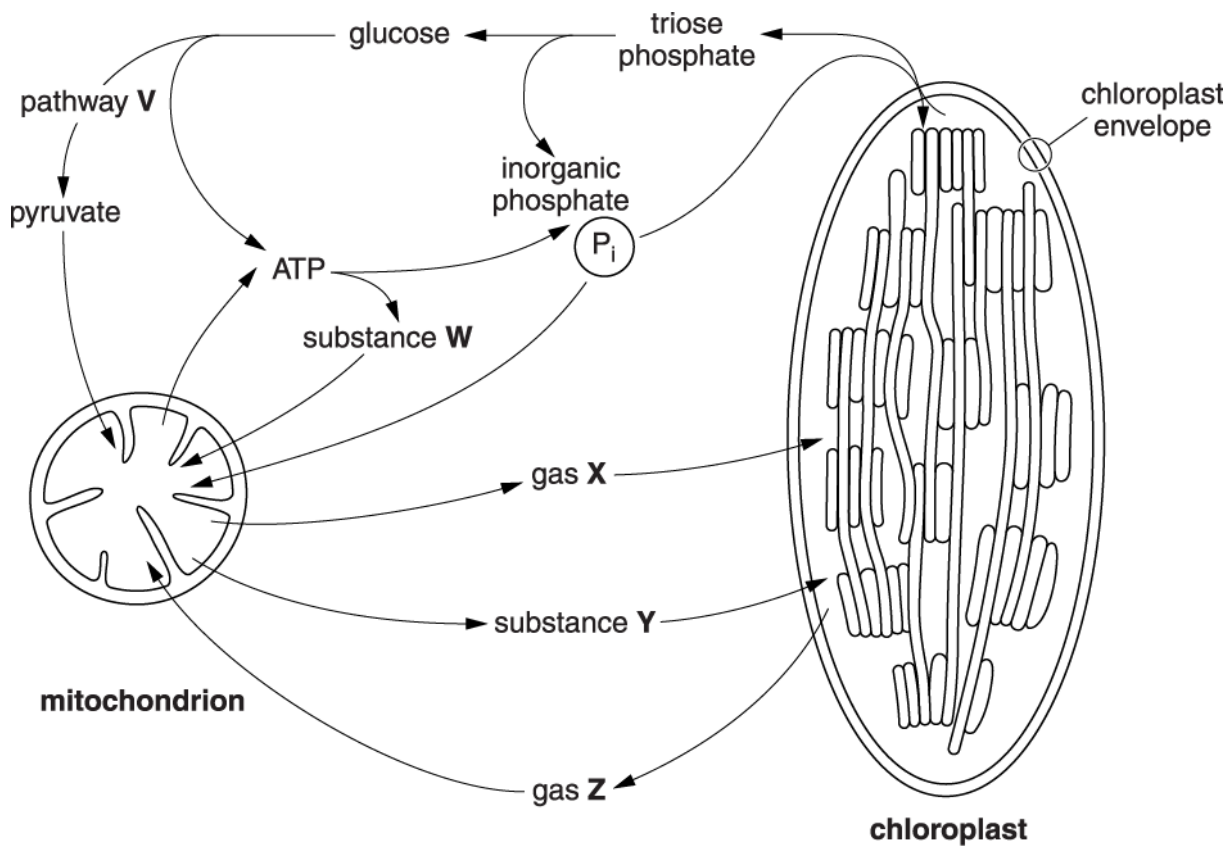
State **and** explain the advantage to human populations of eating dried *Spirulina* directly rather than using it as cattle feed.

[2]

26(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]

27(a) Many towns and cities have areas of wasteland such as sites where car parks or buildings have been abandoned or demolished. Such sites are referred to as 'brownfield sites'.

There is disagreement between some environmentalists and developers regarding the use of the term 'brownfield site'.

- Some environmentalists use the term to refer to recently abandoned land.
- Some developers use the term to refer to previously developed land that has been re-colonised by vegetation.

State the term used to describe the sequence through which vegetation re-colonises an area of wasteland such as an abandoned car park.

[1]

(b) 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.

[41]

(c) 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]

28(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.

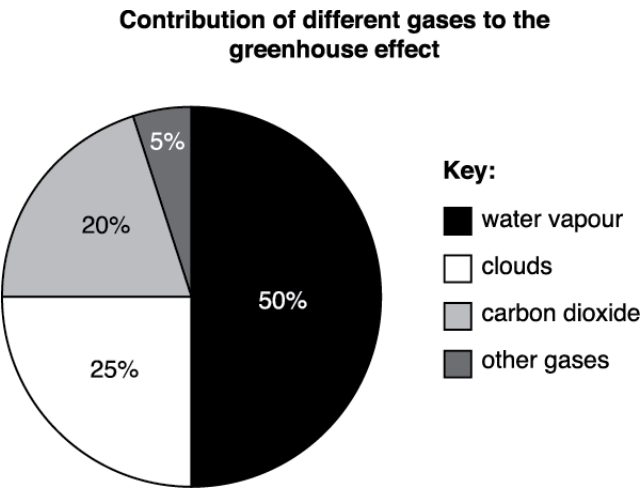
Changes in farming practices have led to a decline in numbers in both of these species since the end of the nineteenth century.

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

[2]

29(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]

- (d) A large supermarket chain has started to use eCO_2 as the coolant in their refrigeration systems.

This eCO₂ refrigerant is obtained during the production of bioethanol from waste sugar beet.

Other CO₂ based refrigerants are produced from hydrocarbons derived from fossil fuels.

- (i) How is carbon dioxide converted to organic molecules in the palisade mesophyll cells of sugar beet plants?



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

[4]

- (ii) Suggest why using eCO₂ is more efficient in reducing the carbon footprint of the supermarket chain than using CO₂ based refrigerants produced from fossil fuels.

[2]

The greenhouses have lighting systems but are unheated. The lighting systems used are controlled electronically and will be turned off when temperatures inside the greenhouses fall below 10°C.

Fig. 4.1 shows a graph of the rate of photosynthesis of maize at different temperatures.

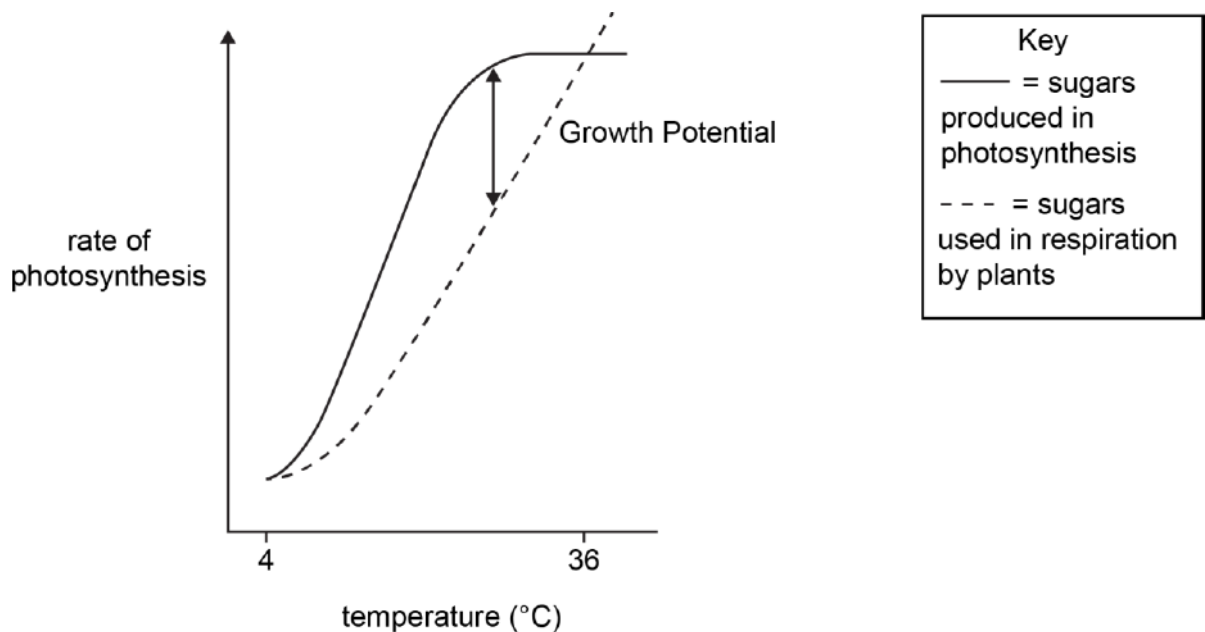


Fig. 4.1

- (i) Indicate, with an arrow, a compensation point on this graph.

The answer to this question must be written on Fig. 4.1.

[1]

- (ii) Suggest why the control system for the lights is programmed to switch them off at low temperatures.

----- [1]

- (iii) Explain why it is necessary to recalibrate the control system regularly.

----- [1]

31 A farmer with an orchard produces cider using the juice from the apples.

An advisor from the Government visits the farm and suggests that the farmer could graze sheep on the grass in the orchard to qualify for additional grant payments. The advisor says that the productivity figures for the sheep will not be as good as the figures for the apples.

Table 1.1 shows some of the energy content and transfer efficiencies for the food chain:

Grass → Sheep → Human

	Energy Content / MJ ha ⁻¹ year ⁻¹
Total incoming solar energy	63 000 000
Energy provided by photosynthetic wavelengths	28 000 000
Total primary production	313 525
Above ground	62 705
Below ground	250 620
Total secondary production	1 257

Table 1.1

- (i) Calculate the percentage efficiency of the conversion of photosynthetic wavelengths into above ground primary production.

Show your working. Give your answer to **two** decimal places.

Answer _____ % [2]

- (ii) The advisor calculates the efficiency of energy conversion for grass (primary production) and sheep (secondary production) in the food chain.

Using your knowledge of food chains, explain why the percentage efficiency figures for primary (0.50%) and secondary (0.002%) production are so different.

(b) Patches of docks, nettles, thistles and other weeds develop over time in the grassland reducing the grazing area and the yield of plant material for use as cattle feed.

Evaluate the use of weed control in this grassland.

[3]

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

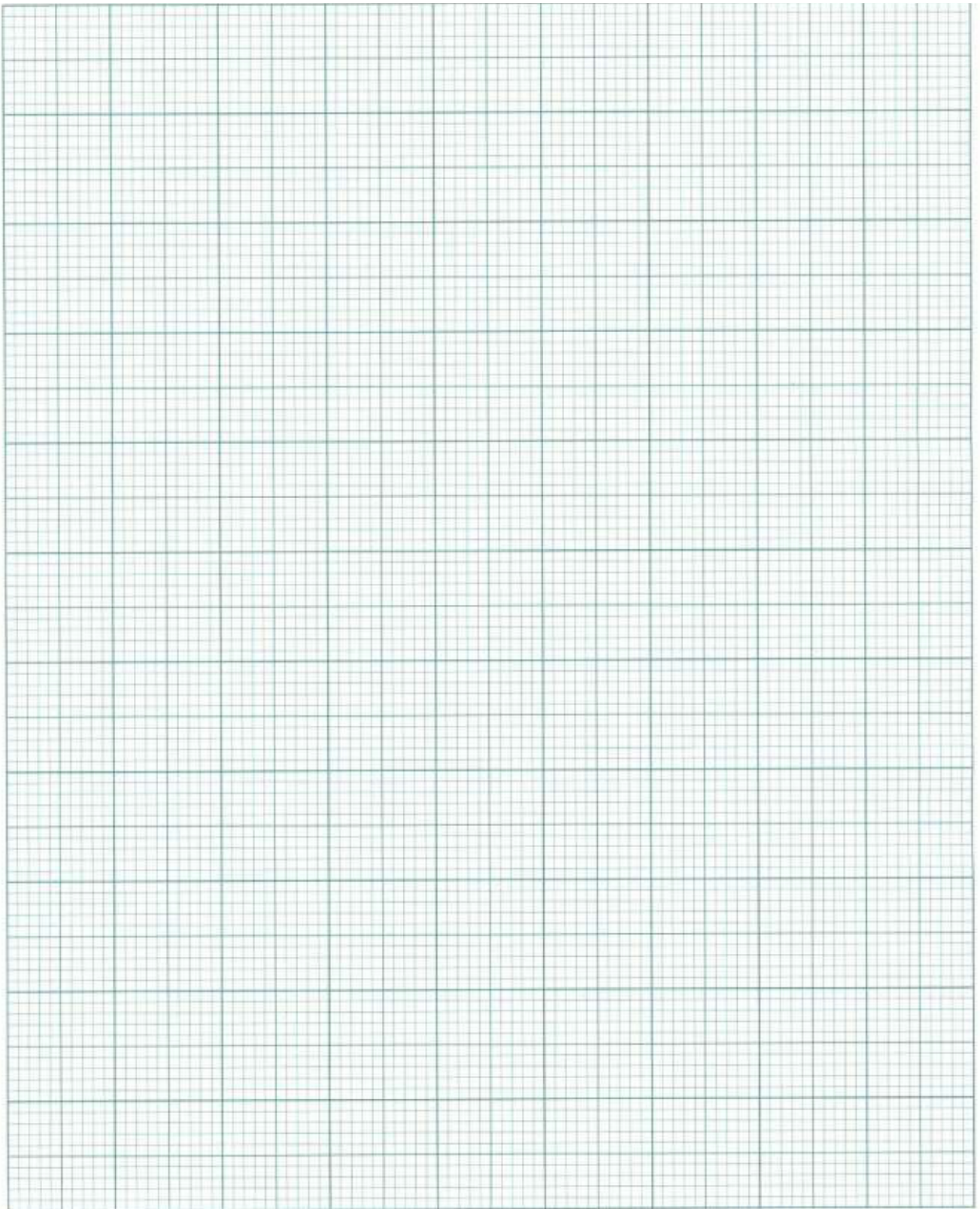
Table 4.1 below shows the UK production in tonnes per hectare for each of these crops in 2012.

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]



Spirulina is sold as a nutrient supplement and is available as a dried powder in health food stores.

- (i) Suggest **two** of the advantages of using *Spirulina* as a source of photosynthetic pigments instead of a culture of a photosynthetic species of bacterium.

[2]

- (ii) Outline how photosynthetic pigments would be **safely** extracted from a sample of *Spirulina* powder for separation by chromatography.

[4]

- (b) Fig. 4.1 shows the chromatography results obtained from a sample of pigments extracted from *Spirulina*. Three pigments, K, L and M, were observed. Pigment L was dark green.

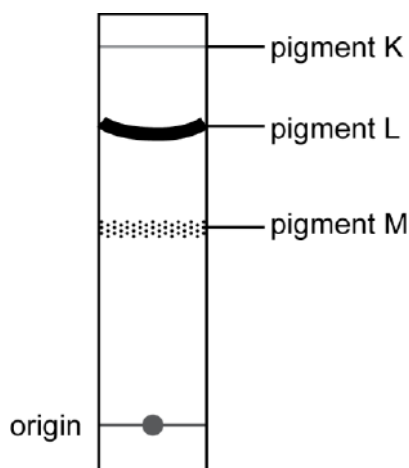


Fig. 4.1

- (i) Pigments K and M were both yellow in colour. Explain how the students could verify that K was carotene.

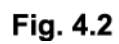
----- [2]

- (ii) Suggest why a similar procedure carried out on an extract from a **plant** would produce **two** green lines at a location close to L.

----- [1]

- (c) * The bacterium *Halobacterium salinarium* uses the pigment **bacteriorhodopsin** to synthesise ATP using light energy.

Fig. 4.2 shows a diagram of the synthesis of ATP in *H. salinarium*.

[illegible]

35(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.

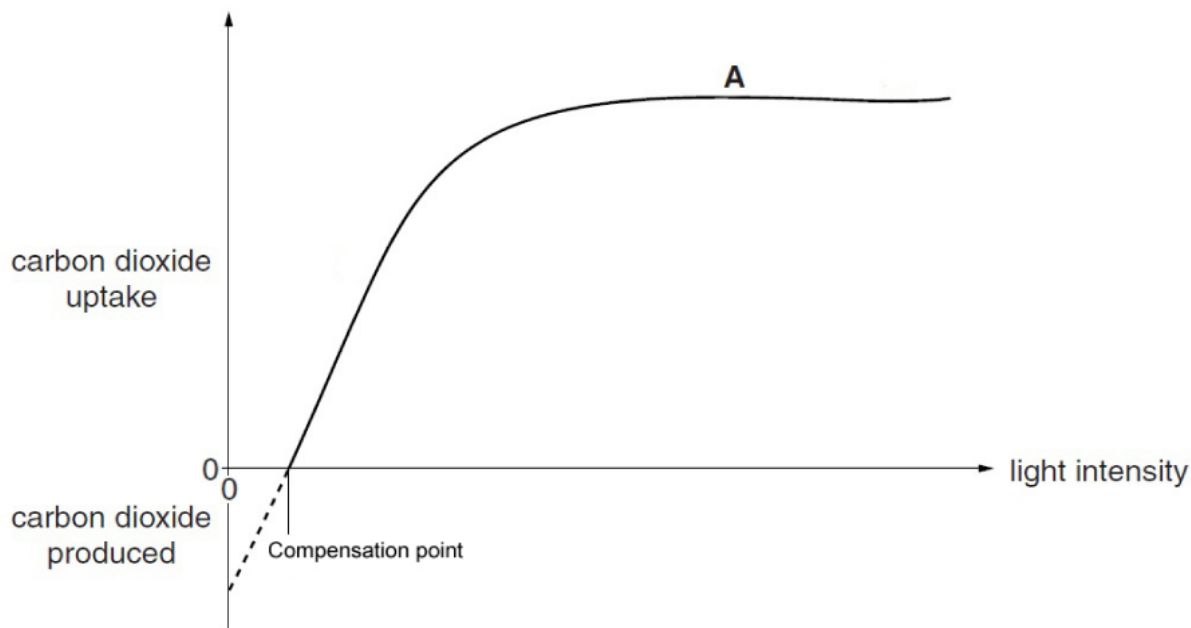


Fig. 5.1

(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]

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

[3]

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 = _____ $\text{cm}^3 \text{min}^{-1}$ [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.

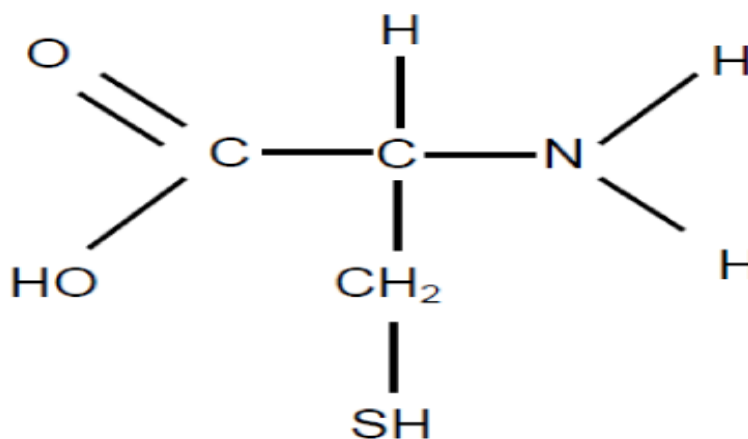


Fig. 5.2

- (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]

36(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]

37(a) A population of nitrogen-fixing bacteria was isolated from a root nodule of the leguminous plant, *Pisum sativum*.

The bacteria were then cultured *in vitro* and viewed using an electron microscope.

The resulting photomicrograph is shown in Fig. 34.1.



Magnification 32 000x

Fig. 34.1

- (i) Name the **genus** of nitrogen-fixing bacteria seen in Fig. 34.1.

-----[1]

- (ii) Calculate the **actual** width of the bacterium labelled X. Show your working.

Answer = ----- μm [2]

- (b) * Farmers provide nitrates to crops in the form of chemical fertilisers. However, excess nitrates can pollute nearby lakes and streams, interrupting their ecosystems.

Cyanobacteria are aquatic organisms. Scientists have genetically engineered a species of cyanobacteria to produce an enzyme that generates luminescence (light) in the presence of nitrate (NO_3^-). This strain is termed a **biosensor**.

A dilution series of known nitrate concentrations was prepared. Each nitrate sample was mixed with the biosensor and the emission of light was recorded using a light meter.

The standard curve produced from the dilution series is shown in Fig. 34.2.

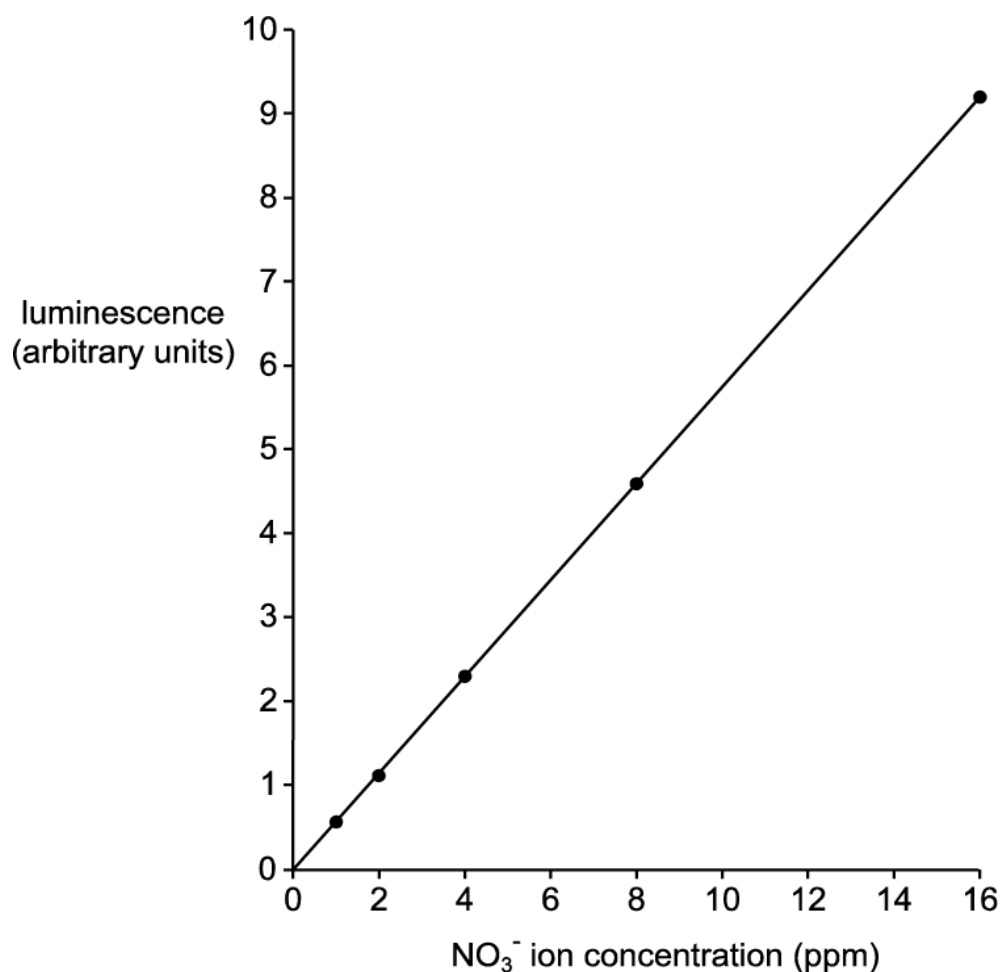


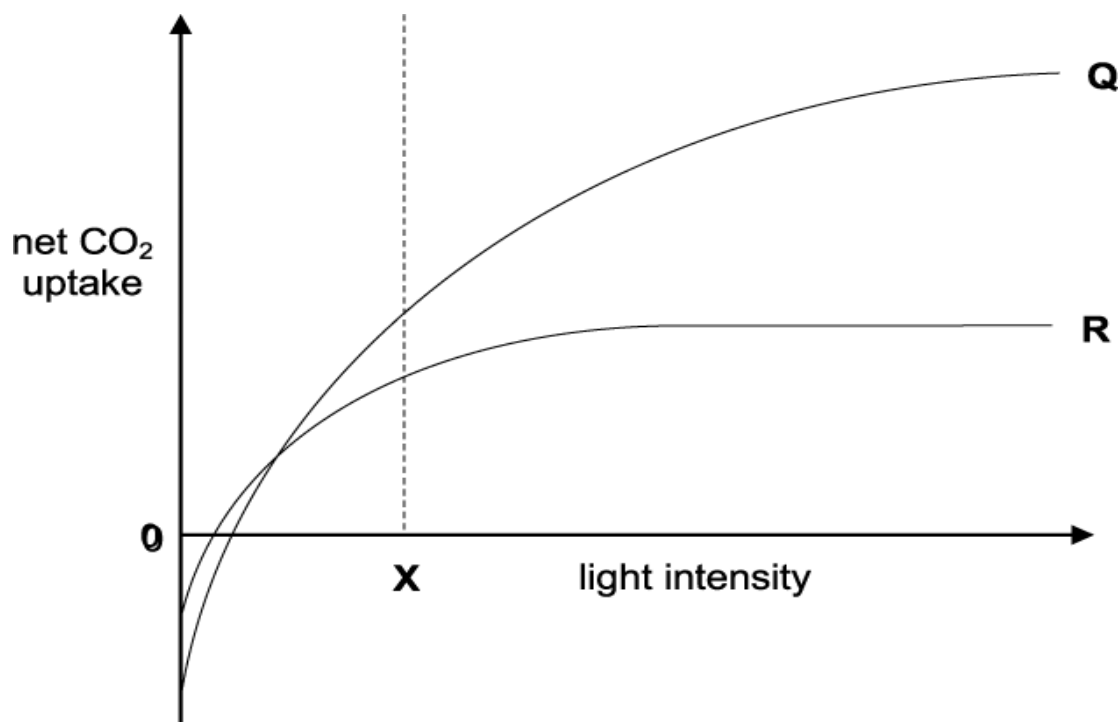
Fig. 34.2

A NO_3^- ion concentration **greater** than 10 ppm is regarded as harmful to aquatic ecosystems.

Using the information provided, discuss how the biosensor could be used to provide **valid** data for **monitoring** the concentration of nitrates in a lake or stream.

[6]

38 The graph below shows the effect of light intensity on the net CO₂ uptake of two vegetable crops, Q and R.



Which of the following statements is / are correct?

- Statement 1:** At light intensity X, crop Q must use stored carbohydrate as a respiratory substrate.
- Statement 2:** For both crops, when net CO₂ uptake is zero, the rate of respiration equals the rate of photosynthesis.
- Statement 3:** Crop R is better adapted to shaded conditions than crop Q.

- A 1, 2 and 3 are correct
- B Only 1 and 2 are correct
- C Only 2 and 3 are correct
- D Only 1 is correct

Your answer

☐

[1]

39(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.

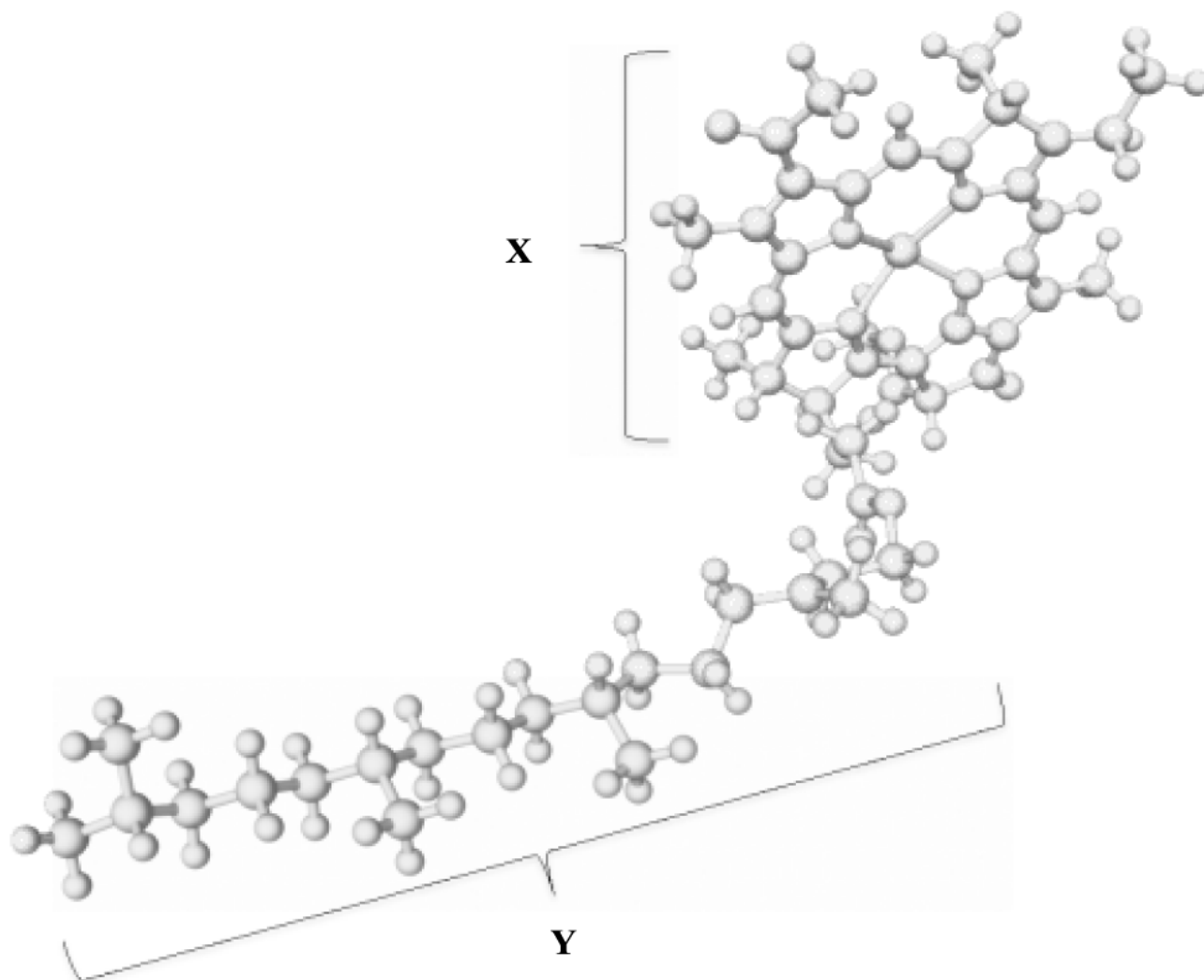


Fig. 34.1

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.

- (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
Chlorophyll 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.

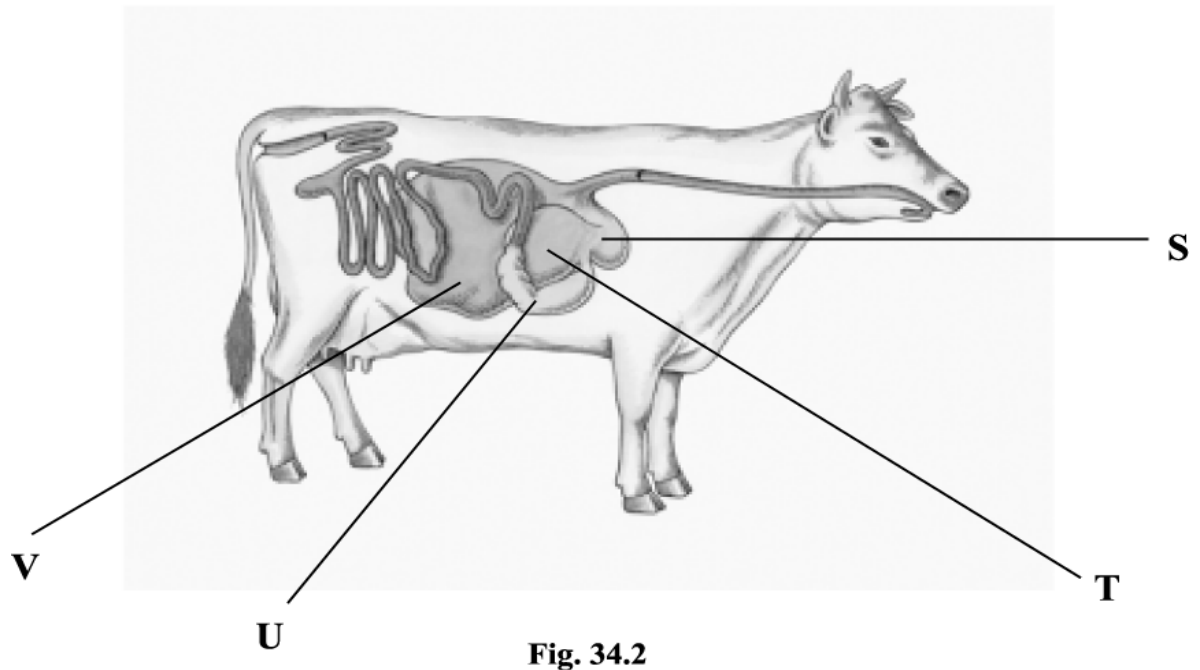


Fig. 34.2

(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.

(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.

40 A student carried out an investigation into the effect of light intensity on photosynthesis.

Several groups of spinach leaf discs were placed in test tubes of water. The discs all sank to the bottoms of the tubes. Each tube was placed at a measured distance from a lamp, as shown below in Fig. 15.1.

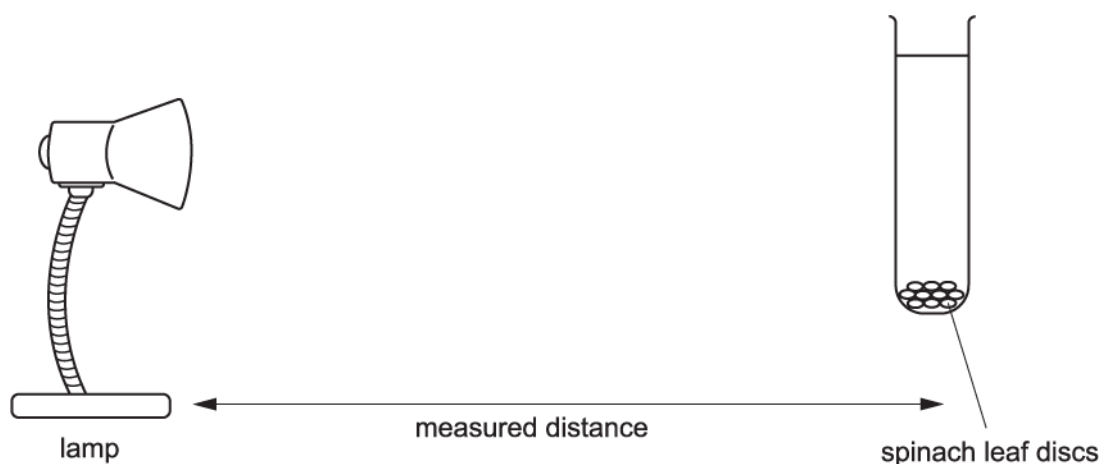


Fig. 15.1

As photosynthesis occurs, the build-up of oxygen gas in the leaf discs causes them to rise from the bottom of the tube upwards.

Table 15.1 shows the results:

Tube number	Distance from lamp (mm)	Time taken for five discs to float (s)
1	50	125
2	100	210
3	150	360
4	200	600
5	250	None floated in the time available

Table 15.1

Which of the following statements is / are true?

- Statement 1:** The compensation point occurs between 200 and 250 mm.
Statement 2: A variable which is controlled is the distance of the tube from the light source.
Statement 3: The time taken for the discs to rise is directly proportional to the distance from the lamp.

- A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer ☐

[1]

- 41 The light independent reaction of photosynthesis needs products from the light dependent reaction.

What are the correct products of the light dependent reaction which are needed for the light independent reaction?

- A reduced NAD, ADP
B reduced NADP, ATP, carbon dioxide
C reduced NADP, ATP
D reduced NAD, ADP, oxygen

Your answer ☐

[1]

- 42 In organic matter, macromolecules containing nitrogen are broken down by decomposers. The decomposers are also respiring aerobically.

Which of the following will be released?

- 1: carbon dioxide
- 2: ammonium ions
- 3: nitrate ions

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

☐

[1]

43(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 <i>Nitrosomonas</i>	Dry maize plantlet mass with <i>Nitrobacter</i>	Dry maize plantlet mass with <i>Nitrosomonas</i> and <i>Nitrobacter</i>	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]

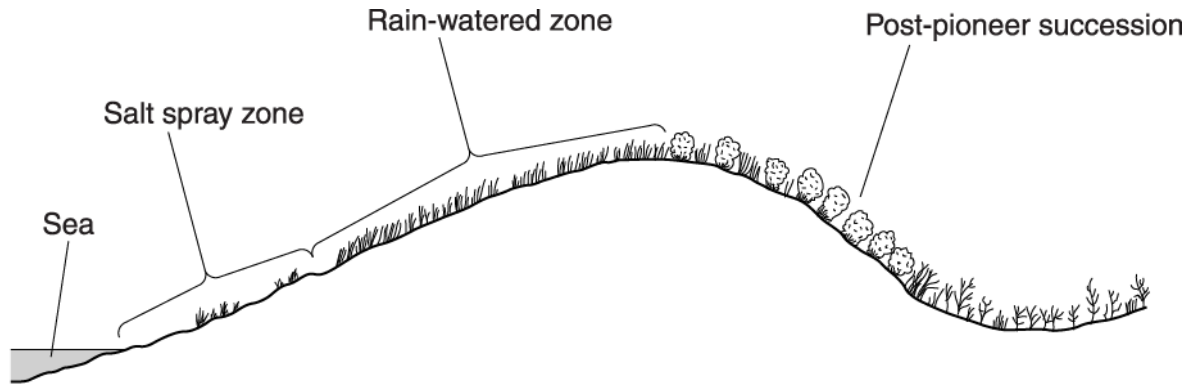
- (ii) Growing conditions in the greenhouse were kept the same for all trays.

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

----- [1]

44 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.

(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]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																																																																																																																																																																								
1		i	least species in rice growing areas due to , disturbance / clearance of habitats , for , planting / harvesting ✓ most species in shrubland and forest due to more different types of habitat available ✓ abandoned rice fields more than existing rice fields due to repopulation of areas ✓	2 max(AO2.1)	ALLOW idea of lack of different habitats / monoculture ALLOW idea that secondary succession is occurring																																																																																																																																																																								
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5	a	i	15.50 ✓✓ Ascending rank <table><tr><th>Sample</th><th>Petiole length (mm)</th><th>Rank</th><th>Leaf width (mm)</th><th>Rank</th><th>d</th><th>d²</th></tr><tr><td>1</td><td>28</td><td>2</td><td>52</td><td>3.5</td><td>-1.5</td><td>2.25</td></tr><tr><td>2</td><td>30</td><td>3</td><td>55</td><td>5</td><td>-2</td><td>4</td></tr><tr><td>3</td><td>17</td><td>1</td><td>31</td><td>1</td><td>0</td><td>0</td></tr><tr><td>4</td><td>31</td><td>4</td><td>52</td><td>3.5</td><td>0.5</td><td>0.25</td></tr><tr><td>5</td><td>35</td><td>6</td><td>56</td><td>6</td><td>0</td><td>0</td></tr><tr><td>6</td><td>45</td><td>7</td><td>61</td><td>7</td><td>0</td><td>0</td></tr><tr><td>7</td><td>46</td><td>8</td><td>62</td><td>8</td><td>0</td><td>0</td></tr><tr><td>8</td><td>77</td><td>10</td><td>98</td><td>10</td><td>0</td><td>0</td></tr><tr><td>9</td><td>33</td><td>5</td><td>40</td><td>2</td><td>3</td><td>9</td></tr><tr><td>10</td><td>57</td><td>9</td><td>69</td><td>9</td><td>0</td><td>0</td></tr><tr><td colspan="5">Total</td><td colspan="2">15.50</td></tr></table> Descending rank <table><tr><th>Sample</th><th>Petiole length (mm)</th><th>Rank</th><th>Leaf width (mm)</th><th>Rank</th><th>d</th><th>d²</th></tr><tr><td>1</td><td>28</td><td>9</td><td>52</td><td>7.5</td><td>1.5</td><td>2.25</td></tr><tr><td>2</td><td>30</td><td>8</td><td>55</td><td>6</td><td>2</td><td>4</td></tr><tr><td>3</td><td>17</td><td>10</td><td>31</td><td>10</td><td>0</td><td>0</td></tr><tr><td>4</td><td>31</td><td>7</td><td>52</td><td>7.5</td><td>-0.5</td><td>0.25</td></tr><tr><td>5</td><td>35</td><td>5</td><td>56</td><td>5</td><td>0</td><td>0</td></tr><tr><td>6</td><td>45</td><td>4</td><td>61</td><td>4</td><td>0</td><td>0</td></tr><tr><td>7</td><td>46</td><td>3</td><td>62</td><td>3</td><td>0</td><td>0</td></tr><tr><td>8</td><td>77</td><td>1</td><td>98</td><td>1</td><td>0</td><td>0</td></tr><tr><td>9</td><td>33</td><td>6</td><td>40</td><td>9</td><td>-3</td><td>9</td></tr><tr><td>10</td><td>57</td><td>2</td><td>69</td><td>2</td><td>0</td><td>0</td></tr><tr><td colspan="5">Total</td><td colspan="2">15.50</td></tr></table>	Sample	Petiole length (mm)	Rank	Leaf width (mm)	Rank	d	d ²	1	28	2	52	3.5	-1.5	2.25	2	30	3	55	5	-2	4	3	17	1	31	1	0	0	4	31	4	52	3.5	0.5	0.25	5	35	6	56	6	0	0	6	45	7	61	7	0	0	7	46	8	62	8	0	0	8	77	10	98	10	0	0	9	33	5	40	2	3	9	10	57	9	69	9	0	0	Total					15.50		Sample	Petiole length (mm)	Rank	Leaf width (mm)	Rank	d	d ²	1	28	9	52	7.5	1.5	2.25	2	30	8	55	6	2	4	3	17	10	31	10	0	0	4	31	7	52	7.5	-0.5	0.25	5	35	5	56	5	0	0	6	45	4	61	4	0	0	7	46	3	62	3	0	0	8	77	1	98	1	0	0	9	33	6	40	9	-3	9	10	57	2	69	2	0	0	Total					15.50		2 AO 2.8	ALLOW 15.5 1 mark for both rank columns correct OR any correct column for d OR d ² (also allowing ECF for incorrect rankings)
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Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$r_s = 0.9061$ ✓✓	2 AO2	ALLOW ECF from i Answer must be given to 4dp (refer to table in iii) ALLOW one mark if calculated correctly but not given to 4dp
		iii	<u>reject</u> the null hypothesis because: (degrees of freedom is 10 so) critical value (at $p=0.05$) = 0.6485 ✓ calculated value is greater than the critical value, so correlation significant (at 0.05 level) ✓ correlation is, a weak positive ✓ results are not due to chance ✓	max 2 AO 2.8	Candidates should use $n = 10$ and critical value at $p=0.05$ / 95% confidence level ALLOW ECF for correct interpretation of incorrect calculation of r_s from ii No mark for stating 'reject null hypothesis' without explanation ALLOW '(relatively) strong'
	b	i	Control (group), for /to allow, comparison ✓	1 AO 3.1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
ii	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. <i>In summary:</i> 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 <i>italics</i>): ◦ 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) Balanced, detailed evaluation with both supporting and undermining statements using information from Fig. 2.2a and Fig. 2.2b/c <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Evaluation with both supporting and undermining statements using information from Fig. 2.2a and Fig. 2.2b/c <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i>	6 AO3.2 AO3.3	Indicative scientific points may include (not exhaustive): ALLOW ORA to shade species throughout <i>Supporting statements:</i> • chloroplast from <i>M.o</i> (2.2a) shows more similar ultrastructure to <i>M. g</i> chloroplast in sun conditions (2.2b) • chloroplast from <i>M.o</i> (2.2a) and chloroplast from <i>M.g</i> in sun conditions have similar sized grana / thylakoid stacks (2.2b) • chloroplast from <i>M.o</i> (2.2a) and chloroplast from <i>M.g</i> in sun conditions (2.2b) have similar numbers of grana • chloroplast from <i>M.o</i> (2.2a) and chloroplast from <i>M.g</i> in sun conditions (2.2b) have similar numbers of thylakoids per granum • chloroplast from <i>M.o</i> (2.2a) don't need as many thylakoids / grana for light capture as they are in high light intensity • fewer thylakoids in both chloroplasts from <i>M.o</i> (2.2a) and chloroplasts from <i>M.g</i> in sun conditions (2.2b) than chloroplast from <i>M.g</i> in shade conditions (2.2c) <i>Undermining statements:</i> • only have one drawing of a chloroplast from each micrograph • student's drawings may be inaccurate • chloroplasts / leaves from extinct species may have been damaged • images / electron micrographs may have been poor quality • methods of obtaining the leaf samples may have been different • more data required to draw this conclusion • there (maybe) different numbers of chloroplasts in different species • there (maybe) different numbers of leaves in different species

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Level 1 (1–2 marks) Limited evaluation with basic descriptive statements that may not include reference to Fig. 2.2a and Fig. 2.2b/c <i>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.</i> 0 marks <i>No response or no response worthy of credit.</i>		
			Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6	a	i	X = oxygen / O ₂ Y = carbon dioxide / CO ₂ Z = adenosine triphosphate / ATP	2 AO 1.1	All 3 correct = 2 marks 2 correct = 1 mark 1 or 0 correct = 0 marks
		ii	grana / granum ✓	1 AO 1.1	ALLOW thylakoid (membrane) DO NOT ALLOW photosystems
		iii	any two from: contain , (named) pigment (molecules) / photosystems ✓ contain , (named) electron carriers / ETC / ATP synth(et)ase ✓ (has a) large surface area for , light absorption / light depended reactions / electron transport ✓ allows formation of electrochemical gradient ✓	2 AO 2.1	IGNORE 'accessory' IGNORE enzymes unqualified NOTE mp 1 & 3 or mp 2 & 3 could be combined in a single sentence
	b	i	any four from: energy lost by electrons in redox reactions ✓ each , ETC component / electron carrier , is at a lower energy level ✓ energy released used to <u>pump</u> protons ✓ into the thylakoid space ✓ proton gradient , created / AW ✓ diffusion of <u>protons</u> through ATP synth(et)ase / chemiosmosis ✓ kinetic energy (of movement of protons) converted to chemical energy (of ATP) ✓	4 AO 1.1 2.1	IGNORE kinetic energy (of electrons) ALLOW H ⁺ / hydrogen ions for 'protons' throughout ALLOW electrochemical gradient DO NOT ALLOW just electrical gradient ALLOW 'move back' for 'diffusion', 'proton motive force'
		ii	(because) energy (of electrons) lost as heat ✓ leakage of protons across membrane ✓	2 AO 2.1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	11	
7			C	1 AO1.1	
			Total	1	
8			A	1 AO2.2	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9	a		1. to ensure the algae are photosynthesising (at a constant rate) OR to allow the, algae / suspension, to equilibrate ✓ 2. to prevent the suspension from overheating OR to prevent denaturation of (photosynthetic) enzymes ✓ 3. to kill the, algae / cells OR to stop the (photosynthetic) reactions ✓	3 AO2.7	ALLOW light dependent stage / LDR , of photosynthesis 3. ALLOW stop photosynthesis for 'stop the reactions' <u>Examiner's Comments</u> Majority of the candidates attempted this question with most candidates recognising the relevance of reason 1. Many candidates discussed reason 2 in terms of not wanting to increase the rate of photosynthesis, from a positive standpoint. A lot of candidates equated alcohol with sterilisation and discussed this in terms of lack of microbial or radioactive contamination. However, the relevance of 'hot' alcohol was not being addressed, in their answers.
	b	i	ribulose-bisphosphate carboxylase (oxygenase) ✓	1 AO1.1	ALLOW RUBISCO / rubisco <u>Examiner's Comments</u> The majority of candidates achieved this mark. A few candidates wrote carboxylase only.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	GP produced first as radioactivity present by 2 seconds. ✓ TP produced, second / after GP, as radioactivity present by 10 seconds ✓ amino acids AND sucrose AND sugar phosphates are produced, last / from TP, as radioactivity present by 30 seconds ✓	3 AO3.1	ALLOW any correct alternative name for GP and/or TP throughout. ALLOW s for seconds <u>Examiner's Comments</u> Most candidates scored maximum marks. Candidates that did not score full marks, did not use the results in the table, they only referred to it. A lot of candidates discussed the fate of each compound in the Calvin cycle which was irrelevant as the fate could not be ascertained by the table of data. Candidates should relate the mark total with the data where there is a clear connection of 3 marks and 3 different timings.
	c		because CO₂ reacts with, RuBP / ribulose bis-phosphate / 5C compound ✓ the first reaction produces an, unstable / 6C, compound that breaks down to form two 3-C compounds ✓	2 AO3.1	<u>Examiner's Comments</u> This was well answered with a lot of candidates scoring 1 mark for RuBP reacting with carbon dioxide. The second mark was often lost as candidates jumped straight to this reaction producing GP without referring to the 6C compound intermediate. Some candidates confused the carbon number in each compound.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	i	465.6 / 466 ✓ ✓	2 AO2.4	Correct answer = 2 marks even if no working shown. If answer is incorrect then award 1 mark if; <i>max uptake per m²:</i> 8.0 x 0.97 / 7.76 <i>max uptake in 1 min:</i> 8.0 x 60 / 480 <i>incorrect calculated value for</i> x 60 <i>max uptake per m²</i> <u>Examiner's Comments</u> Answers to this question were well calculated and well set out with logical steps. Candidates that did not score maximum marks did not take into account the leaf area for their maximum amount (per second) even though they did recognise the relevance of one minute in relation to the units on the y-axis.  AfL It is good practice to tick off all data given when used so any calculations will use all the data provided. Candidates should be reminded that data is only given if relevant to a calculation/part question.
		ii	there is no net (named) gas exchange ✓ (the rate of) photosynthesis and respiration are equal / compensation point ✓	1 max AO2.2	<u>Examiner's Comments</u> The majority of candidates correctly recognised point B, either referring to the equal rates or the term 'compensation point'. Some candidates referred to a decrease in carbon dioxide with an increase in oxygen.
			Total	0	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	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 <u>Examiner's Comments</u> 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 <u>Examiner's Comments</u> Examiners were looking for the idea that snails are ectothermic animals, unlike cattle who lose a lot of energy through heat.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e		Summary of instructions to markers: <i>Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.)</i> <i>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.</i> <i>Then, award the higher or lower mark within the level, according to the Communication Statement (shown in <i>italics</i>):</i> ◦ <i>award the higher mark where the Communication Statement has been met.</i> ◦ <i>award the lower mark where aspects of the Communication Statement have been missed.</i> • <i>The science content determines the level.</i> • <i>The Communication Statement determines the mark within a level.</i> Level 3 (5 – 6 marks) A detailed explanation of digestion, production of fatty acids and protein degradation, with reference to named stomach structures and the role of microorganisms. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) A good explanation of digestion, possibly without mention of fatty acids and proteins. Correct names and roles of stomach structures but the role of microorganisms may not be included. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i>	6	Indicative scientific points may include: • digestion of, cellulose / plant material / polysaccharides • by microorganisms / bacteria in, rumen / reticulum • lack of cellulase enzyme in ruminants • production of mono- and disaccharides • conversion of saccharides (sugars) into fatty acids (by other microorganisms / bacteria) • ref to importance of fatty acids as, respiratory substrates / lipid components • secretion of, hydrochloric acid / protease enzymes, in abomasum • digestion of bacterial proteins into amino acids • ref to essential amino acids • microorganisms in rumen are anaerobic / rumen is anaerobic environment

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	Level 1 (1 – 2 marks) Limited explanation of digestion OR correct naming of stomach structures OR reference to microorganisms. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.		Examiner's Comments More than 70% of candidates scored level 1 or lower on q33e. It was clear that this was a less familiar topic area for many. Candidates were sometimes able to correctly recall names of the stomach chambers, but few were able to correctly assign structure to function. Higher level answers included a description of the different micro-organisms involved in digestion and focused on the products of digestion of cellulose, the conversion of saccharides to fatty acids and the digestion of bacterial proteins into amino acids. Description of regurgitation were common but apart from this distinction many answers were simply variations on the human digestive system and had little relevance to the ruminant stomach. Exemplar 6 <i>The food first enters the reticulum where it is mixed with enzymes to initiate digestion. It then passes to the Rumen. Here the food is mixed with a large bacterial colony which contains the cellulase enzyme which the ruminant doesn't have. The food is often then regurgitated to be chewed again to make its digestion. The presence of the bacteria allow previously undigestible cellulose to be broken down into mono and disaccharides. They also provide a source of protein and fixed nitrogen. Small aliquots of the bacterial colony are regularly taken and passed to the next chamber, the abomasum. Here, the bacteria and food are mixed with acid and proteases to break them down. They are then passed to the omasum where they are broken down further. (continues on back)</i> This answer has several features of a level 3 answer.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 7 First food is chewed and passed down the gullet. Then it enters the rumen which contains microorganisms capable of breaking down cellulose into glucose. Next it moves through the reticulum where it is churned up by the muscles in the stomach before being regurgitated and chewed again. It passes back down the gullet and into the abomasum which ~~acts like~~ continues to churn the food. Finally this food enters the omasum which acts like a human stomach. It contains hydrochloric acid causing an acidic pH which breaks down almost all complex molecules. The food moves through the four chambers of the stomach by peristalsis. [12] This Level 2 answer mentions the stomach chambers and outlines the roles, although there is some confusion between abomasum and omasum. There is little detail and apart from the digestion of cellulose there is no reference to the production of important molecules.
			Total	16	
11			C	1	
			Total	1	
12			C	1	Examiner's Comments This question tests knowledge of the practical demonstration of the Hill reaction during which DCPIP is reduced, turning from blue to colourless. DCPIP therefore mimics NADP.
			Total	1	
13			C	1	
			Total	1	

Mark Scheme

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) <u>Examiner's Comments</u> 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 <u>respiratory</u> 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: <i>Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.)</i> <i>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.</i> <i>Then, award the higher or lower mark within the level, according to the Communication Statement (shown in italics):</i> ◦ 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	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	<i>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.</i> Level 2 (3–4 marks) Outline of method and hazard control with some details missing. <i>There is a line of reasoning presented with some structure and use of appropriate scientific language. The information presented is mostly relevant.</i> Level 1 (1–2 marks) Correct steps in method or hazard control are described but lack detail. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 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.

Mark Scheme

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. <u>Exemplar 1</u> <i>This prevents (or rather minimises) the risk of growing cultures that are harmful to humans as the core body temperature is 37°C so bacteria would not survive at this temperature. Also because this is the temperature at which bacterial enzymes work most efficiently is the optimum.</i> [2]
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	increased CO₂, around Rubisco / in carboxysomes ✓ (therefore) CO₂, binds to / AW, Rubisco not O₂ ✓ (Membrane-bound) pumps for HCO₃⁻ (entry into cell) ✓ carbonic anhydrase for CO₂ (entry into carboxysome) / conversion of HCO₃⁻ ✓	3 max	ACCEPT <i>idea</i> of CO₂ outcompetes O₂ 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 HCO₃⁻ 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.

Mark Scheme

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 $\pm$ 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: CO₂ concentration / mol dm⁻³ y-axis label: (mean) rate / μmol CO₂ 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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	<i>yes because</i> (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 ✓ <i>However</i> only three CO₂ 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	<i>valid because</i> M35 has higher rate of, CO₂ fixation / carboxylase activity (at all concentrations) ✓ <i>not valid because</i> 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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	C		Summary of instructions to markers: <i>Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.)</i> <i>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.</i> <i>Then, award the higher or lower mark within the level, according to the Communication Statement (shown in italics):</i> <i>o award the higher mark where the Communication Statement has been met.</i> <i>o award the lower mark where aspects of the Communication Statement have been missed.</i> <i>The science content determines the level.</i> <i>The Communication Statement determines the mark within a level.</i> Level 3 (5–6 marks) A comprehensive account of the risks and benefits of growing supercrops. The points are clearly linked to the article and their (wider) relevance discussed. <i>There is a well-developed line of reasoning which is clear and logically structured and uses scientific terminology at an appropriate level. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) An account of some risks and benefits of growing supercrops. Some of these points are linked to the article and some discussion of their (wider) relevance. <i>There is a line of reasoning presented with some structure and use of appropriate scientific language. The information</i>	6	Indicative scientific points may include Risks: Modified plants may outcompete wild type plants Dominate or disrupt ecosystems Reduce biodiversity (inserted) genes transferring to wild plants (inserted) genes enter the food chain no information about how modified crops might affect human health herbicide resistant crops leads to superweeds Benefits: Increase in primary productivity of food crops Improved, agricultural yields Could produce more food Upgrading wild plants would make whole ecosystems more productive Increased photosynthesis would reduce

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>presented in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) An account of the risks or benefits of growing supercrops, with reference or a quote from the article. No discussion of wider relevance. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant</i> 0 marks <i>No response or no response worthy of credit.</i>		carbon emissions / greenhouse gases Increased photosynthesis would allow growth / high yield, in all, climates / weather Examiner's Comments Candidate responses to (c) showed that they had clearly read the literature and had a good understanding of the turbo charged plants. They reworded the information well but often failed to go beyond the information provided. Candidates often referred to e.g. food chains being destroyed, without explaining how. Many candidates discussed supercrops in terms of herbicide resistance or vitamin A deficiency without referring to the turbocharged crops in the literature. Again, vague statements were made about decreasing biodiversity without it being clear how, and some inaccuracies crept in e.g. less herbicide would need to be used if there is herbicide resistant crops.
			Total	24	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16		i	any 1 from: cut shoot under water ✓ connect shoot to rubber tubing under water ✓ ensure tight fit between shoot and rubber tubing ✓ seal with Vaseline ✓ set up the potometer under water ✓	max 1	Examiner's Comments (a)(i) and (b) tested AO1, with most of the remainder testing AO2 criteria. In (a)(i) the question addressed practical procedures and it was encouraging to see that most candidates were familiar with the setting up of the potometer.
		ii	0.12 ✓ ✓	2	ALLOW unrounded answer (0.115758...) for 1 mark Examiner's Comments The calculation of the standard deviation in (a)(ii) caused a few problems, although more than 50% achieved the full 2 marks. The most common mistake was candidates who thought that $n - 1 = 4$ (the number of treatments minus 1) rather than $n - 1 = 2$ (the number of replicates minus 1). Candidates should remember that the standard deviation is a measure of variation around the mean and n is the number of values that make up the mean.
		iii	<i>Description:</i> faster the wind speed, faster the (rate of) water uptake ✓ <i>Explanation:</i> wind <u>increases</u> water (vapour) potential gradient (between airspaces in leaf and air in environment) ✓ faster diffusion of water <u>vapour</u> / increased transpiration rate ✓	3	ORA ALLOW wind <u>increases</u> concentration / diffusion gradient Examiner's Comments (a)(iii) required a description of the data which was done well, followed by an explanation which they found more difficult. Few candidates could give a clear and succinct explanation. To achieve full marks candidates needed to give a clear link to increasing air movement reducing the water (vapour) potential around the stomata so that there was a steeper water (vapour) potential gradient. Too many candidates referred to water being blown off the leaf, some even describing droplets being blown away or water moving out of the leaf by osmosis.
		iv	humidity ✓ light intensity ✓ temperature ✓	max 2	Examiner's Comments (a)(iv) was answered well and only a few candidates did not achieve these marks.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		v	water used in photosynthesis / hydrolysis ✓ water produced in respiration / condensation reactions ✓ water used to maintain turgor pressure ✓	max 2	Examiner's Comments There was a poor understanding of what was required by (a)(v). Although many candidates seemed to appreciate that water uptake was not the same as transpiration, fewer were able to explain that water was used (and produced) in the plant. The most common correct answer was that water was used in photosynthesis but it was disappointing to see that few candidates appreciated that water is essential to maintain the turgor of a plant.
			Total	10	
17			D ✓	1	Examiner's Comments Candidates did not perform well on this question. The most common incorrect answer was option B suggesting that candidates had not read the options carefully and failed to spot the reference to reduced NAD in statement 2.
			Total	1	
18			D ✓	1	Examiner's Comments This was a straightforward question about the location of photolysis.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19	a		Advantages (up to a maximum of 2 marks) <i>Line transect</i> enables Spearman's rank to be used to measure correlation ✓ unbiased as only those plants touching the line are sampled ✓ straightforward - no estimation of (number or area of) sub-regions ✓ easily repeatable ✓ <i>Stratified sampling</i> more representative of sub-regions ✓ Disadvantages (up to a maximum of 2 marks) <i>Line transect</i> only plants touching the line should be sampled which may lead to 'gaps' in the data ✓ strategy for choosing a plant nearest to the sampling point may lead to bias ✓ <i>Stratified sampling</i> requires (accurate) estimation of area of sub-regions ✓ time consuming ✓ distance from road must be measured at each sampling point ✓ (time consuming because) target species may be absent in randomly selected area ✓	4	DO NOT ALLOW double marks for statements reversed for the other method ALLOW ORA for any point as long as no double marks e.g. a disadvantage of stratified sampling is that it is less easily repeatable DO NOT ALLOW any suggestion that repeats are done on the same transect

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																								
	b	i	0.7 ✓✓	2	ALLOW 0.75 If answer is incorrect or missing: ALLOW 1 mark for 0.3 OR 0.25 (<i>not subtracting the calculated figure from 1</i>) <table><tr><th>Species</th><th>n</th><th>n/N</th><th>(n/N)²</th></tr><tr><td>A</td><td>2</td><td>0.13</td><td>0.0169</td></tr><tr><td>B</td><td>6</td><td>0.40</td><td>0.1600</td></tr><tr><td>C</td><td>2</td><td>0.13</td><td>0.0169</td></tr><tr><td>D</td><td>2</td><td>0.13</td><td>0.0169</td></tr><tr><td>E</td><td>3</td><td>0.20</td><td>0.0400</td></tr></table> $\Sigma(n/N)^2 = 0.2507$ 1 - 0.2507 = 0.7493	Species	n	n/N	(n/N) ²	A	2	0.13	0.0169	B	6	0.40	0.1600	C	2	0.13	0.0169	D	2	0.13	0.0169	E	3	0.20	0.0400
Species	n	n/N	(n/N) ²																										
A	2	0.13	0.0169																										
B	6	0.40	0.1600																										
C	2	0.13	0.0169																										
D	2	0.13	0.0169																										
E	3	0.20	0.0400																										
		ii	(higher biodiversity) in the Succulent Karoo shows greater species evenness / less dominated by a few species / greater stability ✓ (higher biodiversity) in the Succulent Karoo shows greater species richness / greater number of different species ✓	2	ALLOW ORA throughout																								
			Total	8																									

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20	a	i	light dependent (reactions) ✓	1	ALLOW Hill reaction
		ii	(it acts as an) electron acceptor ✓	1	ALLOW reduced
		iii	maintains (chemical) activity of chloroplasts ✓	1	ALLOW references to maintaining pH in context of (chemical) activity of chloroplasts
	b	i	red ✓	1	
		ii	3 consecutive readings of same value (in test tube E) ✓	1	ALLOW the reaction had stopped in (test tube) E
		iii	chloroplasts physically damaged during preparation of leaf extract ✓ photosystems / chlorophyll present in supernatant ✓ other reducing agents / AW present in supernatant ✓	max 2	DO NOT ALLOW any suggestion of chemical damage
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
21	a	i	light intensity at which rate of photosynthesis equals rate of respiration ✓	1	ALLOW light intensity at which uptake of CO₂ by photosynthesis equals production of CO₂ by respiration OR light intensity at which uptake of O₂ by respiration equals production of O₂ by photosynthesis DO NOT ALLOW CO₂ (or O₂) in equals CO₂ (or O₂) out
		ii	A = shade-intolerant AND B = shade-tolerant ✓ any 2 from: compensation point lower for B than A ✓ light saturation point lower for B than A ✓ crop A: can photosynthesise at higher rate than crop B ✓ is adapted to grow in brighter light than crop B ✓ cannot sustain sufficient rate of respiration to survive in low light levels ✓	max 3	ORA ORA ORA ORA ORA

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		<i>*Summary of instructions to markers:</i> <i>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.</i> <i>Then, award the higher or lower mark within the level, according to the Communication Statement (shown in italics):</i> ◦ <i>award the higher mark where the Communication Statement has been met.</i> ◦ <i>award the lower mark where aspects of the Communication Statement have been missed.</i> • <i>The science content determines the level.</i> • <i>The Communication Statement determines the mark within a level.</i>		

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Level 3 (5 – 6 marks) A detailed outline of how the different molecules are produced in the light-dependent and light-independent stages of photosynthesis. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) A basic outline of how the molecules are produced with some linking of specific processes to the light-dependent and/or light-independent stages of photosynthesis. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) A limited description of how some of the molecules are produced. They may not be linked to the light-dependent or light-independent stages. <i>There is a logical structure to the answer. The explanation, though basic, is clear.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: O₂ • photolysis • details of photolysis, e.g. splitting of water in photosystem II using light Glucose • Calvin cycle • details of intermediates, e.g. production of GP (glycerate 3-phosphate), reduction of GP to TP (triose phosphate) and joining of two TP to produce glucose • requirement for ATP and NADPH (reduced NADP) in reduction of GP to TP • carbon fixation, carbon from CO₂ combines with RuBP • stroma of chloroplasts • dark reaction / light-independent ATP and NADPH • H⁺ ions / protons (in thylakoid space), drive chemiosmosis / drive ATP synthase / allow production of ATP • NADPH (reduced NADP) produced in stroma from NADP⁺ and H⁺ • light-dependent
			Total	10	
22			A ✓	1	
			Total	1	
23			B ✓	1	
			Total	1	
24			A ✓	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25	a		<i>Rhizobium</i> / <i>Azotobacter</i> ;	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 CO₂ 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

Mark Scheme

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		<i>Up to 3 marks for mark points 1 – 5</i> 1 <i>idea that</i> carbon dioxide / CO₂, is combined with, ribulose bisphosphate / RuBP; 2 by enzyme ribulose bisphosphate carboxylase / Rubisco; 3 <i>idea that</i> 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; 6 triose phosphate / TP, is converted to lipids;	Max 3 1	1. ACCEPT carbon is fixed OR RuBP is carboxylated 5 ACCEPT NADPH / NADPH + H⁺ / NADPH₂ / red NADP AWARD using a tick and 'GM' annotation

Mark Scheme

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 biphosphate enzyme ribulose biphosphate 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		<i>idea that</i> a larger human population could be supported; <i>when eating Spirulina directly</i> <i>idea of</i> 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 <i>Spirulina</i> IGNORE 'nutrients'
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
26	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 IGNORE Do not penalise incorrect formatting (e.g. CO2, O2)
		ii	Y water;	1	ACCEPT H ₂ O 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.

Mark Scheme

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 / NADH₂ / NADH and H⁺ / red NAD Examiner's Comments The common error was the suggestion of either NADP or NADPH.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	a		succession;	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 IGNORE 'primary' or 'secondary' Examiner's Comments This encompassed both the social and biological implications of developing 'brownfield sites'. Both in terms of meeting the needs of increasing population numbers and the effects of this development and measures taken to counteract these effects. Previous recolonisation of the sites by vegetation and concentration of soil nutrients was also covered. This question tested AO2 primarily.
	b		1 nitrogen (compounds) / named examples, converted to / AW, ammonia / ammonium ions OR ammonification of (organic) compounds; 2 (ammonium (ions)) converted to nitrite, by <i>Nitrosomonas</i>; 3 nitrite converted to nitrate, by <i>Nitrobacter</i>; 4 <i>idea that nitrifying bacteria</i> are responsible for formation of nitrate;	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			QWC;	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.
	c		<i>idea that</i> (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, CO₂ production ACCEPT reduction in food miles Examiner's Comments The idea that trees use up CO₂ 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 CO₂ 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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28	a	i	nitrogen-fixing bacteria / Rhizobium (in root nodules); nitrogen required for (synthesis of) nitrogen compounds; <i>idea of</i> soil is not depleted of, nitrogen containing compounds / named; <i>idea of</i> 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,

Mark Scheme

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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		<i>idea that</i> (stubble) provides a food source; <i>idea that</i> (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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29	a		<i>idea that</i> (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	<i>idea that</i> it allows comparison between different gases;	1	CREDIT CO₂ 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.

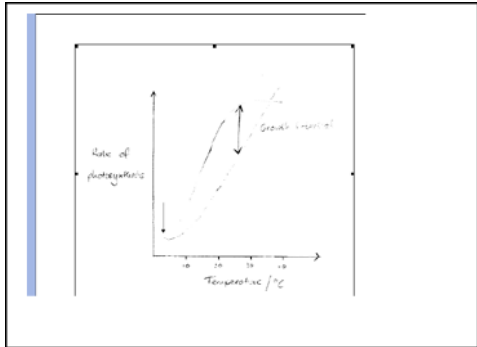
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		(hydrofluorocarbons) have very high GWP; <i>idea that</i> 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 CO₂ 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.
	d	i	carbon fixation / carbon dioxide combines with, ribulose biphosphate / RuBP; formation of, glycerophosphate / glycerate-3-phosphate / GP, from six carbon intermediate; formation of, triose phosphate / TP, from, glycerophosphate / GP, using ATP and reduced NADP; organic molecules formed from, triose phosphate / TP;	Max 3	ACCEPT NADPH ACCEPT named organic molecules (carbohydrates, lipids, aminoacids)

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		i		1	QWC awarded for correct use of three emboldened terms carbon fixation ribulose biphosphate glycerophosphate / glycerate 3- phosphate triose phosphate Examiner's Comments A lot of candidates gained two to four marks for (i) mainly for the combining of CO₂ with ribulose biphosphate and for the formation of organic molecules from triose phosphate. Marks gained for the intermediate stages varied. The marking point for the first stage which was the formation of glycerate-3-phosphate from a six carbon intermediate was gained by more candidates than for the second stage which was the formation of triose phosphate from glycerate-3-phosphate with the use of ATP and reduced NADPH. The QWC mark for this question was not obtained to the same extent as question 3 due to the misspelling of ribulose biphosphate and the fact that carbon fixation was rarely given in the answer.
		ii	(eCO₂) produced using, sugar beet / plants; renewable; fossil fuels not renewable;	Max 2	IGNORE recyclable / biodegradable Examiner's Comments A lot of candidates didn't link the greater efficiency of using eCO₂ to its production from a plant and that it was a renewable source compared to fossil fuels which weren't renewable in (ii). A lot of candidates gave vague refs to eCO₂ releasing less CO₂ to the atmosphere than burning fossil fuels.
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
30		i	compensation point clearly shown with an arrow	1	point indicated where two graph lines touch at bottom left or top right e.g. 
		ii	rate of photosynthesis limited by low temperature AND cost of lighting uneconomic	1	ALLOW (for second part of mp) cost of lighting / electricity / energy greater than profits made by crop production
		iii	to check that the temperature measured by the control system is accurate OR to ensure that the system switches off the light at the correct temperature	1	ALLOW idea of matching actual data with measurements made by control system
			Total	3	
31		i	0.22 (1) (1)	2	If answer incorrect ALLOW 1 mark for correct working $62\,705 / 28\,000\,000 \times 100$ If answer is correct but not given to 2 d.p. ALLOW 1 mark for 0.2239, 0.224
		ii	energy 'losses' occur at each trophic level and there are more trophic levels in the sheep food chain (1) correct example of energy 'losses' (1)	2	e.g. respiration / egestion / excretion / heat DO NOT ALLOW waste unqualified
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32	a	i	* Level 3 (5–6 marks) A broad range of limitations described in detail applying knowledge and understanding of sampling to the context, including the limitations of systematic sampling. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some limitations described applying some knowledge and understanding of sampling to the context, including some of the limitations of systematic sampling. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) An attempt to describe a limitation with partial knowledge and understanding of sampling. <i>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.</i> 0 marks No response or no response worthy of credit.	6	NOTE that the question has asked for limitations, not errors <i>Limitations to consider include:</i> • systematic sampling not appropriate without a gradient e.g. variation in drainage across the site • idea that transects usually run in one direction and it would need to be done in more than one direction to cover the field • some species more easily counted / seen • some species less easily counted / seen / covered by grass or larger species / species may be small therefore not easily seen • similar species wrongly identified • experiment not replicated (in the same location) • experiment only recorded on one day • experiment only carried out at one point in time / season • grass / lichen / moss not identified to species level • plants counted even if only partially within the quadrat • reference to random sampling / bias in area covered.
		ii	Any two from: more objective / less subjective / less of an estimate (of frame or grid quadrat) (1) only records what is, hit / touched (1) could be less representative (as less area covered) (1) may miss plants even though they are abundant (1)	2	IGNORE statements referring to accuracy without suitable qualification as outlined in the bullet points

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		<i>Disadvantages (up to a maximum of 2 marks)</i> cost of purchasing appropriate weedkiller (1) possible accumulation of chemicals up the food chain (1) public perception of use of chemicals (1) reference to environmental impact (1) contamination of water supplies is leading to removal of pesticides from the market (pushing up feed prices) (1) reduces biodiversity, if herbicide is not selective enough (1) health & safety implications re: storage and application (1) <i>Advantages (up to a maximum of 2 marks)</i> greater yield (of hay / silage) means less food needs to be bought in (1) reference to impact of greater grazing (1) increases biodiversity, if other species can now survive (1) increased milk yield in herd / (<i>idea of</i> greater stocking rate) feed more cows on the same area of grassland (1)	3	
			Total	11	
33			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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
34	a	i	<i>idea that</i> (Spirulina) is non-pathogenic (1) <i>idea that</i> not necessary to grow the bacteria (1) <i>idea that</i> aseptic technique would not be necessary (1) <i>idea that</i> it is a concentrated source (1)	2	DO NOT ALLOW 'readily available' as this is given in the question
		ii	<i>Maximum of 3 method marks from:</i> <i>Method</i> add a (named) solvent to (a sample of spirulina) powder (1) ref to small volume of solvent relative to mass of powder (1) <i>idea of</i> vigorous mixing / stirring / (powder and solvent) (1) <i>idea of</i> filtering / centrifuging, to separate debris (1) <i>idea of</i> leaving solution to evaporate (to concentrate more) (1) <i>idea of</i> covered / dark glass container / ice bath to store (so pigments don't break down) (1) <i>Max 3</i> <i>Maximum of 2 marks from:</i> <i>Safety</i> <i>idea of</i> masks when handling powder (1) <i>idea of</i> fume cupboard for handling solvent (1) <i>idea of</i> use of protective, goggles / lab coat (1) <i>Max 2</i>	4	ALLOW 'acetone', 'propanone' or a mixture of organic solvents.
	b	i	<i>idea that</i> chromatography of carotene carried out in same solvent system (1) compare R_f values of carotene and K (1)	2	DO NOT ALLOW 'at same distance' unless it is clear that carotene has been run on the same chromatogram (as then the solvent front would be identical)
		ii	(contain) chlorophyll a and chlorophyll b	1	ALLOW 'two forms of chlorophyll'

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		* Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but 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 set of level descriptors, Level 1, Level 2 or Level 3, best describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme. Once the level is located, award the higher or lower mark. The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met. The lower mark should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing. In summary: • The science content determines the level. • The communication statement determines the mark within a level.		

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Level 3 (5–6 marks) Provides a comprehensive description of the similarities and differences between photophosphorylation in <i>H. salinarium</i> as shown in Fig. 4.2 and the light dependent reaction in plants. <i>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.</i> Level 2 (3–4 marks) Describes some of the similarities and differences between photophosphorylation in <i>H. salinarium</i> as shown in Fig. 4.2 and the light dependent reaction in plants. <i>There is a line of reasoning presented with some structure and use of appropriate scientific language. The information presented is mostly relevant.</i> Level 1 (1–2 marks) Describes either similarities or differences between photophosphorylation in <i>H. salinarium</i> and the light dependent reaction in plants <i>There is a logical structure to the answer. The explanation, though basic, is clear.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include <i>Similarities</i> Pigments present within a membrane Energy released from electrons H⁺ 'pumped' across a membrane H⁺ gradient created H⁺ flow down an electrochemical gradient Chemiosmosis occurring (through) channel in ATP synthase ADP + Pi combine to form ATP <i>Differences</i> Only 1 'photosystem' in <i>H salinarium</i> / two photosystems in plants Bacteriorhodopsin in cell surface membrane / chlorophyll in thylakoid membrane H⁺ build up outside membrane / in cell wall in <i>H salinarium</i> / H⁺ build up in intermembranous space in plants Photolysis of water in plants / no photolysis of water in <i>H. salinarium</i> NADPH production in plants / no NADPH production in <i>H. salinarium</i>. Electron transport chain in plants / no electron transport chain in <i>H. salinarium</i>.
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35	a	i	(rate of) respiration, greater than / higher than, (rate of) photosynthesis	1	ALLOW reverse argument
		ii	<i>Idea that</i> 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: <i>idea of</i> varying light intensity named control variable <i>idea that</i> hydrogencarbonate changes colour as, pH / CO₂ concentration, changes (hydrogencarbonate indicator is) yellow at, low pH / high CO₂ concentration (hydrogencarbonate indicator is) purple at, high pH / low CO₂ 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 / SO₄²⁻ nitrate / NO₃⁻ / ammonium / NH₄⁺	2	
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
36	a		Any 2 from: (bacteria) hydrolyse / digest, cellulose (bacteria have) cellulase (bacteria found) in rumen ecosystem symbiosis / symbiotic relationship	2	
	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. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> 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. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Simple comments about humans and bacteria made with connections not always made. Little exemplification. <i>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.</i> 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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
37	a	i	<i>Rhizobium</i> (1)	1	ALLOW <i>Sino</i> / <i>Meso</i> / <i>Brady</i> / <i>Azorhizobium</i> ALLOW not italicised DO NOT ALLOW lowercase r
		ii	image size ÷ magnification OR 15,000 ÷ 32,000 (1) 0.47 / 0.5 (1)	2	ALLOW 2 marks for correct answer without working ALLOW 0.469
	b		* Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but 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 set of level descriptors, Level 1, Level 2 or Level 3, best describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme. Once the level is located, award the higher or lower mark. The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met. The lower mark should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing. In summary: • The science content determines the level. • The communication statement determines the mark within a level. Level 3 (5–6 marks) A detailed discussion of how to use a	6	Indicative scientific points may include • regular sampling • in the same site(s) • same volume of water • same number of, bacteria / biosensors • same temperature of water (for enzyme activity) • ref to repeats • taken from set points around the lake or along the stream • nitrate / NO₃⁻ concentration, read from, standard curve / standards (derived from the calibration) • calculation of means • identifying trends • continue over time / specify length of investigation • same light meter • same sample-taker / meter operator

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			biosensor to monitor nitrate concentration, including many ways to ensure validity of the data obtained. The requirement for the standard curve is mentioned. <i>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.</i> Level 2 (3–4 marks) A good discussion of how to use a biosensor to monitor nitrate concentration, including several ways to ensure validity of the data obtained. The requirement for the standard curve may be mentioned. <i>There is a line of reasoning presented with some structure and use of appropriate scientific language. The information presented is mostly relevant.</i> Level 1 (1–2 marks) A limited discussion of how to use a biosensor to monitor nitrate concentration, with only some ways to ensure validity of the data obtained. The requirement for the standard curve is not mentioned. <i>There is a logical structure to the answer. The explanation, though basic, is clear.</i> 0 marks No response or no response worthy of credit.		
			Total	9	
38			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance									
39	a		(chlorophyll molecules) in thylakoid membrane Y / hydrocarbon chain, in the (phospholipid) bilayer of thylakoid membranes X / head, at the surface of the thylakoid membrane	3	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									
	b	i	Any 1 from: <i>idea that</i> spot of extract needs to be (very) concentrated / AW allow one spot to dry before adding another sufficient length of chromatography paper AVP	1	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									
		ii	Chlorophyll B = 62 mm Chlorophyll A = 91 mm	2	$0.58 \times 107 = 62.06$ mm $0.85 \times 107 = 90.95$ mm Max 1 if units are not given OR figures not given as whole numbers									
		iii	<i>idea that</i> Chlorophyll A is less soluble than xanthophyll but more soluble than chlorophyll B / AW Rf data quote in support	2	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									
	c	i	<table border="1"><tr><td>Description</td><td>Name</td><td>Letter</td></tr><tr><td></td><td>Abomasum</td><td>U</td></tr><tr><td></td><td>Reticulum</td><td>S</td></tr></table>	Description	Name	Letter		Abomasum	U		Reticulum	S	2	One mark for each correct row ALLOW rumen and V
Description	Name	Letter												
	Abomasum	U												
	Reticulum	S												
		ii	<i>idea that</i> microbes in rumen are a protein source (microbial protein) hydrolysed into amino acids by protease enzymes	2										
		iii	(amino acids are) deaminated / AW	1										
			Total	13										
40			D	1										
			Total	1										

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
41			C	1	
			Total	1	
42			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
43	a	i	<i>idea that Rhizobium</i> is, involved in nitrogen fixation / not involved in nitrification; (<i>Rhizobium</i>) 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. <i>Rhizobium</i> 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 <i>Rhizobium</i> 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 <i>Rhizobium</i> 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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	<i>idea that</i> the desired product is <i>Nitrosomonas (europaea)</i> (cells); enzymes / proteins, are denatured (by incorrect pH); enzymes needed for, (named metabolic) processes in growth; (incorrect pH) disruption of, tertiary / 3D, structure / shape; <i>ref to</i> effect of hydrogen ions on, H / ionic, bonds;	3 max	ACCEPT increases yield of <i>N. europaea</i> IGNORE ref to products of <i>Nitrosomonas europaea</i> 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 <i>Nitrosomonas</i> 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.

Mark Scheme

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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
44			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

Mark Scheme

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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
45		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.

Mark Scheme

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	<i>Marks awarded for link in food chain correctly linked to explanation</i> 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 <i>animals</i>. 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 <i>more</i> energy as heat, or had <i>more</i> 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	