Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

1400U30-1

S23-1400U30-1

WEDNESDAY, 7 JUNE 2023 – AFTERNOON

BIOLOGY – A2 unit 3
Energy, Homeostasis and the Environment

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**11**	
2.	**11**	
3.	**18**	
4.	**16**	
5.	**15**	
6.	**10**	
7.	**9**	
Total	**90**	

1400U301
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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 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 **7**.
The quality of written communication will affect the awarding of marks.

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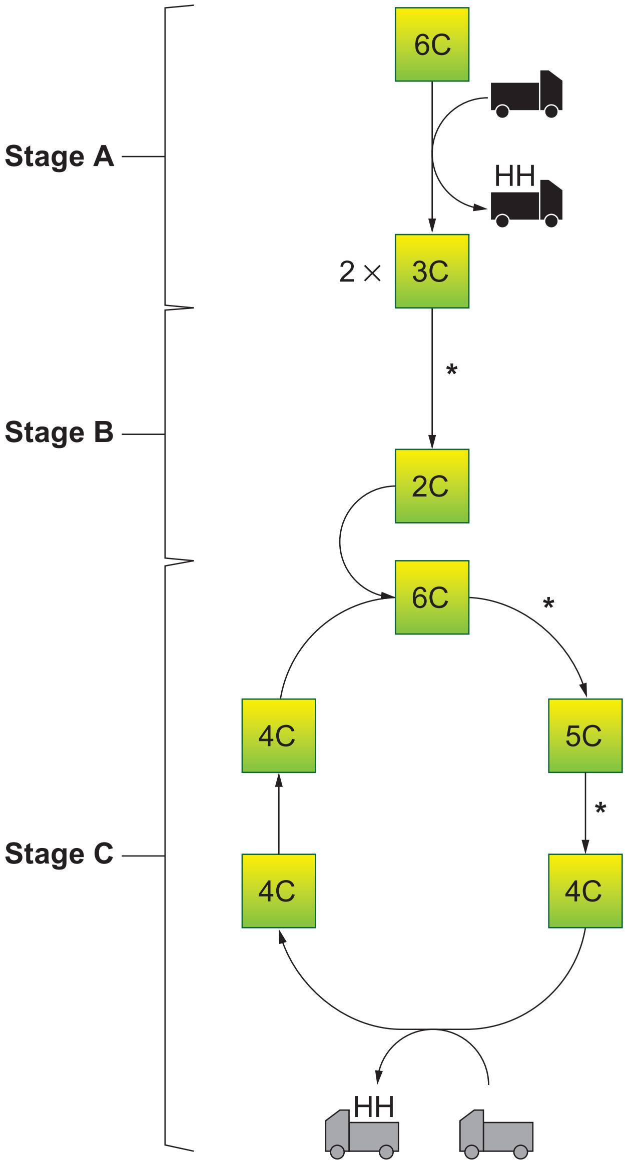
Answer **all** questions.

1. **Image 1.1** shows a simplified summary of the stages in aerobic respiration. The asterisks (*) indicate reactions in which intermediates lose a carbon atom.

The truck symbols  and  represent two different coenzymes.

Note:  is involved at several points, only one is shown.

Image 1.1



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(a) Name stages **A**, **B** and **C** and state **precisely** where in a eukaryotic cell each stage takes place. [3]

Stage	Name	Location
A		
B		
C		

(b) Name the type of enzyme involved in the reactions marked with asterisks (*) in **Image 1.1** and state what happens to the carbon atoms. [2]

Type of enzyme ....

What happens to the carbon atoms ....

....

(c) (i) State the term given to the chemical change occurring in the coenzymes shown in **Image 1.1**. [1]

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(ii) I. Identify the **two** coenzymes. [1]

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II. Describe the role of the **two** coenzymes in aerobic respiration and explain why they result in different yields of ATP. [3]

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(iii) State the term used to describe the role of oxygen in aerobic respiration. [1]

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1400U301 03

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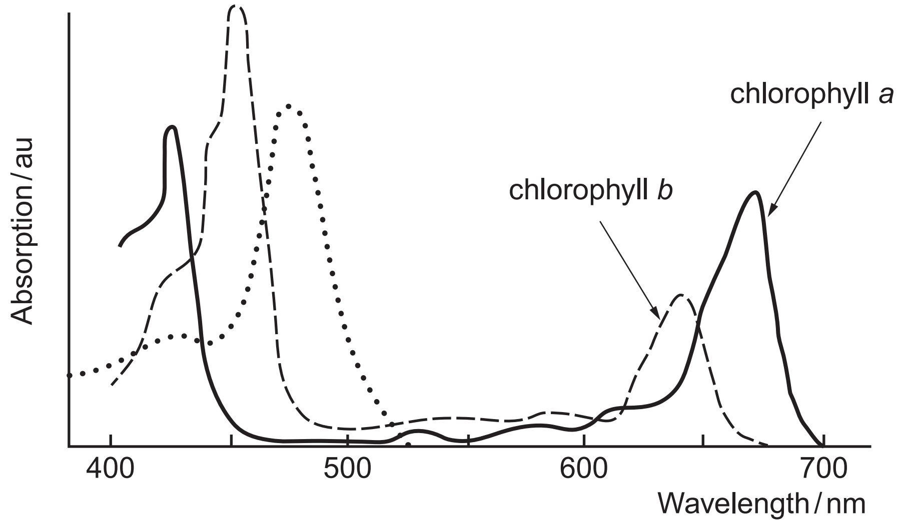
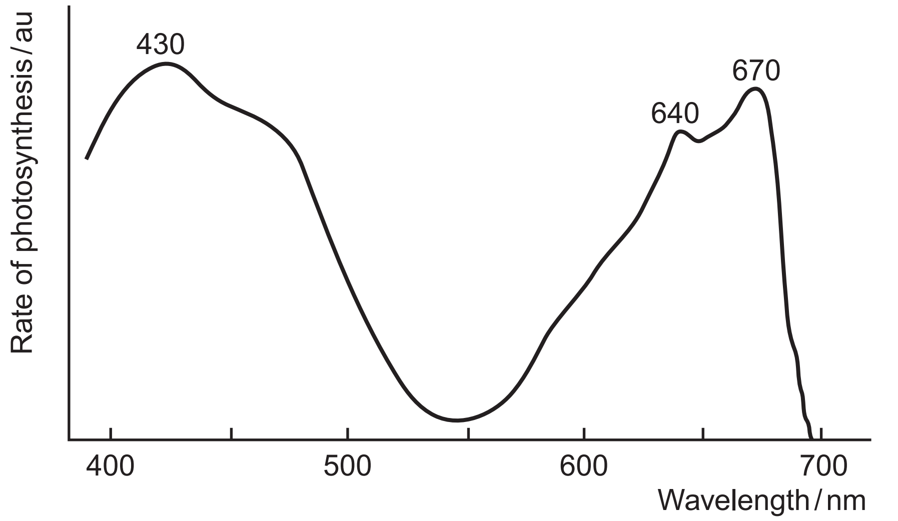
2. Most terrestrial plants use chlorophylls *a* and *b* to construct pigment-protein complexes which harvest light. **Graph 2.1A** shows an absorption spectrum for a terrestrial plant and the **Graph 2.1B** shows corresponding action spectrum.

Graph 2.1A **Absorption spectrum**



Graph 2.1B **Action spectrum**



(a) Describe the relationship between the absorption spectrum and the action spectrum and state a suitable conclusion which explains the relationship. [2]

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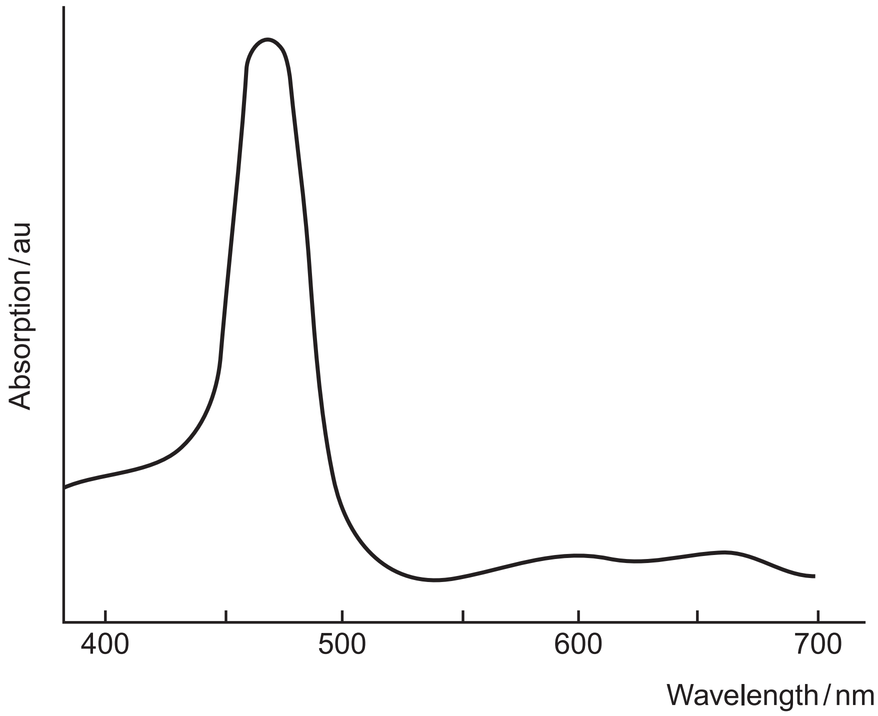
(b) Different taxa contain different photosynthetic pigments.
Diatoms are aquatic photosynthetic organisms. Their chloroplasts contain chlorophyll *a*, but instead of chlorophyll b they contain chlorophyll c. **Graph 2.2** shows the absorption spectrum of chlorophyll c.

Graph 2.2



(i) Describe the main difference between the absorption spectrum for chlorophyll b and the absorption spectrum for chlorophyll c. [1]

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(ii) With reference to the peaks labelled on the action spectrum in **Graph 2.1B**, predict how the action spectrum for diatoms would differ from that of terrestrial plants. [1]

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1400U301
05

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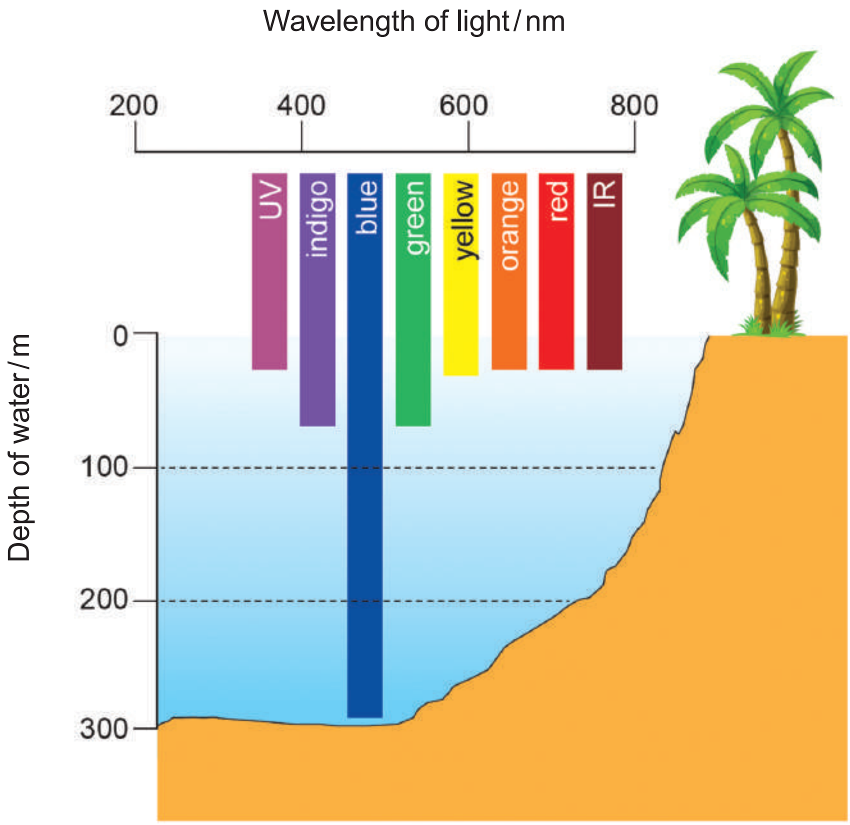
Image 2.3 shows the depths that different wavelengths of light are able to penetrate water.

Image 2.3



(c) Use information from **Graph 2.2** and **Image 2.3** to explain why diatoms living at a depth of 200 m have chlorophyll c instead of chlorophyll b. [1]

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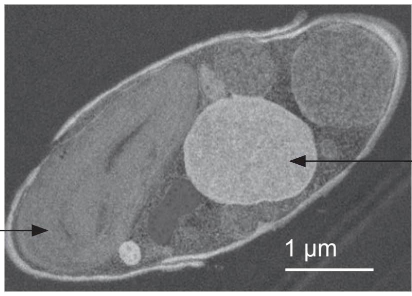
Image 2.4 shows an electronmicrograph of a single diatom.

Image 2.4



(d) Using information from **Image 2.4**, classify diatoms into their Domain. Give a reason for your choice. [2]

Domain ....

Reason ....

1400U301
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Turn over.

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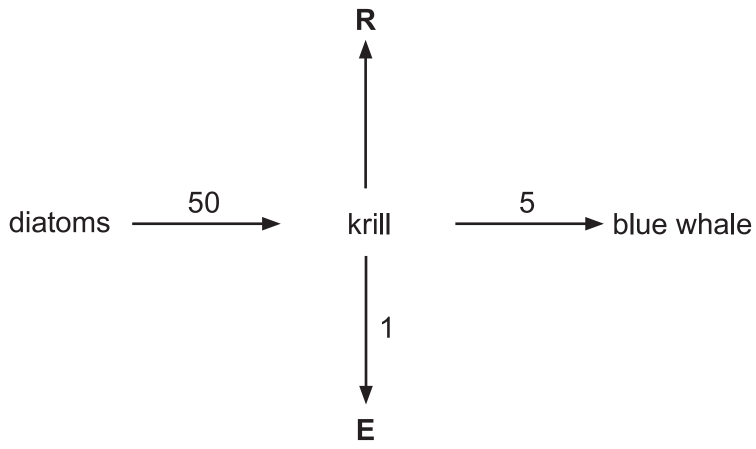
(e) Diatoms are responsible for about 40% of marine productivity and because the oceans cover about 70% of the Earth's surface they make a great contribution to global productivity. Blue whales feed on tiny crustaceans called krill, by filtering seawater through sheets in their mouths called baleen. Krill feed on diatoms.

Net primary productivity (NPP) for diatoms has been estimated to be 50 g m^{-3} day^{-1} and secondary productivity for krill has been estimated to be 5 g m^{-3} day^{-1}. **Image 2.5** shows a simplified food chain, the numbers shown are in g m^{-3} day^{-1}. **R** represents respiration and **E** represents excretion.

Image 2.5



(i) Calculate the rate at which krill use diatom biomass for respiration **(R)**. [1]

Rate = ... g m^{-3} day^{-1}

(ii) It is estimated that a single blue whale needs to consume 8 000 kg of biomass per day. The biomass of krill was estimated as 25 g m^{-3}.
Calculate the volume of water a whale needs to filter per day to take in 8 000 kg of biomass. **Give your answer in standard form**. [3]

Volume of water = ... m^3 day^{-1}

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3. ATP is described as the universal energy currency of cells.

(a) (i) Describe why ATP is described as a universal currency. [2]

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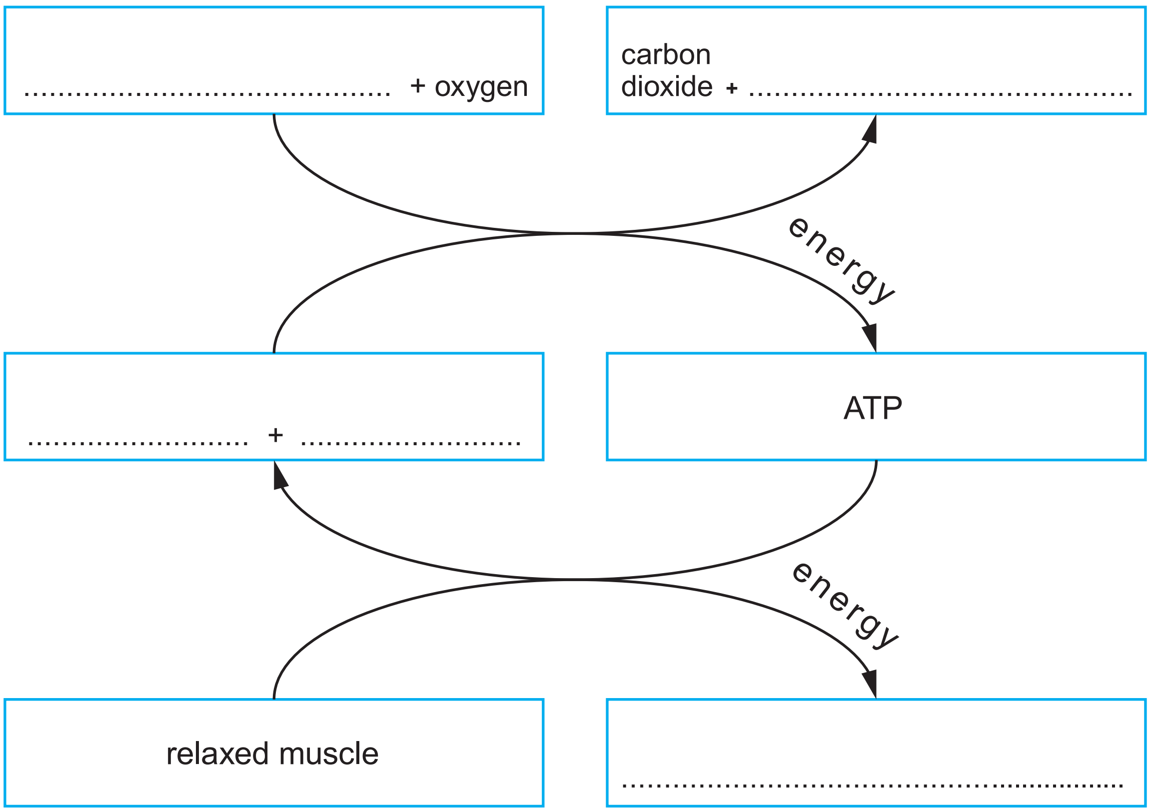
Image 3.1 summarises the production and use of ATP in muscle cells.

(ii) **Complete the diagram** in **Image 3.1**. [3]

Image 3.1



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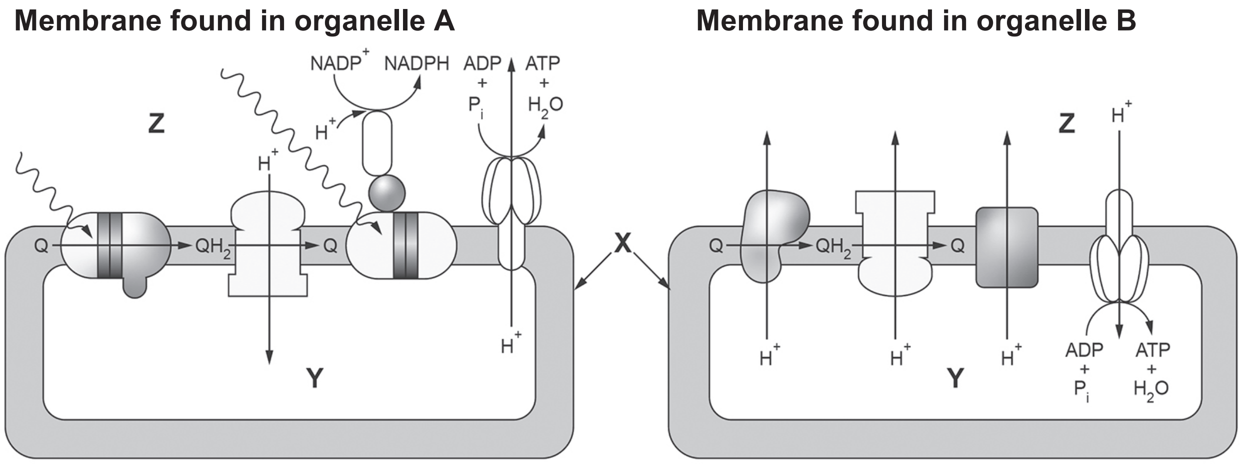
(b) **Image 3.2** shows diagrammatic representations of membranes found in two organelles where ATP synthesis takes place.

Image 3.2



(i) Name the organelles in which the membranes (shown in **Image 3.2**) would be found. [1]

A .... **B** ....

(ii) In **Image 3.2**, **X**, **Y** and **Z** represent membranes and compartments found in organelles **A** and **B**.

Complete the Table 3.3 to name the membranes and compartments represented in **Image 3.2** for each organelle. [3]

Table 3.3

		Name of membrane/compartment	
Letter	Part represented in image	Organelle **A**	Organelle **B**
X	membrane	....	....
Y	compartment enclosed by membrane	....	....
Z	compartment surrounding membrane	....	....

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(iii) Describe how the components in the membrane of organelle **B** are involved in the synthesis of ATP by chemiosmosis. [5]

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1400U301
11

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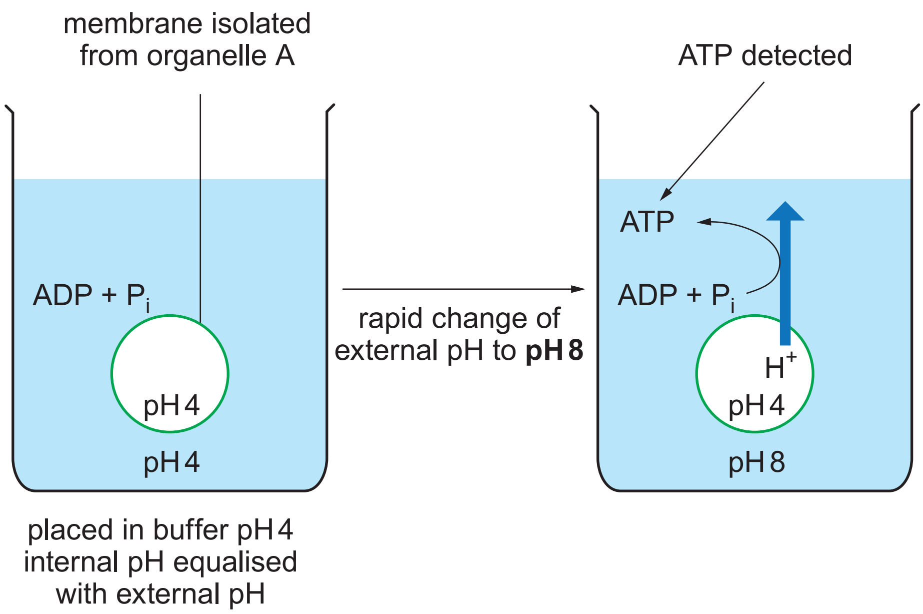
The experiment shown in **Image 3.4** is considered to be evidence supporting the chemiosmotic hypothesis. It was carried out on membranes isolated from organelles of type **A** in **Image 3.2** and made into vesicles. The isolated membranes were placed in buffer solutions, the lower the pH the higher the concentration of protons.

Image 3.4



(c) Explain why the experiment shown in **Image 3.4** supports the chemiosmotic theory. [4]

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4. The size of any population at a given time is determined by the equation:

Number of individuals = (birth rate + immigration) – (death rate + emigration)

In field studies which monitor population size over a period of time the number of individuals often stays constant.

(a) Using the terms in brackets from the above equation, write another equation which shows the relationship between the terms when the population size remains constant. [1]

.... = ...

Scientists monitored the population of frogs in a woodland surrounding a pond. The capture-mark-recapture method was used to determine the number of adult frogs, as follows:

- 19 frogs were caught
- marked by clipping off one toe
- they were then released back into the pond
- a week later the scientists collected as many frogs as they could over three consecutive days
- the results are shown in **Table 4.1**
- captured frogs from the three consecutive days were not released until after the third collection.

1400U301 13

Table 4.1 Result of collections following release of marked frogs

Date	Total no. of frogs captured	No. of marked frogs
Day 1	48	5
Day 2	45	5
Day 3	50	7
Total	143	17

(b) (i) From the figures given in the method and **Table 4.1** estimate the total number of frogs in the woodland, using the following formula: [2]

$$N = \frac{Mn}{m}$$

Where,

- N = number in population
- M = number initially captured and marked
- n = total number subsequently captured
- m = number of marked individuals recaptured.

Estimated number of frogs in the woodland = ...

 (1400U30-1) **Turn over.**

Examiner only

(ii) Explain why the chosen method of marking the frogs might have affected the estimate of the frog population. [1]

....

....

(c) Between capture and release the adult frogs were kept, ten to a tank, partially submerged in water collected from the pond. The frogs in one of the tanks developed red patches on their legs. The scientists suspected they were suffering from 'red-leg disease', caused by the bacterium, *Aeromonas hydrophila*, a Gram-negative bacillus.

The scientists took a swab from the leg of one of the frogs, performed a Gram stain and examined the sample under the microscope.

Describe the shape and colour of the bacteria they would have seen if the frog had been suffering from red-leg disease. [2]

Shape ....

Colour ....

(d) In order to study the survival rates of the larval stage of the frogs (tadpoles), two smaller ponds of equal volume were created from the existing pond using polyethylene sheets. Pond 1 was stocked with 5000 tadpoles per m^3 and pond 2 was stocked with 1000 tadpoles per m^3.

The scientists took 20 samples of water from each pond every ten days and counted the number of tadpoles in each sample. They used the mean counts to calculate the number of tadpoles per m^3. Their results are shown in **Graph 4.2**, the straight lines drawn in black are tangents to the curves.

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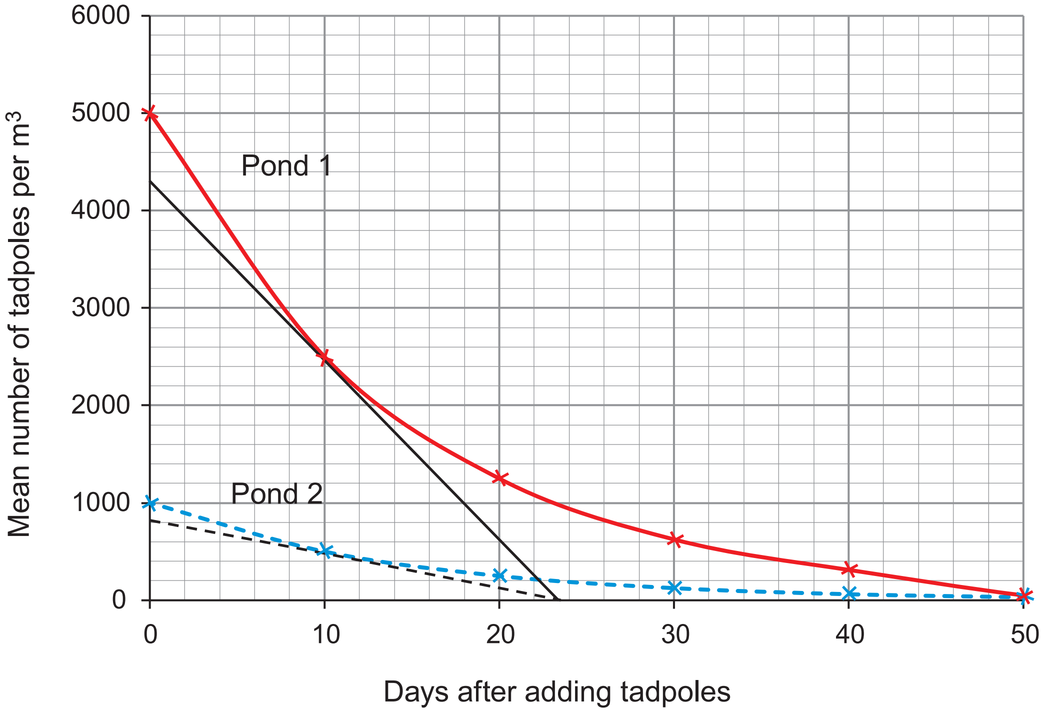
Graph 4.2



(i) Calculate the rate of decline in number of tadpoles for pond 1 **at day 10**. **Give your answer to two significant figures**. [3]

Rate of decline .... tadpoles m^{-3} day^{-1}

(ii) Using the information from **Graph 4.2** it was concluded that a density-dependent factor was causing the change in the tadpole populations. State the evidence for this conclusion and suggest what the factor might have been. [3]

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1400U301
15

Turn over.

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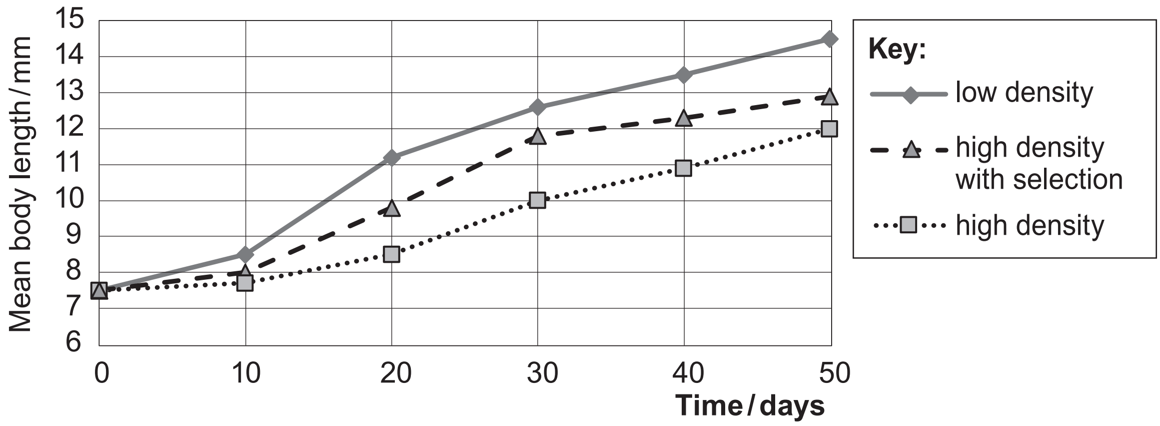
(e) The scientists also carried out a laboratory experiment to investigate the effect of selection on rate of development as measured by body length.
They used 3 different tanks, which contained 10 dm^3 of water.

- Tank 1 – low density (1 tadpole per dm^3)
- Tank 2 – high density (5 tadpoles per dm^3)
- Tank 3 – high density with selection against small individuals (two of the smallest tadpoles were removed each week).

All tanks were kept under the same environmental conditions.
The length of the tadpoles in each tank was measured every 10 days and a mean calculated. The results of the experiment are shown in **Graph 4.3**

Graph 4.3



(i) With reference to **Graph 4.3**, state **two** conclusions that can be drawn about the effect of density and selection on the rate of development of tadpoles in the three tanks. [2]

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(ii) Another group of scientists said that it was not valid to use the results from tank 2 and tank 3 to make a conclusion about the effect of selection. Suggest why it might not be valid to compare these two tanks **and** describe how the method could be changed to enable a more valid conclusion to be made. [2]

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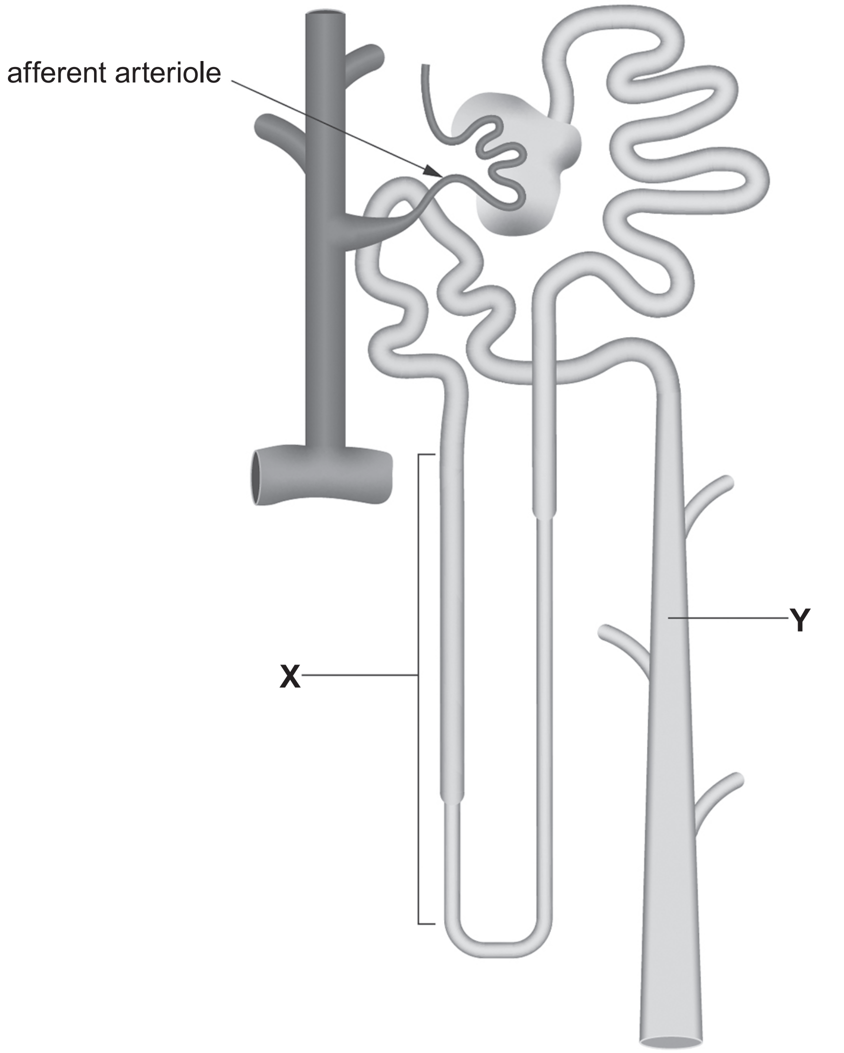
5. The mammalian kidney has a role in two physiological processes, excretion and homeostasis. **Image 5.1** shows a single kidney nephron. The strategy that the kidney uses for excretion is ultrafiltration followed by selective reabsorption.

Image 5.1



(a) (i) Use **labelled lines** on **Image 5.1** to show the sites of: [2]

I. ultrafiltration
II. selective reabsorption

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(ii) Structures labelled **X** and **Y** in **Image 5.1** are involved in homeostasis. Name structures **X** and **Y** and the homeostatic process in which they are involved. [2]

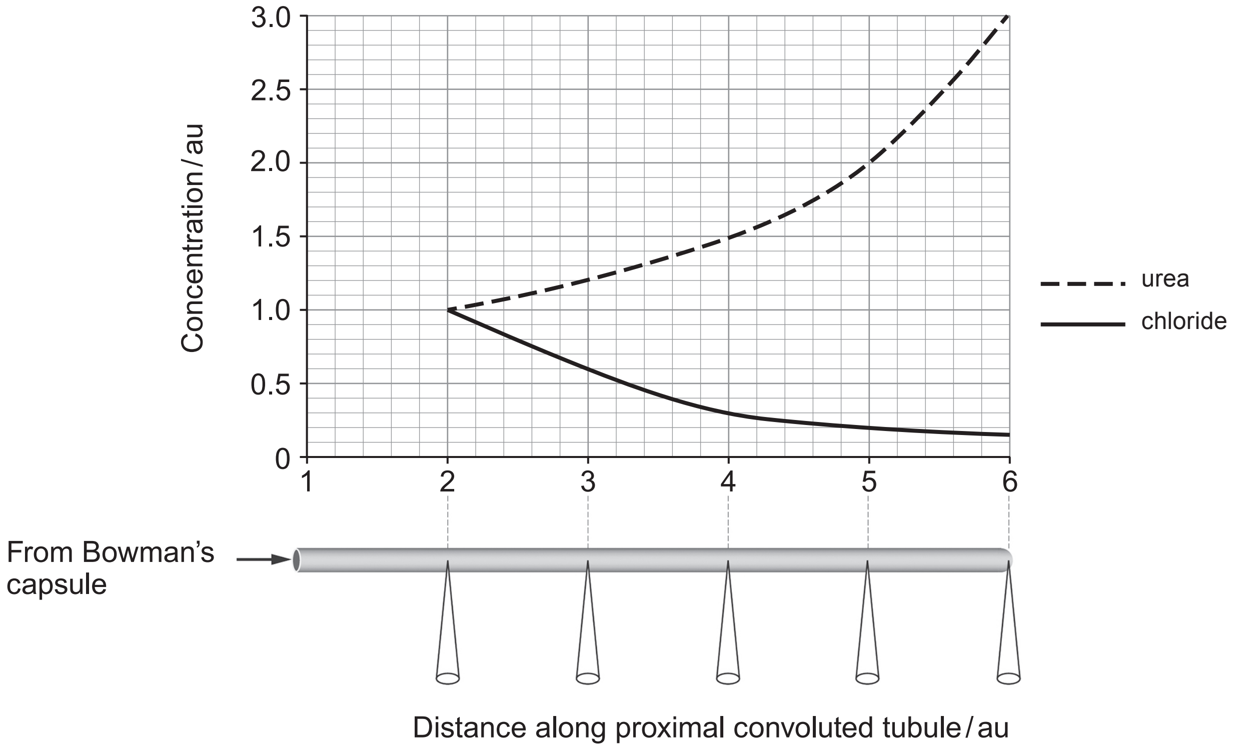
X ....

Y ....

Homeostatic process ....

The use of micropipettes has allowed samples of fluid to be withdrawn from specific points along kidney tubules of experimental animals. Samples of filtrate were taken from five positions along the proximal convoluted tubule and the concentrations of urea and chloride ions were measured. The results are shown in **Graph 5.2**.

Graph 5.2



(b) (i) Use **Graph 5.2** to explain the change in concentrations for urea and chloride ions along the tubule. [2]

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 (1400U30-1) **Turn over.**

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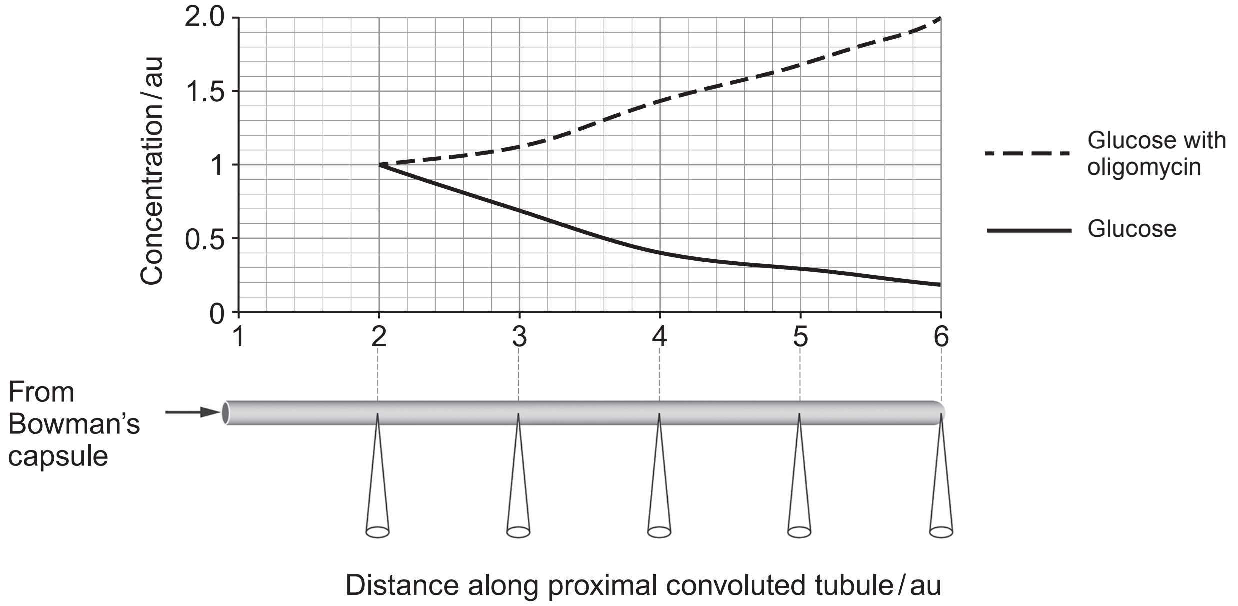
The experiment was repeated but concentrations of glucose were measured with and without oligomycin.

Oligomycin is a chemical compound that specifically inhibits respiration. The results are shown in **Graph 5.3**.

Graph 5.3



(ii) Use **Graph 5.3**, to explain the change in concentration along the tubule for glucose with **and** without the respiratory inhibitor oligomycin. [4]

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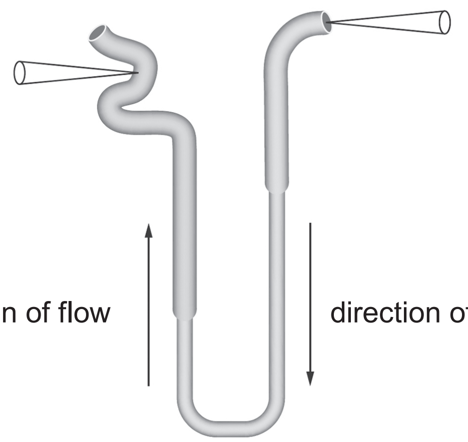
A third experiment was carried out to study how structure **X**, shown in **Image 5.1**, is involved in the formation of urine. **Image 5.4** shows regions of tubule on either side of structure **X**. Samples were withdrawn from two locations, **1** and **2**. The concentration of sodium ions (Na^+) was measured in each location.

Image 5.4



(c) (i) Explain why these locations were chosen for sampling. [1]

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(ii) The Na^+ concentration in the sample taken from **location 1** was higher than the sample taken from **location 2**. Use your knowledge of the function of both limbs of the structure in **Image 5.4** to explain this result. [4]

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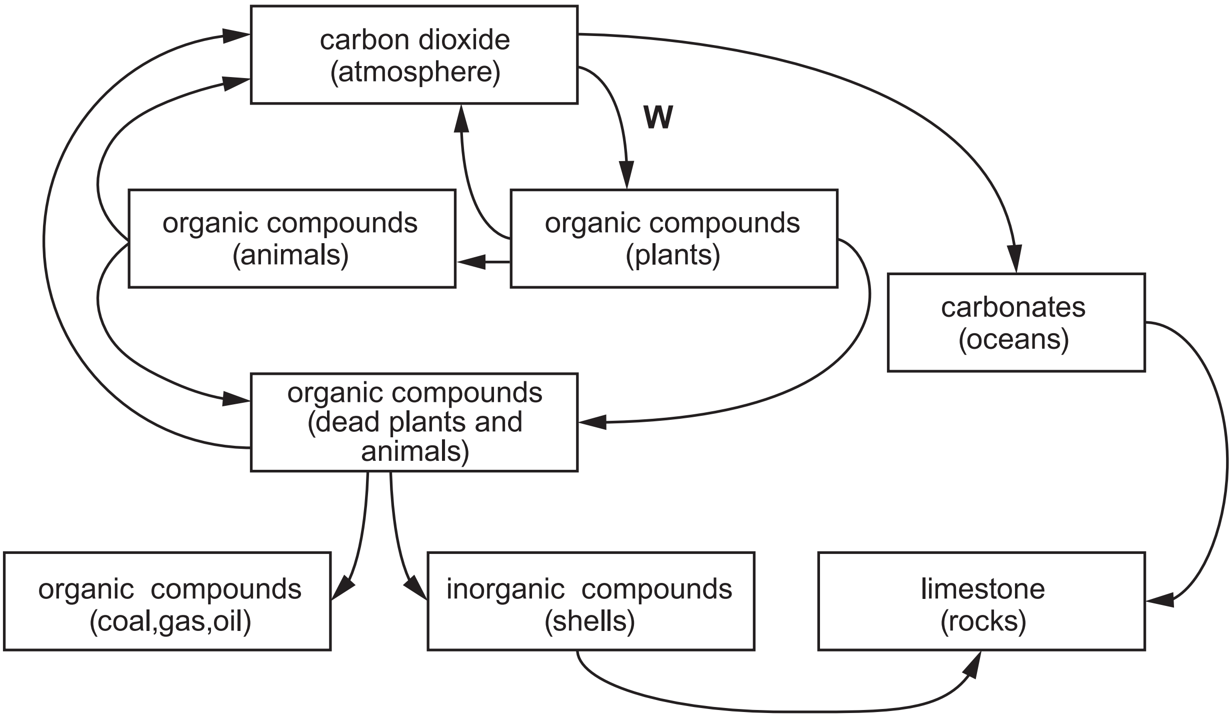
6. **Image 6.1** shows a natural carbon cycle unaffected by human activity. The arrows represent processes which transfer carbon from one form to another.

Image 6.1



(a) (i) Process **W** involves the fixation of carbon in green plants. Name the **two** reactants involved and the enzyme that catalyses this process. [2]

Reactants ....

....

Enzyme ....

(ii) I. On **Image 6.1, label one of the arrows** with an **X** to show a process which involves micro-organisms.

II. Explain the role of micro-organisms in this process. [2]

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(iii) **Add an arrow labelled C** to **Image 6.1** to represent the transfer of carbon as a result of human activity. [1]

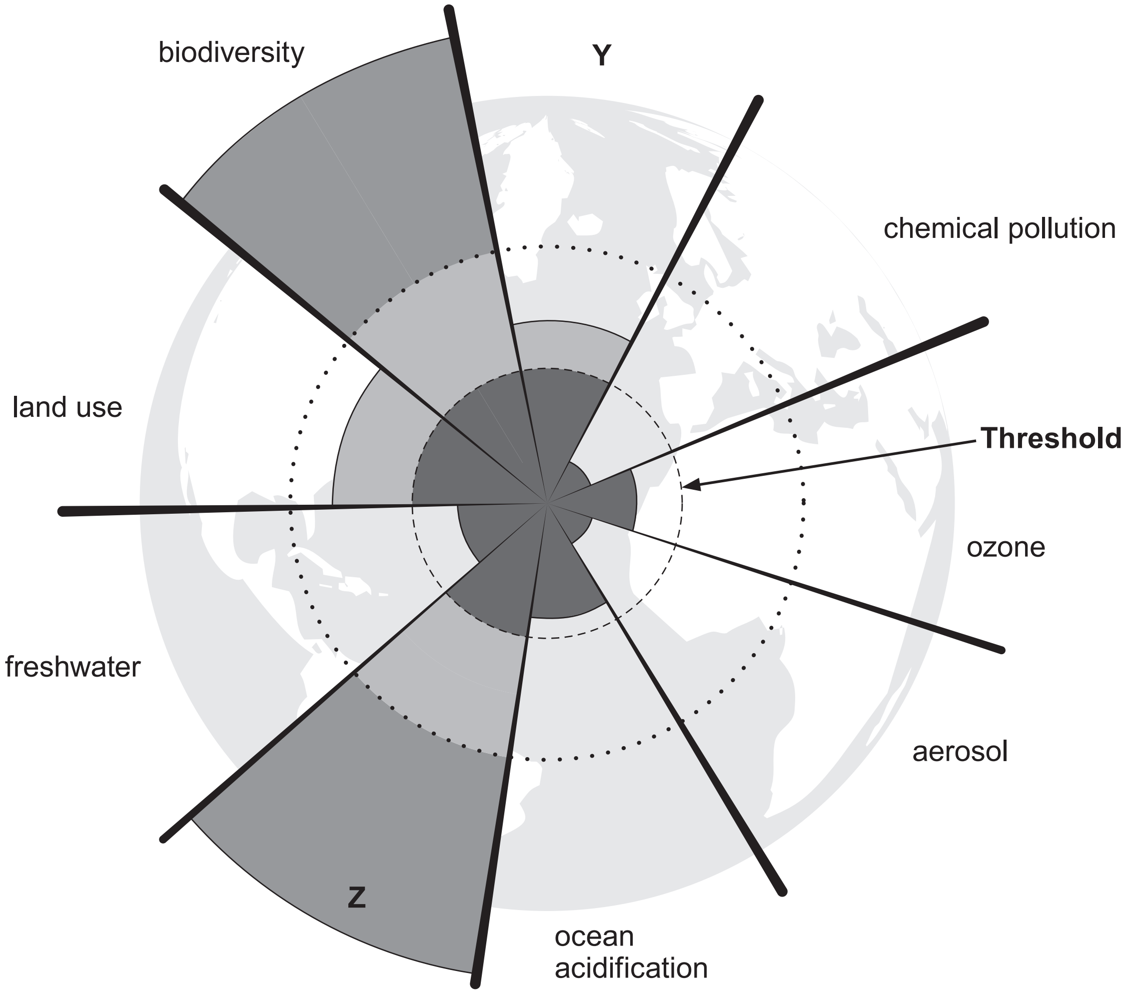
Turn over.

(b) Nine global systems have been identified as being key regulators of the Earth's stability. Values have been proposed that represent boundaries or thresholds. **Table 6.2** shows two of the nine systems together with their threshold values and current values and **Image 6.3** displays the threshold values and current values as a circular graph.

Table 6.2 – Planetary Boundaries

Planetary System	Parameters	Threshold values	Current value
Climate change	Atmospheric carbon dioxide concentration (ppm by volume)	350	387
Nitrogen	How much nitrogen is removed from the atmosphere for human use (tonnes $\times 10^6$ / year)	35	121

Image 6.3



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(i) Use the information in **Table 6.2** to name the **two** missing planetary systems labelled **Y** and **Z** in **Image 6.3**. [1]

Y .... **Z** ....

(ii) Use **Image 6.3** to state what the **two** planetary systems in **Table 6.2** have in common with each other and with the **Land-use** system. [1]

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(c) Explain what is meant by a safe operating space for humanity, describe where that is shown in **Image 6.3**, and describe the consequences of exceeding planetary boundaries. [3]

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7. **Image 7.1** shows the pathway from a tooth to an area of the brain which generates the sensation of pain. It also shows the site of action of two local anaesthetics used in dentistry. **Image 7.2** shows a reflex arc.

Image 7.1

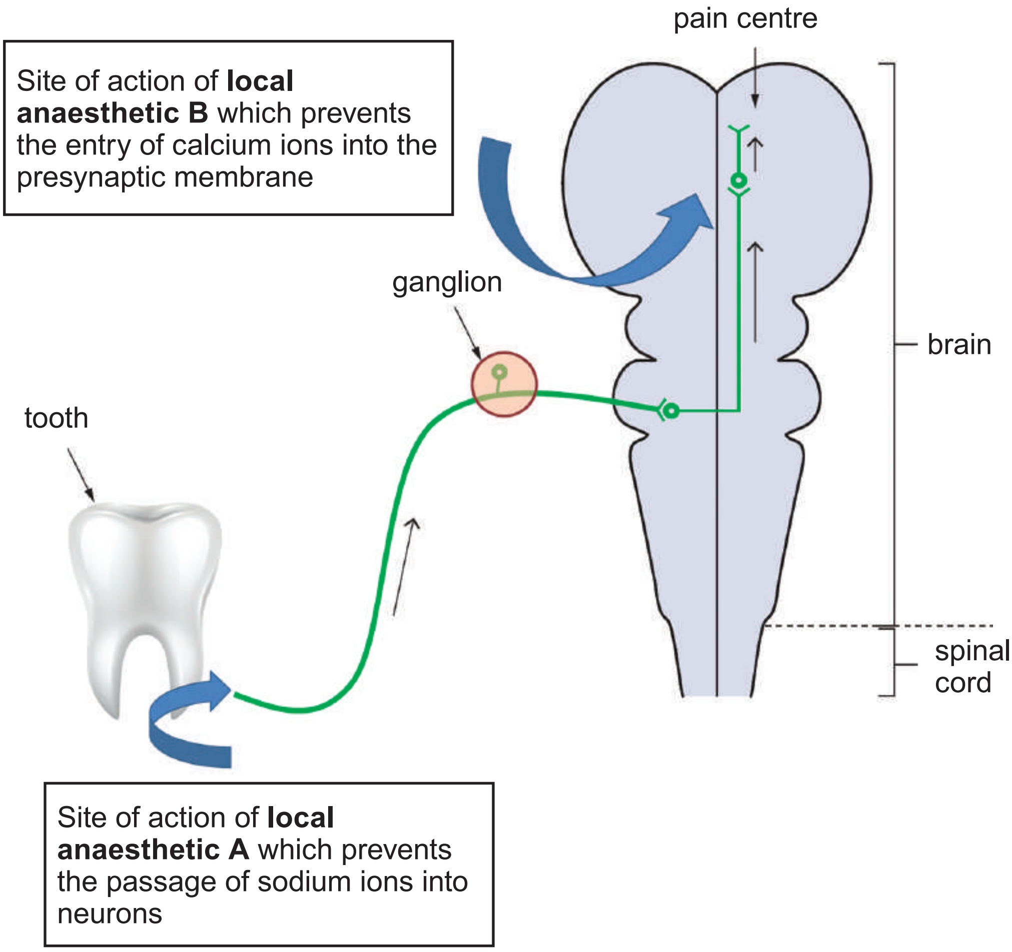
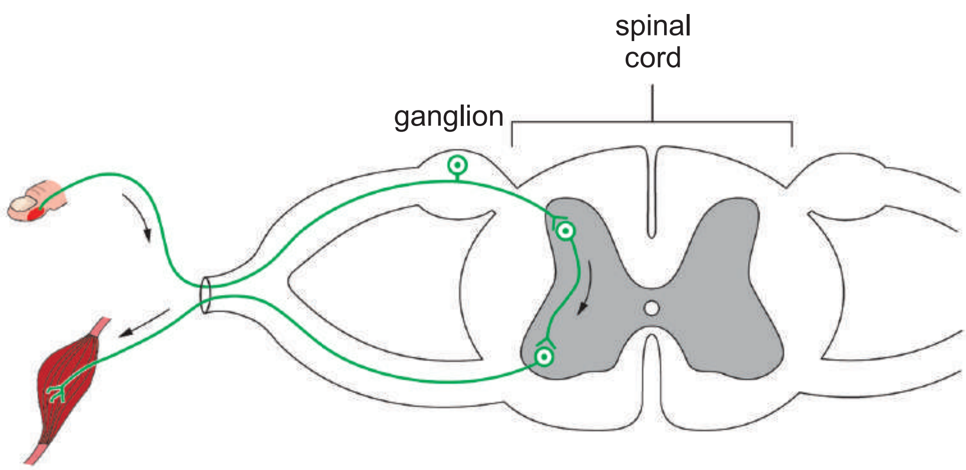


Image 7.2



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Compare and contrast the pathway shown in **Image 7.1** with the reflex arc in **Image 7.2**.
Using your knowledge of the generation of action potentials, suggest how anaesthetic **A** will prevent pain.
Using your knowledge of synaptic transmission, suggest how anaesthetic **B** could also prevent pain. [9 QER]

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9

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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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