



Rewarding Learning

ADVANCED
General Certificate of Education
2022

Centre Number

--	--	--	--	--

Candidate Number

--	--	--	--	--

Biology

StemUp Model Solution

Assessment Unit A2 1

assessing

Physiology, Coordination and
Control, and Ecosystems



[ABY11]

ABY11

WEDNESDAY 1 JUNE, MORNING

TIME

2 hours 15 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen.**

Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100.

Section A carries 82 marks. Section B carries 18 marks.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

You are reminded of the need for good English and clear presentation in your answers.

Use accurate scientific terminology in all answers.

You should spend approximately **25 minutes** on Section B.

You are expected to answer Section B in continuous prose.

Quality of written communication will be assessed in Section B.

13024



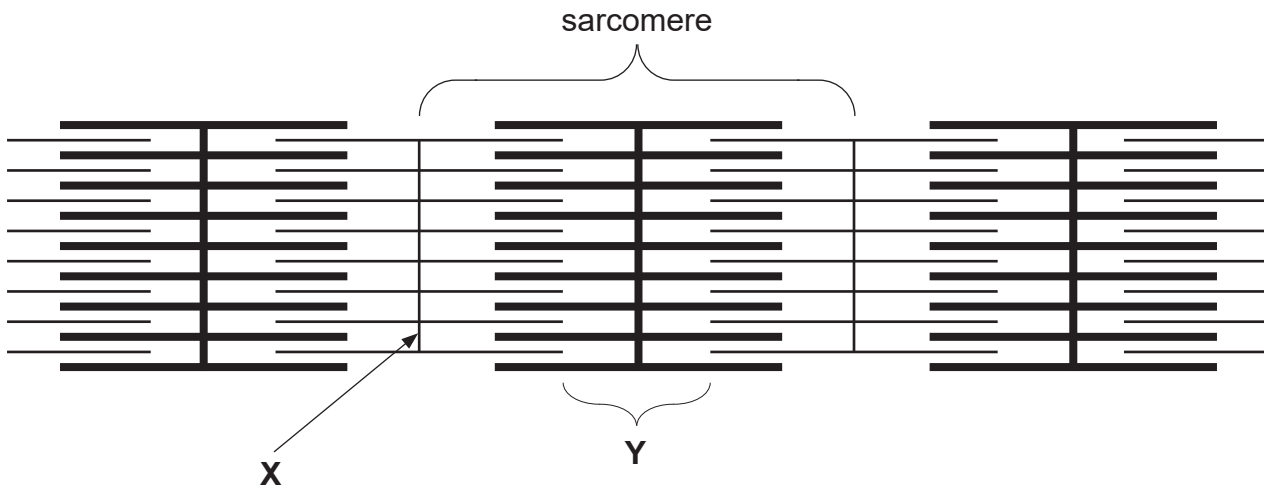
BLANK PAGE
DO NOT WRITE ON THIS PAGE

13024



Section A

- 1 (a) The diagram below represents a section through a myofibril in skeletal muscle.



- (i) Identify the sarcomere components labelled **X** and **Y**.

X Z-line

Y H-zone

[2]

- (ii) The diagram represents the myofibril in a relaxed state. When contracted, the sarcomere will decrease in length. State **two** other changes that would be observed in the myofibril.

1. The H-zone (Y) and the I-band become shorter.

2. The Z-lines (X) move closer to the M-line (more overlap).

[2]

- (b) Describe the role of calcium ions in muscle contraction.

Calcium ions free up the myosin binding sites on the actin filaments,

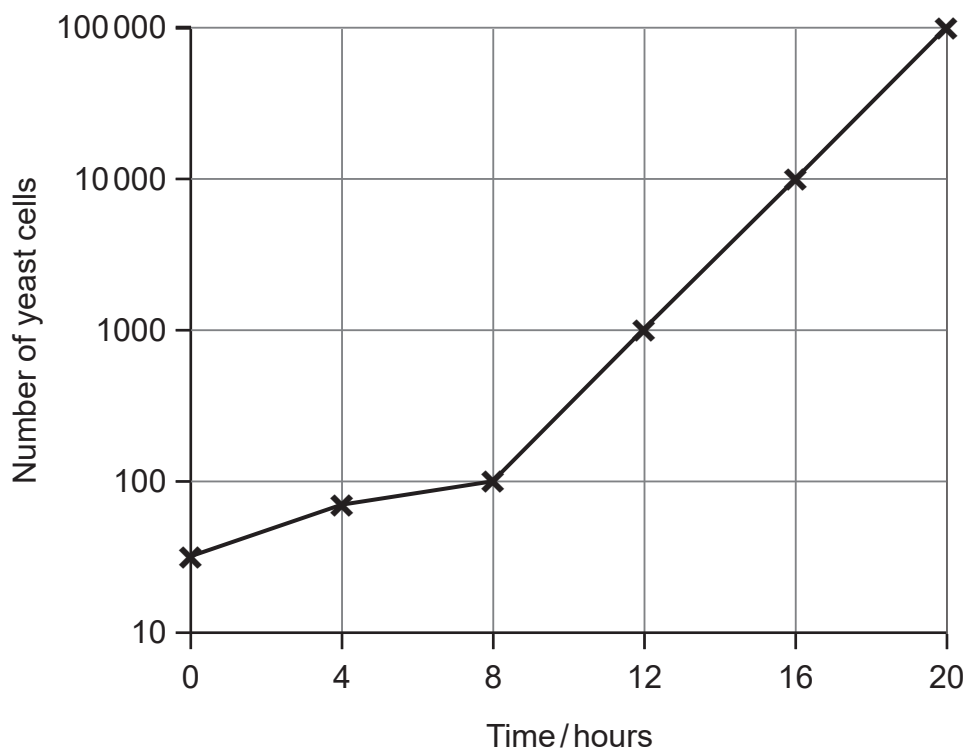
allowing the myosin heads to attach to the actin.

[1]

[Turn over]



- 2 The graph below shows how yeast cell numbers changed after being added to a beaker containing a nutrient-rich solution.



- (a) Name the population growth phase which occurred between 0 and 8 hours.

Lag phase

[1]

- (b) State the evidence which suggests that the carrying capacity of this culture had **not** been reached after 20 hours.

The number of yeast cells was still rising at 20 hours; the plateau
(stationary phase) had not been reached.

[1]



- (c) Calculate the average rate of increase of yeast cells between 8 and 20 hours.
(Show your working.)

At 8 h: 100 cells; at 20 h: 100 000 cells

$$\text{rate} = (100\,000 - 100) \div 12$$

$$= 99\,900 \div 12 = 8325$$

8325

cells hour⁻¹ [2]

- (d) Using your understanding of population growth, describe and explain the pattern shown in the graph.

*Initially (0 to 8 hours) there is a relatively slow increase in cell numbers,
the lag phase.*

*This is due to the cells assimilating nutrients, the induction (synthesis)
of appropriate enzymes and the growth of cells to maturity before they
divide.*

*Then, from 8 to 20 hours, there is an exponential increase in numbers
(log phase), with the number increasing tenfold every 4 hours.*

*This is due to abundant food reserves (nutrients) and no significant
accumulation of toxic waste, so there is little environmental resistance.*

[4]

[Turn over]



- 3 Homeostasis is the maintenance of constant (steady state) conditions within the body. The kidneys control the body's water balance and are therefore important homeostatic organs.

Homeostatic systems have sensors which monitor the factor to be controlled.

- (a) State the precise location of the sensors which monitor the solute potential of the blood.

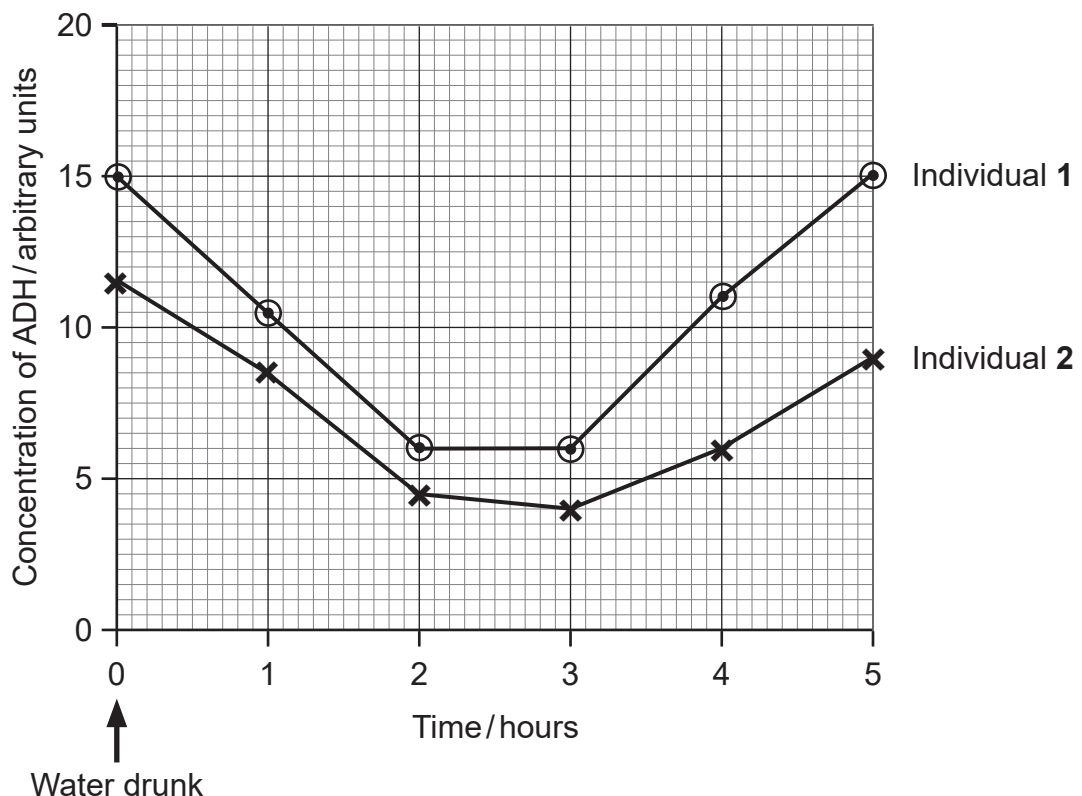
Osmoreceptors in the hypothalamus.

[1]

- (b) Antidiuretic hormone (ADH) is important in osmoregulation. It acts by controlling the amount of reabsorption of water from the collecting ducts of nephrons into surrounding blood vessels.

ADH binds to receptors on the plasma membrane of cells lining the collecting ducts. This binding causes the movement of aquaporins (water channel proteins) towards the plasma membrane. Aquaporins then become incorporated into the membrane.

The graph below shows the concentration of ADH in the blood of two individuals (1 and 2) over a five-hour period, after drinking 600 cm³ of water.



- (i) Describe and explain the results shown for individual 1.

For individual 1, the ADH concentration in the blood falls after drinking the water, reaching its lowest level of 6 arbitrary units after 2 hours (remaining at 6 until 3 hours), then it rises to return to its original level of 15 arbitrary units after 5 hours.

Drinking 600 cm³ of water makes the solute potential of the blood higher (less negative), so less ADH is produced and released.

With less ADH, fewer aquaporins are incorporated into the plasma membranes of the cells lining the collecting ducts, making the walls of the collecting ducts less permeable to water, so less water is reabsorbed into the blood and more dilute urine is produced.

As the solute potential of the blood then lowers (becomes more negative) again, the ADH concentration returns to normal.

[5]

- (ii) The ADH concentration of individual 1 was higher at the start of the investigation. Suggest what might have caused this.

Individual 1 had drunk less water than individual 2 before the investigation (or had been more active, losing water in sweat).

[1]

[Turn over]



- (c) Explain the term 'negative feedback' in the context of osmoregulation.

As the solute potential of the blood approaches the norm (set point), the corrective mechanism, e.g. ADH release, is inactivated (switched off).

[1]

The ADH receptors on the plasma membrane are proteins. Their shape may be distorted, for example as a result of mutation.

- (d) Using the information provided, suggest and explain how the presence of distorted ADH receptors could affect the kidneys' role in osmoregulation.

The ADH will no longer be able to fit to (bind to) the distorted receptors in the membranes of the cells lining the collecting ducts.

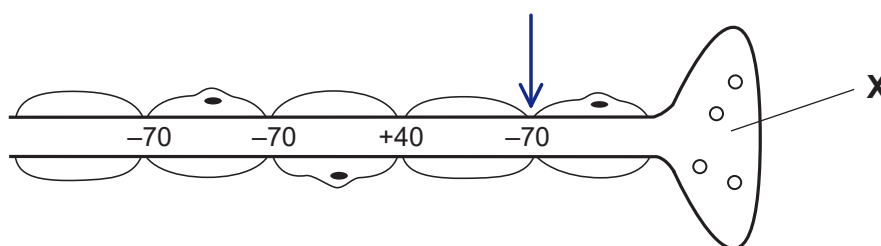
So aquaporins will not be moved to and incorporated into the cell membranes, and the cells remain relatively impermeable to water.

Water remains in the collecting duct, as the kidney fails to reabsorb enough water even when the blood solute potential is low, so large volumes of dilute urine are produced.

[3]



- 4 (a) The diagram below represents part of a myelinated neurone. The membrane potential (in mV) inside the axon membrane relative to the outside is shown at several positions along the axon.



- (i) How many Schwann cells are shown in the diagram?

5

[1]

- (ii) Identify structure X.

Synaptic bulb (synaptic knob)

[1]

- (iii) On the diagram, add an arrow to show the next part of the neurone which will become depolarised.

[1]

- (iv) Explain how the myelin sheath increases the speed of a nerve impulse.

The myelin sheath acts as an electrical insulator, so no depolarisation of the axon membrane can occur under the myelin sheath.

Depolarisation only occurs at the nodes of Ranvier, so the impulses jump from node to node (saltatory conduction), which is faster.

[2]

[Turn over]

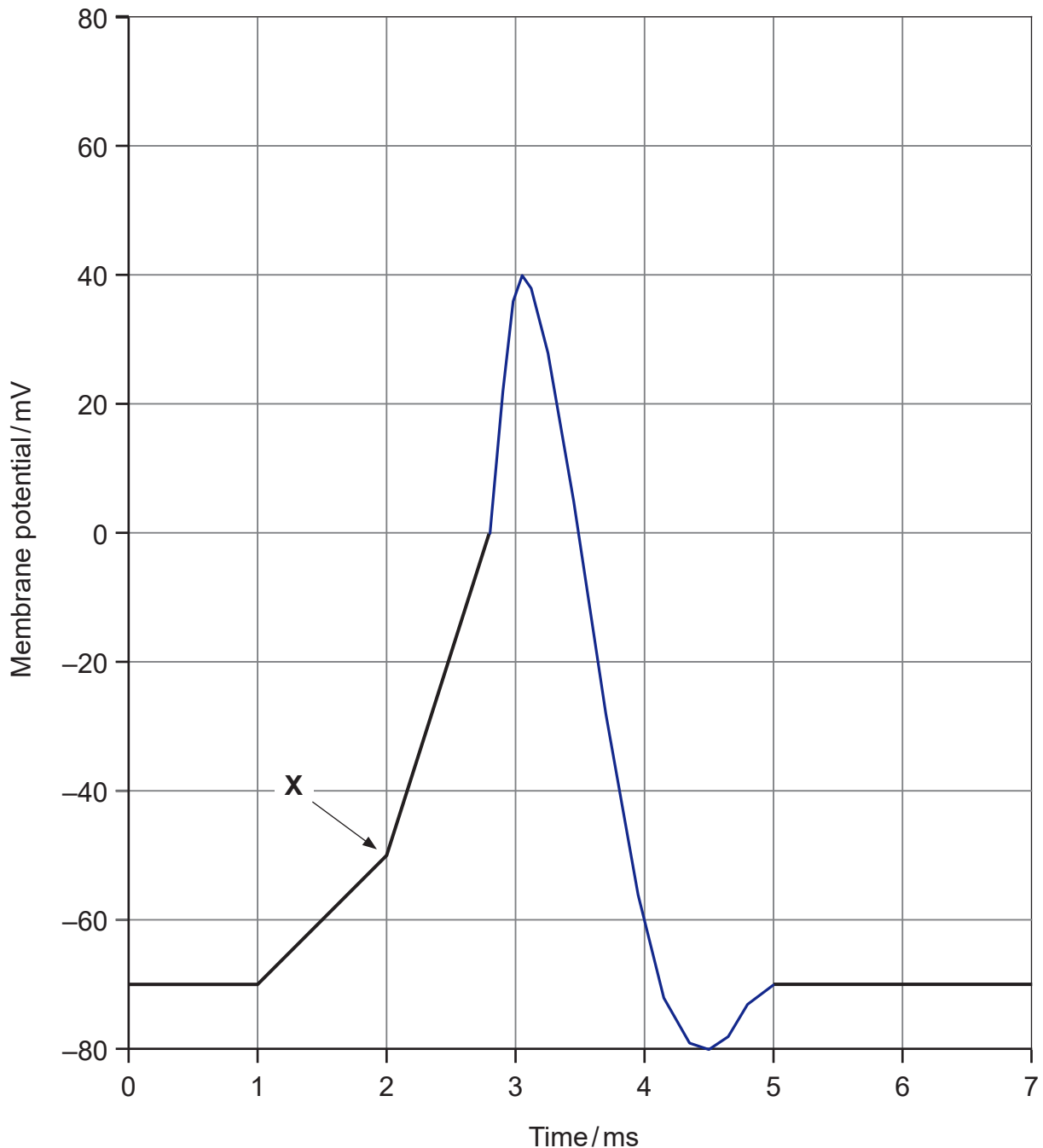


- (v) Apart from the presence of a myelin sheath, state **one** other factor that increases the speed of a nerve impulse.

A thicker (larger diameter) axon, or a higher temperature.

[1]

- (b) The partially completed graph below shows changes in membrane potential as an action potential occurs.



- (i) Complete the graph to show the changes in membrane potential until the resting potential is restored. [2]

- (ii) Suggest what causes the change in rate of depolarisation at position X.

Voltage-gated sodium channels (extra gated channels) open, allowing
an increased number of positive ions (Na^+) to enter the axon.

[1]

- (c) A myelinated neurone is 740 mm long. This neurone is able to conduct nerve impulses at 90 m/s.

Calculate the length of time it takes for an impulse to pass along this neurone.

Give your answer in standard form.
(Show your working.)

$$740 \text{ mm} = 0.74 \text{ m}$$

$$\text{time} = \text{distance} \div \text{speed}$$

$$= 0.74 \div 90$$

$$= 0.0082 \text{ s}$$

$$= 8.2 \times 10^{-3} \text{ s}$$

$$\underline{8.2 \times 10^{-3}} \text{ s [3]}$$

[Turn over]



- 5 (a) Mistletoe (*Viscum album*) is a parasitic plant which grows on trees. The photograph below shows mistletoe growing on the branches of a tree in winter. The tree shown loses its leaves in winter (deciduous), while mistletoe does not (evergreen).



Mistletoe

Source: Chief Examiner

Mistletoe grows in ball-like clumps, as shown in the photograph above. Each clump represents an individual plant. As a parasite, it gains at the expense of its host. The mistletoe plant produces special structures which can penetrate the outer layers of a branch and absorb nutrients and water from the tree.

- (i) Apart from the presence of structures to obtain nutrients and water, and using the information provided, suggest and explain **one** adaptation of mistletoe.

Mistletoe is evergreen, so it can photosynthesise all year, including

during winter;

it can gain more light in winter as the host tree has no leaves, so

the tree's leaves are not blocking the light.

[2]



- (ii) Parasitism can be described as a +/– interaction. Name **one** other type of +/– interaction.

Predation (or grazing / herbivory). [1]

- (b) The photograph below shows ivy (*Hedera helix*) growing on trees.



Source: Chief Examiner

Like mistletoe, ivy is an evergreen plant that has leaves in winter. However, ivy is not classified as parasitic since it has roots that obtain minerals and water from the ground.

Based on the definition of parasitism as a +/– interaction, some scientists suggest that ivy should be classified as parasitic since it can harm the host tree.

- (i) Using the information provided, suggest **two** ways ivy may cause harm to its host tree.

1. It will shade some of the tree's leaves, reducing the tree's photosynthesis.
2. It competes with the tree for water and nutrients, and adds extra weight, acting as a sail in wind, so the tree may fall. [2]

[Turn over



However, the presence of ivy on trees can benefit animal biodiversity in an area.

(ii) Suggest **one** way in which ivy may help benefit animal biodiversity.

It provides nests (shelter) for birds and berries as food in winter.

[1]

(c) The zone of the Earth just south of the Arctic icecaps is known as tundra. In this zone, conditions are very cold and windy throughout the year and there is little rainfall. Lower layers of soil here are frozen all year and the top layers are frozen for part of the year.

Primary succession in tundra habitats can take over 3000 years to reach climax.

Pioneer species are mainly algae and lichen and these are followed by mosses. The stable end stage is usually low-growing shrubs (often evergreen) with lichens, algae and mosses often present. There are very few large animals in this biome (zone).

Using the information provided, answer the following questions.

(i) Name the type of climax community found in the tundra.

Climatic climax

[1]

(ii) Suggest **two** reasons why there are usually very few trees in the tundra.

1. *Not enough water or nutrients are available for large trees to grow.*

2. *Roots cannot penetrate the frozen soil, and it is too windy for tall trees.*

[2]



- (iii) Suggest **one** reason why many of the shrubs are 'evergreen'.

Conditions are harsh, so being evergreen allows photosynthesis throughout the year (whenever possible) and avoids the metabolic costs of producing new leaves.

[1]

- (iv) Succession in the tundra takes much longer than successions in warmer regions, e.g. the British Isles. The main reason for this is the very low temperature in the tundra. Using your understanding of cellular metabolism, suggest an explanation for succession being so slow.

Rates of respiration, photosynthesis and plant growth, and rates of decomposition, are very slow, because at low temperatures enzymes (and substrates) have very low kinetic energy, so fewer enzyme-substrate complexes form; the enzymes are far below their optimum temperature and work less effectively.

[2]

[Turn over]



- 6 (a) The structure and function of the mammalian eye allow light rays to be focused on photoreceptor cells in the retina.

- (i) Describe and explain how the eye focuses on a **near** object.

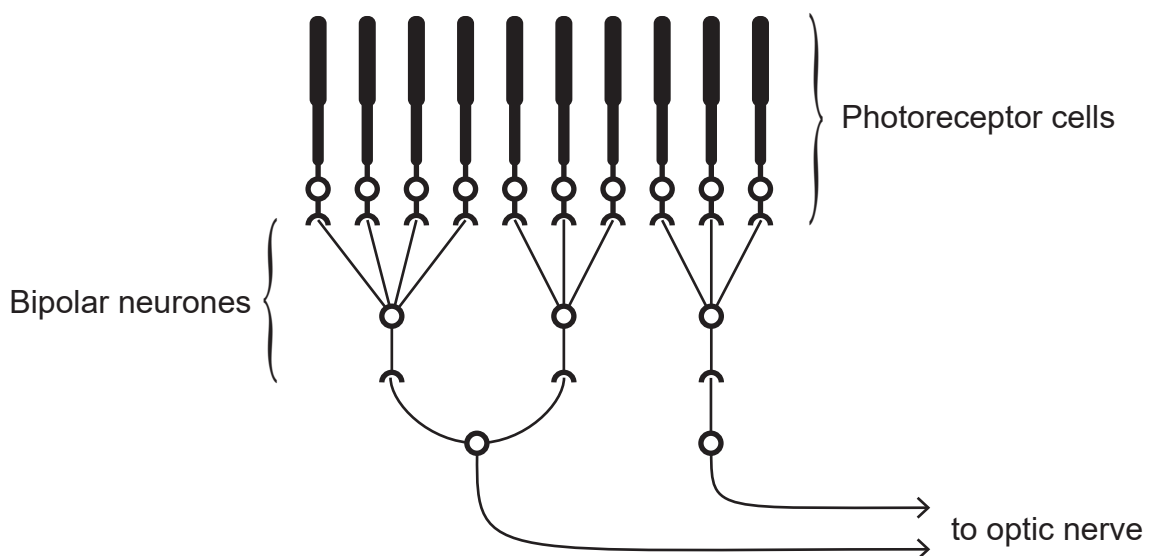
The ciliary muscle (in the ciliary body) contracts,

causing the suspensory ligaments to slacken, so the tension on the lens is reduced.

The elastic lens returns to its thicker, more convex shape, causing more refraction of the light rays, so the image of the near object is focused on the retina.

[3]

The diagram below represents a small section of the retina. Photoreceptor cells are sensitive to visual stimuli.



(ii) Name the photoreceptor cells shown in the diagram.

Rods

[1]

(iii) Using the diagram, describe what is meant by the term 'high visual sensitivity' and explain how high visual sensitivity is achieved.

High visual sensitivity is the ability of the photoreceptors to be
stimulated in low light intensities, i.e. to see in dim light.

This is due to the convergence of rods: several rods synapse with a
single bipolar neurone, as shown in the diagram.

This enables summation of sub-threshold light stimuli: the small
generator potentials from several rods add together at the bipolar
neurone,

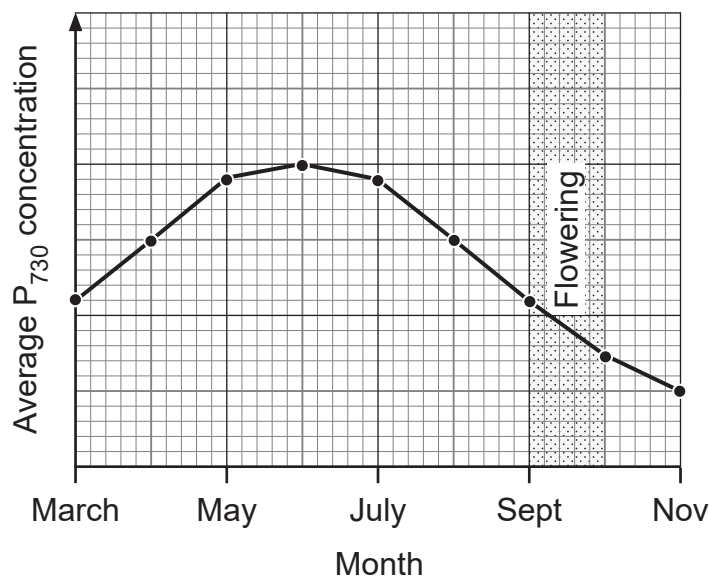
so the threshold is reached, producing an action potential in the
bipolar neurone (and ganglion cells) leading to the optic nerve.

[4]

[Turn over



- (b) Phytochrome is a photoreceptor molecule involved in the flowering process in plants. The graph below shows how the average monthly concentration of the P_{730} form of phytochrome changed between March and November in a particular plant.



- (i) In terms of phytochrome conversions, explain the changes in concentration of P_{730} between March and November.

Daylight causes the conversion of P_{660} to P_{730} , and P_{730} is converted back to P_{660} in darkness.

From March to June, as daylength increases, there is increased conversion of P_{660} to P_{730} and shorter nights give less time to convert P_{730} back to P_{660} , so P_{730} rises.

From June to November, as daylength decreases, there is reduced conversion of P_{660} to P_{730} and longer nights give more time to convert P_{730} back to P_{660} , so P_{730} falls.

[3]



- (ii) Using the graph, describe the evidence which suggests that this plant is a short-day plant.

Flowering occurs when the P_{730} concentration falls to a critically low level (in September).

[1]

- (iii) The graph shows that flowering in this plant occurs in the autumn. Suggest how the photoperiod could be manipulated to delay flowering until December. Explain your answer.

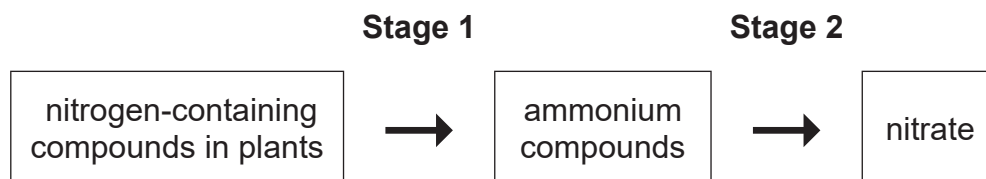
Artificially increase the daylength in the period after June (using artificial lighting), or add a flash of light during the night, so more P_{660} is converted to P_{730} ; this delays the date when P_{730} falls to the critical level that initiates flowering, until December.

[2]

[Turn over]



- 7 (a) The flow diagram below summarises the cycling of nitrogen in nitrogen-containing compounds following the death of plants.



- (i) State the general name given to the organisms involved in **Stage 1**.

Decomposers (saprotrophs)

[1]

- (ii) **Stage 2** takes place faster in non-compacted soil that is well drained. Using your knowledge of nitrification, suggest an explanation for this.

Nitrifying bacteria require oxygen, as nitrification is an aerobic process.

Drainage and non-compaction increase the air spaces in the soil and
so increase oxygen availability (and discourage denitrification).

[2]





BLANK PAGE

DO NOT WRITE ON THIS PAGE

(Questions continue overleaf)

13024

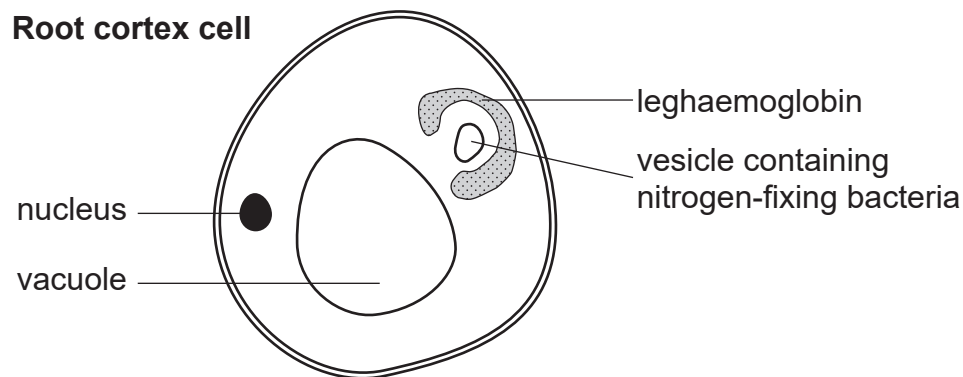
[Turn over



Legumes are plants which are able to fix nitrogen. In these species, nitrogen-fixing bacteria are usually found in cells of the root cortex (between the epidermis and the vascular tissue in the centre of the root).

These bacteria require some oxygen for respiration, but many of the enzymes involved in nitrogen-fixation work best in very low or oxygen-deficient environments.

In some species of legumes, a substance called leghaemoglobin is found in the cytoplasm of the root cortex cells containing the nitrogen-fixing bacteria. This is shown below. Leghaemoglobin is a form of haemoglobin, similar to human haemoglobin. It binds to oxygen if the partial pressure of oxygen reaches a high level.



(b) Using the information provided, suggest and explain the role of leghaemoglobin.

Leghaemoglobin will bind to oxygen diffusing through the root into the cortex cells when the partial pressure of oxygen is high.

In this way it controls the oxygen availability to the nitrogen-fixing bacteria, absorbing excess oxygen,

so that the bacteria receive just enough oxygen for respiration (to make ATP), but the nitrogen-fixing enzymes do not receive too much oxygen, which would inhibit them.

[3]



In contrast to nitrogen fixation, denitrification is the process in which nitrate is converted to nitrogen gas. The table below summarises denitrification activity over a range of soil depths in a marsh, an environment in which soil water levels are usually high.

Soil depth / cm	Denitrification activity / arbitrary units
5	23
10	56
15	84
20	80
25	86

(c) Describe the trend shown and suggest an explanation.

Denitrification activity increases with soil depth, from 23 arbitrary units at 5 cm to 84 at 15 cm, then levels out (80 to 86) from 15 cm to 25 cm.

Denitrifying bacteria are anaerobic: denitrification is an anaerobic process. At increasing depth the soil is more waterlogged and so contains less oxygen, favouring denitrifying bacteria.

[3]

[Turn over



- 8 The human immunodeficiency virus (HIV) is the virus that can lead to Acquired Immunodeficiency Syndrome (AIDS). AIDS is the term used to describe the characteristic range of 'opportunistic' infections and diseases that can develop in people who have been infected by HIV.

HIV is a retrovirus and is very closely related to the simian immunodeficiency virus (SIV), a virus frequently present in chimpanzees, although causing little harm. It is thought that HIV mutated from SIV and that the chimpanzee acted as a 'reservoir' for HIV before it passed to humans. Evidence indicates that the transfer of the virus between a chimpanzee and a human occurred in the forests of central Africa in a region where the chimpanzees and humans live in close proximity.

- (a) (i) Define the term retrovirus.

A virus which has RNA rather than DNA as its genetic material, and uses reverse transcriptase to make DNA from the RNA.

[1]

- (ii) Suggest **one** way in which the HIV virus could have passed from chimpanzees to humans.

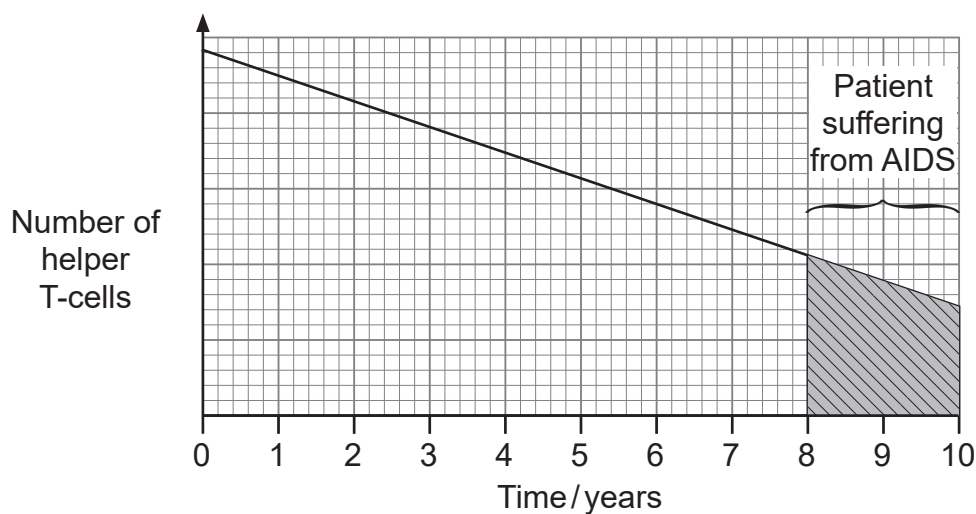
Humans eating chimpanzees as food (bushmeat), or through a chimpanzee bite.

[1]



- (b) The main target cell for HIV in humans is the helper T-cell.

The graph below shows how the number of helper T-cells changed over a ten-year period in an individual infected with HIV.



- (i) Using the information provided and your understanding of immunity, suggest why people with AIDS suffer from a range of 'opportunistic' infections and diseases that seldom affect people who do not have AIDS.

In people with AIDS the number of helper T-cells has fallen below a critical level.

So the helper T-cells are not able to stimulate the production of killer T-cells (and memory cells),

and are not able to stimulate B-cells to produce plasma cells and antibodies, or to promote phagocytosis.

So the immune system cannot fight pathogens that would normally be destroyed quickly.

[3]

[Turn over]



Once in the body, HIV attaches to a specific receptor on the surface membrane of helper T-cells, known as the CD4 receptor.

- (ii) When scientists were developing drugs to combat AIDS, there was a major focus on the CD4 receptor. Suggest how these drugs could work.

The drugs could block (bind to) the CD4 receptors, e.g. a molecule with a complementary shape, or change the receptor's shape, so HIV cannot attach to and infect the helper T-cells.

[2]

- (c) T-cells are also involved in 'autoimmune' diseases, where cells of the immune system destroy the body's own cells. For example, in Type 1 diabetes, killer T-cells destroy the insulin-secreting cells of the pancreas.

Scientists suggest that autoimmune diseases can be a consequence of reduced production of suppressor T-cells.

- (i) State the function of suppressor T-cells and explain how reduced production could lead to the development of Type 1 diabetes.

Suppressor T-cells regulate (deactivate) immune responses once a pathogen is destroyed.

With reduced production there is no regulation of killer T-cell activity (number), so killer T-cells are not prevented from attacking the insulin-secreting cells.

[2]



- (ii) Type 1 diabetes often begins in childhood. In many cases, the onset of the condition occurs a few months after a child has suffered from an infectious viral disease such as chickenpox.

Using the information given, suggest an explanation for the link between having an infectious disease and the development of Type 1 diabetes.

The immune system is triggered and more active than normal as a consequence of the earlier viral infection.

This heightened immune activity continues, as suppressor T-cells are damaged (or reduced), and killer T-cells destroy the insulin-producing cells.

[2]



Section B

Quality of written communication will be assessed in this section.

- 9 (a) Phytoplankton are single-celled, photosynthesising prototists that live in the surface layers of seas. They are the producers in many food chains. A typical example is shown below.

phytoplankton → herring (fish) → puffins (birds) → eagles (birds)

Explain why only a very small percentage of the solar energy reaching the sea surface is available for eagle growth in the above food chain. [12]

- (b) Increasing efficiency of energy transfer is an important factor in intensive agriculture.

Explain the role of fertiliser, confinement and high-energy and high-protein foods in increasing efficiency in agriculture. [6]



- (a) Phytoplankton are single-celled, photosynthesising protists that live in the surface layers of seas. They are the producers in many food chains. A typical example is shown below.

phytoplankton → herring (fish) → puffins (birds) → eagles (birds)

Explain why only a very small percentage of the solar energy reaching the sea surface is available for eagle growth in the above food chain.

Only a very small percentage of the solar energy reaching the sea surface ends up in eagle growth, because energy is lost at every stage of the food chain.

Much of the solar energy is reflected by the sea surface, and some is used in the evaporation of water rather than reaching the phytoplankton.

Some light misses the phytoplankton cells altogether, passing between them, and of the light entering a cell some misses the chloroplasts.

Much of the light is of the wrong wavelength to be absorbed by the photosynthetic pigments, e.g. green light is reflected or transmitted.

There are also biochemical inefficiencies in photosynthesis, as energy is lost as heat during the light-dependent and light-independent reactions.

As a result, typically less than 1% of the solar energy is converted into production (biomass) in the phytoplankton.

Energy is then lost at each transfer between trophic levels. Herring are unable to digest the cellulose cell walls of the phytoplankton, so much of the energy is lost in egestion (faeces).

The energy loss between producer and primary consumer is therefore greater than the subsequent losses between consumers, as plant material

[Turn over]



is less digestible than animal material.

At each trophic level energy is also lost in excretion, e.g. urea or uric acid, which contains chemical energy.

A large proportion of the energy is lost in respiration, used for movement (e.g. swimming and flying) and released as heat, so it is not available for growth.

Dead organisms and waste products that are not eaten pass to the decomposer (detritus) food chain, so this energy is also lost to the grazing food chain.

Puffins and eagles are unable to eat or digest all of their prey; for example they cannot eat or digest bones, scales or feathers, which are rejected or egested.

Puffins and eagles are endotherms, so they have greater energy losses via respiration in order to maintain a constant body temperature.

As a result, the efficiency of energy transfer between consumers is typically only 10 to 20%, and even lower in endotherms.

This food chain is particularly inefficient because it contains two endotherms (puffins and eagles), and these birds live in particularly difficult, cold and windy habitats, so heat loss and therefore respiration losses will be particularly high.

Eagles are also the fourth trophic level, so the energy has passed through three transfers, each with large losses.



Therefore the energy available for eagle growth (their net production) is only a tiny fraction of the solar energy reaching the sea surface.

[Turn over





- (b) Increasing efficiency of energy transfer is an important factor in intensive agriculture.

Explain the role of fertiliser, confinement and high-energy and high-protein foods in increasing efficiency in agriculture.

Fertiliser increases primary productivity (the growth of crops and grass), by increasing the soil mineral content, e.g. nitrate, phosphate and potassium, which prevents mineral content becoming limiting.

Confinement of livestock (in sheds or small field sections) reduces their movement, therefore reducing respiration losses, so more energy is available for growth.

Confinement in heated sheds, or in close proximity to each other, reduces heat loss from the livestock, so less energy is required (respired) to maintain body temperature.

Confinement in fields (small sections) allows manure to be spread more evenly, gives more efficient grazing of grass, and allows the grass in unused sections more time to recover.

Feeding livestock high-energy foods means that less food is required to maintain growth, therefore increasing the production to input ratio.

High-protein foods provide the protein needed for more growth (muscle), and contain a reduced quantity of indigestible material, so less energy is lost in egestion.

Together these measures increase the efficiency of energy transfer, so a greater proportion of the energy input ends up in the food produced.

[Turn over



[illegible]



THIS IS THE END OF THE QUESTION PAPER

BLANK PAGE

DO NOT WRITE ON THIS PAGE

13024



DO NOT WRITE ON THIS PAGE

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	

Total Marks	
-------------	--

Examiner Number

Permission to reproduce all copyright material has been applied for.
In some cases, efforts to contact copyright holders may have been unsuccessful and CCEA will be happy to rectify any omissions of acknowledgement in future if notified.

