Surname	StemUp Model Solution	Centre Number	Candidate Number
First name(s)			2

GCE A LEVEL

A400U30-1

Z22-A400U30-1

FRIDAY, 24 JUNE 2022 – MORNING

BIOLOGY – A level component 3
Requirements for Life

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**10**	
	2.	**10**	
	3.	**17**	
	4.	**15**	
	5.	**19**	
	6.	**9**	
Section B	**Option**	**20**	
	Total	**100**	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will need a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.

Section A: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 minutes on this section.

Section B: Options; 20 marks. Answer **one option only**. You are advised to spend about 25 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **6**.

The quality of written communication will affect the awarding of marks.

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SECTION A

Answer **all** questions.

1. Melittin is a protein found in a toxin produced by bees. It consists of a chain of twenty six amino acids.

(a) State the minimum number of nucleotides on the DNA strand coding for melittin. [1]

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(b) When a bee stings a human, it injects melittin. One model of the action of melittin proposes that it causes more sodium ion channels to open in the membrane of pain receptor neurones.

Explain how melittin could cause the perception of pain by the brain. [4]

Melittin opens more sodium ion channels, so Na^+ ions continue to enter the pain receptor neurone (axon), making the inside of the membrane less negative.

The membrane is depolarised until the threshold is reached, so an action potential is formed (generator potential becomes an action potential).

The action potential is in a sensory neurone, which carries the impulses to the central nervous system (brain), where they are perceived as pain.

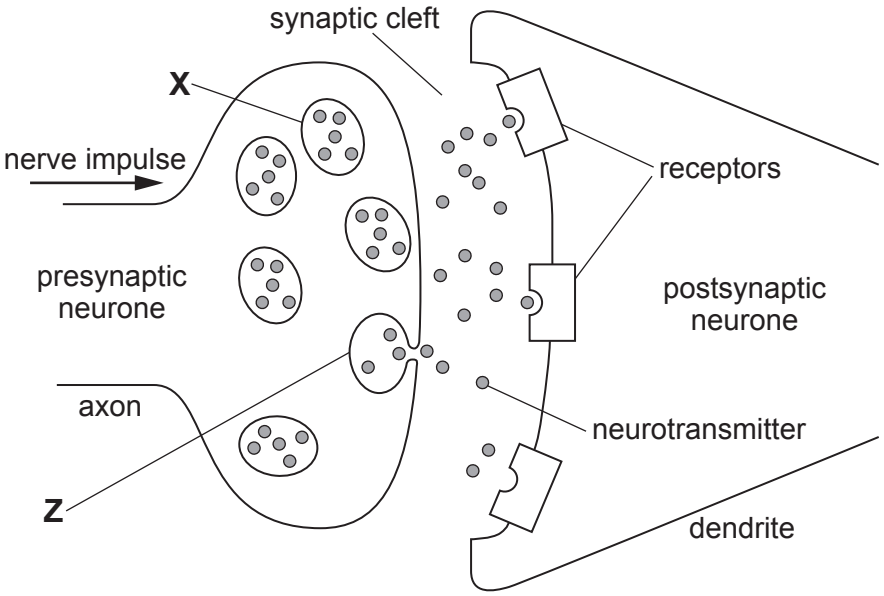
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(c) Nervous impulses are transmitted between neurones using synapses. The structure of a synapse is shown in **Image 1.1**.

Image 1.1



(i) Name the structure labelled **X** and the process taking place at **Z**. [2]

Structure **X** Synaptic (neurotransmitter) vesicle

Process taking place at **Z** Exocytosis

(ii) ATP is required for the processes shown in **Image 1.1**. Explain how ATP is used at a synapse. [3]

ATP provides energy to synthesise neurotransmitter, for its reuptake and to package the neurotransmitter into synaptic vesicles.

ATP is used to move vesicles to the presynaptic membrane for exocytosis.

It is used to actively transport Ca^{2+} ions out of the knob.

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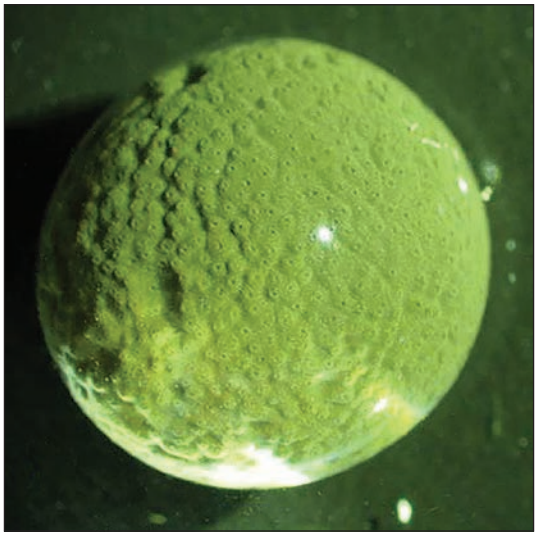
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2. *Gromia sphaerica* is a single-celled protoctist. Individuals have been discovered with a diameter of 40 mm in the Arabian Sea and others with a diameter of 30 mm in the sea in the Bahamas. **Image 2.1** shows one of these cells.

Image 2.1



(a) Individuals of *Gromia* are approximately spherical.

(i) The surface area of the *Gromia* from the Arabian sea was 20 096 mm^2 and the volume was 296 947 mm^3. Calculate the surface area to volume ratio for this organism. [2]

SA : V = 20 096 ÷ 296 947 = 0.0677 (: 1)

Surface area : volume ratio = 0.068 : 1

(ii) State whether the *Gromia* discovered in the Bahamas would have a larger or smaller surface area : volume ratio than the Arabian *Gromia*. Explain your answer. [1]

Larger, because the Bahamas Gromia has a smaller diameter (30 mm), so it has a larger surface area : volume ratio.

(iii) Explain why most single-celled organisms do not need a specialised gas exchange surface. [2]

They have a large surface area to volume ratio and a short diffusion distance, so they can rely on diffusion over their external surface for gas exchange at a sufficient rate.

They also have a comparatively low metabolic rate (oxygen demand).

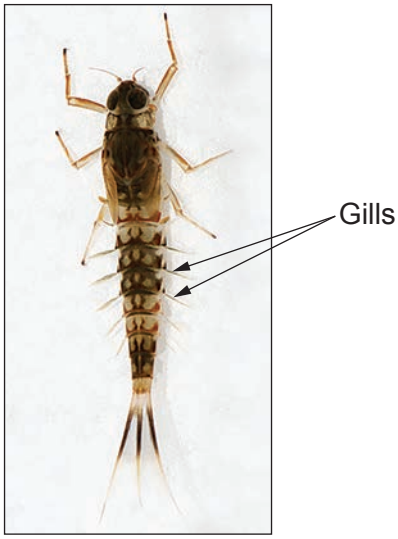
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(b) Some aquatic insects, such as the mayfly nymph shown in **Image 2.2**, have external gills along the side of their bodies. The gills are moved forwards and backwards through the water.

Image 2.2



(i) Explain the reason for the movement of the gills. [2]

Moving the gills replaces the water next to them, keeping a high oxygen concentration (diffusion) gradient, which maintains the rate of oxygen diffusion so it gets enough oxygen.

(ii) In humans, oxygen binds to haemoglobin in order to be transported to respiring cells.
Suggest why terrestrial insects do not require haemoglobin. [2]

Terrestrial insects have a tracheal system: oxygen diffuses directly from the tracheoles into the cells (tissues), so oxygen does not need to be carried in the blood.

(iii) Insects have an open circulatory system. Explain what is meant by the term open circulatory system. [1]

The blood is not contained in blood vessels; it is pumped into the body cavity (haemocoel) and bathes the organs directly.

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3. (a) Humans use holozoic nutrition.

(i) Define the term holozoic. [1]

Internal digestion: food is ingested and then digested inside the body (then absorbed and assimilated).

(ii) Pepsinogen is released into the stomach and converted to the active endopeptidase pepsin.

Explain why pepsinogen rather than pepsin is released by some of the cells lining the stomach and describe how it is activated. [2]

If pepsin were released it could digest the cells that produce it (autolysis), so the inactive pepsinogen is released instead.

Pepsinogen is only converted to pepsin when hydrochloric acid (HCl) is present in the stomach.

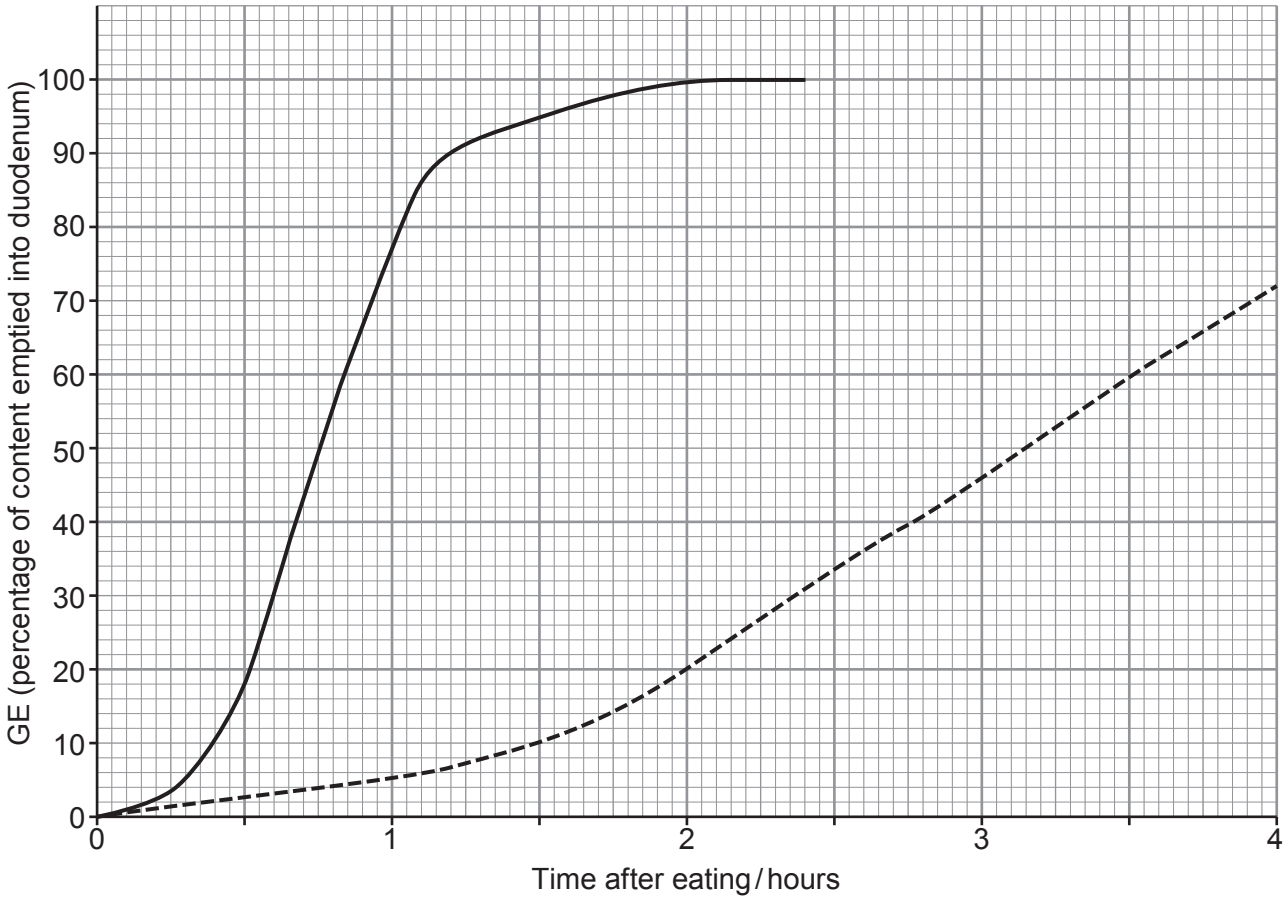
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Gastric emptying (GE) is measured as the percentage of stomach contents emptied into the duodenum at different times after eating. The GE of a sugar-rich drink and a portion of solid protein was determined.

The results are shown in **Image 3.1**.

Image 3.1



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(b) (i) Use your knowledge of digestion to suggest an explanation for the differences in the GE for the sugar-rich drink and the portion of solid protein as shown in **Image 3.1**. [4]

The sugar-rich drink is emptied faster: 100% by about 2.2 hours, whereas only about 72% of the solid protein has been emptied after 4 hours.

The solid needs more mechanical digestion (churning) before it can leave.

Proteins are large molecules which take longer to digest, so the protein remains in the stomach longer so that it can be broken down by pepsin.

Carbohydrates are not digested in the stomach but in the small intestine.

(ii) Many indigestion remedies neutralise the acid in the stomach.

Describe and explain how these remedies will affect the rate of protein digestion in the stomach. [2]

The rate of protein digestion decreases (digestion takes longer), because the enzymes in the stomach (pepsin) have a low optimum pH and require acid conditions, and acid is needed to activate pepsinogen.

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(c) Casein is a protein found in milk. Scientists investigated the use of immobilised enzymes for the digestion of casein. They set up a column of immobilised enzymes and a solution of the protein casein was poured into the column. The resulting liquid was collected and analysed for free amino acids.

Three columns were set up, these contained either endopeptidase, exopeptidase or a mixture of endopeptidase and exopeptidase.

The results are shown in **Table 3.2**.

Table 3.2

Enzyme present	Free amino acids collected as a % of resulting liquid
endopeptidase	2
exopeptidase	5
endopeptidase and exopeptidase	17

(i) Explain the results shown in **Table 3.2**. [3]

Endopeptidase hydrolyses peptide bonds in the middle of the chain, producing shorter polypeptides but few free amino acids (2%). Exopeptidase only removes the terminal amino acids, so more free amino acids are produced (5%). The combination gives more ends for the exopeptidase to work on, so the most free amino acids are released (17%).

The scientists then poured water into the column which contained immobilised endopeptidase and exopeptidase and collected the resulting liquid at the end of the column.

(ii) Describe how they could test the resulting liquid to show that no enzyme had left the column. Explain why this test is used. [2]

Add biuret reagent to the liquid: it stays blue (does not turn lilac/purple), showing no protein is present. This test is used because enzymes are proteins.

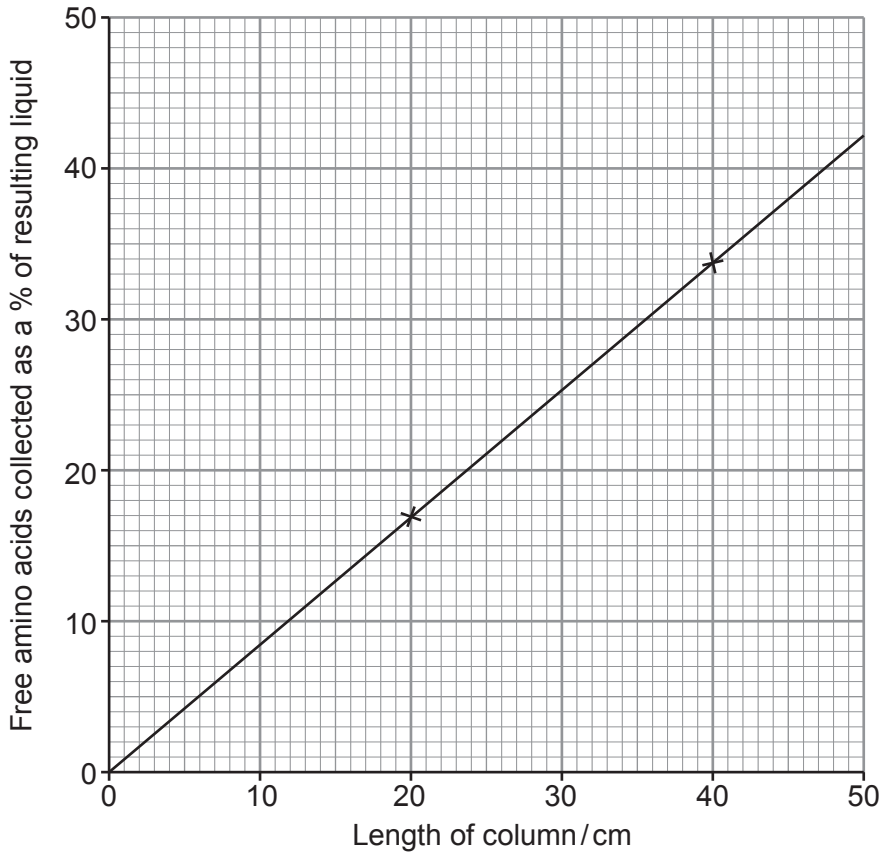
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The initial column used was 20 cm in length. When the scientists used a 40 cm long column containing endopeptidase and exopeptidase the resulting liquid contained 34% free amino acids.
They plotted the results on **Graph 3.3**.

Graph 3.3



The scientists found the line on the graph to follow the equation

$$y = mx + c$$

The gradient of the line in this graph was found to be 0.85.

(iii) Using the equation and the information provided, estimate the concentration of the free amino acids collected as a percentage of the resulting liquid when the column is 70 cm long. [2]

y = mx + c, where c = 0 as the line passes through the origin

y = 0.85 × 70 + 0 = 59.5

Concentration of the free amino acids = ... 59.5 ..... %

(iv) When the scientists used a 70 cm column, they found that their estimate was incorrect. With reference to **Graph 3.3**, suggest why this might be the case. [1]

Only two results were used, so they cannot assume a straight line: the line may plateau (level off), so it cannot be extrapolated.

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4. **Image 4.1** shows a kidney that has been dissected using a scalpel.

Image 4.1



(a) Complete the risk assessment below for **one** hazard involved in this dissection. [2]

Hazard	Risk	Control measure
Scalpel (instruments) are sharp	Cutting your hand when dissecting	Cut away from the body and down onto a hard tile

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(b) ADPKD is a condition that causes small fluid-filled sacs (cysts) to form in kidney tubules. This results in some kidney tubules becoming blocked. Other tubules in the kidney have a higher rate of filtration.

(i) Using your knowledge of ultrafiltration, explain why the body responds to ADPKD by increasing the blood pressure to above normal levels. [2]

Ultrafiltration depends on the hydrostatic pressure of the blood in the glomerulus, so high blood pressure increases the filtration rate (more filtrate formed).

Higher rates of filtration are needed in the unaffected (unblocked) tubules to compensate for the blocked tubules, so the normal total filtration rate is maintained.

(ii) Explain how high blood pressure can also lead to the swelling of some tissues of the body (oedema). [3]

High blood pressure causes a high hydrostatic pressure at the arterial end of the capillaries, which is greater than the osmotic pressure (water potential) of the blood.

So more tissue fluid is forced out than can be reabsorbed at the venous end (excess fluid cannot be reabsorbed).

The fluid accumulates in the tissues, causing swelling.

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(c) Another symptom of ADPKD is severe pain in the kidneys. A study was carried out to determine whether a procedure to destroy the pain receptors in the kidney would improve the quality of life for patients suffering from ADPKD.

The study was carried out on 15 male volunteers. They rated the pain on a scale from 0 (no pain) to 10 (very severe pain) before and after the procedure.

The results are shown in **Table 4.2**.

Table 4.2

Patient	Pain rating before procedure	Pain rating after procedure
A	6	5
B	8	6
C	6	6
D	7	5
E	8	6
F	7	7
G	7	5
H	8	5
I	6	8
J	9	6
K	7	4
L	6	3
M	7	7
N	7	5
O	8	6

A student concluded from the results that the procedure did reduce the pain felt by ADPKD patients.

Use the results in **Table 4.2** to evaluate the student's conclusion. [4]

For: most (11 out of 15) of the pain scores decreased after the procedure.

Against: some scores stayed the same (C, F and M) and one increased (I, from 6 to 8).

The sample size of 15 is too small, and no statistical test has been carried out to show the difference is significant.

The pain scale is subjective, the study was only carried out on men and there is no information on other medicines (painkillers) taken.

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(d) ADPKD is an inherited condition caused by an autosomal dominant allele.

(i) Describe what is meant by the term autosomal dominant allele. [2]

An allele on an autosome, a chromosome that is not a sex chromosome (not sex linked).

Only one copy of the allele is needed to inherit the disease: it is always expressed in the phenotype when present.

(ii) The frequency of the allele for ADPKD has remained constant and low in the UK population. The Hardy-Weinberg equation can be used to estimate the allele frequency. However, the use of this equation depends on a number of assumptions being made.
State **two** of these assumptions. [2]

There are no mutations (no new alleles are created).

There is no immigration or emigration, there is no selection, mating is random and the population is large.

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5. A student investigated the number of stomata on the lower epidermis of a leaf. **Image 5.1** shows a small area of the lower epidermis of the leaf at a magnification of ×100.

Image 5.1



(a) (i) The student counted **9** stomata in this field of view.

The diameter of the field of view is 0.18 mm.

Using this information, calculate the number of stomata per mm^2.

Express your answer to the nearest whole figure.

Area of field of view=πr^2 [3]

π = 3.14

r = 0.18 ÷ 2 = 0.09 mm

area = 3.14 × 0.09^2 = 0.025434 mm^2

9 ÷ 0.025434 = 353.86

Number of stomata / mm^2 = ..*354*..

(ii) State **two** ways in which the student could improve their confidence in the results. [2]

Count the stomata in several fields of view (different areas of the leaf), repeat and calculate a mean.

Use a method for stomata cut by the edge of the field of view, e.g. count half stomata on one half of the edge only, and make sure each stoma is only counted once.

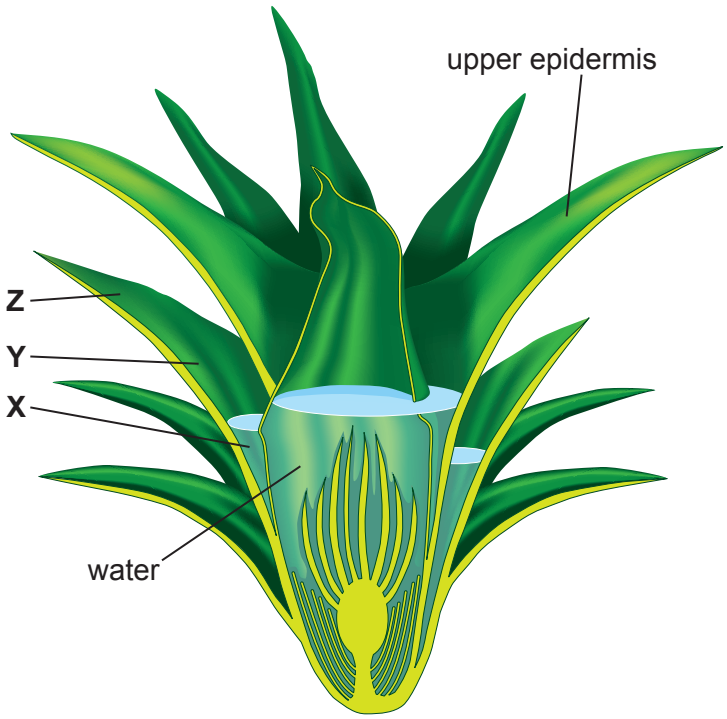
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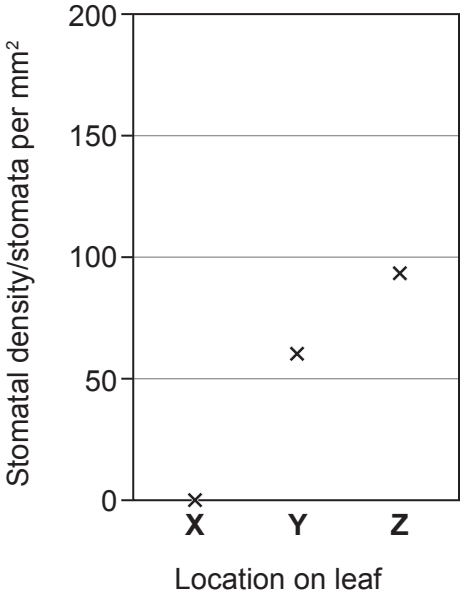
(b) Bromeliads are plants found in tropical areas of the Americas. Some species have tightly overlapping leaf bases that can hold water, as seen in **Image 5.2**. Bromeliad leaves have an uneven distribution of stomata on their upper epidermis. The number of stomata at locations **X**, **Y** and **Z** (shown in **Image 5.2**) are shown in **Graph 5.3**.

Image 5.2



Bromeliad cross-section

Graph 5.3



(i) Using the information given explain why there are no stomata in location **X**. [2]

Location X is below the level of the water held in the leaf bases, so it is covered by water.

No gas exchange could take place there: carbon dioxide (air) cannot enter, so stomata would be useless.

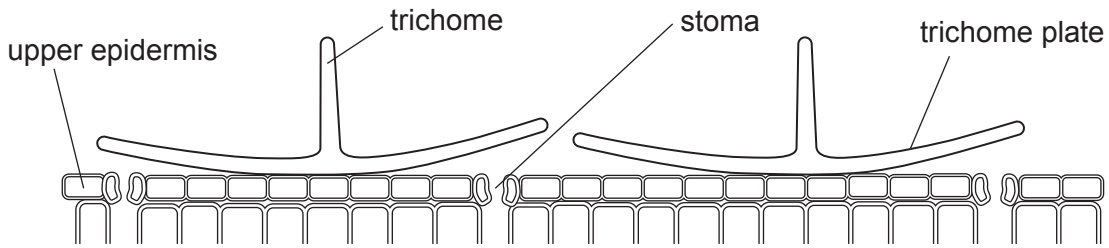
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Tillandsia punctulata, a bromeliad species, lives high in the canopy layer of the rainforest where there is a higher temperature and a lower relative humidity. This species shows an adaptation to the environment as they have hair-like structures (trichomes) which stick up from plates which cover the stomata. The arrangement is shown in **Image 5.4**

Image 5.4



(ii) Using all the information provided, suggest why this arrangement of trichome plates and stomata is an adaptation for survival in the exposed conditions of the upper canopy. [3]

The trichome plates cover the stomata and trap a layer of still air (prevent the wind blowing water vapour away). This layer becomes saturated with water vapour (increased humidity) around the stomata, which reduces the water potential gradient between the leaf and the air, so less water is lost by transpiration in the hot, dry, exposed canopy.

(iii) *Tillandsia punctulata* absorbs water collected in the trichome plates rather than through its roots. Other species of bromeliad, which live on the ground, take in water through roots in the soil. When water passes through the roots, all water passes through the endodermis by the same pathway.
Name this pathway and explain how the structure of the endodermis causes water to enter this pathway. [2]

The symplast pathway. The Casparian strip, a layer of suberin in the endodermal cell walls, is impermeable to water, so it blocks the apoplast and water must enter the cytoplasm.

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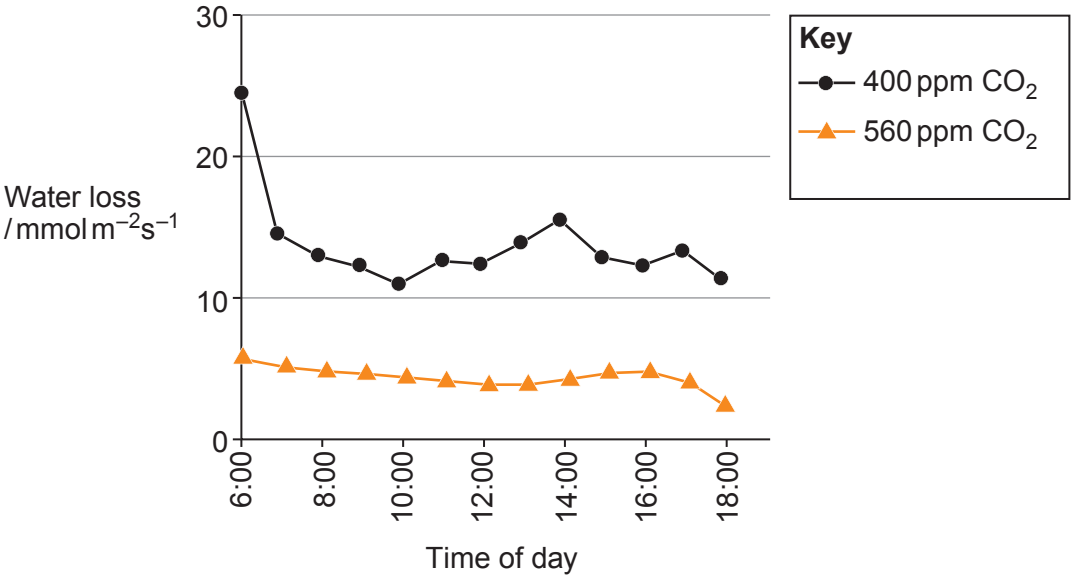
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(c) It has been predicted that atmospheric carbon dioxide concentrations will increase to 560 ppm (parts per million) by the year 2050. This is 160 ppm higher than we have today.

The effect of increasing carbon dioxide concentrations on water loss by plants was investigated. Plants were exposed to 400 ppm and 560 ppm of carbon dioxide in the air and the volume of water loss monitored over a 12-hour period.

The results are shown in **Image 5.6**.

Image 5.6



Explain why the water loss is less when there is more carbon dioxide in the atmosphere. [3]

Stomata open to allow CO_2 to diffuse in for photosynthesis, but water vapour is lost when they are open.

At higher CO_2 concentration there is a steeper gradient so an increased rate of CO_2 uptake (diffusion).

So sufficient CO_2 can be absorbed with fewer stomata open (stomata open less), so less water is lost by transpiration.

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(d) One type of bromeliad plant is the pineapple *(Ananas comosus)*.

Pineapple is an important economic crop cultivated across the tropics. In 2016, Costa Rica grew pineapples on 43 000 hectares of land with a planting density of 70 000 individual plants per hectare.

It was calculated that one pineapple plant lost 7 500 cm^3 of water in a year in 2016. It has also been calculated that a pineapple plant would lose 3 400 cm^3 of water per year if the surrounding air contained 560 ppm of carbon dioxide.

(i) Using these figures and assuming the area and density of planting remain the same, calculate the difference between the volume of water lost by the entire pineapple crop in Costa Rica in 2016 compared to 2050 if the carbon dioxide concentration reached 560 ppm. **Give your answer in standard form.** [3]

difference per plant = 7500 − 3400 = 4100 cm^3

number of plants = 70 000 × 43 000 = 3.01 × 10^9

4100 × 70 000 × 43 000 = 1.2341 × 10^{13}

Difference = *1.23 × 10^{13}* $cm^3\ yr^{-1}$

(ii) A group of ecologists have predicted that the change in water loss by the pineapple crops may lead to more flooding in Costa Rica. Suggest why. [1]

Decrease in transpiration, so less water is absorbed by the roots and lost by the leaves, so more water remains on the ground.

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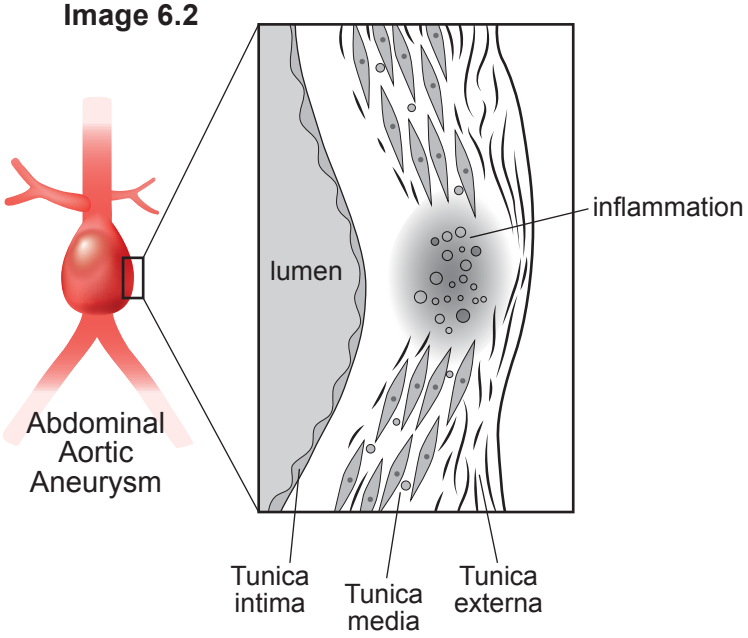
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6. **Image 6.1** is a photomicrograph of human tissue. Two different types of blood vessel, labelled **X** and **Y**, are shown. Sometimes high blood pressure can lead to an aneurysm in a blood vessel. A diagrammatic cross-section of the wall of a vessel with an aneurysm is shown in **Image 6.2**.

Image 6.1



Image 6.2



Identify the two types of blood vessel, labelled **X** and **Y**, shown in **Image 6.1**, giving reasons for your answer.
Describe and explain how the structure of vessels **X** and **Y** is related to their function.
Describe what has happened to the wall of the vessel in **Image 6.2** and suggest possible problems associated with an aneurysm. [9 QER]

X is an artery and Y is a vein. X has a thicker wall with a thick muscle layer and a smaller, round lumen, whereas Y has a thinner wall, a less muscular wall and a large, irregular lumen.

Artery X: the thick wall (thick layer of smooth muscle) allows it to withstand and maintain the high pressure produced by ventricular contraction. The thick layer of elastic tissue stretches as blood surges in and then recoils when the pressure falls, which evens out the flow. The muscle layer can contract to give a smaller lumen diameter (vasoconstriction), which alters the blood supply to different organs.

Vein Y: blood is at low pressure, so the wall is thinner with less muscle. The thin wall allows contracting skeletal muscles to squeeze the vein and increase the pressure in the lumen, pushing blood back towards the heart. The large

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(wide) lumen reduces resistance to flow. Backflow of blood is prevented by the presence of valves.

Aneurysm (Image 6.2): the wall of the vessel has been stretched and is bulging outwards. The outer layer (tunica externa) is not broken, but the smooth muscle of the tunica media has been torn (damaged) and there is inflammation of the tunica media.

Possible problems: the weakened wall may burst (rupture), causing internal bleeding, and the person may bleed out. Blood pools in the bulge, so less blood (and oxygen) reaches the destination tissues beyond the aneurysm.

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SECTION B: OPTIONAL TOPICS

Option A: **Immunology and Disease** ☑

Option B: **Human Musculoskeletal Anatomy** ☐

Option C: **Neurobiology and Behaviour** ☐

Answer the question on **one topic only**.

Place a **tick (✓)** in **one** of the boxes above, to show which topic you are answering.

You are advised to spend about 25 minutes on this section.

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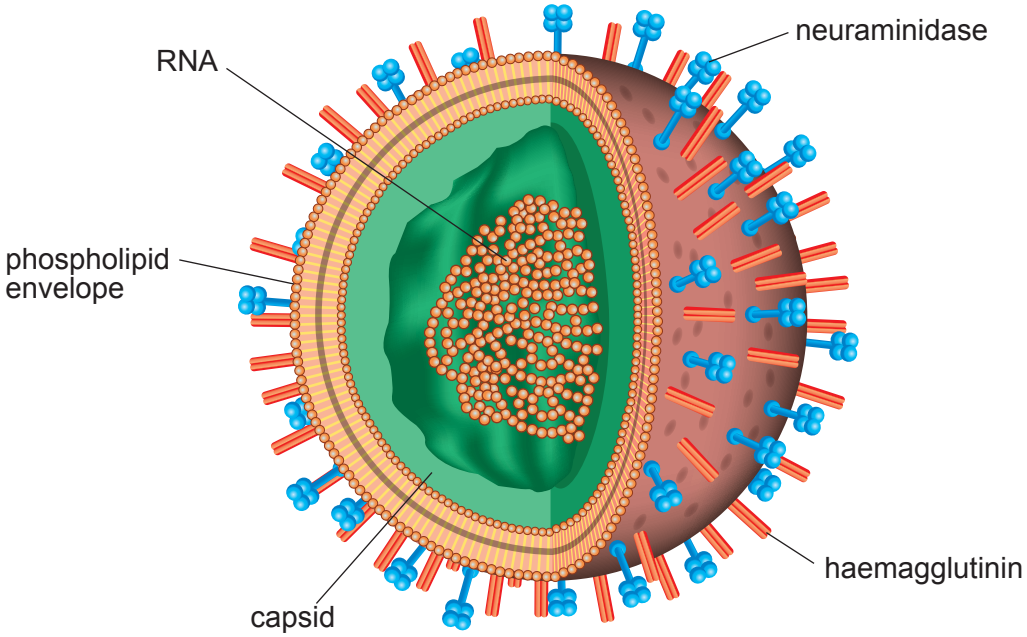
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Option A: Immunology and Disease

7. (a) Influenza, 'flu', is an infectious disease of the respiratory tract caused by a retrovirus, shown in **Image 7.1**.

Symptoms include sore throat, coughing and fever.

Image 7.1



Neuraminidase and haemagglutinin are proteins on the phospholipid envelope. They are classified as antigens.

(i) Describe what is meant by the term antigen. [1]

A molecule (protein) that causes an immune response, e.g. the production of antibodies by the host.

(ii) Explain why viruses require a host cell in order to be able to reproduce and why one of the symptoms of flu is a sore throat. [2]

Viruses do not contain ribosomes for protein synthesis or enzymes to replicate nucleic acid.

Sore throat: infected cells lyse (burst) and there is inflammation (histamines released).

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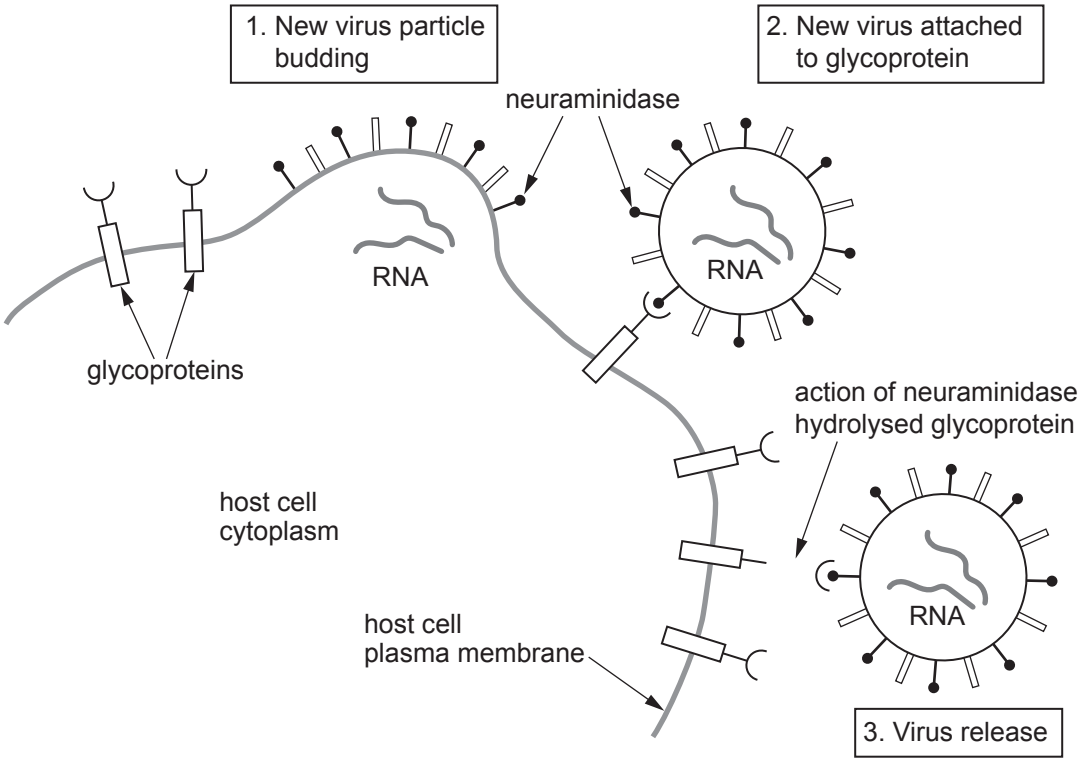
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Newly formed virus particles are attached to the cell surface membrane of the host cell by a glycoprotein. Neuraminidase is an enzyme that hydrolyses the glycoprotein resulting in the release of the virus.

A diagram illustrating the action of neuraminidase in viral replication is shown in **Image 7.2**.

Image 7.2



In 2007, during a flu outbreak in North Wales, some patients were treated with the drug 'Tamiflu' which contains a molecule that inhibits neuraminidase.

(iii) Explain how 'Tamiflu' could reduce or prevent the progress of the flu infection in patients. [3]

Tamiflu inhibits neuraminidase, so it is unable to hydrolyse the glycoprotein.

So the new virus particles are not released and remain attached to the host cell.

So they cannot infect other host cells, and antibodies and phagocytes are better able to target the virus.

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(b) Random changes in viral antigens, known as antigen shift, may originate in animals and then transfer to humans who may live in close proximity to them. The 2007 flu outbreak originated from imported poultry.

Several forms of haemagglutinin (H) and neuraminidase (N) exist. Combinations of different forms of the two proteins produce different strains of the flu virus. The 2007 flu strain was H7N1.

A new flu vaccine is produced each year. It contains the H and N protein combination found to be most prominent during that year.

(i) Explain why a flu vaccine should contain only the H and N proteins and no viral RNA. [1]

Without viral RNA the vaccine cannot replicate inside human cells, so it cannot cause flu.

(ii) Vaccination against flu results in an active cell-mediated immune response.

Describe how **cell-mediated immunity** to the flu virus develops following vaccination. [3]

The H and N antigens are taken up by macrophages and presented on their surface (antigen presentation).

Specific T helper cells bind to them and are activated, then divide by mitosis (clonal expansion).

T cells release cytokines, which stimulate phagocytes (macrophages) to engulf the virus, and T memory cells are formed.

(iii) Explain why people belonging to the following specific groups are advised to obtain a flu vaccination. [2]

I. people with chronic illnesses;

They have a weaker immune system, and flu may make the symptoms of their other conditions worse.

II. health professionals.

They come into contact with many infected people, and could infect vulnerable patients.

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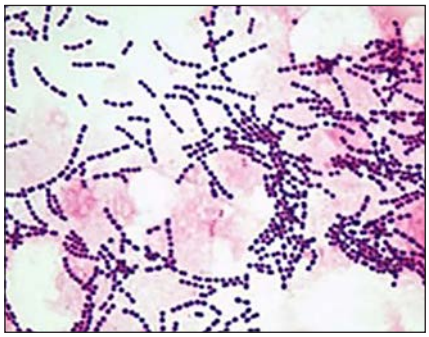
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(c) A GP suspected that a patient suffering from a sore throat may have a bacterial infection.

Some bacteria from a throat swab taken from the patient were stained and viewed with an optical microscope. They appeared as purple spherical cells arranged in chains, shown in **Image 7.3**.

The bacteria were identified as *Streptococcus pyogenes*.

Image 7.3



(i) Name the type of bacterium indicated by the purple colour and describe what this indicates about the structure of the cell wall of *Streptococcus pyogenes*. [2]

Gram positive.

The cell wall has no lipopolysaccharide outer layer and has a thick layer of peptidoglycan (murein).

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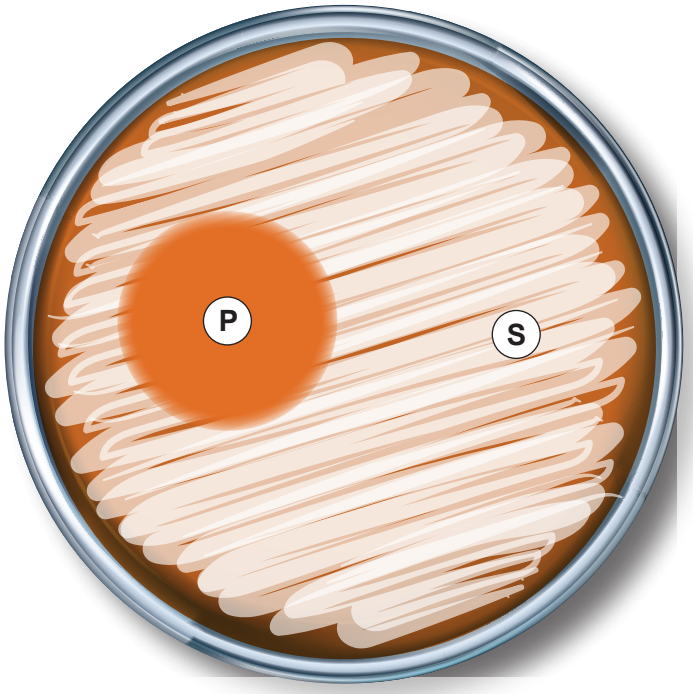
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The antibiotics penicillin and streptomycin are usually effective against *Streptococcus pyogenes*.

Bacteria from this patient were grown on an agar plate. Discs of filter paper saturated with either penicillin (disc **P**) or streptomycin (disc **S**) were placed onto the agar before incubation. The bacterial growth after incubation is indicated by the lighter areas in **Image 7.4**.

Image 7.4



(ii) Using the information in **Image 7.4**, explain why penicillin was selected to treat the patient. [2]

There is a clear zone of inhibition around disc P (bacteria have not grown), but bacteria have grown around disc S.

So the bacteria are killed by penicillin (not resistant), but are resistant to streptomycin.

(iii) Explain why unnecessary overuse of antibiotics is likely to result in greater numbers of antibiotic resistant individuals in populations of bacteria. [2]

Random mutation during DNA replication produces a resistance allele (or plasmids carrying it are obtained from other bacteria).

With antibiotics present, resistant bacteria have a selective advantage.

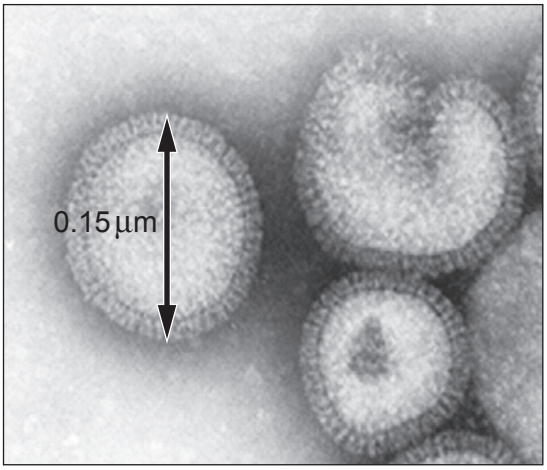
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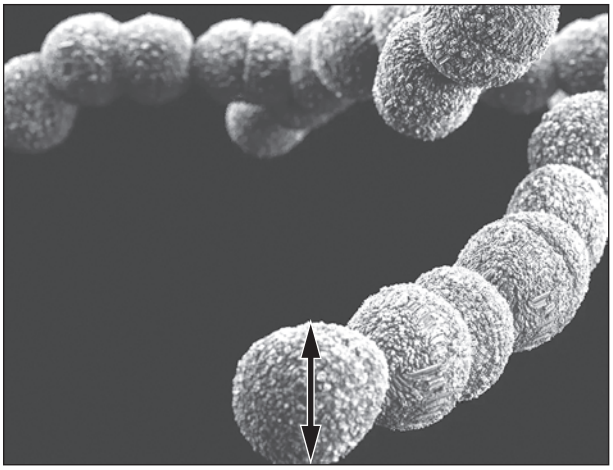
Images 7.5A and **7.5B** shows electron micrographs of flu viruses and *Streptococcus* bacteria. They have a similar shape although their size and structure are different.

Image 7.5A



Flu virus
Magnification = × 200 000

Image 7.5B



Streptoccocus bacteria
Magnification = × 20 000

(d) The diameter of the bacterium in **Image 7.5B** at the position of the arrow was calculated to be **0.75 µm**.
Calculate how many times larger the *Streptoccocus* bacterium is compared to the flu virus. [2]

flu virus diameter = 0.15 µm

0.75 ÷ 0.15 = 5

Answer = ... 5 ..... times larger

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Option B: Musculoskeletal Anatomy

8. (a) Synovial joints enable movement of limbs and are composed of several tissues. **Image 8.1** shows a diagram of a section through a synovial joint.

Image 8.2 is a photomicrograph of the structure of the articular cartilage.

Image 8.1

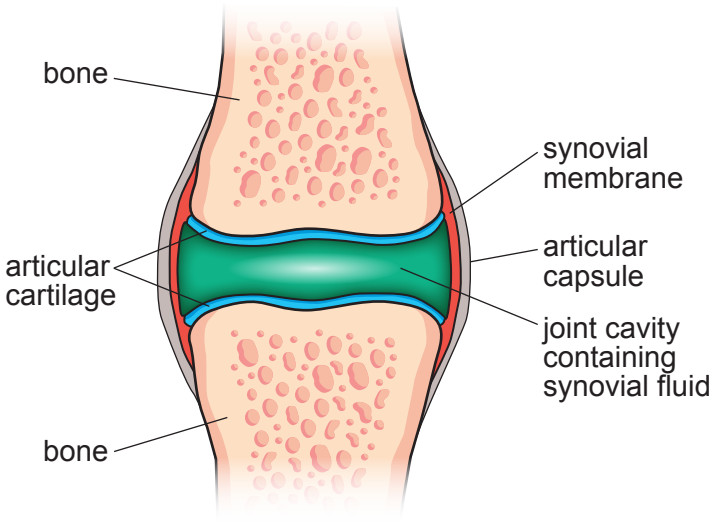
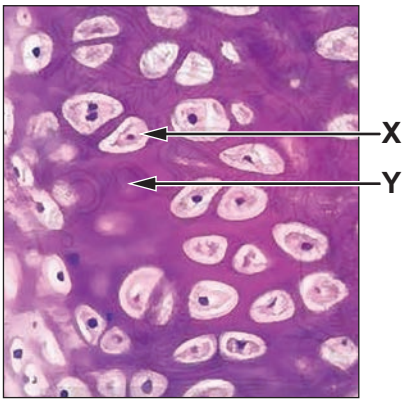


Image 8.2



(i) Name the type of cartilage that forms articular cartilage and state its function in a joint such as the knee. [2]

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(ii) State the name of the cells labelled **X** and the structure labelled **Y** in **Image 8.2**. [1]

X .....

Y .....

(iii) Using the information in **Image 8.2**, suggest why the transport of nutrients and oxygen to the cells in the cartilage is limited and describe how oxygen and nutrients are likely to reach these cells. [2]

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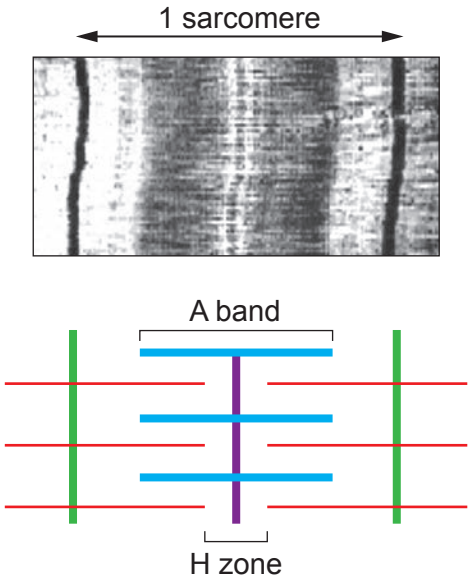
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(b) Several groups of striated muscles cause movement at the knee joint.

In **Image 8.3** an electron micrograph and diagram show the arrangement of protein filaments in one sarcomere of a relaxed myofibril.

Image 8.3



(i) Describe and explain the appearance of the H zone and the A band when the sarcomere is **contracted**. [2]

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(ii) Sarcomeres, such as the one shown in **Image 8.3**, have a mean length of 40 µm.

Calculate how many sarcomeres there would be in a single myofibril from a muscle in the thigh, which measures 280 mm when it is relaxed. [2]

Number of sarcomeres = ...

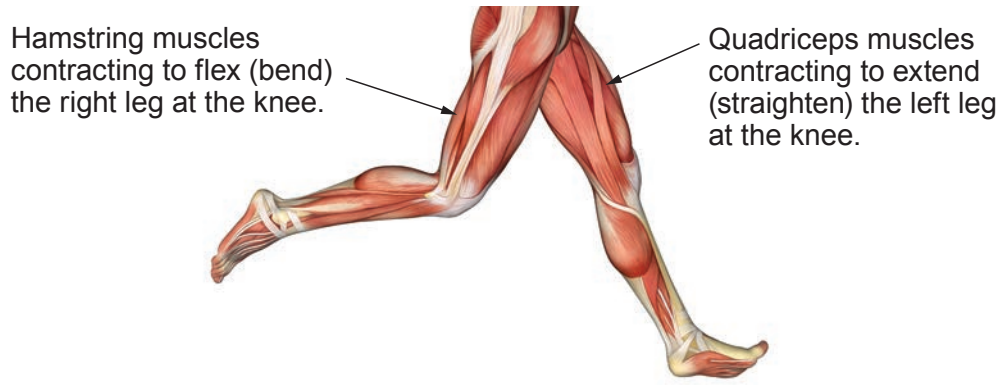
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Image 8.4 shows the leg muscles while a person is running.

Image 8.4



(iii) State the term that describes how the quadriceps and hamstring muscles work together to enable movement at the knee joint. [1]

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(c) Inorganic compounds, such as calcium phosphate, are deposited into bone tissue as it grows, a process known as mineralisation.

Osteomalacia is the result of a deficiency in bone mineralisation.

The X-ray photograph in **Image 8.5** shows the legs of a child suffering from rickets, a form of osteomalacia that results from a deficiency of vitamin D.

Image 8.5



(i) In bones affected by vitamin D deficiency, specific bone cells are unable to add inorganic calcium salts. State the name of these cells and explain why the tibia and fibula in **Image 8.5** have become bowed as a result. [3]

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Vitamin D can be ingested in foods such as milk and animal fats. UV light absorbed from the sun converts a molecule in the skin to vitamin D. However, melanin pigment in the skin reduces UV absorption.

Scientists investigated the effect of sunlight and vitamin D food supplements on bone growth in albino rats (rats with no melanin in their skin or fur).

- 36 young, male rats were kept in artificial 12-hour day and night cycles at 25°C in a laboratory for six weeks.
- The laboratory lights emitted no UV light.
- All the rats were fed adequate calcium but no vitamin D so that they **all** became vitamin D deficient.
- After six weeks, they were divided into three experimental groups, shown in **Table 8.6**
- The area of a growing region of the bone was measured in each of the three groups at the start and end of a ten-day period.

A summary of the results of the experiment is given in **Table 8.6**.

Table 8.6

Vitamin D Intake and UV Exposure of Experimental Groups			Mean area of new bone growth / mm^2 (+/– SD)	
Group	Diet	Environment	Day 0	Day 10
1	No vitamin D intake	placed outside in sunshine for 1 hour each day	13.48 (±0.35)	20.94 (±0.17)
2	Vitamin D supplement	remained in the laboratory	14.75 (±0.49)	19.78 (± 0.5)
3	No vitamin D intake	remained in the laboratory	15.56 (±2.73)	16.34 (±3.16)

(ii) Suggest why **young**, **albino** rats were used in the experiment. [2]

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(iii) Describe the conclusions that can be made from the data in **Table 8.6** and explain whether the results can be considered significant. [3]

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(d) **Image 8.7** is an X-ray photograph showing a different type of deformity of the skeleton.

Image 8.7



(i) Identify the condition shown in **Image 8.7**. [1]

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(ii) State **one** potential cause of this condition. [1]

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Option C: Neurobiology and Behaviour

9. (a) Some termite species live in eusocial colonies inside large termite mounds **(Image 9.1)** that they construct from wood pulp glued with saliva.

Image 9.1



Termites feed on dead wood and organic material growing within the termite mound.

The flow chart in **Image 9.2** summarises the life stages of termites.

Image 9.2

A single queen lays many eggs fertilised by sperm from a single king.

1. Eggs

↓

2. Larvae / immature termites

↙ EITHER ↘ OR

3. **Non-reproductive adults**

Permanently wingless

Females are worker termites

Males are soldier termites

↓

Function in existing colony

Reproductive adults

Winged for a short time

Females are potential queens

Males are potential kings

↓

Establish new colonies

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(i) One feature of a eusocial colony is division of labour.
Describe what is meant by division of labour and suggest **one** role that worker termites may carry out that would contribute to the survival of the colony. [2]

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Termites exhibit an innate directional response to light. Wingless termites show a negative response (move away from light) whereas winged termites show a positive response to the same stimulus.

(ii) I. State the specific name of this type of innate response. [1]

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II. Suggest the advantage **to the colony** of the responses to light shown by wingless and winged adult individuals during the life cycle of termites. [3]

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(b) Chimpanzees *(Pan troglodytes)* belong to an order of mammals called primates. They exhibit social behaviour within a linear social group known as a dominance hierarchy.

(i) Explain **one** advantage of a dominance hierarchy to a group of chimpanzees. [1]

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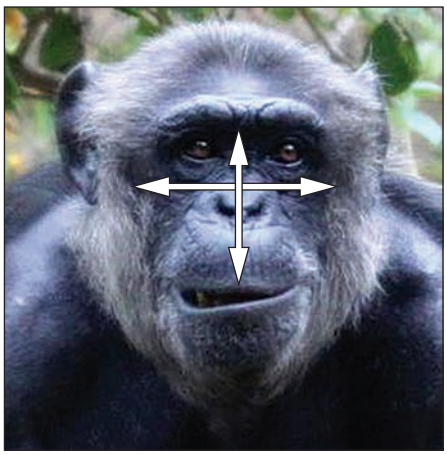
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Dominant males in the group show more assertive behaviour than other males.

They also exhibit specific physical characteristics including a larger facial width-to-height ratio (fWHR) which can be measured from a photograph.

Image 9.3, The points of measurement for facial width and facial height are marked with arrows on a photograph of chimpanzee **X**.

Image 9.3



Facial width = distance between the two cheekbones.

Facial height = distance from the top of the upper lip to top of the eyes.

(ii) Using the arrows marked on **Image 9.3**, calculate the facial width-to-height ratio (fWHR) of chimpanzee **X**. [2]

Ratio ..... :1

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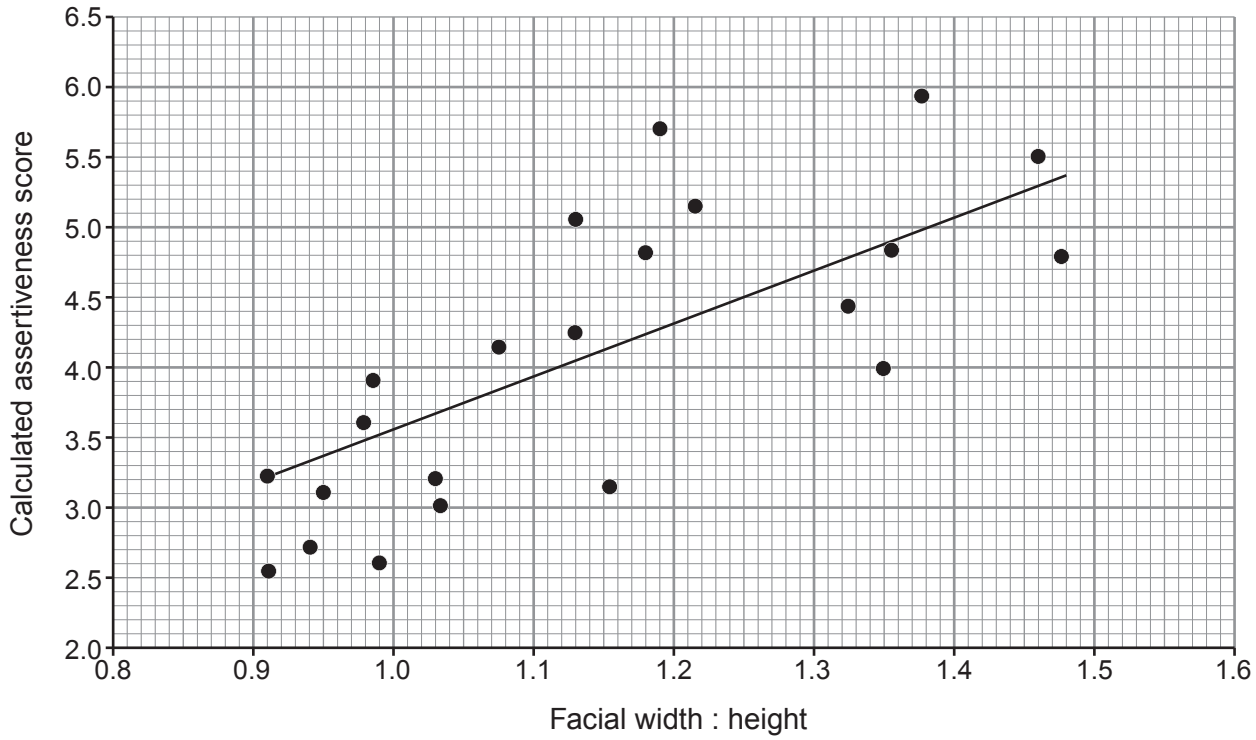
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Scientists calculated an assertiveness score for each of 22 male chimpanzees in a captive group.

They applied positive numerical values to types of assertive behaviour such as threat or defiance. Submissive behaviour was given negative numerical values.

A total score was calculated after monitoring behaviour over a given time interval and then correlated with facial width : height shown in **Graph 9.5**.

Graph 9.5



(iii) Use your answer from (b)(ii) and **Graph 9.5** to predict the expected assertiveness score for chimpanzee **X**. [1]

Expected assertiveness score = ...

(iv) The graph shows considerable variation in data for the calculated assertiveness scores compared to facial width-to-height ratio. Suggest why the calculated assertiveness score for chimpanzee **X** is likely to be different from the expected value. [1]

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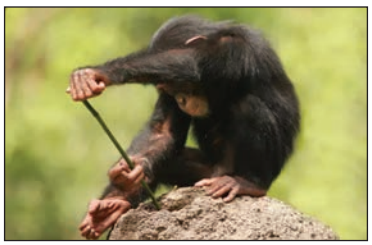
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(c) Chimpanzee social structure allows individuals to learn from others.

Some chimpanzees learn to use sticks as tools to collect termites from inside a mound, as shown in **Image 9.6**. After inserting a stick and waiting, the chimpanzee extracts the stick and eats the termites that have walked onto it.

Image 9.6



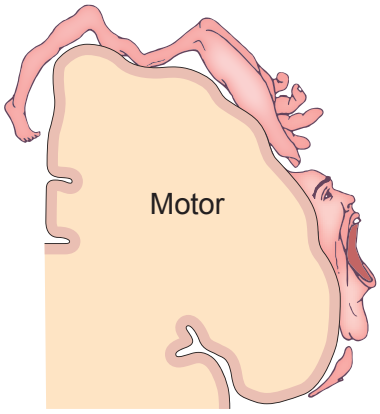
(i) Suggest which form of learning behaviour enables many chimpanzees in this group to acquire the skill shown in **Image 9.6**. [1]

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All primates can use an opposable thumb to grip or manipulate objects. Neurones in the cerebral cortex of the brain control thumb movements.

The diagram in **Image 9.7** is known as a homunculus and represents the cerebral **motor** cortex of a human brain. Some parts of the body are illustrated alongside the brain in the diagram.

Image 9.7



(ii) Explain why the shape and size of the hand appears distorted and disproportionately large compared to other parts of the body in **Image 9.7**. [2]

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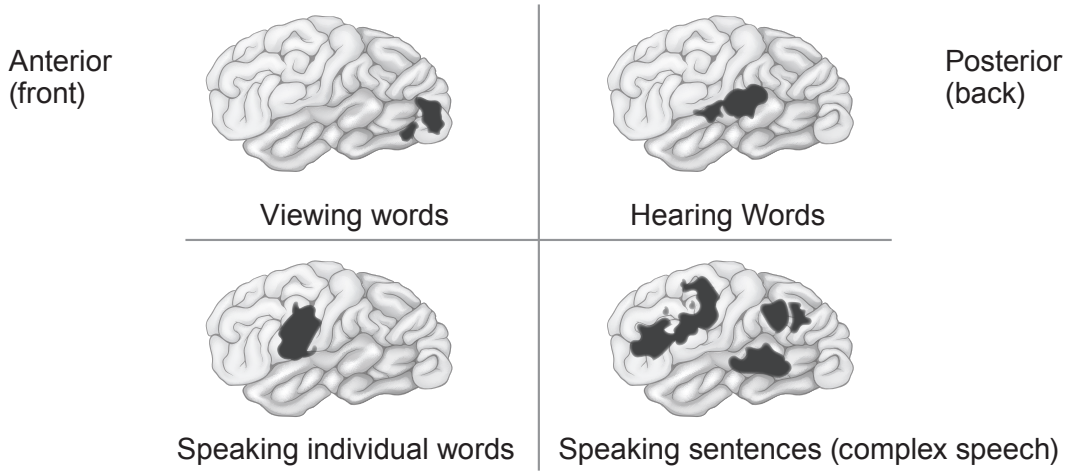
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(d) Humans are the only primates to develop the ability to use speech.

Image 9.8 shows a PET scan of the brain of a single individual. It indicates the highest activity in different parts of the brain as the individual carries out activities associated with speech and language. These areas appear darker on the image.

Image 9.8



A PET scanner detects the quantity of radiation from the most active areas of the brain then uses the data to produce an image.

(i) Describe and explain the procedure that causes the areas of highest brain activity to appear darker in a PET scan image. [3]

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(ii) Using **Image 9.8**, name the areas of the cerebral cortex that show **greatest** activity when the subject is:

I. **viewing** written words. [1]

.....

II. **speaking** individual words. [1]

.....

(iii) Suggest why speaking sentences (complex speech) uses a greater area of the cerebral cortex than all the other components combined. [1]

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

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