



Rewarding Learning

ADVANCED
General Certificate of Education
2025

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

MONDAY 2 JUNE, AFTERNOON

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 questions in black ink and use a dark HB pencil for drawings and graphs.

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 may use a scientific calculator.

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.

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Section A

1 Plant growth substances (hormones) have a role in stem elongation.

(a) Identify the role of the following hormones:

- gibberellins

Gibberellins promote stem elongation by causing cell elongation in the internodal regions.

- cytokinins

Cytokinins promote cell division (mitosis), producing new cells for growth.

[2]

(b) Phytochromes are pigments which control flowering in some plants. Two interchangeable forms of phytochrome have been identified in flowering plants.

(i) Name these **two** forms of phytochrome.

P_{660} (P_R , red-absorbing) and P_{730} (P_{FR} , far-red-absorbing)

[1]

(ii) Using your knowledge of phytochrome conversions, explain the effect on a short-day plant of interrupting the middle of a 12-hour period of darkness with 15 minutes of light.

The light converts P_{660} into P_{730} , so P_{730} levels become too high. The plant does not flower.

This is because the interruption makes each dark period (6 hours) too short for P_{730} to convert back and fall below the critical value needed for flowering.

[2]

[Turn over]



- 2 A banded pattern is visible in voluntary muscle when viewed with an electron microscope. Structures called sarcomeres have Z-lines at each end. Myosin and actin are the main components of a sarcomere.

(a) (i) State **one** structural similarity between myosin and actin filaments.

Both are protein molecules (made of amino acids).

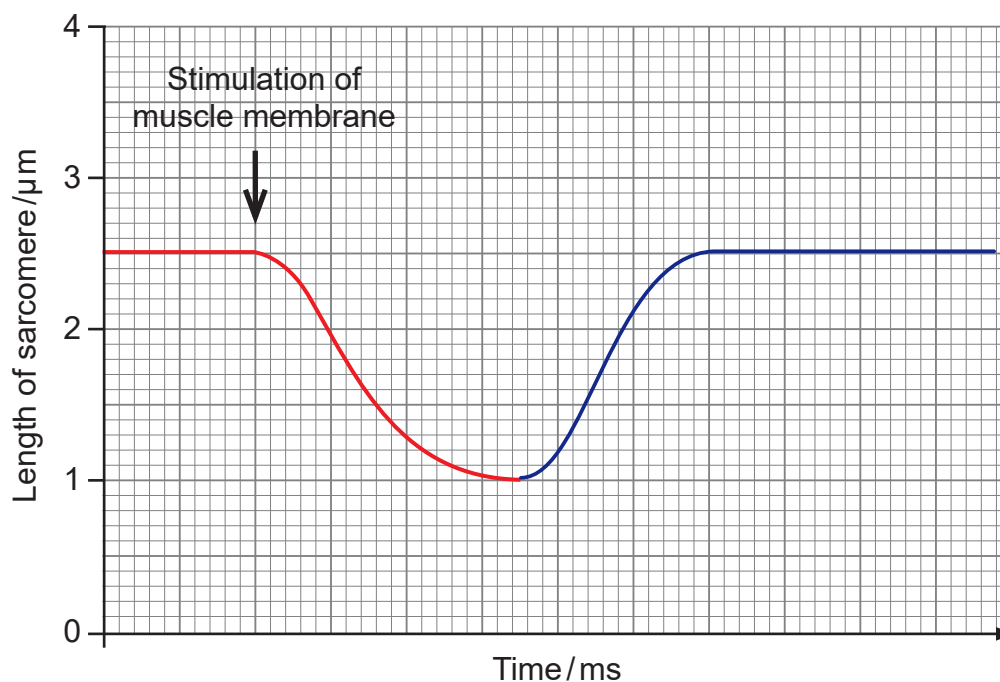
[1]

(ii) Name the region of a sarcomere which consists of actin filaments only.

I-band (isotropic band)

[1]

(b) The graph below shows the length of a sarcomere before and during muscle contraction.



(i) Complete the graph to show how the length of the sarcomere changes as the muscle relaxes.

[1]



- (ii) Describe and explain how myosin and actin filaments bring about the decrease in sarcomere length during muscle contraction.

When stimulated, calcium ions expose the binding sites on the actin filaments, so the myosin heads attach to the binding sites, forming cross-bridges.

The myosin heads then rotate ("rock back", the power stroke), pulling the actin filaments over the myosin filaments towards the centre (M-line) of the sarcomere.

The myosin heads detach using ATP and reattach further along, so the Z-lines move closer and the sarcomere shortens.

[3]

The graph shows that during contraction a sarcomere only shortens by approximately $1.5\text{ }\mu\text{m}$.

- (iii) Explain how a muscle fibre can contract by several centimetres when stimulated.

A muscle fibre contains many sarcomeres lined up end to end in each myofibril, and they all contract together, so the small shortenings add up.

[1]

[Turn over]

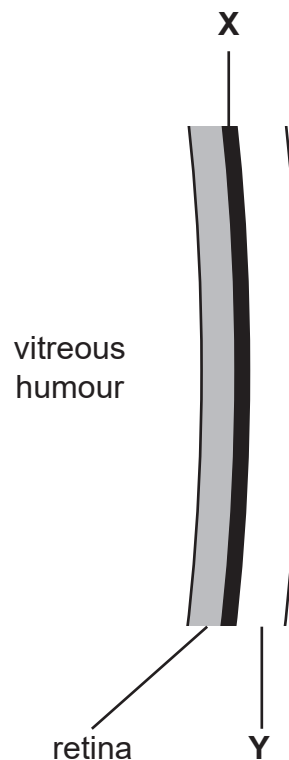


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- 3 (a) The diagram below represents a small cross-section of the back of the human eye.



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

X choroid

Y sclera

[1]

- (ii) State **one** function of **X**.

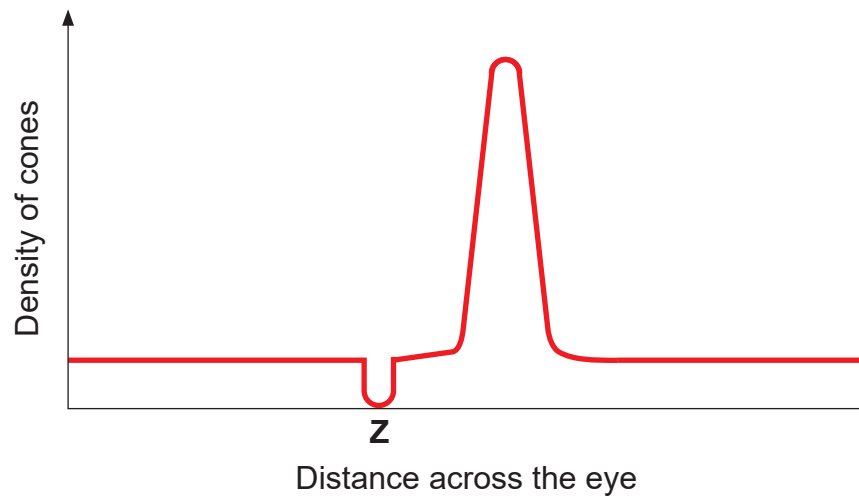
It is pigmented (black), so it absorbs light and prevents internal reflection of light within the eye.

[1]

[Turn over]



- (b) The graph below shows the distribution of cones across the retina. Cones are the photoreceptors responsible for visual acuity.



- (i) Using your knowledge and the graph, explain how the distribution of cones, as well as their relationship with other neurones, results in high visual acuity.

The graph shows that cones are concentrated at the fovea, with a very large number of cones packed into one small area.

Each cone synapses with its own single bipolar neurone (no retinal convergence).

Therefore each cone sends a separate, discrete impulse to the brain, so two points of light close together are seen as separate, giving high visual acuity.

[3]



(ii) Describe and explain the density of cones at position Z.

Cones are absent at Z (density falls to zero).

Z is the blind spot, the position where the neurones of the retina leave the eye as the optic nerve, so there are no photoreceptors there.

[2]

(c) Describe what is meant by depth perception and explain how this is achieved in humans.

Depth perception is the ability to judge distance, i.e. how far away an object is.

It is achieved because humans have two eyes at the front of the head which focus on the same object simultaneously, giving binocular (stereoscopic) vision.

[2]

[Turn over]

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- 4 (a) Deciduous woodlands contain trees such as oak and ash which lose their leaves in autumn. In these woodlands, a layer of these dead leaves ('leaf litter') covers the soil.

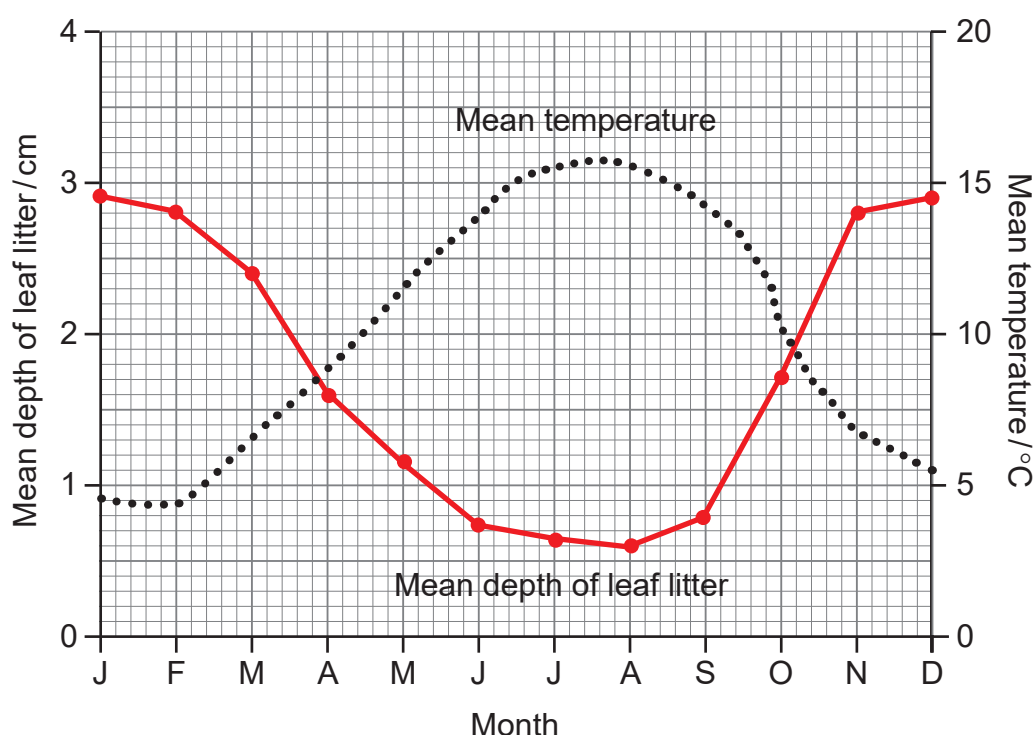
Scientists investigated how the amount of leaf litter in a deciduous woodland changed throughout the year, by recording the mean depth of leaf litter over a 12-month period.

- (i) Suggest **one** advantage of recording leaf litter depth rather than dry mass of leaf litter.

Depth is fast to measure and can be recorded in the field, without having to collect and dry the leaf litter.

[1]

The results of the investigation are shown in the graph below. Mean monthly temperatures are also included.



- (ii) Using the graph and your knowledge, explain the changes in mean depth of leaf litter from:

September – November

Leaf fall: the deciduous trees lose their leaves in autumn, so dead leaves are added to the leaf litter and its depth increases.

March – June

Decomposition occurs: the leaf litter is broken down by decomposers (bacteria, fungi and detritivores), so the depth decreases.

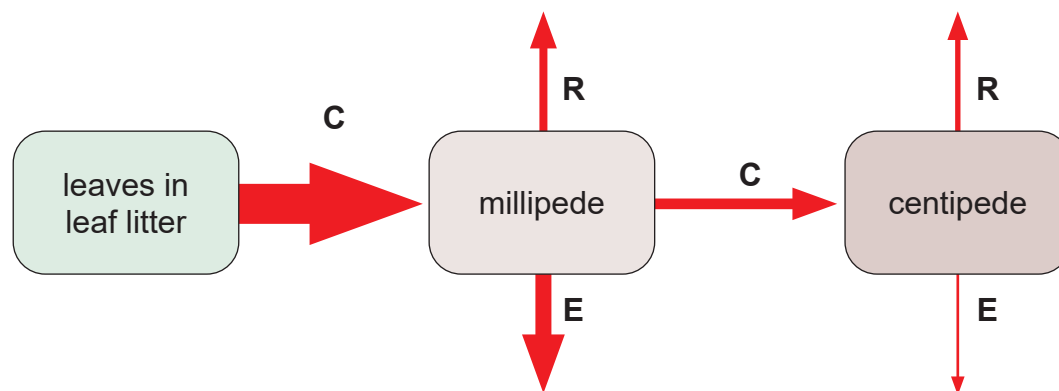
The mean temperature rises from March to June, which increases the decomposer population and their enzyme activity, so decomposition is faster.

[3]

[Turn over]



The diagram below represents part of a food chain in a deciduous woodland. Relative energy flow is represented by arrow thickness. Only consumption, respiration and egestion are shown.



C = consumption R = respiration E = egestion

- (b) Describe the differences in relative energy flow for millipedes and centipedes and suggest reasons for these differences.

Millipedes have a much larger consumption (C arrow) than centipedes, because centipedes are at a higher trophic level and less energy is available to them, as energy is lost at each step of the food chain.

Millipedes egest a larger amount than centipedes, as most of the leaf litter they eat is indigestible since it contains high levels of cellulose (and lignin).

Respiratory losses are higher in the millipede than in the centipede, as the millipede is more active (e.g. constantly moving through the litter to feed) and so uses more energy in respiration.

[4]





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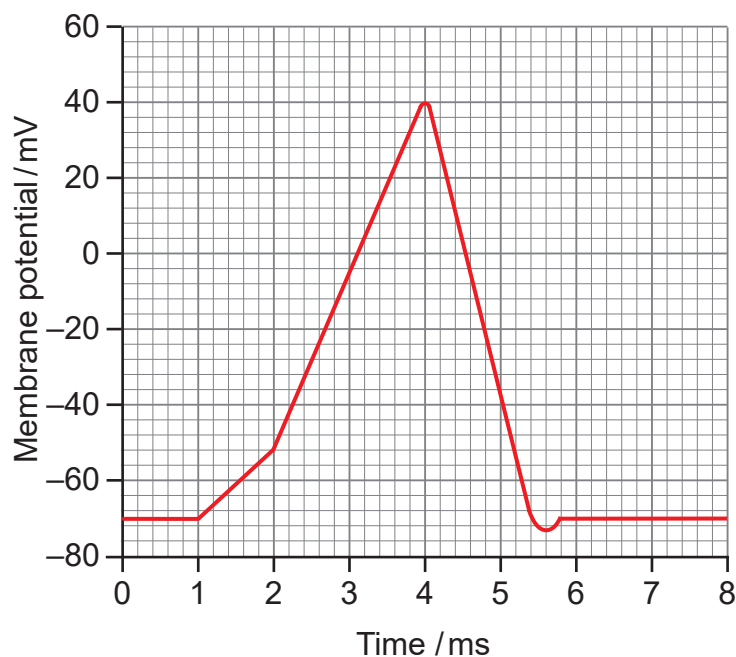
(Questions continue overleaf)

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[Turn over



- 5 (a) The graph below represents changes in membrane potential during the generation of an action potential in a neurone.



- (i) Calculate the total length of time the neurone was **not** at resting potential during the period shown.

Not at resting potential from 1.0 ms to 5.8 ms

$$5.8 - 1.0 = 4.8 \text{ ms}$$

4.8

_____ ms [1]

- (ii) Suggest what caused the rapid increase in membrane potential at 2 ms.

Voltage-gated sodium ion channels open, so there is a rapid influx of

Na⁺ (positive ions) into the axon.

[1]



- (iii) Describe and explain the changes in membrane potential between 4 and 5.5 ms.

The membrane potential decreases rapidly from +40 mV to about -72 mV, becoming more negative.

This is because voltage-gated sodium channels close and voltage-gated potassium channels open, so positive K^+ ions diffuse out of the axon.

The membrane is repolarised and then briefly hyperpolarised (undershoot below -70 mV), which gives the refractory period.

[3]



(b) Synapses are junctions between neurones.

- (i) Suggest **one** reason why synapses are important in nervous communication.

They ensure impulses travel in one direction only (unidirectionality),

as only the presynaptic neurone releases neurotransmitter.

[1]

The speed of synaptic transmission across a synaptic cleft of 40 nm is 0.50 ms^{-1} .

- (ii) Calculate the time taken for a neurotransmitter to cross the synapse. ($1 \text{ nm} = 1 \times 10^{-9} \text{ m}$.)

Show your working out.

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

$$= (40 \times 10^{-9} \text{ m}) \div 0.50 \text{ m s}^{-1}$$

$$= 8 \times 10^{-8} \text{ s}$$

$$8 \times 10^{-8}$$

s [2]

- (iii) Describe and explain the role of acetylcholinesterase in synaptic transmission.

Acetylcholinesterase hydrolyses (breaks down) acetylcholine (ACh) in

the synaptic cleft, removing it from the receptors on the

post-synaptic membrane.

This stops continuous stimulation and allows repolarisation of the

post-synaptic membrane, so it is ready for the next impulse.

[2]



Short-sightedness is a condition in which individuals see close-up objects clearly, but distant objects appear blurred. This can be a consequence of the ciliary muscles remaining (partially) contracted when viewing distant objects, leading to the light rays being focused in front of the retina, rather than on the photoreceptor cells.

Atropine is a chemical which acts by blocking acetylcholine receptors. Atropine can be used to treat short-sightedness, resulting in improved focus on distant objects.

- (c) Using the information provided, suggest and explain how atropine can help improve distant vision in individuals with short-sightedness.

Atropine blocks acetylcholine receptors, so it reduces synaptic transmission at the neurones supplying the ciliary muscle and fewer impulses stimulate it.

This reduces contraction of the ciliary muscle (it relaxes), so the suspensory ligaments remain taut.

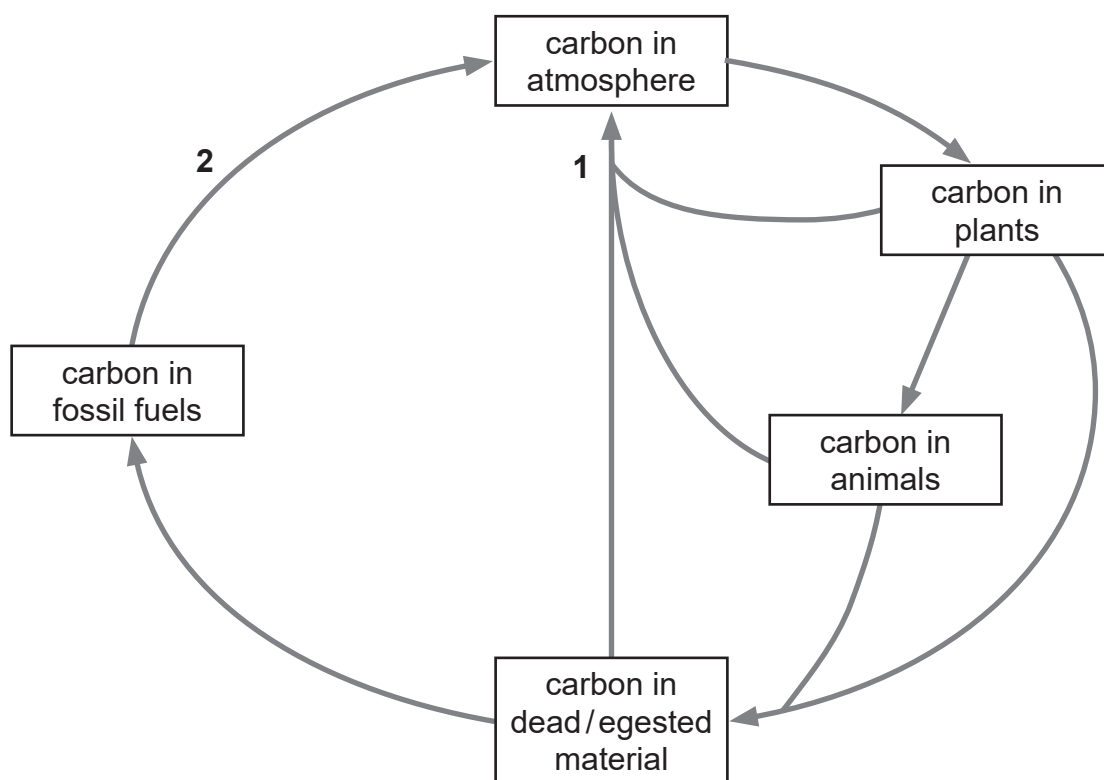
As a result the lens is pulled into its thinner shape, with reduced refractive power, so light from distant objects is focused on the retina rather than in front of it.

[3]

[Turn over]



6 (a) The carbon cycle is represented by the diagram below.



(i) Identify the processes labelled 1 and 2.

1 respiration

2 combustion

[1]



Peatlands are habitats which are typically waterlogged and acidic. Decomposition of dead organisms and organic compounds cannot occur in these soils, partially due to low oxygen levels in waterlogged conditions.

Peat consists of the remains of dead moss that has accumulated over centuries because of lack of decay and decomposition. In 'healthy' peatlands, the moss continues to grow as a thin living layer on top of the peat.

- (ii) Using the information provided and your knowledge, suggest and explain the environmental benefit of healthy peatlands.

The living moss continues to photosynthesise, absorbing carbon dioxide from the air.

Dead moss (peat) does not decompose, so the carbon is stored rather than released, reducing the rate of carbon dioxide build-up in the atmosphere (less global warming).

[2]

Drainage of peatlands has a significant effect on carbon cycling.

- (iii) Suggest and explain the effect of peatland drainage on carbon cycling.

Drainage causes the peatland to dry out, so it is no longer waterlogged and oxygen enters the soil.

Decomposers can now carry out decomposition and respire aerobically, so more carbon (as carbon dioxide) is released from the peat into the atmosphere.

[2]

[Turn over]



(b) The nitrogen cycle is also significantly affected by conditions found in peatlands.

- (i) Name a major group of biological molecules which always contain nitrogen in their structure.

Proteins (amino acids)

[1]

- (ii) Using the information provided and your knowledge, describe and explain the effects of waterlogged conditions on nitrification and denitrification.

In waterlogged soil the rate of nitrification is decreased and the rate of denitrification is increased.

Nitrification decreases because the nitrifying bacteria (Nitrosomonas and Nitrobacter) require aerobic conditions (oxygen), which are lacking.

Denitrification increases because denitrifying bacteria thrive in anaerobic conditions (lack of oxygen), converting nitrate into nitrogen gas.

[3]



- (c) Sundews are plants which live in waterlogged habitats. They have small, round leaves as shown in the photograph below. The leaves produce a sticky liquid on their surface. Sundews use the liquid to trap small insects which then die and are digested with enzymes.



leaves

Source: James Napier

- (i) Using the information provided and your knowledge, suggest how sundews are adapted to maximise their growth in waterlogged habitats.

Waterlogged soil is low in nitrates, so the digested insects provide a source of nitrogen (amino acids from the digested protein).

This enables the production of proteins, allowing growth.

[2]

[Turn over



Sundews can also gain nutrients through photosynthesis. However, rates of photosynthesis are lower in sundews than in many other plant species.

(ii) Using the information provided and your knowledge, suggest **two** reasons for this.

1. The leaves have a small surface area, so less light is absorbed.

2. The sticky liquid on the leaf surface reduces the light reaching the chloroplasts, so less light is absorbed.

[2]

(iii) Explain why it is difficult to assign sundews to a particular trophic level in a food chain.

Sundews are both producers (photosynthesise) and consumers (digest insects), so they can be placed in two trophic levels.

[1]



7 Cell-mediated immune responses involve the sensitisation of T-lymphocytes. Following sensitisation, T-lymphocytes clone and produce a range of cells including killer T-cells and helper T-cells.

(a) Distinguish between the roles of killer T-cells and helper T-cells in immune responses.

Killer T-cells destroy infected (or foreign) cells by enzyme action, e.g. releasing perforins.

Helper T-cells do not destroy cells; they stimulate B-cells to divide and produce plasma cells for antibody production, and stimulate phagocytosis.

[2]

(b) Rejection of organ transplants between individuals is a consequence of cell-mediated immunity.

(i) Explain how a cell-mediated immune response brings about transplant rejection.

The non-self (foreign) antigens on the transplanted tissue sensitise the recipient's T-lymphocytes.

The T-lymphocytes clone and produce killer T-cells, which destroy the transplanted cells containing the non-self antigens.

[2]

[Turn over]



A range of treatments can be used to reduce the possibility of transplant rejection. These include the use of drugs to inhibit DNA replication.

- (ii) Explain how the use of these drugs reduces the possibility of transplant rejection.

The drugs prevent the cloning (division) of T-cells, as DNA replication is needed for mitosis.

Therefore killer T-cells cannot be produced to attack the transplanted tissue.

[2]

- (iii) State **one** other method of reducing the possibility of transplant rejection.

Tissue typing (matching donor and recipient tissue).

[1]



(c) Blood transfusions between individuals can also provoke an immune response.

- (i) Explain precisely why an individual with blood group O should not be given a transfusion of blood group AB.

Blood group AB has both A and B antigens on the red blood cells,

and blood group O plasma contains both anti-A (a) and anti-B (b)

antibodies.

The antibodies react with the antigens, causing agglutination

(clumping) of the donated red blood cells.

[2]

Blood group compatibility is important for organ transplants as well as blood transfusions. In addition to tissue matching, this also affects the availability of suitable transplants.

Consequently, the probability of individuals with rarer blood groups having a suitable donor match is less than for those with a more common blood group.

Scientists are currently researching the possibility of treating potential transplant organs with enzymes that mask the blood group antigens.

- (ii) Describe and explain the advantage of being able to do this.

Organs could be donated regardless of blood type, as the masked

antigens on the transplanted organ will not be recognised as foreign.

Therefore the number of transplants available increases (especially for rarer blood groups) and rejection is less likely.

[2]

[Turn over]



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- 8 Himalayan Balsam (*Impatiens glandulifera*) grows in many natural habitats in the UK and Ireland. It was brought here from Asia about two hundred years ago as an ornamental garden plant. It then spread from gardens to natural habitats, its population increasing rapidly, often reaching its biotic potential.

(a) Define the term 'biotic potential'.

The maximum reproductive potential (growth rate) of a population under optimum environmental conditions with unlimited resources.

[1]



Himalayan Balsam growing on a riverbank

Source: James Napier

[Turn over]



Himalayan Balsam is a large plant, growing up to two metres in height in a few weeks. It typically grows on riverbanks, lake edges and surrounding areas. Seeds spread via an 'explosive' method of dispersal. When seed pods are ripe, they burst, ejecting large numbers of seeds several metres away from the parent plant. The seeds are also able to float.

- (b) Himalayan Balsam typically forms large populations on riverbanks and lake edges.

Using the information provided, explain why.

It has a very rapid growth rate (2 m in a few weeks), and being a tall plant it outcompetes slower-growing, shorter species for light.

Explosive seed dispersal ejects seeds several metres from the parent, allowing the species to spread widely along the bank.

The seeds are able to float, so they are spread via waterways (rivers and lakes) and colonise new riverside habitats downstream.

Each plant produces many seeds, so many more plants develop, allowing the population to increase rapidly.

[4]



- (c) Once established as part of a community, Himalayan Balsam interacts with other populations living in the same habitat.

One type of interaction is with insect populations. As with many other flowering plants, Himalayan Balsam requires transfer of pollen for reproduction, and many insect species carry out this process of pollination.

An adaptation often shown in flowering plants is the production of nectar on which pollinating insects feed.



nectar
store

Bumblebee entering a Himalayan Balsam flower in search of nectar

Source: James Napier

Himalayan Balsam is a very valuable source of nectar for many insect species. It can produce up to 0.30 mg h^{-1} of nectar per flower.

- (i) Calculate the mass of nectar which an individual plant with 20 flowers can produce in 24 hours.

Show your working out.

$$\text{mass} = 0.30 \text{ mg h}^{-1} \times 20 \text{ flowers} \times 24 \text{ h}$$

$$= 6.0 \text{ mg h}^{-1} \times 24 \text{ h} = 144 \text{ mg}$$

144

mg [2]

[Turn over



Another type of interaction is competition with other plant populations.

Himalayan Balsam can flower from July to October – later than most other nectar-producing plants. Its large open flowers allow access to a wide range of insects including bumblebees, honeybees and wasps.

Scientists investigated whether the ground area covered by Himalayan Balsam affected pollination rates in three native plant species (Species **A–C**), usually found in the same habitat.

Several riverbank habitats of 30 m² were investigated. The results are shown in the table below.

Ground area covered by Himalayan Balsam in habitat/m ²	Flowers pollinated/%		
	Species A	Species B	Species C
0 (no Himalayan Balsam in habitat)	48	71	87
5	44	62	82
10	41	52	94
20+	38	33	88

(A pollination rate of 100% means that all the flowers in all the plants of that species in the sampled habitat were pollinated.)



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

As ground coverage of Himalayan Balsam increases, the pollination rates of species A and B are reduced (A falls from 48% to 38%, B falls greatly from 71% to 33%).

This is because pollinating insects visit the Himalayan Balsam flowers instead, as they produce lots of nectar, so less pollen is transferred between flowers of A and B.

Species C is largely unaffected (82 to 94%, initially decreasing then increasing).

This suggests species C is not pollinated by the insects involved in the pollination of Himalayan Balsam (e.g. it is wind pollinated or uses other insects).

[4]

Many scientists express concern over the effect of Himalayan Balsam on native habitats. However, some scientists argue that there is a benefit in allowing some of its plants to survive in the wild.

(d) Using the information provided, suggest reasons for this.

Himalayan Balsam produces high levels of nectar for a wide range of insect species (bumblebees, honeybees and wasps), at a time (July to October) when most other nectar-producing plant species are not in flower, so it supports pollinator populations late in the season.

[2]

[Turn over



- (e) Using the information provided, suggest why it is difficult to define Himalayan Balsam as either a K-selected or r-selected species.

It shows features of both K-selected and r-selected species.

K-selected: large size (up to 2 m) and high competitive ability;

r-selected: rapid growth, many seeds and rapid colonisation of new habitats.

[2]



Section B

In this question you will be assessed on the quality of your written communication skills including the use of specialist scientific terms.

9 The kidney is an organ involved in excretion and osmoregulation.

(a) Describe how the kidney allows excretion of the waste products of metabolism, yet ensures that useful substances are retained. [12]

(b) The loop of Henle and the collecting ducts are parts of the kidney important in osmoregulation.

Describe and explain their roles in osmoregulation in the kidney. [6]

(a) Describe how the kidney allows excretion of the waste products of metabolism, yet ensures that useful substances are retained.

The main waste product of metabolism excreted by the kidney is urea, made in the liver from excess amino acids, along with creatinine. Blood enters each nephron through the afferent arteriole, which leads into the glomerulus, a knot of capillaries inside the Bowman's capsule.

Ultrafiltration occurs at the glomerulus. The blood is under high hydrostatic pressure because the renal artery branches off the aorta close to the heart, and because the efferent arteriole leaving the glomerulus is narrower than the afferent arteriole. The coiling of the glomerular capillaries also gives a large surface area for filtration.

The basement membrane of the capillary is the effective filter: it allows small molecules such as water, glucose, amino acids, mineral ions and urea

[Turn over]



to pass, but retains blood cells and large plasma proteins in the blood.

The podocytes of the capsule wall have foot processes with gaps between them, which aid filtration into the capsule space.

Useful substances are retained by selective reabsorption in the proximal convoluted tubule (PCT). The capillary network surrounding the nephron is in close proximity to the PCT. All of the glucose and amino acids, small proteins and many mineral ions (e.g. Na^+) are reabsorbed back into the blood by facilitated diffusion and active transport, and water follows by osmosis.

The cuboidal epithelial cells lining the PCT are adapted for this: they have microvilli on the lumen side and basal invaginations, which greatly increase the surface area available for transport into the blood capillaries. Their membranes contain many protein carriers (and co-transporter proteins) which aid transport, and the cells contain many mitochondria which provide ATP for active transport.

Some urea also returns to the blood by diffusion, as it is a small molecule, but most remains in the filtrate. The filtrate, now containing the waste products, passes along the nephron into the collecting duct and then into the ureter, so the wastes are excreted as urine while useful substances have been returned to the blood.



[illegible]

- (b) The loop of Henle and the collecting ducts are parts of the kidney important in osmoregulation.

Describe and explain their roles in osmoregulation in the kidney.

The descending limb of the loop of Henle is permeable to water (and ions), whereas the ascending limb is impermeable to water.

The thick ascending limb actively transports (pumps) sodium and chloride ions out of the filtrate into the interstitial fluid of the medulla. This produces a solution in the medulla with a very negative (low) water potential, i.e. a high solute concentration.



This enables the osmotic extraction of water from the descending limb, and also from the collecting duct as it passes down through the medulla, so the loop of Henle acts as a counter-current multiplier and allows a hypertonic urine to be produced.

When the water potential of the blood falls, osmoreceptors in the hypothalamus are stimulated and ADH is released from the posterior pituitary gland. ADH travels in the blood to the kidney and increases the permeability of the cells lining the distal convoluted tubule and collecting ducts to water.

It does this by causing vesicles containing aquaporins (water channel proteins) to fuse with the cell surface membranes. More water is therefore reabsorbed from the urinary filtrate by osmosis into the medulla and blood, so a small volume of concentrated urine is produced. When the blood water potential is high, less ADH is released, fewer aquaporins are inserted and more dilute urine is produced.



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