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Candidate number

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Forename(s)

Candidate signature

I declare this is my own work.

INTERNATIONAL A-LEVEL BIOLOGY (9610)

Unit 3 Populations and Genes

Tuesday 3 January 2023 07:00 GMT Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 75.

For Examiner's Use	
Question	Mark
1	
2	
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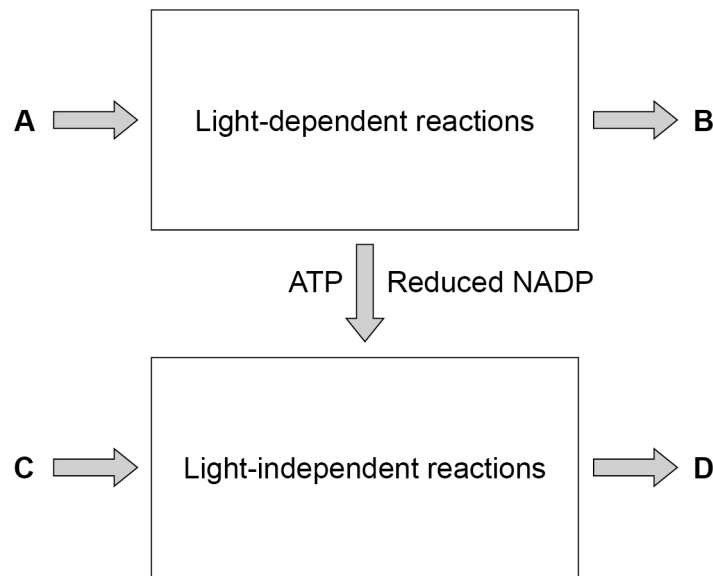
Answer **all** questions in the spaces provided.

0 1

Photosynthesis occurs inside chloroplasts.

Figure 1 shows a summary of photosynthesis. **A** and **C** are substances that enter the chloroplast, **B** and **D** are substances that leave the chloroplast.

Figure 1



0 1 . 1

Name the substances labelled **A**, **B**, **C** and **D** shown in **Figure 1**.

[2 marks]

Substance **A** water (H₂O)

Substance **B** oxygen (O₂)

Substance **C** carbon dioxide (CO₂)

Substance **D** glucose (carbohydrate / sugar)

0 1 . 2

State the precise locations of the light-dependent and the light-independent reactions in the chloroplast.

[2 marks]

Light-dependent reaction thylakoid membranes (grana)

Light-independent reaction stroma



0 1 . 3

Describe how reduced NADP is produced in the light-dependent reactions of photosynthesis.

[4 marks]

Light is absorbed by chlorophyll, which excites electrons (raises them to a higher energy level) so they are emitted from the chlorophyll

(photoionisation).

The electrons are passed down the electron transfer chain and are then accepted by NADP.

Water is split by light (photolysis of water), and the electrons from water replace the electrons lost from chlorophyll.

The protons (H^+) from water also combine with NADP, reducing it to form reduced NADP (NADPH).

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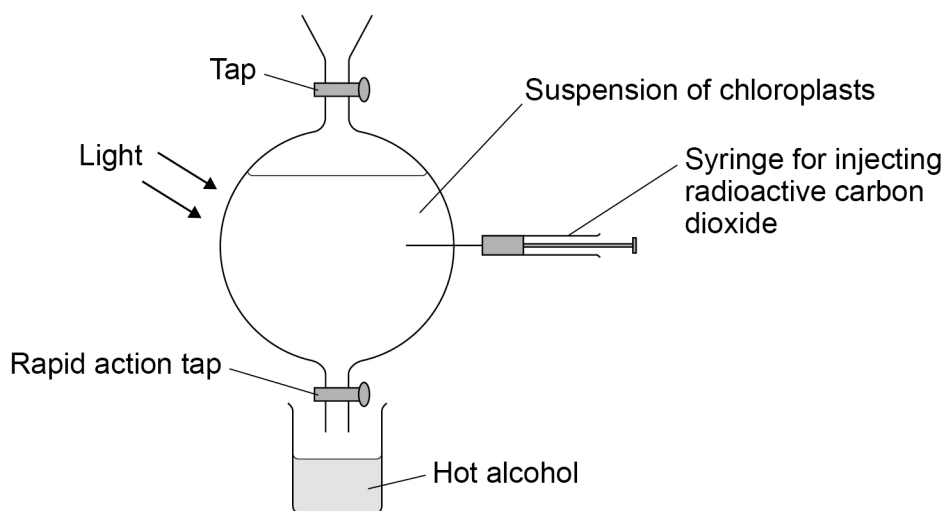


Scientists use the apparatus shown in **Figure 2** to investigate photosynthesis.

The scientists:

- add radioactive carbon dioxide ($^{14}\text{CO}_2$) to a suspension of chloroplasts
- shine light at the chloroplasts so that the chloroplasts photosynthesise
- open the rapid action tap after 5 seconds to allow the chloroplasts to fall into the hot alcohol which immediately stops chemical reactions
- analyse the chloroplasts for different radioactively labelled compounds
- repeat the experiment allowing the chloroplasts to photosynthesise for 30 seconds before opening the tap.

Figure 2



0 1 . 4

Explain how the sequence of chemical reactions in photosynthesis can be determined using radioactive carbon dioxide.

[2 marks]

The radioactive $^{14}\text{CO}_2$ is fixed (incorporated) by RuBP.

Identifying the radioactive compounds at different times (eg GP, TP, glucose) allows the sequence to be worked out.

0 1 . 5

Suggest **two** advantages of using a suspension of chloroplasts, rather than a green plant in this investigation.

[2 marks]

Advantage 1 *Easier to remove samples at specific times and quicker to stop the reactions.*

Advantage 2 *More rapid absorption of radioactive carbon dioxide and light, and the products are not used in other cellular reactions.*



Question 1 continues on the next page

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The scientists separate the compounds in the chloroplasts by paper chromatography.

The chromatograms are placed on photographic film.

Dark patches are produced where there are radioactive compounds.

The size of the dark patches indicates the amount of radioactive compound present.

Figure 3 and **Figure 4** show the results after 5 and 30 seconds of photosynthesis.

Figure 3

After 5 seconds photosynthesis with $^{14}\text{CO}_2$

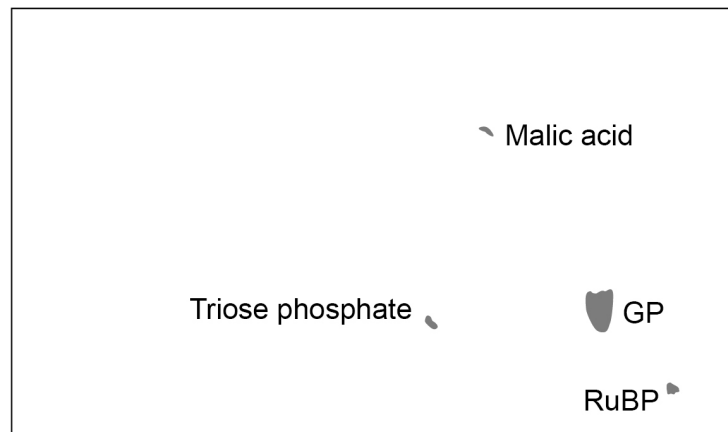
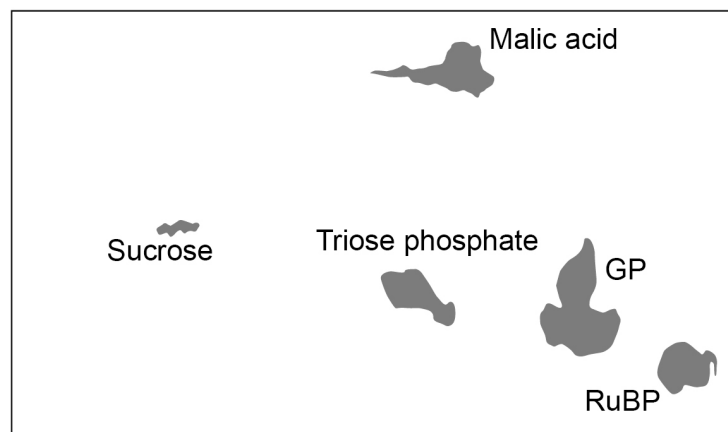


Figure 4

After 30 seconds photosynthesis with $^{14}\text{CO}_2$



0 1 . 6

Identify which compound is produced first, using information from **Figure 3**.**[1 mark]***GP (glycerate 3-phosphate)*

0 1 . 7

Explain why the amount of radioactive RuBP increases between 5 seconds and 30 seconds.

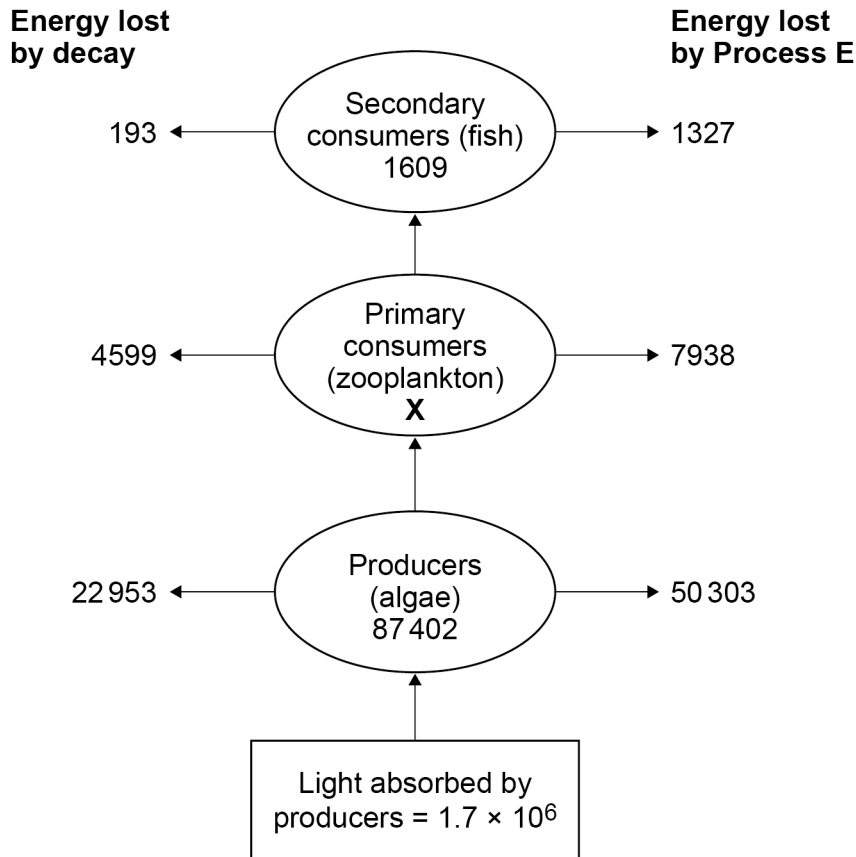
[2 marks]*The light-independent reactions are a cycle (the Calvin cycle).**RuBP is regenerated from GP / TP that contains ^{14}C from the $^{14}\text{CO}_2$, so more of the RuBP becomes radioactive over time.*

15

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0 2

Figure 5 shows the energy flow through a freshwater ecosystem in a lake. Algae are single-celled photosynthetic organisms and zooplankton are tiny animals that feed on algae.

Figure 5

0 2 . 1

Suggest suitable units for the numbers shown in **Figure 5**.

[2 marks]

$\text{kJ m}^{-2} \text{ year}^{-1}$ (energy per unit area per unit time)

0 2 . 2

Name process **E** shown on **Figure 5**.

[1 mark]

Process **E** *Respiration*



0 2 . 3

Calculate the gross primary production (GPP) of the producers as a percentage of the light energy they absorb.

Give your answer to 3 significant figures.

[2 marks]

$$GPP = 87\,402$$

$$(87\,402 \div 1.7 \times 10^6) \times 100 = 5.1413...$$

Answer = 5.14 %

0 2 . 4

Value **X** in **Figure 5** is the gross production by the primary consumers.

Calculate the value of **X** and use this value to determine the efficiency of energy transfer between the producers and the primary consumers.

[2 marks]

$$X = 4599 + 7938 + 1609 = 14\,146$$

$$(14\,146 \div 87\,402) \times 100 = 16.18...$$

Value **X** = 14 146

Efficiency of energy transfer = 16.2 %

0 2 . 5

A typical value for the efficiency of energy transfer between producers and primary consumers in terrestrial ecosystems is approximately 10%.

Suggest a reason for the efficiency transfer being higher than 10% in the ecosystem shown in **Figure 5** where single-celled algae are the producers.

[1 mark]

Higher because (all of) the algae are easier to digest (break down)

than plants, eg they have no lignin or woody tissue, so less energy is

lost in faeces.

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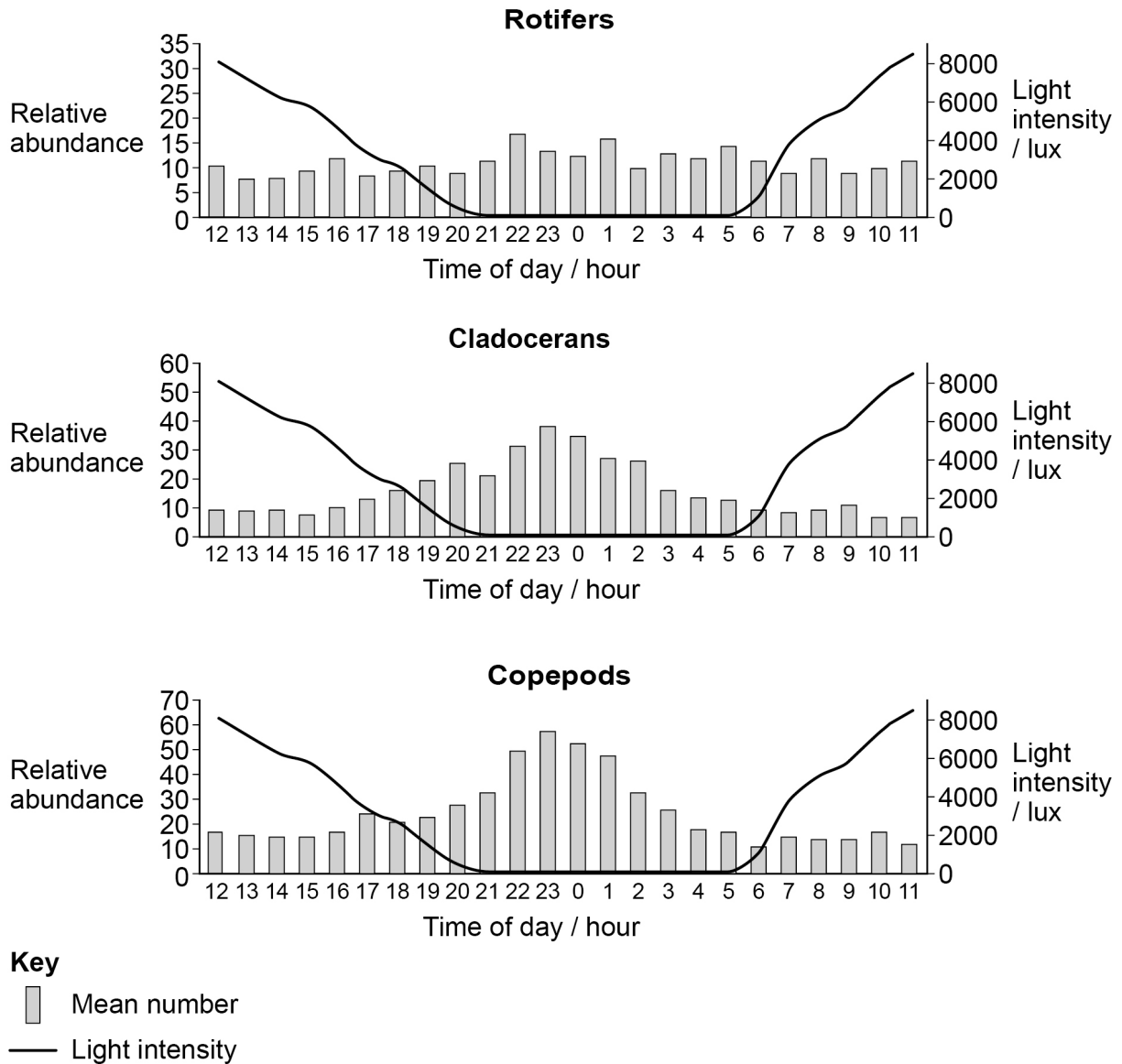
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Zooplankton are tiny animals that eat the producers in the freshwater ecosystem.

Figure 6 shows the abundance of three types of zooplankton at different times of the day and the relative light intensity. All samples were taken at the surface of the lake.

Figure 6



0 2 . 6

Compare the relative abundance of rotifers with the relative abundance of copepods during the 24 hours shown in **Figure 6**.

[2 marks]

Rotifer abundance remains fairly constant (between about 8 and 17) throughout the 24 hours.

Copepod abundance is much higher at night (up to about 57 at 23:00) than during the day (about 10 to 25).

0 2 . 7

Predatory fish also live in the lake.

The fish:

- feed on zooplankton
- hunt by sight.

Some types of zooplankton show vertical migratory patterns (move to different depths) over a 24-hour period.

Suggest how the differences in behaviour of the zooplankton may have evolved.

[6 marks]

Copepods and cladocerans show vertical migration (at the surface at night) but rotifers do not.

Copepods and cladocerans find more food (algae) near the surface, but predatory fish hunt near the surface in daylight as they can see their prey.

Mutation produced genetic variation (a new allele) for migratory behaviour. Zooplankton that moved deeper in daylight were more likely to survive (fewer eaten), so had a selective advantage.

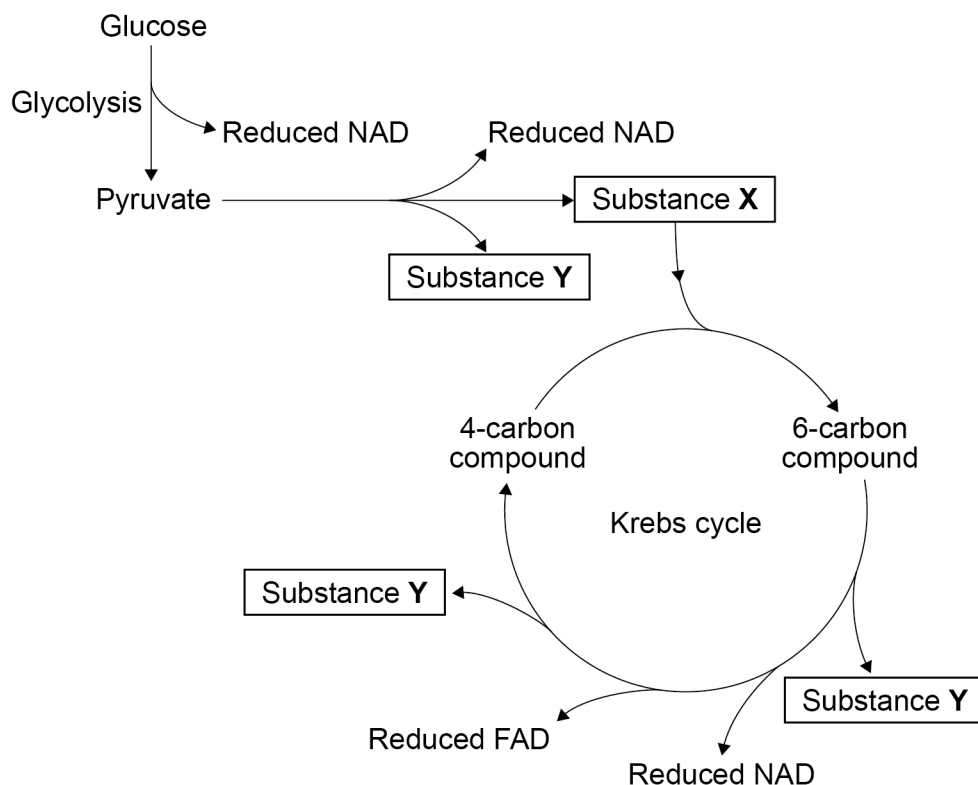
The survivors reproduced and passed on the beneficial alleles, so over many generations the frequency of the beneficial allele increased.



0 3

Figure 7 shows some of the reactions in respiration.

Figure 7



0 3 . 1

Name:

[2 marks]

Substance X acetyl coenzyme A (acetyl CoA)Substance Y carbon dioxide (CO₂)

0 3 . 2

State where in the cell the Krebs cycle occurs.

[1 mark]

Mitochondria (the mitochondrial matrix)

0 3 . 3

Give the number of carbon atoms that substance X adds to the Krebs cycle.

Use information from Figure 7.

[1 mark]

2

0 3 . 4

The reduced FAD and reduced NAD are passed to the electron transfer chain.

Explain how the reduced FAD and reduced NAD are used to synthesise ATP.

[4 marks]

Reduced NAD and reduced FAD carry hydrogen (electrons) to the electron transfer chain on the inner mitochondrial membrane.

As the electrons are passed along the electron transfer chain, the energy released is used to pump protons (H^+) into the intermembrane space (active transport).

Protons (H^+) move back into the matrix by diffusion, down their concentration gradient, through the stalked particles (ATP synthase).

ATP synthase (stalked particles) combines ADP and P_i to make ATP.

0 3 . 5

Anaerobic respiration in animals produces lactate.

Explain how the production of lactate allows glycolysis to continue.

Use **Figure 7** and your own knowledge.

[2 marks]

Pyruvate accepts hydrogen from reduced NAD ($NADH$), so pyruvate is reduced to lactate.

This regenerates (oxidised) NAD, which can accept hydrogen again in glycolysis, allowing glycolysis to continue (producing ATP).

10

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0 4

Light intensity and wavelength can affect the rate of photosynthesis.

0 4 . 1

Describe an experiment to determine the effect of light intensity on the rate of photosynthesis.

[5 marks]

Place a piece of pondweed (eg Elodea) in a boiling tube of water, connected to a capillary tube (photosynthometer) or upturned measuring cylinder to collect gas.

Stand the tube in a water bath to keep the temperature constant (check with a thermometer).

Add sodium hydrogencarbonate (NaHCO_3) solution to the water so that carbon dioxide concentration is constant and not limiting.

Place a lamp at several different distances from the plant (eg 10, 20, 30, 40 and 50 cm) to vary light intensity (light intensity $\propto 1/d^2$), in a darkened room.

At each new distance, allow the plant to equilibrate (acclimatise) for about 5 minutes before measuring the rate.

Measure the rate, eg collect the oxygen and measure its volume (or count bubbles) per minute; repeat at least 3 times at each distance and calculate the mean.



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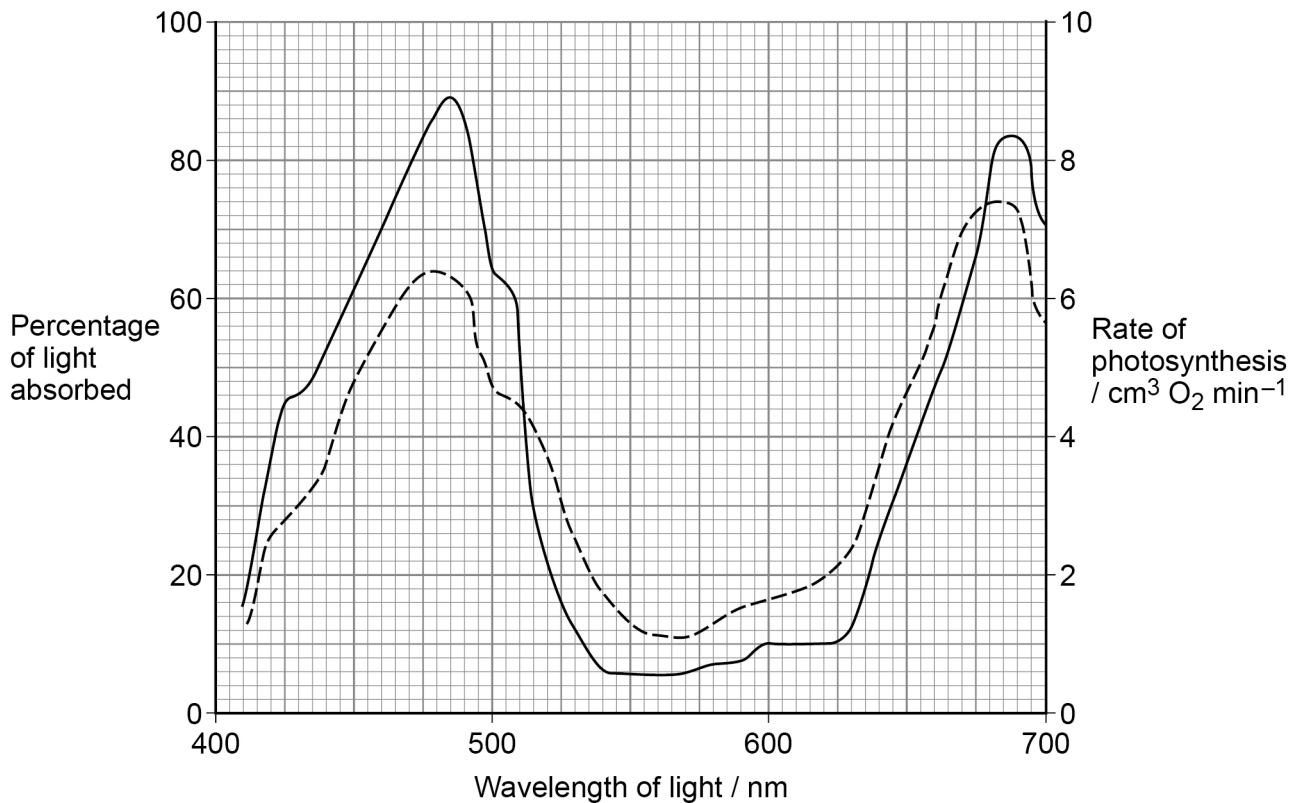
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The rate of photosynthesis can also be measured when a plant is exposed to different wavelengths of light.

Figure 8 shows the rate of photosynthesis and the percentage of light absorbed when a plant is exposed to different wavelengths of light.

Figure 8



Key

- Percentage of light absorbed
 ---- Rate of photosynthesis

0 4 . 2 Describe the pattern in the percentage of light absorbed shown in **Figure 8**.

Use data from **Figure 8**.

[2 marks]

Two main peaks of light absorbed: blue light at about 485 nm (89%)

and red light at about 685 nm (83%).

Very little light is absorbed between about 540 and 625 nm (about 6 to 10%).



0 4 . 3

Give **one** reason a plant can absorb a range of different wavelengths of light.

[1 mark]

The plant contains a mixture of pigments (eg chlorophyll a, chlorophyll b and carotenoids) which absorb different wavelengths (colours).

0 4 . 4

Give the reason why the two curves shown in **Figure 8** follow a similar pattern.

[1 mark]

The wavelengths that are absorbed are the ones used in photosynthesis.

0 4 . 5

State the range of wavelengths on **Figure 8** which correspond to green light.

Give a reason for your answer.

[2 marks]

Range of wavelengths = 540 to 625 nm

Reason: *These wavelengths are not absorbed (very little absorption, under 10%), so they are reflected, making the plant appear green.*

As light passes through water some wavelengths are absorbed. Seaweeds are photosynthetic organisms found on sea shores. Seaweeds that are covered with water for most of the time appear red in colour because they contain a red pigment called phycoerythrin.

0 4 . 6

Suggest the advantage to these seaweeds of containing phycoerythrin.

[2 marks]

Blue light is less absorbed by water than red light, so blue light can penetrate deeper into the water (red light is absorbed by the water).

Phycoerythrin absorbs the blue (and other) wavelengths that reach the seaweed, which are used for photosynthesis.



0 5

Some alleles are described as being recessive.
Some genes are described as being sex-linked.

0 5 . 1

Define the terms:

- recessive
- sex-linked.

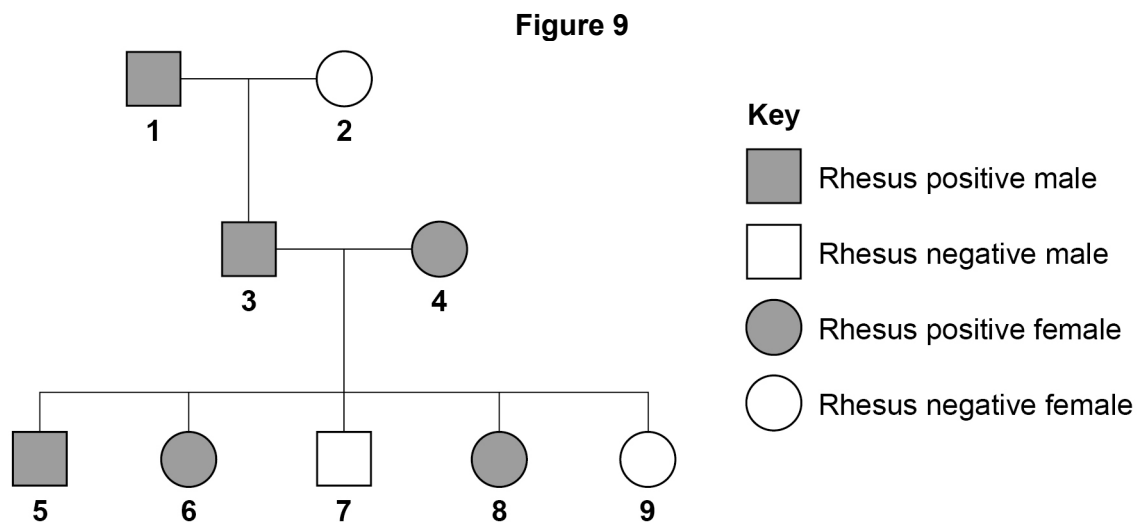
[2 marks]

Recessive An allele only expressed in the phenotype if homozygous (not expressed when heterozygous).

Sex-linked A gene carried on only one sex chromosome (only the X chromosome).

The Rhesus blood group is genetically controlled.
The gene for the Rhesus blood group has two alleles.
The allele for Rhesus positive is dominant to the allele for Rhesus negative.

Figure 9 shows the inheritance of the Rhesus blood group in a family.



0 5 . 2

Explain how **Figure 9** shows that the allele for Rhesus positive is **not** sex-linked.

[2 marks]

Child 3 is a Rhesus positive male even though his mother (2) is Rhesus negative.

He must have received his X chromosome from his recessive (Rhesus negative) mother, which would make him Rhesus negative if it were sex-linked.



0 5 . 3

In Asia, 3% of the population are Rhesus negative.

Calculate the percentage of the population expected to be heterozygous for the Rhesus gene. Use the Hardy–Weinberg equation.

[2 marks]

$$q^2 = 0.03, \text{ so } q = \sqrt{0.03} = 0.1732$$

$$p = 1 - 0.1732 = 0.8268$$

$$\text{Heterozygous} = 2pq$$

$$2pq = 2 \times 0.8268 \times 0.1732 = 0.2864$$

$$0.2864 \times 100 = 28.6\%$$

Answer = 28.6 %

6

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0 6 . 1

Nitrogen is an essential element in all living organisms.

Describe how nitrogen in the organic compounds of dead organisms is made available to plants.

Include the role of microorganisms in this process.

[5 marks]

Dead organisms are broken down by decomposers (saprobionts / saprophytic bacteria and fungi).

They secrete enzymes for extracellular digestion, hydrolysing the proteins, nucleic acids and urea into smaller soluble molecules.

Nitrogen-containing compounds are converted to ammonia / ammonium ions (ammonification).

Ammonium ions are converted to nitrite ions by nitrifying bacteria (Nitrosomonas).

Nitrite ions are converted to nitrate ions by nitrifying bacteria (Nitrobacter).

Nitrate ions are absorbed by the plant roots by active transport.



0 6 . 2

Describe how plants can use the nitrogen found in the substances they absorb from the soil to make useful organic compounds.

Give specific examples of organic compounds that contain nitrogen.

[4 marks]

Nitrate is reduced to ammonia / ammonium ions in the plant.

This nitrogen is used to make amino acids, which are joined together to make proteins, eg enzymes, cytochromes and cell membrane components (carrier and channel proteins).

Nitrogen is an essential element in nucleotides, eg DNA, RNA and ATP, and in NADP and chlorophyll.

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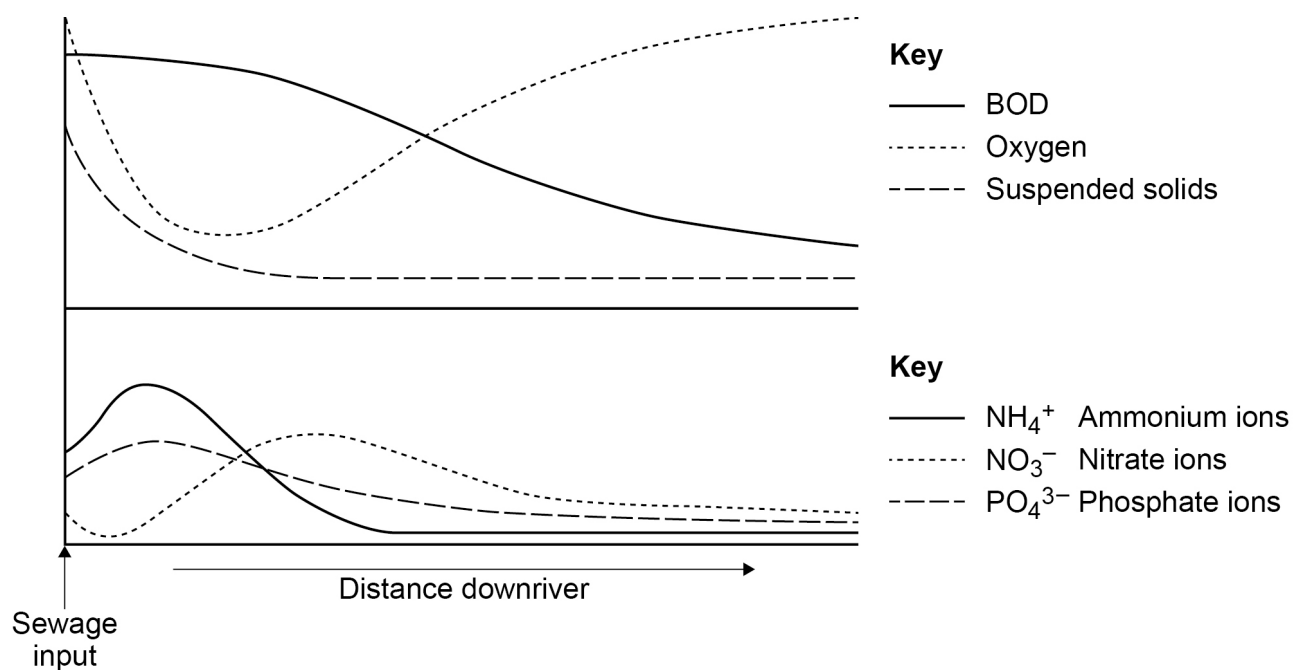


Sometimes sewage from human homes drains into rivers.

Figure 10 shows the amounts of different substances in a river downstream from a sewage input.

The **Biochemical oxygen demand (BOD)** is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in the water.

Figure 10



0 6 . 3

Explain the changes shown in **Figure 10**.**[6 marks]**

Initially BOD is high because aerobic decomposers (bacteria) break down the organic waste and suspended solids in the sewage, so oxygen levels fall sharply.

Further downriver the BOD decreases as the organic matter is broken down, and oxygen levels increase as oxygen dissolves from the air at the surface and from photosynthesis by algae and plants.

Suspended solids decrease rapidly as they are broken down by decomposers.

Ammonium and phosphate levels are high at first, released from the breakdown of the organic waste in the sewage (ammonification by saprobionts).

Nitrate levels then increase as ammonium is converted to nitrite and then nitrate by nitrifying bacteria.

Further downriver nitrate and phosphate levels decrease as they are absorbed (used up) by plants and algae for growth.

15

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