Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

S24-1400U30-1

1400U30-1

WEDNESDAY, 5 JUNE 2024 – AFTERNOON

BIOLOGY – A2 unit 3
Energy, Homeostasis and the Environment

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**10**	
2.	**16**	
3.	**15**	
4.	**13**	
5.	**11**	
6.	**16**	
7.	**9**	
Total	**90**	

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ADDITIONAL MATERIALS

In addition to this paper, you will require 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.

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 **7**.

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

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Answer **all** questions.

1. The Krebs cycle is a set of enzyme-controlled reactions that take place in aerobic organisms. **Image 1.1A** shows a simplified diagram of the Krebs cycle and **Image 1.1B** shows the structural formulae of two key intermediates.

Image 1.1A

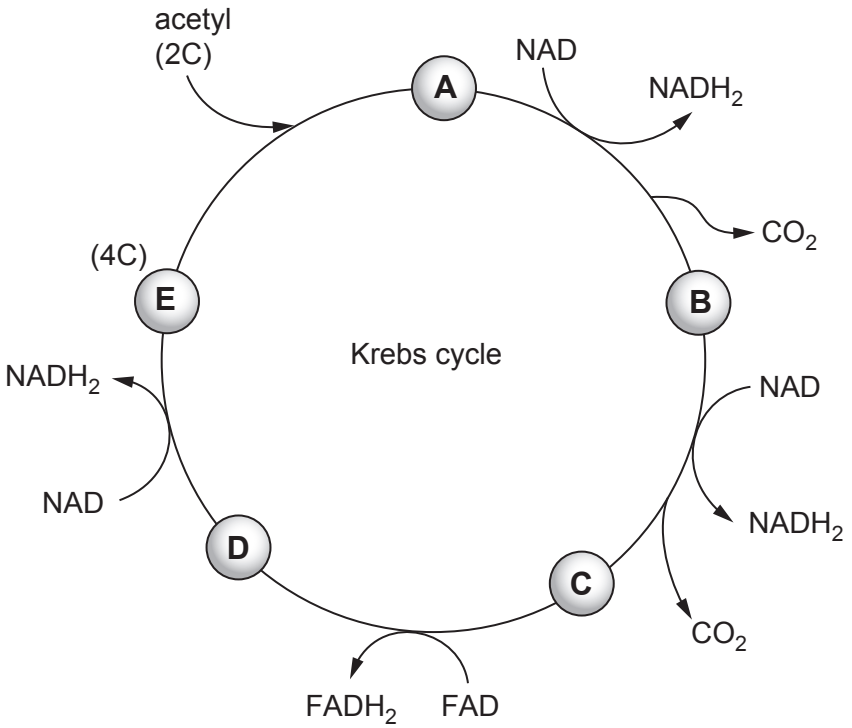
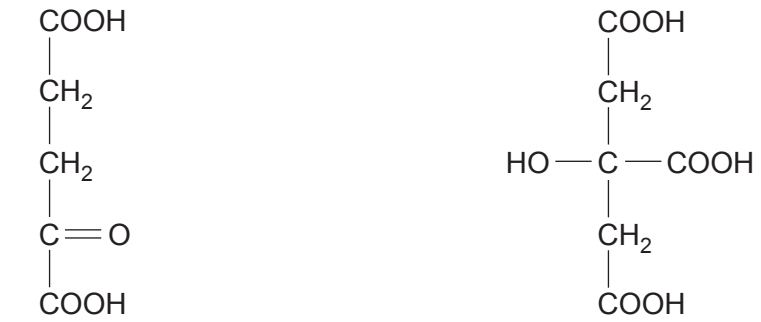


Image 1.1B



α ketoglutaric acid citric acid

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(a) (i) Complete **Table 1.2** by recording the number of each type of atom present in the two named compounds shown in **Image 1.1B**. [2]

Table 1.2

Type of atom	Number of atoms present	
	α ketoglutaric acid	citric acid
Carbon	.....	.....
Hydrogen	.....	.....
Oxygen	.....	.....

(ii) Using the information provided in **Images 1.1A** and **1.1B**, identify which of the intermediates labelled **A–E** on the drawing of the Krebs cycle is α ketoglutaric acid and which is citric acid. [1]

α ketoglutaric acid .....

citric acid .....

(iii) Use the information in **Image 1.1A** to state what happens to each of the following atoms in the conversion of **A** to **B**. [2]

Carbon .....

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Hydrogen .....

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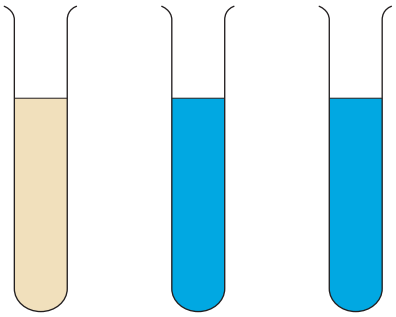
(b) Malonic acid is a dicarboxylic acid with the chemical formula $C_3H_4O_4$. **Image 1.3** shows a summary of an experiment to test the hypothesis that malonic acid is a respiratory poison in yeast.

Methylene blue is used to monitor **dehydrogenase** activity because it acts as a hydrogen acceptor and turns from blue to colourless when it is reduced.

Image 1.3



Tube	1	2	3
Boiled and cooled yeast suspension (cm^3)	0	0	10
Active yeast suspension (cm^3)	10	10	0
Malonic acid solution (cm^3)	0	5	0
Water (cm^3)	5	0	5
Methylene blue solution (cm^3)	1	1	1
Colour after 30 mins	cream	blue	blue

(i) Tube **3** in **Image 1.3** acts as a control. Describe the purpose of tube **3** in this experiment. [1]

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(ii) Describe the evidence from **Image 1.3** which supports the hypothesis that malonic acid is a respiratory poison. [2]

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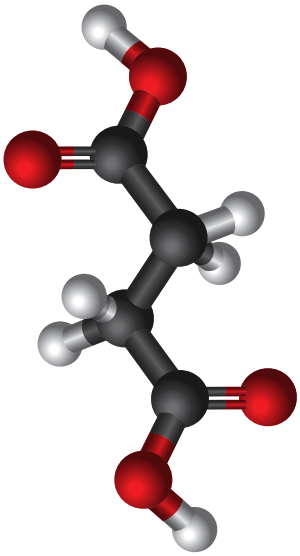
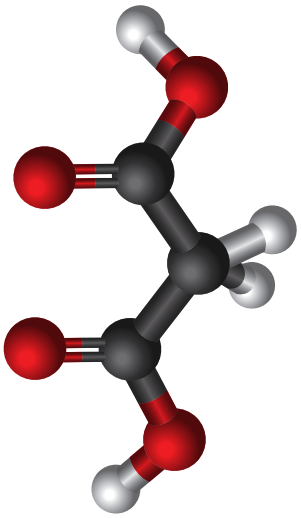
(iii) **Image 1.4** shows ball and stick models of another Krebs cycle intermediate, succinic acid, and a molecule that is believed to act as a respiratory poison, malonic acid.

Image 1.4



succinic acid



malonic acid

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Using information from **Image 1.4** and your knowledge of enzymes suggest how malonic acid could act as a respiratory poison. Explain your answer. [2]

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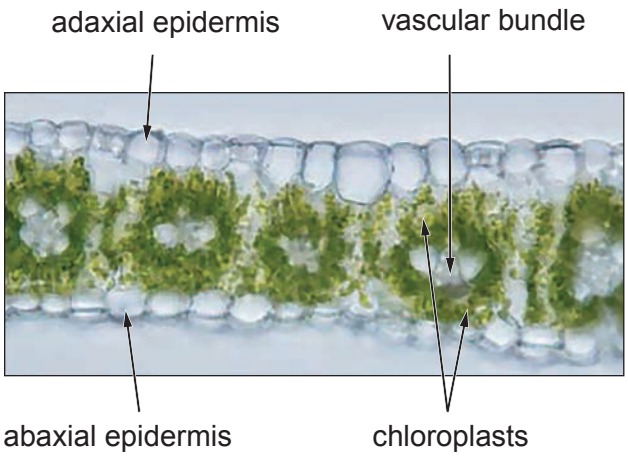
2. The distribution of chloroplasts inside leaves is important for efficient photosynthesis. Millet is a grass-like plant in which the leaves grow upwards so that they have an inward-facing (adaxial) surface and an outward-facing (abaxial) surface. **Image 2.1** shows a millet plant and **Image 2.2** shows a transverse section of a millet leaf.

Image 2.1

position of section shown in **Image 2.2**

Image 2.2



(a) (i) Compare the distribution of chloroplasts in the millet leaf with the distribution of chloroplasts in a typical leaf such as *Ligustrum*. [2]

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(ii) With reference to **Images 2.1** and **2.2**, conclude how the distribution of chloroplasts enables more efficient light absorption in millet plants. [2]

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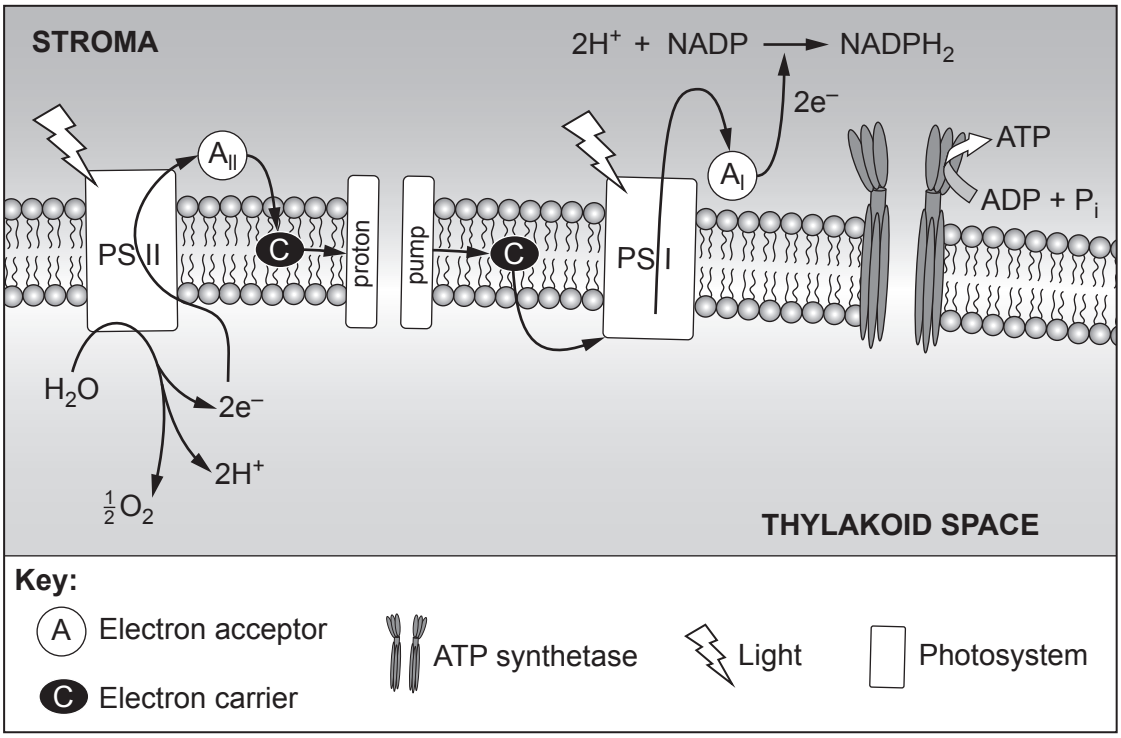
Image 2.3 shows how electrons pass between components of thylakoid membranes during non-cyclic photophosphorylation.

Image 2.3



(b) (i) Name the process shown in **Image 2.3** by which electrons are released from water. [1]

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The relative energy levels of the electrons in some of the components in **Image 2.3** are shown in **Table 2.4**.

Table 2.4

Membrane component	Relative electron energy level / au
Photosystem II (PSII)	0
Electron acceptor A_{II}	1.8
Photosystem I (PSI)	1.0
Electron acceptor A_I	2.0

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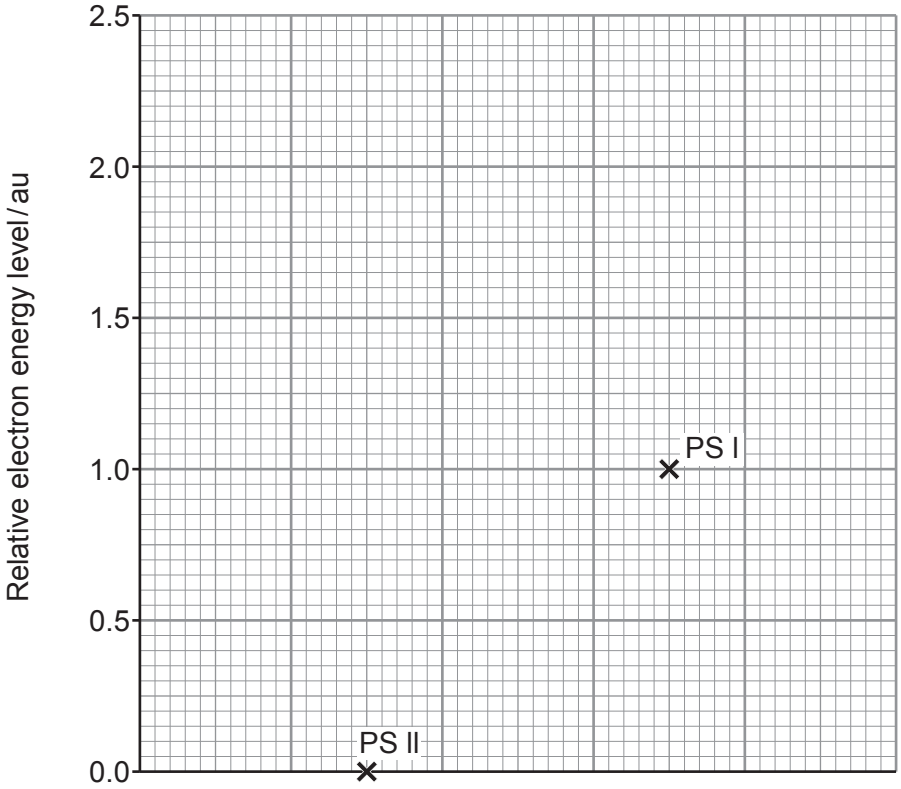
(ii) **Plot and label** the positions of the **electron acceptors A_I and A_{II}** on **Graph 2.5** (PSI and PSII have been done for you) and **join the four components** with **three straight lines** to show the **energy profile** of **non-cyclic photophosphorylation**. [2]

Graph 2.5



(iii) Use your knowledge of non-cyclic photophosphorylation to describe and explain the changes in relative electron energy levels shown in **Graph 2.5**. [5]

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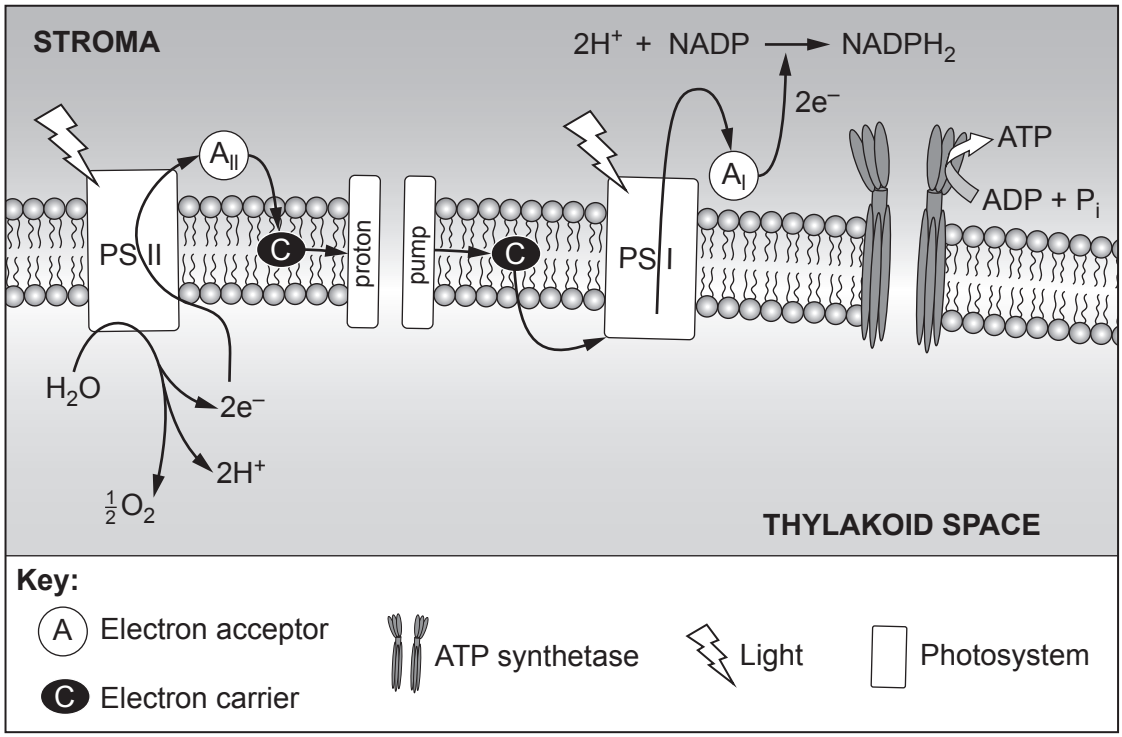
ATP production is carried out in chloroplasts by chemiosmosis which involves creating a proton gradient across the thylakoid membrane.

Image 2.6



(c) (i) **On Image 2.6:**
draw an arrow labelled P through the proton pump to show the direction in which protons are pumped;
draw an arrow labelled D through the ATP synthetase molecule to show the direction in which protons diffuse to activate ATP synthetase. [1]

(ii) In addition to proton pumps, two other processes shown in **Image 2.6** also contribute to creating a proton gradient across the thylakoid membrane. Describe these **two** processes and state where each occurs. [3]

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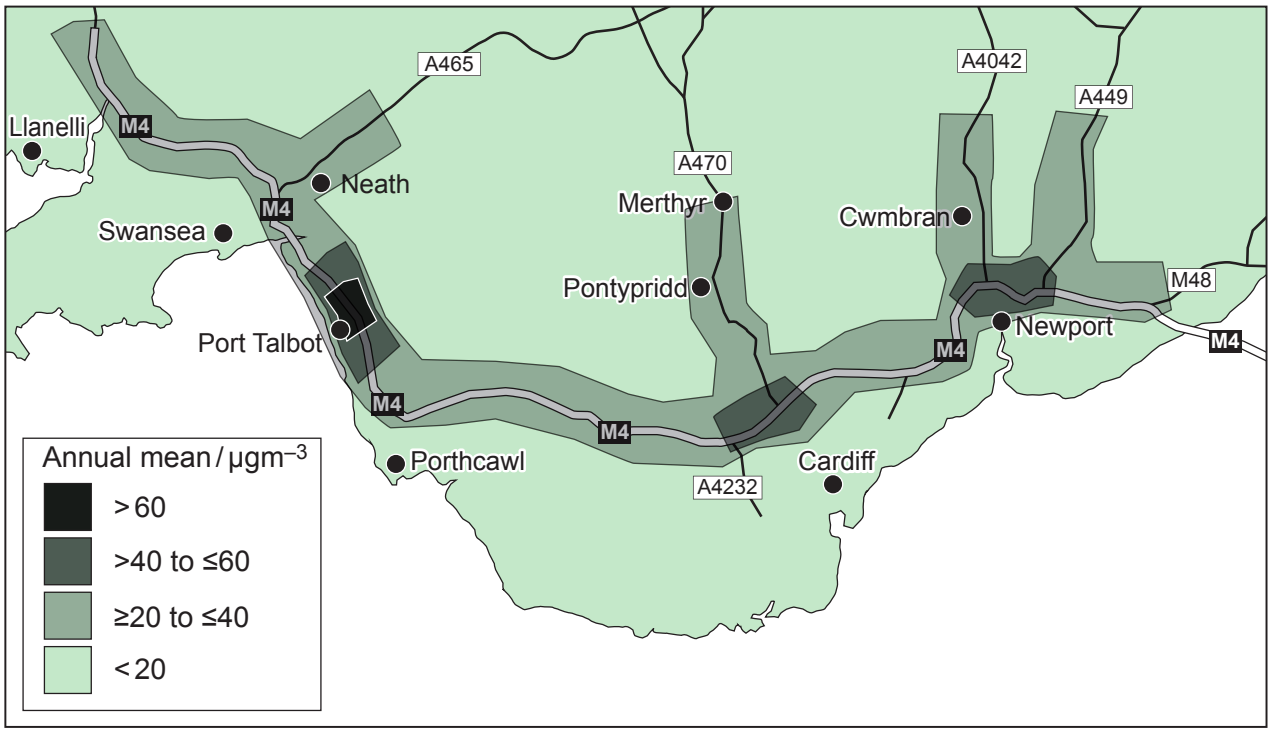
3. In Wales, over a thousand deaths are attributed annually to nitrogen dioxide (NO_2) pollution. Although the planetary boundary for chemical pollution remains to be determined, the World Health Organisation (WHO) suggests that the NO_2 annual mean value should not exceed 40 micrograms per cubic metre (μgm^{-3}).

The map in **Image 3.1** shows the background levels of airborne NO_2, measured by a network of air sampling machines located along the M4 motorway and major A-roads in South Wales. The key shows mean NO_2 levels in $\mu g\,m^{-3}$ for 2015.

Image 3.1



(a) (i) Describe how the distribution of measured NO_2 levels supports the hypothesis that motor vehicle exhausts are the main source of airborne NO_2. [1]

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(ii) I. **Draw a circle** on the map in **Image 3.1** to show the position on the M4 where traffic control measures were most urgently needed in 2015. [1]

II. Explain your choice in terms of WHO limits. [1]

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In Wales, Air Quality Management is the responsibility of local authorities. One local authority carried out an experiment to test the impact of closing a junction of the M4. They measured the concentration of NO_2 at 15 sites surrounding the junction for 4 months (April–July) before closing it and for 4 months after closing it (August–November).
A t-test value was calculated to assess whether the difference in mean NO_2 concentration was significant.
The results are summarised in **Table 3.2**.

Table 3.2

	April–July (before closure)	August–November (after closure)
Mean NO_2 concentration / $\mu g\,m^{-3}$	20.04	23.09
Number of measurements	15	15
Standard deviation	±4.14	±5.23
t-test value	1.769	
Degrees of freedom	28	

(b) The null hypothesis used in the experiment was that 'there was no significant difference in mean NO_2 concentration before and after closing the junction'.

Table 3.3

Degrees of freedom	Level of Probability							
		0.1	0.05	0.025	0.01	0.005	0.001	0.0005
	26	1.315	1.706	2.056	2.479	2.779	3.435	3.707
	27	1.314	1.703	2.052	2.473	2.771	3.421	3.690
	28	1.313	1.701	2.048	2.467	2.763	3.408	3.674
	29	1.311	1.699	2.045	2.462	2.756	3.396	3.659
	30	1.310	1.697	2.042	2.457	2.750	3.385	3.646

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(i) Use the information from **Table 3.2** and the probabilities shown in **Table 3.3** to decide whether to accept or reject the null hypothesis at a suitable probability level. Explain your answer. [4]

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(ii) State why the local authority might use the results of this experiment to justify keeping the motorway junction open. [2]

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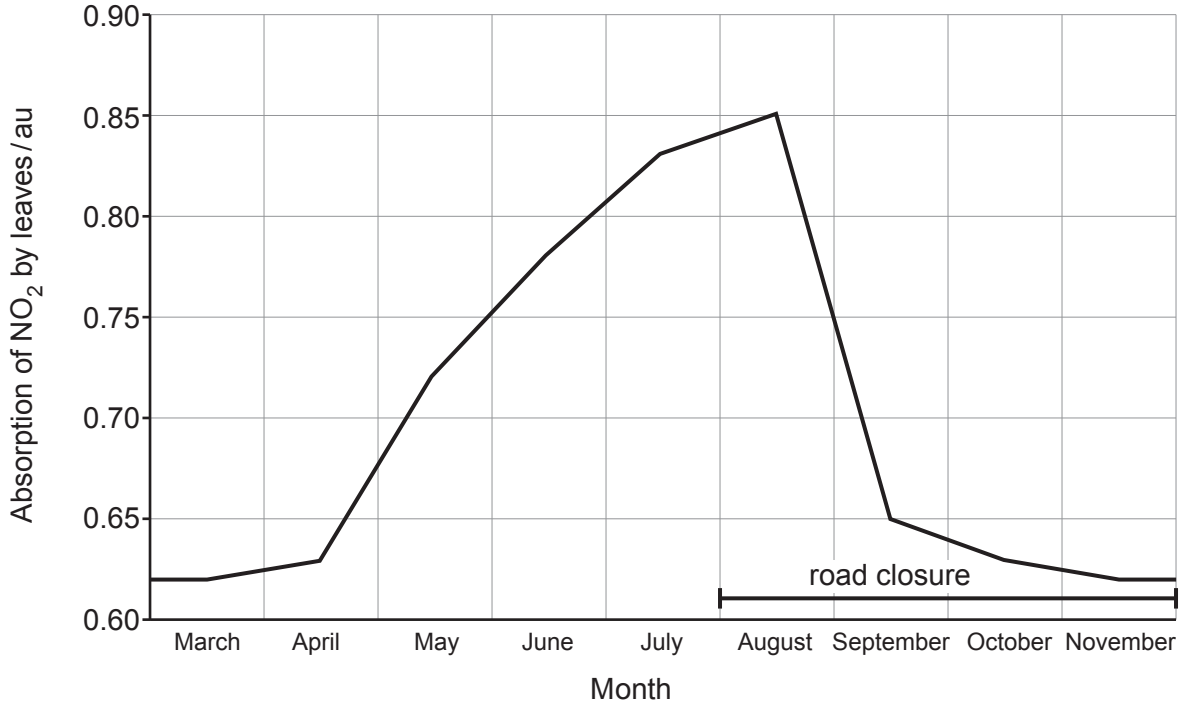
In a separate experiment, scientists measured the absorption of NO_2 by leaves on trees near the motorway at different times throughout the year. The trends are shown in **Graph 3.4**.

Graph 3.4



(iii) With reference to the results of the road closure experiment.

I. Explain how the **trends** shown in **Graph 3.4** affect confidence in the conclusion of the road closure experiment. [2]

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II. Explain how the design of the road closure experiment could be changed to take account of these findings. [1]

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NO_2 dissolves in rainwater to form nitrous acids which break down to form nitrite ions and wash into the soil.

(c) Name the soil bacteria that act on nitrite ions and explain how the soil bacteria change the nitrite ions so they are able to continue to circulate in the nitrogen cycle. [3]

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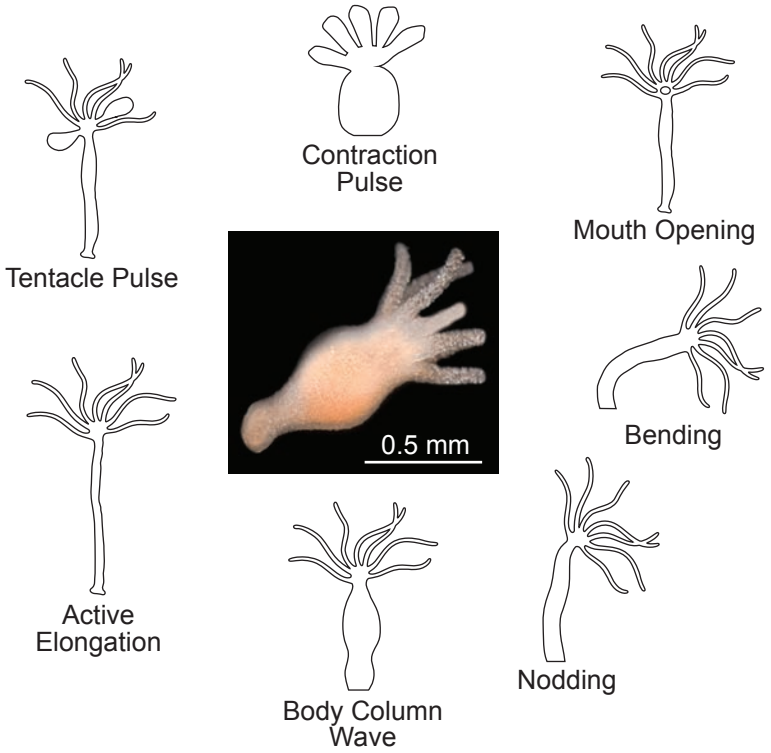
4. **Image 4.1** shows a photograph of a live *Hydra* and drawings of a range of activities that may be observed in *Hydra.* The activities shown take between 3 seconds and 17 seconds to complete.

Image 4.1



(a) Name the type of nervous system in *Hydra* and explain why its movements take a relatively long time. [2]

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In humans, nerve cells are differentiated to carry out specific functions.
Image 4.2 is a diagram of a specialised nerve cell. The rectangle represents the area that is shown in **Image 4.3**.
Image 4.3 is an electron micrograph of the tip of a specialised nerve cell together with part of an adjacent cell.

Image 4.2

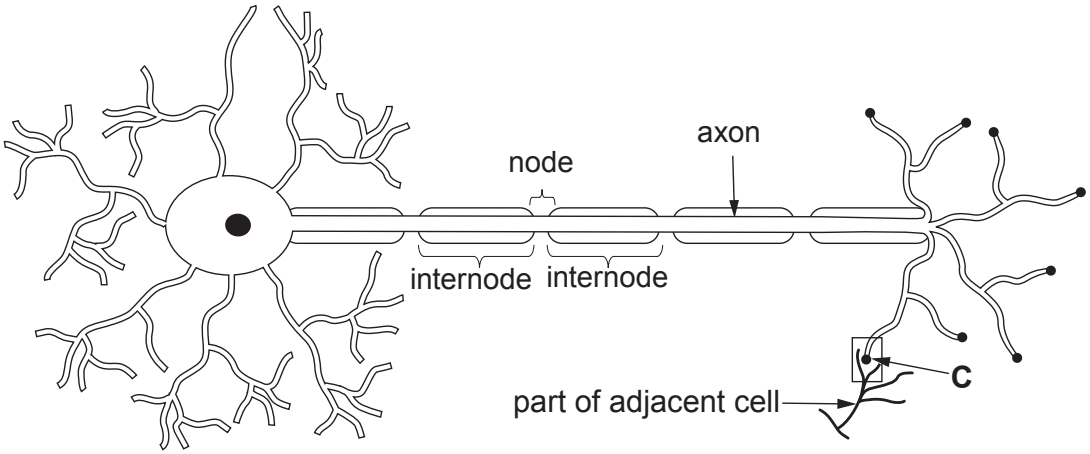
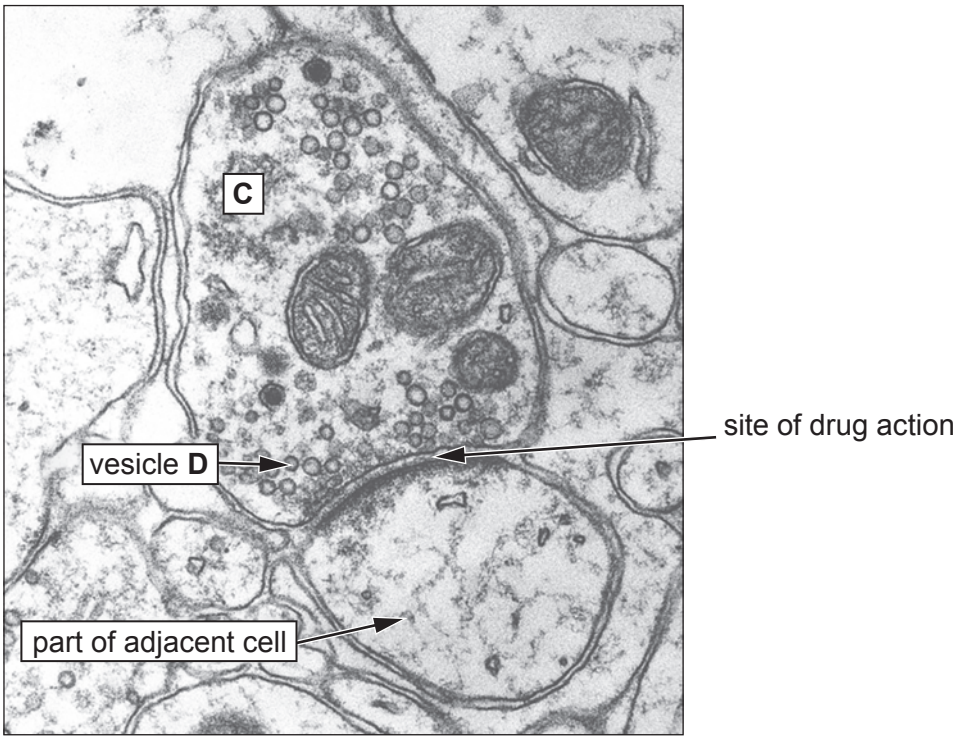


Image 4.3



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(b) (i) Name the structure labelled **C** in **Images 4.2** and **4.3**. [1]

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(ii) Name the type of vesicle labelled **D** in **Image 4.3** and describe its function. [1]

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(iii) Some drugs are described as acetylcholinesterase inhibitors. The site of action of these drugs is labelled on **Image 4.3**.
Suggest why these drugs cause over-stimulation of the membrane of the adjacent cell. [2]

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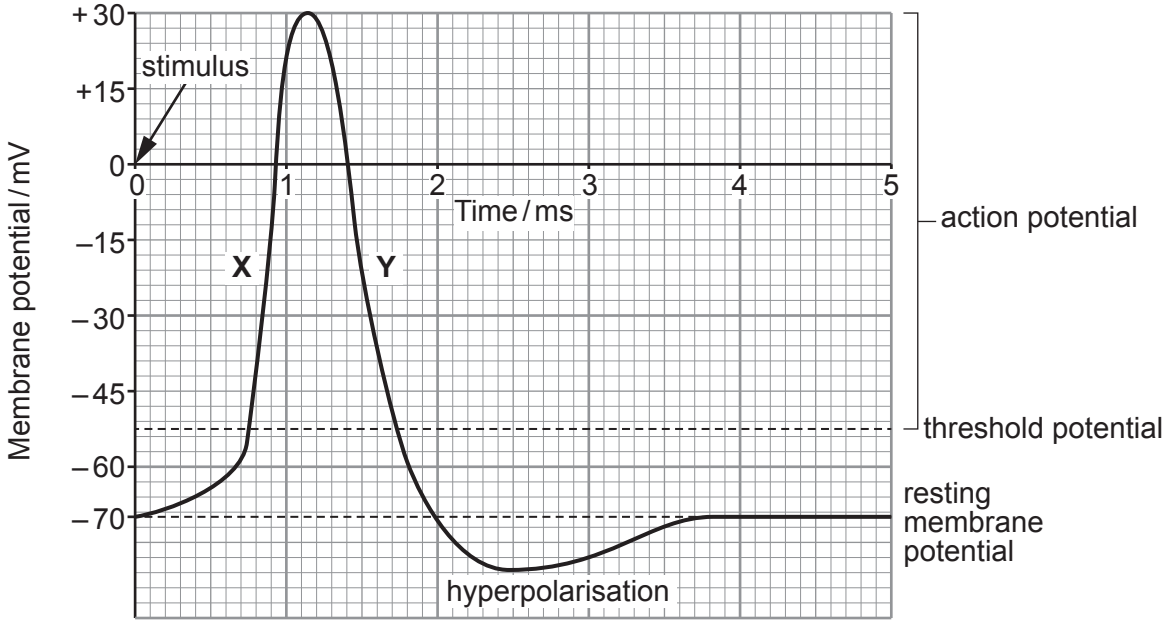
Graph 4.4 shows an oscilloscope trace from an experiment to measure the potential difference across the membrane of a squid giant axon.

Graph 4.4



(c) (i) Name the processes represented by letters **X** and **Y** in **Graph 4.4**. [1]

X ..... **Y** .....

(ii) With reference to **Graph 4.4**, explain how voltage-gated sodium ion channels bring about process **X**. [2]

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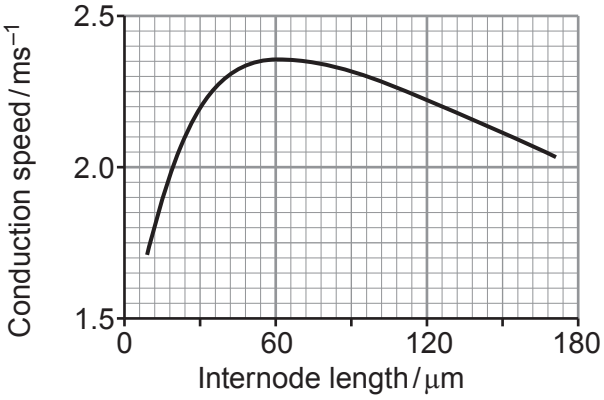
The speed at which nerve impulses are conducted along nerve fibres depends on a number of factors, including myelination. **Graph 4.5** shows the results of a computer simulation to investigate the effect of length of myelin internode (see **Image 4.2**) on conduction speed.

Graph 4.5



(d) Describe the relationship between internode length and conduction speed and use your knowledge of nerve impulse transmission to explain the results. [4]

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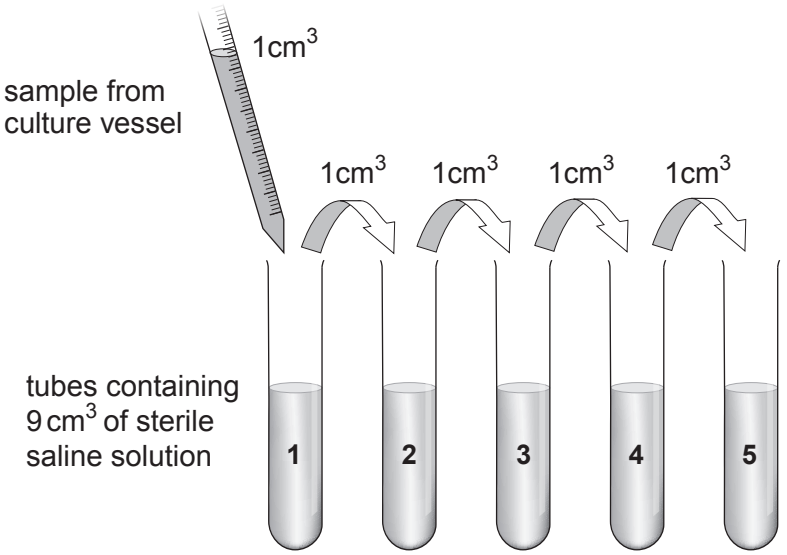
5. A large-scale culture of *Escherichia coli* was set up in an electronically maintained fermenter. Every ten minutes a sample was removed and serially diluted using the method shown in **Image 5.1**.
A 0.5 cm^3 sample from each tube was then plated onto separate sterile agar plates using aseptic techniques. The plates were incubated at 25 °C for 48 hours and the number of colonies counted.

Image 5.1



(a) (i) Describe **two** precautions that should have been taken to prevent contamination of the 0.5 cm^3 samples **as they were transferred to the agar plates**. [2]

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The results for the 160-minute sample and the 240-minute sample are shown in **Table 5.2**.

Table 5.2

Sample time / min	Number of colonies counted				
	Tube 1	Tube 2	Tube 3	Tube 4	Tube 5
160	Too many to count	Too many to count	>100	32	4
240	Too many to count	Too many to count	Too many to count	>100	32

(ii) Use **all** the information provided to calculate the number of bacterial cells **per cm^3** in the culture at **160 minutes. Express your answer in standard form.** [2]

Number of bacterial cells = ... per cm^3

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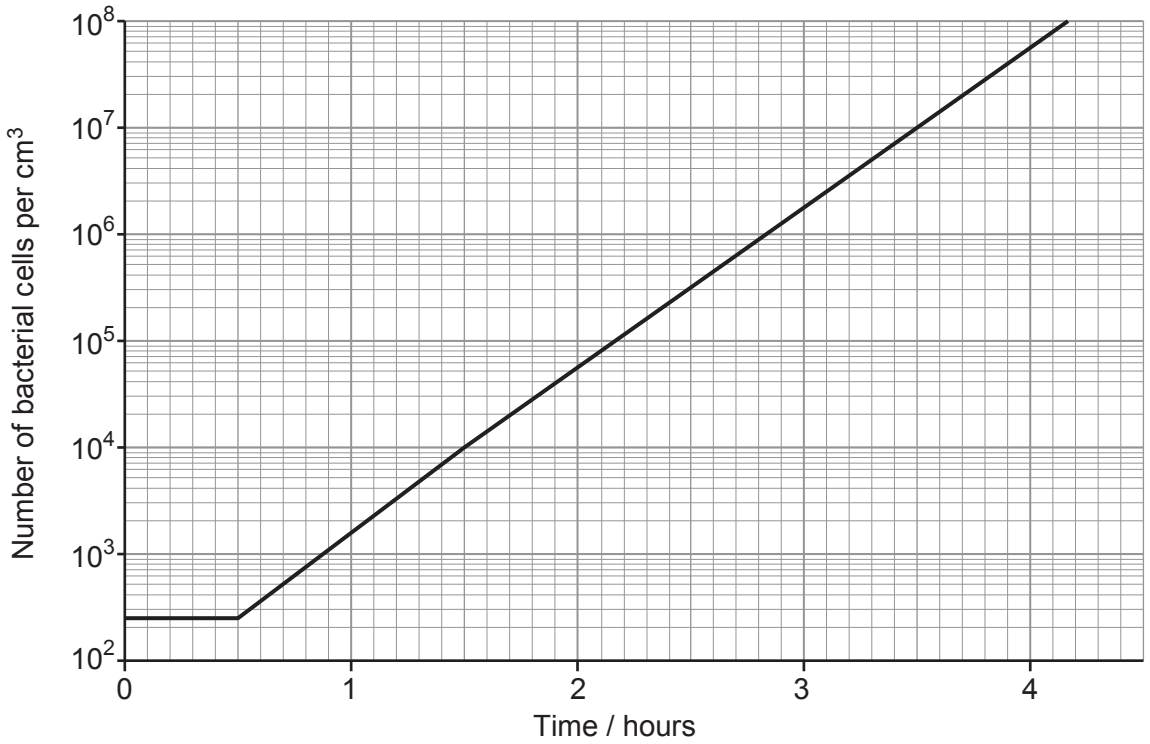
During the experiment, the number of bacterial cells was also monitored by continuously measuring the optical density (cloudiness) of the culture using a colorimeter. **Graph 5.3** shows the population growth curve in the fermenter over a 4-hour period using the optical density method.

Graph 5.3



(b) (i) Use **Graph 5.3** and the formula given below to calculate the number of generations produced per hour between **1.5 hours** and **3.5 hours**.

Express your answer to the nearest whole number. [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 bacterial cells per cm^3 at the end of the growth period
X_0 = number of bacterial cells per cm^3 at the start of the growth period
t = length of growth period in hours

Number of generations per hour = ...

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(ii) Explain the shape of the growth curve over the first 30 minutes. [1]

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(iii) For the first 40 minutes, the number of cells per cm^3 calculated from the agar plates as outlined in **Image 5.1** was not significantly different from the number of cells per cm^3 calculated using optical density. However, as time passed the number calculated from the agar plates was significantly lower than the number calculated using optical density.

Explain why there was no difference between the values from the two methods over the first 40 minutes but an increasing difference over the remaining time. [3]

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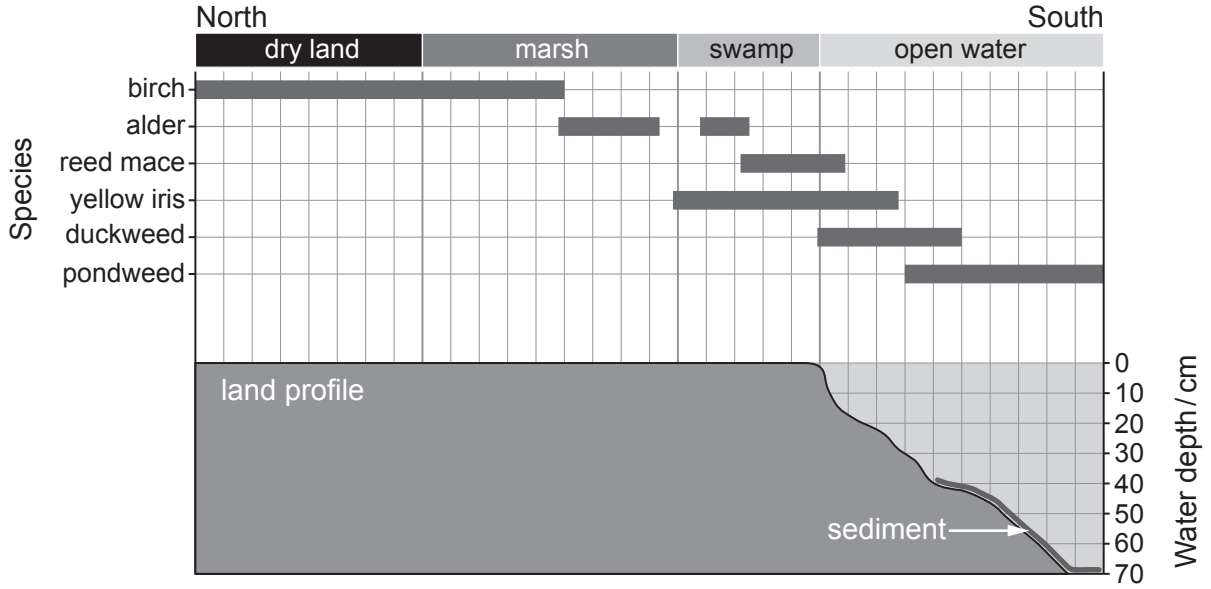
6. Wetland ecosystems are increasingly threatened as land is drained for agriculture. **Image 6.1** shows some of the results of a survey carried out at Valley Wetlands Centre, Anglesey.

Image 6.1



In order to carry out this survey, the team laid a rope across the area from north to south and identified the plant species that touched the rope.

(a) (i) State the name given to the type of sampling technique used in this survey. [1]

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(ii) The swamp in this survey could be correctly termed as both a habitat and an ecosystem.
Distinguish between the terms, habitat and ecosystem. [2]

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(iii) Using the information provided in **Image 6.1**, state the ranges of water depth over which duckweed and pondweed were found. [2]

Duckweed .....

Pondweed .....

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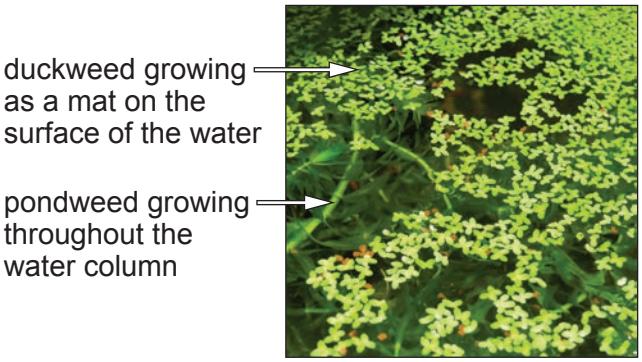
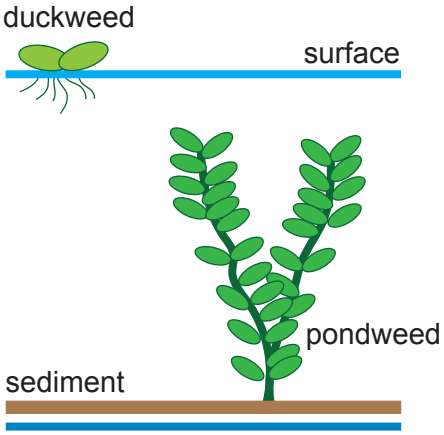
Image 6.2 shows a photograph of duckweed and pondweed growing together and a diagram of their growth patterns.

Image 6.2



Growth patterns



(b) (i) With reference to **Image 6.2** suggest why duckweed outcompetes pondweed in the shallower part of the range. [1]

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(ii) Name **two** nutrients for which the plants will compete **and** explain what each nutrient is used for in the plants. [3]

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(iii) Explain why the concentration of nutrients is likely to be greater at the bottom of the pools and suggest a hypothesis to explain why pondweed outcompetes duckweed in the deeper water. [3]

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(c) **Image 6.3** shows two snails that were found during the survey. Sampling revealed that the banded form was more common on dry land but the unbanded form was more common on the marsh.

Image 6.3

Cepaea nemoralis
banded form

Cepaea nemoralis
unbanded form

(i) State how biologists would determine that the snails shown in **Image 6.3** belong to the same species. [1]

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(ii) Give the term used for the type of variation shown in **Image 6.3**. [1]

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(iii) Suggest the advantage of bands to snails which live amongst twigs and leaves on the floor of the birch wood. [2]

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7. Feedback loops are essential to homeostasis. **Image 7.1** shows a generalised feedback loop and **Image 7.2** is a photograph of a person suffering from a condition caused by excessive alcohol consumption.

Image 7.1

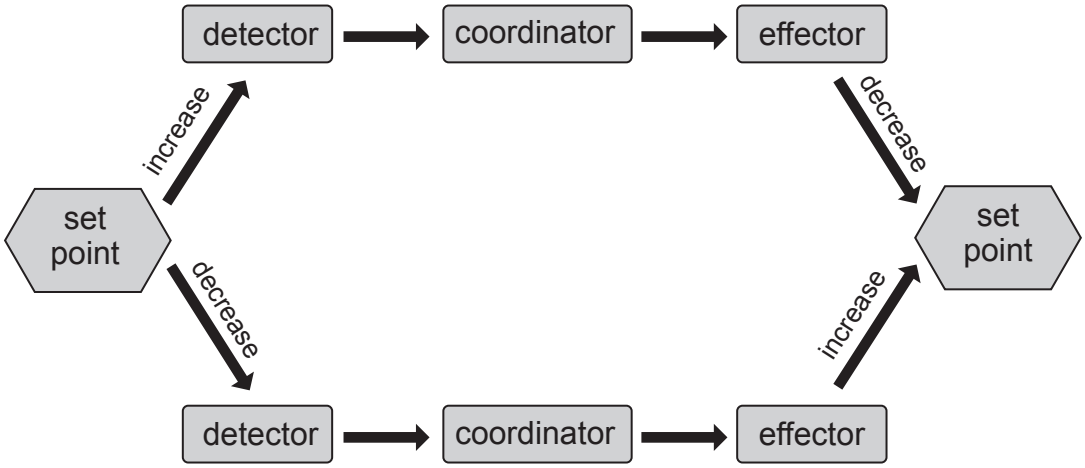

Image 7.2

Oedema: excess fluid retention.

This condition can occur if the solute concentration of blood is too low, meaning that the water potential is not negative enough. This means that water cannot be drawn back into the blood from the surrounding tissue fluid.

Explain the functions of each of the **three** components of a generalised feedback loop shown in **Image 7.1**.

With reference to the generalised feedback loop shown in **Image 7.1**, describe the role of ADH in osmoregulation.

Long-term alcohol use has been shown to cause thickening of the basement membrane of glomeruli. Explain how this change could cause the condition shown in **Image 7.2**. (Details of tissue fluid formation are not required.) [9 QER]

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