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

GCE A LEVEL

A400U10-1

S24-A400U10-1

**WEDNESDAY, 5 JUNE 2024 – AFTERNOON**

# BIOLOGY – A level component 1
## Energy for Life

2 hours

| For Examiner's use only | | |
|---|---|---|
| **Question** | **Maximum Mark** | **Mark Awarded** |
| **1.** | **15** | |
| **2.** | **18** | |
| **3.** | **18** | |
| **4.** | **19** | |
| **5.** | **21** | |
| **6.** | **9** | |
| **Total** | **100** | |

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01

**ADDITIONAL MATERIALS**

A calculator and a ruler.

**INSTRUCTIONS TO CANDIDATES**

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

You may use a pencil for graphs and diagrams only.

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 **6**.

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



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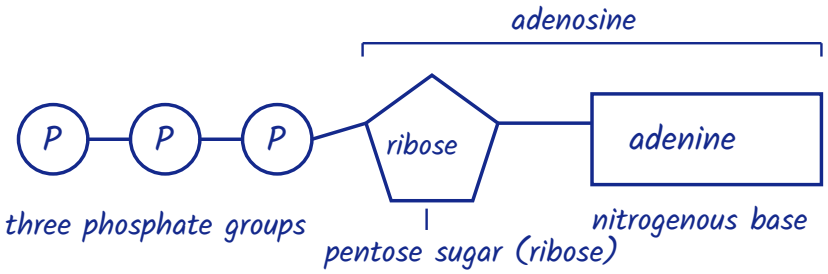
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Answer **all** questions.

**1.** ATP has been described as the universal energy currency in cells.

(a) (i) **Draw** and **label** a simple diagram to show the structure of ATP. [2]




(ii) With reference to the **structure of ATP**, explain what is meant by the term **universal energy currency**. [2]

ATP is the immediate source of energy for nearly all reactions in all cells and organisms, so it is universal. Energy is stored in the high energy bonds between the phosphate groups and is released when the terminal phosphate to phosphate bond is hydrolysed (ATP → ADP + $P_i$).

(iii) State **one** structural difference between the nucleotides found in **DNA** compared to those found in an **ATP** nucleotide. [1]

ATP contains ribose but DNA nucleotides contain deoxyribose.



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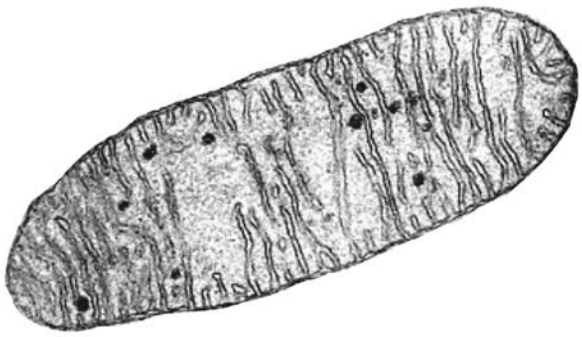


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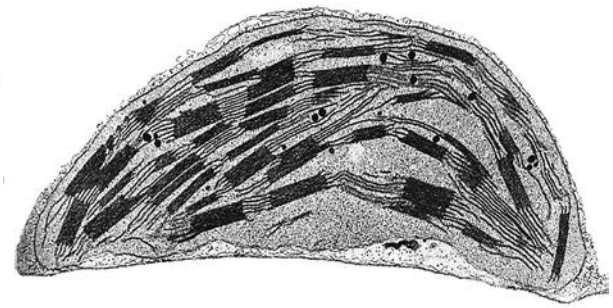
(b) In eukaryotic cells ATP is produced mainly by mitochondria and chloroplasts. Electron micrographs of these organelles are shown in **Images 1.1** and **1.2**.

**Image 1.1**



**a mitochondrion**

**Image 1.2**



**a chloroplast**

The endosymbiotic theory proposes that both mitochondria and chloroplasts evolved from prokaryotic ancestors.

(i) Identify **two** structural features of mitochondria and chloroplasts that are also found in prokaryotic cells. [2]

I. 70S (smaller) ribosomes

II. Circular DNA (a loop of DNA), free in the matrix / stroma

(ii) Name the **two** Domains which contain prokaryotic organisms. [1]

Bacteria (Eubacteria)

Archaea (Archaebacteria)

In both mitochondria and chloroplasts ATP synthesis requires the movement of protons and electrons, which results in the transfer of energy to ATP molecules.

(iii) Complete the table below to identify **where** in chloroplasts and mitochondria the following processes in ATP synthesis take place. [2]

| Process in ATP synthesis | Chloroplasts | Mitochondria |
|---|---|---|
| Protons are pumped across this membrane by proton pumps using energy from electrons. | thylakoid membrane | inner membrane / cristae |
| A high concentration of protons is formed here. | thylakoid space (lumen) | intermembrane space |

A400U101 03



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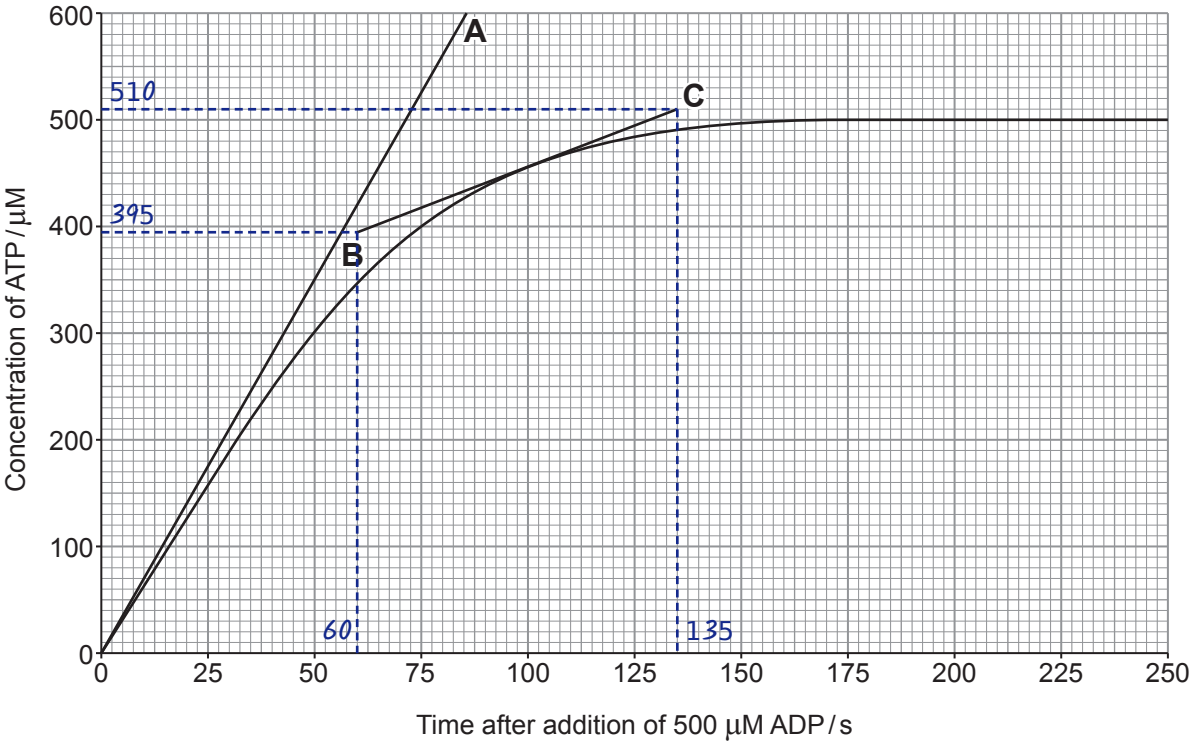


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(c) A laboratory experiment was carried out on isolated mitochondria to determine the rate of ATP synthesis. Isolated mitochondria were mixed with 500$\mu$M of ADP and excess inorganic phosphate. The concentration of ATP was recorded every 25 seconds over a period of 250 seconds. The results are shown in **Graph 1.3**.

**Graph 1.3**




(i) Use the tangent marked **B–C** to calculate the rate at 100 seconds following the addition of ADP and **state the unit** of your calculated value.
**Show how you obtained the values used in your calculation on Graph 1.3**.
[4]

Rate = change in y ÷ change in x = (510 – 395) ÷ (135 – 60)

= 115 ÷ 75 = 1.53

Rate at 100 s = 1.53 unit = $\mu M\ s^{-1}$

(ii) Explain why the initial rate calculated using the line marked **A** was higher than the rate at 100 s. [1]

ADP (substrate) concentration is highest at the start; by 100 s ADP is being used up so it becomes limiting.

15



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**2.** All animals are consumers and depend on producers as sources of nutrients and energy. Due to the increasing human population size, questions have been raised about the sustainability of human consumption of farmed and natural food sources. Some scientists believe that we are approaching the maximum human population that can be sustained by current plant productivity levels.

(a) (i) State the **types of nutrition** used by the following to obtain energy: [1]

producers photoautotrophic

consumers heterotrophic (holozoic)

(ii) Plant productivity can be expressed as GPP or NPP.
Explain why only NPP is available to consumers. [2]

NPP is the energy stored in new growth (biomass) of the plant. Energy is lost from GPP through respiration (NPP = GPP – R), so only the energy left in the biomass (NPP) can be eaten by consumers.

(iii) Human population density is increasing exponentially.
Explain what is meant by the term **exponential growth**. [1]

The growth rate keeps on increasing over time, so the population density increases faster and faster.

(iv) State the term used to describe the phrase:

'… maximum human population that can be sustained by current plant productivity levels.' [1]

carrying capacity

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(b) NPP is limited by the amount of light energy available to plants and the efficiency at which light energy can be transferred to organic compounds.

(i) Deserts and arctic-alpine regions have very low NPP per $km^2$.
Identify **one density-independent** factor that accounts for the very low NPP per $km^2$ of **both** regions.
Explain your answer. [2]

Lack of water: there is little rainfall in deserts and the water is frozen in arctic-alpine regions. Water is a raw material for photosynthesis (photolysis) and lack of it causes stomata to close, so the rate of photosynthesis is reduced and NPP is low.

(ii) Wavelengths of light between 650 and 750 nm (red light) are absorbed more readily by water than shorter wavelengths (blue light).
Use this information and your own knowledge of photosynthesis to explain why marine ecosystems only account for 40.8% of global NPP even though they cover 71.1% of the world's surface. [3]

Chlorophyll absorbs red light (650 to 750 nm) and uses this light energy for photosynthesis. In the sea the red wavelengths are absorbed by the water, so less red light (less light energy) reaches marine producers and mainly blue light is left, whereas on land all wavelengths are available. So the rate of photosynthesis per $km^2$ is lower in marine producers than in land plants, giving a lower NPP despite the larger area.



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(c) In 1987, there were approximately $5 \times 10^9$ humans on planet Earth. The mass of organic matter produced and consumed each year is usually expressed in petagrams (Pg), where 1 Pg = $10^{15}$ g.

(i) Calculate the **annual** consumption of organic matter by humans in 1987 if the average consumption of organic matter was 500 g per human per day.
**Express your answer in petagrams to two significant figures.** [3]

Daily consumption = $5 \times 10^9 \times 500 = 2.5 \times 10^{12}$ g

Annual = $2.5 \times 10^{12} \times 365 = 9.125 \times 10^{14}$ g

$9.125 \times 10^{14} \div 10^{15} = 0.9125$ Pg

Annual human consumption of organic matter = 0.91 Pg

(ii) In 1987, it was estimated that humans harvested 1.15 Pg of global NPP and directly consumed 0.76 Pg of organic matter derived from plants.
Calculate the percentage of harvested NPP lost or wasted by the human population at that time. [2]

$(1.15 - 0.76) \div 1.15 \times 100 = 0.39 \div 1.15 \times 100 = 33.91$

Percentage of harvested NPP lost or wasted by humans = 33.9 %

A400U101
07

(iii) Annual consumption of animal products by humans in 1987 was estimated at 0.15 Pg. Estimated global consumption of plants by livestock in 1987 was 2.2 Pg.

It has been recommended that humans eat fewer animal products as one way of improving sustainability.
Use the data provided to justify this conclusion. [3]

Livestock consumed 2.2 Pg of plants but humans obtained only 0.15 Pg of animal products, so 2.2 − 0.15 = 2.05 Pg of NPP is lost raising animals (efficiency only about 7%). Consumption of plants by livestock is much greater than by humans (2.2 Pg compared with 0.76 Pg). Eating plants directly means fewer trophic levels, so less energy is lost between trophic levels and there is less wastage. Less land would be needed to grow crops for livestock, so more land is available to grow crops for humans.

18



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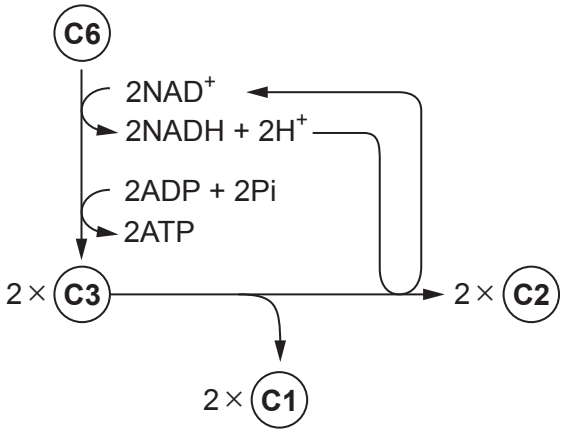


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**3.** Yeast (*Saccharomyces cerevisiae*) is a unicellular fungus that feeds saprotrophically on a range of substrates which are rich in sugars. Yeast is used extensively in the production of bread and sparkling (fizzy) wine through a process known as fermentation. Fermentation is summarised in **Image 3.1**.

**Image 3.1**




(a) (i) Explain what is meant by the term **saprotrophically**. [1]

Digestion of the food (substrate) takes place outside the organism by secreted enzymes, followed by absorption of the soluble products.

(ii) Name the type of respiration shown in **Image 3.1**. [1]

anaerobic (alcoholic fermentation)



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(iii) In **Image 3.1**, **C1**, **C2**, **C3** and **C6** indicate the number of carbon atoms in different organic molecules.

I. Name the molecules that contain 1, 2 and 3 carbon atoms. [2]

**C1** carbon dioxide ($CO_2$)

**C2** ethanol

**C3** pyruvate

II. Suggest why the **C1** molecule is important when producing bread and why both the **C1** and **C2** molecules are used when producing sparkling wine. [2]

Carbon dioxide (C1) gas makes the bread dough rise (leavening agent). In sparkling wine the carbon dioxide provides the bubbles and the ethanol (C2) is the alcohol in the wine.

(iv) If yeast cells respire for a long time using the process summarised in **Image 3.1** they eventually die. When animal cells respire in a similar way it does not cause cell death. Explain these statements. [3]

Yeast produces ethanol, which accumulates and is toxic; yeast cannot break it down or convert it to non-toxic substances, so the yeast cells die. Animal cells produce lactate (lactic acid) instead. Lactate production is reversible: when oxygen is available again the lactate is removed, being converted back to pyruvate or broken down in the liver, so the cells do not die.

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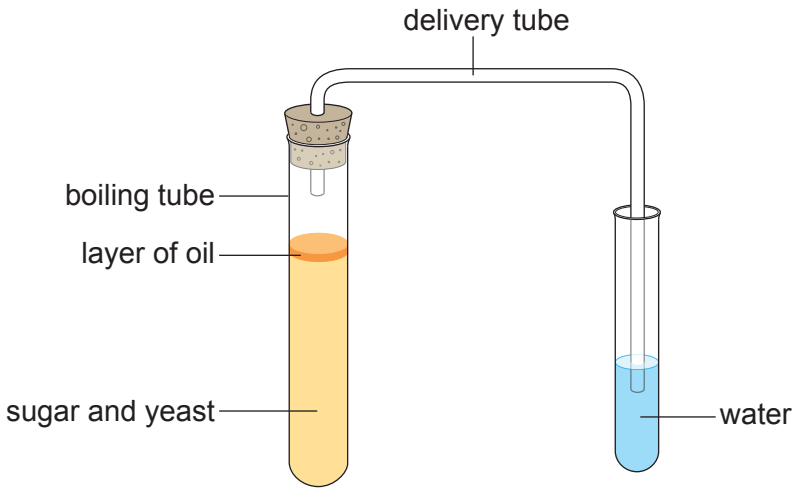
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(b) During the production of sparkling wine, additional sugar and yeast are added during a second fermentation.
An experiment was carried out to determine the best sugar to use when producing sparkling wine.

For each sugar, the following method was followed:

1. Add 10 $cm^3$ of 1 g $cm^{-3}$ yeast suspension to a boiling tube.
2. Add 10 $cm^3$ of a 2 g $cm^{-3}$ solution of the sugar being tested to a test tube.
3. Place both test tubes in a water bath at 30°C and leave for 5 minutes.
4. Pour the sugar solution into the yeast suspension and mix well.
5. Cover the surface with a thin layer of oil and place the bung with the delivery tube into the boiling tube as shown in **Image 3.2**.

**Image 3.2**




6. When gas bubbles emerge regularly from the delivery tube, count the number released in one minute.
7. Repeat step 6 for two more periods of 1 minute.



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(i) Both test tubes were left in the water bath for 5 minutes in step 3. Explain why this was necessary. [1]

To allow the yeast (enzymes) and the sugar solution to equilibrate, so that both reach the same temperature (30 °C) before they are mixed.

(ii) Explain the purpose of the layer of oil. [2]

The oil prevents oxygen from the air entering the mixture, creating anaerobic conditions, so the yeast respires anaerobically by fermentation (producing the $CO_2$ counted as bubbles).

(c) Four naturally occurring sugars were tested. **Table 3.3** shows the results of this experiment.

**Table 3.3**

| Sugar | Number of bubbles produced in 1 minute | | | |
|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | mean |
| fructose | 13 | 14 | 14 | 14 |
| glucose | 31 | 48 | 45 | 41 |
| lactose | 0 | 0 | 0 | 0 |
| sucrose | 12 | 8 | 11 | 10 |

Both glucose and fructose are sugars containing six carbons. Lactose and sucrose are disaccharides.

(i) Explain why glucose and fructose are known as structural isomers of each other. [1]

They have the same molecular formula ($C_6H_{12}O_6$) but a different arrangement of atoms (different structural formula).

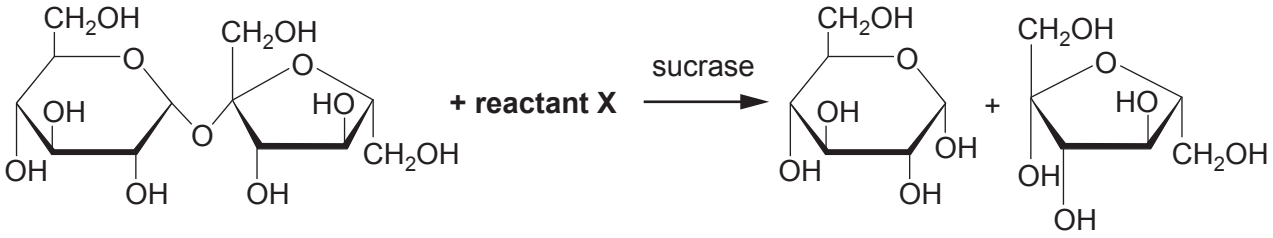


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**Image 3.4** shows the hydrolysis of sucrose catalysed by the enzyme sucrase.

**Image 3.4**




sucrose

monosaccharide **Y**

monosaccharide **Z**

(ii) Name reactant **X**, monosaccharide **Y** and monosaccharide **Z** in **Image 3.4**. [2]

reactant **X** water

monosaccharide **Y** α-glucose

monosaccharide **Z** fructose

(iii) Give **one** reason why using sucrose as the respiratory substrate resulted in fewer bubbles being produced than when using glucose. [1]

Sucrose must first be broken down (hydrolysed by sucrase into glucose and fructose) before it can be used in respiration, which takes time.



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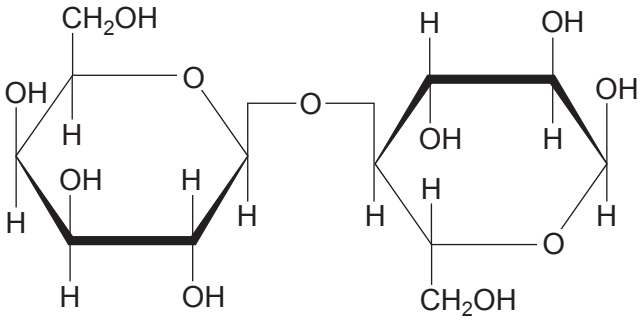


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Lactose is the sugar found in milk. **Image 3.5** shows the structure of lactose.

**Image 3.5**




(iv) Suggest an explanation for the results of the experiment for lactose shown in **Table 3.3**. [2]

Yeast does not produce the enzyme lactase, so lactose cannot be hydrolysed (metabolised) by the yeast. So glucose (respiratory substrate) cannot be produced, no respiration occurs and no $CO_2$ bubbles are released.

A400U101
13

18



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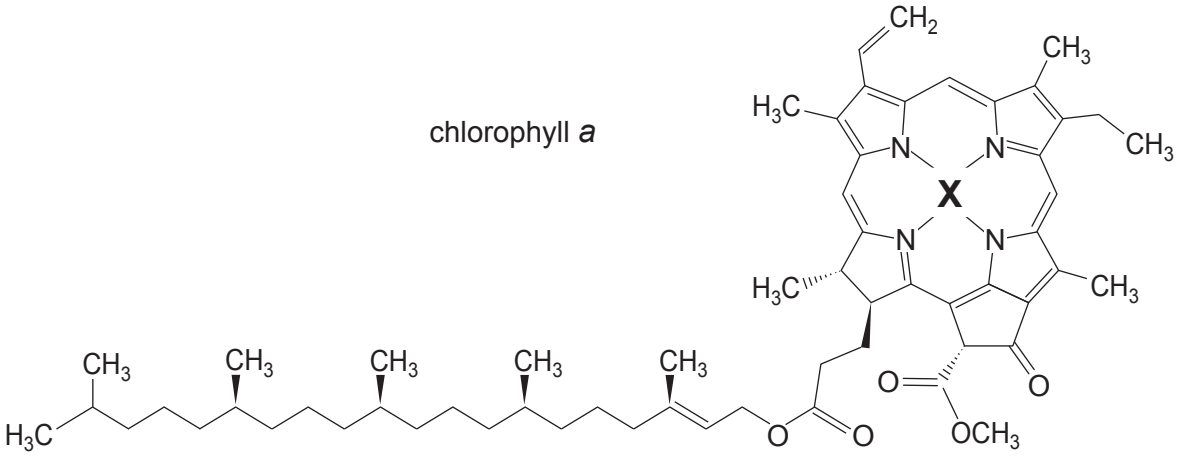
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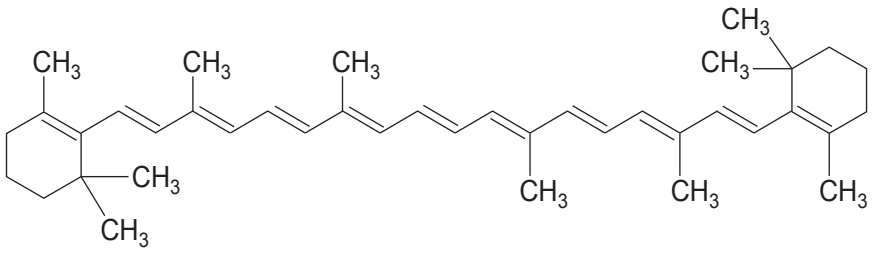
**4.** Photosynthetic pigments are compounds which absorb some wavelengths of light and reflect others.
**Image 4.1** shows the molecular structure of two photosynthetic pigments found in chloroplasts.

**Image 4.1**

chlorophyll *a*




carotene




(a) (i) Name the inorganic ion **X** found in chlorophyll *a*. [1]

magnesium ($Mg^{2+}$)

(ii) Hydrocarbons, such as carotene, contain atoms of carbon and hydrogen only. Apart from the presence of ion **X**, explain why chlorophyll *a* cannot be classified as a hydrocarbon. [1]

Chlorophyll a also contains oxygen and nitrogen atoms, not just carbon and hydrogen.



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(iii) Carotene is a hydrophobic molecule.
Suggest why carotene molecules are found embedded in thylakoid membranes rather than in the stroma. [2]

The centre of the thylakoid membrane (the fatty acid tails of the phospholipid bilayer) is hydrophobic / non-polar, so carotene dissolves there, whereas the stroma is aqueous, hydrophilic / polar.

(iv) Research has shown that carotenes have a similar function in membranes to that of cholesterol.
Describe this function. [1]

Stabilises the membrane by regulating its fluidity (maintains fluidity / rigidity).

**Question continued overleaf**



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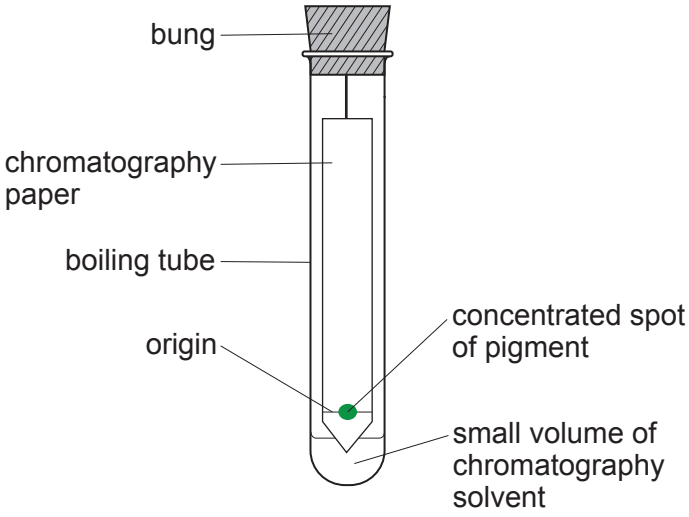


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(b) In a school laboratory, photosynthetic pigments can be separated and identified using chromatography. This is shown in **Image 4.2**.

**Image 4.2**




(i) Propanone is one of the solvents used to extract and separate the pigments. The safety symbol shown in **Image 4.3** is shown on bottles containing this solvent.

**Image 4.3**



Explain why the method for this practical should include the instruction to make sure that there are no naked flames when this practical is carried out. [1]

*Propanone is highly flammable, so it could easily catch fire if exposed to a naked flame.*

(ii) Explain why a pencil is used to draw the origin line on the chromatography paper. [1]

*Pencil is insoluble in the solvent, so it does not move, whereas ink would dissolve.*



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(c) Paper chromatography was used to separate the pigments found in the leaves of a plant. The results are shown in **Image 4.4**. Reference values for the main photosynthetic pigments are given in **Table 4.5**.

**Image 4.4**

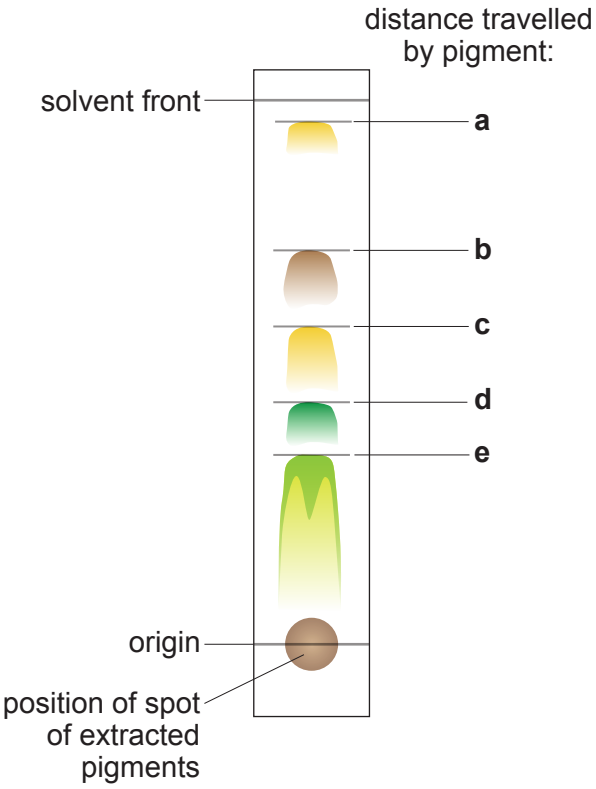



**Table 4.5**

| Reference Rf Values | |
|---|---|
| Pigment | Rf |
| beta carotene | 0.96 |
| chlorophyll *a* | 0.58 |
| chlorophyll *b* | 0.48 |
| phaeophytin | 0.70 |
| xanthophylls | 0.15 to 0.40 |

Pigments can be identified by calculating an Rf value and comparing this against reference values obtained using the same solvent and chromatography paper.

(i) I. Use the following formula to calculate the Rf value for pigment **b**. [2]

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

*distance travelled by pigment b = 52 mm*

*distance travelled by solvent front = 72 mm*

*Rf = 52 ÷ 72 = 0.72*

Rf = *0.72*

II. Use your calculated Rf value and **Table 4.5** to identify pigment **b**. [1]

*phaeophytin*



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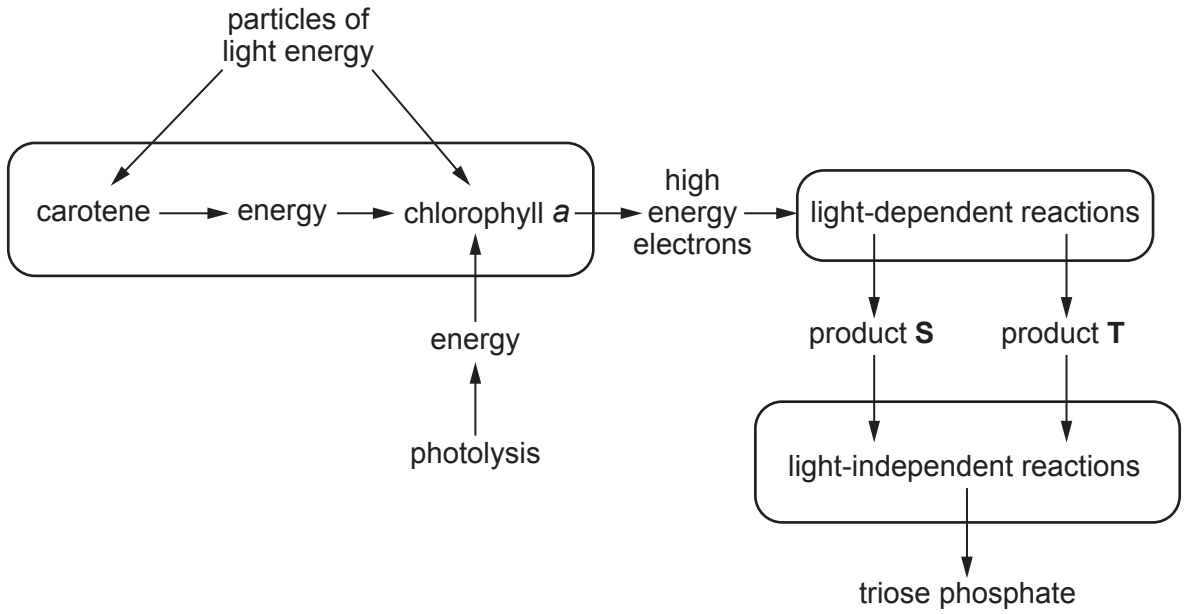
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(ii) Suggest why it is important that the calculated Rf values are compared to reference Rf values obtained using the same solvent and chromatography paper. [3]

*Pigments have different solubilities in different solvents, and different papers have different properties (absorption / adhesion), so the pigments move up the stationary phase at different rates. So the same pigment may travel different distances in a different solvent or paper, and the Rf values would be different and not comparable, giving an incorrect identification.*

(d) **Image 4.6** summarises the light-dependent and light-independent stages of photosynthesis.

**Image 4.6**




(i) State the term used to describe the **particles of light energy**. [1]

*photons*

(ii) Product **S** is synthesised via an electron transport chain while product **T** is synthesised from the final electron acceptor of this series of reactions. Name products **S** and **T**. [2]

Product **S** *ATP*

Product **T** *reduced NADP (NADPH)*



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(iii) At high light intensities, carotene passes energy to other electron acceptor molecules rather than to chlorophyll *a*. This reduces the rate of photolysis to prevent chlorophyll *a* being damaged.
Some weedkillers inhibit the synthesis of carotene.
Using all the information provided, explain **one** way in which this type of weedkiller can cause plant death. [3]

Without carotene, chlorophyll a is damaged at high light intensities. Damaged chlorophyll a cannot pass high energy electrons into the electron transport chain and there is less photolysis of water, so less ATP and reduced NADP are made by photophosphorylation. With less ATP and reduced NADP, glycerate-3-phosphate cannot be reduced to triose phosphate and ribulose bisphosphate cannot be regenerated, so carbon fixation stops. No TP is made for glucose synthesis, so respiration stops and the plant dies.

19



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**5.** Avocados (*Persea americana*) have become a popular food in all parts of the world. More than 50% of world production is based in one Central American country and most are grown in a single region of this country.
To meet global demand, nearly 90 000 hectares (900 000 000 $m^2$) of land have been converted to avocado plantations. **Image 5** shows an avocado plantation.

**Image 5**




(a) With reference to **Image 5** suggest how avocado production may have contributed to:

(i) biodiversity loss; [2]

*The original forest has been cut down (deforestation) to plant the avocado trees, causing loss of habitat and fewer ecological niches. The plantation is a monoculture so it supports fewer species.*

(ii) climate change. [2]

*There are fewer large trees to carry out photosynthesis, so less $CO_2$ is removed and more $CO_2$ remains in the atmosphere. Burning or decomposition of the felled trees also releases $CO_2$.*



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(b) The original forest shown in **Image 5** is an example of a climax community.

(i) State what is meant by the term **climax community**. [1]

*The final, stable stage of succession, in which the community remains stable with no further change.*

(ii) Suggest how the following abiotic factors would have changed following the establishment of the avocado plantation.
Explain your answers.

I. soil moisture content; [2]

*There is less plant cover after deforestation, so the soil is exposed and more water evaporates from the soil, resulting in a lower soil moisture content.*

II. soil fertility. [3]

*Soil fertility would decrease. There is less dead plant material to decay, so fewer minerals are returned to the soil. The avocados are harvested, so nutrients are removed from the ecosystem, and as a monoculture they remove the same minerals from the soil. The exposed soil is also more prone to leaching and soil erosion, so there are fewer nitrates and minerals in the soil.*

(iii) Outline a method that could be used to estimate and compare the plant biodiversity of the original forest and the avocado plantation. [4]

*Set up a grid over each area (two tapes at right angles) and use a random number generator to select quadrat co-ordinates randomly. At each point place a quadrat and count the number of individuals of each plant species present, using the same number of quadrats in each area. Calculate Simpson's diversity index, $D = 1 - (\Sigma n(n-1) \div N(N-1))$, for each area and compare: a higher value means greater biodiversity.*



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(c) In North America, 95% of all avocados consumed are of the Hass variety and most are imported from Central America. New varieties of avocado are produced by cross-pollination.
Avocados have a high degree of genetic polymorphism. Due to this, most attempts to breed useful new varieties have low success rates.

(i) Use the information to suggest why attempts to breed new useful varieties of avocado have low success rates. [2]

There are many alleles of the same genes in the population, so the outcome of genetic crosses (cross-pollination) is unpredictable; there is high variability in the offspring and a low chance of getting the desired phenotype.

(ii) The Hass avocado is highly susceptible to a soil-borne pathogen, *Phytophthora cinnamomi*, which causes a disease called root rot.
Infected plants wilt easily due to the pathogen affecting transpiration in the plant. Leaf death follows as a result.
Use the information given to identify the tissue affected by this pathogen and conclude why infected plants wilt and eventually die. [3]

Xylem. The pathogen affects the xylem, so less water is transported to the shoots and leaves. The leaf cells lose water and are no longer turgid, so there is less support for the tissues and the plant wilts. With less water (and fewer leaves) available for photosynthesis, less glucose is made for respiration, so the plant eventually dies.



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(iii) Some wild species of avocado show resistance to *P. cinnamomi*.
Current practices in establishing avocado plantations are leading to some wild species becoming extinct.
Explain why it is important that these wild species are conserved **and** suggest **two** ways of conserving them for the future. [2]

Wild species are a source of valuable alleles (resistance to P. cinnamomi), so conserving them maintains the genetic diversity of the gene pool, which can be used to breed resistant varieties. They could be conserved in seed banks (seed stores) and by habitat protection in nature reserves.

21



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**6.** In 2004, it was estimated that approximately 18% of the human population lacked access to safe drinking water.
In most industrialised nations, samples of drinking water are cultured in laboratories. Any bacteria present are identified using microscopic methods. The samples are monitored for the presence and level of different types of faecal bacteria, some of which can be pathogenic. Bacterial load (the number of bacteria per $cm^3$) is determined using a viable count.

State the conditions needed to culture bacteria in a laboratory and explain why each of these conditions is required.
Describe how different types of bacteria can be identified using microscopic methods.
Explain what is meant by a viable count and describe how you could determine the bacterial load of a sample of drinking water. (Details of aseptic technique are not required.) [9 QER]

Culturing bacteria: bacteria are grown on a sterile nutrient medium (nutrient broth or agar) which must supply everything they need. Water is needed as a solvent for metabolic reactions, for transport of substances and for hydrolysis reactions. A carbon source such as glucose is needed for respiration to release energy and for the synthesis of organic compounds. A nitrogen source such as amino acids or nitrate is needed to synthesise amino acids, proteins and nucleic acids. Minerals (e.g. phosphate, magnesium), vitamins and growth factors are needed as some bacteria cannot synthesise these themselves, e.g. as enzyme cofactors. The culture must be kept at a suitable (optimum) temperature and pH so that the bacterial enzymes work at their maximum rate and are not denatured. Oxygen requirements must be met: obligate aerobes need oxygen for aerobic respiration, so cultures are aerated or shaken, whereas obligate anaerobes must be grown without oxygen because oxygen is toxic to them.

Identification by microscopy: bacteria can be identified by their size and by their shape. Cocci are spherical, bacilli are rod-shaped, spirilla are spiral-shaped and vibrios are comma-shaped. They can also be identified by their staining characteristics using the Gram stain: Gram positive bacteria retain the crystal violet stain and appear purple, whereas Gram negative bacteria lose the crystal violet and take up the red counterstain (safranin), so they appear red / pink


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under the microscope.

Viable count: a viable count is a method of determining the number of living cells in a sample, as only living cells can divide to form colonies. A known volume of the drinking water is diluted by serial dilution, e.g. in ten-fold steps (1 $cm^3$ of sample added to 9 $cm^3$ of sterile water, then repeated). A known volume (e.g. 0.1 $cm^3$) of each dilution is spread onto separate agar plates, which are incubated (e.g. at 25 °C for 48 hours) and then the colonies are counted. A plate with a countable number of separate colonies (e.g. 30 to 300) is chosen, as there are enough colonies to be confident in the estimate but they have not merged together. It is assumed that each colony grew from one viable cell, so the number of colonies is multiplied by the dilution factor and divided by the volume plated to give the bacterial load in bacteria per $cm^3$ of the original sample.



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