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

GCE A LEVEL

A400U10-1

Z22-A400U10-1-R1

THURSDAY, 9 JUNE 2022 – AFTERNOON

BIOLOGY – A level component 1
Energy for Life

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**13**	
2.	**12**	
3.	**18**	
4.	**11**	
5.	**17**	
6.	**20**	
7.	**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 or 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 **7**.

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

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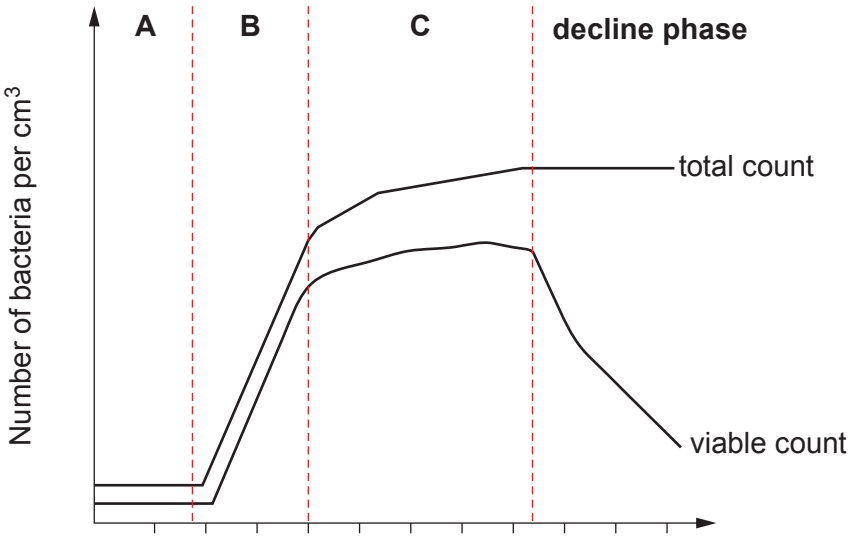
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Answer **all** questions.

1. A flask of sterile culture medium was inoculated with a small number of bacterial cells. The number of bacteria per cm^3 of culture medium was monitored at regular intervals using a total count and a viable count. The results were plotted as shown in **Image 1.1**.

Image 1.1



(a) (i) **Complete the table below** to name stages **A**, **B** and **C** of the population growth curve shown in **Image 1.1** and explain the shape of the growth curve in each stage. [3]

Stage	Name of Stage	Explanation of the shape of the population growth curve
A	Lag phase	Enzymes, RNA and proteins are being synthesised and nutrients absorbed, so cells grow but there is little cell division and numbers stay almost constant.
B	Log phase	Rapid cell division: the number of cells doubles in each unit of time (each generation), so growth is exponential as nutrients are plentiful.
C	Stationary phase	Rate of cell death = rate of cell production, as nutrients are reduced and toxic waste products accumulate; the carrying capacity has been reached.

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(ii) Explain the difference between the shape of the decline phase obtained using a total count and a viable count. [1]

The total count includes dead and living cells, whereas the viable count only counts living cells (so the total count stays high).

(iii) One method of estimating the number of bacteria is to dilute a sample of the bacterial culture, plate out known volumes onto agar plates and count the number of colonies following incubation. Explain why you could not use this method to collect **all** the data shown in **Image 1.1**. [1]

Colonies only grow from living (viable) bacteria, so dead cells would not be counted and the total count could not be obtained.

(b) Bacterial cells divide at a constant rate when conditions are optimum.

The generation time for bacteria is defined as the time for a bacterial population to double in number. Generation times of different species of bacteria vary from approximately 12 minutes to 30 hours.

(i) State **two** environmental conditions that could affect the rate of bacterial cell division. [1]

Temperature and pH (also nutrient concentration, oxygen concentration).

(ii) For a culture in which cells divide every 20 minutes, calculate how many cells will be produced after eight hours from a single bacterium. **Express your answer in the form 2^n where n = the number of generations.** [2]

8 hours = 480 minutes

number of generations = 480 ÷ 20 = 24

number of cells = 2^{24} (= 16 777 216)

Number of bacteria after eight hours = 2^{24}

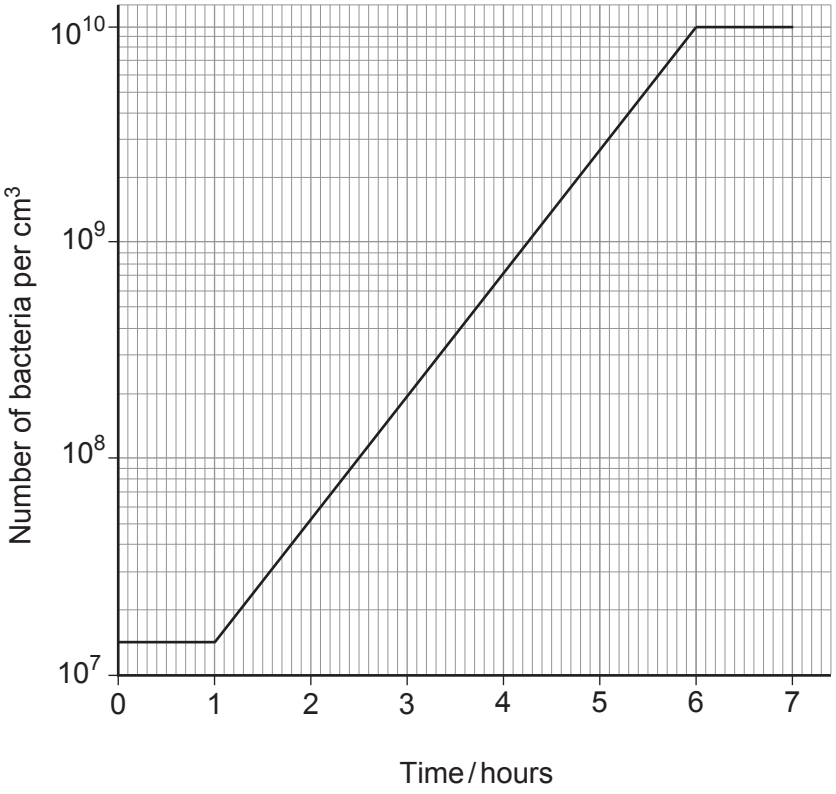
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(c) A different method of assessing the growth of bacterial populations is to determine the number of generations of bacteria produced in a given time period. **Image 1.2** shows the number of bacteria per cm^3 present in a culture over a seven hour period.

Image 1.2



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(i) Use the graph in **Image 1.2** and the formula given below to calculate the number of generations produced per hour between **2.5** hours and **6** hours. **Express your answer to one decimal place.** [3]

$$\text{Number of generations per hour} = \frac{\log_{10}[X_t] - \log_{10}[X_0]}{0.301 \times t}$$

Where:

X_t = number of bacteria per cm^3 at the end of the growth period
X_0 = number of bacteria per cm^3 at the start of the growth period
t = length of growth period in hours

At 2.5 hours $X_0 = 10^8$ and at 6 hours $X_t = 10^{10}$; $t = 3.5$ hours

$\log_{10}[X_t] - \log_{10}[X_0] = 10 - 8 = 2$

$0.301 \times 3.5 = 1.0535$

$2 \div 1.0535 = 1.898$

Number of generations per hour = 1.9

(ii) Under optimum conditions this species of bacteria should have a generation time of 30 minutes. Using your calculated figure for the number of generations per hour, conclude whether the bacteria in this culture were grown under optimum conditions during this time period. Explain your answer. [2]

1.9 generations per hour is approximately 2 generations per hour, i.e. about 0.95 generations per 30 minutes (a generation time of about 32 minutes).

Therefore the conditions were almost optimum, although slightly below optimum as the rate is a little less than 2 generations per hour.

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05

13

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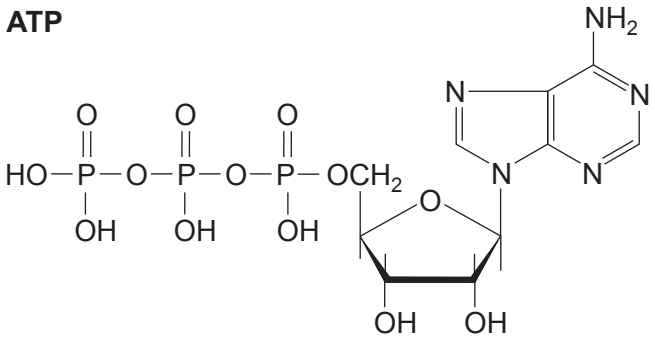
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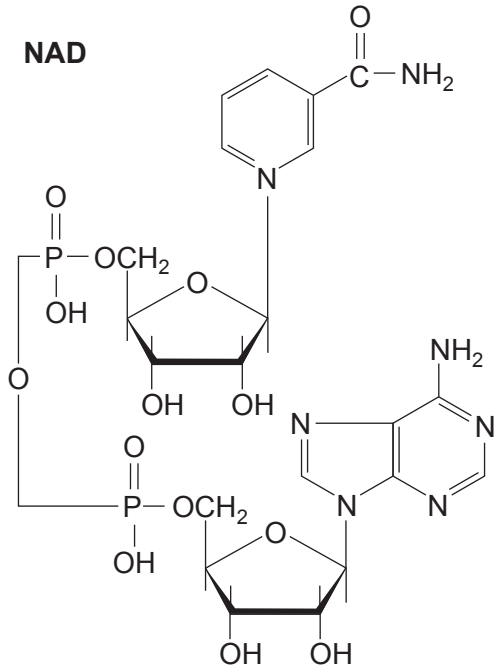
2. Both ATP and NAD (nicotinamide adenine dinucleotide) have roles in respiration. The biochemical structures of ATP and NAD are shown in **Image 2.1**.

Image 2.1

ATP



NAD



(a) (i) Name the **three** biochemical components found in **both** ATP and NAD. [2]

Ribose (pentose sugar)

Adenine (base)

Phosphate (groups)

(ii) State how **one** biochemical component of a nucleotide found in **DNA** would differ from **both** of the molecules shown in **Image 2.1**. [1]

The sugar in a DNA nucleotide is deoxyribose rather than ribose.

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(iii) ATP acts as a common energy source for reactions in the cells of all living organisms. Most ATP in eukaryotic cells is synthesised in the mitochondria. Describe the role of NAD in the synthesis of ATP. [4]

NAD is reduced (accepts hydrogen) in glycolysis, the link reaction and the Krebs cycle.

Reduced NAD delivers the hydrogen atoms to the electron transport chain on the inner membrane.

Energy released as electrons pass along the carriers is used to pump H^+ (fuels the proton pumps) into the inter-membrane space.

This creates an electrochemical (chemiosmotic) gradient, so H^+ flows back through ATP synthetase, providing the energy for ATP synthesis.

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07

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(b) Some flowers are able to generate heat. The heat is used to evaporate chemicals. In flowers such as the titan arum, *Amorphophallus titanum*, shown in **Image 2.2**, the evaporated chemicals smell like rotting meat. These chemicals attract flies and other insects.

Image 2.2



(i) The inner membranes of mitochondria in some cells of the flowers are permeable to protons. Using your knowledge of respiration in mitochondria, explain how this enables the flower to generate heat. [3]

Protons leak back across the inner membrane, so no proton gradient is produced and fewer (no) protons flow through the stalked particles (ATP synthetase), so less ATP is produced.

So the energy released by the electron transport chain is lost as heat instead.

The respiration rate increases (to make enough ATP), so more heat is generated.

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(ii) Explain why the generation of heat helps to increase genetic diversity in this species. [2]

The heat evaporates the smelly chemicals, which attracts more insects to the flower.

The insects carry pollen between flowers, increasing the chance of cross-pollination (fertilisation by gametes from another plant) and so less self-pollination.

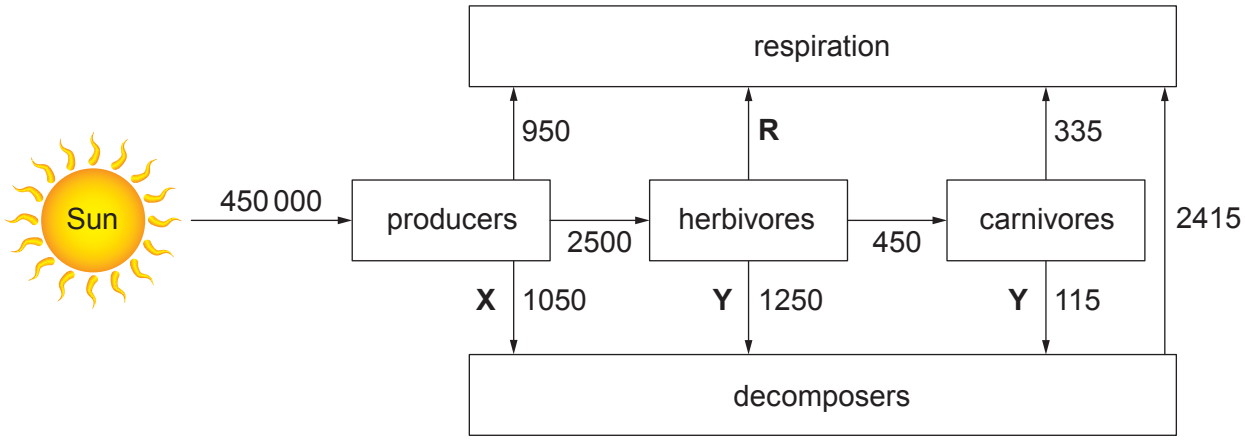
12

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3. In terrestrial ecosystems the Sun is the ultimate source of energy. The flow of energy through one ecosystem is shown in **Image 3.1** where **R** = respiration. The figures are given in kJ m^{-2} year^{-1}.

Image 3.1



(a) The productivity of the producers can be represented as:

GPP = NPP + R

(i) State what is represented by the following abbreviations: [1]

GPP *gross primary productivity*

NPP *net primary productivity*

(ii) Using figures from **Image 3.1**, calculate the following:

I. The **GPP** of the producers. [1]

GPP = 950 + 1050 + 2500

= 4500

GPP = *4500* kJ m^{-2} year^{-1}

II. The **NPP** of the producers. [1]

NPP = 1050 + 2500

= 3550

NPP = *3550* kJ m^{-2} year^{-1}

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(b) The energy transferred from plants and animals to the decomposers is represented in **Image 3.1** by **X** and **Y** respectively. For plants, the energy transferred at **X** is in the form of dead tissue.

(i) Apart from dead tissue, name **two** other processes carried out by herbivores and carnivores that would also transfer energy to decomposers at **Y**. [2]

I. Egestion (faeces)

II. Excretion (urine / urea)

(ii) Using figures from **Image 3.1**, calculate the secondary productivity of the herbivores and use this to calculate **R** for this trophic level. [2]

Secondary productivity = 450 + 1250 = 1700

R = 2500 − 1700 = 800

Secondary productivity = 1700 kJ m^{-2} year^{-1}

R = 800 kJ m^{-2} year^{-1}

(iii) State **two** types of organisms which act as decomposers. [1]

Bacteria

Fungi

(iv) In the UK, most plants die or shed their leaves in the Autumn. Using your knowledge of the nitrogen cycle, explain why you would expect the nitrogen content of soil to **increase during the winter** but then **decrease during the spring and summer months**. [4]

In winter, decomposers (saprophytic bacteria and fungi) break down the dead leaves and convert the nitrogenous compounds (proteins, amino acids, urea) into ammonium ions (ammonification).

Nitrifying bacteria (Nitrosomonas) convert ammonium ions to nitrites, and Nitrobacter converts nitrites to nitrates, so nitrate accumulates in the soil as few plants are growing to absorb it.

In spring and summer, as new leaves grow, plants absorb the nitrates and ammonium ions from the soil

to make proteins, amino acids and nucleic acids in new plant tissue, so the nitrogen content of the soil falls.

A400U101 11

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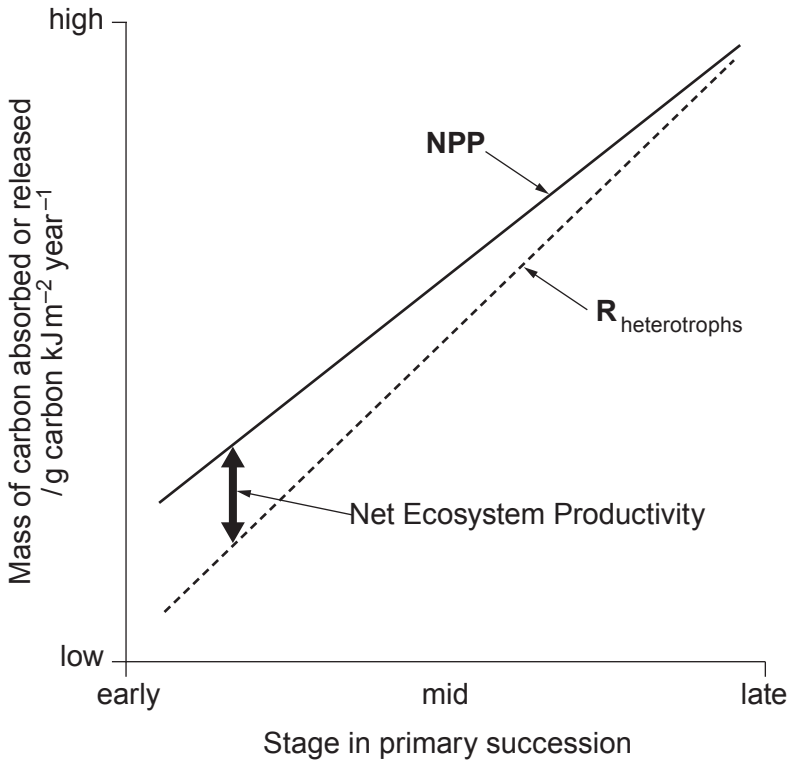
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(c) Net Ecosystem Productivity (NEP) is defined as the rate of accumulation of organic matter in an ecosystem. It can be calculated as:

$$\mathbf{NEP = NPP - R_{heterotrophs}}$$

Image 3.2 summarises the relationship between **NPP** and the rate of respiration by heterotrophs during the development of a forest ecosystem.

Image 3.2



(i) A forest is often the final stage in the development of an ecosystem which can then exist for hundreds of years. State the term used to describe the last stage in the development of an ecosystem. [1]

Climax community

(ii) With reference to the terms **GPP** and **R**, explain why the productivity of an ecosystem can be expressed in terms of absorption of carbon dioxide or by the release of carbon dioxide. [2]

CO_2 is absorbed during photosynthesis, which is equivalent to GPP.

CO_2 is released during respiration (R), so NPP = GPP – R is the net CO_2 absorbed.

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(iii) With reference to the information provided and your knowledge of succession, conclude why Net Ecosystem Productivity eventually approaches zero. [3]

During primary succession biodiversity and biomass increase, so there are more heterotrophs and heterotroph respiration (R heterotrophs) increases. So more energy is lost from the ecosystem (trophic levels) as heat, until R heterotrophs equals NPP, so NEP approaches zero.

18

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13

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4. Respiration is a catabolic process during which glucose, lipids and proteins can be broken down to release energy. Some of the energy is transferred to chemical energy in the form of ATP.

(a) Theoretically, the energy released from one molecule of glucose by aerobic respiration is sufficient to produce 38 molecules of ATP. The removal of the terminal phosphate group from one ATP molecule by hydrolysis releases 30.6 kJ mol^{-1}. When glucose reacts directly with oxygen 2870.0 kJ mol^{-1} are released.

(i) Calculate the efficiency of aerobic respiration of glucose. **Give your answer to a suitable number of decimal places.** [2]

energy in ATP = 38 × 30.6 = 1162.8 kJ mol^{-1}

efficiency = 1162.8 ÷ 2870.0 × 100 = 40.5157 %

Efficiency of aerobic respiration = *40.5* %

(ii) State what happens to the energy which is not used to generate ATP. [1]

It is lost (released) as heat.

(iii) **Table 4.1** compares figures from the respiration of carbohydrate and lipid.

Table 4.1

Energy source	Energy released / kJ g^{-1} food	Metabolic water produced / g g^{-1} food	Oxygen consumed / dm^3 g^{-1} food
Carbohydrate	17.2	0.56	0.83
Lipid	38.9	1.07	2.02

With reference to the figures in **Table 4.1**:

I. Explain why the food store in many plant seeds is in the form of a lipid rather than carbohydrate. [2]

Lipid has a higher energy value (38.9 kJ g^{-1} compared with 17.2 kJ g^{-1}), so the seed is much lighter (less mass is stored) for the same amount of energy.

II. Suggest why animals living in very dry habitats use lipids to supply their energy rather than carbohydrates. [1]

Lipids release more metabolic water (1.07 g g^{-1} compared with 0.56 g g^{-1}).

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15

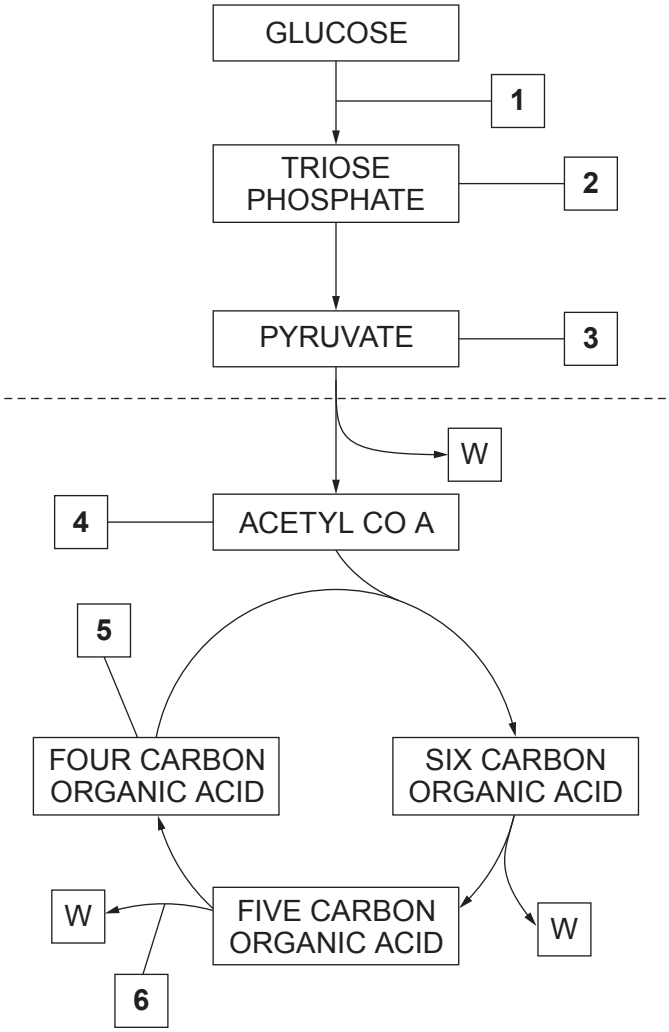
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(b) **Image 4.2** shows a summary of the stages involved in the aerobic respiration of glucose.

Image 4.2



(i) Lipids are digested into glycerol, a three carbon compound, and fatty acids. The fatty acids are then broken down further in the liver into two carbon fragments.

Using numbers from **Image 4.2** indicate where the products of fat digestion could enter the respiratory pathway. [2]

Glycerol ..... 2 .....

Fatty acids ..... 4 .....

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(ii) Before proteins can enter the respiratory pathway they must be hydrolysed. Describe how proteins are hydrolysed and suggest which stage of respiration the products of protein hydrolysis are **most likely** to enter. [3]

Water is added to break the peptide bonds (hydrolysis by protease enzymes), so the protein is hydrolysed into amino acids. After deamination the amino acids enter as organic acids (e.g. keto acids or acetic acid), most likely in the Krebs cycle (point 5) or as pyruvate (point 3).

11

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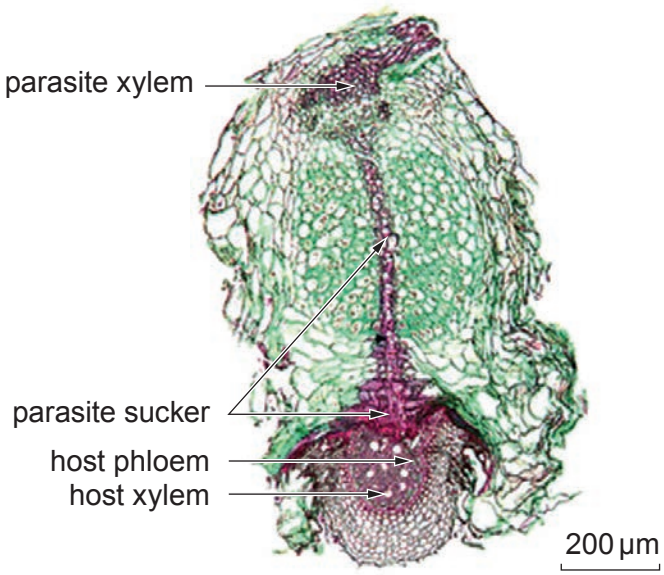
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5. Yellow rattle, *Rhinanthus minor*, is a plant which is a parasite of grass. It absorbs its nutrients from grass roots. **Image 5.1** shows the flowers of yellow rattle growing in grassland and **Image 5.2** shows a transverse section through a grass root parasitized by yellow rattle.

Image 5.1



Image 5.2



(a) (i) **Using the scale bar**, calculate the magnification of **Image 5.2**. [2]

length of scale bar = 13 mm = 13 000 µm

magnification = 13 000 ÷ 200 = 65

Magnification = × ..... *65* .....

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(ii) Studies have shown that the parasite sucker penetrates the host phloem sieve tubes and host xylem vessels.

I. State the name of the hypothesis that provides an explanation of how sucrose could move from host to parasite tissue. [1]

Mass flow hypothesis

II. Water and minerals move from the host tissues to the parasite vessels through the apoplast and symplast pathways. Explain what is meant by these terms.

[2]

Apoplast pathway

Water and minerals move along (through) the cell walls (and intercellular spaces).

Symplast pathway

Water and minerals move through the cytoplasm of cells, from cell to cell via the plasmodesmata.

(b) Grasslands contain a wide variety of flowering plants which produce flowers at different times of the year. The biodiversity of these grasslands decreases when they are invaded by species of fast-growing grass. Using the information provided, suggest why the introduction of yellow rattle to these grasslands might restore biodiversity. [3]

Yellow rattle absorbs nutrients (nitrates, sugars) from the roots of the grass, so the fast-growing grass plants grow less well (their growth is inhibited). This means there is less interspecific competition for the other flowering plants, so more light, water and nutrients are available for the flowering plants, which can survive and grow, increasing the number of species.

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To investigate whether the introduction of yellow rattle into grassland might restore biodiversity, grassland containing a single species of fast-growing grass was divided into two equal areas, area **A** and area **B**

Area **A** was seeded using a mixture of flowering plants and yellow rattle seeds

Area **B** was seeded using the same mixture of flowering plants but with no yellow rattle seeds.

The abundance and distribution of plant species in areas **A** and **B** were determined before seeding and one year after seeding.

(c) Explain why the following steps were taken when collecting data on the abundance and distribution of plant species in both areas:

(i) Each area was divided into a grid **and** a random number generator used. [2]

Random numbers are used to identify coordinates on the grid where the quadrats are placed, so samples are selected at random, to reduce (avoid) bias.

(ii) Area **B** was not seeded with yellow-rattle seeds. [2]

To act as a control, for comparison, to make sure that it is the yellow rattle having an effect on biodiversity and not just time (or the flowering plant seeds).

(iii) The experiment was conducted **several times** on grassland with the same species of fast-growing grass. [2]

To test the repeatability of the results, and it allows a mean (average) Simpson's Diversity Index to be calculated.

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(d) The data collected from areas **A** and **B** were used to calculate a Simpson's biodiversity index. **Table 5.3** shows the mean values of the Simpson's Diversity Index of areas **A** and **B** before and one year after seeding.

Table 5.3

	Value of Simpson's Diversity Index	
	Area **A**	Area **B**
Before seeding	0.45	0.46
One year after seeding	0.51	0.47

Based on these data only, it was concluded that seeding grassland with yellow rattle did result in an increase in biodiversity. However, it was decided that more data would be needed to improve confidence in this conclusion.

The following modifications to the method were suggested. Explain how each change to the method can be justified. [3]

Change	Justification
Calculate the biodiversity index again five years after seeding	Yellow rattle may not have an effect in one growing season, as it takes time to grow; this checks it is still there and still having an effect.
Calculate the biodiversity index a number of different times in the same year	Different plant species grow and flower at different times of the year, so they may not be present in a single sampling period.
Carry out the investigation in different areas with different fast-growing grass species	To determine whether yellow rattle has the same effect on different grass species, so the conclusion can be applied more widely.

17

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6. The traditional balanced equation for photosynthesis is given as:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

It was once believed that all the oxygen released by photosynthesis came from the carbon dioxide molecules.

(a) (i) With reference to the equation explain why this statement could be correct. [2]

$6CO_2$ contains $6 \times 2 = 12$ oxygen atoms.

The $6O_2$ produced also contains 12 oxygen atoms (6 molecules of oxygen), so all the oxygen released could have come from the carbon dioxide (with the oxygen from water going into glucose).

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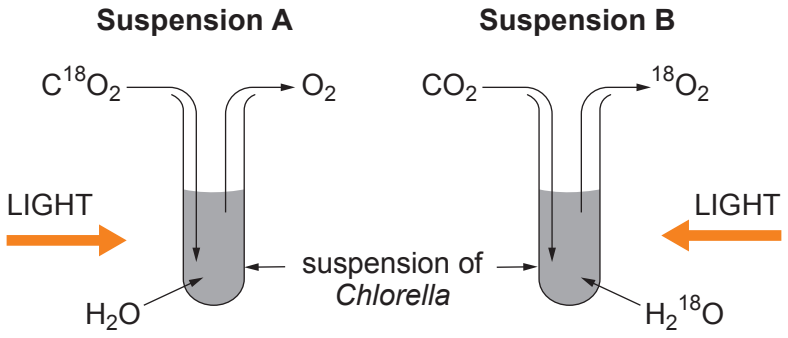
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An experiment, shown in **Image 6.1**, was carried out to confirm the origin of the oxygen molecules released in photosynthesis. In this experiment two suspensions of a photosynthetic unicellular alga, *Chlorella*, were treated as follows:

Suspension A
- provided with water containing a non-radioactive isotope of oxygen (H_2O)
- and carbon dioxide containing a radioactive isotope of oxygen ($C^{18}O_2$)

Suspension B
- provided with water containing a radioactive isotope of oxygen ($H_2{}^{18}O$)
- and carbon dioxide containing a non-radioactive isotope of oxygen (CO_2)

Image 6.1



(ii) Using evidence from this experiment and your knowledge of photosynthesis, deduce the actual origin of the atoms in the oxygen molecules. Explain your answer. [2]

The oxygen released comes from water, by photolysis.

This is because $^{18}O_2$ was only produced in suspension B, where $H_2{}^{18}O$ was supplied, and not in suspension A, where $C^{18}O_2$ was supplied (normal O_2 was released).

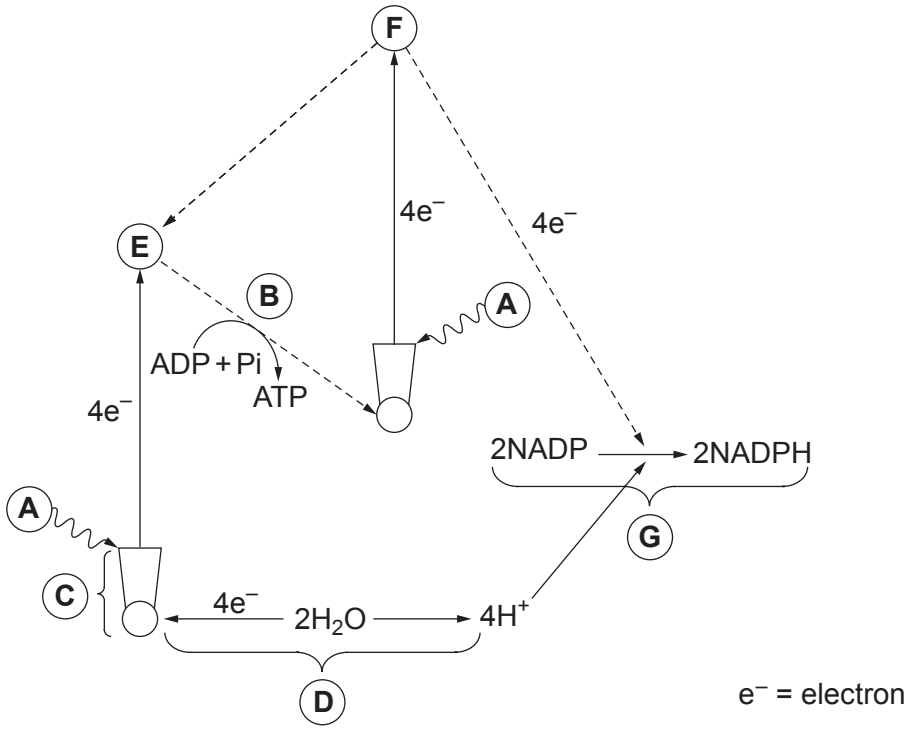
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(b) The light dependent stage of photosynthesis relies on the flow of electrons between different molecules as shown in **Image 6.2**.

Image 6.2



(i) State what is represented by the following letters in **Image 6.2**. [3]

A *Light energy (photons)*

B *Electron transport chain (photophosphorylation / ATP synthase)*

C *Photosystem II (PSII, P680)*

D *Photolysis of water*

E and **F** *Electron acceptors (carriers)*

(ii) State the type of reaction occurring at **G**. Explain your answer. [2]

Reduction.

NADP gains electrons (and H^+, i.e. hydrogen) to form reduced NADP (NADPH).

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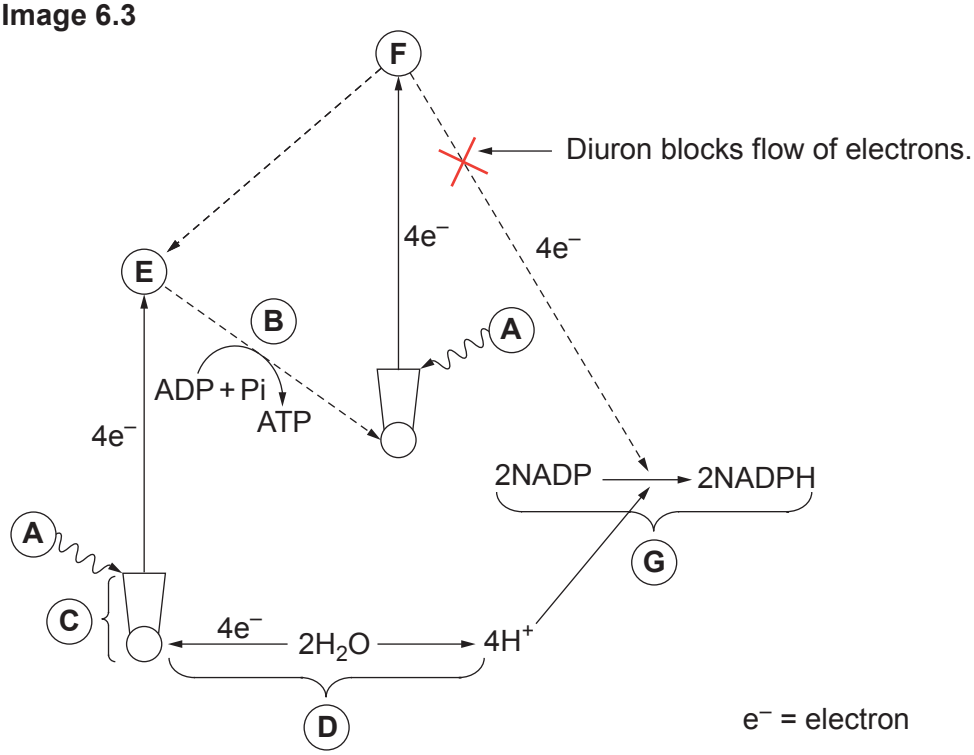
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(iii) The events shown in **Image 6.2** take place in chloroplasts, which act as transducers. With reference to **Image 6.2**, explain how chloroplasts act as transducers in photosynthesis. [1]

They transfer the energy in photons of light into chemical energy in ATP and NADPH.

(iv) Weeds are commonly controlled by using herbicides. Diuron is a herbicide which binds to a molecule preventing the flow of electrons, as shown by **X** in **Image 6.3**.

Image 6.3



Using information from **Image 6.3**, and your knowledge of photosynthesis, suggest how the action of Diuron results in the death of weeds. [4]

Diuron blocks the flow of electrons from F to NADP, so reduced NADP (NADPH) is not produced,

and less ATP is made because non-cyclic photophosphorylation stops.

So GP (glycerate 3-phosphate) is not reduced to triose phosphate, and RuBP is not regenerated,

therefore carbon fixation stops and the Calvin cycle (light independent stage) cannot take place.

No glucose is produced for respiration, so the weed dies.

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(c) DCPIP (2,6-dichlorophenol-indophenol) is a blue dye which acts as an electron acceptor and becomes colourless when it accepts electrons.

The flow diagram describes the method used by a student to isolate chloroplasts. **Image 6.4** shows a centrifuge tube containing the isolated chloroplasts.

Method

Grind spinach leaves in an ice-cold solution of sucrose and buffer.

↓

Filter extract.

↓

Centrifuge to obtain a small pellet of chloroplasts.

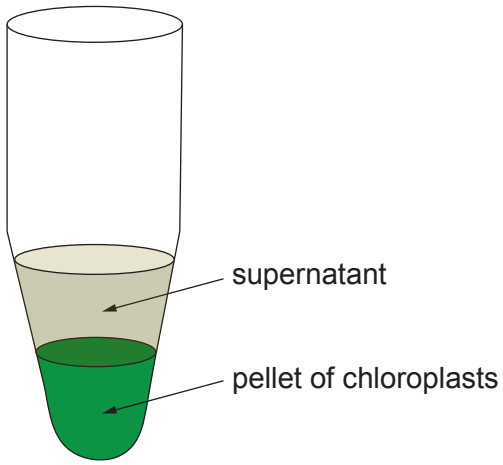
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Separate pellet from supernatant.

↓

Re-suspend the chloroplasts and keep cool.

Image 6.4



(i) State the role of the buffer in this experiment. [1]

To maintain a constant pH.

(ii) The solution used in the experiment was isotonic to the stroma in the chloroplasts. State the meaning of the term isotonic. [1]

The solution has the same concentration of solutes (the same water potential) as the stroma.

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The student used the isolated chloroplasts to prove that electrons are released by chlorophyll during photosynthesis. **Table 6.5** shows how four different experimental tubes were set up, whether they were exposed to light or not and the colour change observed.

Table 6.5

Tube	Volume / cm^3				Light or no light	DCPIP colour change
	suspended chloroplasts	supernatant	sucrose and buffer solution	DCPIP solution		
1	0.5			5	light	blue to colourless
2			0.5	5	light	no colour change
3	0.5			5	no light	no colour change
4		0.5		5	light	no colour change

(iii) Explain why each of the **experimental tubes 1–4** were included in this investigation and conclude whether the results prove that electrons are released by chlorophyll during photosynthesis or not. Explain your answer. [4]

Tube 1: in the light the chloroplasts release electrons, which reduce DCPIP, causing the colour change from blue to colourless.

Tube 2: shows that the sucrose buffer does not release electrons, so cell contents must cause the colour change.

Tube 3: with no light the chloroplasts (light dependent reactions) do not release electrons, so no colour change.

Tube 4: the supernatant does not contain chloroplasts, so it must be the chloroplasts causing the colour change.

Chlorophyll is only found in the chloroplasts, so the results prove that it is chlorophyll that releases electrons.

20

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7. It has been estimated that 10 million km^2 of forest have been lost from the planet since the beginning of the 20^{th} century. One of the reasons for deforestation is to meet the demands for food for an increasing human population.

Explain how the conversion of forests to areas of intensive human food production using modern agricultural practices often leads to the death of fish and aquatic invertebrates. Describe the harmful impacts of deforestation on the environment and suggest how the conflicts of interest between food production and conservation can be resolved. [9 QER]

Converting forests to intensive farmland involves heavy use of (nitrate) fertilisers and keeping large numbers of animals, producing animal waste (manure and slurry). After rain these are washed (leached) from the soil into rivers and lakes.

This increases the nutrient (nitrate and phosphate) level in the water, causing eutrophication: algal growth increases, producing an algal bloom on the surface. The algae block light, so plants and algae lower in the water cannot photosynthesise and die.

Bacteria (saprobionts) decompose the dead algae and plants. Respiration by these decomposers uses up the dissolved oxygen, so oxygen levels fall and the biochemical oxygen demand (BOD) increases. Fish and aquatic invertebrates then die due to lack of oxygen for aerobic respiration.

Deforestation itself also harms the environment. It causes habitat destruction, so many organisms lose food and shelter. This reduces biodiversity and genetic diversity, and can lead to the extinction of species, especially endemic ones.

Fewer trees means less carbon dioxide is absorbed by photosynthesis, and burning the trees releases CO_2, so atmospheric CO_2 increases, enhancing the greenhouse effect and causing global warming and climate change. Without tree roots the soil becomes unstable, so soil erosion and landslides increase, and nutrients are lost from the soil.

The conflict between food production and conservation can be resolved in several ways. Farmers can use sustainable farming techniques, such as applying

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less nitrate fertiliser, not spreading it before rain or close to water courses, and leaving buffer strips beside rivers. Forests can be regenerated by replanting endemic tree species. Lifestyle changes, such as encouraging people to eat less meat or using alternatives to palm oil, reduce the land needed for food. Areas of forest can be protected as national parks or SSSIs, and ecotourism encouraged as an alternative source of income for local people; seed banks can conserve plant species. Finally, changes in government policy (e.g. laws and subsidies), together with public awareness and education, help balance food production with conservation.

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