Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A400U30-1

O21-A400U30-1

TUESDAY, 19 OCTOBER 2021 – AFTERNOON

BIOLOGY – A level component 3
Requirements for Life

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**11**	
	2.	**19**	
	3.	**17**	
	4.	**16**	
	5.	**8**	
	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. Do not use 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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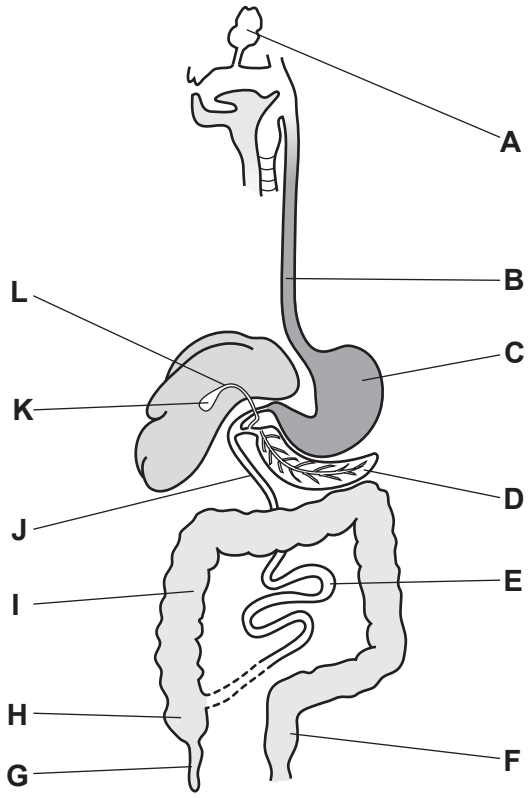
SECTION A

Answer **all** *questions.*

1. Carbohydrates are an important part of the human diet and are digested in different places as they pass through the human digestive system. **Image 1.1** shows a diagram of the human digestive system.

Image 1.1



(a) Name the enzyme that digests starch **and** identify the structure(s) that produce this enzyme using letter(s) from **image 1.1**. [2]

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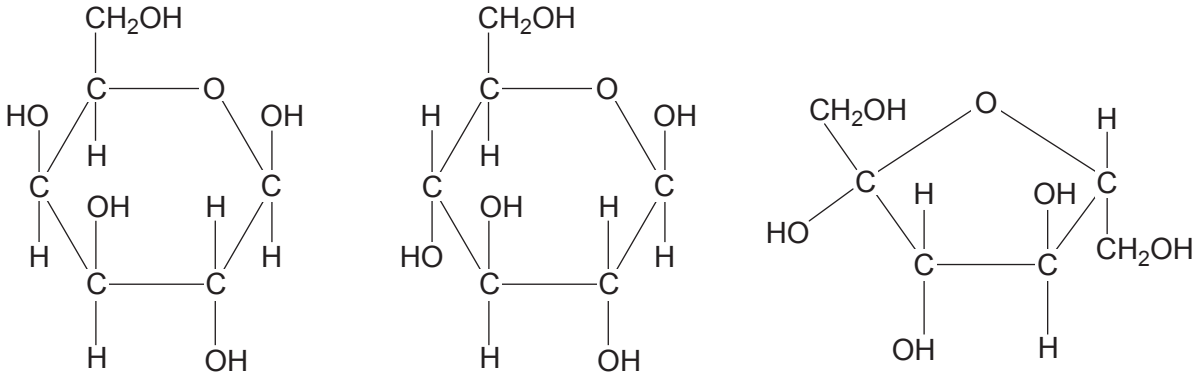
(b) Raffinose is a trisaccharide composed of galactose, glucose and fructose. It is found in some vegetables. Galactose, glucose and fructose are shown in **image 1.2**.

Image 1.2



When the three molecules are bonded together to form raffinose there are two condensation reactions. The molecular formula for each of glucose, fructose and galactose is $C_6H_{12}O_6$.

(i) Give the molecular formula of raffinose. [1]

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(ii) State why two different enzymes would be needed to synthesise raffinose. [1]

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(c) Starch is a storage polysaccharide made up of glucose.

(i) State **two** properties of starch that make it an effective storage molecule. [2]

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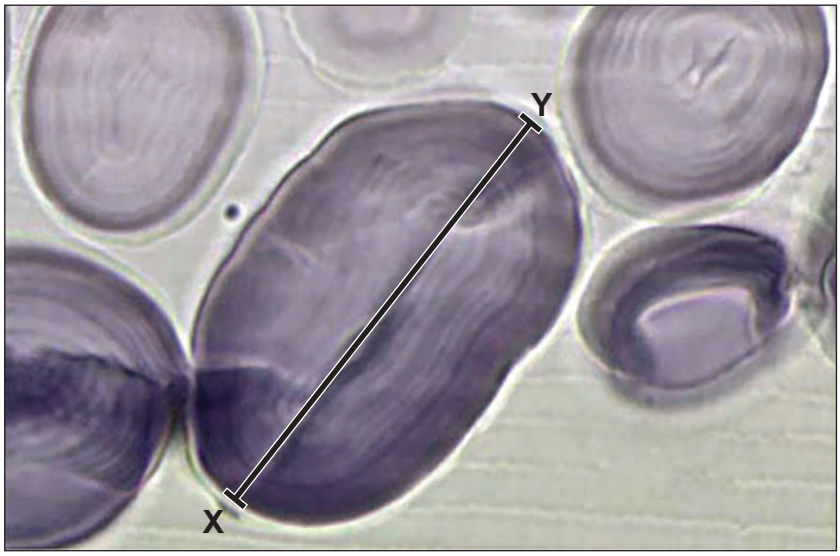
Image 1.3 shows starch grains in a plant cell.

Image 1.3



(ii) Starch grains are normally transparent, but can be treated to become visible under the microscope. Suggest why these starch grains appear to be blue. [1]

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(iii) The actual length of the starch grain from **X** to **Y** is 27 µm. Use this information and the line on **image 1.3** to calculate the magnification of the image. Show your working. [2]

Magnification = × .....

Cellulose is another polysaccharide found in the cell walls of plants.

(d) Give **two** differences between a starch molecule and a cellulose molecule. [2]

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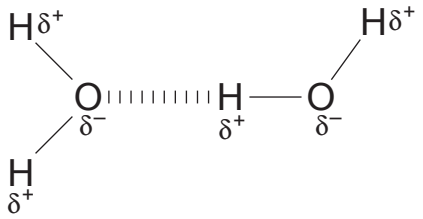
2. **Image 2.1** shows two adjacent water molecules.

Image 2.1



(a) Explain how **one** feature shown in **image 2.1** enables water molecules to travel up the xylem. [3]

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(b) Cadmium is a heavy metal that can contaminate soil.

Cuttings of equal length were taken from a single plant. They were grown in cadmium free soil to allow roots to form.

The plants were then treated frequently with different concentrations of cadmium chloride ranging from 0 μmol dm^{-3} to 30 μmol dm^{-3}.

At the end of the treatment, the transpiration rate for each plant was determined. This investigation was carried out six times and the mean rates of transpiration were calculated.

(i) Explain why all the cuttings in this investigation were taken from a single plant. [2]

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(ii) Name the apparatus used to determine the transpiration rate. [1]

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(iii) State **two** conditions that should have been kept constant when measuring the transpiration rates of the plants. [2]

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(iv) Explain how the plant treated with 0 μmol dm^{-3} of cadmium chloride acted as a control. [1]

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The results are summarised in **table 2.2**.

Table 2.2

Concentration of cadmium chloride / μmol dm^{-3}	Mean transpiration rate / mg dm^{-2} min^{-1}	Rate of transpiration as a % of the control
0	4.77	100
10	2.88	60
20	2.61	55
30	2.30	.....

(v) Calculate the rate of transpiration at 30 μmol dm^{-3} of cadmium chloride as a percentage of the control. **Write your answer in the table.** [2]
Space for working

(vi) I. Cadmium has been found to interfere with potassium ion movement in plant cells. Using your knowledge of stomatal opening, suggest an explanation for the results of this experiment. [3]

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II. Suggest why the rate of photosynthesis decreases when the concentration of cadmium chloride is high. [2]

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(c) Cadmium is also thought to affect enzymes involved in the light-independent stage of photosynthesis. Palisade mesophyll cells taken from a plant grown in high concentrations of cadmium were found to contain more triose phosphate than normal. Using your knowledge of the Calvin cycle, explain this observation. [3]

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3. During inspiration, the ribcage moves upwards and outwards. This pulls on the outer pleural membrane and the pressure in the pleural cavity decreases.

(a) Explain how this causes an increase in the lung volume. [2]

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The D_{LCO} gas transfer test is used in hospitals to measure the ability of the lungs to exchange gases with the blood.

- A single breath of air containing 0.3 % carbon monoxide is inhaled.
- The partial pressure difference between the inspired and expired carbon monoxide is then measured.
- Normally 80 % or less of the carbon monoxide breathed in is exhaled.

(b) Suggest why carbon monoxide gas is used even though it can be toxic. [1]

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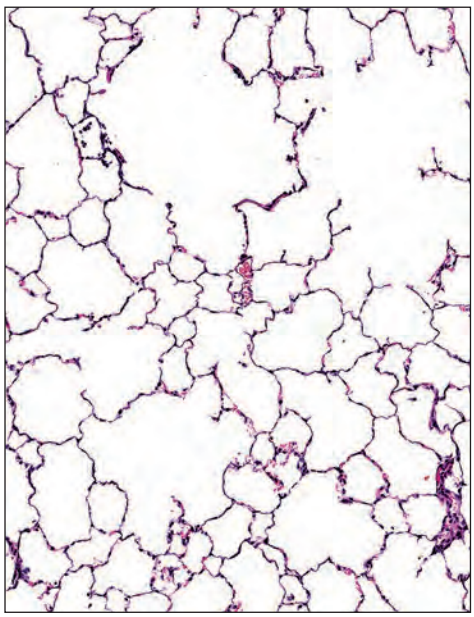
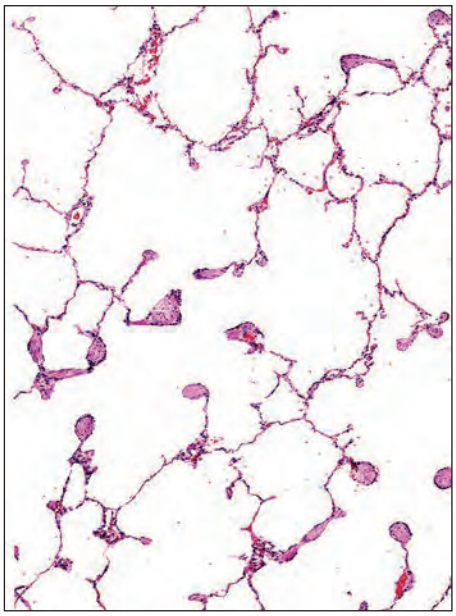
(c) **Image 3.1** shows alveoli in a normal lung and in someone who suffers emphysema.

Image 3.1



Normal alveoli



Alveoli in an emphysema sufferer

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(i) Using **image 3.1**, explain why the D_{LCO} is higher than 80 % in people who suffer from emphysema. [2]

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(ii) Suggest the effect of an increased blood flow through the lung capillaries on the value of D_{LCO}. Explain your answer. [2]

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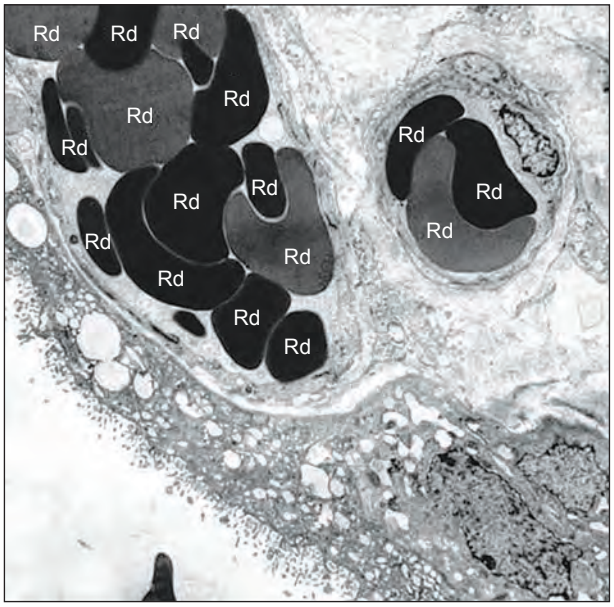
(d) Another example of a gas exchange surface in humans is the placenta.

Image 3.2 is a cross section through part of a chorionic villus of the placenta.

Image 3.2



Key:

Rd = red blood cells

(i) Red blood cells are all the same size and shape. Explain why the red blood cells in this cross section appear to be different sizes and shapes. [1]

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(ii) Explain **one** advantage of capillaries being narrow. [2]

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(iii) Apart from the exchange of gases and nutrients, state **three** other roles of the placenta. [3]

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(e) The average blood volume for an adult human is 70 $cm^3 kg^{-1}$ of body mass. 42 % of the blood volume is red blood cells.

The average mass of an adult in Europe is 70.8 kg.

(i) I. Calculate the total blood volume in cm^3 of an adult human who has a mass of 70.8 kg. [1]

Blood volume = ... cm^3

II. Calculate the total red blood cell volume in **dm^3** of this person. [2]

Total red blood cell volume = ... dm^3

(ii) The mass of red blood cells in a pregnant woman shows an increase of 25 %. Explain the advantage of this increase. [1]

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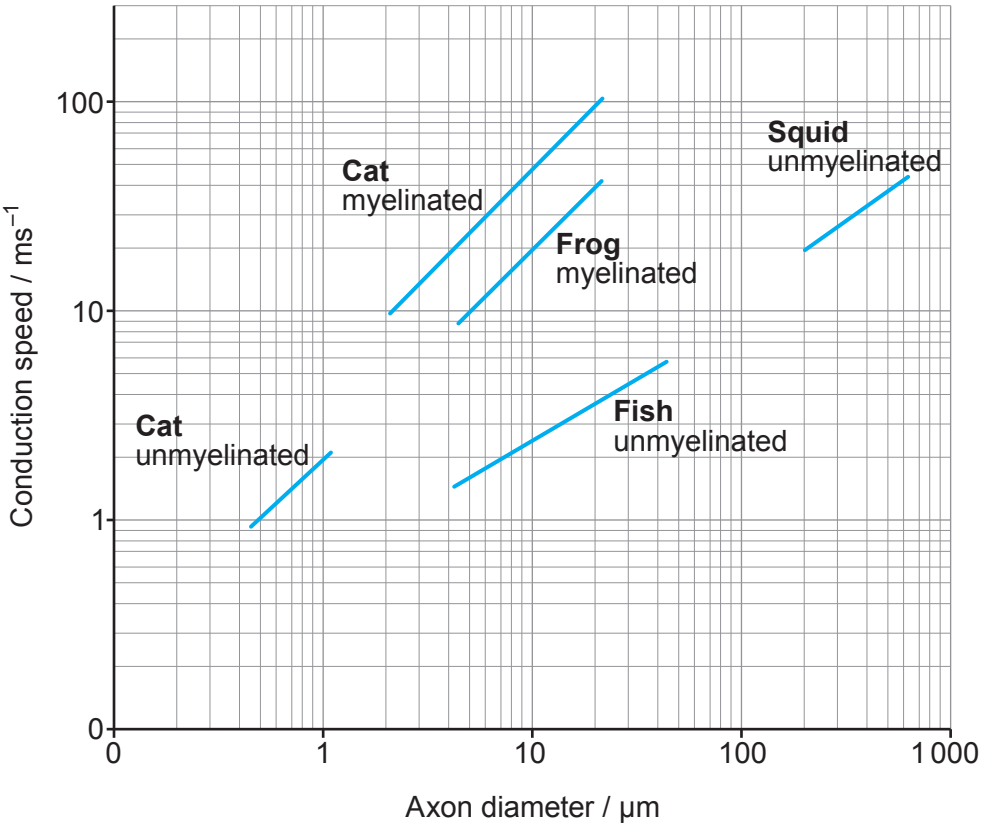
4. **Image 4.1** shows the speed of conduction of nerve impulses in myelinated and unmyelinated axons of different diameters in a range of organisms.

Image 4.1



(a) (i) Suggest why log scales are used on the axes of the graph. [1]

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(ii) For each organism, as the axon diameter increases, the speed of conduction increases. Suggest an explanation for this increase in speed of conduction. [2]

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(b) **Table 4.2** shows the body temperatures of the organisms from **image 4.1**.

Table 4.2

Organism	Body temperature / °C
Cat	38
Fish	4
Frog	12
Squid	4

With reference to the information provided and your own knowledge, suggest reasons for the following:

(i) A 10 µm diameter myelinated frog axon has a lower speed of conduction than a 10 µm diameter myelinated cat axon. [2]

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(ii) A 10 µm diameter myelinated frog axon uses less ATP to transmit impulses than a 10 µm diameter unmyelinated fish axon. [2]

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(c) Some studies have suggested that lead ions (Pb^{2+}) may block calcium ion channels on the pre-synaptic membrane of a synapse. This may cause loss of sensitivity in some areas of the body.

Describe and explain how blocked calcium ion channels could cause these symptoms. [3]

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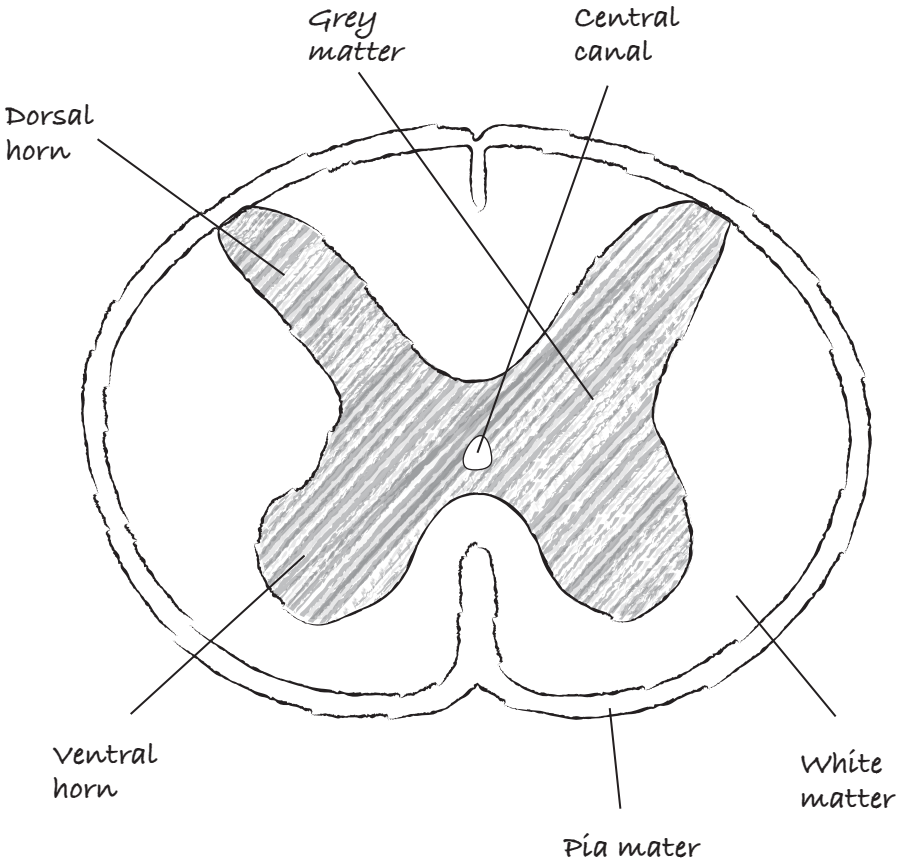
(d) A student viewed a cross section of a spinal cord down a microscope. He drew a low power plan using a sharp pencil and used a text book to label the structures he observed.

His low power plan is shown in **image 4.3**.

Image 4.3



(i) If this student were to draw a low power plan of a leaf or artery in the future, suggest **three** guidelines for the student to follow to ensure they present their diagrams correctly. [3]

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When a mammal responds to a stimulus as part of a reflex arc, an impulse exits the spinal cord via a motor neurone.

(ii) **Using labels from image 4.3**, state where:

I. the axon of a sensory neurone enters the spinal cord; [1]

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II. you would find the position of a cell body of a motor neurone. [1]

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(iii) Simple organisms, such as *Cnidaria*, have nerve cells with short extensions joined to each other and branching in a number of different directions.

State the name given to this type of nervous system. [1]

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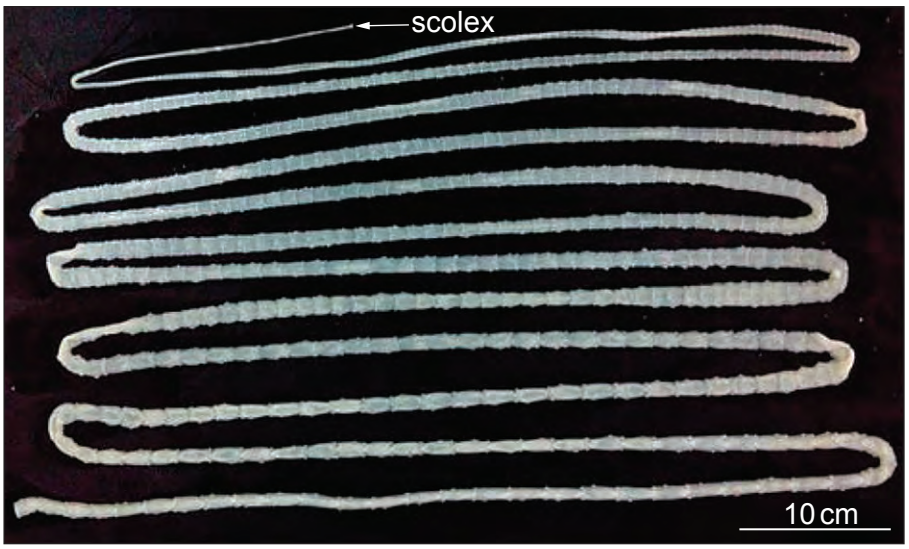
5. The pork tapeworm, *Taenia solium*, is a parasite that lives in the intestines of humans. **Image 5.1** shows one tapeworm removed from a human.

Image 5.1



(a) Use the scale bar to **estimate** the length (cm) of the tapeworm shown in the photograph. **Give your answer in cm.** [1]

Length = ... cm

(b) (i) The adult tapeworm does not secrete digestive enzymes. Explain why and suggest **one** advantage of this to the tapeworm. [2]

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(ii) Tapeworms have been found to secrete hydrogen ions (H^+) into their surroundings which reduces the pH.

Suggest why this may decrease the rate of uptake of digested food molecules into the blood of the host organism. [3]

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(iii) The hydrogen ions also enter the bloodstream of the host. This causes more oxygen to be released by the haemoglobin in the red blood cells of the host. Explain why. [2]

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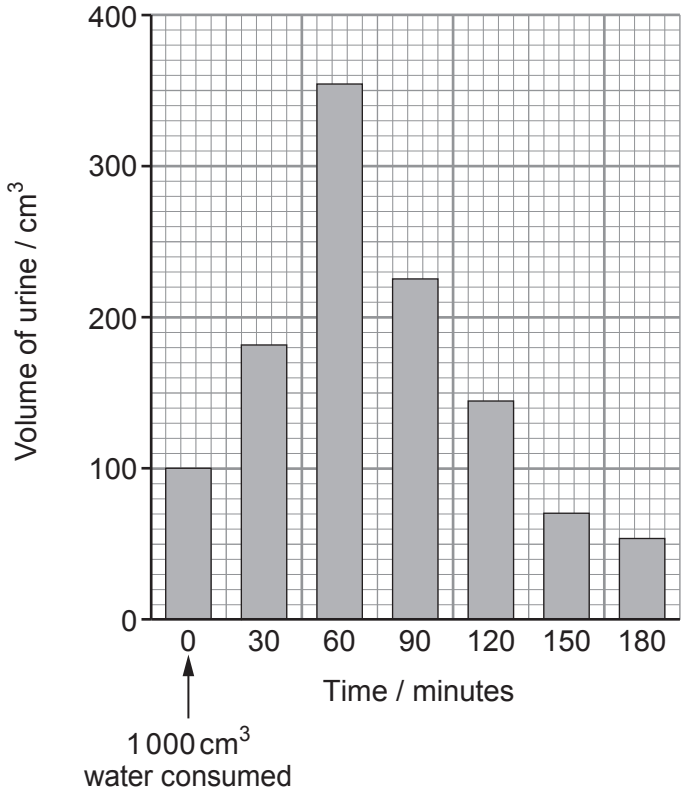
6. A student drank 1 000 cm^3 of distilled water. The student's urine was collected immediately after drinking the water and then at 30-minute intervals for three hours.
The volume of urine collected at each point is shown on **image 6**.

Image 6



Describe the role of antidiuretic hormone (ADH) in osmoregulation.

Using your knowledge of homeostasis, explain the change in volume of urine collected between **0 and 60 minutes** in **image 6**.

If the student had exercised for ten minutes before drinking 1 000 cm^3 of distilled water, describe how **and** explain why the results would differ. [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)* Cholera is a disease caused by the bacterium *Vibrio cholerae* and is transmitted through contaminated water.

The last major cholera pandemic began in Indonesia in 1961 and eventually spread to parts of Europe by 1975.

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

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Some people can be carriers of *V. cholerae* and harbour a reservoir of the bacteria in their gut without showing symptoms. A vaccine against cholera exists but there is no mass vaccination programme in the UK.

(ii) Suggest why cholera is now rare in the UK despite there being no vaccination programme. [1]

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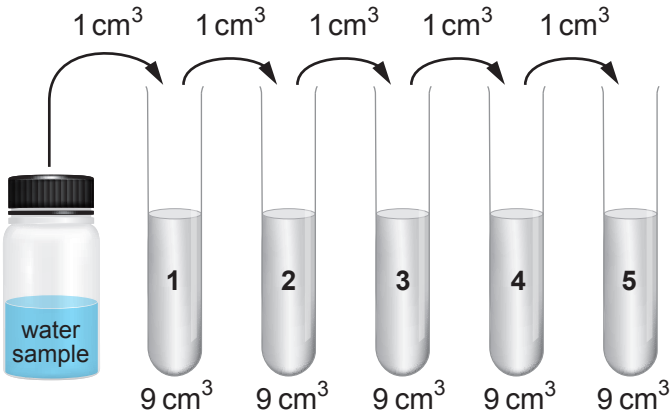
(b) In 2010, after a catastrophic earthquake, there was an outbreak of cholera in Haiti. It was the worst outbreak in recent history with over 665 000 cases and 8 183 fatalities.

A group of scientists investigated the level of contamination in one source of water in Haiti. They took samples from the water supply at monthly intervals following the earthquake.

From each sample, 1 cm^3 was used to produce a serial dilution with 9 cm^3 distilled water as shown in **image 7.1**.

Image 7.1



From each of the five dilutions, 1 cm^3 was transferred to separate petri dishes containing sterile agar gel. The 5 petri dishes were incubated for 24 hours at 37 °C.

After incubation, the numbers of visible colonies were counted and the bacterial concentration in the original sample calculated.

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(i) One bacterium will produce one visible colony after 24 hours' incubation. Explain why the original sample needed to be diluted before transferring 1 cm^3 to an agar plate. [1]

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The number of bacteria in a sample from the water supply one month after the earthquake was calculated to be $3.5 \times 10^4 cm^{-3}$.

The same procedure was carried out two months after the earthquake and after incubation, 1 cm^3 from tube 4 produced 21 colonies.

(ii) Calculate the increase in the number of bacteria in the water samples between one and two months after the earthquake. [2]
Space for working

Increase = ...

(c) Despite ingesting some *V.cholerae* from the water supply, many people remained free of the disease.

(i) State **one** of the body's innate natural barriers that may provide some protection against these bacteria **after** they have been ingested. [1]

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V. cholerae produces a protein referred to as CT (Cholera Toxin). **Image 7.3** shows the protein structure of CT. It has three sub units or polypeptides forming a protein complex or quaternary structure.

Antibiotics such as tetracycline may be used to treat cholera.

Tetracycline interferes with the synthesis of the CT protein as illustrated in **image 7.4**.

Image 7.3

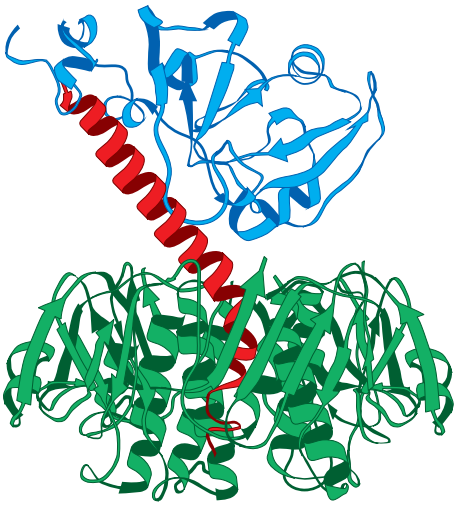
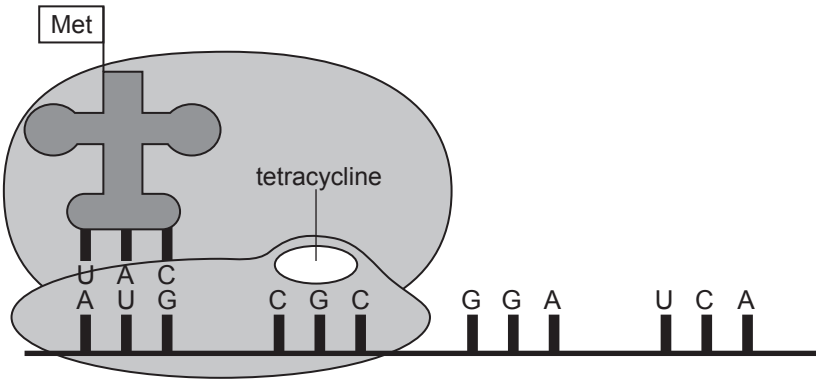


Image 7.4



(ii) Use **image 7.4** and your own knowledge to explain how tetracycline would prevent the synthesis of cholera toxin (CT). [3]

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(iii) The bacterium is not killed by this mechanism. State the name that describes the mode of action represented by this type of antibiotic. [1]

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The main symptom of cholera is severe dehydration, which can be fatal.

The CT (Cholera Toxin) protein fits into cell surface receptors on the plasma membrane of intestinal epithelium cells, causing chloride ion channels to become activated.

As a result, there is a rapid movement of chloride ions from the epithelial cell to the gut lumen as illustrated in **image 7.5**. This causes water to move into the intestinal lumen by osmosis.

Scientists have researched the use of stable, microscopic structures known as nanoparticles to treat cholera.

GM1 – NP is a nanoparticle. Part of its structure is complementary to part of the CT protein and binds to the toxin.

Image 7.6 shows the effect of GM1 – NP nanoparticles on chloride ion movement in the gut epithelium.

Image 7.5

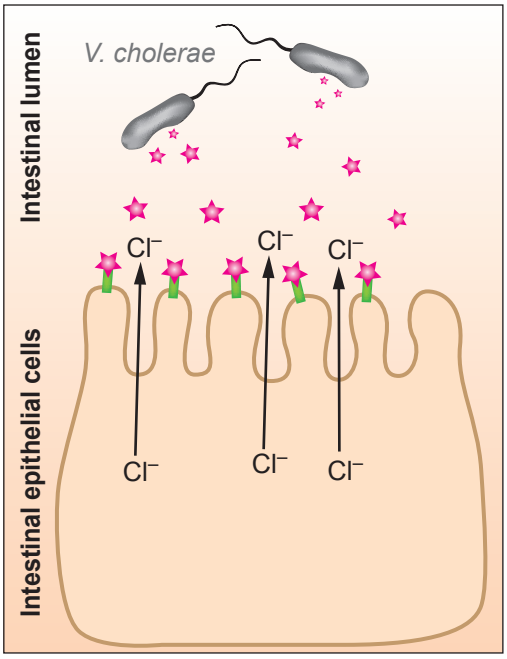
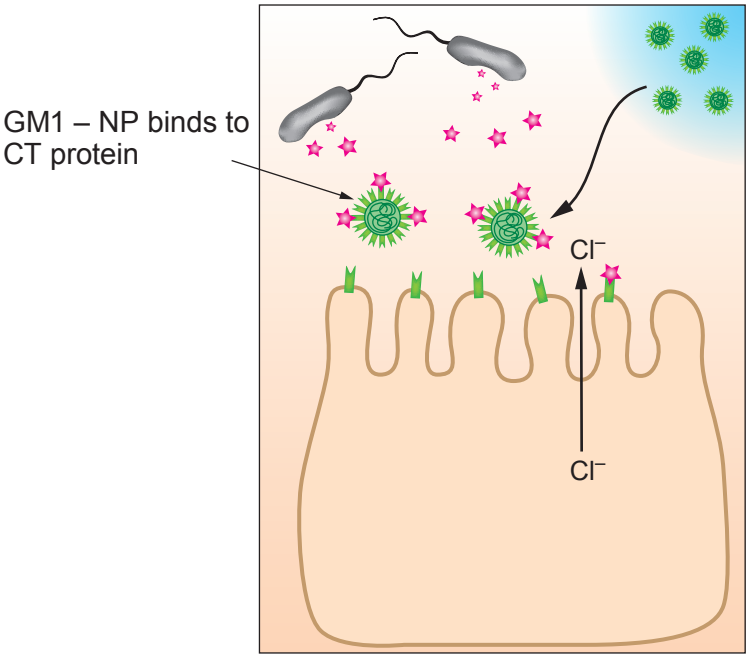


Image 7.6



Key:

- CT (Cholera Toxin)
- GM1 – NP
- Plasma membrane receptor protein

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(iv) Use the information in **images 7.5** and **7.6** to interpret how these nanoparticles could prevent dehydration due to cholera. [3]

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(v) Explain how the use of nanoparticles might have an advantage over the use of antibiotics in the treatment of cholera. [1]

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(d) A vaccine is available for some people travelling to parts of the world affected by cholera. The vaccine contains killed whole cells of *V. cholerae* **and** a sub-unit (one of the polypeptides) of the CT protein.

(i) Explain how the use of these **two** components in the cholera vaccine ensure that it is both effective and safe. [3]

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(ii) UK government policy cannot impose compulsory vaccination as it is the right of the individual to choose. Health care workers travelling to areas affected by cholera are offered cholera vaccination prior to travel. Suggest **one** reason for making a case for compulsory vaccination of health workers. [1]

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There have been a number of clinical trials for cholera vaccines using hundreds of volunteers in several countries.

One trial in Minnesota, America gave 85 volunteers a single dose of either an inactive strain of *V. cholerae* or a placebo in a double blind randomised trial. This meant that neither volunteers nor scientists knew who had received the vaccine or a placebo.

Three months later, volunteers were exposed to a small dose of a virulent (active) form of the bacterium and their blood antibody concentrations were measured.

(iii) Explain how **one** feature of the method described above increased the reliability of the data and explain **one** feature of the method that reduced the reliability of the data. [2]

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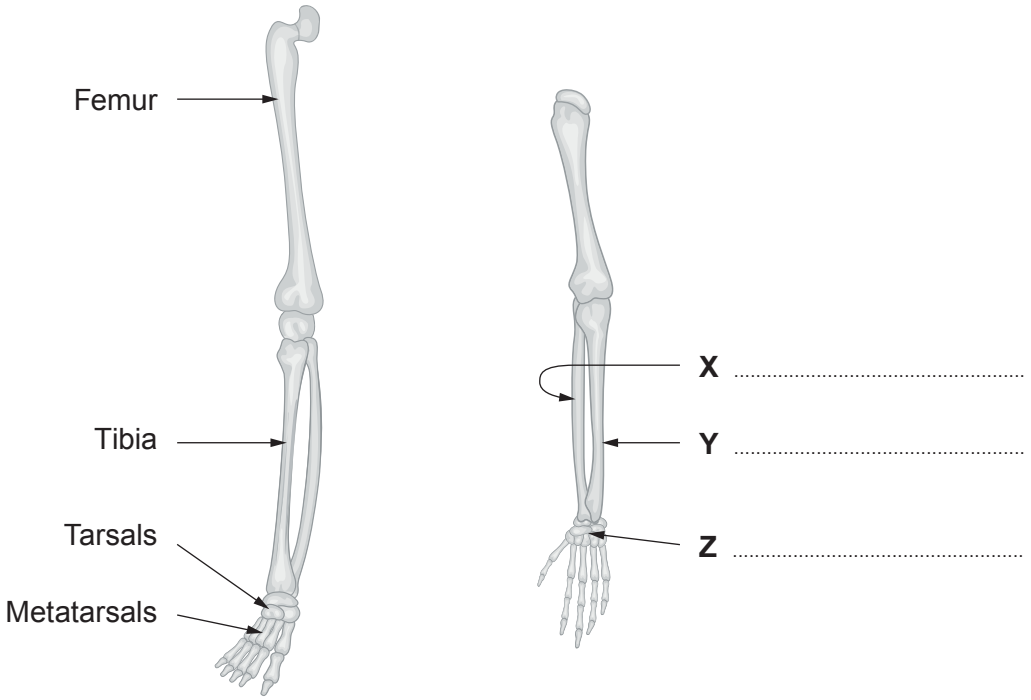
Option B: Human Musculoskeletal Anatomy

8. The human appendicular skeleton includes two pairs of limbs.

Image 8.1 shows the arrangement of human arm and leg bones (not to the same scale). Some of the bones of the leg are labelled.

Image 8.1



(a) On the image of the arm, **identify the bones labelled X, Y and Z** in the spaces provided. [2]

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(b) In the human skeleton, the arms are used predominantly for manipulation and gripping and the legs for locomotion and support.

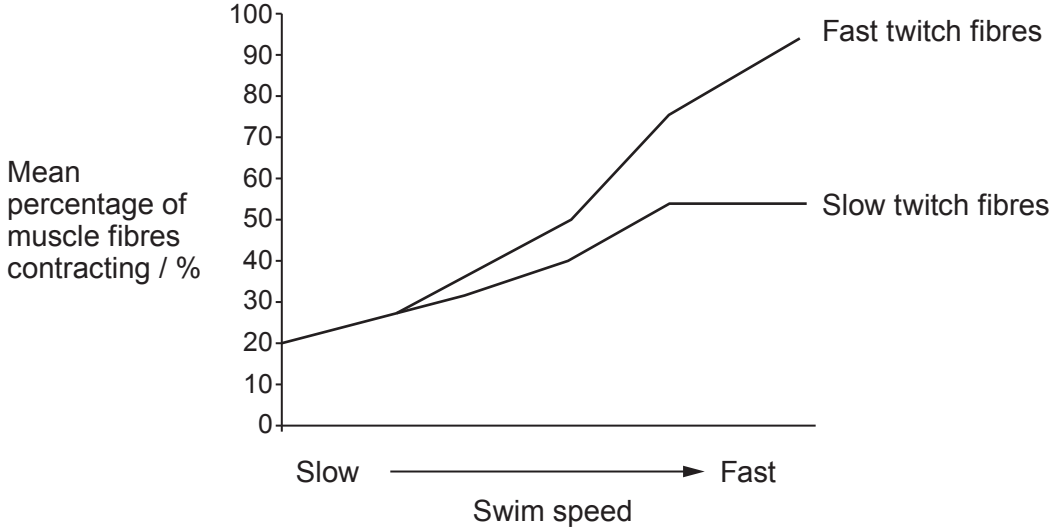
In swimming, however, both the arms and the legs are used for locomotion.

Swimmers carry out training to develop strength and stamina in the muscles of their arms and legs. Increased muscular effort results in increasing speed.

Muscles can have different proportions of contractile fibres known as fast twitch or slow twitch fibres.

Image 8.2 shows the mean percentage of fast and slow twitch muscle fibres that are contracting as speed increases in swimmers during training.

Image 8.2



(i) Explain how changes in the proportion of fast and slow twitch fibres contracting in the muscles enable swimmers to achieve greater speed. [2]

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Some swimmers have a higher proportion of slow twitch fibres in their muscles. These individuals are often better adapted for longer distance races such as 1 500 metres.

(ii) Slow twitch fibres are dark red due to the presence of myoglobin and have larger numbers of mitochondria than fast twitch fibres. Explain how these **two** features provide an advantage for long distance swimming. [2]

Myoglobin .....

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Mitochondria .....

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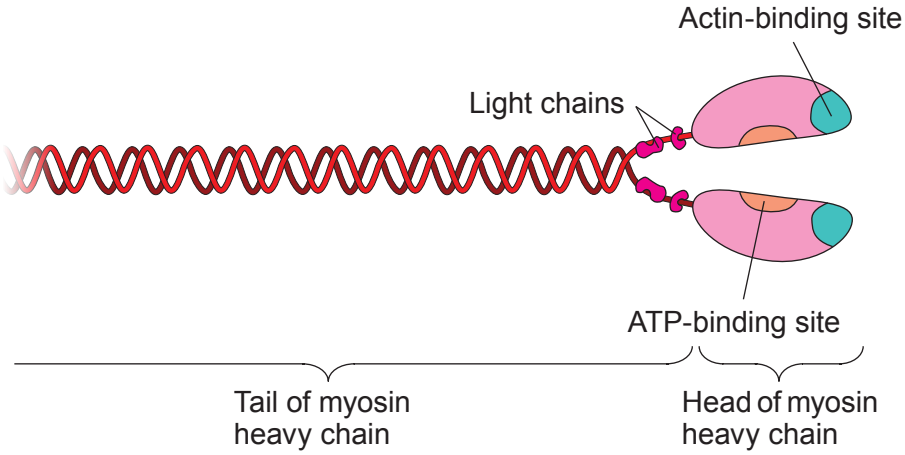
Myosin is a protein found in both fast twitch and slow twitch fibres. It is a quaternary protein with heavy and light sub unit polypeptide chains.

Image 8.3 represents a myosin molecule.
The head region catalyses the hydrolysis of ATP by the enzyme ATPase.

Image 8.3



(iii) Describe the function of ATP in the molecular mechanism of muscle contraction and explain why a change in the shape of the head region of the myosin molecule could slow the process of contraction. [3]

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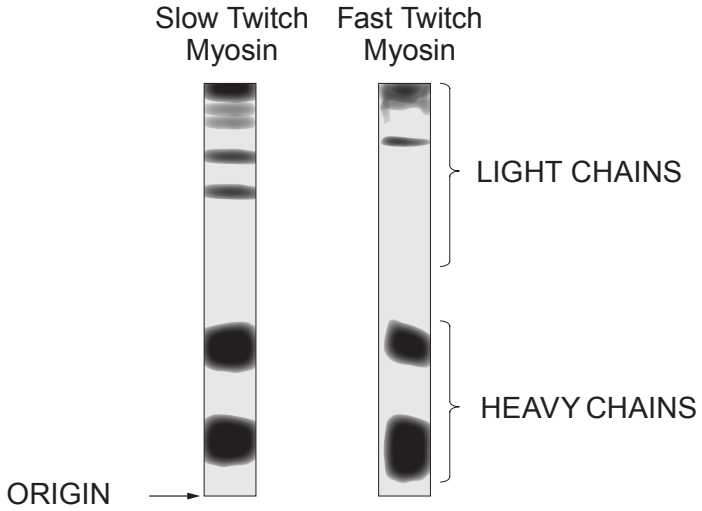
An investigation was carried out to discover whether there were differences in the molecular mass of the polypeptide sub units of myosin from fast and slow twitch muscle fibres.

- Samples of myosin were isolated from two types of muscle from the hind leg of several 6-week-old rats.
- Myosin from fast twitch fibres and slow twitch fibres was purified.
- The individual polypeptide sub units were identified using electrophoresis to separate them through a gel medium.
- A protein specific dye was added to the gel so that the position and quantity of each subunit polypeptide chain could be seen.
- The procedure was carried out at 0 °C in a buffer solution.

The results are shown in **image 8.4**.

Image 8.4



(iv) State why the procedure was carried out at **0 °C** using a **buffer solution**. [2]

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The scientists concluded that there was very little difference in the molecular mass of the two heavy chains from the fast and slow twitch myosin sample but that there was a significant difference between the molecular mass of some of the light chains from each sample.

(v) Use **image 8.4** together with your knowledge of electrophoresis to assess why they came to this conclusion. [1]

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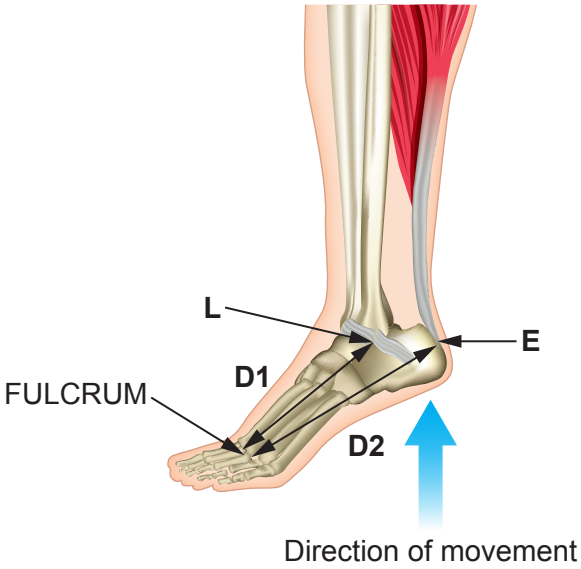
(c) A swimmer trained in the gym using weights to increase muscle strength. She held a 4 kg weight while lifting her 56 kg body mass onto her toes using her left leg only.

Image 8.5



(i) The fulcrum is at the articulation of the big toe and metatarsals as shown in **image 8.5**.

D1 measures 0.12 m and is the distance between the fulcrum and the load (weight acting downward) at **L**.

D2 measures 0.18 m and is the distance between the fulcrum and the effort (produced by the calf muscle) at **E**.

Calculate the minimum force (F_2), in Newtons, generated by the calf muscle in order to lift the athlete onto her toes while holding 4 kg. [2]

$F_1 \times D_1 = F_2 \times D_2$ 1 kg ≡ 9.8 N (Newtons)

Force = ... N

(ii) Name the type of lever illustrated by the movement described above. [1]

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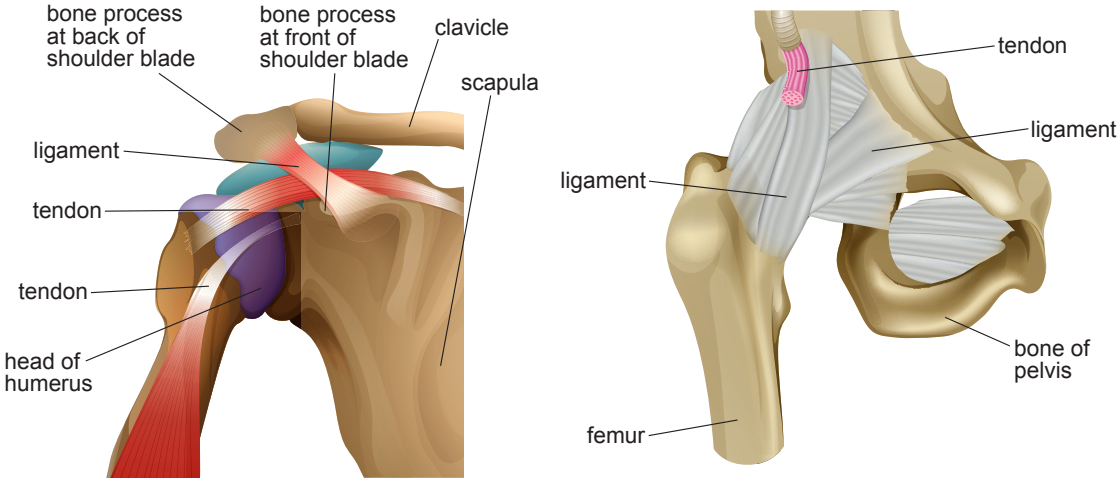
(d) The articulation of the limbs with the pectoral and pelvic girdles each form a ball and socket joint. The diagrams in **image 8.6** show a shoulder and a hip joint.

Image 8.6



Skiing is a sport that uses the arms to assist locomotion. Some injuries to the pectoral girdle are more likely to occur in skiers than swimmers.

After a fall, a skier suffered a dislocation at the shoulder and a fracture of the clavicle (collar bone).

(i) Use the information in **image 8.6** and your knowledge of the structure of ball and socket joints in the pectoral and pelvic girdles to explain why shoulder dislocation is more common than a hip dislocation. [2]

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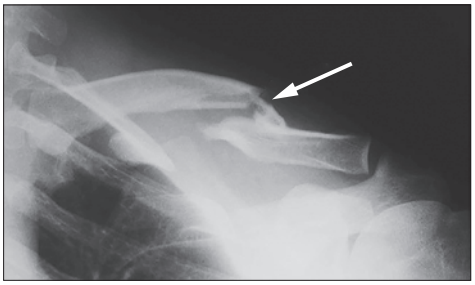
Image 8.7 shows an X-ray photograph of the skier's fractured clavicle. The bone has not broken through the skin.

Image 8.7



(ii) Identify the type of fracture shown in **image 8.7**. [1]

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(iii) After administering pain killing and anti-inflammatory drugs, suggest how this fractured clavicle might be treated in order to allow the bone to heal. [2]

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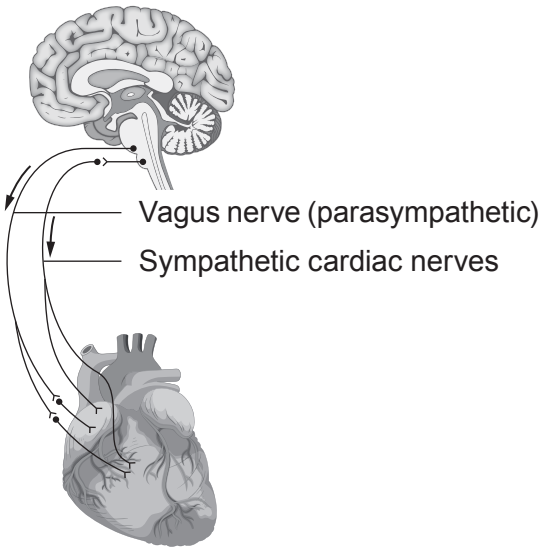
Option C: Neurobiology and Behaviour

9. The autonomic nervous system controls the function of many organs and tissues without conscious intervention.

Image 9.1 shows peripheral nerves of the autonomic nervous system supplying the heart.

Image 9.1



(a) (i) Name the main region of the brain responsible for controlling the autonomic nervous system. [1]

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The sympathetic nerves release the neurotransmitter noradrenaline from nerve endings when an individual is under stress.

Noradrenaline binds to adrenergic receptors on the plasma membranes of several tissues. This causes the effects experienced during the fight or flight response.

(ii) I. Name the area of heart tissue that has adrenergic receptors and initiates the heartbeat. [1]

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II. Explain why this tissue has a nerve supply from both the parasympathetic and the sympathetic branch of the autonomic nervous system. [1]

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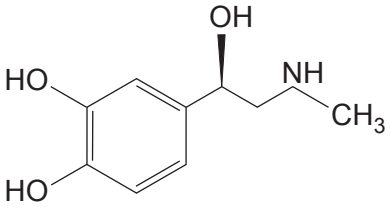
Adrenaline is a hormone released from the adrenal gland into the bloodstream under similar conditions of stress.

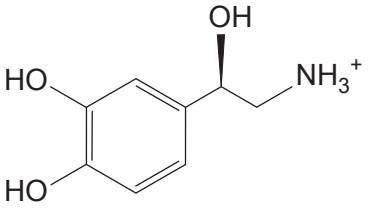
Image 9.2 shows the structure of noradrenaline and adrenaline molecules.

Image 9.2

Adrenaline
$C_9H_{13}NO_3$



Noradrenaline
$C_8H_{12}NO_3$



(iii) Explain why noradrenaline and adrenaline exert similar effects on body tissues. [1]

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(b) Research has shown that severe trauma and abuse during childhood can cause epigenetic modification of DNA.

(i) Describe what is meant by an epigenetic change in the DNA. [1]

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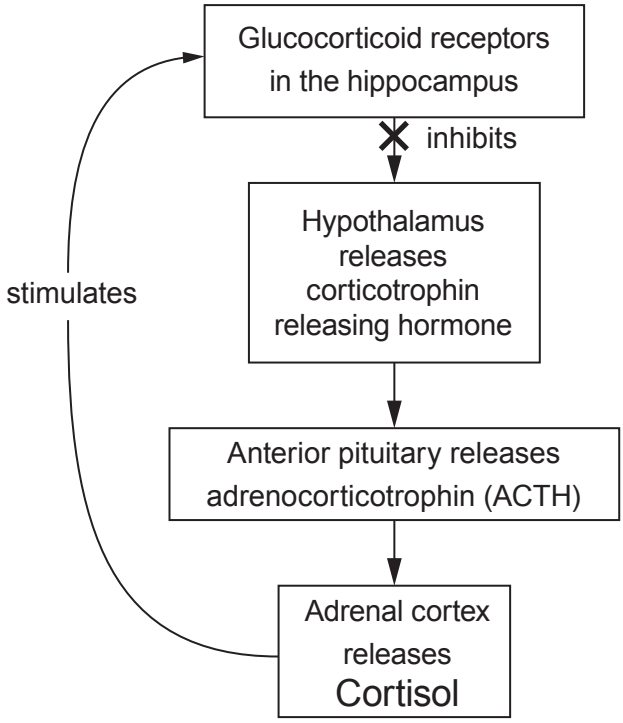
One example of epigenetic modification is the methylation of DNA that prevents transcription of a gene called NR3C1. This gene codes for glucocorticoid receptor proteins in the hippocampus of the brain.

Image 9.3 shows how glucocorticoid receptors are involved in controlling the release of the hormone cortisol.

Image 9.3



Cortisol is a glucocorticoid hormone released by the adrenal cortex as a result of prolonged exposure to stress.

Blood samples from adults who suffered childhood Post Traumatic Stress Disorder (PTSD) show higher concentrations of cortisol than normal.

(ii) Use the information in **image 9.3** to explain how methylation of the NR3C1 gene could lead to higher incidences of stress-related mental illnesses in survivors of childhood PTSD. [3]

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The same symptoms can occur in the children and grandchildren of adults who have survived childhood PTSD.

A child's age when exposed to severe stress has been found to have an effect on the quantity of cortisol produced by their offspring and future generations.

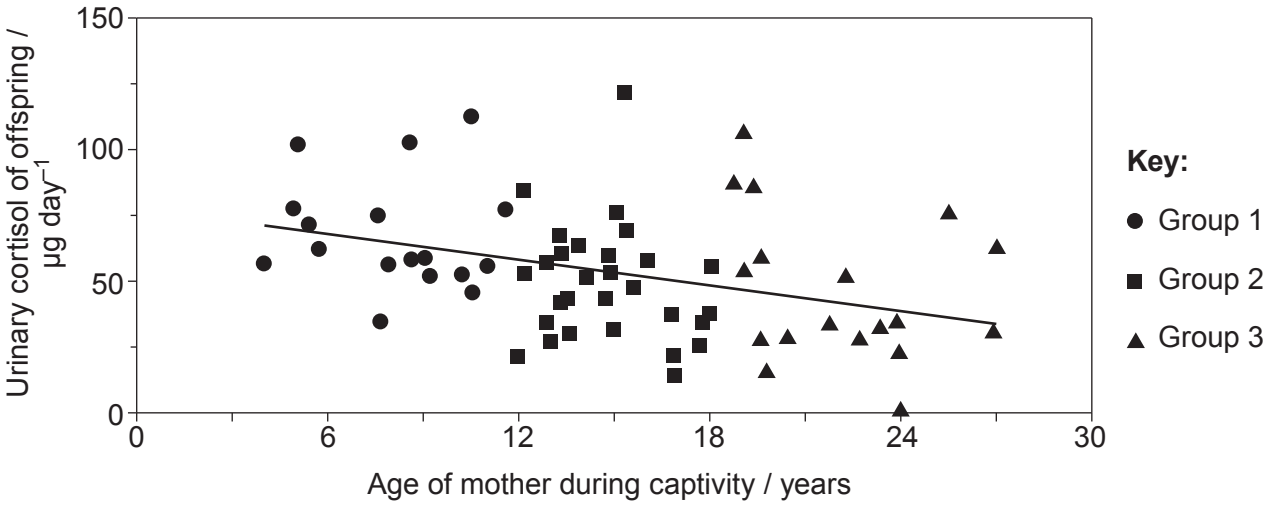
A group of scientists investigated cortisol production in 96 adult descendants of females who had survived imprisonment in concentration camps during World War 2. All the descendants were born after the end of World War 2 so had no direct experience of such imprisonment.

The descendants were placed into three groups based on the **age of their mother** while **she was in captivity** during World War 2.

Group	Age of mother during captivity / years
1	0 – 11 (child)
2	12 – 18 (adolescent)
3	18 + (adult)

The mass of cortisol excreted in the urine of each descendant was measured over a 24 hr period. **Image 9.4** shows the resulting data plotted on a graph.

Image 9.4



(iii) Evaluate whether the graph supports the hypothesis that as the age of maternal exposure to trauma increases, the production of cortisol in their descendants decreases. [2]

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(iv) Explain why the **mass** of cortisol excreted in the urine over 24 hours was measured and not the **concentration** of cortisol. [1]

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(v) Suggest **two** features of the sample of people in this investigation that reduce the reliability of the data. [2]

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(c) African elephants *(Loxodonta africana)* exhibit a type of society known as fission–fusion. Most of the time adult females and young elephants live together in a herd separate from adult males (fission stage). Adult males join a herd temporarily for the purpose of mating (fusion stage).

The presence of large tusks in one male elephant may stimulate aggressive behaviour in another male elephant.

Large tusks are considered to be an example of a sign stimulus.

(i) Explain what is meant by the term 'sign stimulus' and state the name given to the type or pattern of behaviour that is the result of this type of stimulus. [2]

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(ii) Larger tusks place male elephants at a social advantage.

Describe **two** ways by which male elephants gain social advantage from having larger tusks. [2]

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The presence or absence of tusks in elephants is genetically controlled. Sexual selection favours larger tusk size in males. Elephants without tusks are usually present at lower frequencies in populations.

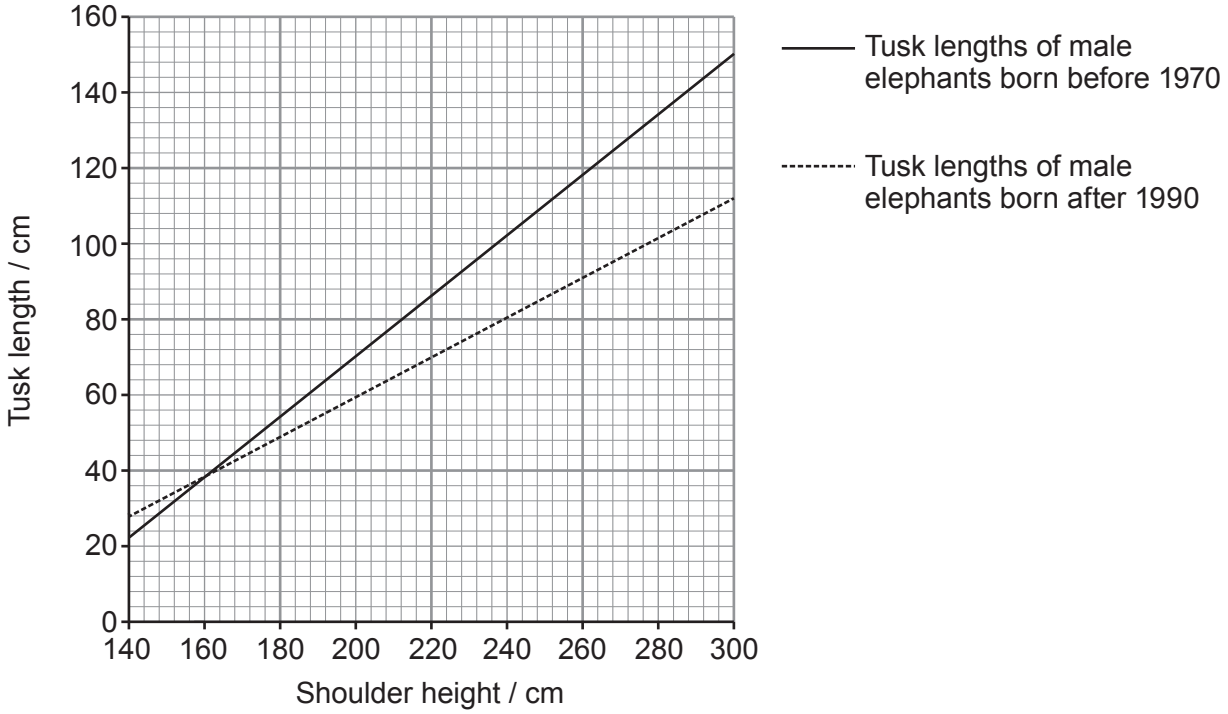
Poaching animals that have larger tusks for ivory has altered the gene pool in elephant populations.

There are fewer animals with tusks and a greater proportion of individuals who do not grow tusks.

Between 1970 and 1990 there were high levels of poaching.
Scientists recorded the exposed tusk length and shoulder height of adult male elephants born before and after these dates for comparison.

Image 9.5 shows the mean tusk length compared to shoulder height for male elephants born before and after this period.

Image 9.5



(iii) Using the information in **image 9.5**, calculate the percentage decrease in the mean length of the tusks of male elephants with a shoulder height of 2 metres. [2]

Percentage decrease = ...

(iv) One attempt to reduce poaching has been to anaesthetise elephants with larger tusks and remove the tusks so that poachers have no reason to kill these individuals.

Suggest why the elephant population continues to decline and the proportion of male elephants able to grow tusks remains low, despite the efforts described above to prevent them being killed. [1]

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END OF PAPER

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