Surname	StemUp Model Solution	Centre Number	Candidate Number
First name(s)			2

GCE A LEVEL

A400U10-1

O21-A400U10-1

MONDAY, 11 OCTOBER 2021 – MORNING

BIOLOGY – A level component 1
Energy for Life

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**13**	
2.	**8**	
3.	**16**	
4.	**14**	
5.	**14**	
6.	**10**	
7.	**16**	
8.	**9**	
Total	**100**	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will need a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **8**.

The quality of written communication will affect the awarding of marks.

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Answer **all** *questions.*

1. Plants can harvest light energy using photosystems and use this energy to synthesise organic molecules.

(a) (i) State the precise location of photosystems in plants. [1]

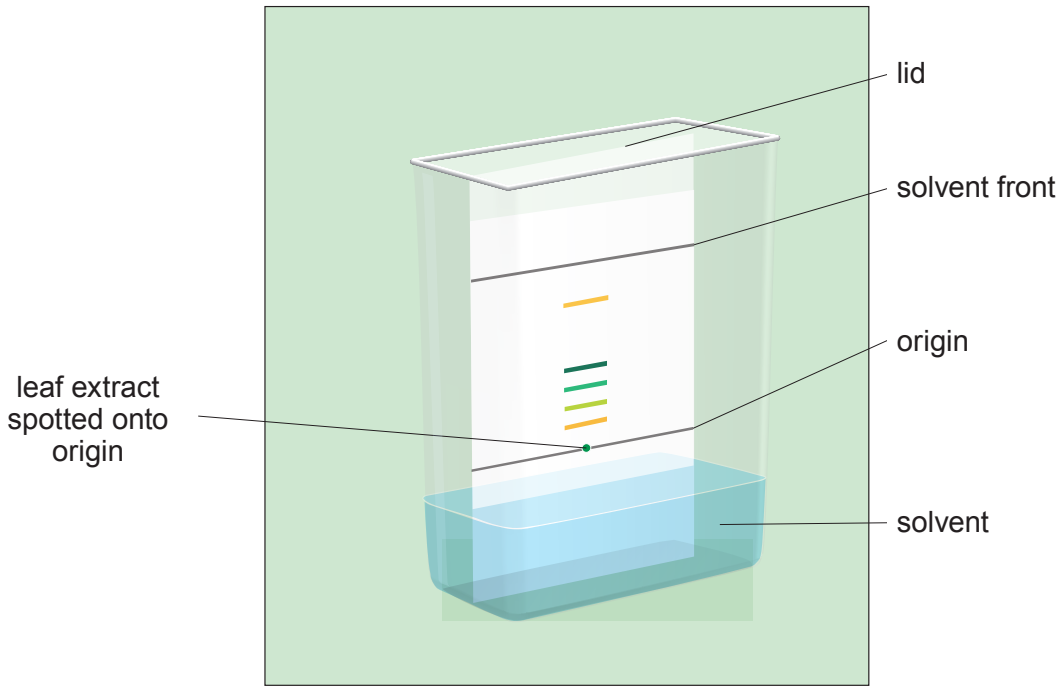
In the thylakoid membranes of the grana in the chloroplasts.

(ii) Explain how the arrangement of pigments in photosystems harvests light energy. [3]

Photosystems (PSI and PSII) contain groups of different pigments: accessory pigments (chlorophyll b, carotenoids) absorb light at different wavelengths, so a wider range of wavelengths is harvested. The energy is passed to chlorophyll a at the centre (the reaction centre). The chlorophyll a in the reaction centres of PSI and PSII absorbs slightly different wavelengths (700 nm and 680 nm).

(b) The pigments in a leaf can be separated by either paper or thin layer chromatography in the apparatus shown in **image 1.1**.

Image 1.1

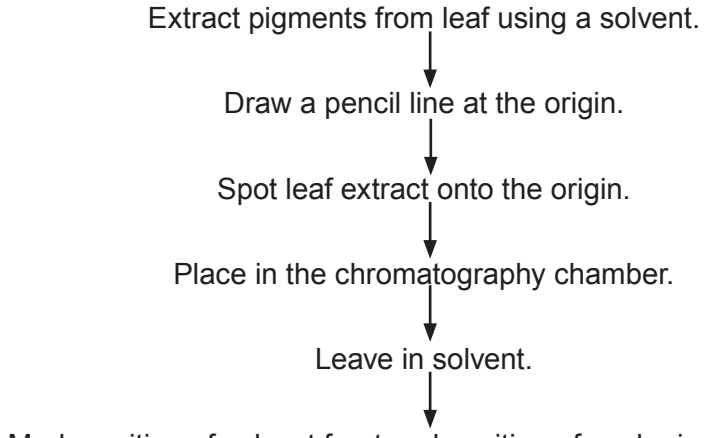


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The flow diagram gives an outline of the method used.



(i) Explain why the origin line is drawn in pencil **and** why the level of the solvent used is below the origin line. [2]

Pencil does not dissolve in the solvent, whereas the pigments in ink would dissolve and run up the paper, mixing with the sample. The solvent is below the origin so the pigments in the sample do not dissolve into the solvent in the chamber.

(ii) Describe the method by which the pigment is concentrated on the origin line. [1]

Spot a small amount of extract on the origin, let it evaporate (dry), then repeat many times on the same spot.

(iii) Complete the risk assessment below for this experiment. [1]

Hazard	Risk	Control measure
Solvents are irritants	*Solvent splashes onto hands / into eyes when pouring*	*Wear gloves and eye protection (goggles)*

(iv) State **one** variable which would need to be controlled if this method was used to compare the pigments in leaves of two different species of plant. [1]

The same solvent (and the same type of chromatography paper).

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(c) A pigment can be identified by calculating its Rf value.

$$Rf = \frac{\text{Distance travelled by pigment}}{\text{Distance travelled by solvent front}}$$

Image 1.2 below shows the separation of pigments using the method shown.

Image 1.2

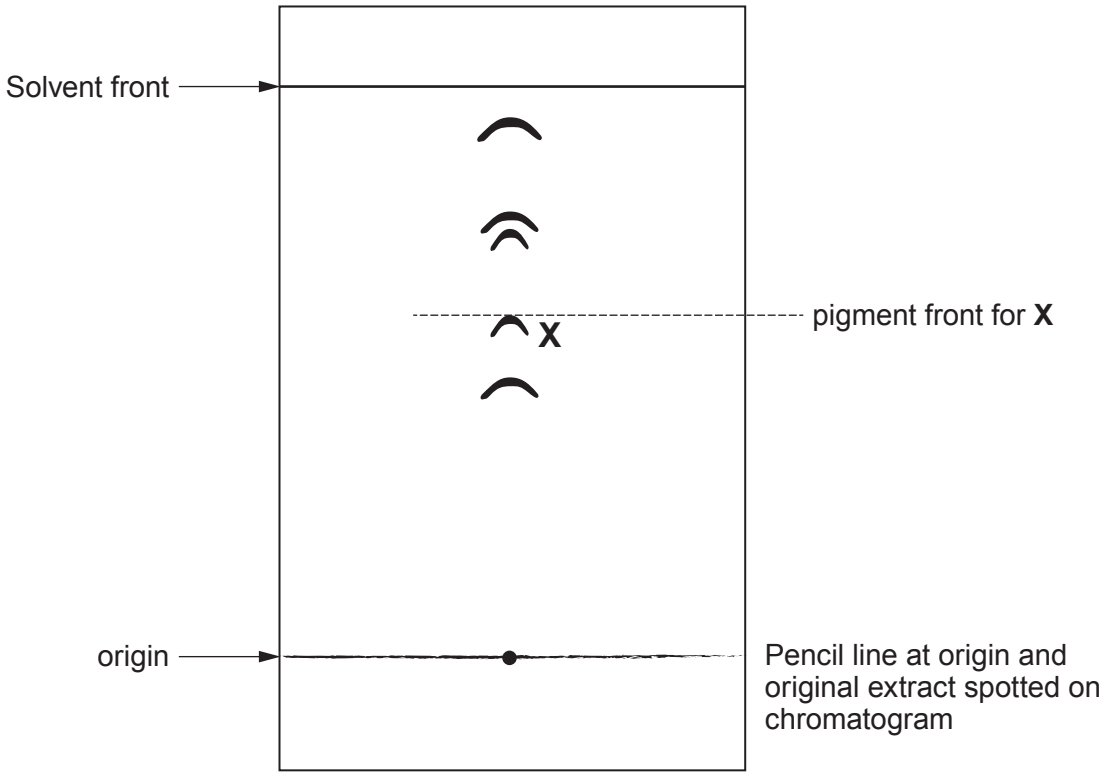


Table 1.3 shows data for separation in 2:1 propanone:petroleum ether.

Table 1.3

Pigment	Rf
β-carotene	0.96
phaeophytin	0.70
Chlorophyll a	0.60
Chlorophyll b	0.48
Xanthophyll	0.75

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(i) Calculate the Rf value for pigment **X** in **image 1.2** and use **table 1.3** to identify the pigment.
Show all your working. [2]

Distance moved by X = 45 mm

Distance moved by solvent front = 75 mm

Rf = 45 / 75 = 0.60

Rf value = 0.60

Pigment = Chlorophyll a

(ii) You are provided with a pure solution of each pigment. Describe how you could confirm that your identification of pigment **X** using the Rf value was correct. [2]

Spot each pure pigment (and the leaf extract) on the same origin line of the same paper and run them together in the same solvent.

Compare the position of each pure pigment with pigment X: the one that travels the same distance (same Rf) confirms it.

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2. Bacteria can be distinguished from each other by their size, shape, staining characteristics and their metabolic features. **Image 2.1** shows three different types of bacteria. **Image 2.2** shows two different types of bacteria after Gram staining.

Image 2.1

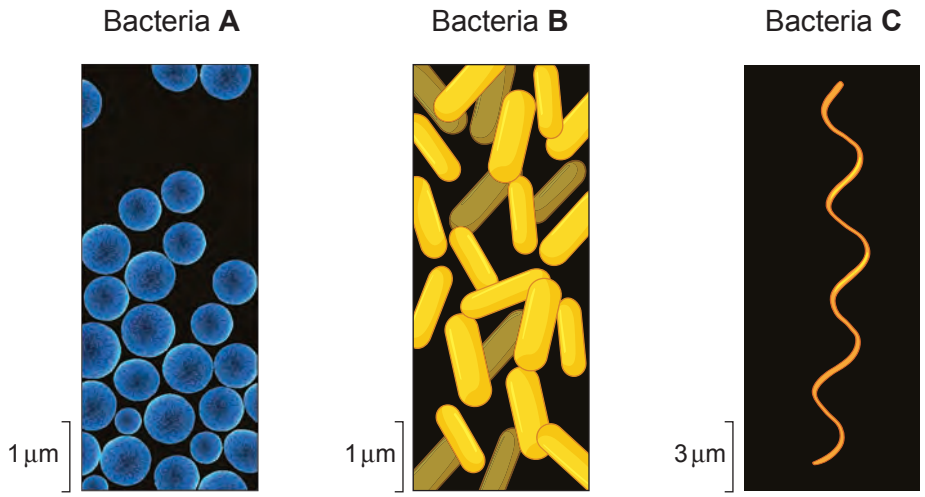
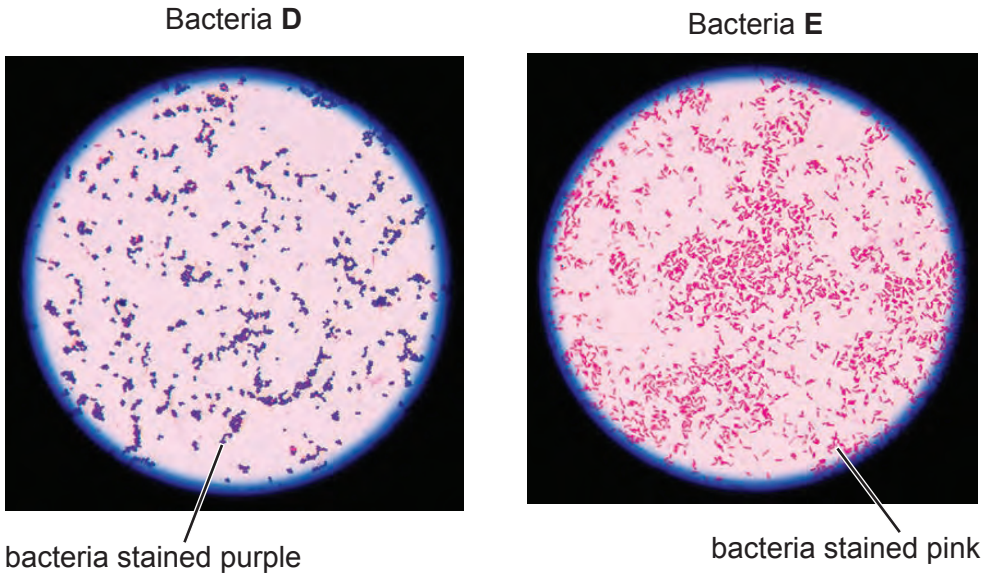


Image 2.2



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(a) (i) State the names given to the shapes of bacteria, **A**, **B** and **C** shown in **image 2.1**. [1]

A coccus (cocci)

B bacillus (rods)

C spirillum

(ii) State and explain what the results of the staining shown in **image 2.2** indicates about the structure of the cell walls of bacteria **D** and **E**. [2]

D is Gram positive (purple), so it has a thick peptidoglycan (murein) cell wall which retains the crystal violet.

E is Gram negative (pink), so it has a thin peptidoglycan wall with an additional outer layer of lipopolysaccharide / lipoprotein.

(iii) Micro-organisms may be grown in the laboratory if supplied with suitable nutrients.

Explain why micro-organisms must be provided with a source of:

I. nitrogen [1]

To make amino acids / proteins and nucleic acids (DNA, RNA) and ATP.

II. phosphorus [1]

To make phospholipids for membranes, nucleic acids (DNA) and ATP.

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(b) Nutrient agars can be modified so that only particular types or species of bacteria can grow in them.
MacConkey's mannitol salt agar contains a chemical called mannitol and a pH indicator. It will only allow:

- the growth of Gram negative bacteria;
- the growth of bacteria that can tolerate high concentrations of sodium chloride (halophiles).

Some species of bacteria can break down mannitol producing an acid which causes the pH indicator to change from pink to yellow.

Staphylococcus aureus, *Staphylococcus epidermidis* and *Micrococcus luteus* are all species of bacteria which live on human skin.

Table 2.3 shows some information about these three species.

Table 2.3

Species of bacterium	Disease causing	Gram staining	Halophile	Breakdown of mannitol (which produces an acid)
Staphylococcus aureus	Pathogen	Gram negative	Yes	Yes
Staphylococcus epidermidis	Non pathogenic	Gram negative	Yes	No
Micrococcus luteus	Non pathogenic	Gram positive	No	No

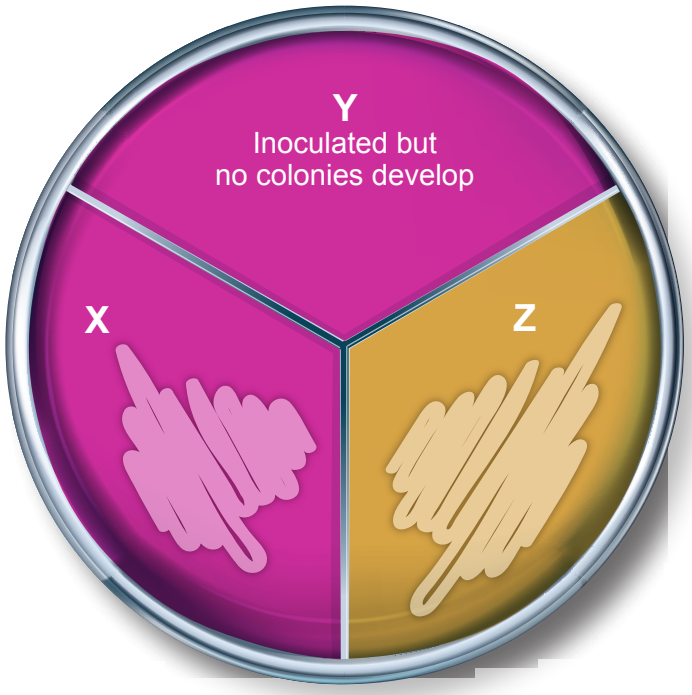
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An agar plate containing MacConkey's mannitol salt agar was inoculated with pure samples of the three bacteria and incubated. The plate is shown in **image 2.4**.

Image 2.4



Use **all** the information given in **table 2.3** and **image 2.4** to **complete the table**, and identify the bacteria in zones **X**, **Y** and **Z**. [3]

	Gram staining (positive or negative)	Able to break down mannitol (✓ or ×)	Halophile (✓ or ×)	Name of bacterium
X	negative	×	✓	Staphylococcus epidermidis
Y	positive	×	×	Micrococcus luteus
Z	negative	✓	✓	Staphylococcus aureus

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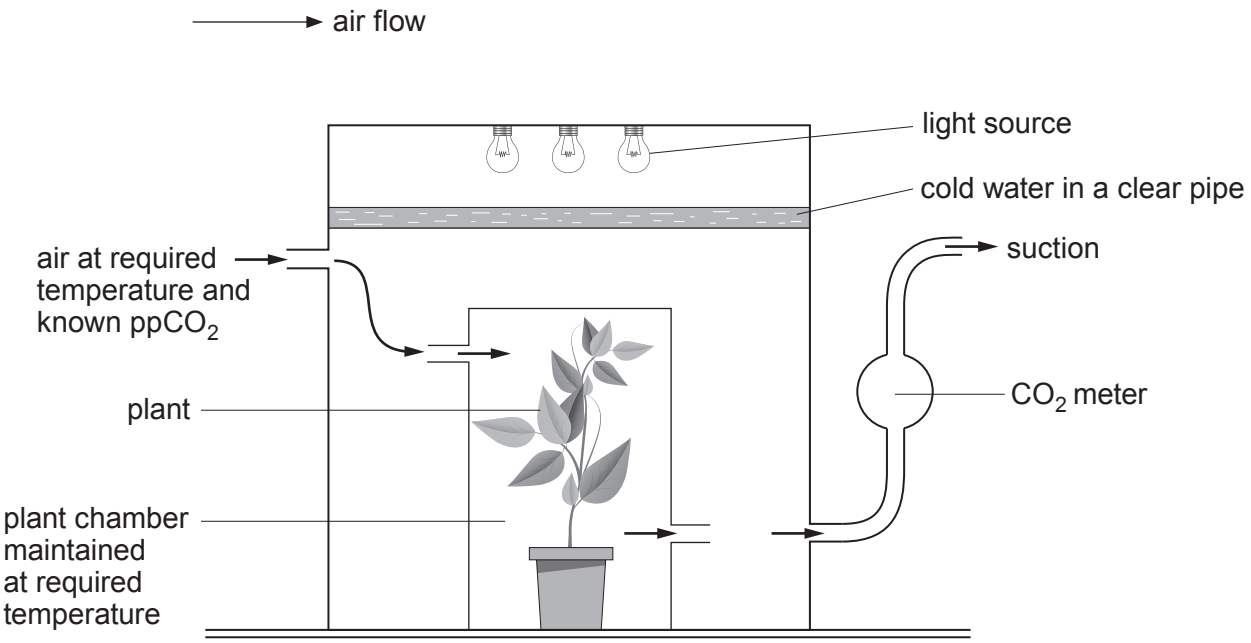
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3. The rate of photosynthesis at different temperatures was determined by measuring the rate of carbon dioxide exchange using the apparatus shown in **image 3.1**.

Image 3.1



The mass of carbon dioxide absorbed by ten tomato plants in 1 hour was measured at 15, 20, 30 and 40 °C. The same group of plants were grown at the same light intensity at all temperatures.

(a) (i) Suggest why cold water was placed between the light source and plant chamber. [1]

To absorb heat from the light source so the temperature in the plant chamber does not increase.

(ii) Explain why it is important that the same ten plants were used in all tests. [1]

Different plants would have different leaf surface areas / numbers of chloroplasts, so only the temperature (independent variable) changes.

(iii) Suggest a suitable control for this experiment. [2]

Repeat the experiment with the same apparatus and the same conditions (temperatures, light intensity, air flow) but with no plant in the chamber.

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(iv) Describe how the experiment could be modified to determine the mass of CO_2 released by respiration. [1]

Repeat the experiment at each temperature in the dark, so no photosynthesis occurs and only CO_2 from respiration is measured.

The results of the experiments are shown in **table 3.2**. The rate of photosynthesis is given by the total mass of CO_2 used by photosynthesis.

Table 3.2

Temperature of the plant chamber / °C	CO_2 absorbed / mg hour^{-1}	CO_2 produced by respiration / mg hour^{-1}	Rate of photosynthesis / mg hour^{-1}
15	30.2	0.2	30.4
20	30.7	2.4	33.1
30	30.1	5.2	35.3
40	17.2	8.2	25.4

(b) (i) Explain why both the mass of carbon dioxide absorbed during photosynthesis and the mass of carbon dioxide produced during respiration are needed to determine the rate of photosynthesis. [1]

The true rate of photosynthesis is the total mass of CO_2 used: the mass absorbed from the air plus the mass produced by respiration, which is used in photosynthesis without being measured.

(ii) **Complete table 3.2** to show the CO_2 absorbed at temperatures 15 °C – 40 °C. [1]

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The sugar content of tomatoes varies depending on the temperature at which they are grown. This is due to changes in temperature affecting the rate of respiration and photosynthesis differently.

(c) (i) Use the data in **table 3.2** to describe **and** explain how the temperature at which tomato plants are grown affects the sugar content of the tomato. [4]

The rate of photosynthesis increases slightly from 15 to 30 °C (30.4 to 35.3 mg hour^{-1}), so more sugar is produced.

Above 30 °C photosynthesis falls (25.4 at 40 °C), so less sugar is produced.

The rate of respiration increases much more from 15 to 40 °C (0.2 to 8.2 mg hour^{-1}), so more sugar is broken down as temperature increases.

So there is a temperature above which more sugar is broken down than produced and sugar content falls.

(ii) At high wind speeds stomata close. Explain **one** advantage and **one** disadvantage of this response to the plant. [2]

Advantage: less water is lost by transpiration, so the plant does not wilt.

Disadvantage: carbon dioxide cannot diffuse into the leaf, so the rate of photosynthesis falls.

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(d) The production of certain chemicals by enzymes contribute to the sweetness of tomatoes. When tomatoes are kept below 5 °C the genes which code for these enzymes are methylated and the genes are switched off. This is a permanent change in gene expression and does not return when the tomato temperature rises.

(i) State the name given to a change in gene expression brought about by methylation. [1]

Epigenetics

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(ii) Use the information given and your knowledge of protein synthesis to explain why the sweetness of the tomatoes will not increase after they have been stored at low temperatures, even if they are returned to higher temperatures. [2]

Methylation means the genes cannot be transcribed, so no mRNA is produced.

So translation does not take place and the enzymes which produce the sweet chemicals are not made, even at higher temperatures, as the methylation is permanent.

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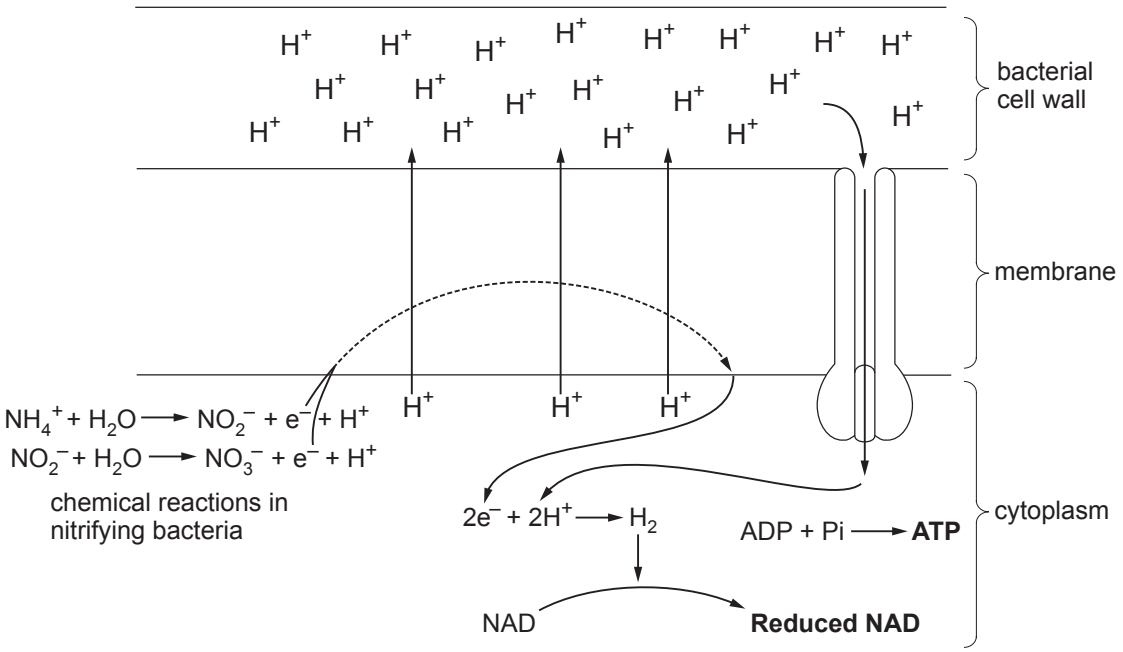
4. Carbon dioxide and atmospheric nitrogen can be fixed by living organisms.

(a) State the meaning of the word *fixed* as used in this context. [1]

Converted into organic compounds, a form which can be used by living organisms.

(b) **Image 4.1** represents the production of ATP and reduced NAD by nitrifying bacteria.

Image 4.1



Use the information in **image 4.1** and your own knowledge to answer the following.

(i) Name the nitrifying bacteria **and** describe how they produce a source of electrons and protons (H^+). [3]

Nitrosomonas and Nitrobacter.

Nitrosomonas oxidises ammonium ions (NH_4^+) to nitrite ions (NO_2^-).

Nitrobacter oxidises nitrite ions (NO_2^-) to nitrate ions (NO_3^-).

These reactions release electrons and H^+ from water.

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(ii) The electrons are passed along a series of molecules in the membrane. State the name given to this series of molecules. [1]

Electron transport chain

(iii) Describe how the energy released from the movement of these electrons is used. [3]

The energy is used to pump protons (H^+) against their concentration gradient, from the cytoplasm across the membrane into the space by the bacterial cell wall, creating a proton gradient (electrochemical gradient) across the membrane.

(iv) Describe how ADP is phosphorylated as a result of the reaction shown in **image 4.1**. [3]

Protons flow back down their concentration gradient into the cytoplasm, through the stalked particle, ATP synthase (ATP synthetase), in the membrane. This provides the energy to join ADP and inorganic phosphate (Pi) to form ATP.

(c) Nitrifying bacteria are chemoautotrophs. From your knowledge of the light independent reactions of photosynthesis (Calvin cycle), suggest how the bacteria use the **products of the reactions shown in bold in image 4.1**. [3]

Reduced NAD is used to reduce glycerate 3-phosphate (GP) to triose phosphate (TP), using energy from ATP. ATP also donates a phosphate group to regenerate RuBP from RuP. So the bacteria can fix carbon dioxide and produce TP, glucose and other organic compounds.

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5. Wading birds (waders) feed in shallow water. Areas of the Western Isles off the coast of Scotland are the most important breeding grounds for waders in Europe. The numbers of breeding pairs of lapwing, redshank, dunlin and snipe were monitored in the areas shown in **image 5.1** in 1983 and 2000. These waders are ground nesting birds.

Image 5.1



Area 1 is not colonised by hedgehogs.

Area 2 is where seven hedgehogs were introduced by a house owner to eat slugs in their garden. Since their introduction numbers have increased and they have established a large population.

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Hedgehogs normally feed on worms, insects, slugs and snails but will also eat the eggs of ground nesting birds such as waders.

The results of the monitoring of the wading birds are shown in **table 5.2**.

Table 5.2

Species of wading bird	Percentage change in number of breeding pairs between 1983 and 2000	
	Area 1 (hedgehogs absent)	**Area 2** (hedgehogs present)
lapwing	+24	–31
redshank	+51	–41
dunlin	–30	–56
snipe	–2	–57

(a) (i) Calculate the percentage change in the number of breeding pairs of redshank in **Area 2** if the population in 1983 was 1288 breeding pairs and in 2000 it was 760 breeding pairs.

Write your answer in the table. [3]

(760 – 1288) / 1288 × 100

= –528 / 1288 × 100 = –40.99

= –41 %

(ii) With reference to the data in **table 5.2** and the information provided, evaluate the conclusion that hedgehogs are the main reason for the decline in wading bird numbers. [2]

All species declined in Area 2 where hedgehogs are present, and lapwing and redshank increased where they are absent, which supports the conclusion.

But hedgehogs are not the only cause, as dunlin and snipe also declined in Area 1 where hedgehogs are absent.

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(iii) Explain **one** advantage and **one** disadvantage of expressing the change in the number of breeding pairs as a percentage. [2]

Advantage: allows comparison between species / areas with different starting numbers.

Disadvantage: if numbers are small, any change gives a large % change, which can seem more significant than it really is.

(iv) State **two** factors which could have allowed a very large population of hedgehogs to have been produced from the original seven individuals. [2]

I. No natural predators of hedgehogs on the islands.

II. Abundance of food / no interspecific competition.

(b) Brown rats, polecats and gulls are also predators of wader eggs. An investigation into the effect of hedgehogs on wader eggs was carried out as follows:

- Two plots of land were enclosed by hedgehog-proof fencing and all the hedgehogs were removed from these plots.
- An area of land adjacent to each plot of similar size was not fenced. These acted as control areas.
- Egg loss in the fenced and unfenced areas was compared and the type of predator causing the egg loss recorded.

(i) State why it was necessary to carry out such a study before a decision was made to control the number of hedgehogs. [2]

To confirm that hedgehogs were responsible for the decline (egg loss) and to assess the impact of the other predators (rats, polecats, gulls).

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(ii) The number of hedgehogs in the British countryside is now under 1 million which is a 97 % fall since the 1950s.

The following measures were proposed to control the hedgehog numbers in the Western Isles. Suggest **one** ecological problem for each control measure.

I. Trapping and moving hedgehogs to the mainland. [1]

It may cause a problem in the area they are moved into, e.g. spreading disease or affecting the balance of that ecosystem.

II. Remove hedgehogs from wader breeding areas and then erect 1 metre high hedgehog-proof fencing around the area. [1]

The fencing would prevent the natural movement of other species into and out of the area.

III. Trapping of hedgehogs followed by humane killing. [1]

It is wrong to kill the animals when the species is already in decline (97 % fall) and its numbers are threatened.

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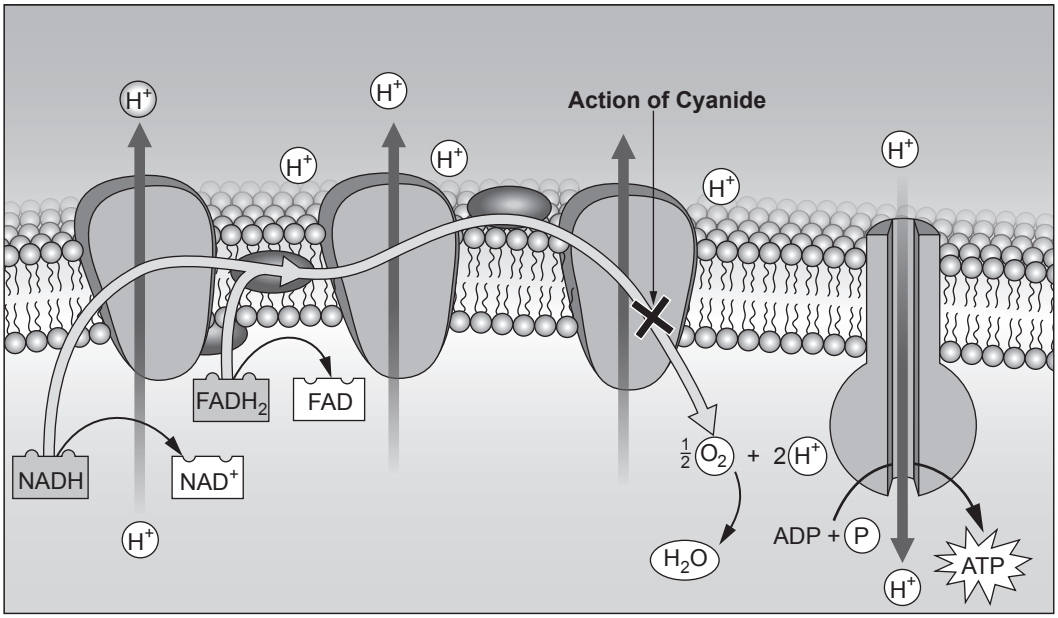
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6. Cyanide is an extremely poisonous chemical that affects aerobic respiration in mitochondria. The symptoms of cyanide poisoning include an increase in heart rate, breathing problems and eventually death.

Image 6.1 shows the site of action of cyanide.

Image 6.1



(a) (i) With reference to **image 6.1** explain how cyanide would prevent the process of aerobic respiration. [4]

Cyanide stops the transfer of electrons to oxygen, the final electron acceptor, at the end of the electron transport chain.

So electrons cannot be accepted by the electron carriers (cytochromes) along the chain and the flow of electrons stops.

The electron donors $NADH_2$ and $FADH_2$ cannot be oxidised, so NAD and FAD are not regenerated for the Krebs cycle.

No protons are pumped, so ATP synthesis via the electron transport chain (oxidative phosphorylation) stops.

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(ii) Explain why blood lactate concentration rises as a symptom of cyanide poisoning. [3]

Reduced NAD (NADH) from glycolysis cannot pass its hydrogen to the Krebs cycle / electron transport chain.

Instead the hydrogen is given to pyruvate, which is reduced to lactate.

This regenerates NAD so that glycolysis can continue and make ATP anaerobically, so lactate builds up in the blood.

(b) Apple seeds (pips) contain cyanide. If an apple seed is swallowed whole, it passes through the gut and will not poison the animal. If the seed is chewed cyanide will be released. In small quantities this will not harm the animal but in large quantities it could be fatal.

- 125 mg of cyanide would be sufficient to kill an adult pig.
- 1 apple seed weighs 0.6 g
- 1 gram of apple seeds when chewed releases 0.09 mg of cyanide.

Calculate how many apple seeds would need to be chewed by the adult pig to cause death.

Give your answer to the nearest whole number. [3]

Mass of seeds needed = 125 / 0.09 = 1388.9 g

Number of seeds = 1388.9 / 0.6 = 2314.8

= 2315 seeds (nearest whole number)

Number of seeds = 2315

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7. Sea otters *(Enhydra lutris)*, shown in **image 7.1**, are found in the cold waters off the Northern Pacific Ocean coastline, where they feed on sea urchins, crabs and shellfish.

Image 7.1



Sea urchins feed on kelp (a type of seaweed). In areas where sea otters are no longer present, kelp forests have declined and there has been a major decrease in biodiversity as shown in **image 7.2**.

Image 7.2



Kelp forest in an area inhabited by sea otters



Sea floor in an area where sea otters are no longer present

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(a) Kelp forests are an example of a climax community. In areas where sea otters are reintroduced, kelp forests can regrow.

(i) Explain what is meant by a climax community **and** why regrowth of a kelp forest is an example of secondary succession. [2]

A climax community is the final stage of succession, in which the species composition remains relatively stable.

Secondary succession is the recolonisation of an area that had been previously colonised (soil / substrate already present).

(ii) In addition to sea urchins, sea otters also eat crabs and shellfish. Using your knowledge of **predator prey relationships**, suggest how the presence of sea otters in a habitat maintains biodiversity. [4]

Sea otters eat sea urchins, so the kelp forest can regrow, providing a wider range of ecological niches.

As the density of a particular prey (e.g. urchins) increases, more are eaten, so that prey population decreases.

The otter then eats more of a different species (crabs or shellfish), so no single species dominates the habitat.

(iii) Explain why scientists consider that the destruction of sea otter populations could contribute to an increase in global warming. [3]

As sea otter numbers decline, sea urchins are not eaten, so they graze the kelp and there is less kelp.

So there is less photosynthesis and less CO_2 is removed from the atmosphere, so more CO_2 remains in the environment.

Carbon dioxide is a greenhouse gas, so global warming increases.

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(iv) Explain why an increase in global warming could have been a contributory factor in the planetary boundary for biodiversity being crossed. [2]

Sea temperatures increase above what is suitable for organisms, e.g. the algae in corals die and coral bleaches, and temperature increases faster than organisms can adapt, so species become extinct.

(b) In the past, sea otters were hunted by humans for their very thick, waterproof fur and by the 1900s were almost extinct.

(i) An adult male sea otter with a surface area of $7.2 \times 10^3\,cm^2$ has approximately 8.64×10^8 hairs on its body surface.

Calculate the number of hairs per cm^2 of body surface. **Give your answer in standard form**. [2]

$8.64 \times 10^8 / 7.2 \times 10^3 = 120\,000$

$= 1.2 \times 10^5$ hairs per cm^2

Number of hairs per cm^2 = 1.2×10^5

(ii) Suggest the homeostatic role of the high density of hair in sea otters. [1]

Insulation (traps air), reducing heat loss to help maintain a constant core body temperature.

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(iii) In recent years, the numbers of sea otters has increased as a result of many different conservation measures. Describe **two** conservation measures which may have aided the recovery of the sea otter population. [2]

Legislation to prevent hunting, and international cooperation (e.g. CITES) restricting trade in sea otter fur.

Setting up protected areas (marine reserves) where sea otters live.

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8. **Images 8.1** and **8.2** show the structure of mitochondria and chloroplasts.

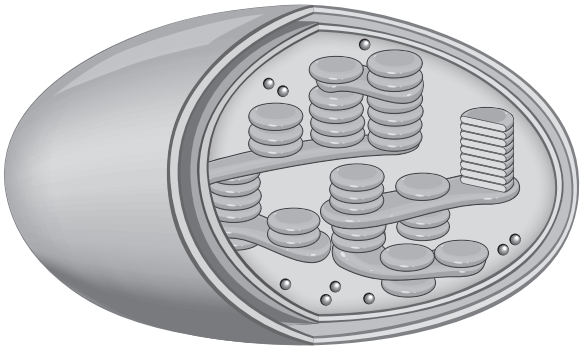
Image 8.1

Mitochondria



Image 8.2

Chloroplast



Explain how the internal structures of mitochondria and chloroplasts are adapted to carry out respiration and photosynthesis respectively. Using your knowledge and evidence from the images, describe the evidence that suggests that both mitochondria and chloroplasts have evolved from bacteria. [9 QER]

Mitochondria are adapted for aerobic respiration. The inner mitochondrial membrane contains the electron transport chain and ATP synthase (stalked particles) for ATP synthesis by oxidative phosphorylation.

The inner membrane is folded into cristae, which increases the surface area for more electron carriers and ATP synthase, so more ATP can be made.

The intermembrane space is small, so protons pumped into it by the electron transport chain build up quickly, enabling a proton gradient to be established, which drives chemiosmosis.

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The matrix contains the enzymes of the link reaction and Krebs cycle (dehydrogenases and decarboxylases) which produce the reduced hydrogen carriers $NADH_2$ and $FADH_2$. The matrix also contains ribosomes which produce these enzymes, and its own DNA.

Chloroplasts are adapted for photosynthesis. The thylakoid membranes contain the photosystems with photosynthetic pigments for harvesting light, and the electron transfer chain and ATP synthase for the production of ATP in the light dependent stage.

The thylakoids are stacked into grana, which gives a large area of thylakoid membranes (large number of thylakoids) so more light can be absorbed.

The thylakoid space is small, so protons pumped into it enable a proton gradient to be established across the thylakoid membrane for photophosphorylation.

The stroma surrounds the thylakoids and contains the enzymes for the Calvin cycle, such as rubisco, so ATP and reduced NADP from the grana are used close by. The stroma also contains ribosomes which produce enzymes such as rubisco.

Endosymbiont theory suggests that both organelles evolved from free-living bacteria that were engulfed by an ancestral eukaryotic cell. The evidence for this is:

The cristae of mitochondria are similar to the mesosomes in bacteria, and the thylakoid membranes in chloroplasts are similar to the photosynthetic membranes in photosynthetic bacteria.

Both organelles contain their own circular DNA, with no histones associated with the DNA, and the DNA is not enclosed by a nuclear membrane, as in prokaryotes.

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Both contain small 70S ribosomes, like bacteria, whereas the eukaryotic cytoplasm has 80S ribosomes.

Both are surrounded by a double membrane, the inner membrane coming from the engulfed bacterium and the outer membrane from the host cell, and both are capable of division by binary fission independently of the cell.

These shared features of mitochondria and chloroplasts strongly suggest that they evolved from bacteria.

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