GCE A LEVEL

1400U30 – 1

WEDNESDAY, 5 JUNE 2024 – AFTERNOON

BIOLOGY – A2 UNIT 3
ENERGY, HOMEOSTASIS AND THE ENVIRONMENT

2 hours plus your additional time allowance

Surname: ____________________

First name(s): ____________________

Centre Number: ____________________

Candidate Number: 2 ____________________

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	

(Turn over)

ADDITIONAL MATERIALS

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

ITEMS INCLUDED WITH QUESTION PAPER

A separate Diagram Booklet.

The Diagram Booklet MUST be handed in to the invigilators and sent for marking.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball – point pen, black felt tip or your usual method.

Write your name, centre number and candidate number in the spaces on the front cover.

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 this booklet, taking care to number the question(s) correctly.

(Turn over)

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.

(Turn over)

Answer ALL questions.

1. The Krebs cycle is a set of enzyme − controlled reactions that take place in aerobic organisms. Refer to IMAGE 1.1A and IMAGE 1.1B in the separate Diagram Booklet. IMAGE 1.1A shows a simplified diagram of the Krebs cycle and IMAGE 1.1B shows the structural formulae of two key intermediates.

   (a) (i) Complete TABLE 1.2 below by recording the number of each type of atom present in the two named compounds shown in IMAGE 1.1B.

TABLE 1.2

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

[2 marks]

continued on the next page . . .

(Turn over)

Question 1 (a) continued

1. (a) (ii) Using the information provided in IMAGES 1.1A and 1.1B, identify which of the intermediates labelled V – Z on the drawing of the Krebs cycle is α ketoglutaric acid and which is citric acid.

α ketoglutaric acid = ______________________________

citric acid = ______________________________________

[1 mark]

continued on the next page . . .

Question 1 (a) continued

1. (a) (iii) Use the information in IMAGE 1.1A to state what happens to each of the following atoms in the conversion of **V** to **W**.

Carbon ______________________________________

____

____

Hydrogen ______________________________________

____

____

[2 marks]

continued on the next page . . .

Question 1 continued

1. (b) Malonic acid is a dicarboxylic acid with the chemical formula $C_3H_4O_4$ TABLE 1.3 provided in the separate Diagram Booklet, 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.

1. (b) (i) Tube 3 in TABLE 1.3 acts as a control. Describe the purpose of tube 3 in this experiment.

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____

____

[1 mark]

continued on the next page . . .

(Turn over)

Question 1 (b) continued

1. (b) (ii) Describe the evidence from TABLE 1.3 which supports the hypothesis that malonic acid is a respiratory poison.

[2 marks]

continued on the next page . . .

Question 1 (b) continued

1. (b) (iii) Refer to IMAGE 1.4 in the separate Diagram Booklet. IMAGE 1.4 shows the structural formulae of another Krebs cycle intermediate, succinic acid, and a molecule that is believed to act as a respiratory poison, malonic acid.

Using information from IMAGE 1.4 and your knowledge of enzymes suggest how malonic acid could act as a respiratory poison. Explain your answer.

(Turn over)

[2 marks]

(Total for Question 1 = 10 marks)

2. Refer to IMAGE 2.1 and IMAGE 2.2 in the separate Diagram Booklet. 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.

(a) (i) Compare the distribution of chloroplasts in the millet leaf with the distribution of chloroplasts in a typical leaf such as LIGUSTRUM.

(Turn over)

[2 marks]

2. (a) (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 marks]

continued on the next page . . .

(Turn over)

Question 2 continued

2. (b) During non-cyclic photophosphorylation electrons are passed between components in the thylakoid membranes.

(i) Name the process by which electrons are released from water.

____

____

[1 mark]

continued on the next page . . .

Question 2 (b) continued

The relative energy levels of the electrons in some of the components in the thylakoid membrane are shown in TABLE 2.3

TABLE 2.3

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

continued on the next page . . .

Question 2 (b) continued

2. (b) (ii) Refer to GRAPH 2.4 in the separate Diagram Booklet. PLOT AND LABEL the positions of the ELECTRON ACCEPTORS A_{I} AND A_{II} on GRAPH 2.4 (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 marks]

continued on the next page . . .

Question 2 (b) continued

2. (b) (iii) Use your knowledge of non − cyclic photophosphorylation to describe and explain the changes in relative electron energy levels shown in GRAPH 2.4

(Turn over)

[5 marks]

2. (c) Refer to IMAGE 2.5 in the separate Diagram Booklet. ATP production is carried out in chloroplasts by chemiosmosis which involves creating a proton gradient across the thylakoid membrane.

(i) On IMAGE 2.5:

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 mark]

continued on the next page . . .

(Turn over)

Question 2 (c) continued

2. (c) (ii) In addition to proton pumps, two other processes shown in IMAGE 2.5 also contribute to creating a proton gradient across the thylakoid membrane.

Describe these TWO processes and state where each occurs.

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[3 marks]

(Total for Question 2 = 16 marks)

(Turn over)

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}).**

Refer to IMAGE 3.1 in the separate Diagram Booklet. 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.

continued on the next page . . .

Question 3 continued

3. (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 mark]

(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 mark]

continued on the next page . . .

Question 3 (a) (ii) continued

3. (a) (ii) II. Explain your choice in terms of WHO limits.

[1 mark]

continued on the next page . . .

Question 3 continued

3. (b) 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 in the separate Diagram Booklet.

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'.

continued on the next page . . .

Question 3 (b) continued

3. (b) (i) Use the information from TABLE 3.2 and the probabilities shown in TABLE 3.3 in the separate Diagram Booklet, to decide whether to accept or reject the null hypothesis at a suitable probability level. Explain your answer.

(Turn over)

[4 marks]

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

[2 marks]

continued on the next page . . .

Question 3 (b) continued

3. (b) (iii) 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 in the separate Diagram Booklet.

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.

(Turn over)

[2 marks]

3. (b) (iii) II. Explain how the design of the road closure experiment could be changed to take account of these findings.

[1 mark]

continued on the next page . . .

Question 3 continued

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

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 marks]

(Total for Question 3 = 15 marks)

(Turn over)

4. Refer to IMAGE 4.1 in the separate Diagram Booklet. 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.

(a) Name the type of nervous system in HYDRA and explain why its movements take a relatively long time.

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[2 marks]

continued on the next page . . .

Question 4 continued

4. (b) Refer to IMAGE 4.2 and IMAGE 4.3 in the separate Diagram Booklet. 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 represents an electron micrograph of the tip of a specialised nerve cell together with part of an adjacent cell.

(i) Name the structure labelled C in IMAGE 4.2

[1 mark]

continued on the next page . . .

Question 4 (b) continued

4. (b) (ii) Name the type of vesicle in IMAGE 4.3 and describe its function.

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[1 mark]

(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.

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(Turn over)

[2 marks]

4. (c) Refer to GRAPH 4.4 in the separate Diagram Booklet. GRAPH 4.4 shows an oscilloscope trace from an experiment to measure the potential difference across the membrane of a squid giant axon.

(i) Name the processes represented by letters **X** and **Y** in GRAPH 4.4

X ______________________________

Y ______________________________

[1 mark]

continued on the next page . . .

(Turn over)

Question 4 (c) continued

4. (c) (ii) With reference to GRAPH 4.4 explain how voltage − gated sodium ion channels bring about process X.

[2 marks]

continued on the next page . . .

Question 4 continued

4. (d) Refer to the GRAPH 4.5 in the separate Diagram Booklet. 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.

Describe the relationship between internode length and conduction speed and use your knowledge of nerve impulse transmission to explain the results.

(Turn over)

[4 marks]

(Total for Question 4 = 13 marks)

(Turn over)

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 in the separate Diagram Booklet.

A $0 \bullet 5\ cm^3$ 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.

(a) (i) Describe TWO precautions that should have been taken to prevent contamination of the $0 \bullet 5\ cm^3$ samples AS THEY WERE TRANSFERRED TO THE AGAR PLATES.

(Turn over)

[2 marks]

5. (a) The results for the 160 – minute sample and the 240 – minute sample are shown in TABLE 5.2 in the separate Diagram Booklet.

continued on the next page . . .

(Turn over)

Question 5 (a) continued

5. (a) (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.

Number of bacterial cells = ____________________ per cm^3

[2 marks]

continued on the next page . . .

Question 5 continued

5. (b) Refer to GRAPH 5.3 in the separate Diagram Booklet. 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.

(i) Use GRAPH 5.3 and the formula given on the next page to calculate the number of generations produced per hour between 1•5 hours and 3•5 hours.

continued on the next page . . .

Question 5 (b) (i) continued

EXPRESS YOUR ANSWER TO THE NEAREST WHOLE NUMBER.

Number of generations per hour =

$$\frac{\log_{10}[X_t] - \log_{10}[X_0]}{0 \cdot 301 \times t}$$

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 = ______________________

[3 marks]

continued on the next page . . .

(Turn over)

Question 5 (b) continued

5. (b) (ii) Explain the shape of the growth curve over the first 30 minutes.

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[1 mark]

(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.

continued on the next page . . .

(Turn over)

Question 5 (b) (iii) continued

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 marks]

(Total for Question 5 = 11 marks)

(Turn over)

6. Refer to IMAGE 6.1 in the separate Diagram Booklet. 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.

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 mark]

continued on the next page . . .

Question 6 (a) continued

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

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[2 marks]

continued on the next page . . .

(Turn over)

Question 6 (a) continued

6. (a) (iii) Using the information provided in IMAGE 6.1, state the ranges of water depth over which duckweed and pondweed were found.

Duckweed ______________________________

Pondweed ______________________________

[2 marks]

(b) Refer to IMAGE 6.2 in the separate Diagram Booklet. IMAGE 6.2 shows a diagram of their growth patterns.

continued on the next page . . .

Question 6 (b) continued

6. (b) (i) With reference to IMAGE 6.2 suggest why duckweed outcompetes pondweed in the shallower part of the range.

[1 mark]

(ii) Name TWO nutrients for which the plants will compete AND explain what each nutrient is used for in the plants.

[3 marks]

continued on the next page . . .

(Turn over)

Question 6 (b) continued

6. (b) (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 marks]

continued on the next page . . .

Question 6 continued

6. (c) CEPAEA NEMORALIS is a species of snail that exists in a banded form (dark bands on its shell) and a non−banded form (plain shells with no bands). Both of these forms 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.

(i) State how biologists would determine that the snails found in the survey belong to the same species.

[1 mark]

continued on the next page . . .

Question 6 (c) continued

6. (c) (ii) Give the term used for the type of variation shown by the two forms of snail found.

____

[1 mark]

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

____

____

____

____

____

____

[2 marks]

(Total for Question 6 = 16 marks)

(Turn over)

7. Refer to IMAGES 7.1 and 7.2 in the separate Diagram Booklet. 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. The condition is called OEDEMA.

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.

continued on the next page . . .

Question 7 continued

Long − term alcohol use has been shown to cause thickening of the basement membrane of glomeruli. Explain how this change could cause OEDEMA (Details of tissue fluid formation are not required.)

(Turn over)

(Turn over)

(Turn over)

(Turn over)

(Turn over)

(Turn over)

[9 QER marks]

(Total for Question 7 = 9 marks)

TOTAL FOR PAPER = 90 MARKS

END OF PAPER

Question Number	Additional pages, if required. Write the question number(s) in the left – hand margin.

(Turn over)

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(Turn over)

Question Number	Additional pages, if required. Write the question number(s) in the left – hand margin.

GCE A LEVEL

1400U30 – 1

WEDNESDAY, 5 JUNE 2024 – AFTERNOON

BIOLOGY − A2 UNIT 3
ENERGY, HOMEOSTASIS AND THE ENVIRONMENT

The Diagram Booklet MUST be handed in to the invigilators and sent for marking.

Diagram Booklet

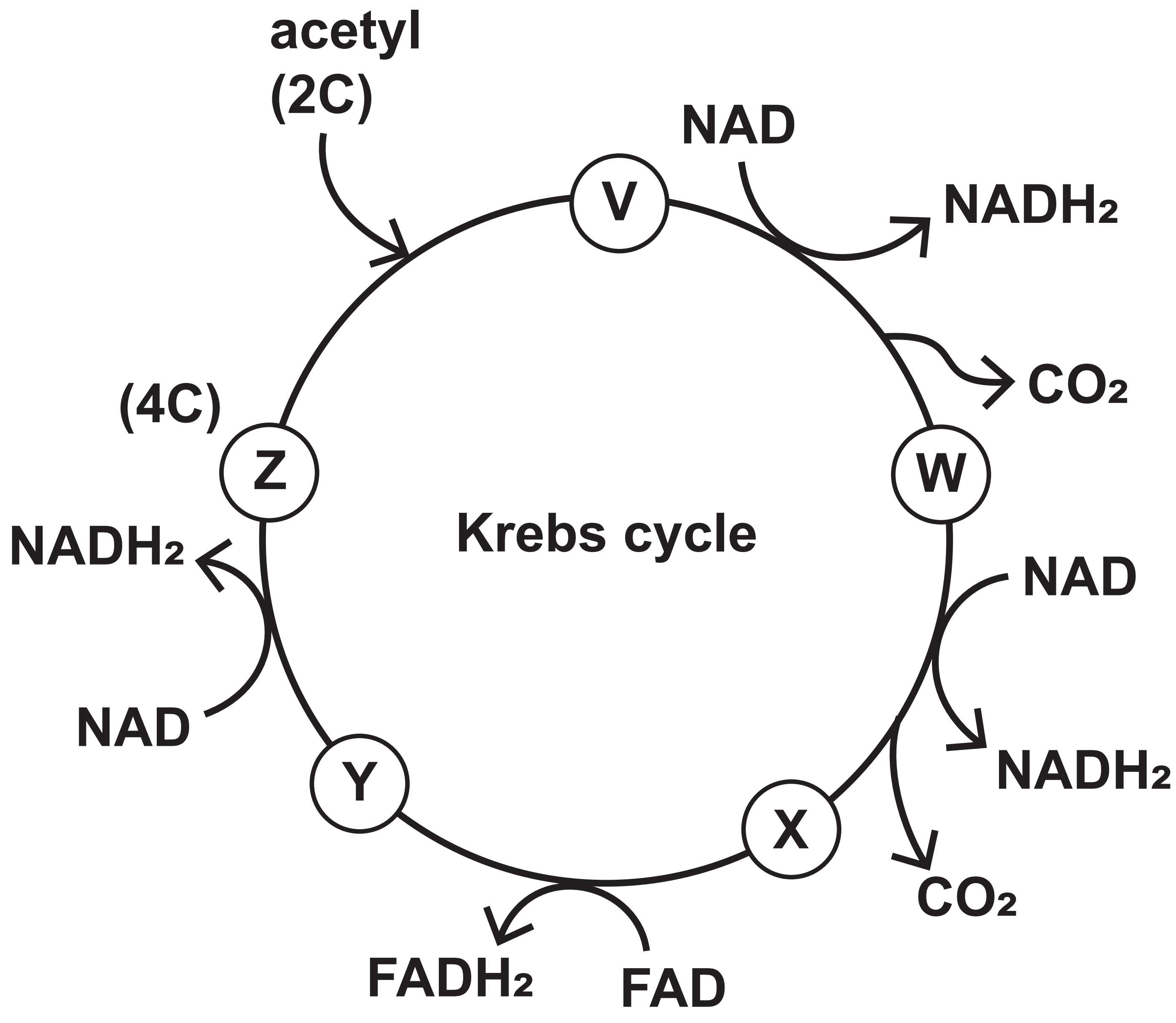
Surname: ______________________

First name(s): ______________________

Centre Number: ______________________

Candidate Number: 2 ______________________

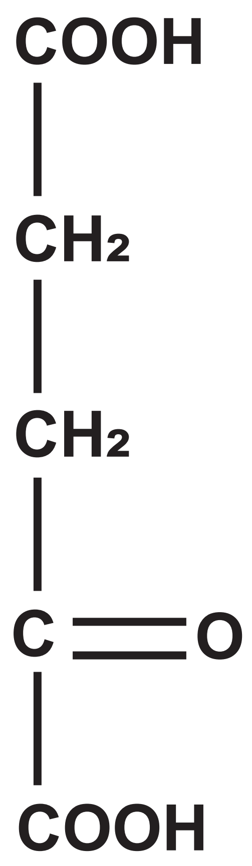
IMAGE 1.1A



acetyl
(2C)
V
NAD
NADH₂
CO₂
W
NAD
NADH₂
CO₂
X
FAD
FADH₂
Y
NAD
NADH₂
Z
(4C)
Krebs cycle

IMAGE 1.1B

α ketoglutaric acid



citric acid

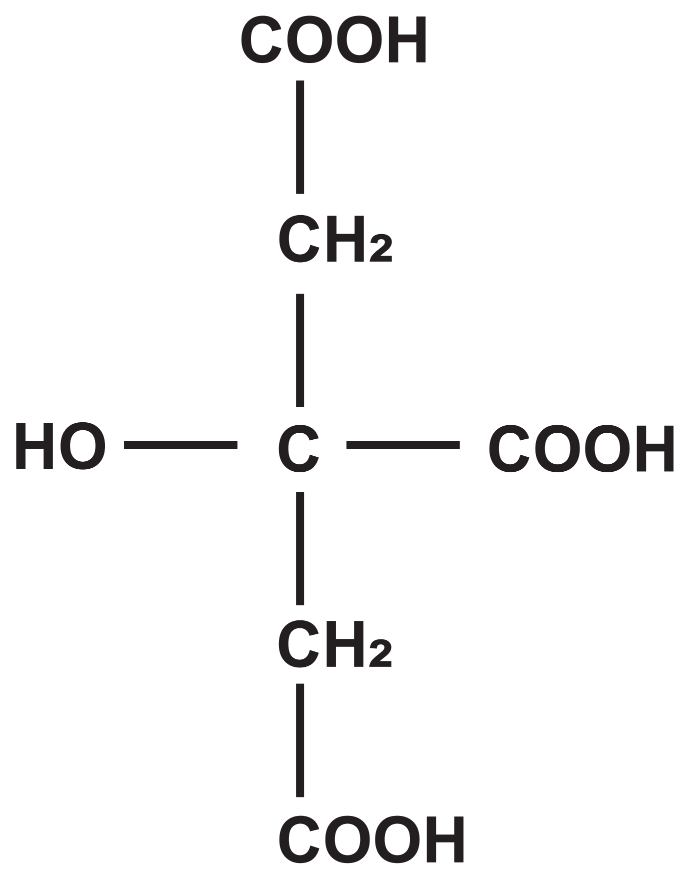
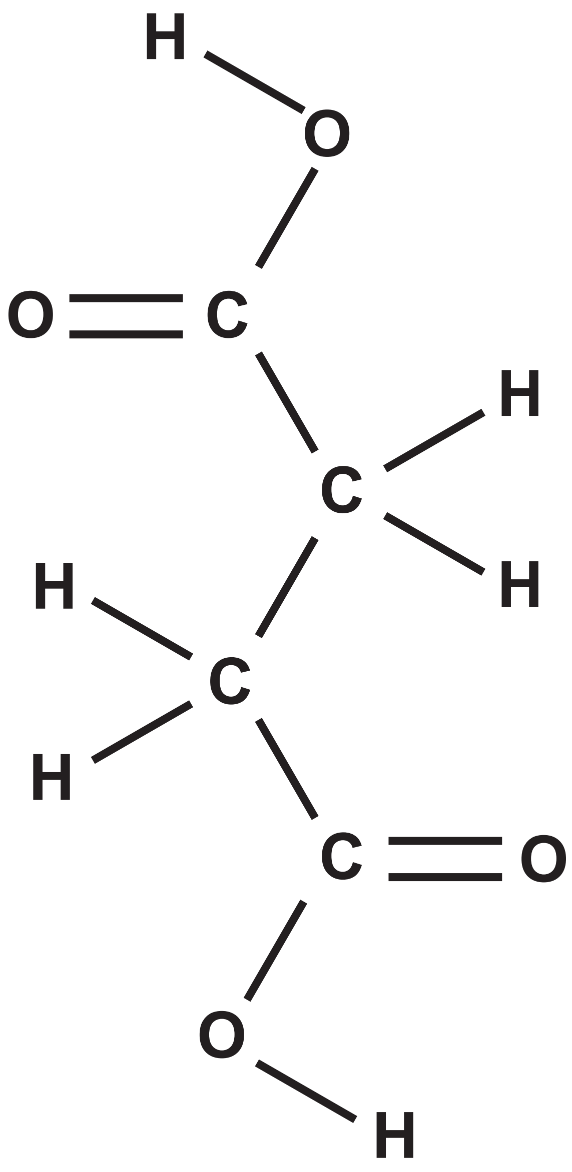


TABLE 1.3

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

IMAGE 1.4

succinic acid



malonic acid

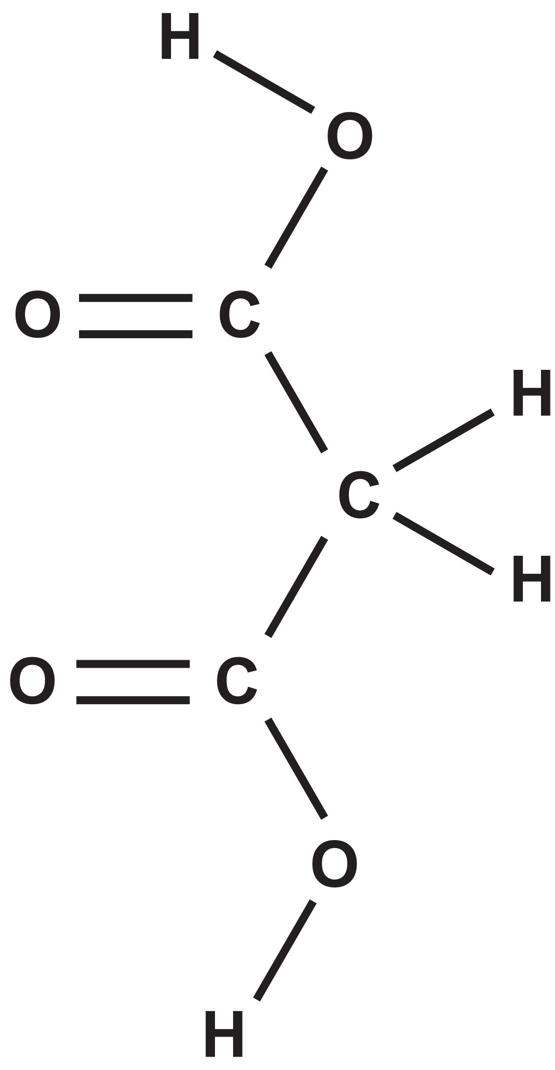
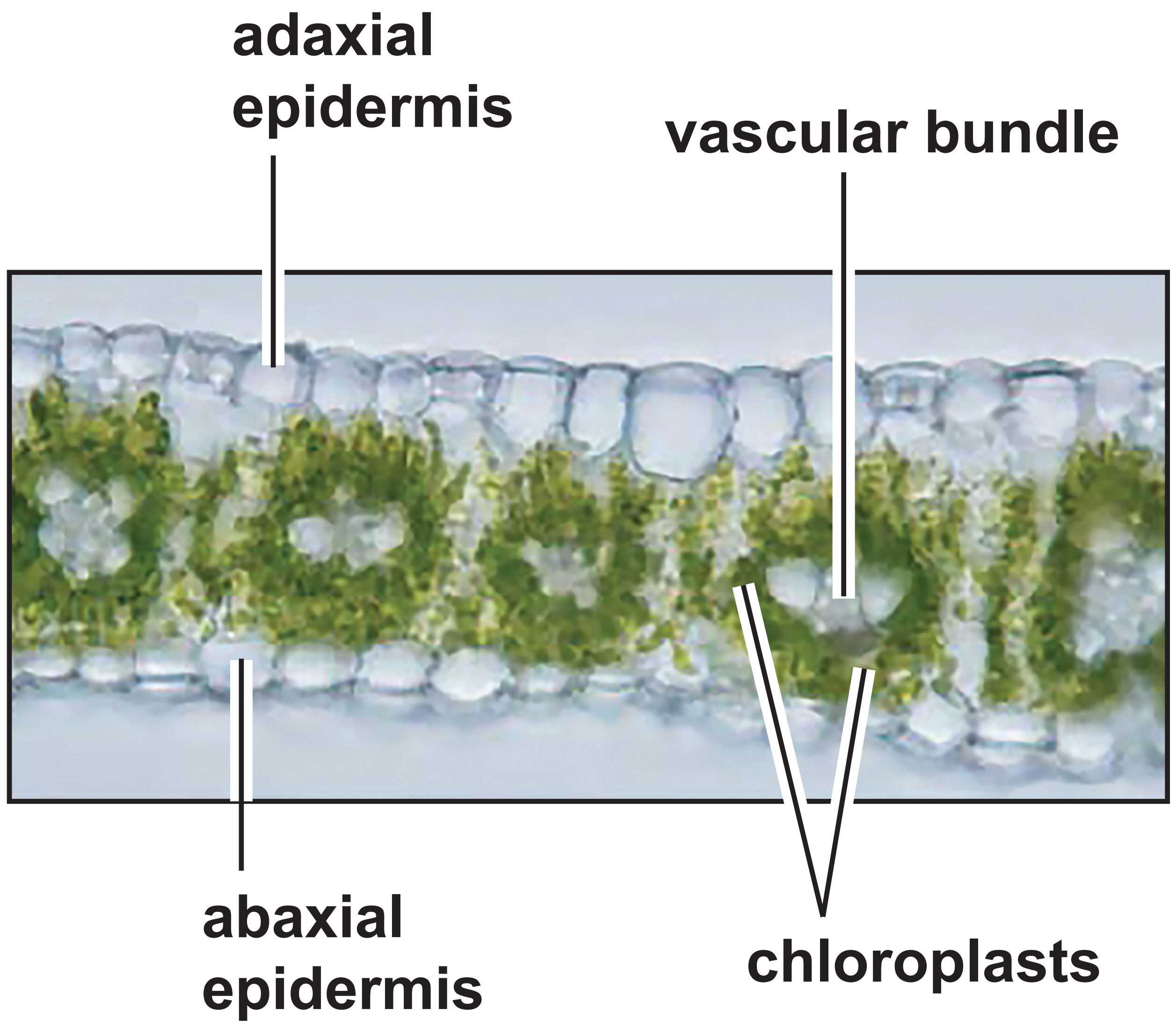


IMAGE 2.1 and IMAGE 2.2

IMAGE 2.1

IMAGE 2.2



GRAPH 2.4

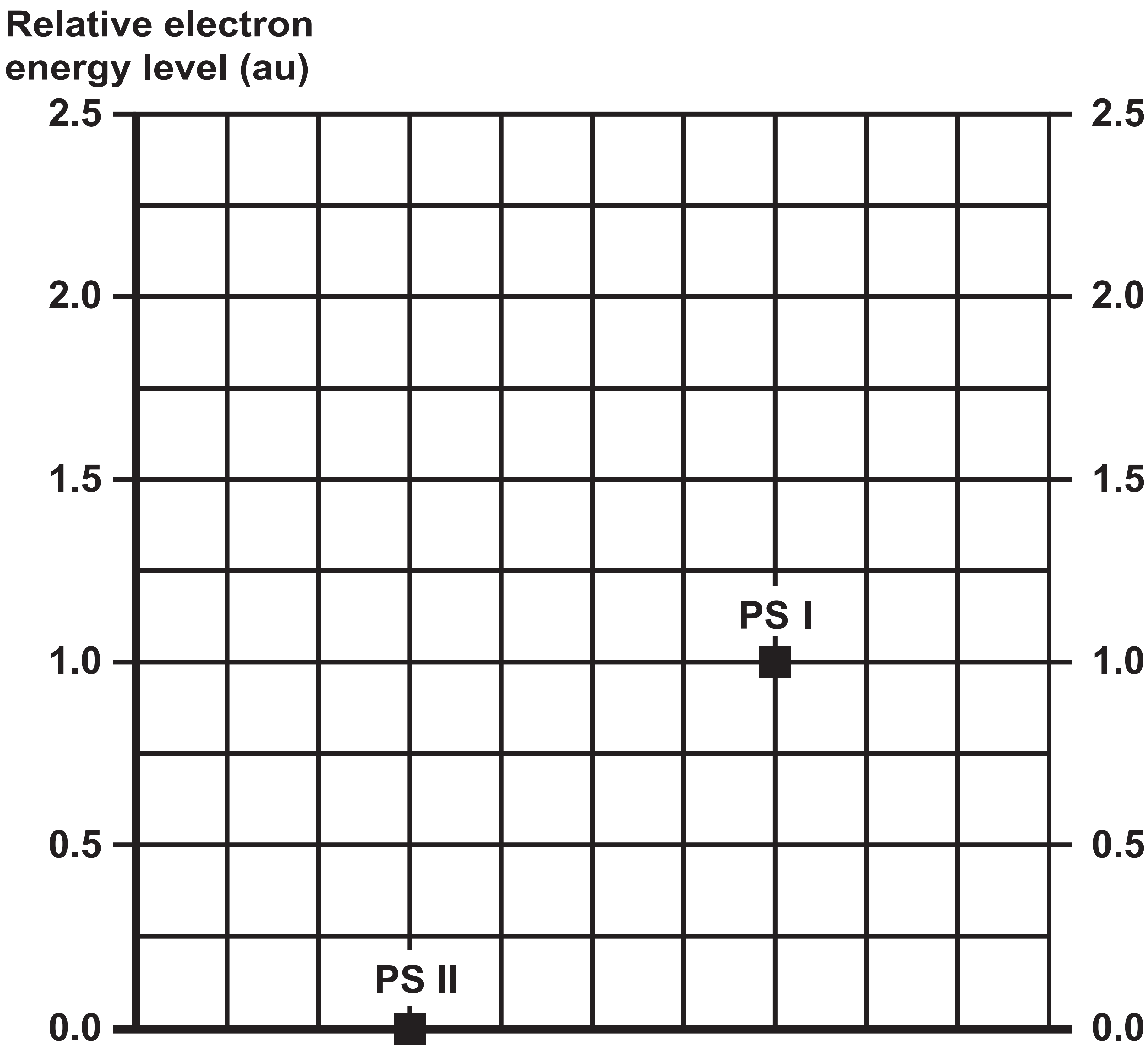

Relative electron
energy level (au)
2.5
2.0
1.5
1.0
0.5
0.0
PS I
PS II
2.5
2.0
1.5
1.0
0.5
0.0

IMAGE 2.5

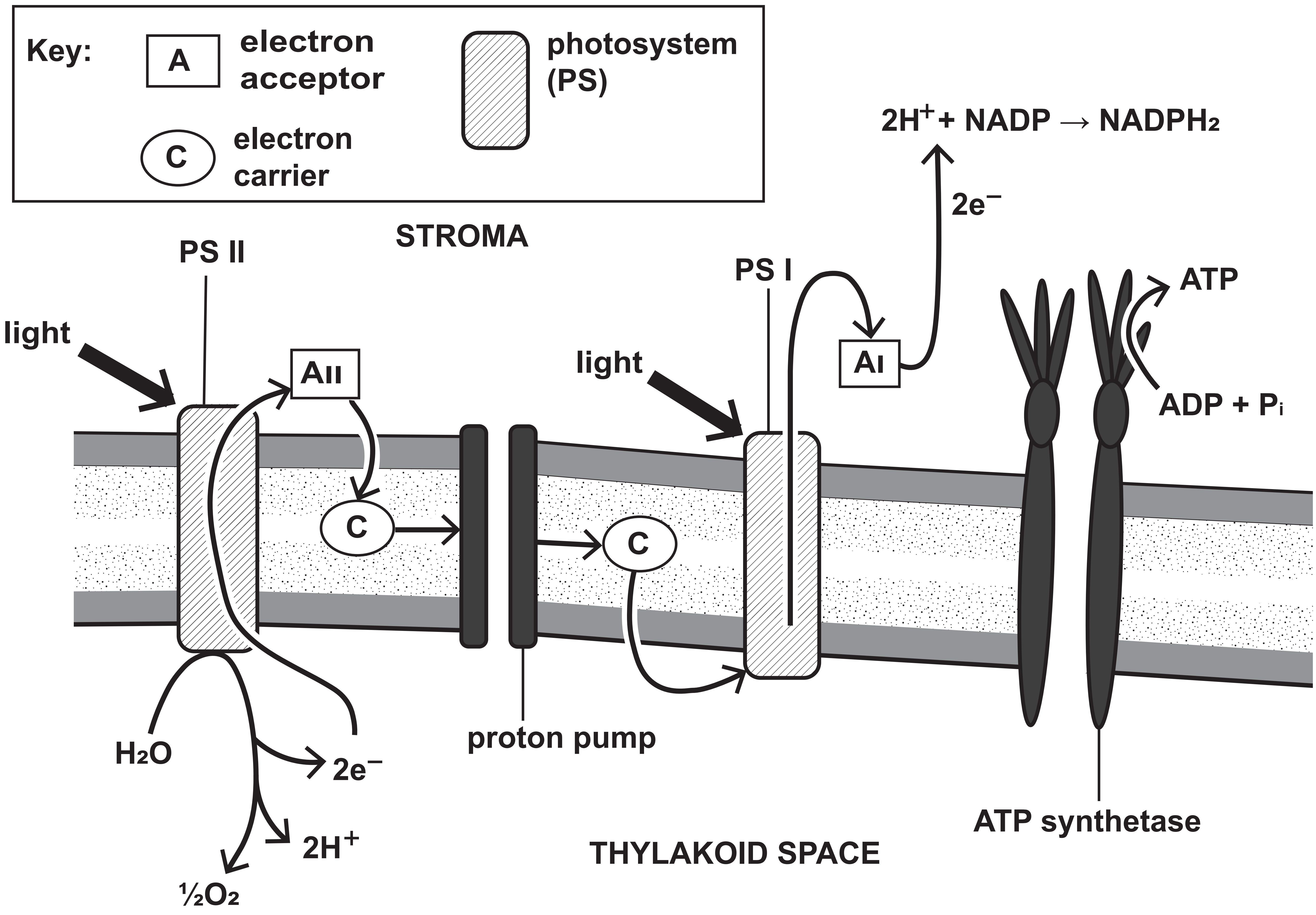

Key:
A electron acceptor
C electron carrier
photosystem (PS)
2H+ + NADP → NADPH2
2e−
STROMA
PS II
PS I
ATP
light
AII
light
AI
ADP + Pi
C
C
H2O
2e−
proton pump
2H+
ATP synthetase
½O2
THYLAKOID SPACE

IMAGE 3.1

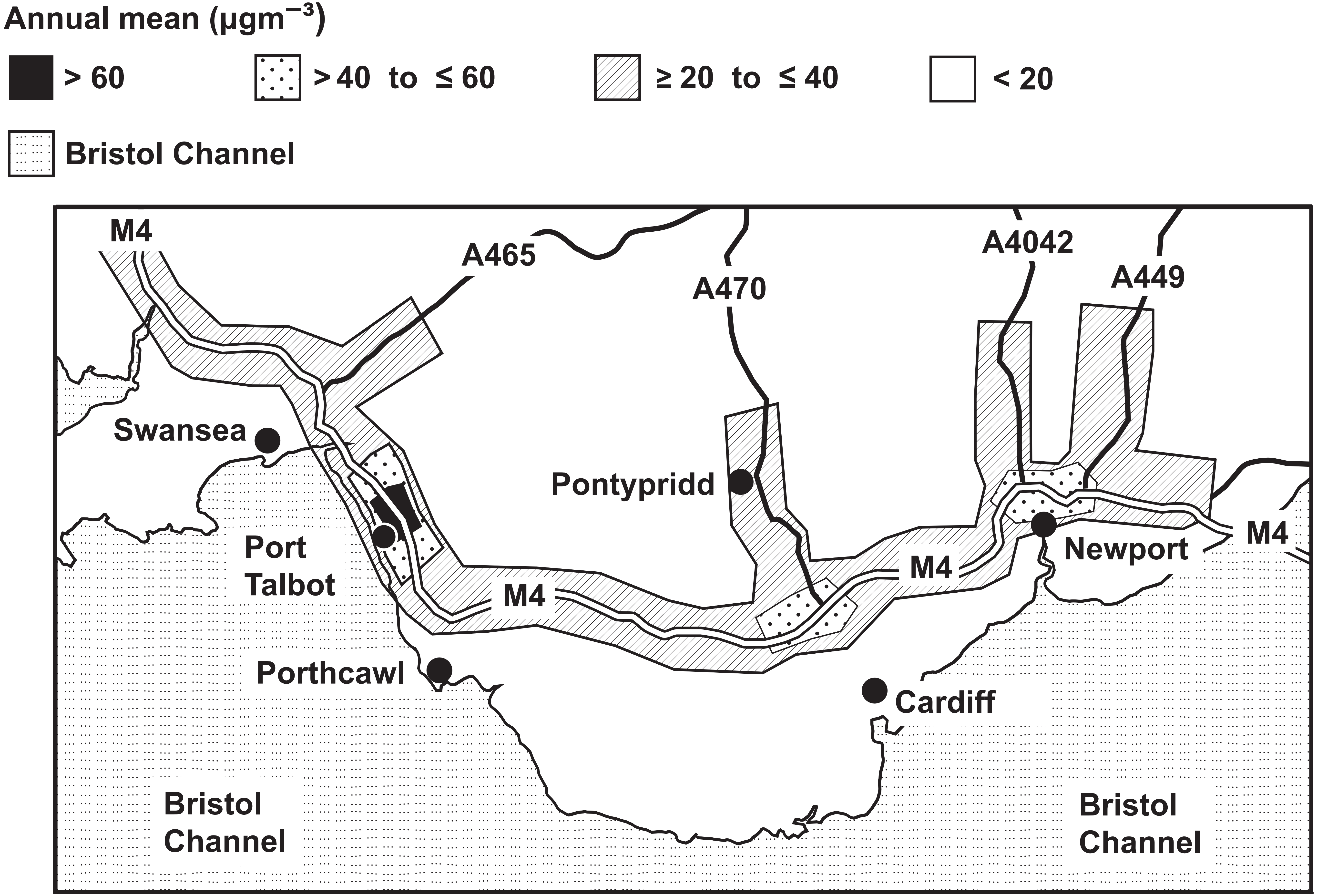

Annual mean (μgm⁻³)
> 60
> 40 to ≤ 60
≥ 20 to ≤ 40
< 20
Bristol Channel
M4
A465
A470
A4042
A449
Swansea
Pontypridd
Newport
Port Talbot
Porthcawl
Cardiff
Bristol Channel
Bristol Channel

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	

TABLE 3.3

Degrees of freedom	Level of Probability					
	0•1	0•05	0•025	0•01	0•005	0•001
27	1•314	1•703	2•052	2•473	2•771	3•421
28	1•313	1•701	2•048	2•467	2•763	3•408
29	1•311	1•699	2•045	2•462	2•756	3•396
30	1•310	1•697	2•042	2•457	2•750	3•385

GRAPH 3.4

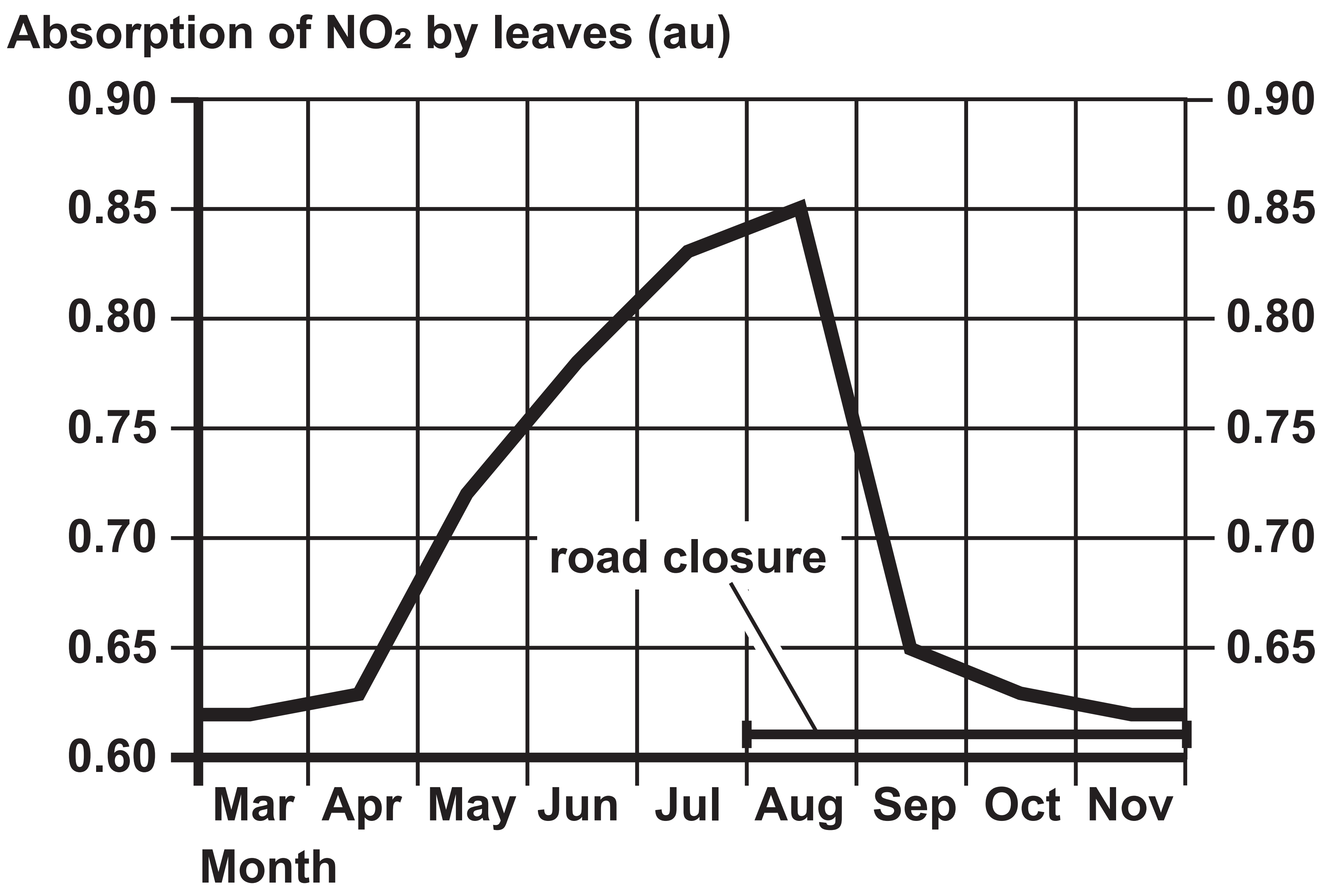
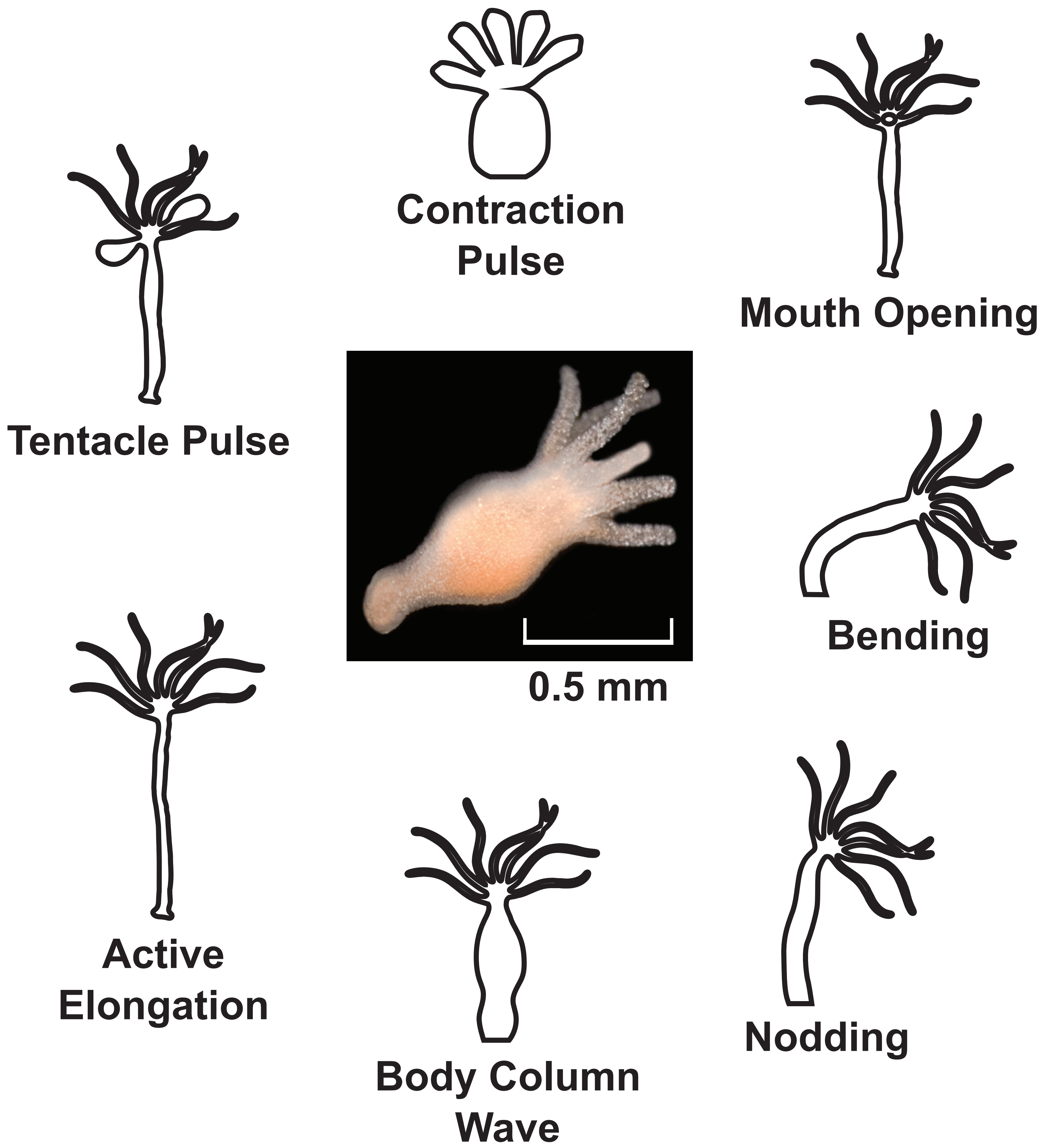

Absorption of NO₂ by leaves (au)
0.90
0.85
0.80
0.75
0.70
0.65
0.60
road closure
Mar Apr May Jun Jul Aug Sep Oct Nov
Month

IMAGE 4.1



Contraction
Pulse
Mouth Opening
Tentacle Pulse
Bending
0.5 mm
Active
Elongation
Body Column
Wave
Nodding

IMAGE 4.2 and IMAGE 4.3

IMAGE 4.2

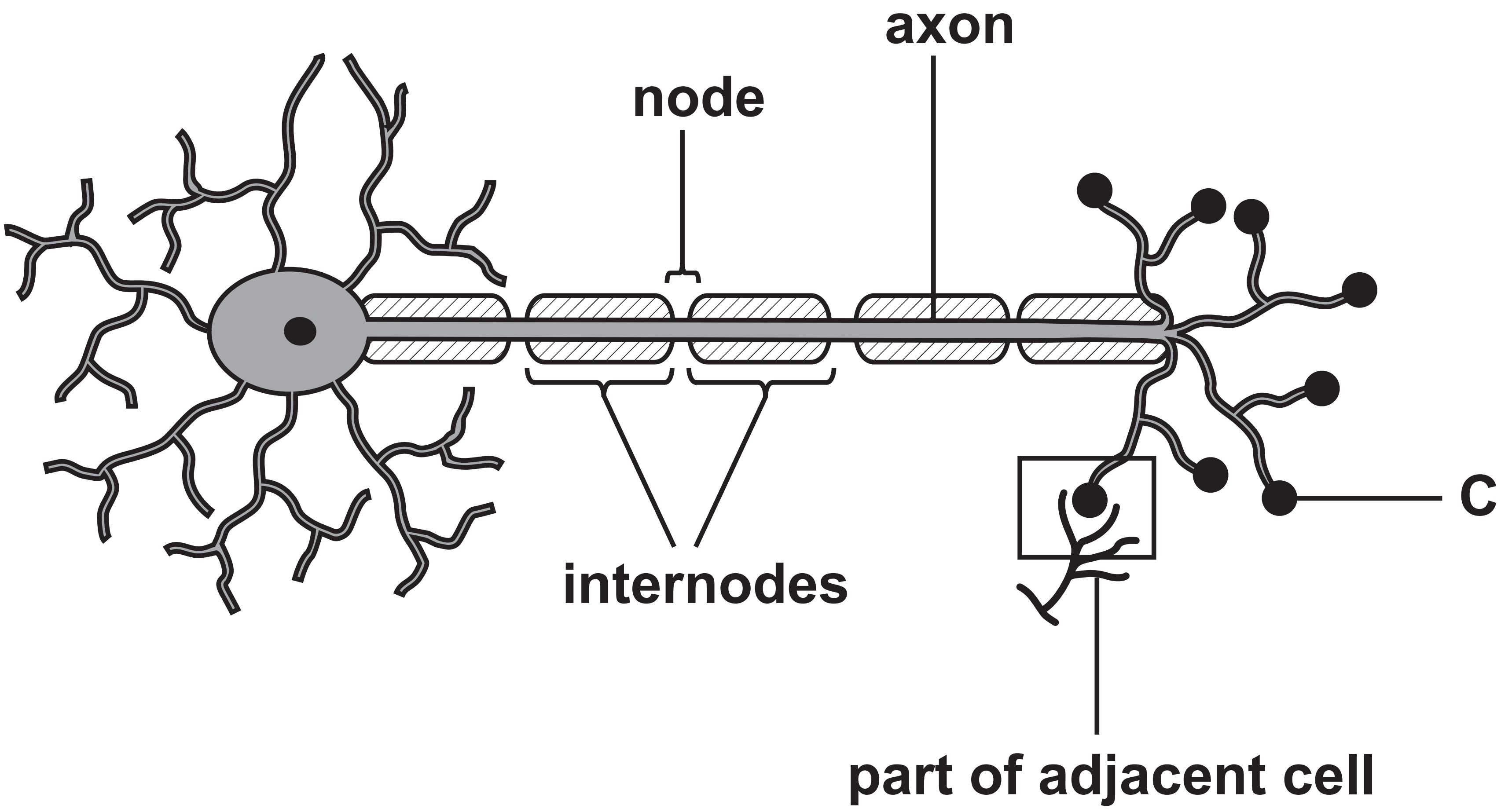
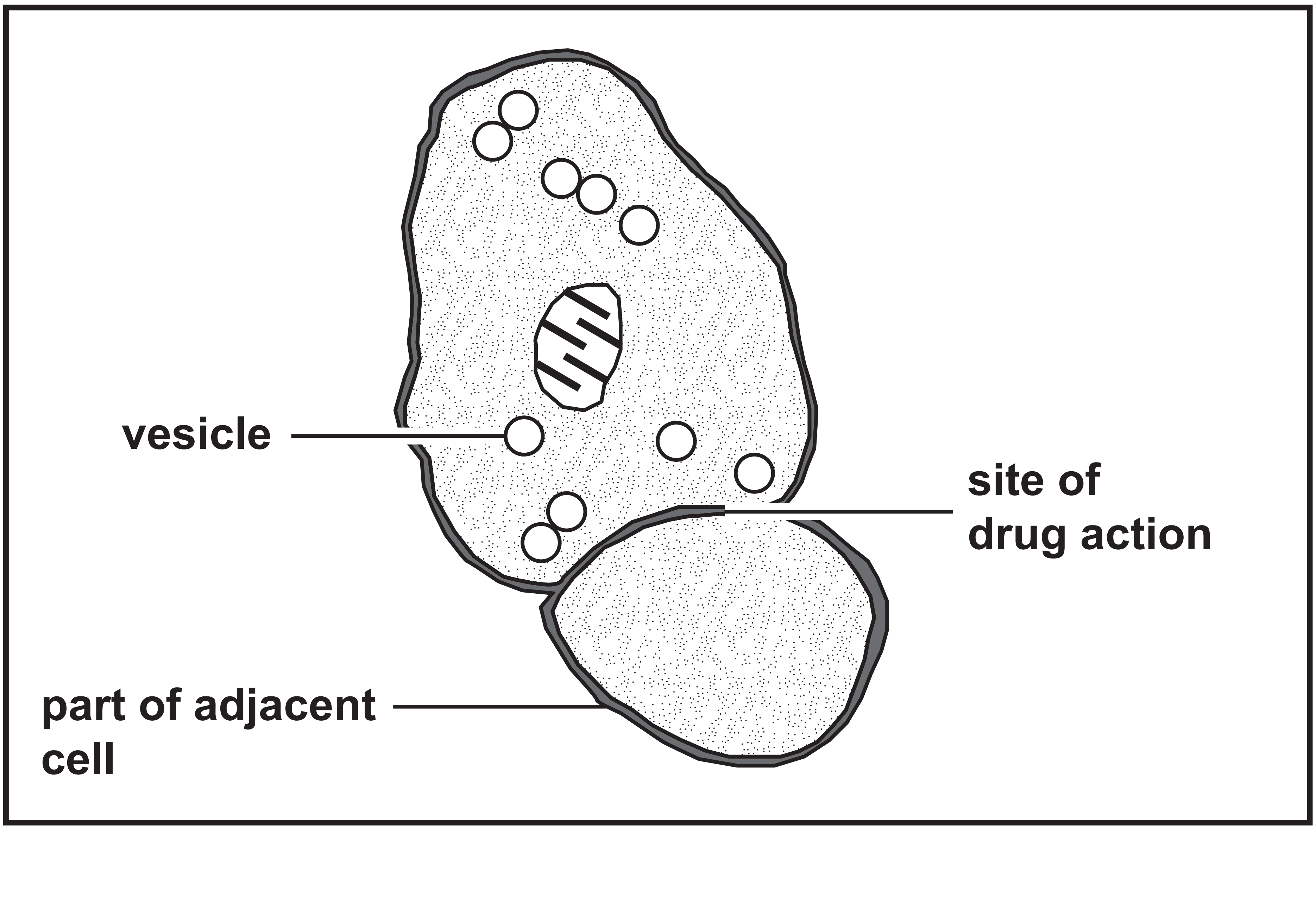
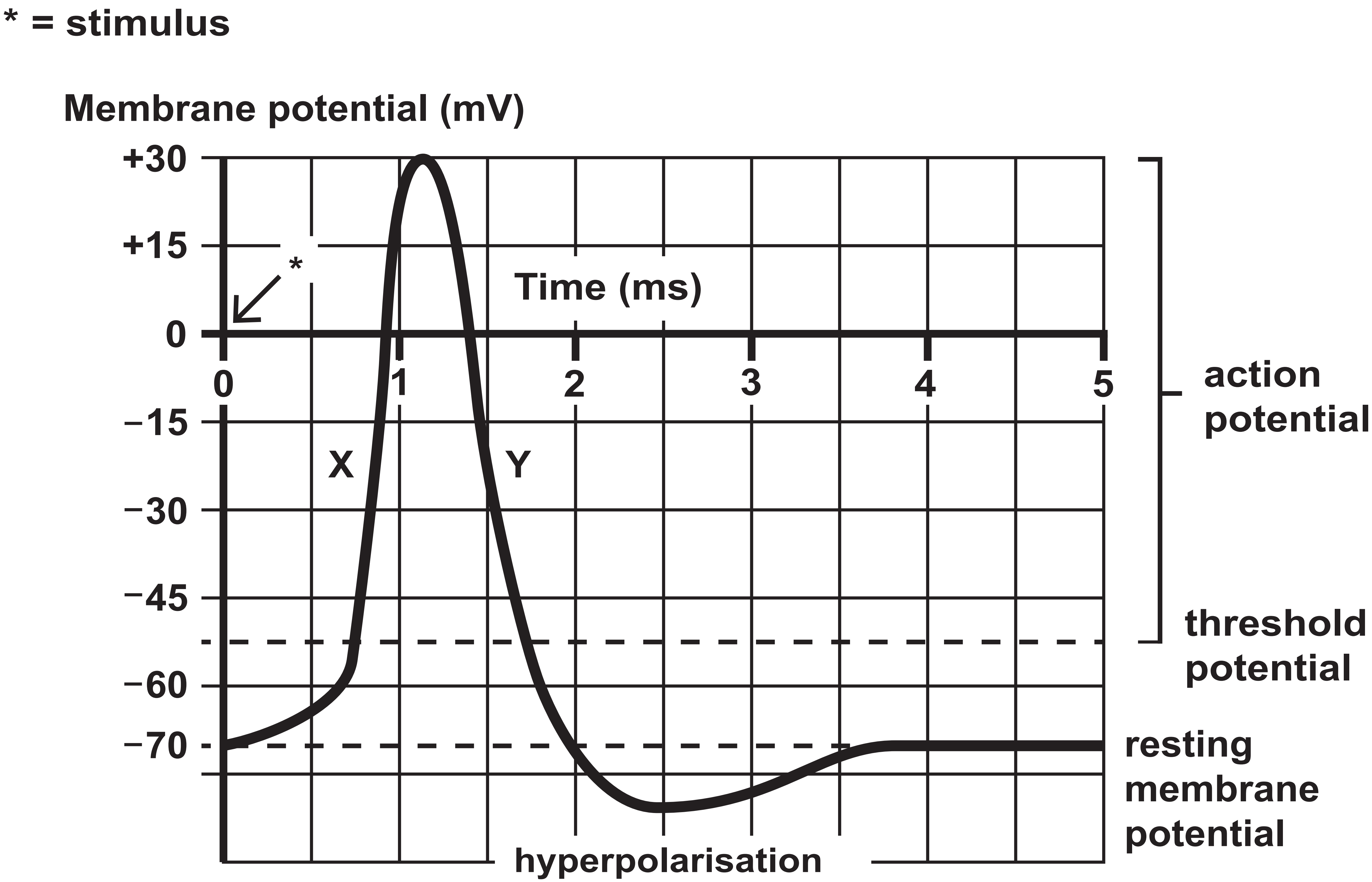


IMAGE 4.3



GRAPH 4.4



* = stimulus
Membrane potential (mV)
+30
+15
0
−15
−30
−45
−60
−70
*
Time (ms)
0
1
2
3
4
5
X
Y
action potential
threshold potential
resting membrane potential
hyperpolarisation

GRAPH 4.5

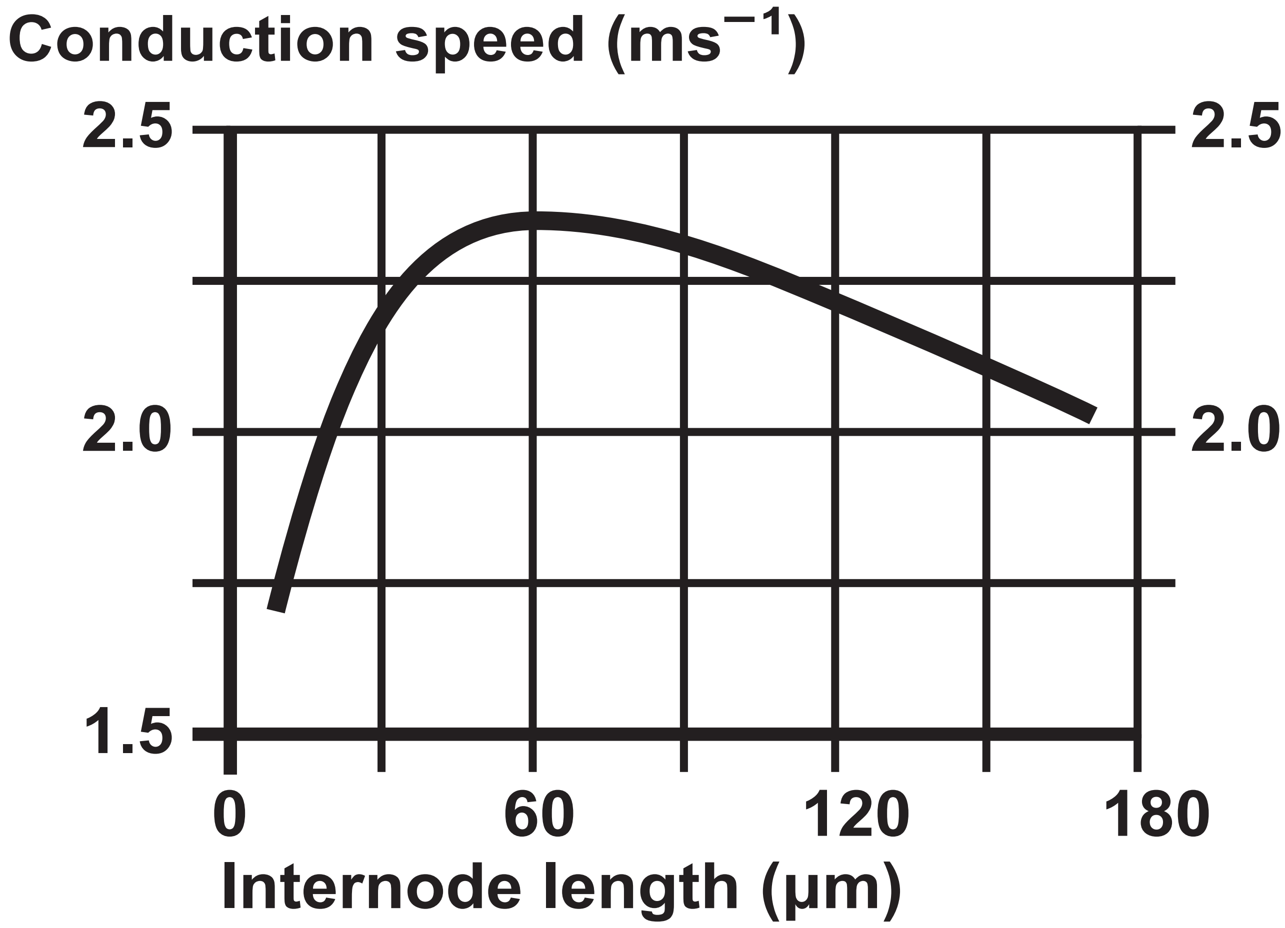

Conduction speed (ms^{-1})
2.5
2.0
1.5
2.5
2.0
0
60
120
180
Internode length (µm)

IMAGE 5.1

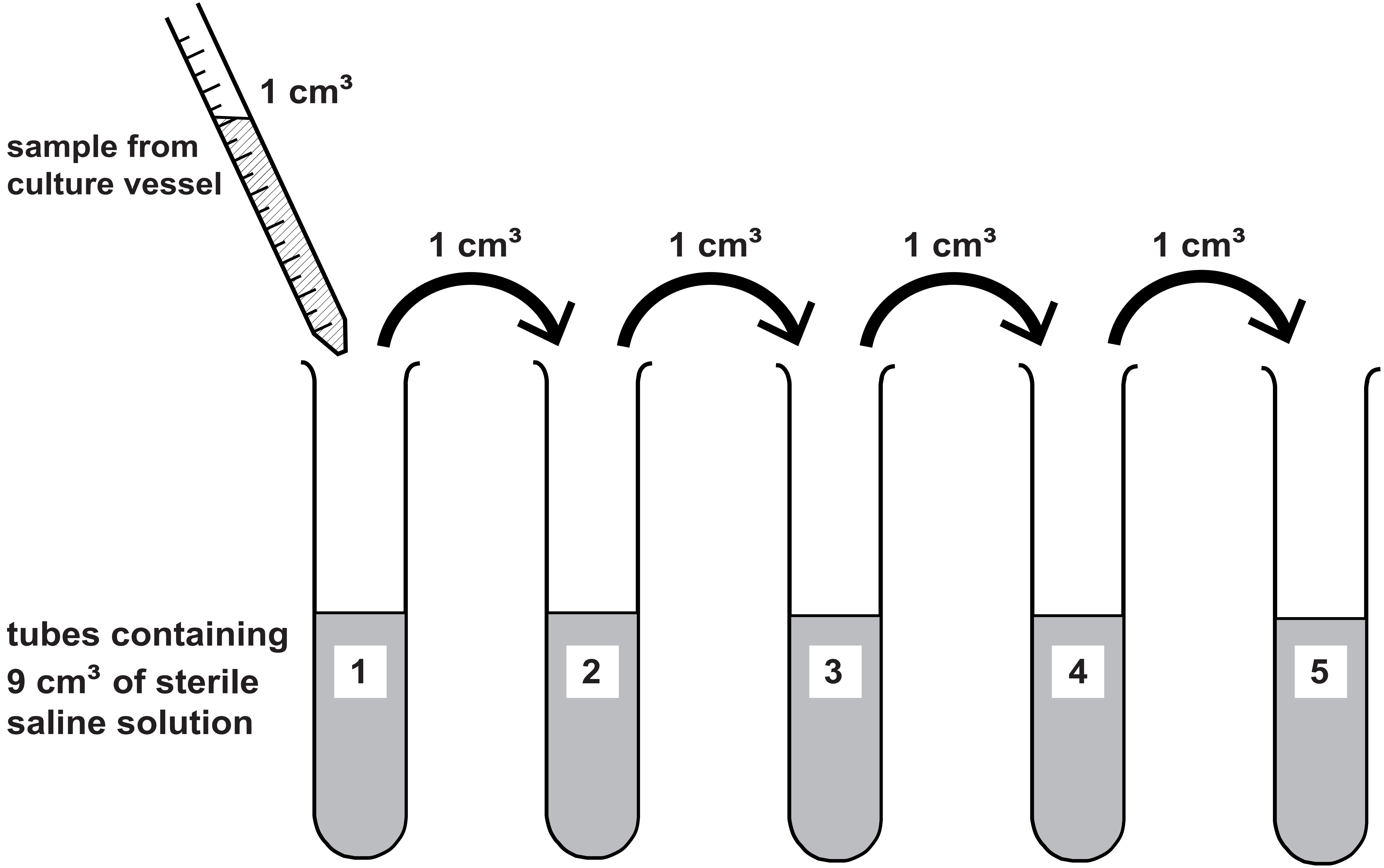

1 cm³
sample from
culture vessel
1 cm³
1 cm³
1 cm³
1 cm³
tubes containing
9 cm³ of sterile
saline solution
1
2
3
4
5

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

GRAPH 5.3

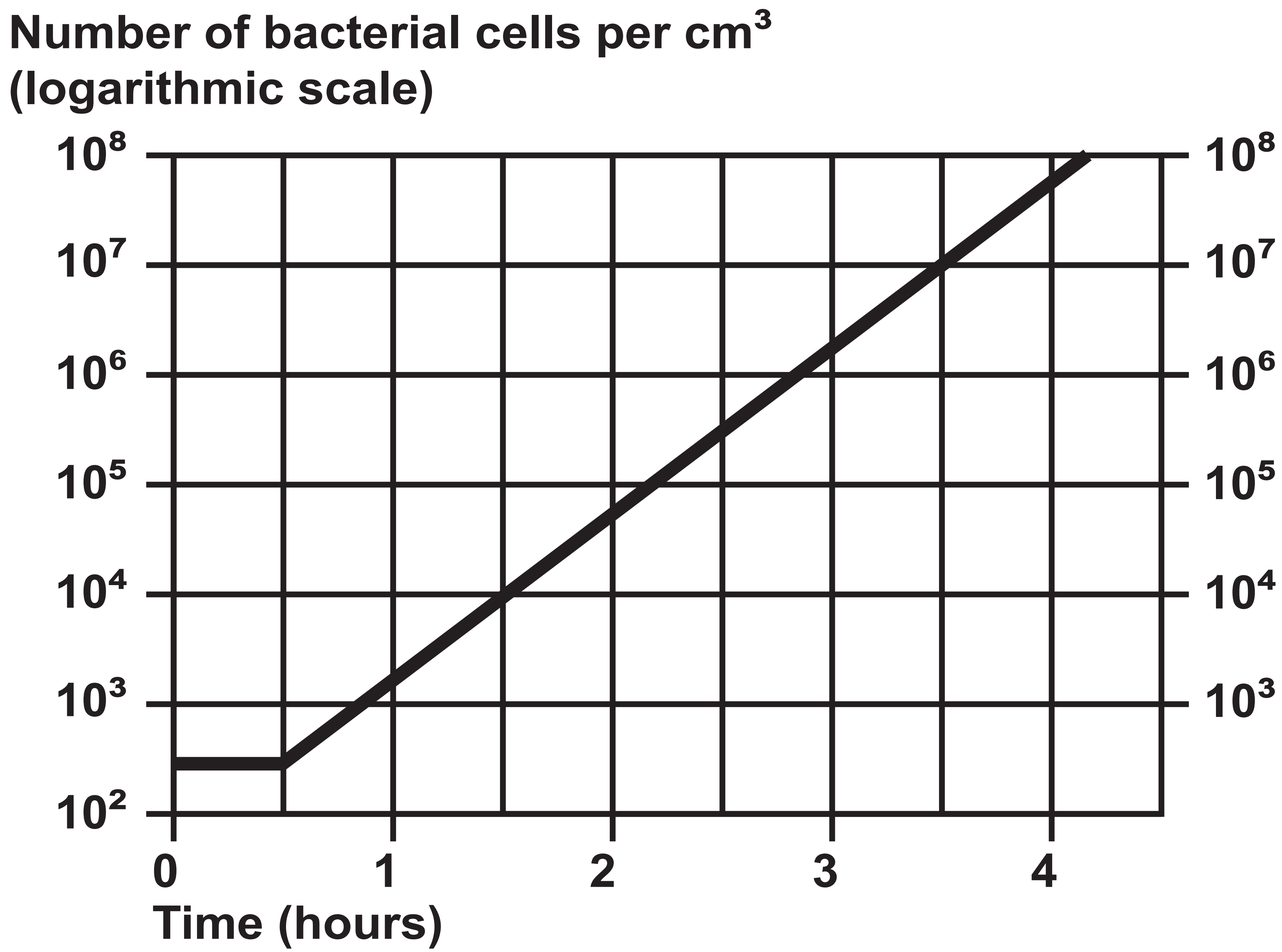

Number of bacterial cells per cm³
(logarithmic scale)
10⁸
10⁷
10⁶
10⁵
10⁴
10³
10²
0
1
2
3
4
Time (hours)

IMAGE 6.1

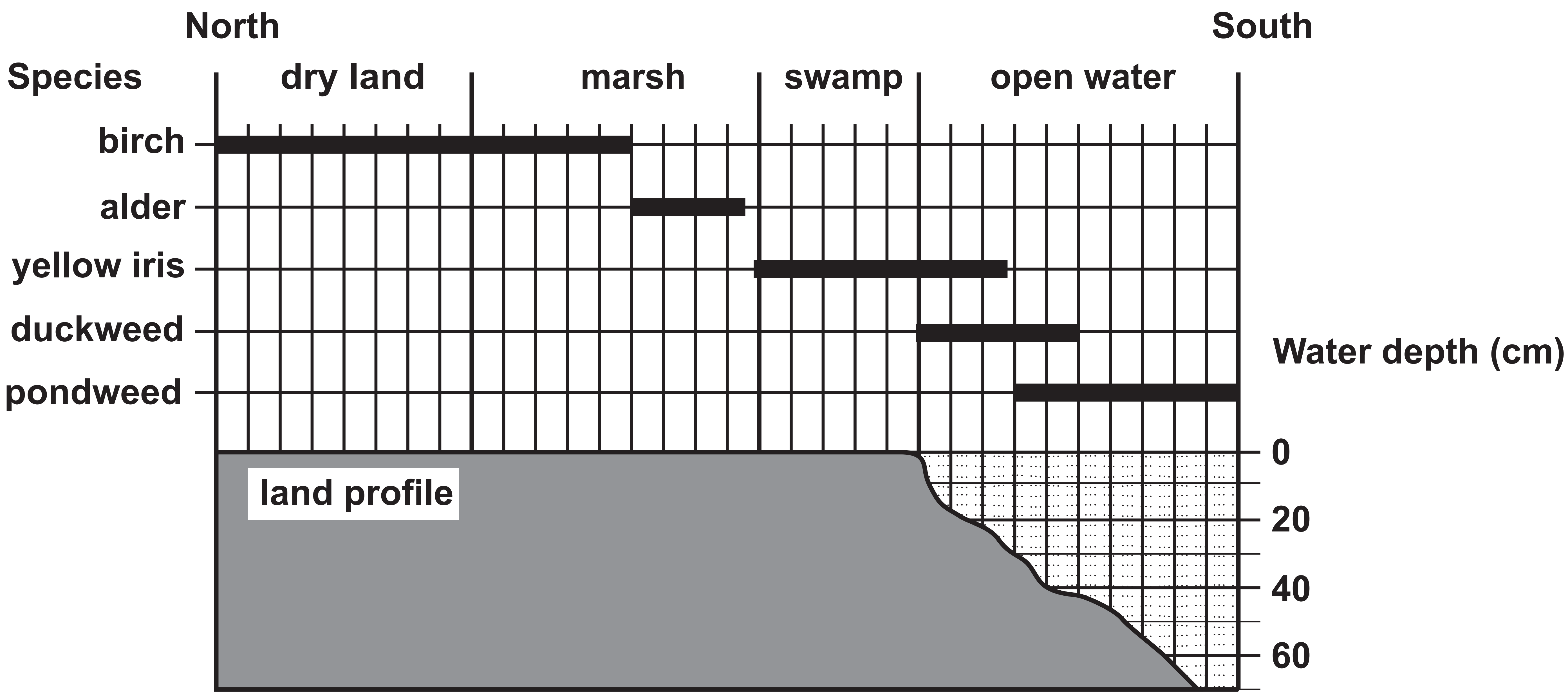

North
South
Species
dry land
marsh
swamp
open water
birch
alder
yellow iris
duckweed
pondweed
Water depth (cm)
0
20
40
60
land profile

IMAGE 6.2

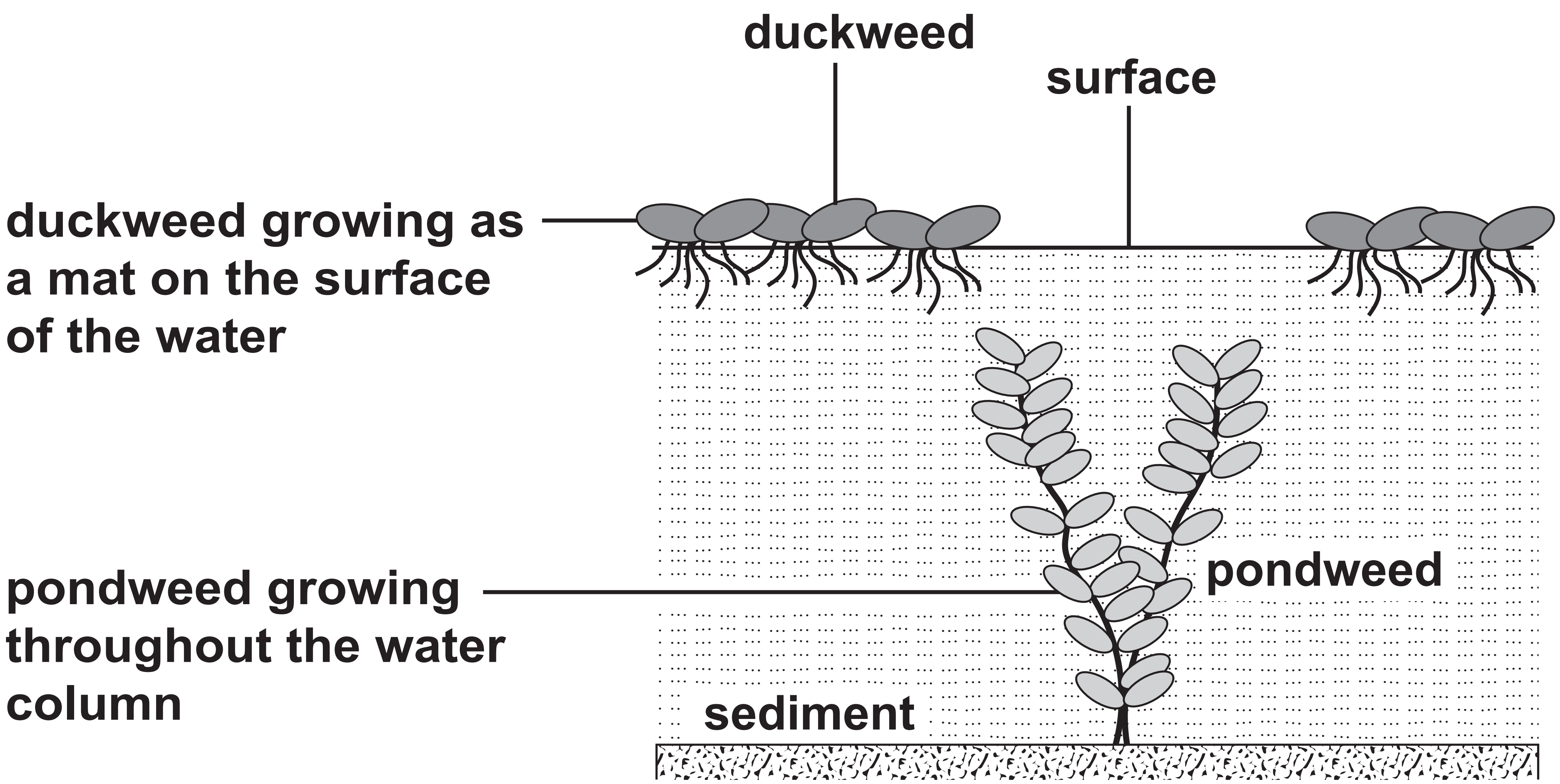

duckweed
surface
duckweed growing as a mat on the surface of the water
pondweed
pondweed growing throughout the water column
sediment

IMAGE 7.1

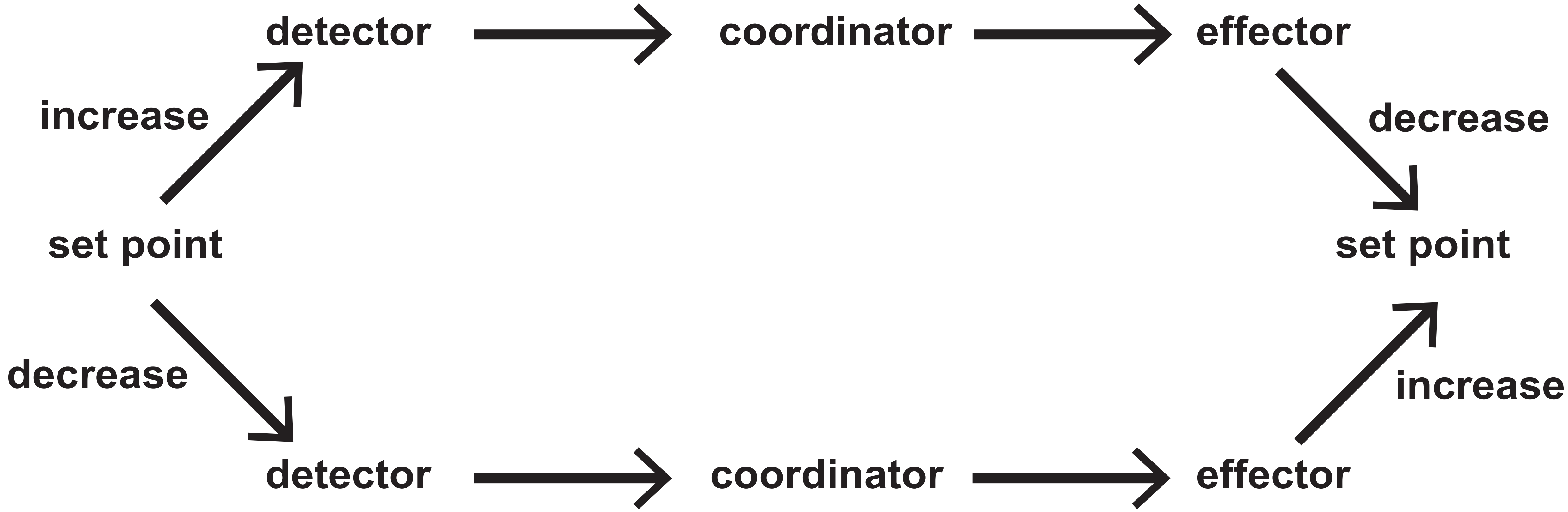

detector
coordinator
effector
increase
decrease
set point
set point
decrease
increase
detector
coordinator
effector

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.