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

# GCE A LEVEL

1400U30-1

Z22-1400U30-1

**MONDAY, 6 JUNE 2022 – MORNING**

# BIOLOGY – A2 unit 3

## Energy, Homeostasis and the Environment

2 hours

| For Examiner's use only | | |
|---|---|---|
| **Question** | **Maximum Mark** | **Mark Awarded** |
| **1.** | **15** | |
| **2.** | **18** | |
| **3.** | **8** | |
| **4.** | **14** | |
| **5.** | **14** | |
| **6.** | **12** | |
| **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 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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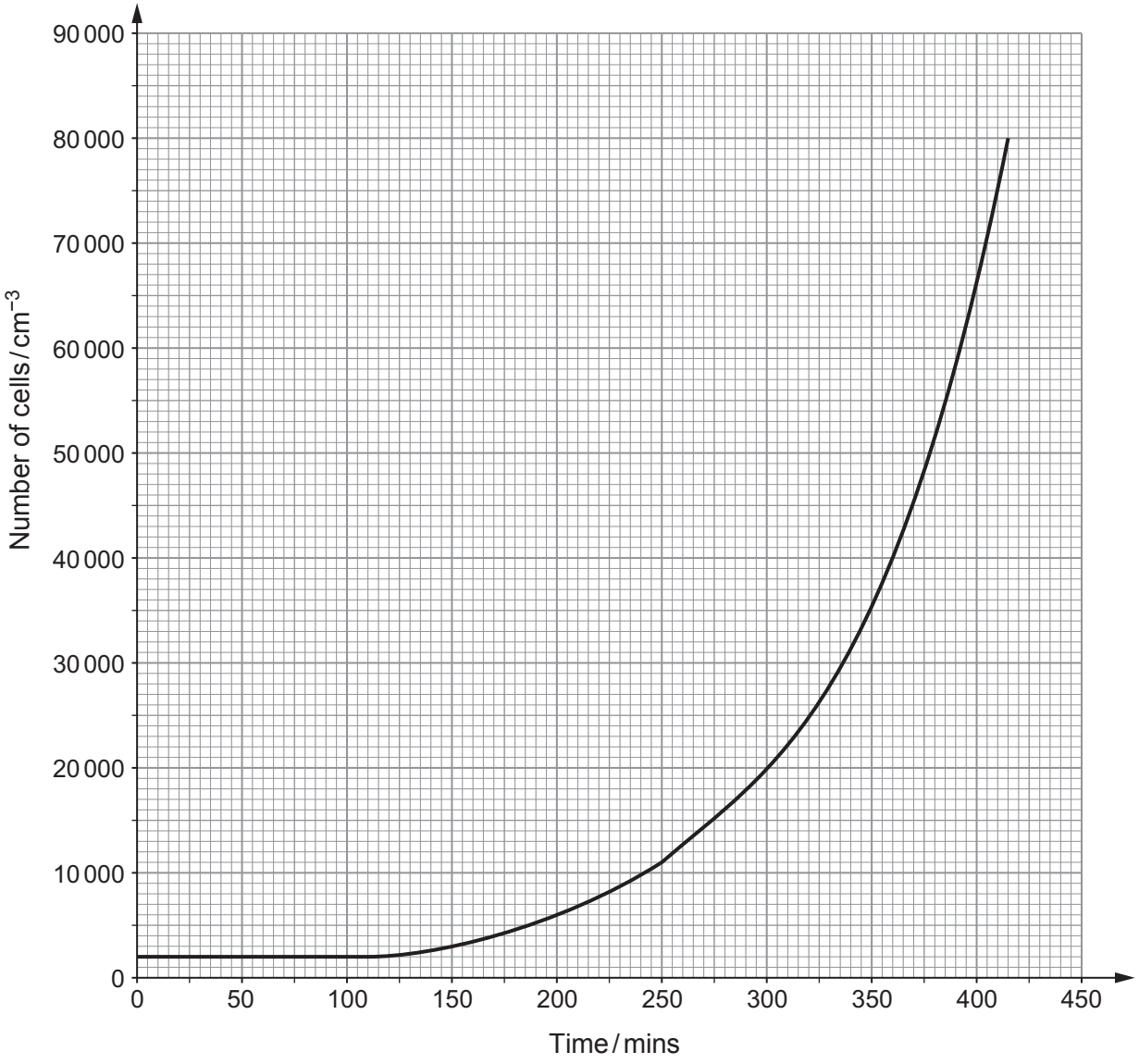
Answer **all** questions.

**1.** A student inoculated 900 $cm^3$ of fresh, sterile nutrient broth with 100 $cm^3$ of a culture of *Escherichia coli*. She incubated the new culture at 37 °C and monitored the concentration of bacteria using a total count with an electronic cell counter. The results are shown in **Graph 1.1**.

**Graph 1.1**




(a) (i) Calculate the concentration of bacteria in the **original** culture used to inoculate the broth. [2]

Concentration = ..... $cm^{-3}$

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(ii) Calculate the time taken for the number of bacteria to double after the number of cells counted by the electronic cell counter had reached 20 000 $cm^{-3}$. [1]

Time taken for the number of bacteria to double = ..... minutes

(b) Growth curves for bacteria may be used to model growth in populations of animals, because the same phases of growth are recognisable. The following passage, taken from a website, is a description of one of the phases.

"The accumulation of waste materials, toxic metabolites and inhibitory compounds in the medium shifts the conditions of the medium such as pH and temperature. This creates an unfavourable environment for the bacterial growth. … the number of cells undergoing division is equal to the number of cell deaths."

(i) Identify the phase of growth described in the passage. [1]

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(ii) Explain why the method used to monitor the number of bacteria meant that the phase identified in part (i) was not seen in **Graph 1.1**. [1]

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(iii) List the main steps of a different method of counting bacteria which would allow the phase described above to be seen in **Graph 1.1**. Details of aseptic technique are **not** required. [4]

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(c) Syphilis and gonorrhoea are sexually transmitted diseases (STDs) caused by the bacteria *Treponema pallidum* and *Neisseria gonorrhoeae* respectively.

*Treponema pallidum* is a helically coiled micro-organism usually 6–15$\mu$m long and 0.1–0.2 $\mu$m wide. It has a plasma membrane and an outer lipopolysaccharide membrane.

*Neisseria gonorrhoeae*, also known as *gonococcus*, is a species of Gram negative cocci.

Using the information given;

(i) Describe the three-dimensional shape of *Neisseria gonorrhoeae* cells. [1]

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(ii) State whether *Treponema pallidum* is Gram positive or Gram negative and explain your choice. [1]

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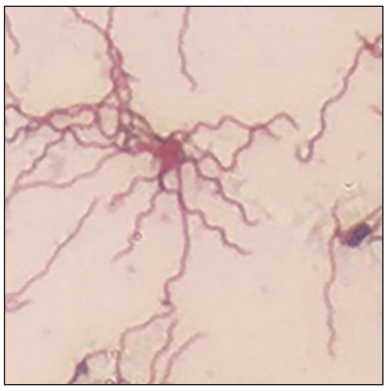
(d) A 21-year-old man attended a clinic with a painless ulcer on his penis. Bacteria taken from the ulcer were Gram stained. The results are shown in **Image 1.2**.

**Image 1.2**



**Note:**
The bacteria all stained pink.

(i) State the result of the Gram test shown in **Image 1.2** and explain why it does not help distinguish between the two types of STD described above. [2]

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(ii) Suggest which of the two types of STD the man is most likely to be suffering from and explain your choice. [2]

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**2.** Loss of suitable habitat by destruction, degradation or fragmentation is the most important cause of species becoming endangered around the world.

(a) (i) Distinguish between the terms endangered and extinct. [1]

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(ii) Apart from habitat loss, name **two** other causes of species extinction. [2]

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Following a forest fire, given time, the forest will regenerate.

(b) (i) Give the full name of the biological process involved in forest regeneration. [1]

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(ii) Using relevant **technical terms**, describe and explain the process of forest regeneration. [3]

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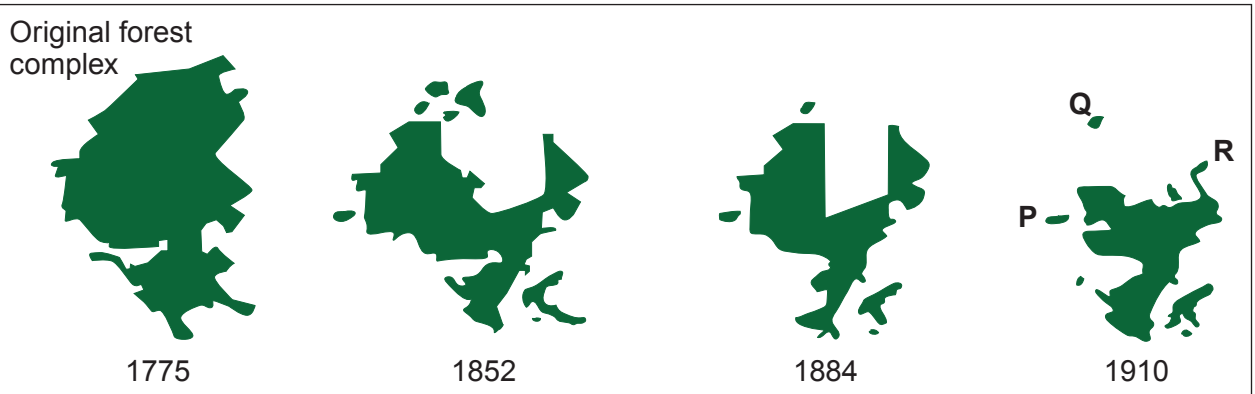
(c) Human activity has resulted in the forest landscapes of Europe existing as a mixture of fragments of different ages and sizes. **Image 2.1** shows the fragmentation of forests surrounded by developed land. Three fragments of forest **P**, **Q** and **R** are labelled on the 1910 map.

**Image 2.1**




(i) The Hardy-Weinberg principle states that allele frequencies remain constant from generation to generation. Explain **two** reasons why this would not apply to the gene pools of species in fragments **P**, **Q** and **R**. [2]

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(ii) List fragments **P**, **Q** and **R** in order of risk of species extinction, from most to least. Explain your answer. [4]

Most risk ..... ..... ..... Least risk

Explanation

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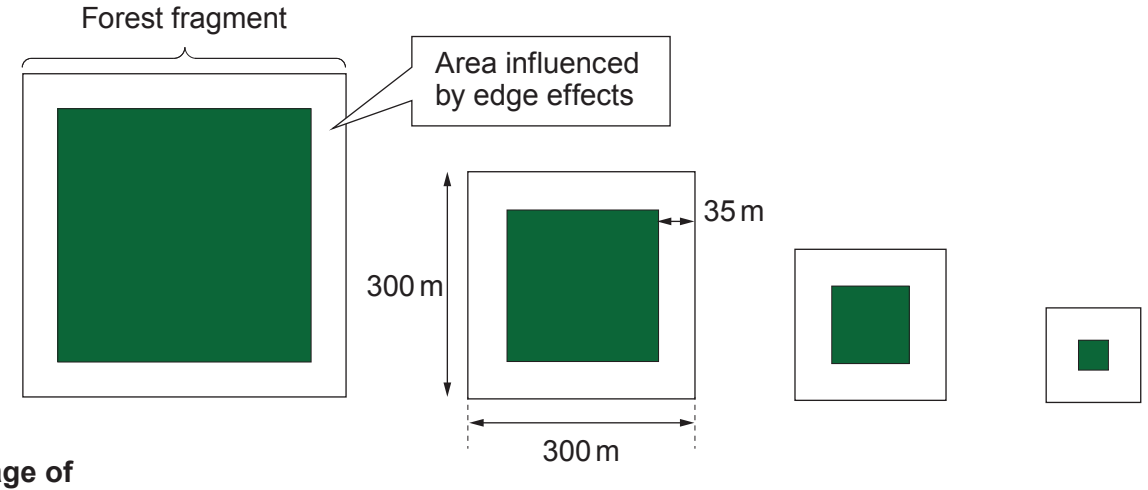
(d) As well as gene pool effects, fragmentation exposes species to potentially harmful environmental effects. These are called 'edge effects' because conditions at the edge of a forest differ from those further inside. **Image 2.2** shows how square forest fragments of different sizes are affected by edge effects.

**Image 2.2**




| | | | | |
|---|---|---|---|---|
| **Percentage of the fragment influenced by edge effects** | **30.6%** | ..... | **64.0%** | **88.8%** |

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(i) Assuming edge effects extend 35 m into each habitat patch, calculate the percentage of the fragment influenced by the edge effects for the second largest patch.
**Write your answer in the space in Image 2.2.** [2]

Space for working.

(ii) Describe the trend in the data and suggest **two** abiotic conditions that would differ in the area affected by edge effects. [3]

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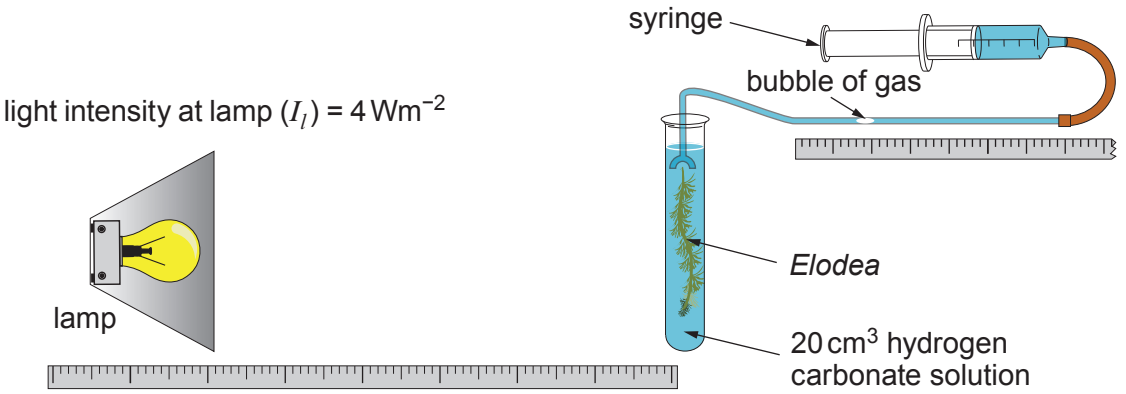
**3.** A group of students used the apparatus shown in **Image 3.1** to investigate the effect of light intensity on the rate of photosynthesis. The volume of gas was measured after a minute by drawing it up with the syringe and measured using the scale.

**Image 3.1**




The students' results are shown in **Table 3.2**:

**Table 3.2**

| Distance from lamp / m | Distance from lamp$^2$ / m$^2$ | Light intensity at plant / Wm$^{-2}$ | Volume of gas / mm$^3$ min$^{-1}$ | | | |
|---|---|---|---|---|---|---|
| | | | Trial 1 | Trial 2 | Trial 3 | mean |
| 0.30 | 0.0900 | 44 | 1222 | 978 | 1098 | 1099 |
| 0.25 | 0.0625 | 64 | 2098 | 1897 | 2134 | 2043 |
| 0.20 | 0.0400 | 100 | 3302 | 2788 | 3100 | 3063 |
| 0.15 | 0.0225 | 178 | 4012 | 3876 | 4100 | 3996 |
| 0.10 | ..... | ..... | 3998 | 3887 | 4100 | 3995 |
| 0.05 | 0.0025 | 1600 | 4011 | 3888 | 3998 | 3966 |

(a) **Complete Table 3.2** using information from **Image 3.1** and the formula for light intensity below: [3]

Light intensity at plant, $I_p = I_l\left(\frac{1}{d^2}\right)$

Where: $I_p$ = light intensity at plant,
$I_l$ = light intensity at lamp,
$d$ = distance from lamp in metres.

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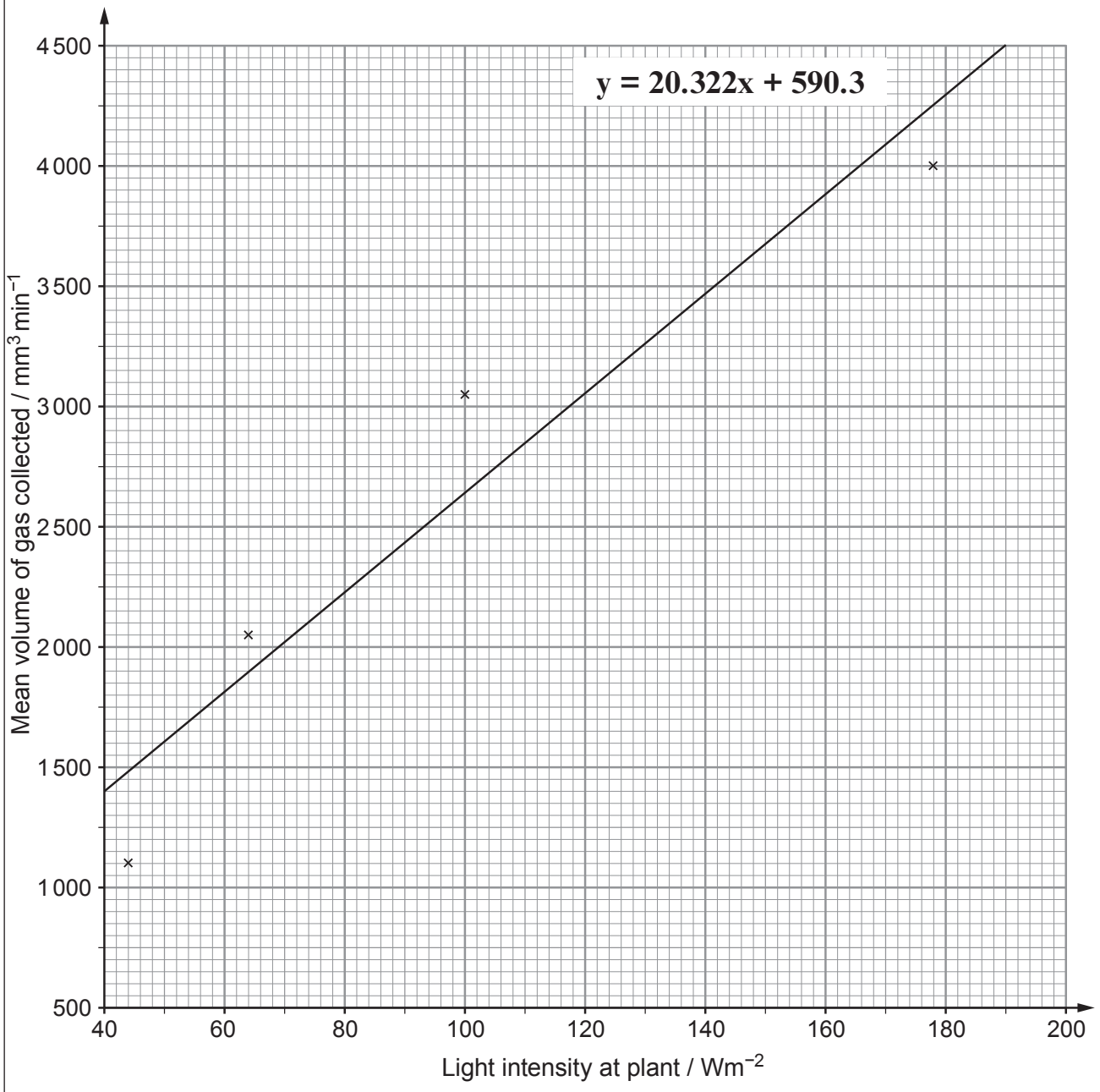
Some of the results were plotted in **Graph 3.3**. The students assumed that the mean volume of gas collected was directly proportional to light intensity. The equation for their line of best fit is shown above the line.

**Graph 3.3**




(b) (i) Use the equation given on **Graph 3.3** and the relevant values from **Table 3.2** to calculate the mean volume of gas that should have been collected when the lamp was 0.15 m from the plant. [2]

Expected mean volume of gas = ..... $mm^3 min^{-1}$

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(ii) State **one** environmental factor that should have been maintained at a constant value during the experiment. [1]

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(iii) The **expected** mean volume of gas collected (calculated from the equation on **Graph 3.3**), when the lamp was 0.05 m from the plant, was 33 105.5 $mm^3 min^{-1}$. Explain why the expected volume of gas was higher than the volume **actually** collected when the lamp was 0.05 m from the plant (shown in **Table 3.2**). [2]

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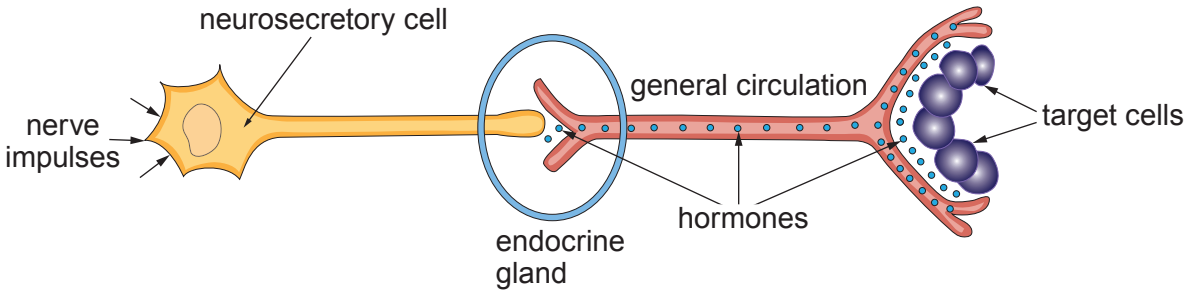
**4.** Osmoregulation is carried out by the kidneys, under hormonal control.
The regulatory process is represented in **Image 4.1**.

**Image 4.1**




(a) Using your knowledge of homeostasis and the mammalian kidney, identify each of the following shown in **Image 4.1**: [4]

(i) the source of the nerve impulses;

.....

(ii) the endocrine gland;

.....

(iii) the hormone;

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(iv) the precise location of the target cells.

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(b) Explain how the hormone involved in the process shown in **Image 4.1** affects the target cells and how it prevents excessive water loss. [3]

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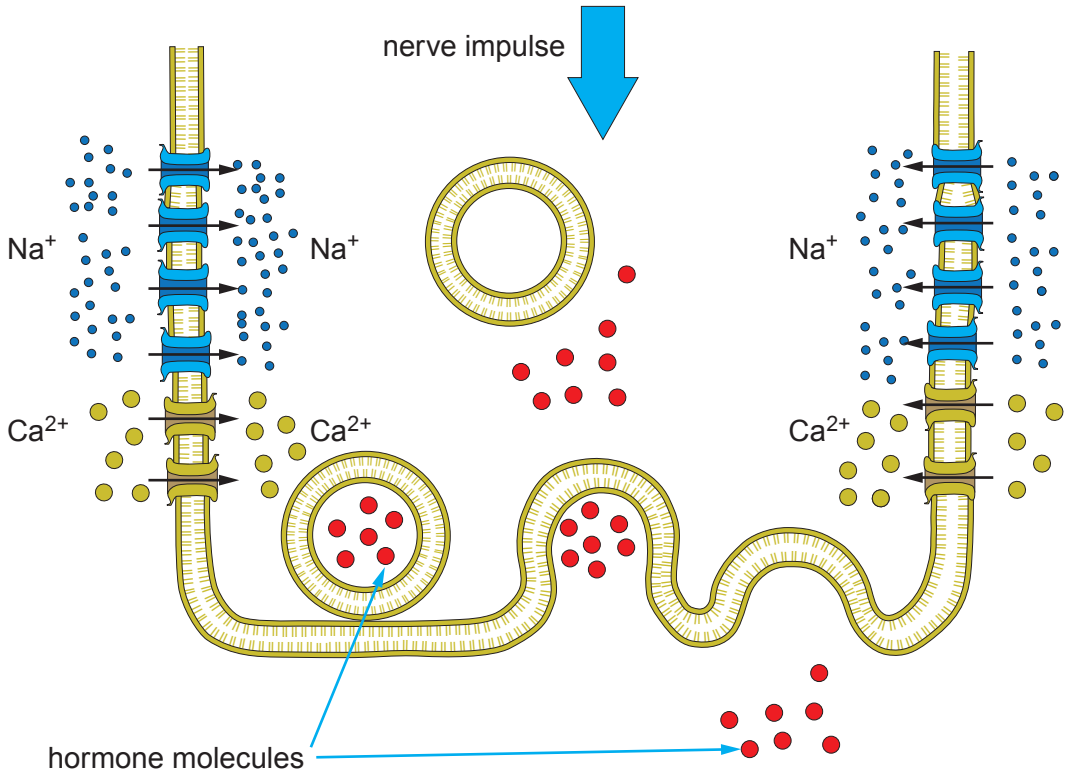
The release of the hormone is brought about by the arrival of a nerve impulse. This is similar to the way in which neurotransmitters are released. The process is shown in **Image 4.2**.

**Image 4.2**




(c) Using all the relevant information from both **Images 4.1** and **4.2** describe how the hormone molecules are released from the end of the neurosecretory cell. [5]









**Turn over.**

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Haemodialysis is one method of treating kidney failure.

Between dialysis sessions patients retain fluid and gain weight. Excess fluid is removed during the next dialysis session to return the patient to their target weight.

(d) Explain why it is important to remove excess fluid during haemodialysis. [2]

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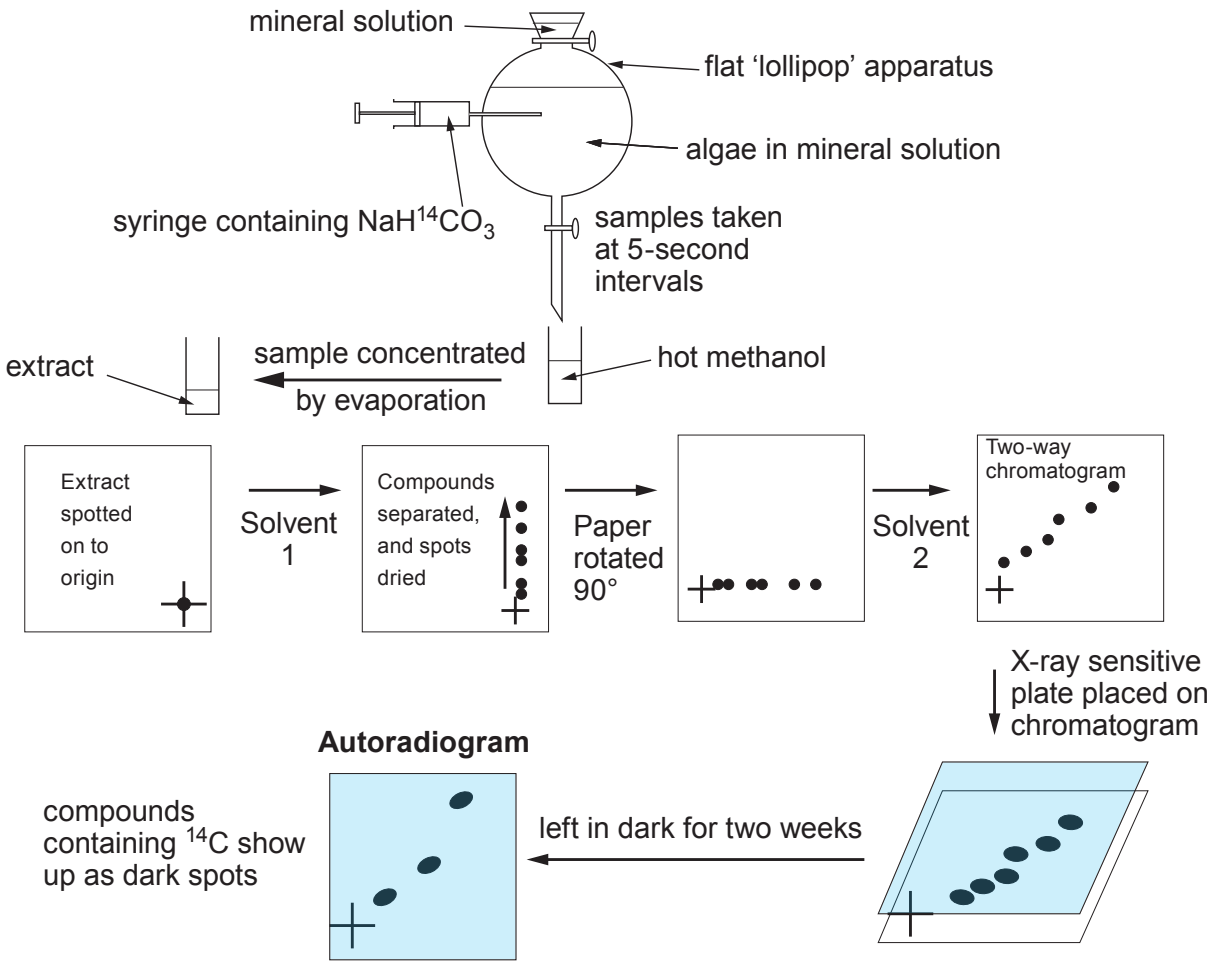
**5.** **Image 5.1** summarises experiments carried out by Melvin Calvin to investigate the '**light-independent**' reactions of photosynthesis.

**Image 5.1**




(a) Calvin placed the lollipop apparatus in bright light, even though he was studying '**light-independent**' reactions.
Using your knowledge of how the products of the '**light-dependent**' reactions are used in the '**light-independent**' reaction, explain why he placed the apparatus in bright light. [2]

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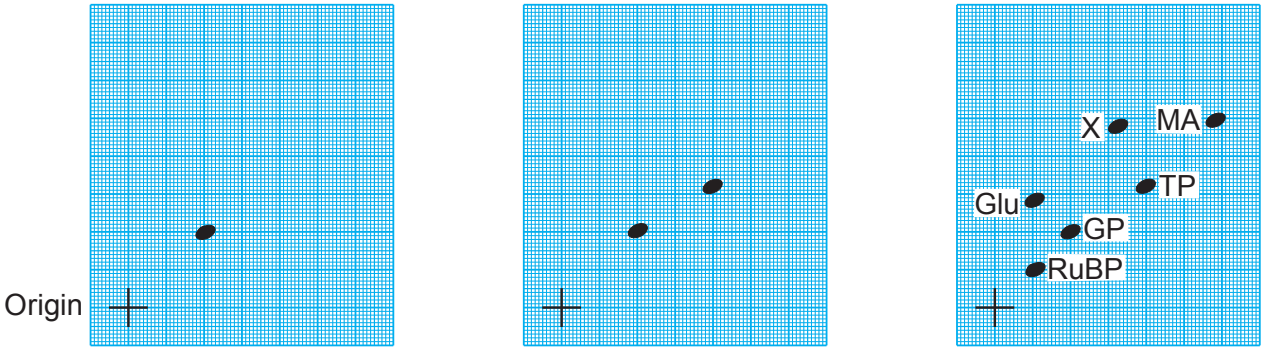
**Turn over.**

Examiner only

The autoradiograms in **Image 5.2** illustrate some of Calvin's results.

**Image 5.2**

**Experiment 1**. Samples taken at short intervals from injection of $NaH^{14}CO_3$.




Time: 5 seconds 10 seconds 15 seconds

The times shown are the times at which the samples were dropped into hot alcohol.

**Key**: Glu – glucose, RuBP – ribulose bisphosphate, GP – glycerate-3-phosphate, TP – triose phosphate, MA – malic acid

(b) (i) Using evidence from **Image 5.2**, identify which of the following sequences of reactions is most likely to be correct. Explain your answer. [2]

**A** Ribulose Bisphosphate ⟶ Triose Phosphate ⟶ Glycerate-3-Phosphate

**B** Glycerate-3-Phosphate ⟶ Triose Phosphate ⟶ Ribulose Bisphosphate

**C** Triose Phosphate ⟶ Glycerate-3-Phosphate ⟶ Ribulose Bisphosphate

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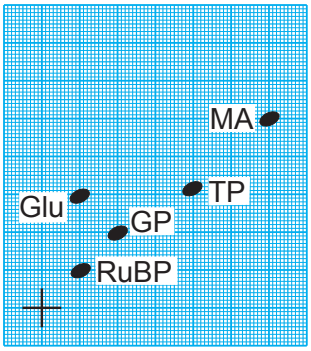
**Experiment 2** was carried out using exactly the same method as **Experiment 1**, except that the mineral solution used contained no nitrate ions. The results are shown in **Image 5.3**.

**Image 5.3**

**Experiment 2**. Mineral solution lacking nitrate.




15 seconds

(ii) Interpret the results of **Experiment 2** to explain the difference between the 15-second autoradiograms from **Experiments 1** and **2** and suggest the nature of compound **X** shown on the **15-second** autoradiogram in **Experiment 1**. [2]

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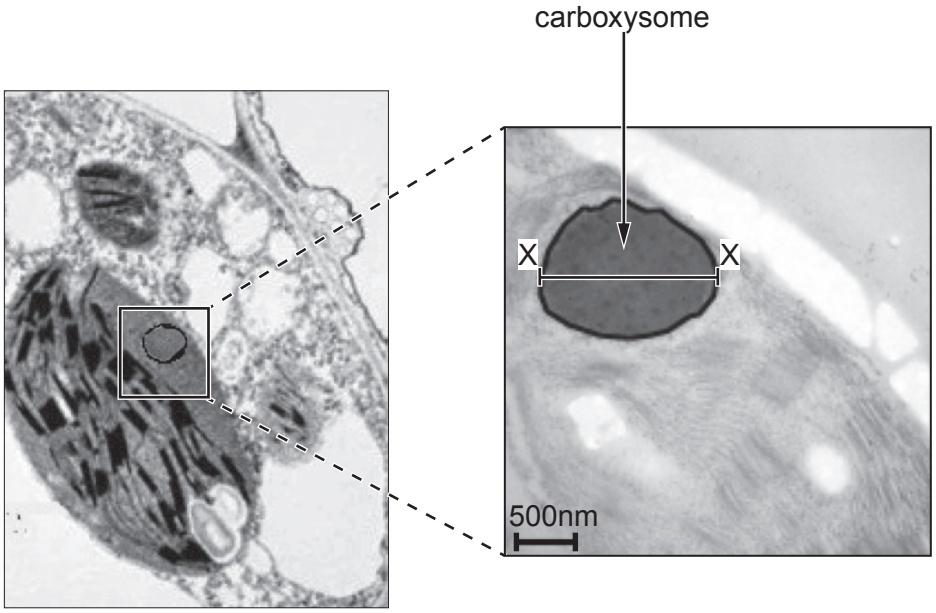
In Cyanobacteria the carbon fixing reaction, catalysed by RuBisCO, is carried out in micro-compartments called carboxysomes. Scientists have used genetic engineering techniques to produce maize plant cells which have carboxysomes. **Image 5.4** shows part of such an engineered cell.

**Image 5.4**




(c) (i) With reference to **Image 5.4**, describe precisely where the carboxysome is located. [1]

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(ii) **Use the scale bar** to calculate the length, **X**–**X**, of the carboxysome in $\mu$m. [2]

Length = ..... $\mu$m

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In addition to RuBisCO, carboxysomes contain the enzyme carbonic anhydrase. Having carbonic anhydrase inside **enhances uptake of carbon dioxide** by catalysing its combination with water.

(d) (i) Suggest an advantage to farmers of introducing carboxysomes into crop plants. Explain your answer. [2]

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(ii) Predict the effect that widespread use of crops engineered to contain carboxysomes might have on the carbon cycle and explain the impact this effect might have on the prospects for endangered species. [3]

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**6.** The chemical reactions carried out by living organisms are collectively called metabolism. Respiration is an essential part of metabolism in all living organisms.

(a) With reference to **two** specific cell activities explain why **all** living organisms must carry out respiration. [2]

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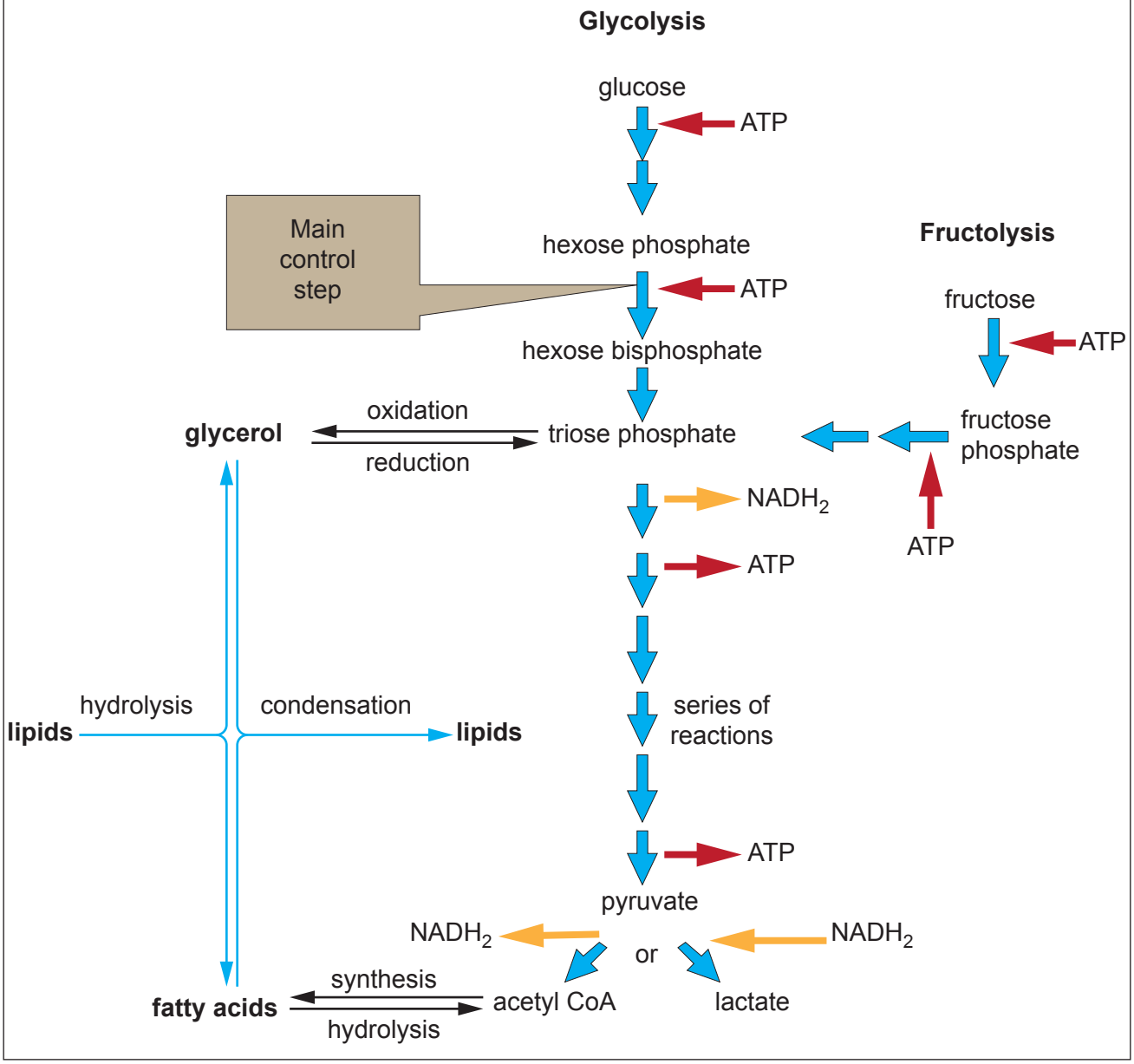
Glucose is an important fuel in almost all living organisms and is processed in the same way in all cells. Fructose is less commonly used as a fuel in cells but is present in the human diet. The way cells process these two **hexose** sugars is compared in **Image 6.1**.

**Image 6.1**



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(b) State the net number of molecules of ATP formed when **one** molecule of each of the following compounds is processed to lactate. Note: two molecules of triose phosphate are formed from each hexose molecule processed. [3]

I. Glucose (C6) .....

II. Fructose phosphate (C6) .....

III. Sucrose (C12) .....

(c) (i) Describe the conditions inside a cell which would determine whether pyruvate is converted to lactate or acetyl CoA. [1]

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(ii) Answer the following questions about the conversion of pyruvate to lactate. [3]

I. Name the type of chemical reaction the pyruvate undergoes.

.....

II. Describe the part played by the coenzyme NAD.

.....

III. Name the type of chemical reaction the coenzyme undergoes.

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(d) When glucose is used as the respiratory substrate, the rate of glycolysis can be controlled to meet the demands of a cell for ATP. Fructose metabolism is not controlled: **Image 6.1** shows how fructose skips the main control step of glycolysis.

When this happens acetyl CoA accumulates more quickly than it can enter the Krebs cycle; this causes a subsequent build-up of triose phosphate.

(i) Using information from **Image 6.1**, name the product of triose phosphate oxidation. [1]

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(ii) With reference to **Image 6.1**, explain why accumulation of acetyl CoA might lead to obesity. [2]

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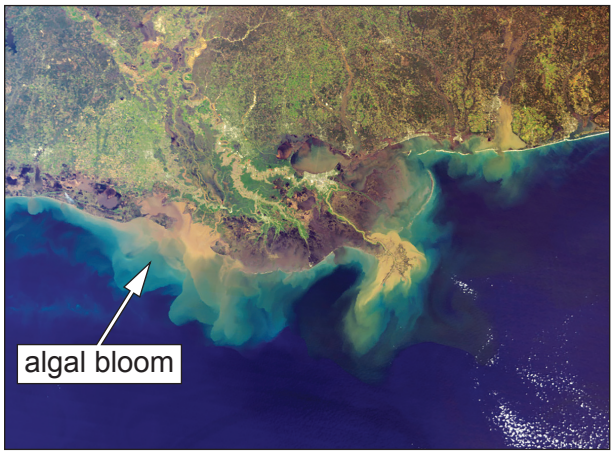
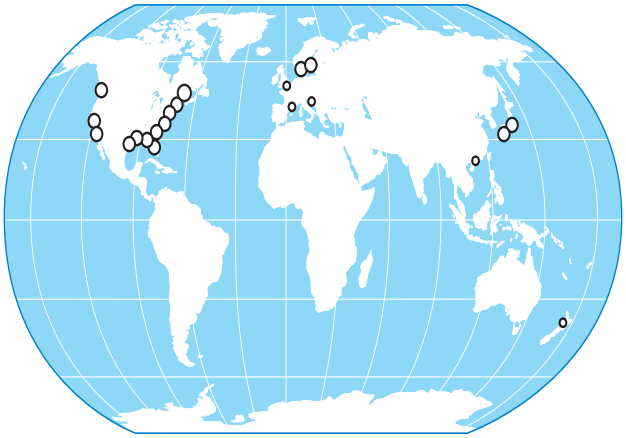
**7.** The impact of an intensive agricultural practice is illustrated in the aerial photograph (**Image 7.1**) and map (**Image 7.2**).

**Image 7.1**




True colour image of the north bank of the Mississippi river

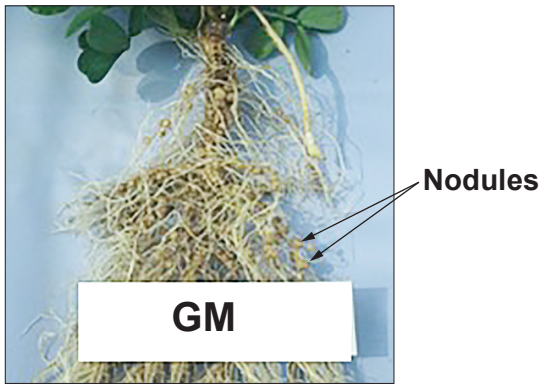
**Image 7.2**



Aquatic dead zones across the world, shown as circles on the map

**Image 7.3** shows the results of an experiment in which plants that do not produce root nodules in the wild were genetically modified.

**Image 7.3**




Roots of genetically modified plants


Wild type and genetically modified plants grown in low nitrate medium

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Describe and explain how agricultural practice resulted in the environmental impact shown in **Images 7.1** and **7.2**.

Explain the results of the experiment to compare growth of wild type and genetically modified plants shown in **Image 7.3**.

Suggest how growing crops genetically modified in this way might lessen the environmental impact of intensive agriculture. [9 QER]

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**END OF PAPER**

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