Surname	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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01

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]

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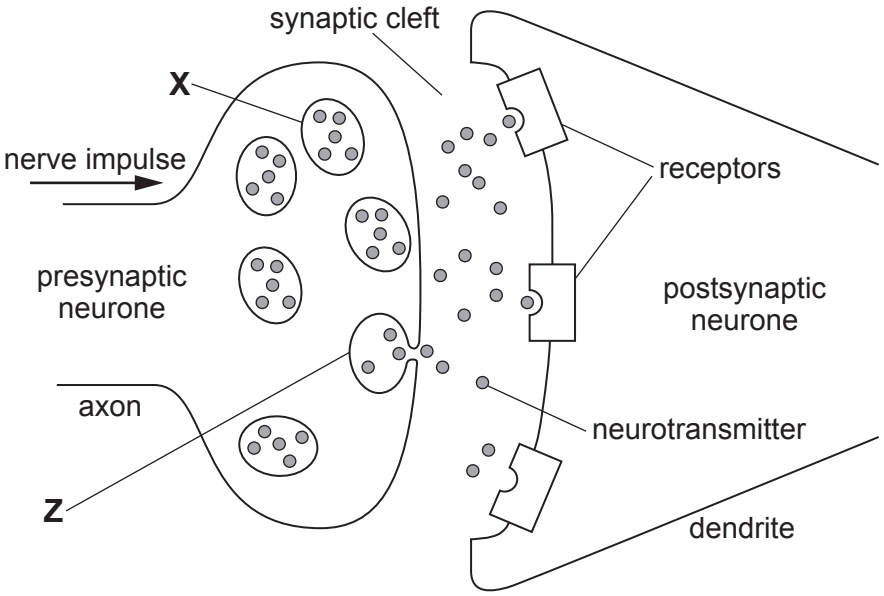
(c) Nervous impulses are transmitted between neurones using synapses. The structure of a synapse is shown in **Image 1.1**.

Image 1.1



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

Structure **X** .....

Process taking place at **Z** .....

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

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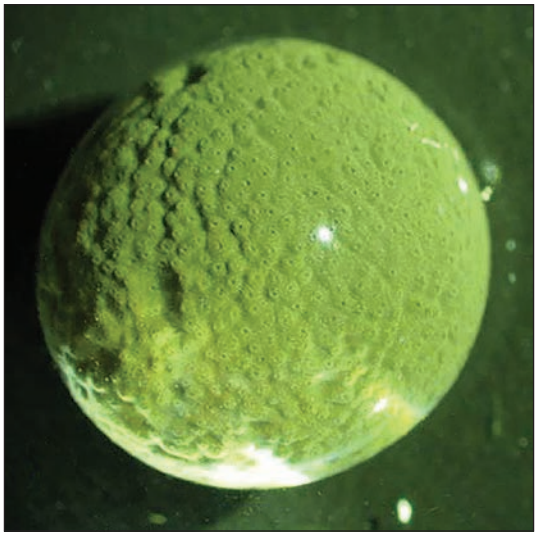
2. *Gromia sphaerica* is a single-celled protoctist. Individuals have been discovered with a diameter of 40 mm in the Arabian Sea and others with a diameter of 30 mm in the sea in the Bahamas. **Image 2.1** shows one of these cells.

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]

Surface area : volume ratio = ... : 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]

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

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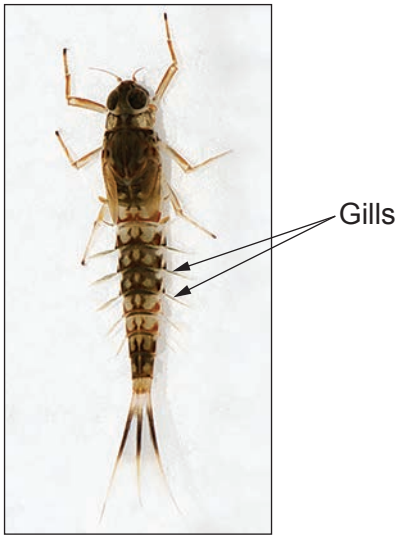
(b) Some aquatic insects, such as the mayfly nymph shown in **Image 2.2**, have external gills along the side of their bodies. The gills are moved forwards and backwards through the water.

Image 2.2



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

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

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

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3. (a) Humans use holozoic nutrition.

(i) Define the term holozoic. [1]

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(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]

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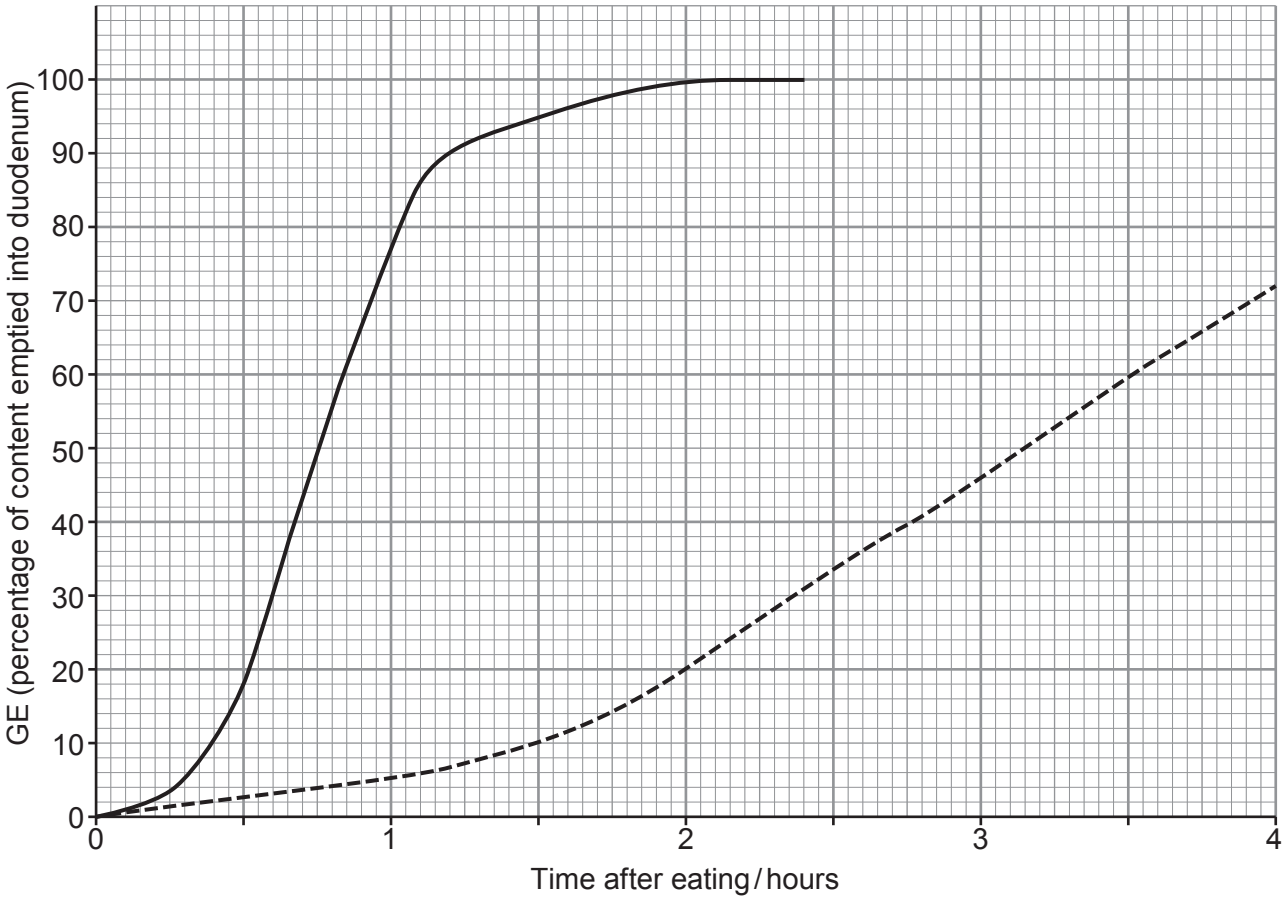
Gastric emptying (GE) is measured as the percentage of stomach contents emptied into the duodenum at different times after eating. The GE of a sugar-rich drink and a portion of solid protein was determined.

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

Image 3.1



Key: ——— sugar-rich drink
- - - - - - - solid protein

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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]

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(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]

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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]

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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]

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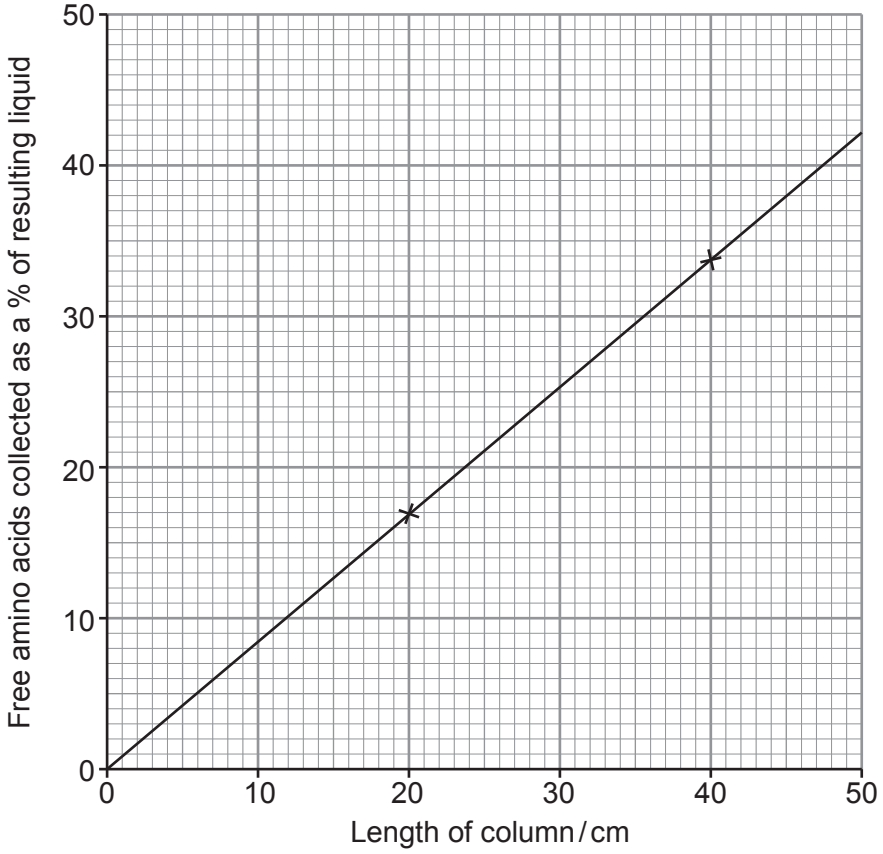
The initial column used was 20 cm in length. When the scientists used a 40 cm long column containing endopeptidase and exopeptidase the resulting liquid contained 34% free amino acids.
They plotted the results on **Graph 3.3**.

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]

Concentration of the free amino acids = ... %

(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]

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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
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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]

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

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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]

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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]

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(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]

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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

Number of stomata / mm^2 = ...

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

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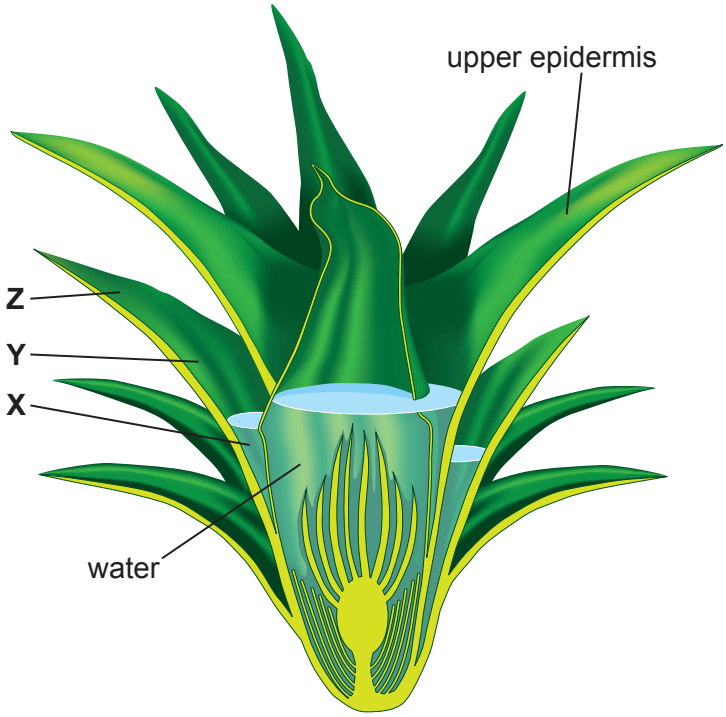
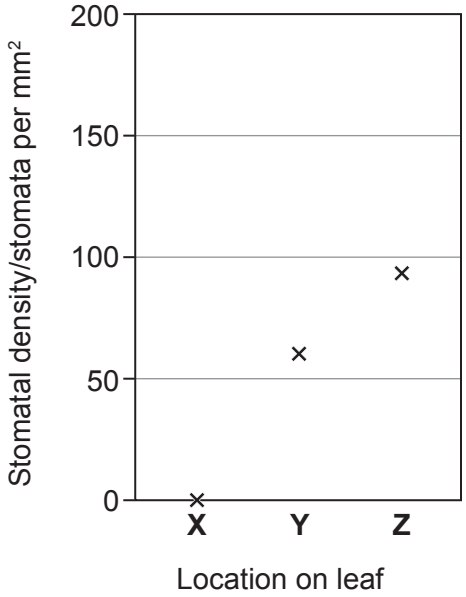
(b) Bromeliads are plants found in tropical areas of the Americas. Some species have tightly overlapping leaf bases that can hold water, as seen in **Image 5.2**. Bromeliad leaves have an uneven distribution of stomata on their upper epidermis. The number of stomata at locations **X**, **Y** and **Z**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

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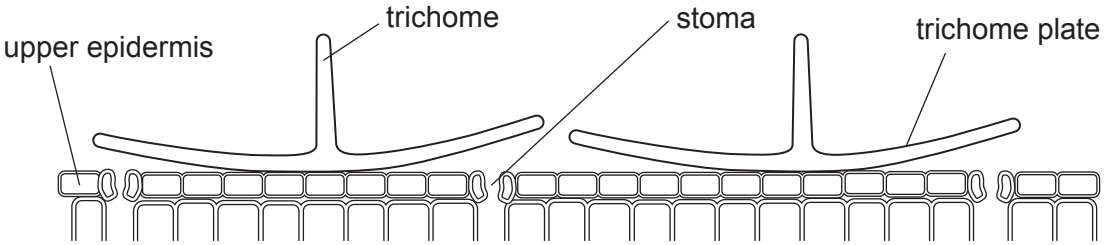
Tillandsia punctulata, a bromeliad species, lives high in the canopy layer of the rainforest where there is a higher temperature and a lower relative humidity. This species shows an adaptation to the environment as they have hair-like structures (trichomes) which stick up from plates which cover the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

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(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]

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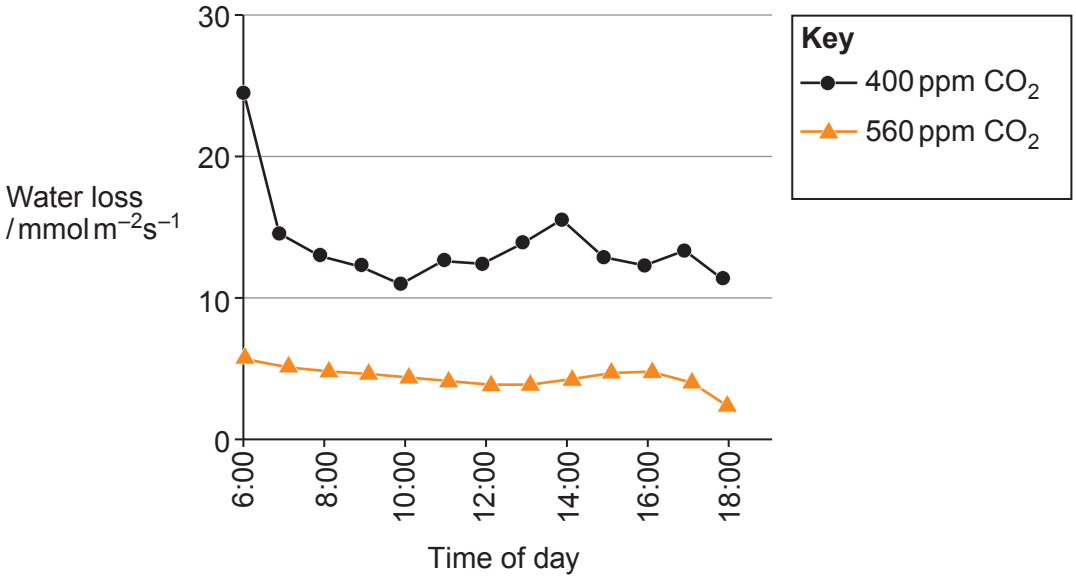
(c) It has been predicted that atmospheric carbon dioxide concentrations will increase to 560 ppm (parts per million) by the year 2050. This is 160 ppm higher than we have today.

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]

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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 = ... $cm^3\ yr^{-1}$

(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]

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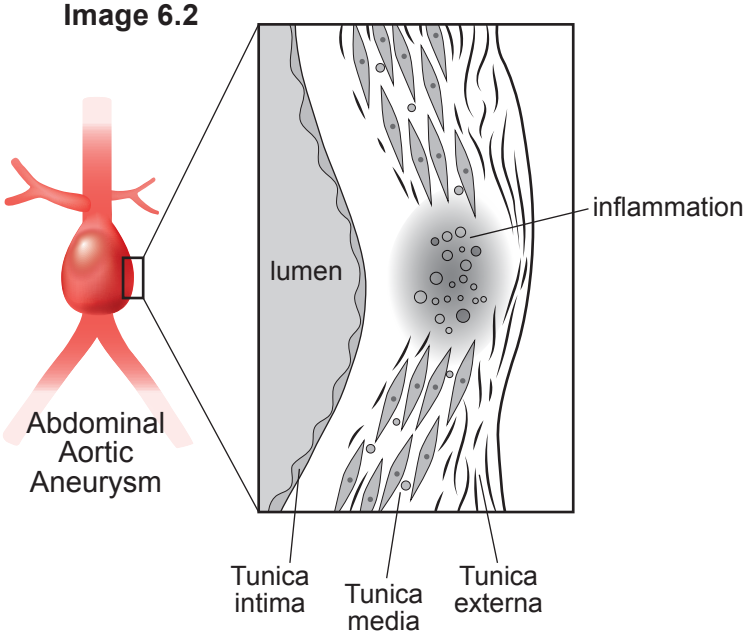
6. **Image 6.1** is a photomicrograph of human tissue. Two different types of blood vessel, labelled **X** and **Y**, are shown. Sometimes high blood pressure can lead to an aneurysm in a blood vessel. A diagrammatic cross-section of the wall of a vessel with an aneurysm is shown in **Image 6.2**.

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]

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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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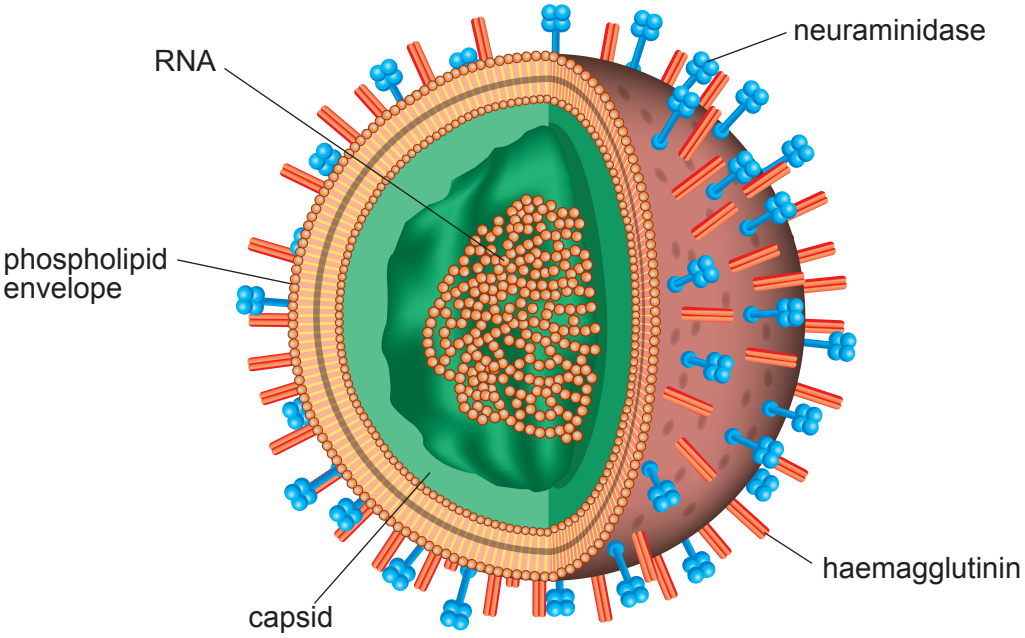
Option A: Immunology and Disease

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]

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(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]

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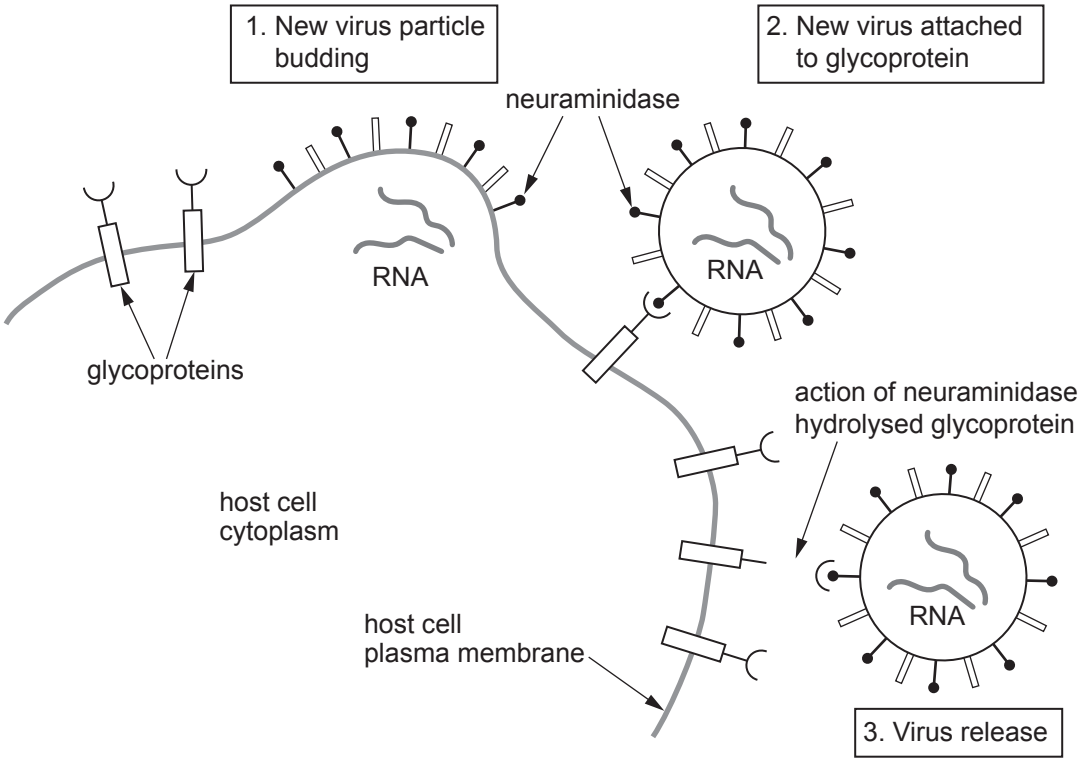
Newly formed virus particles are attached to the cell surface membrane of the host cell by a glycoprotein. Neuraminidase is an enzyme that hydrolyses the glycoprotein resulting in the release of the virus.

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]

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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]

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(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]

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

I. people with chronic illnesses;

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II. health professionals.

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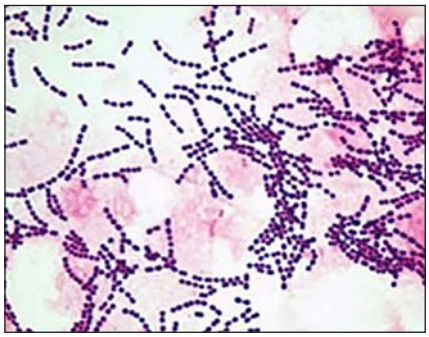
(c) A GP suspected that a patient suffering from a sore throat may have a bacterial infection.

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]

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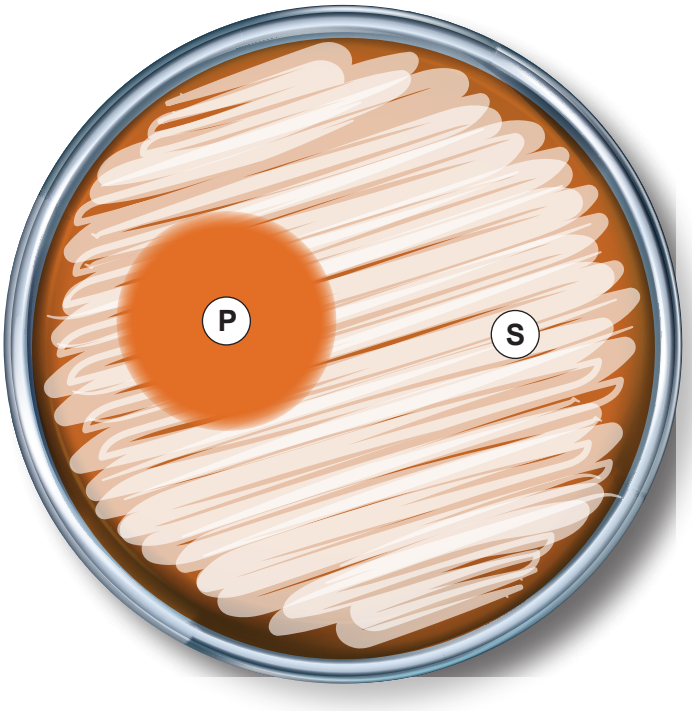
The antibiotics penicillin and streptomycin are usually effective against *Streptococcus pyogenes*.

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]

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

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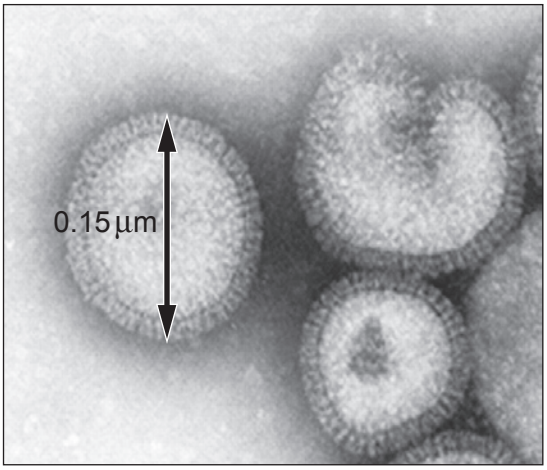
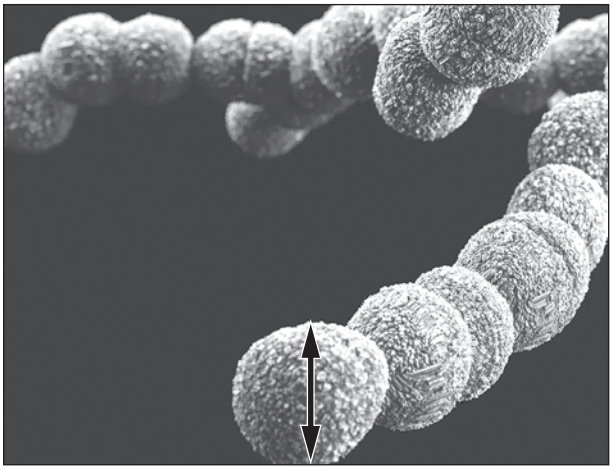
Images 7.5A and **7.5B** shows electron micrographs of flu viruses and *Streptococcus* bacteria. They have a similar shape although their size and structure are different.

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]

Answer = ... times larger

20

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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

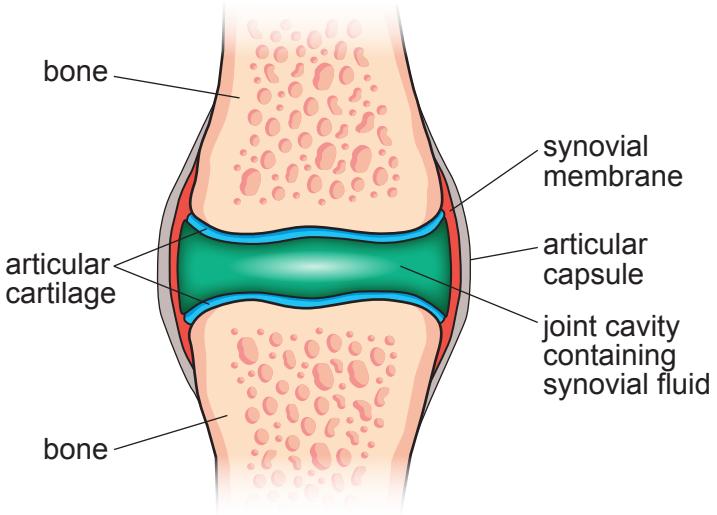
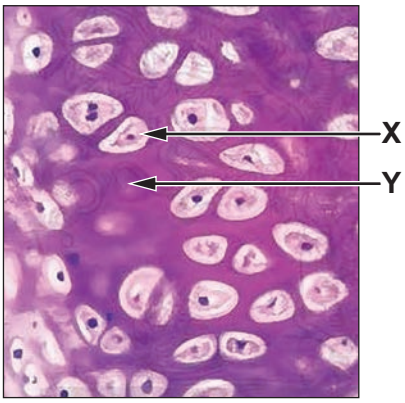


Image 8.2



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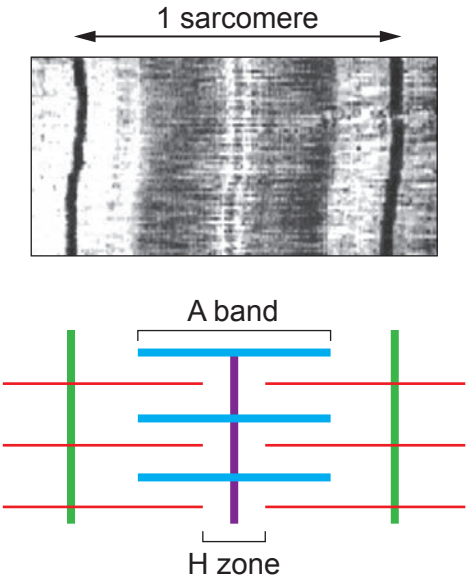
(b) Several groups of striated muscles cause movement at the knee joint.

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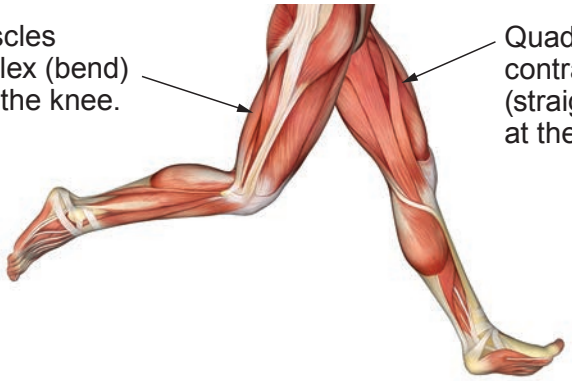
Image 8.4 shows the leg muscles while a person is running.

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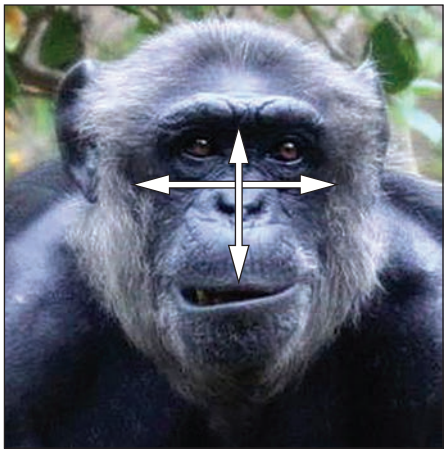
Dominant males in the group show more assertive behaviour than other males.

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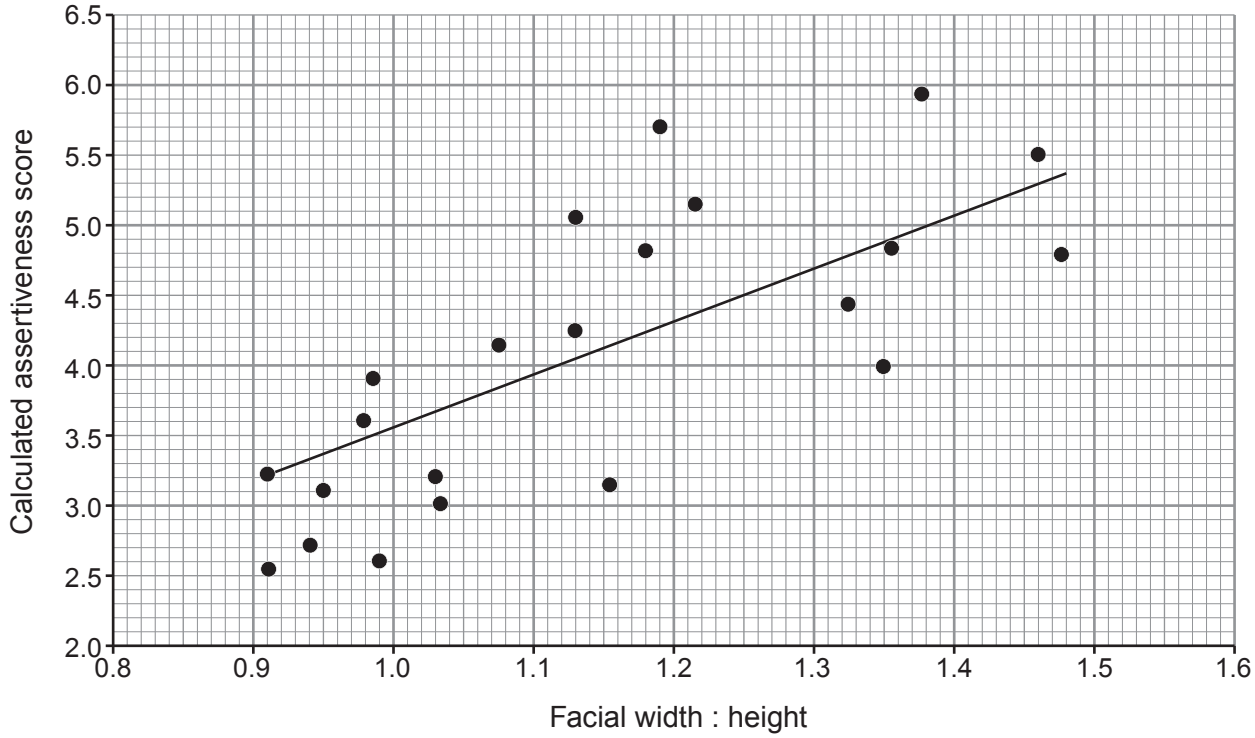
Scientists calculated an assertiveness score for each of 22 male chimpanzees in a captive group.

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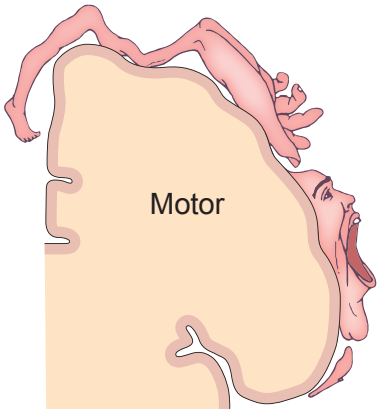
All primates can use an opposable thumb to grip or manipulate objects. Neurones in the cerebral cortex of the brain control thumb movements.

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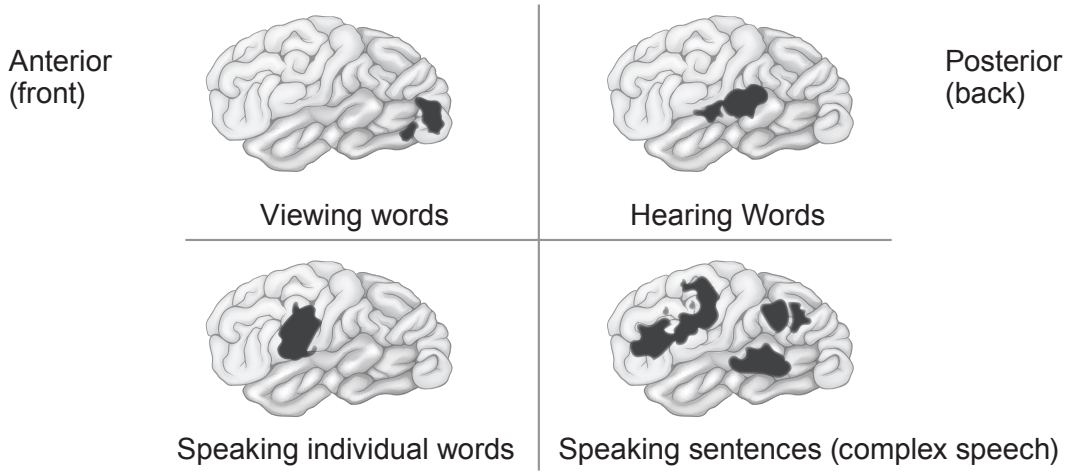
(d) Humans are the only primates to develop the ability to use speech.

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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END OF PAPER

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

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