



Rewarding Learning

ADVANCED
General Certificate of Education
2019

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 6 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.

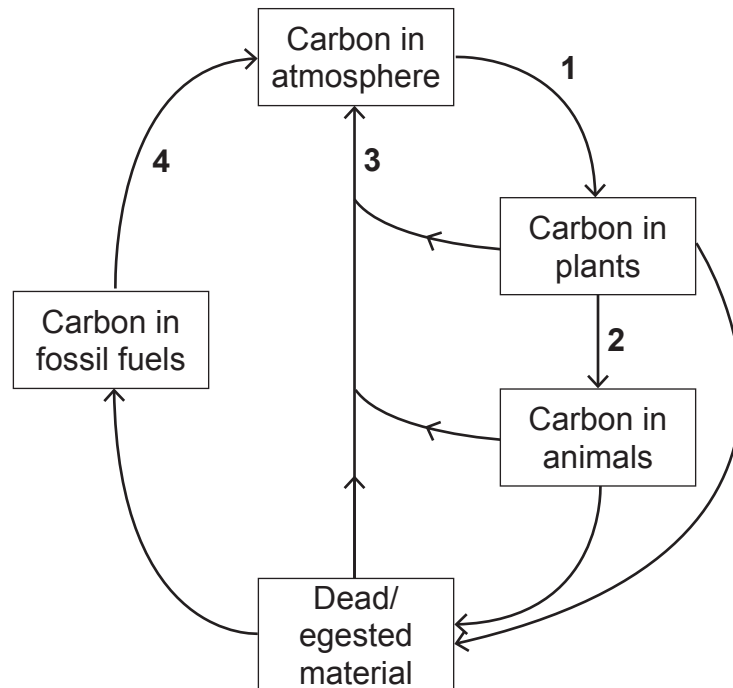
Quality of written communication will be assessed in Section B.

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Section A

- 1 The carbon cycle is represented in the diagram below.



- (a) Identify the processes labelled 1–4.

- 1 Photosynthesis
- 2 Feeding
- 3 Respiration
- 4 Combustion

[2]



- (b) State **one** way in which carbon may be stored within the cycle for a very long period of time.

Fossilisation, forming fossil fuels such as coal, oil and peat. [1]

- (c) Reducing deforestation and fossil fuel use are strategies used to limit the rate of increase of atmospheric carbon dioxide.

- (i) Many scientists argue that reduced use of fossil fuels should be the greater priority.

Suggest **one** reason why.

Burning fossil fuels releases far more carbon dioxide each year than
deforestation, so reducing it has more effect on the atmospheric CO₂
level. [1]

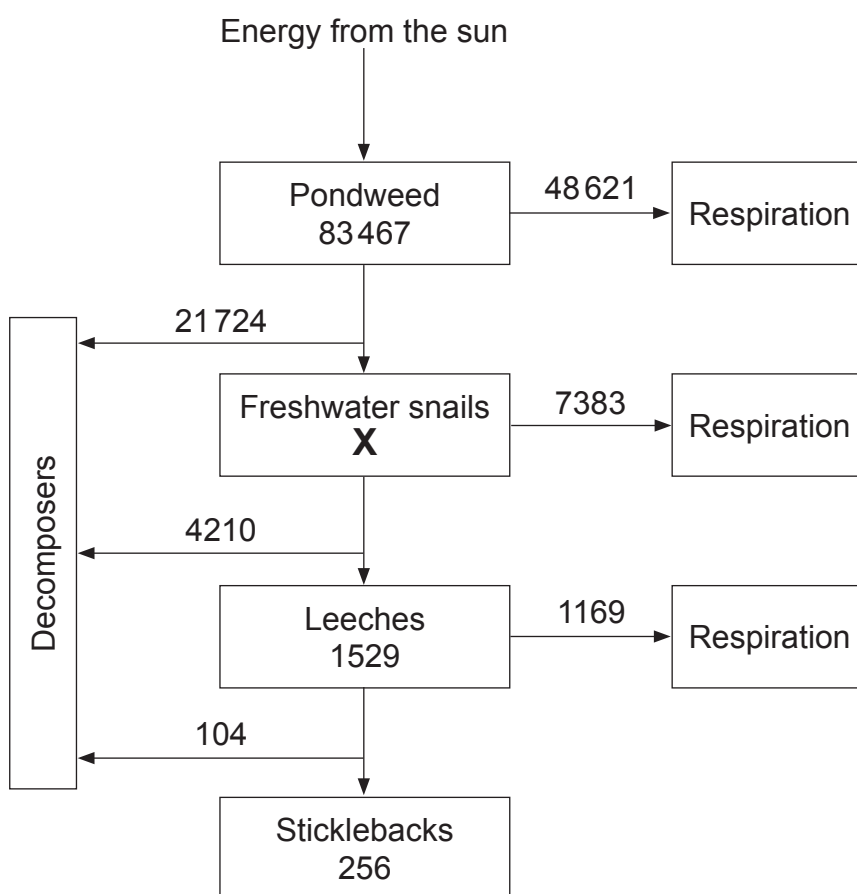
- (ii) Suggest **one** argument for making reduced deforestation the higher priority.

Reducing deforestation keeps the trees removing CO₂ by
photosynthesis and also conserves habitats, increasing biodiversity.
_____ [1]

[Turn over]



- 2 (a) The energy flow through a freshwater food chain is shown below.
Units are $\text{kJ m}^{-2} \text{ year}^{-1}$.



- (i) Identify the primary consumer in this food chain.

Freshwater snails

[1]

- (ii) Calculate the energy (X) which passes to the freshwater snails.
(Show your working.)

$$X = 83\,467 - 48\,621 - 21\,724$$

13 122 $\text{kJ m}^{-2} \text{ year}^{-1}$ [1]



- (iii) Calculate the percentage efficiency of energy transfer between leeches and sticklebacks.
(Show your working.)

$$\begin{aligned}\text{efficiency} &= (256 \div 1529) \times 100 \\ &= 0.167 \times 100\end{aligned}$$

16.7 % [2]

- (b) When a bird is consumed by a mammal, the efficiency of energy transfer is typically lower than that from a leech to a stickleback. Suggest reasons for this.

*The mammal does not eat all of the bird (e.g. feathers, beak and bones),
and not all parts eaten are digested, so more energy is lost to
decomposers in egested material.*

*Birds and mammals are endotherms with a high metabolic rate, so a
greater proportion of energy is lost in respiration (as heat).*

*This energy is used to maintain a constant body temperature and, in the
bird, for flight, so less is available to be transferred to the next trophic
level.*

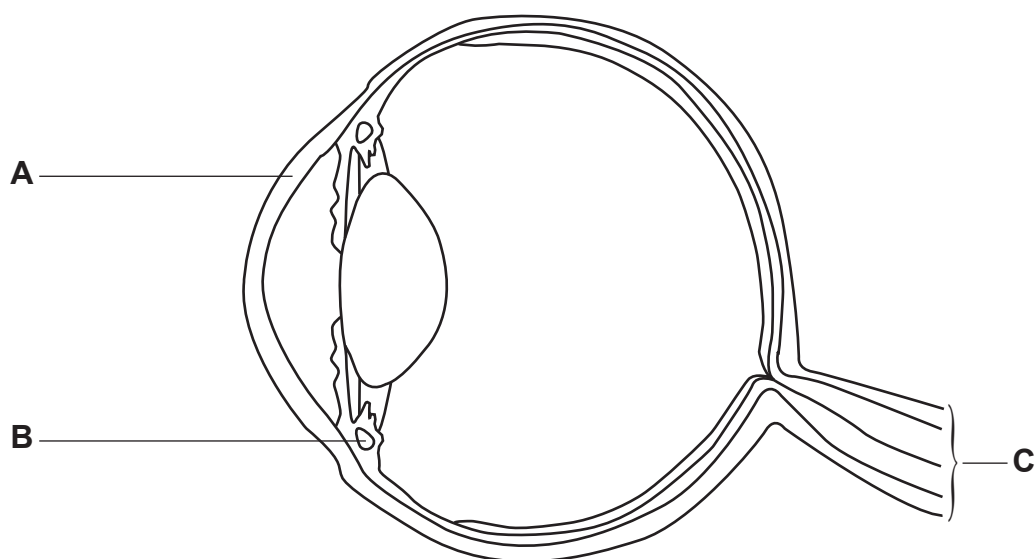
[3]

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3 A longitudinal section through the mammalian eye is shown in the diagram below.

(a) Identify the structures labelled **A**, **B** and **C**.



Source: Principal examiner

A Cornea

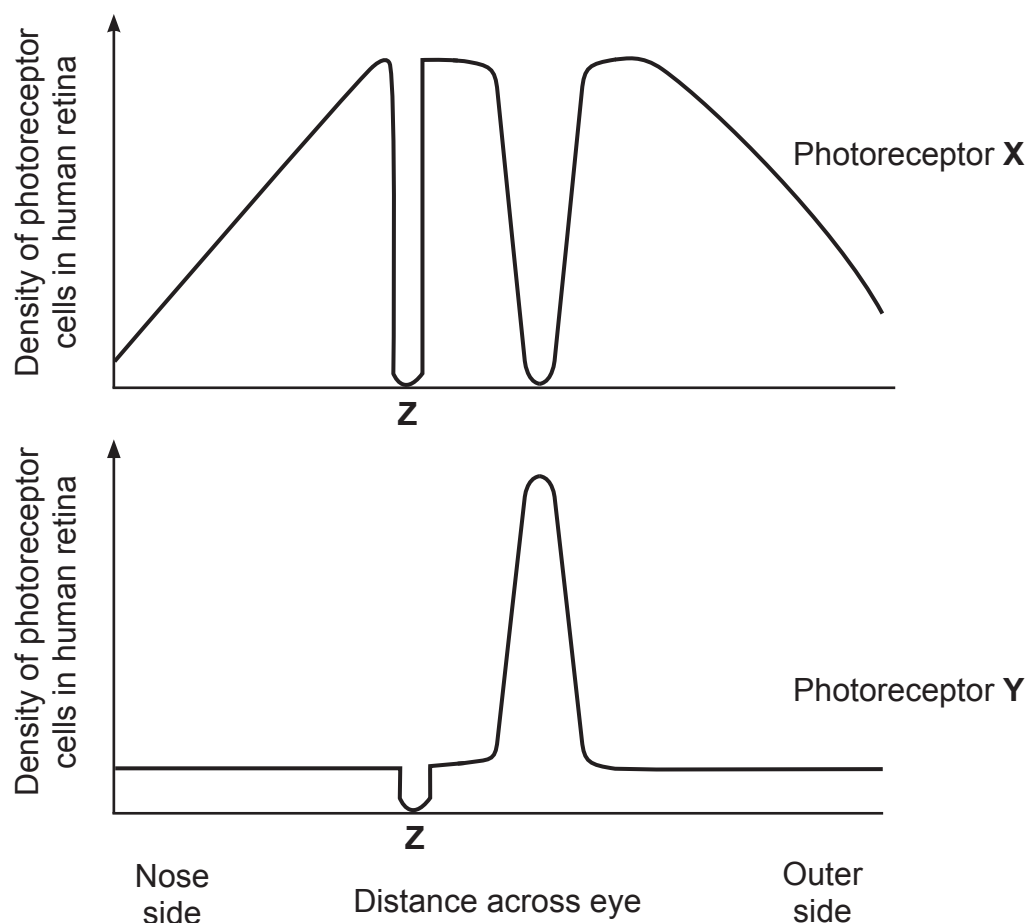
B Ciliary body (ciliary muscle)

C Optic nerve

[3]



- (b) The two types of photoreceptor cells (**X** and **Y**) are not distributed evenly across the retina. The graphs below show the distribution of each of the two types of photoreceptor cells across the retina of the human eye.



- (i) Identify the photoreceptor cells **X** and **Y**.

X Rods

Y Cones

[1]

[Turn over]



- (ii) Explain the absence of both types of photoreceptor cells at position Z.

Z is the blind spot.

*It is the point where the optic nerve (neurones from the retina)
and the blood vessels leave and enter the eye, so there is no room
for photoreceptors.*

[2]

- (iii) In a dimly-lit room, people may find it easier to see an object by looking to one side of it, rather than looking directly at it.

Using the information provided and your knowledge of photoreceptor cells, suggest an explanation for this.

*Light from the object then falls on the periphery of the retina,
where rods are dense, not on the fovea (cones only).*

*Rods have high sensitivity: rhodopsin is broken down at low light
intensity, and several rods converge on one bipolar neurone (retinal
convergence), so their generator potentials summate.*

[3]





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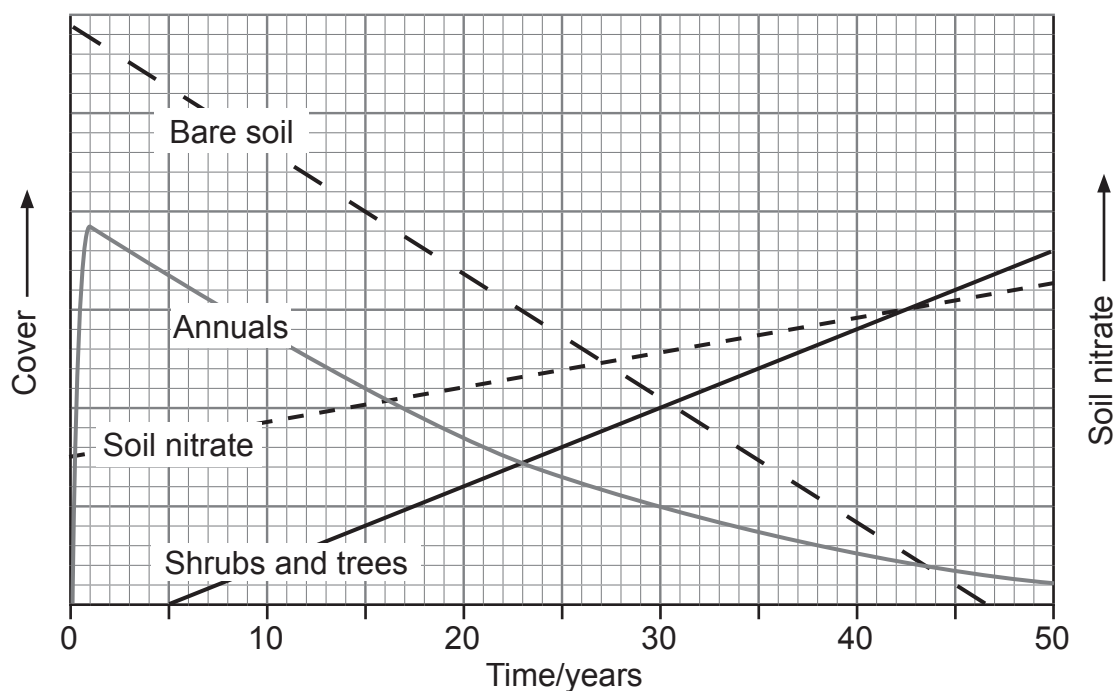
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- 4 The graph below shows how the cover of bare soil and some types of plants changed in a field that was ploughed then abandoned over a 50-year period. Annuals are plants that live for only one year. Soil nitrate is also shown.



- (a) (i) State the type of succession that would occur in an abandoned crop field.

Secondary succession

[1]

- (ii) Many of the annual plants have root nodules containing nitrogen-fixing bacteria. Describe and explain the advantage of this adaptation in the early years of this succession.

The nitrogen-fixing bacteria convert nitrogen gas into ammonia,
which the plants use to make amino acids (nitrogen-containing
compounds), without relying on soil nitrate.

So they can grow where soil nitrate is low and are better
competitors than other plants.

[2]



- (iii) Using your knowledge of the nitrogen cycle, explain the increase in soil nitrate concentration during the 50-year period.

Dead plant and animal material and nitrogenous waste are decomposed by saprotrophic bacteria and fungi, releasing ammonia (ammonium compounds).

Nitrifying bacteria (Nitrosomonas and Nitrobacter) then oxidise the ammonium compounds to nitrites and then nitrates.

[2]

- (b) Describe and explain the changes in plant cover over the 50-year period.

In the early stages there is little plant cover and a lot of bare soil; the bare soil decreases as vegetation increases.

Annuals increase dramatically in the early years because resources such as space and light are available on the bare ground and there is little competition.

The annuals then decline as larger, better adapted plants (grasses, shrubs and trees) become established and outcompete them, e.g. by shading.

Shrubs and trees increase steadily (after about year 5) because the soil quality improves, with greater soil nitrate, and because they are slower growing.

[4]

[Turn over]



- (c) Explain how the introduction of sheep to the field after ten years would change the pattern of succession.

Sheep are grazers that feed on the plants, eating the young shoots and seedlings.

Therefore the growth of larger species such as shrubs and trees is prevented, stopping the progression of the sere.

The climatic climax community (woodland) does not develop; instead a biotic (plagio) climax, such as grassland, is maintained.

[3]





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- 5 The Galapagos Islands provide unique ecosystems for plants and animals. However, tourism has resulted in the introduction of non-native species.

One example, identified in 1982, is the cottony cushion scale insect (*Icerya purchasi*). Having both male and female reproductive organs, this organism had the potential of becoming a significant pest when introduced.



© Nigel Cattlin / Science Photo Library

Adults lay eggs which hatch and then develop through several stages. One of the early stages is referred to as the 'crawler' stage, since the individuals can move easily during this stage. The insects tend to move much less during other stages of the life cycle.

The adult insects use piercing, sucking mouthparts to feed on the phloem sap of plants. The insects egest a sticky, sugary substance called honeydew, which is known to attract their natural predators, including ladybirds.

The phloem sap of some plants can contain high concentrations of molecules called alkaloids. If a cottony cushion scale insect feeds on these plants, the alkaloids are present in its honeydew. The alkaloids have been shown to greatly increase the time taken for a ladybird egg to hatch and develop into an adult.



- (a) (i) Define the term 'pest'.

An organism that causes economic damage, e.g. by reducing crop yield.

[1]

- (ii) Suggest how possessing both male and female reproductive organs can allow rapid population growth in new habitats.

A single individual (or very few) introduced to an island can found a new population, since reproduction does not require a male and a female to meet: any two individuals can mate, so all individuals can produce offspring.

[2]

- (iii) Explain how the 'crawler' stage in the insect's life cycle represents an adaptation for survival.

The crawler stage allows the young insects to disperse (be distributed) to new plants.

This reduces competition for food (phloem sap) and prevents the accumulation of predators in one place.

[2]

[Turn over]



- (iv) Explain how the production of honeydew may affect the adult cottony cushion scale population in the short term.

*The honeydew attracts natural predators such as ladybirds, increasing predation,
so reducing the population of adult cottony cushion scale insects.*

[2]

- (v) When cottony cushion scale insects feed on plants containing alkaloids, the ladybird population may be affected. Describe and explain how it may be affected.

*The ladybird population would decrease (grow more slowly) because the alkaloids in the honeydew increase the time taken for ladybird eggs and larvae to develop into adults,
so there are fewer adult predators (fewer offspring) and a delay in feeding on the prey.*

[2]



Control measures were put in place to prevent the cottony cushion scale insects becoming a significant pest.

Due to the ecological sensitivity of the Galapagos Islands, pesticide use was not considered an option. After much research was carried out in controlled environments, the ladybird species *Rodolia cardinalis* was introduced to the islands in 2002.

By 2009, the cottony cushion scale had been greatly reduced in number, or eradicated, on many of the islands under threat from its presence. This is an example of successful biological control.

- (b) Give reasons why it is necessary to carry out detailed research before releasing a biological control agent into a habitat.

To ensure the ladybird can survive and thrive in the new environment and reproduce in sufficient numbers to be effective.

To check there is no predator on the islands that would remove the ladybird, and that it can survive at low prey density.

To ensure it does not prey on other native organisms, disrupt existing food chains, outcompete native species or carry disease into the new environment.

Research in a controlled environment prevents accidental release of a species that may become invasive, and identifies the most effective species for control.

[4]

[Turn over



- (c) This example of biological control was first used in California where the insect was damaging citrus fruit crops. Before the 1940s, pesticides were not widely available. The changes in population density of the cottony cushion scale over a period of time after the introduction of *R. cardinalis* are shown in the graph below.

Image removed due to copyright

- (i) Explain what is meant by the term 'economic threshold' as shown on the graph.

The population density of the pest below which the crop loss

(damage) is economically acceptable, so control is not worth its

cost.

[1]



(ii) Suggest **two** reasons why the pest population did not decline immediately upon the introduction of ladybirds.

1. *The ladybirds must first acclimatise to the new environment (or their development is delayed by alkaloids in the honeydew).*

2. *There is a time lag while the ladybirds reproduce to large enough numbers to have an impact on the prey population.*

[2]

(iii) Suggest and explain a reason for the resurgence of the pest after 1947.

Pesticides were introduced in 1947 (became widely available) and their use killed many ladybirds, reducing the ladybird population.

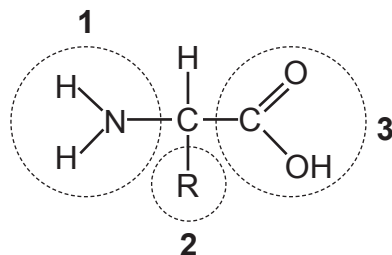
This reduced the predation pressure on the prey, so the pest population increased again.

[2]

[Turn over]



- 6 (a) Excess amino acids cannot be stored by mammals. These molecules are broken down and the products are excreted or further metabolised. The diagram below represents the general structure of an amino acid.



Source: Principal examiner

- (i) Identify the part of the amino acid molecule (1, 2 or 3) used to make urea.

1

[1]

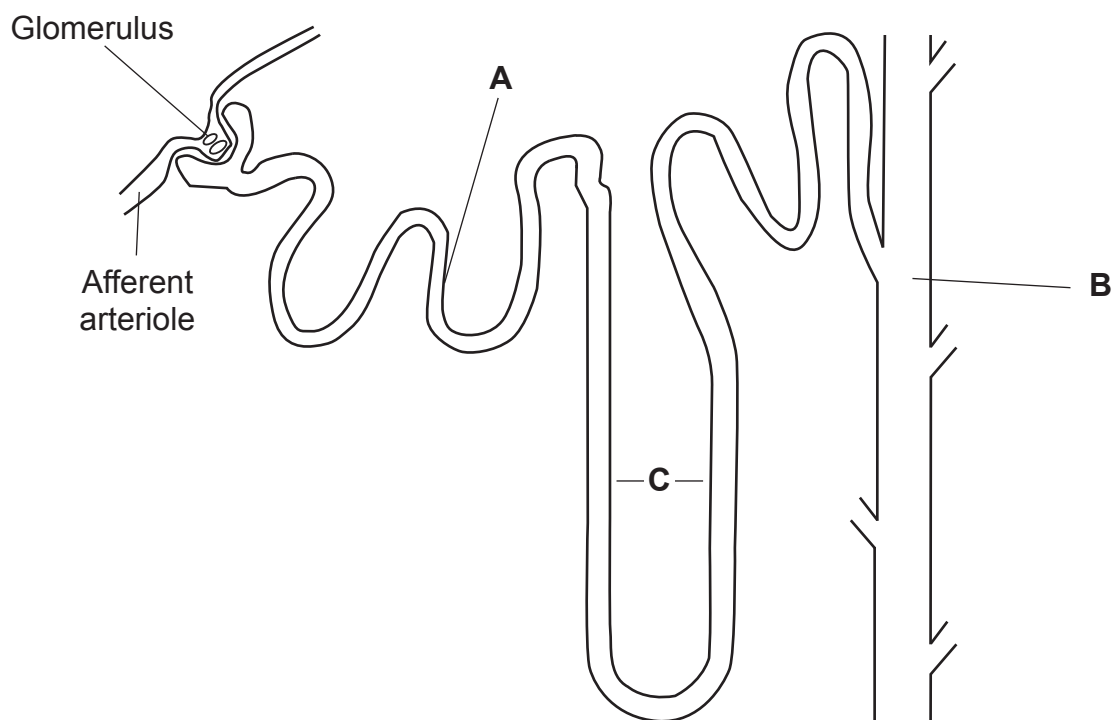
- (ii) Urea is removed by the kidneys. Name another excretory product removed by the kidney in mammals.

Creatinine

[1]



(b) A nephron from a human kidney is represented in the diagram below.



Source: Principal examiner

(i) State the **functions** of the regions labelled **A**, **B** and **C**.

A Selective reabsorption (e.g. of glucose and amino acids).

B Osmoregulation (reabsorbs water), carrying urine to the pelvis.

C Creates a salt (sodium chloride) gradient in the medulla.

[3]



(ii) Explain the term 'ultrafiltration'.

Filtration under high (hydrostatic) pressure, separating substances by size as they pass from the blood into the Bowman's capsule.

[1]

(iii) State **two** ways in which the glomerulus is adapted to carry out the process of ultrafiltration.

1. *The afferent arteriole is wider than the efferent arteriole, raising the pressure.*

2. *The glomerular capillaries are highly branched (knotted) and have pores (fenestrations) in their endothelium.*

[2]

(iv) Name **one** substance present in the blood in the afferent arteriole that will normally not be found in region **A**. Explain your answer.

Large plasma proteins (e.g. albumin).

They are too large to pass through the basement membrane, which acts as the filter.

[2]



- (c) The properties of some excretory products from different animals are summarised in the table below.

Animal	Excretory product	Toxicity	Solubility	Volume of water required for removal of excretory product
Freshwater fish	Ammonia	High	High	High
Human	Urea	Moderate	Moderate	Moderate
Bird	Uric acid	Low	Low	Low

- (i) Describe the relationship between the toxicity of the excretory product and the volume of water required for its removal from the body and suggest an explanation for this relationship.

As the toxicity of the excretory product increases, a greater volume of water is required for its removal.

A highly toxic product such as ammonia must be diluted to keep its concentration low, so it has a dilution effect.

[2]

[Turn over]



- (ii) The lower the toxicity of the excretory product, the less risk of damage to the animal. Use the table on the previous page to suggest **one** other advantage of making a less toxic excretory product. Explain your answer.

Less water is required for its removal (uric acid needs little water),

so more water is conserved, which aids survival in dry conditions

(drought) or reduces mass for flight.

[2]



(d) Sharks are fish which live in salt water and produce some urea as well as ammonia. Some of the urea is stored in the blood and this ultimately aids the removal of ammonia. This dissolved urea causes the blood to be hypertonic to (more concentrated than) seawater.

(i) State the effect of dissolved urea on the water potential of the shark's blood.

It decreases the water potential of the blood (makes it more negative).

[1]

(ii) As the shark's blood flows through the capillaries of its gills, exchange can take place between the blood and sea water.

Using the information provided, explain how the presence of the urea in the shark's blood indirectly aids the removal of ammonia.

Water moves by osmosis from the sea water into the blood in the gill capillaries, down the water potential gradient.

This increases the volume of water in the blood; ammonia requires a large volume of water for its removal, so it is diluted and excreted.

[2]

[Turn over]



- 7 Many diseases are the result of viral infection. Measles is a highly infectious childhood disease that may have serious effects on the individual. Vaccination protects individuals from measles.

If a population is to be protected from measles, a high proportion of the population must be vaccinated. This contributes to 'herd' immunity, where even individuals who are not vaccinated are protected from the viral illness due to the general immunity of the 'herd'.

- (a) (i) Define the term 'vaccine'.

A preparation of dead or weakened (attenuated) pathogens, a modified toxin or isolated antigens, that is introduced into the body and results in a specific immune response.

[2]

- (ii) Suggest **two economic** benefits of vaccination programmes.

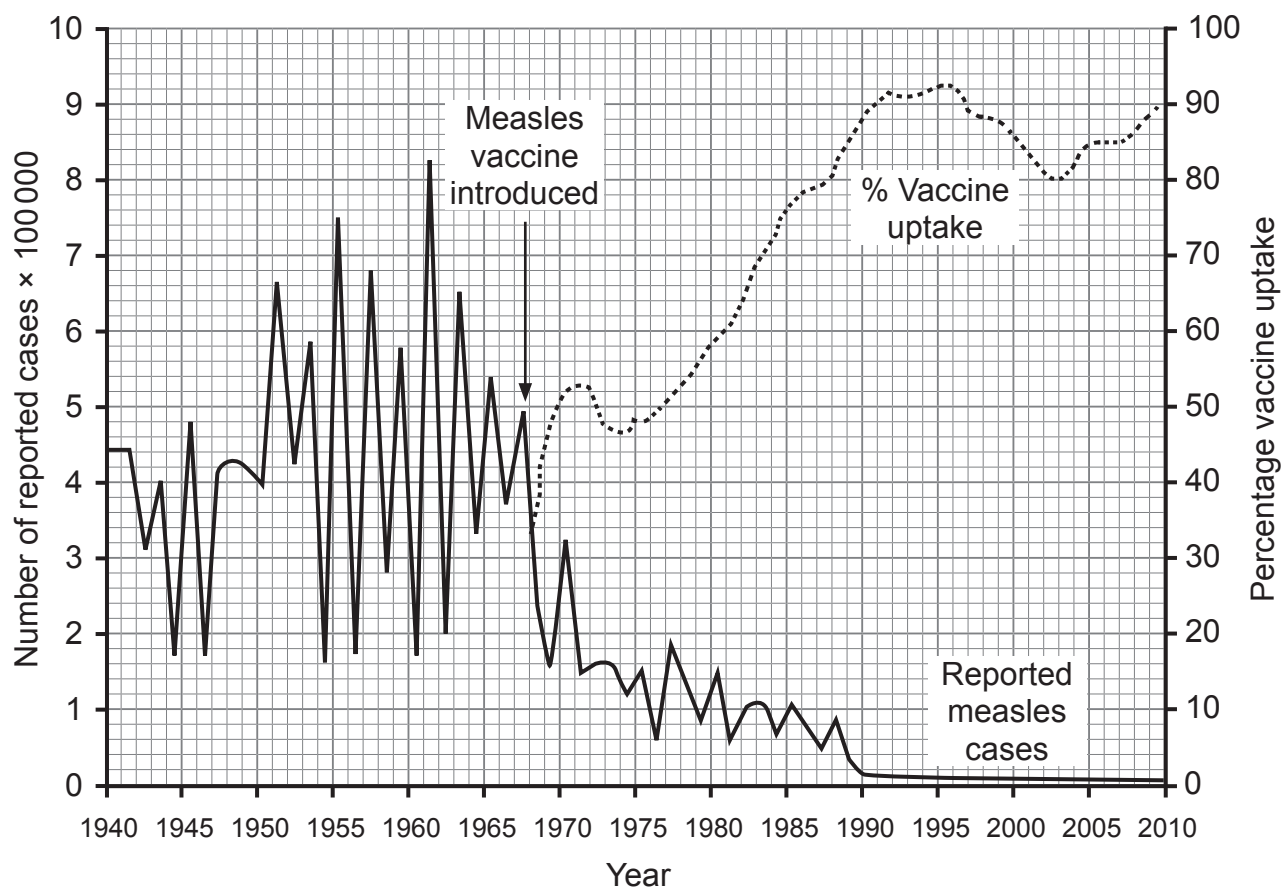
1. *Lower treatment costs for the health service.*

2. *Fewer work days lost, so increased productivity.*

[2]



The number of reported cases of measles and the percentage uptake of the measles vaccine in England and Wales is shown in the graph below for the period 1940–2010.



Data source: Public Health England, Measles notifications and deaths in England and Wales, 1940-2013 (http://webarchive.nationalarchives.gov.uk/2014505192926/http://www.hpa.org.uk/HPAweb&HPAwebStandard/HPAweb_C/1195733835814) Compiled by @visualvaccines

- (b) Explain how the data from 1990–2010 provides evidence of the effectiveness of 'herd' immunity.

From 1990 to 2010 the percentage vaccine uptake is high (around 80 to 92%) and the incidence of measles is very low.

When the uptake drops (to about 80% around 2004 to 2005) the number of measles cases still remains low, so unvaccinated individuals are protected.

[2]

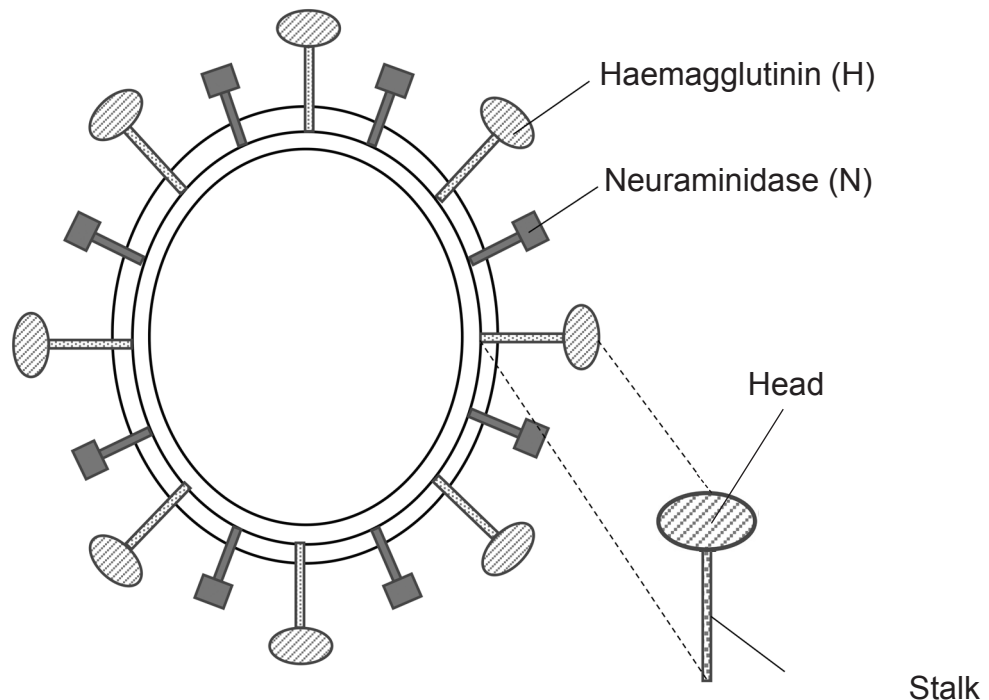
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- (c) 'Seasonal flu' is a condition caused by infection with one strain of the influenza virus. Two of the main coat proteins (antigens) on the virus are haemagglutinin (H) and neuraminidase (N); both are directly involved in the ability of the virus to infect host cells.

Many strains of the flu virus are named depending on the particular types of coat proteins they have, e.g. Spanish Flu (1918) was identified as H1N1.

The diagram below represents the arrangement of H and N coat proteins on a strain of flu virus.



Source: Principal examiner

The H coat protein consists of a head region and a stalk region as shown. The head region is the region which differs between H1, H2, etc. while the stalk region remains the same.

Currently, flu vaccines are based on the head region of the H protein.



- (i) Identify and describe the type of immunity caused by vaccination.

Active (artificial) immunity.

The person produces their own antibodies, B memory cells and T memory cells (T killer cells) against the antigen.

[2]

- (ii) Suggest why it is difficult to produce a 'universal' vaccine which is effective against all strains of the flu virus.

The head of the haemagglutinin protein is highly variable between strains (and mutates often), so a vaccinated individual's memory cells do not recognise the new antigen and complementary antibodies are not produced.

[2]

- (iii) The stalk region of the H protein is described as 'highly conserved'. Using your knowledge of protein structure, suggest a possible meaning for the term 'highly conserved' in this context.

The stalk has the same primary structure (amino acid sequence) across many different strains of the virus.

[1]

[Turn over]



- (iv) Using the information provided, suggest and explain how a flu vaccine could be designed which provides protection against several strains of the flu virus.

Design a vaccine against the stalk region of the H coat protein (or one containing a range of head region antigens).

The antibodies and memory cells produced would be complementary to the stalk, which is the same in all strains, so they are effective against several (all) strains of flu.

Changes (mutations) to the head region will therefore not reduce the effectiveness of the vaccine.

[3]





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Section B

- 8 The functioning of the nervous system requires passage of impulses from one neurone to another across synapses. Inhibitory synapses can play an important role in regulating synaptic transmission.

- (a) Give an account of synaptic transmission and explain the role of inhibitory synapses. [12]
- (b) Describe and explain adaptations of neurones to maximise speed of impulse conduction. [6]

- (a) Give an account of synaptic transmission and explain the role of inhibitory synapses.

When an impulse (action potential) arrives at the end of the presynaptic neurone, the depolarisation causes voltage-gated calcium ion channels in the presynaptic membrane to open, and calcium ions diffuse into the synaptic knob.

The influx of calcium ions causes synaptic vesicles containing the neurotransmitter, e.g. acetylcholine, to move towards the presynaptic membrane.

The vesicles fuse with the presynaptic membrane, releasing acetylcholine into the synaptic cleft by exocytosis.

The acetylcholine diffuses across the synaptic cleft and binds to complementary receptors on the postsynaptic membrane.

This causes ion (sodium) channels in the postsynaptic membrane to open, resulting in an influx of positive sodium ions into the postsynaptic neurone.



This depolarisation produces an excitatory postsynaptic potential (EPSP). If enough positive ions enter, so that the EPSP crosses the threshold intensity, an action potential is generated in the postsynaptic neurone.

Cholinesterase in the cleft then hydrolyses the acetylcholine, removing it from the receptors so that the postsynaptic membrane can repolarise and the signal is not continuous.

The breakdown products (choline and ethanoic acid) diffuse back across the synaptic cleft into the presynaptic neurone, where they are resynthesised into acetylcholine and stored in synaptic vesicles.

The ATP required for resynthesis and for transport is provided by the many mitochondria in the synaptic knob.

Inhibitory synapses make it more difficult for transmission to take place.

At an inhibitory synapse, a neurotransmitter such as GABA is released from the inhibitory neurone and binds to receptors on the postsynaptic membrane.

This opens channels causing an influx of negative chloride ions (or an efflux of potassium ions), making the inside of the membrane more negative than the resting potential (hyperpolarisation).

This creates an inhibitory postsynaptic potential (IPSP). Because the membrane potential is now more negative, it is more difficult for EPSPs to reach the threshold, so an action potential is less likely to be generated.

IPSPs and EPSPs summate at the postsynaptic neurone, so inhibitory

[Turn over



synapses allow the integration and fine control of responses.

For example, in a reflex arc in which a flexor muscle contracts, inhibitory synapses prevent impulses reaching the antagonistic extensor muscle, so it relaxes.



- (b) Describe and explain adaptations of neurones to maximise speed of impulse conduction.

Many vertebrate neurones are myelinated: Schwann cells wrap around the axon forming a myelin sheath.

The myelin sheath acts as an electrical insulator, so ions cannot flow across the axon membrane and depolarisation cannot occur where the sheath is present.

The sheath is interrupted at the nodes of Ranvier, the gaps between adjacent Schwann cells, and depolarisation can only occur at these nodes.

Local circuits are set up between nodes, so the action potential jumps from node to node, called saltatory conduction, which is much faster than in a non-myelinated neurone.

A high density of ion channels at the nodes of Ranvier allows rapid depolarisation there, which helps to overcome the problem of small

[Turn over]



diameter neurones.

Axon diameter also affects speed: the thicker the axon, the faster the action potential travels.

This is because a large diameter axon has a smaller surface area to volume ratio, so there is proportionally less leakage of ions across the membrane.

Ion leakage makes it difficult to maintain the potential gradient that forms the resting and action potentials, so with less leakage the impulse is conducted faster (e.g. the giant axons of the squid).





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