



Rewarding Learning

ADVANCED
General Certificate of Education
2023

Centre Number

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Candidate Number

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Biology

StemUp Model Solution

Assessment Unit A2 1

assessing

Physiology, Coordination and
Control, and Ecosystems



[ABY11]

ABY11

THURSDAY 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 eight** 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.

13756



Section A

1 The statements below relate to the structure of muscles.

State the most appropriate word defined by each statement:

- the protein which forms the thin filaments in a myofibril

Actin

- the region of a myofibril between adjacent Z-lines

Sarcomere

- the zone or band which does **not** change in length as a myofibril contracts

A-band (dark band / anisotropic band)

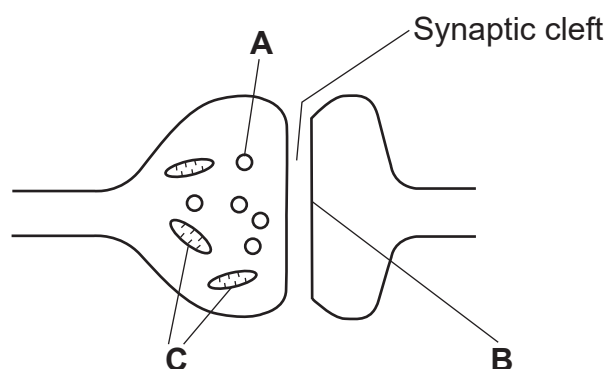
- the ions released which stimulate muscle contraction.

Calcium ions (Ca^{2+})

[4]



- 2 (a) The diagram below shows parts of two adjacent neurones at a synapse.



Source: Chief Examiner

- (i) Identify structures **A** and **B**.

A Synaptic vesicles (containing neurotransmitter)

B Post-synaptic membrane (with transmitter receptors)

[2]

- (ii) Describe precisely the function of structures **C**.

Mitochondria produce ATP (release energy) needed to resynthesise the neurotransmitter, e.g. acetylcholine, in the synaptic knob.

[1]

- (iii) In some species, synapses involved in reflex and other defensive actions have narrower synaptic clefts compared to other synapses.

Suggest the advantage of narrower synaptic clefts. Explain your answer.

A narrower cleft means the neurotransmitter takes less time to diffuse across the cleft to the receptors on the post-synaptic membrane,

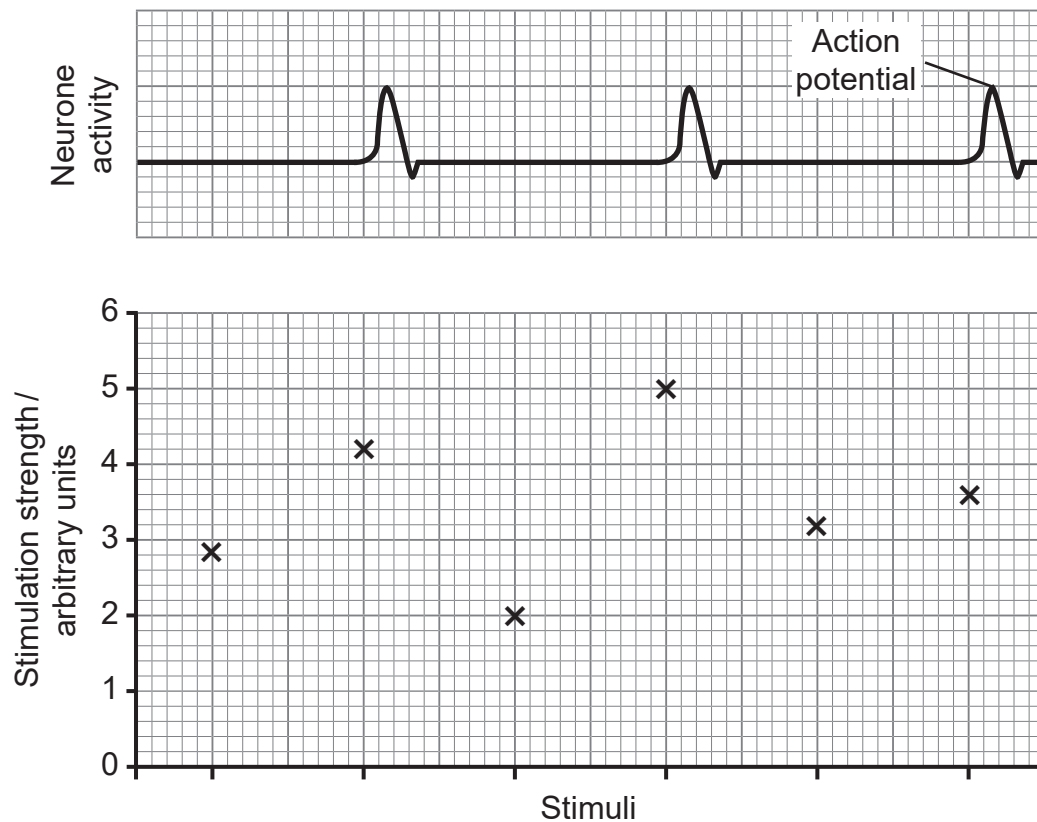
so the synaptic delay is shorter, giving a faster reflex response and the body is less likely to suffer harm.

[2]

[Turn over]



- (b) A study investigated the relationship between stimulus strength and the generation of action potentials in a neurone. The results for six stimuli of different strengths are shown in the graph below.



- (i) From the results shown, estimate the stimulus threshold value.

3.4 arbitrary units [1]

- (ii) Explain how the results demonstrate the 'all-or-nothing' law.

All the action potentials produced are the same;

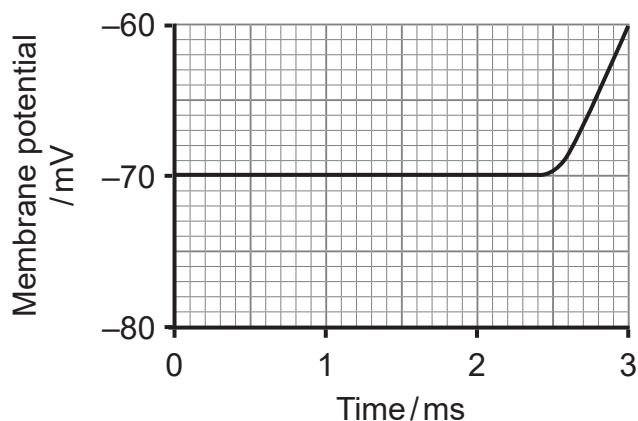
they have the same amplitude regardless of the strength of the

stimulus above threshold; below it there are none.

[2]



The graph below represents the membrane potential of a neurone immediately before and at the start of an action potential.



(c) Explain fully the membrane potential between 2 and 3 ms.

Between 2 and about 2.5 ms the potential is -70 mV, which is the resting potential, during which the membrane is polarised (inside negative relative to outside).

At about 2.5 ms the action potential starts: depolarisation begins as the potential rises towards -60 mV, due to positive ions (Na^+) entering the neurone as voltage-gated sodium channels open.

[3]

[Turn over]



3 The kidney is both an excretory and an osmoregulatory organ.

- (a) Urine is the mixture of substances excreted from the body following kidney filtration. Name the three parts of the excretory system that urine passes through after leaving the kidney until its removal from the body. List these parts in the correct order.

Ureter bladder urethra [1]

- (b) The proximal convoluted tubule (PCT) is the part of a nephron where selective reabsorption of glucose and amino acids takes place. The cells lining PCTs are highly adapted for the selective reabsorption of these substances. For example, they have large numbers of mitochondria to produce the ATP required for active transport.

- (i) Describe and explain one **other** way in which the cells lining the PCT are adapted for selective reabsorption.

The cells have microvilli on their luminal surface (and basal
invaginations),
which greatly increase the surface area across which glucose and
amino acids can be absorbed, providing space for more carrier /
channel proteins. [2]

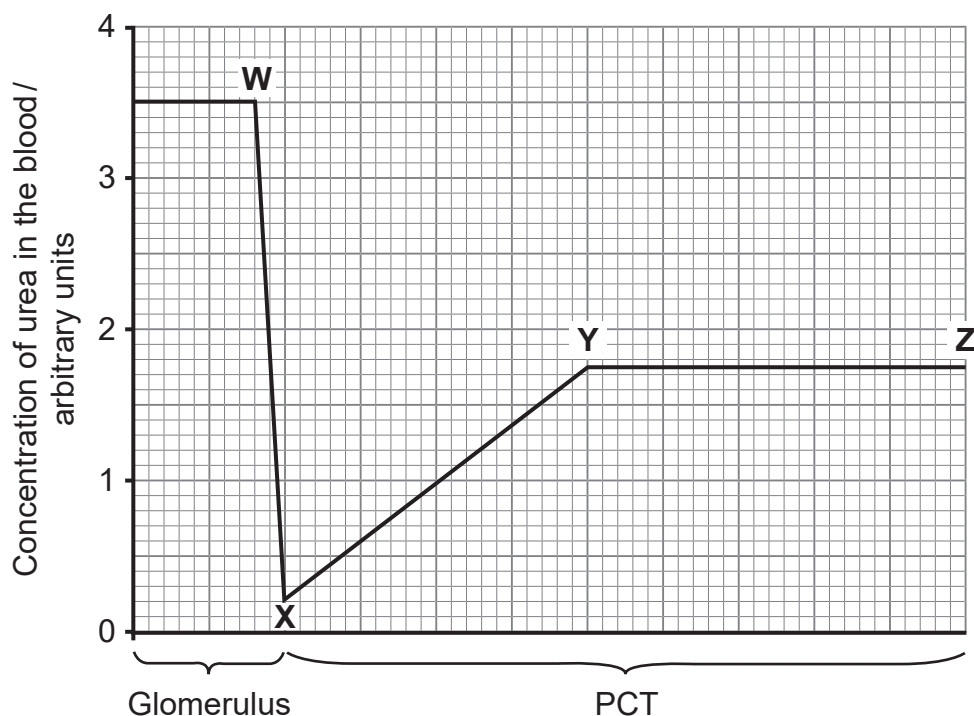
- (ii) Explain how selective reabsorption of glucose and amino acids from the PCT facilitates the reabsorption of water.

Reabsorbing glucose and amino acids lowers (makes more negative)
the solute potential in the epithelial cells and then the blood,
creating an osmotic gradient (water potential gradient), so water is
reabsorbed by osmosis from the filtrate.

_____ [2]



- (c) The diagram below shows how the concentration of urea **in the blood** changes as it passes through the blood vessels in certain parts of the kidney.



- (i) Name the process which occurs between **W** and **X**. Explain how this process causes the concentration of urea in the blood to decrease.

Ultrafiltration.

Urea is a small molecule so it is able to pass through the filter

(basement membrane), being forced out of the glomerular capillaries

by high hydrostatic pressure into the filtrate.

[2]

- (ii) Explain the increase in concentration of urea in the blood between **X** and **Y**.

Urea diffuses back into the blood from the proximal tubule, as its

concentration in the tubule is greater than in the blood.

[1]

[Turn over]



- (iii) Explain why the concentration of urea in the blood remains constant between **Y** and **Z**.

An equilibrium is reached between the concentration of urea in the blood and in the proximal tubule; urea is not selectively reabsorbed.

[1]



The diagram below summarises the osmoregulatory role of the kidney when blood solute potential decreases (becomes more negative).

Osmoreceptors detect a decrease in blood solute potential



Corrective action



Normal blood solute potential restored

- (d) Describe and explain the corrective action which restores the normal blood solute potential in this situation.

Osmoreceptors in the hypothalamus stimulate the hypothalamus to

increase the synthesis of ADH,

and more ADH is released into the blood from the posterior pituitary gland.

ADH increases the permeability of the collecting ducts (and distal convoluted tubules) to water, as more aquaporins are inserted into the membranes,

so more water is reabsorbed into the blood, raising the blood solute potential, and a small volume of concentrated urine is produced.

[3]

[Turn over



4 A range of substances are involved in promoting plant growth.

- (a) Write the most appropriate word(s) into the blank spaces to complete the passage below.

The elongation of internodal regions in stems is promoted by the substance

gibberellin, whereas cytokinin acts by

promoting *cell division*.

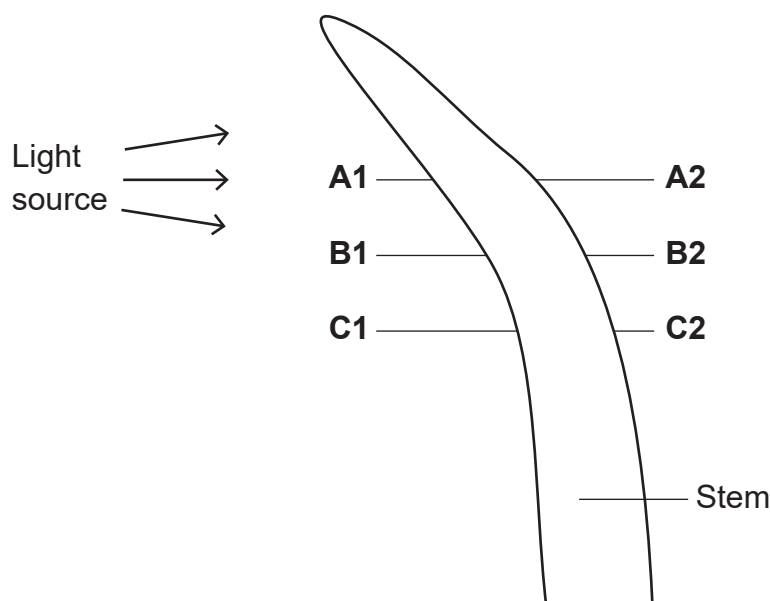
[2]

- (b) Auxin is a plant growth substance produced in the stem tip. It is translocated down the stem to the regions in which it acts.

Historically, scientists developed two hypotheses to explain auxin distribution and phototropism (the growth of a stem in the direction of a light source).

1. Auxin is destroyed on the illuminated side (with the auxin concentration on the shaded side unaffected).
2. Auxin is moved from the illuminated to the shaded side.

In an investigation, mean auxin concentrations in three sections of a plant stem (**A**, **B** and **C**) were measured on each of the illuminated (**1**) and the shaded (**2**) sides. The stem was displaying a phototropic response, as shown below.



The mean auxin concentrations for each area are shown in the table below.

Section of plant stem	Mean auxin concentration / arbitrary units
A1	275
A2	304
B1	201
B2	380
C1	167
C2	409

- (i) Summarise the results and explain how the evidence supports hypothesis 2, and not hypothesis 1.

At each of A, B and C there is more auxin on the shaded side than on the illuminated side, and the difference between the sides increases down the stem from A to C.

However, the total auxin concentration at each level is similar (A 579, B 581, C 576), so auxin has not been destroyed on the illuminated side, which rejects hypothesis 1.

Instead auxin is moved from the illuminated side to the shaded side, supporting hypothesis 2.

[3]

[Turn over



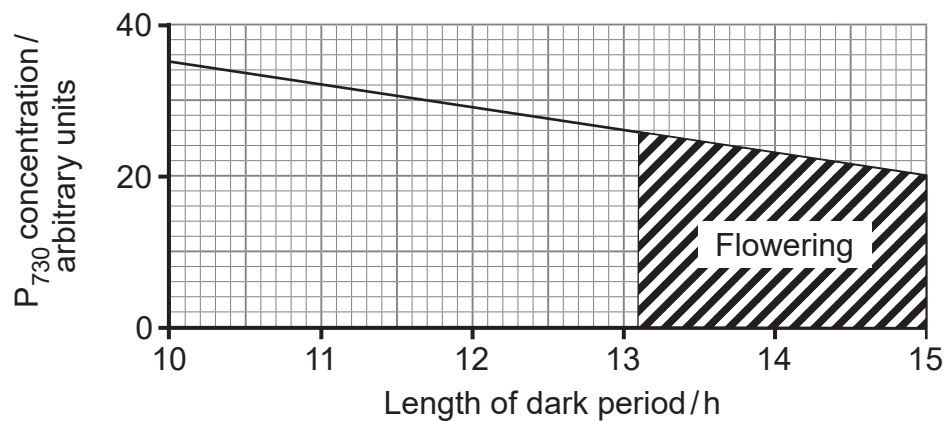
- (ii) Explain the role of auxin in phototropism.

The greater concentration of auxin on the shaded side of the stem leads to increased cell elongation there, causing differential growth on the two sides, so the stem bends towards the light source.

[2]

- (c) Phytochrome is a plant pigment which is important in the control of flowering. It exists in two interchangeable forms, P_{660} and P_{730} .

The graph below shows how length of night (dark period) and P_{730} concentration affects the initiation of flowering in a species.



- (i) Identify precisely the critical length of the dark period required to initiate flowering.

13.1 hours

[1]



- (ii) With reference to phytochrome conversions, explain the effect of changing the length of the dark period on flowering in this species.

As the length of the dark period increases, the level of P_{730} decreases until a critically low level is reached (about 13.1 h), removing its inhibitory effect so flowering is initiated (a short-day plant). This is because a longer dark period allows more P_{730} to be broken down / converted back to P_{660} , and the shorter light period means less P_{660} is converted to P_{730} during the day. Shorter nights leave P_{730} above the critical level, so flowering is inhibited.

[3]

[Turn over]



- 5 Growth of plants can be affected by interactions, both positive and negative, with other organisms.

(a) Define the term 'biotic potential'.

Biotic potential is the maximum rate of growth of a population (under ideal conditions with no environmental resistance).

[1]

(b) In Lime trees, dispersal of seeds is aided by the presence of a leaf-like 'parachute'. Dispersal assists colonisation of new areas and reduces competition with the parent tree and other seedlings.



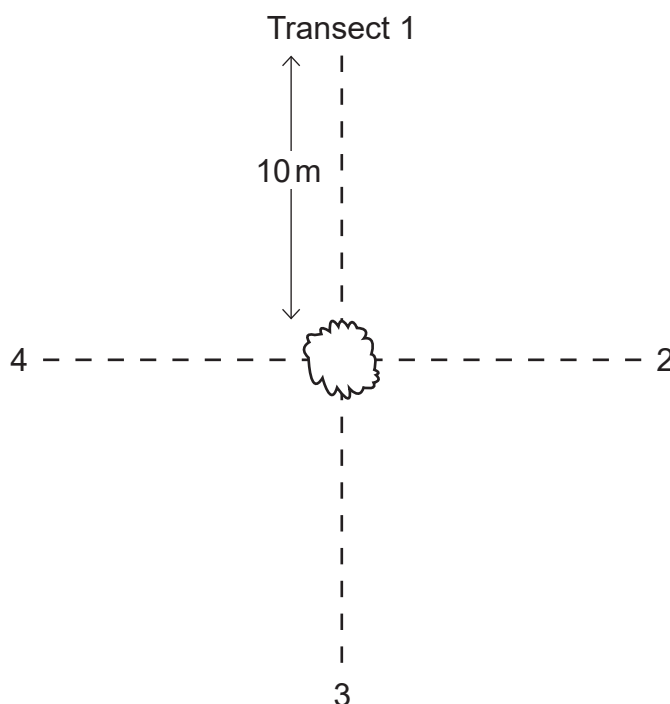
Source: Chief Examiner



An investigation was carried out on seed dispersal from a Lime tree. Initially, the mean number of seeds per square metre found up to 10m away from the tree was recorded.

Subsequently, the number of seedlings surviving two years and then five years following dispersal was recorded.

The method involved four transects taken in straight lines away from the base of the tree trunk (with the second transect being at a right angle to the first and so on), as shown in the diagram below.



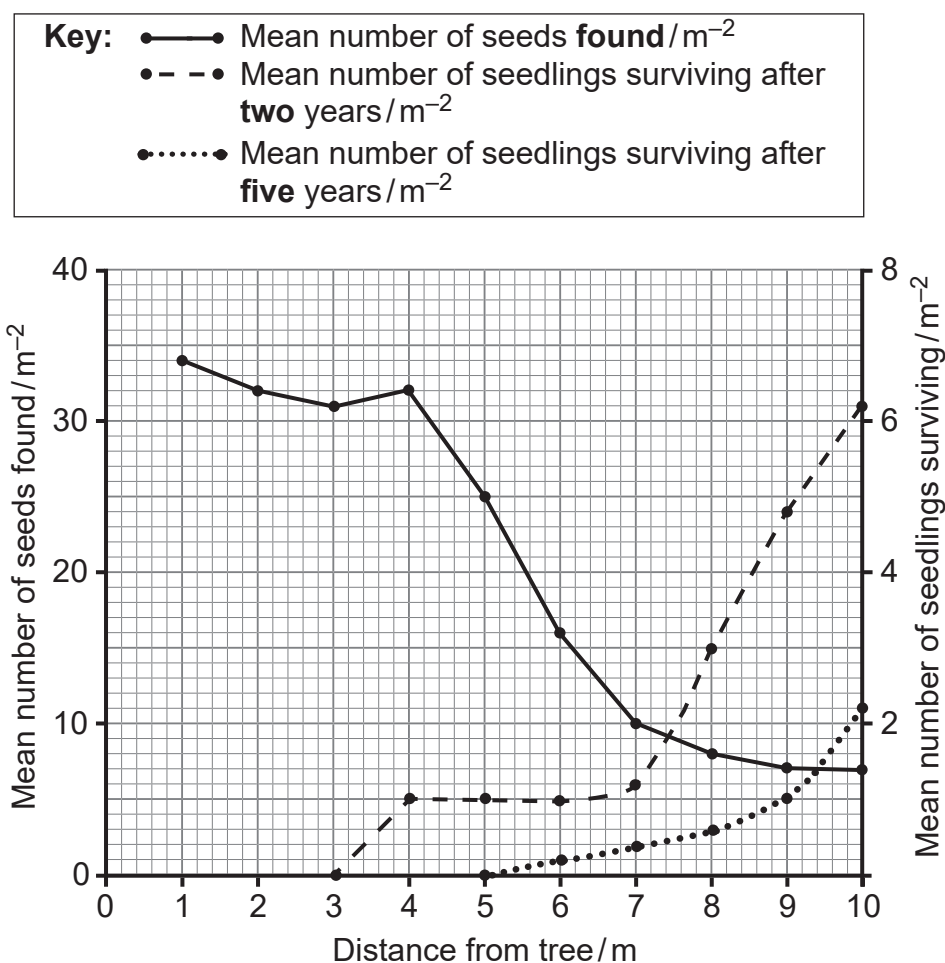
- (i) In this investigation, a single mature Lime tree in an isolated field was chosen, rather than a tree within a woodland. Suggest **one** reason for this.

It avoids confusion with seeds and seedlings from other trees, so all seeds counted came from that one tree. [1]

[Turn over]



The results are shown in the graph below.



- (ii) Calculate the percentage of seeds found at a distance of 10 metres which survive as seedlings for at least two years.

(Show your working.)

At 10 m: seeds found = 7 m⁻²

seedlings surviving 2 years = 6.2 m⁻²

% = 6.2 ÷ 7 × 100 = 88.57

88.6 % [2]



(iii) Describe the results for seeds **found**.

*Most seeds are dispersed close to the tree, within 4 m of the trunk
(over 30 seeds m⁻²).*

*Between 4 and 10 m the number of seeds found decreases with
distance from the tree, falling to about 7 seeds m⁻² at 10 m.*

[2]

(iv) Explain the results for seedling **survival** after each of two and five years.

*No seedlings survive within 3 m of the tree due to competition from
the parent tree for water, minerals and light (shade).*

*From 3 m, increasing numbers of seedlings survive with distance from
the tree as competition with the parent tree is reduced.*

*More seedlings survive for 2 years than for 5 years, as 5-year
seedlings are larger and there is greater competition between
seedlings for water, minerals and light,*

*and there is more time for seedlings to be eaten (predated) or
destroyed for other reasons.*

[4]

[Turn over]



- (c) Mycorrhiza are soil fungi which form mutualistic associations with many species of tree and other plants.

In woodland, the fungi penetrate tree roots and their hyphae extend between the cells of the root cortex. Water and minerals absorbed by the fungi can pass into the trees. The mycorrhizal association thus extends the effective distance over which the trees can absorb water and minerals.

- (i) Suggest how this mutualistic association benefits the fungi.

The fungi are provided with carbohydrate (sugars), products of photosynthesis, by the tree.

[1]

The importance of mycorrhizal fungi was investigated as follows.

Seeds of one species of tree were planted in pots of woodland soil. Half of the pots contained untreated woodland soil and the other half contained woodland soil which had been heated at 100°C for 24 hours. The pots were then all placed in identical environmental conditions and the development of seedlings was monitored.

At the end of the investigation, it was observed that all the seeds placed in untreated soil had germinated to produce healthy seedlings. However, in the soil which had been heated, less than 20% of the seeds had developed into seedlings. The seedlings which had developed weighed less than half of the weight of the seedlings in untreated soil.

- (ii) Using the information provided, outline the conclusions which can be drawn from this investigation. Explain your answer.

The heat treatment killed the mycorrhizal fungi in the soil.

So mycorrhizal associations are necessary for the normal growth and survival of seedlings of this species, as they need the fungi to absorb enough water and minerals.

[2]



- (d) Environmental agencies are trying to increase the percentage of land in Northern Ireland covered by woodland. Increasing biodiversity is a goal, as is reducing the rate of carbon dioxide increase in the atmosphere.

Both coniferous and deciduous plantations are used as part of this strategy. Conifers are evergreen and retain their leaves over winter, casting a dense shade under their canopy. Deciduous trees shed their leaves every winter and grow new leaves each spring.

Using the information provided, answer the questions below.

- (i) Suggest and explain **one** reason why conifers may be more effective than deciduous trees at reducing the rate of increase of carbon dioxide in the atmosphere.

Conifers keep their leaves for longer, throughout the year including winter,
so they photosynthesise for more of the year and therefore absorb more carbon dioxide from the atmosphere.

[2]

- (ii) Most scientists agree that deciduous trees are more beneficial to biodiversity than conifers. Suggest **one** reason for this.

Light reaches the ground in deciduous woods (in spring), giving a greater range of habitats, whereas conifers cast too dense a shade for many ground plants to survive.

[1]

[Turn over]



6 Antibody-mediated immunity involves the production of specific antibodies in response to the presence of foreign antigens.

(a) (i) Outline briefly the steps involved between the introduction of a foreign antigen into the body for the first time and antibody production.

Certain B-lymphocytes with complementary receptors are sensitised (stimulated) by the antigen and divide by mitosis (clonal selection), forming plasma cells which produce and secrete the specific antibodies.

[2]

Secondary immune responses, following vaccination or previous infection, often involve antibodies being produced faster and in greater numbers.

(ii) Explain why there is:

faster antibody production *memory cells are already present and can produce antibodies quickly without needing to be sensitised.*

greater antibody production *both memory cells and B-lymphocytes produce plasma cells, as memory cells clone rapidly.*

[2]



- (b) Part of the reason why people can become ill very quickly after infection is that bacteria can divide rapidly.

Assuming that bacteria divide every 20 minutes, calculate the number present after four hours following infection by a single bacterium.

$$4 \text{ hours} = 240 \text{ min}; \quad 240 \div 20 = 12 \text{ divisions}$$

$$\text{number} = 2^{12}$$

4096 [1]



- (c) Antibiotic resistance in bacteria has developed in many ways. For example, some species (or strains) of bacteria have evolved relatively impermeable cell walls, whereas others have developed the ability to remove the antibiotic chemicals once they enter the cells.

The development of resistance involves a considerable energy cost to the bacteria.

In a study of antibiotic resistance, a bacterial sample was cultured on agar jelly in Petri dishes in a laboratory. During the study an antibiotic was added to the growth medium on day 3.

The results are shown in the table below.

Day	Percentage of bacteria which were resistant to antibiotic
1	3
2	2
3	2
4	81
5	97
6	100
7	100

- (i) Using the information provided and your understanding, describe and explain the results shown in the table.

For the first 3 days the percentage of resistant bacteria was very low (3% or less).

In an antibiotic-free environment resistance has a high metabolic (energy) cost, so it is selected against: non-resistant bacteria grow and multiply faster.

From day 4 (after the antibiotic was added) almost all bacteria were



resistant, reaching 100% by day 6,

*as the antibiotic killed the non-resistant bacteria, so only resistant
bacteria survived and reproduced (natural selection).*

[4]

Further research has been carried out on the effects of low concentrations of antibiotics on bacteria.

Studies have shown that in these circumstances, some bacteria can 'switch off' the cellular processes that check and correct mistakes in DNA replication.

- (ii) Suggest and explain the possible benefit to these bacteria of switching off these processes.

*Not correcting replication errors will increase the probability (rate) of
mutation taking place,
and so increases the possibility of a mutation for antibiotic resistance
arising, allowing the bacteria to survive the antibiotic.*

[2]

[Turn over]



- 7 Grasslands are ecosystems dominated by grass species with few, if any, shrubs or trees. There is a wide range of grassland types, usually determined by soil characteristics. Examples include damp meadow grasslands and dry coastal grasslands.

(a) Define the term 'ecosystem'.

*An ecosystem is a community of organisms interacting with each other
and with their abiotic environment.*

[1]

(b) Meadow grasslands are often characterised by having deep fertile soils. If not grazed by cattle, the grass is usually cut late in the summer. This is necessary to conserve them as grasslands.

(i) Using your understanding of succession, suggest why grazing or cutting is necessary to maintain meadow grassland.

*Otherwise succession will take place, leading to the growth of shrubs
and trees, and the grassland would be lost.*

[1]



The table below shows the estimated mean number of organisms in a meadow grassland.

Trophic level	Estimated mean organisms / m ⁻²
producers	3350
primary consumers	240
secondary consumers	33
tertiary consumers	0.02

- (ii) Calculate the percentage of organisms in the grassland which are tertiary consumers.

(Show your working.)

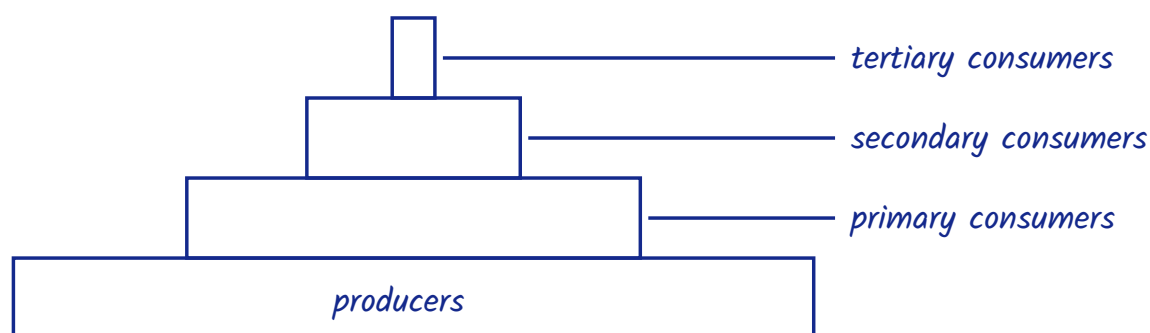
$$\text{total} = 3350 + 240 + 33 + 0.02 = 3623.02$$

$$\% = 0.02 \div 3623.02 \times 100$$

$$= 5.5 \times 10^{-4}$$

$$\underline{5.5 \times 10^{-4}} \% [2]$$

- (iii) In the space below, draw and label a pyramid of numbers for this grassland.



[2]

[Turn over]



(c) Unlike meadow grasslands, coastal grasslands often have shallow sandy soils which drain rapidly.

(i) Suggest why coastal grasslands remain as grasslands, without the need for grazing or mowing each year.

Too few nutrients, and water is not retained in the sandy soil, so

succession cannot take place and shrubs and trees cannot grow.

[1]

Common Bird's-foot-trefoil (*Lotus corniculatus*) is a common plant of coastal grasslands. It is a species which is able to fix nitrogen.



Source: Chief Examiner

(ii) Describe what is meant by 'nitrogen fixation' and explain the advantage of this in coastal grasslands.

Nitrogen fixation is the synthesis of organic nitrogen-containing

compounds (amino acids) from gaseous nitrogen (N_2), by bacteria in root nodules.

Nitrates are easily leached from sandy soil, so very few nitrates are available; the plant can still obtain nitrogen.

[2]



(d) Meadow Buttercup (*Ranunculus acris*) and Bulbous Buttercup (*Ranunculus bulbosus*) are also common in coastal grasslands.

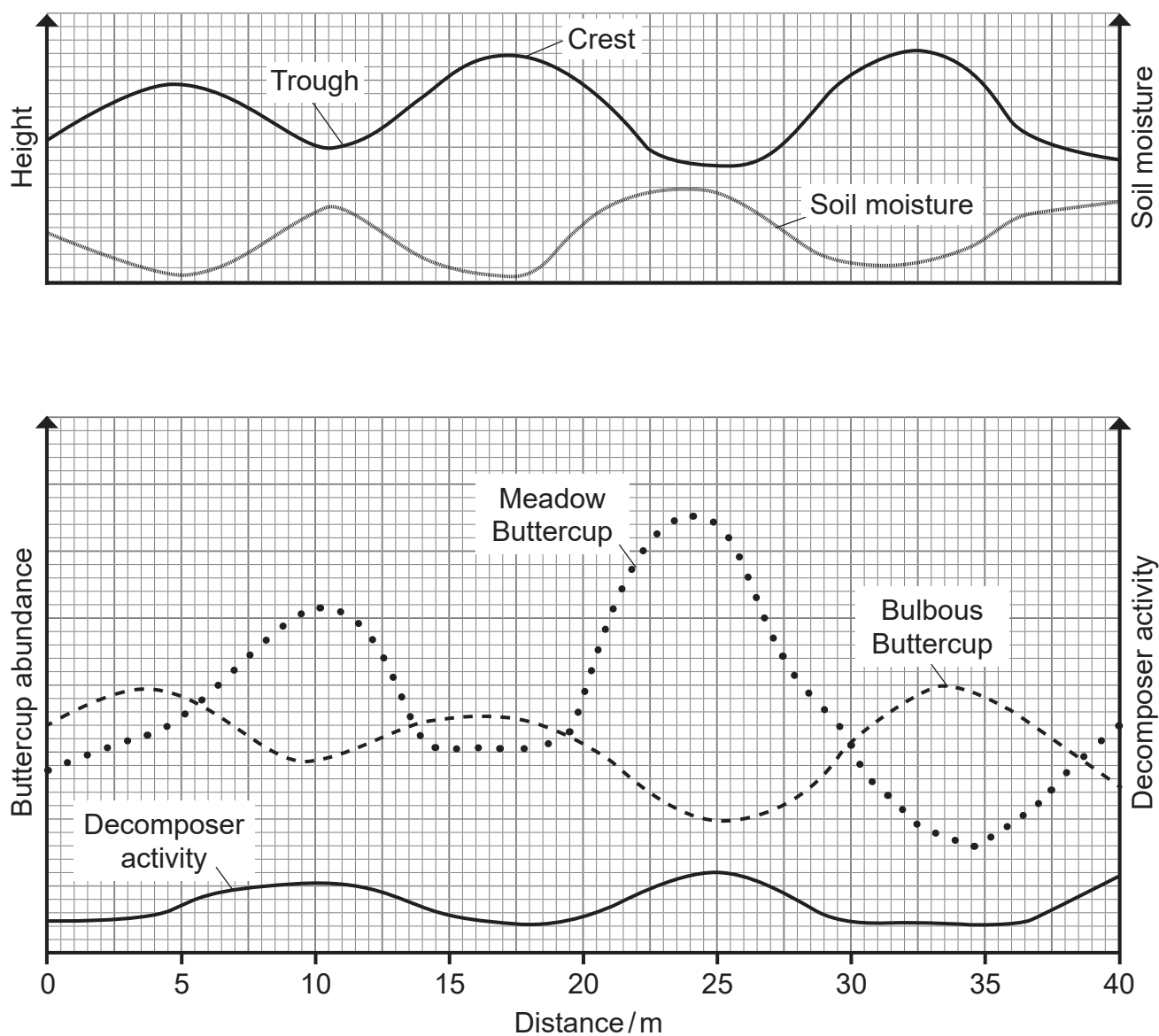
- (i) State precisely what can be determined about the classification of *R. acris* and *R. bulbosus* from their binomial names.

They are different species within the same genus, *Ranunculus*.

[1]



In a study, the distribution and abundance of these two buttercup species and the activity of decomposers was investigated. The ground in the study area was undulating (consisting of a series of crests and troughs). The results of the investigation are summarised in the graphs below.



(ii) Describe and suggest explanations for the results shown.

Bulbous Buttercup is most abundant on the crests, whereas Meadow Buttercup is most abundant in the troughs.

Bulbous Buttercups are adapted for drier soils with greater drainage on the crests, and Meadow Buttercups are adapted for the moister soils in the troughs.

Decomposer activity is greater in the troughs (e.g. at about 10 m and 25 m).

This is because dead plant material (debris) accumulates in the troughs and the soil there is more moist, favouring decomposers.

Also, decomposer activity is high where Meadow Buttercup abundance is high, as more Meadow (than Bulbous) Buttercups provide more material to decompose.

[5]

[Turn over]



- (e) Rabbits can be harmful to grasslands, because they graze the grasses very close to the ground and dig burrows.

Around 60 years ago, some rabbit populations were deliberately infected with a virus which caused myxomatosis, a disease fatal to rabbits. This was done to try to reduce damage to agricultural grasslands.

- (i) State the term used to describe this method of reducing the numbers of a pest species.

Biological control

[1]

- (ii) The use of a virus in this role caused some concern in the scientific community.

Suggest **one** reason for this.

Viruses mutate easily, so it could mutate and infect other mammals;

it is difficult to control.

[1]



Section B

Quality of written communication will be assessed in this section.

- 8 The mammalian eye is adapted to focus light rays on to photoreceptors in the retina.

Rods and cones are the photoreceptors in the retina.

- (a) Describe the structure of rods and outline how the structure of cones differs from that of rods. [6]

- (b) The arrangement and distribution of rods, cones, and associated neurones in the retina enable the eye to achieve high levels of both visual sensitivity and visual acuity. Describe how high visual sensitivity and high visual acuity are achieved. [12]

- (a) Describe the structure of rods and outline how the structure of cones differs from that of rods.

Rods are thin, elongated cells, which allows large numbers of them to be packed into the retina.

Each rod has an outer segment, the end closest to the choroid (and sclera), which consists of a stack of membranes (discs) containing the light-sensitive pigment rhodopsin.

The inner segment, the section closest to the vitreous humour, contains the nucleus and many mitochondria, which provide ATP for resynthesising rhodopsin.

At its inner end each rod has a synaptic ending, where it synapses with a bipolar neurone.

Cones have a similar basic structure of outer segment, inner segment and

[Turn over



synaptic ending, but differ in several ways.

Cones contain the pigment iodopsin in the membranes of their outer segment rather than rhodopsin.

There are three types of cone, each with a different form of iodopsin sensitive to different wavelengths (red, green and blue light), and this range of pigment types allows colour perception.

Cones are less elongated than rods: they are shorter and wider, with a tapering, cone-shaped outer segment.



- (b) The arrangement and distribution of rods, cones, and associated neurones in the retina enable the eye to achieve high levels of both visual sensitivity and visual acuity. Describe how high visual sensitivity and high visual acuity are achieved.

High visual sensitivity is achieved by rods. Rods are more abundant than cones at the periphery of the retina, and they are responsible for sensitivity of vision, allowing shapes and outlines to be distinguished in dim light.

Rhodopsin is readily broken down even in low light intensities, whereas cones require high light intensities to function.

Several rod cells synapse with a single bipolar neurone; this is called retinal convergence.

In dim light the generator potential in each individual rod may be sub-threshold, but the potentials from several rods combine (summate) at the bipolar neurone, so that the threshold potential required to generate an action potential in the bipolar neurone is reached.

Bipolar neurones also show retinal convergence, as several bipolar neurones synapse with one ganglion cell, further increasing sensitivity.

However, as a consequence of retinal convergence, rods do not provide acuity of vision: the brain cannot tell which of the rods sharing a bipolar neurone was stimulated, so two close points of light are seen as one.

High visual acuity is achieved by cones. Cones are concentrated in the fovea, where light rays are focused during precision vision; the fovea

[Turn over



contains no rods.

Cones are responsible for visual acuity, the accuracy of vision (detail), which includes colour vision, since three types of cone respond to different wavelengths.

Each cone cell synapses with a single bipolar neurone (no retinal convergence),

allowing each cone cell to produce a discrete impulse to the brain, so that light falling on two adjacent cones is perceived as two separate points, giving a detailed image.

Because cones do not summate, they need bright light, so acuity is high only in good light, whereas rods give sensitivity in dim light.

There are no rods or cones at the blind spot, where the optic nerve leaves the eye, so no image is detected there.

Therefore the distribution of rods (periphery, convergence) and cones (fovea, one to one connection) allows the eye to achieve both high sensitivity and high acuity.





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Question Number	Marks
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Total Marks	
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Examiner Number

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