Surname	Centre Number	Candidate Number
Other Names		2

GCE A LEVEL – NEW

A400U30-1

S17-A400U30-1

BIOLOGY – A level component 3
Requirements for Life

MONDAY, 26 JUNE 2017 – MORNING

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**15**	
	2.	**15**	
	3.	**11**	
	4.	**11**	
	5.	**19**	
	6.	**9**	
Section B	**Option**	**20**	
	Total	**100**	

A400U301
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. 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 continuation pages 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. The surface area to volume ratio of an organism is related to its ability to exchange gases with the environment. Heat can also be lost or gained through the body surface. As organisms increase in mass their surface area to volume ratio decreases. However, most large organisms do not rely on their external body surfaces for gas exchange.

(a) Describe and explain the common adaptations of the gas exchange surfaces found in fish and mammals. [3]

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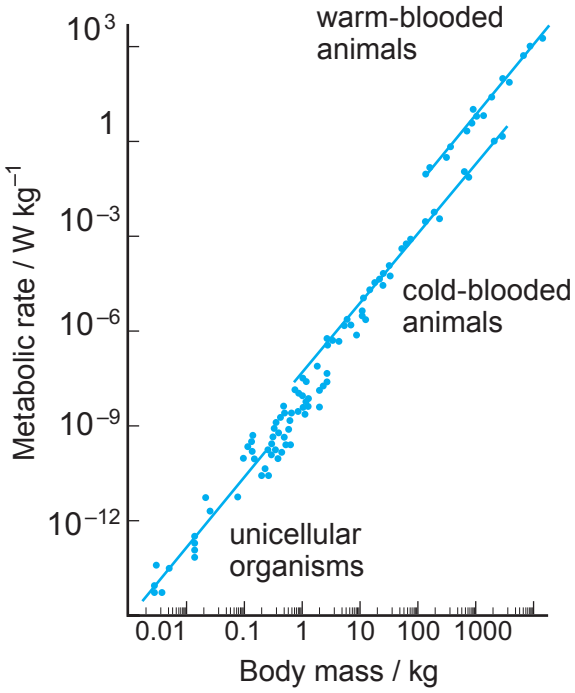
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The graph below shows how the metabolic rates of three different groups of organisms vary with body mass. All readings were taken at an external environmental temperature of 20 °C.



(b) (i) Describe the general relationship between body mass and metabolic rate. [1]

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(ii) The body temperature of cold-blooded animals, e.g. fish, varies with the temperature of the environment. Suggest why warm-blooded animals which have a constant body temperature, e.g. mammals, have a higher metabolic rate. [2]

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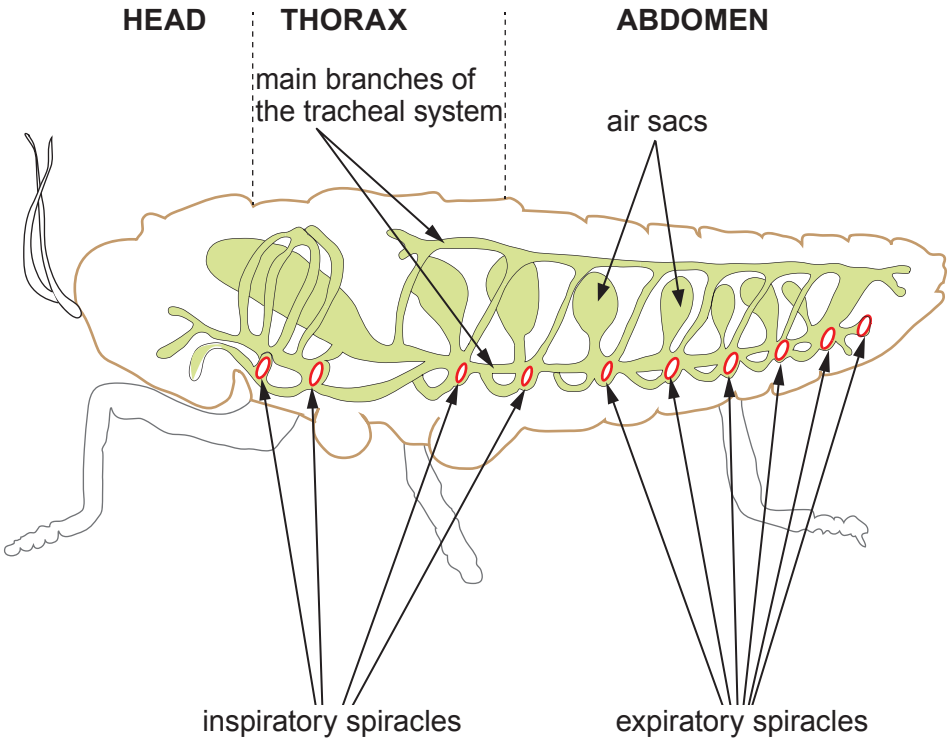
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(c) Insects are terrestrial animals that have an exoskeleton. Air is delivered directly to the tissues through a network of tubes called tracheae. The tracheal system is ventilated by contractions of the abdomen. During flight, contractions of muscles in the thorax produce the same effect. Valves regulate the flow of air so that air enters through the first four pairs of spiracles and exits through the last six pairs. The diagram below shows the main branches of the tracheal system of an insect (left side only).



(i) Explain the advantage to the insect of closing the spiracles. [1]

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(ii) Suggest a role of the air sacs. [1]

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(iii) Explain the advantage to the insect of having a ventilation system. [1]

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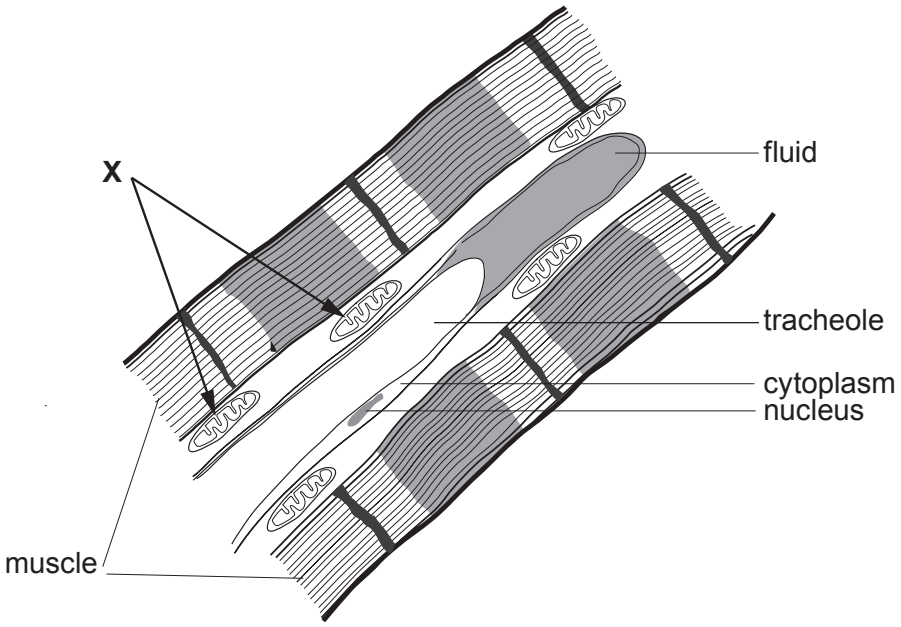
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(d) The tracheae are lined with a thin strip of chitin and have a layer of waxy cuticle covering their interior surface. The ends of the tracheae are called tracheoles. These penetrate between cells and are not lined with either chitin or cuticle. Their ends are filled with a fluid.
The diagram below shows the position of a tracheole in a muscle cell.



(i) The chitin in the walls of the tracheae has a similar chemical bonding and function as cellulose in plant cell walls. Explain how the chemical bonding in chitin enables it to carry out this function in insects. [3]

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(ii) Identify organelles **X** in the diagram on page 5 and explain why they are found close to the tracheoles. [3]

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2. Tomatoes *(Lycopersicon esculentum)* are an important greenhouse crop. Plant growers need to control conditions in their greenhouses to achieve a high yield of tomato production.

An investigation was carried out to determine the effect of light intensity ($W\,m^{-2}$) on the density of stomata in the leaves of tomato plants.

(a) (i) Outline a method by which the density of stomata could have been determined. [3]

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(ii) The plants used in the investigation were grown either under $100\,W\,m^{-2}$ or $20\,W\,m^{-2}$ light sources for 8 hours each day at 20°C.
State **two *other*** environmental factors that should have been controlled in this investigation. [2]

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(b) The hypothesis tested was: *'the higher the light intensity, the higher the density of stomata on the lower leaf surface'*.
The results of the investigation are shown in the table below.

Tomato plant	Mean density of stomata per plant / number cm^{-2}			
	100 $W m^{-2}$		20 $W m^{-2}$	
	upper leaf surface	lower leaf surface	upper leaf surface	lower leaf surface
1	3.33	6.31	0.09	7.88
2	2.91	9.96	0.11	7.98
3	2.84	9.67	0.08	9.35
4	2.86	8.18	0.07	7.56
5	2.92	9.38	0.10	8.52
6	1.91	7.87	0.15	7.70
7	3.20	9.51	0.04	9.25
8	2.74	8.45	0.14	8.80
9	2.24	7.95	0.02	8.26
10	4.10	7.02	0.06	8.12
Overall mean	2.91	8.43	0.09	8.34
Standard deviation	0.56	.....	0.04	0.59

(i) Using the table below, calculate the standard deviation for the density of stomata on the lower leaf surface at 100 $W m^{-2}$. **Enter the standard deviation into the table of results above**. State your answer to three significant figures. [3]

lower leaf surface at 100 $W m^{-2}$		
x	$x - \bar{x}$	$(x - \bar{x})^2$
6.31	–2.12	4.49
9.96	1.53	2.35
9.67	1.24	1.54
8.18	–0.25	0.06
9.38	0.95	0.90
7.87	–0.56	0.31
9.51	1.08	1.17
8.45	0.02	0.00
7.95	–0.48	0.23
7.02	–1.41	1.99
$\bar{x}$ 8.43		Σ

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The formula for standard deviation is:

$$\sqrt{\frac{\sum(x-\bar{x})^2}{N}}$$

Where

x = individual result $\bar{x}$ = mean result
N = number of trials $\sum$ = sum of

(ii) What information do the standard deviations shown in the table of results opposite provide regarding the reliability of the results of this experiment? [3]

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(iii) To what extent do these results support the hypothesis stated in *(b)*? [3]

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(iv) Based on these results, suggest an alternative hypothesis for the effect of light intensity on stomatal density in tomato plants. [1]

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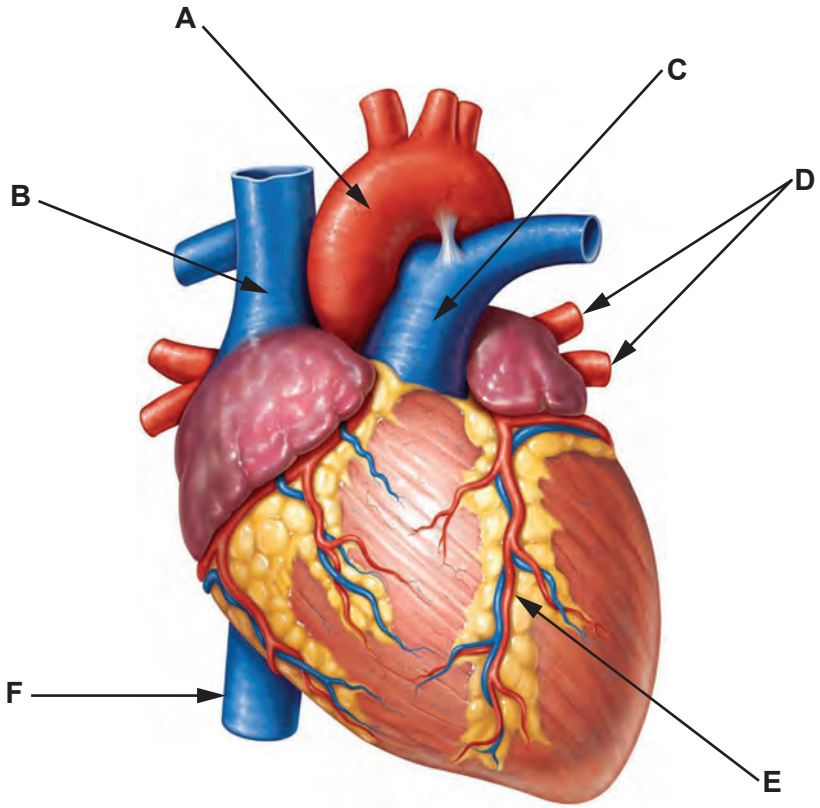
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3. In the UK, coronary heart disease accounts for nearly 73 000 deaths per year and it is estimated that approximately 2.3 million people suffer from a condition called angina. This form of heart disease develops when the blood vessels supplying the heart muscle become narrowed due to the build-up of fatty substances on the inside wall of the vessels. The fatty deposits are called atheroma and cause a condition called atherosclerosis.

The image below shows a model of the human heart together with some of its associated blood vessels.



(a) (i) In which of the blood vessels labelled **A** to **F** on the image could an atheroma develop that could cause angina? Name this blood vessel. [2]

Letter ..... **Name** .....

(ii) Explain why narrowing of these blood vessels could lead to the heart not contracting. [2]

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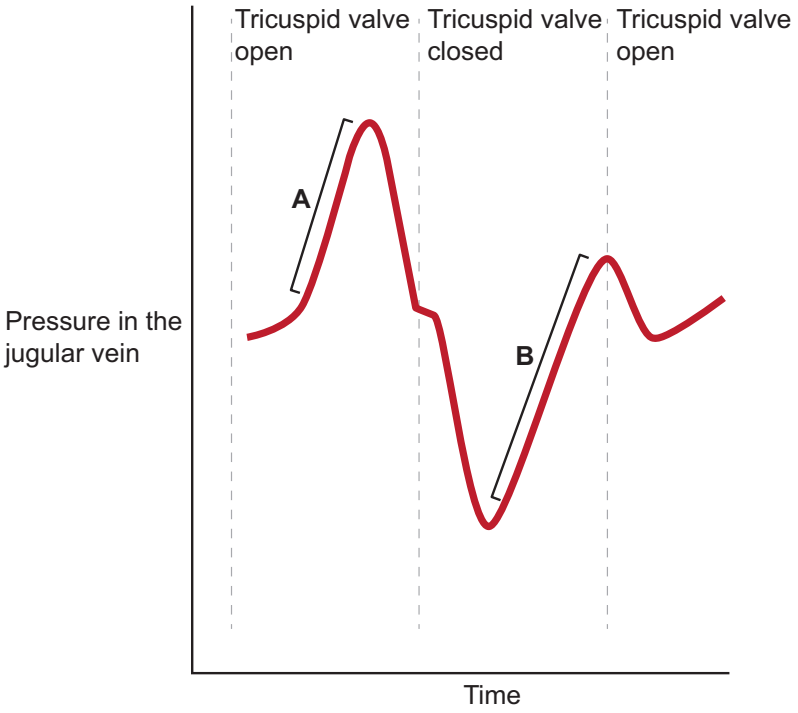
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(b) The jugular vein carries blood from the head back to the heart via the vena cava. There are no valves between the jugular vein and the heart. Therefore, the pressure in the jugular vein can be used as an indication of the ability of the heart to pump blood around the body.

(i) Which of the blood vessels labelled **A** to **F** on the image of the heart opposite will return blood from the jugular vein to the heart? [1]

Letter .....

The graph below shows how the pressure in the jugular vein changes during the course of one cardiac cycle.



(ii) State the name of the stages in the cardiac cycle during which the tricuspid valve is: [2]

I. **open** .....

II. **closed** .....

(iii) Suggest what causes the increase in pressure in the jugular vein in the regions labelled **A** and **B** on the graph. [4]

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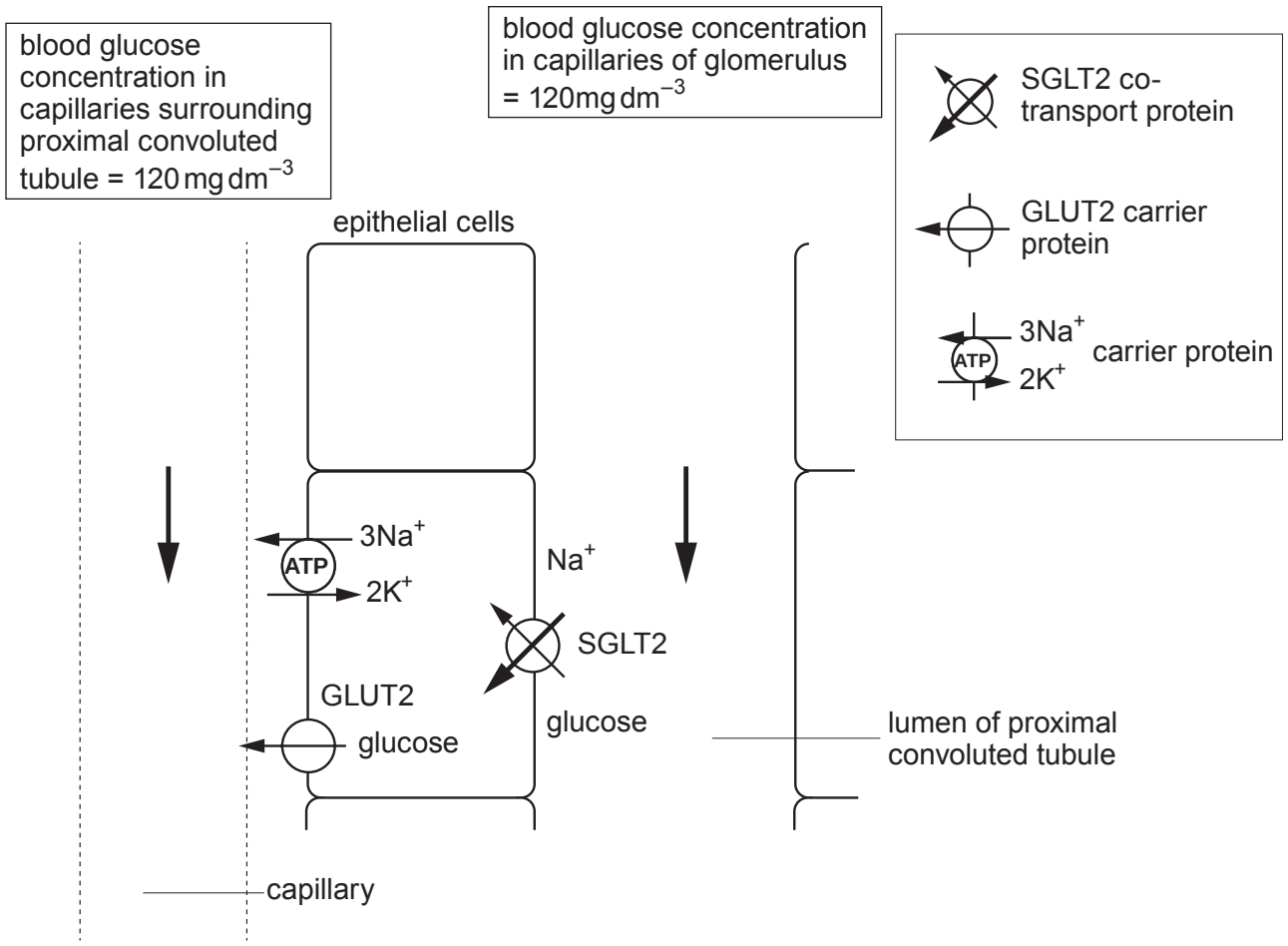
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4. Type 2 diabetes affects nearly three million adults in the UK and is particularly prevalent in obese people. Under normal conditions, almost all of the filtered glucose is reabsorbed and returned to the circulation in the proximal convoluted tubule of the nephron but in people with type 2 diabetes, glucose starts to appear in the urine when blood glucose concentration exceeds 180 – 200 mg dm^{-3}.

The diagram below shows how glucose is reabsorbed in the first part of the proximal convoluted tubule.



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(a) (i) Describe a biochemical test that could demonstrate the presence of glucose in urine and explain why this test can only provide semi-quantitative results. [3]

(ii) Explain how glucose is reabsorbed from the filtrate into the blood even at very high blood glucose levels. [4]

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(b) Reabsorption of glucose into the blood of people with Type 2 diabetes can increase the risk of hyperglycaemia (dangerously high glucose levels). Under these conditions damage can be caused to the retina and other tissues. Scientists are trialling the use of an inhibitor of the SGLT2 co-transport protein as a possible method of controlling blood glucose levels.

(i) Using the information provided above and on page 12, explain how an SGLT2 inhibitor could be used to treat Type 2 Diabetes and control blood glucose levels. [2]

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(ii) Suggest how the use of an SGLT2 inhibitor could also be used to help obese people lose weight. [2]

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5. Rennet is a mixture of enzymes that are produced by young ruminants to help improve the effectiveness of the digestion of casein (milk protein). Chymosin is the main enzyme in the mixture and is responsible for breaking a specific chemical bond in k-casein, one of the proteins found in casein. This enables digested k-casein to coagulate the other proteins found in milk and form a semi-solid mass.

(a) Chymosin is secreted as a precursor molecule by cells in gastric glands found in the abomasum (true stomach). Pepsinogen and hydrochloric acid are also secreted by these glands. Explain the role of these **three** secretions in digesting milk protein. [3]

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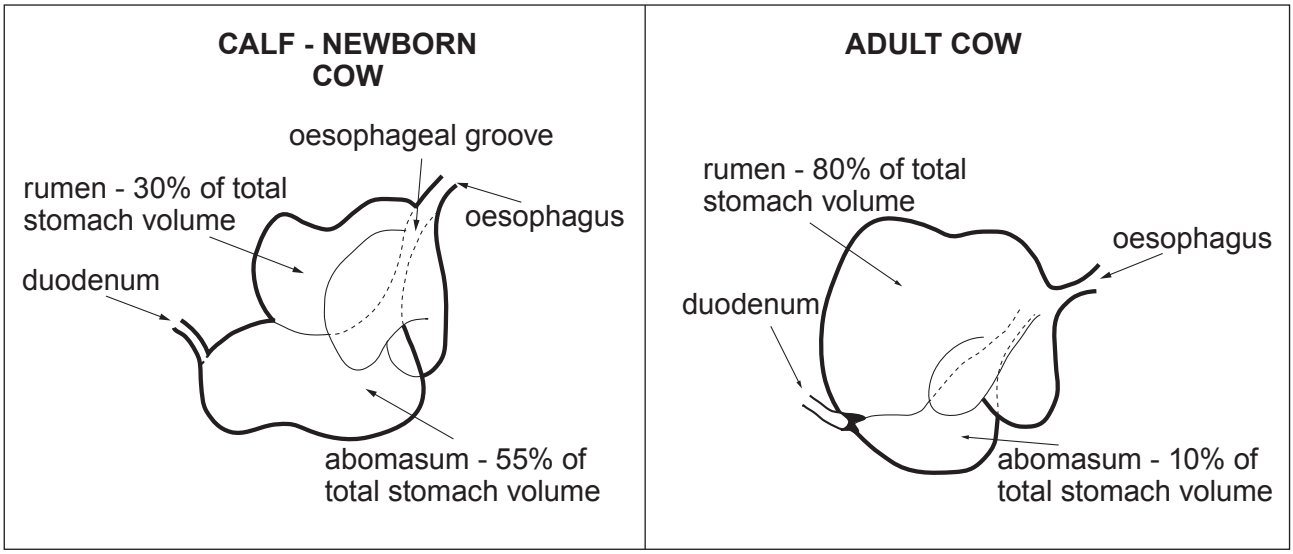
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In the ruminant gut, the relative proportions of the compartments of the stomach called the rumen and abomasum (true stomach) change as the animal grows older. The relative proportions of the rumen and abomasum of a newborn cow and adult cow are shown in the diagram below.



(b) With reference to their diets, explain the changes in the proportions of the rumen and abomasum as a calf grows older and its diet changes from milk to grass. [5]

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(c) Animal chymosin (the form of rennet used in traditional cheese production) is obtained from the stomachs of dead calves. Supplies of chymosin from this source are limited and make the cheese produced unsuitable for vegetarians. Most of the rennet now used in the cheese industry is produced from genetically engineered bacteria and yeasts.

(i) Suggest why it is generally considered that the use of GM chymosin is more ethically sound than using chymosin from animal rennet. [1]

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(ii) Bacteria of the species *Escherichia coli* were genetically engineered to contain the gene for chymosin. Due to the presence of multiple introns in the chymosin gene, bacteria may not be able to carry out the RNA splicing. Therefore they may not be able to produce the functional mRNA molecule needed to synthesise the chymosin protein.
Outline how an intron free DNA molecule containing the chymosin gene could have been produced. [3]

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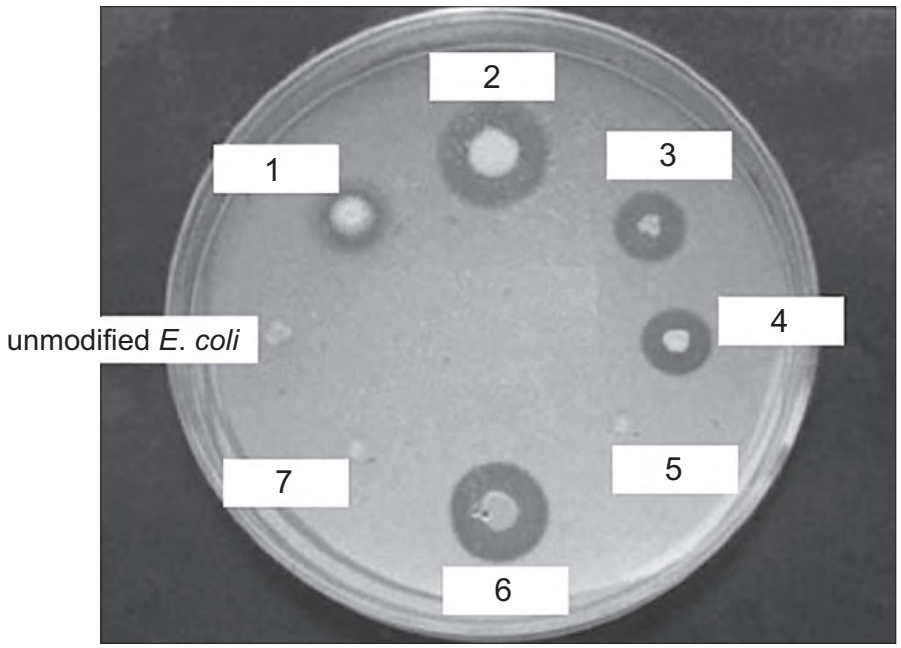
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Seven different genetically engineered *E.coli* strains were tested for their ability to synthesise and secrete chymosin. Pure cultures of each strain were grown on milk agar plates for 24 hours at a temperature of 37 °C.

The results of one test are shown in the image below. Unmodified *E.coli* was also grown on the same plate.



(iii) Suggest why the bacteria were cultured at 37 °C and explain why an unmodified strain of *E.coli* was included. [2]

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(iv) The agar contained 0.02 g cm^{-3} milk protein. The clear zone surrounding bacterial colonies was due to the digestion of milk protein.

The clear zone surrounding strain **3** was found to be 13 mm in diameter using a 3 mm depth of agar.

I. Calculate the volume of the agar in the clear zone. Express your answer to one decimal place. [2]

[π = 3.142; volume of a cylinder = $\pi r^2 h$; h = depth of agar]

Volume of agar in clear zone = ... cm^3

II. Calculate the mass of milk protein digested and hence the rate of protein digestion by the chymosin secreted by *E.coli* strain **3**. Express your answer in standard form. [3]

Rate of milk protein digestion = ... g hour^{-1}

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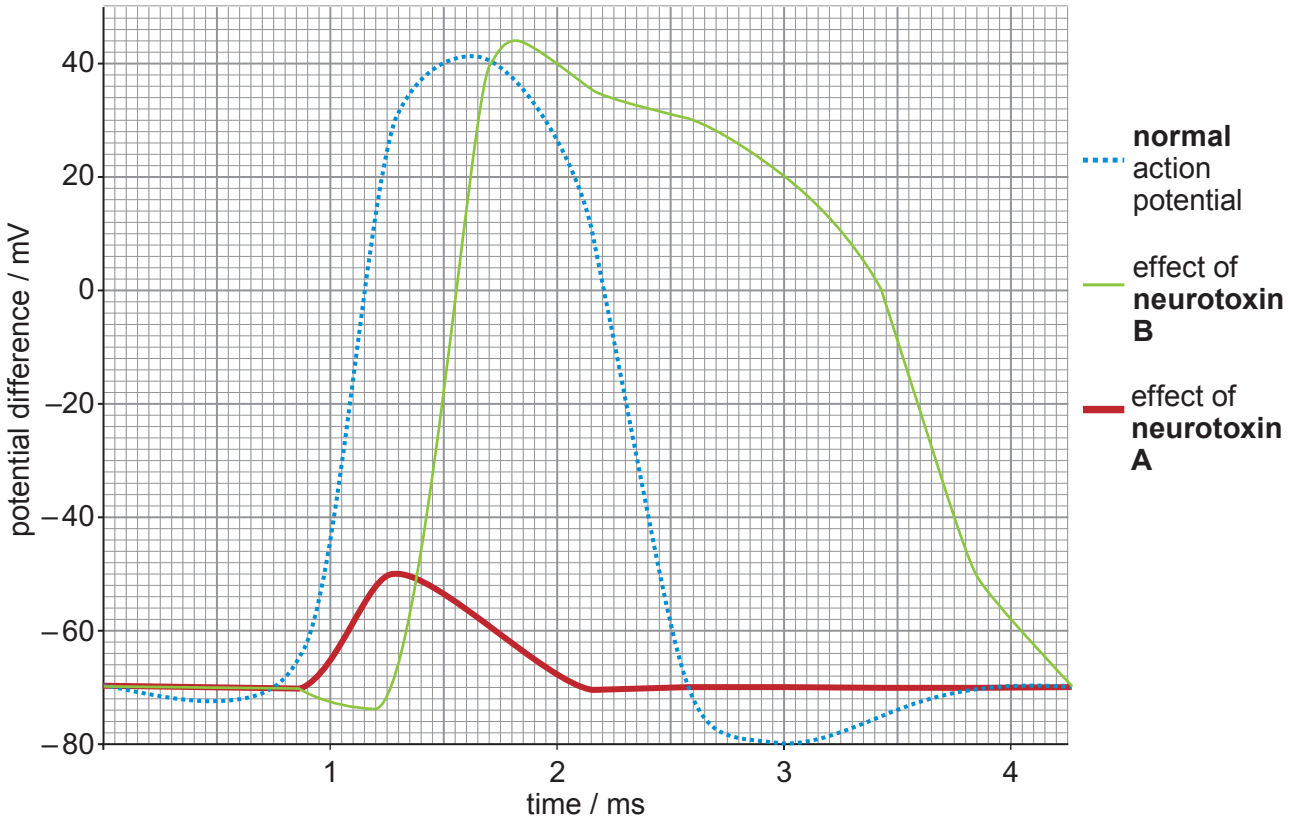
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6. Neurotoxins are chemicals produced by many organisms as a defence against predators. Most neurotoxins cause paralysis of muscles and eventually death. Different neurotoxins affect the transmission of a nervous impulse from the central nervous system to muscles in different ways.

Effect of neurotoxins A and B on an action potential



Effect of neurotoxin C:
Neurotoxin C has **no effect** on the generation or transmission of an action potential in an axon but prevents the generation of an action potential in a post-synaptic membrane.

	Ion concentration in the terminal of a presynaptic neurone / mmol dm^{-3}					
	At rest		Immediately after stimulation			
			Without neurotoxin C		With neurotoxin C	
Ion	**Inside neurone**	**Outside neurone**	**Inside neurone**	**Outside neurone**	**Inside neurone**	**Outside neurone**
Na^+	14	145	130	15	125	25
K^+	155	5	15	145	20	135
Ca^{2+}	0.001	5	3.9	1.1	0.008	4.9

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Using the information provided and your knowledge and understanding of the transmission of nervous impulses, explain how each of the neurotoxins **A**, **B** and **C** could cause muscle paralysis. [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.

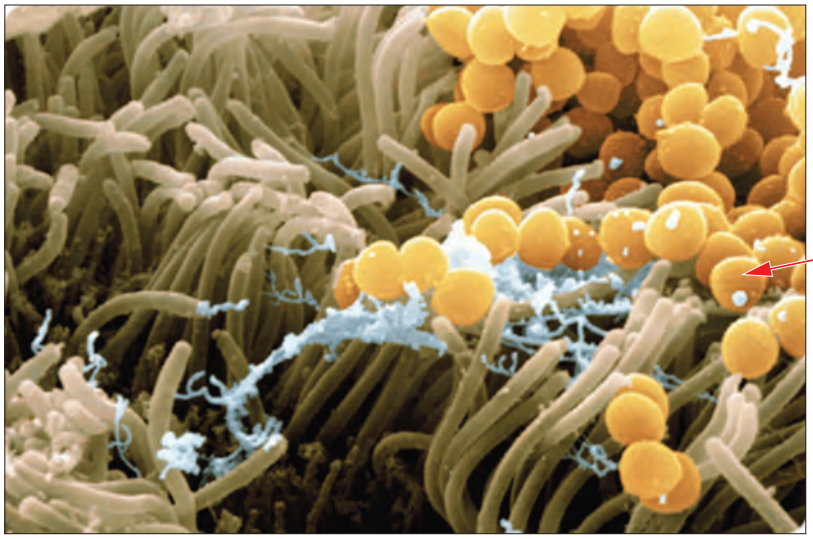
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OPTION A: IMMUNOLOGY AND DISEASE

7. *Neisseria meningitidis* is an airborne pathogenic bacterium that can cause one type of meningitis.

The photomicrograph below of an airway's lining shows an example of the body's natural barriers to infection by pathogenic bacteria.



(a) With reference to the photograph, describe this first line of defence. [1]

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(b) *Pseudomonas aeruginosa* is a Gram-negative bacterium that can be easily spread by hands as a type of direct contact. *P. aeruginosa* infections can be treated with a bactericidal antibiotic called Colistin that binds to lipopolysaccharides and phospholipids in the outer cell layer of Gram-negative bacteria.

Using your knowledge of bacterial structure and antibiotics explain how penicillin acts and why it cannot be used to treat *P. aeruginosa*. [3]

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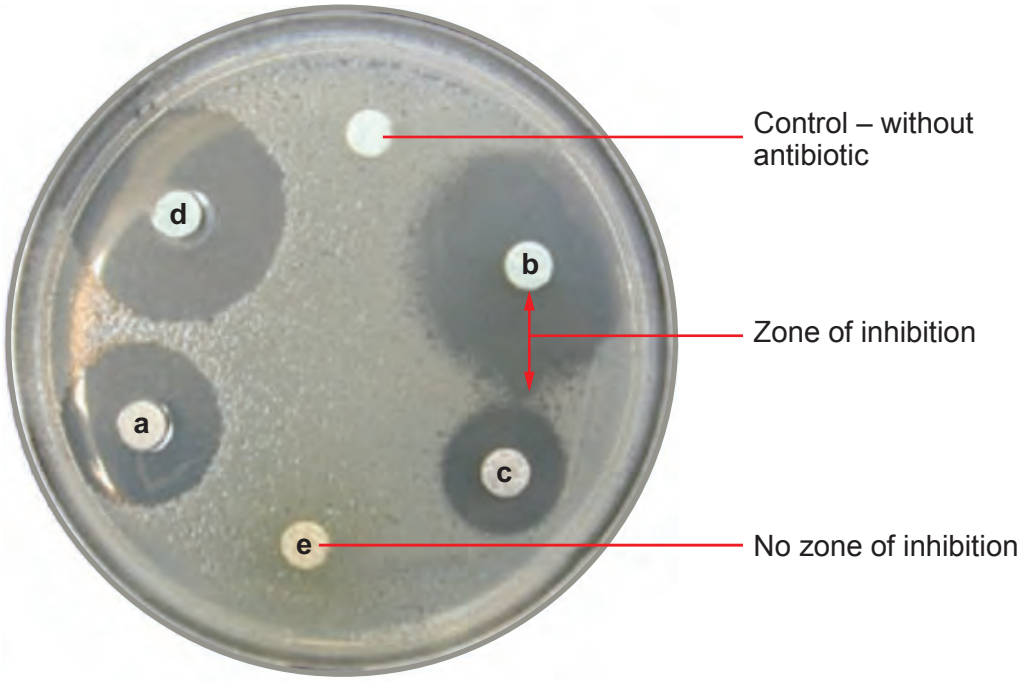
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Colistin is known as a “last resort” antibiotic, increasingly used to treat infections that resist every other antibiotic. However, in November 2015, bacteria were found resistant to this antibiotic. Microbiologists are constantly researching new antibiotic compounds.

The illustration below shows zones of inhibition around filter paper discs. The discs are all the same size and saturated with the same concentration of different antibiotic compounds and placed on bacteria growing on agar. The antibiotic will diffuse out of the filter paper. The radius of the zone of inhibition is a measure of the effectiveness of the antibiotic compound.



(c) Since this method depends on diffusion of the antibiotic, it is important to keep several factors constant.

(i) State **two** variables that should be controlled. [2]

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(ii) Explain how you could identify which antibiotic worked the best. [1]

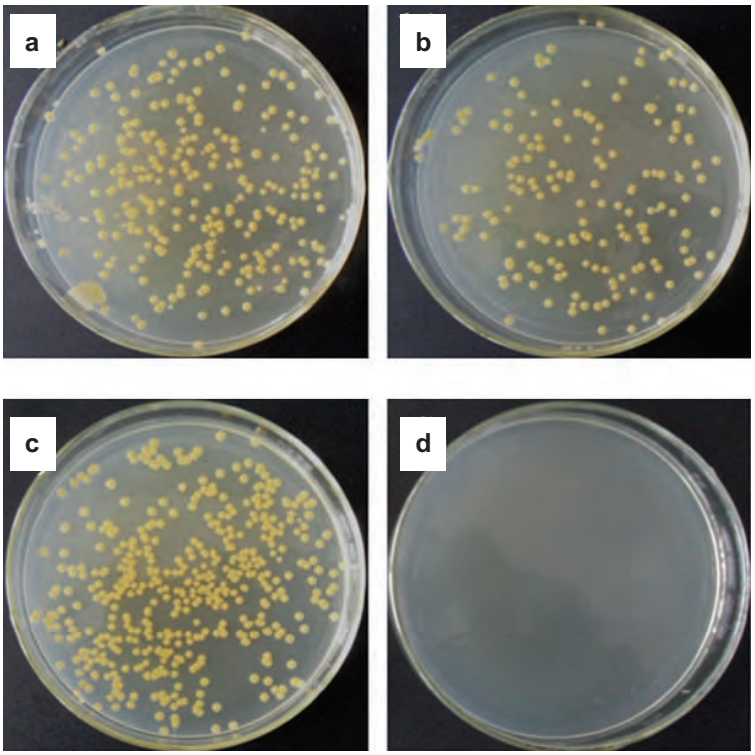
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(iii) A sample of bacteria was removed from each zone of inhibition generated by the working antibiotics. These bacteria were then re-plated without the antibiotics and cultured.
The images below show the results for antibiotics **a** to **d**.



Conclude the mode of action of each of these antibiotics. Explain how you reached this conclusion. [2]

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(d) Antibiotics have no effect on viruses. Chickenpox is a highly infectious airborne disease caused by the varicella-zoster virus. The virus spreads easily in the air when an infected person coughs or sneezes. Airborne viruses have antigens that can attach to the surface membrane of cells lining the trachea.

Explain why the varicella-zoster virus needs to enter the cells of the trachea and the effect this has on the cells. [2]

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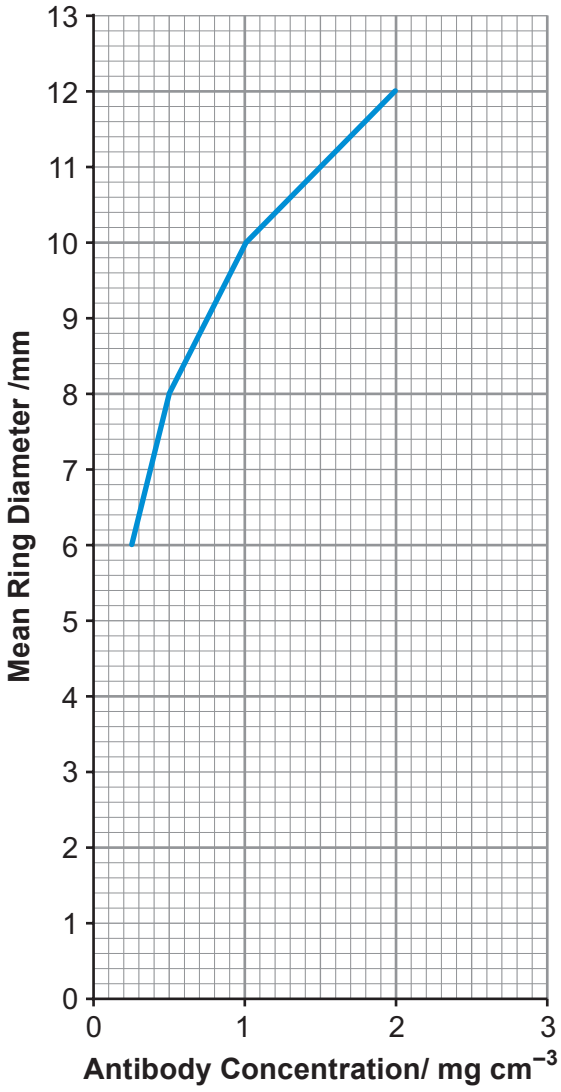
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(e) Radial Immuno Diffusion is a quantitative technique used to estimate antibody concentration. Agar plates are set up with a known concentration of antibody included in the agar. Pure antigens are added to the centre of each plate. The antigens diffuse through the agar and form antigen-antibody complexes which can be seen as a precipitation ring. The diameter of the ring is used to plot a calibration curve to estimate the concentration of antibodies in the blood samples as shown below.



(i) Use the graph to estimate the antibody concentration of the sample taken before vaccination and after. **Write your answers in the table below**. [1]

Sample	Ring diameter / mm	Antibody Concentration / mg cm^{-3}
Before Vaccination	7	
Following Vaccination	11	

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(ii) Using your knowledge of the humoral response, explain the concentration of antibodies after the vaccination. [3]

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(iii) To assess the effectiveness of the vaccine the technique was repeated with several blood samples taken from a number of volunteers. A statistical test was used to assess the significance of the differences in the antibody levels before and after vaccination.
State the null hypothesis. [1]

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(iv) The test gave a value greater than the critical value at a probability of 0.05.
State whether you would accept or reject the null hypothesis and explain why. [1]

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(v) A protective antibody response to a vaccine requires at least a fourfold increase in antibody concentration. **Using the table opposite**, calculate the minimum antibody concentration that would be required to be protective. [1]

increase in antibody concentration = ...

(vi) State whether the results shown opposite indicate a successful vaccination and explain why annual vaccination programmes against influenza are not always effective. [2]

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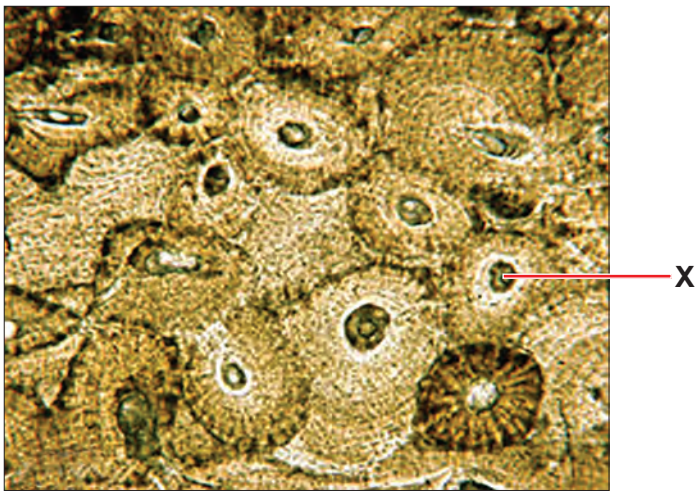
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OPTION B: HUMAN MUSCULOSKELETAL ANATOMY

8. Limb bones have a strong outer shell of compact bone, surrounding a softer, spongier core called trabecular bone making them light and strong. The electron micrograph shows a cross section through compact bone.



(a) (i) Name structure **X** and describe its role in bone. [2]

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(ii) State the percentages of organic and inorganic material in compact bone. [1]

Organic ..... Inorganic .....

Bone mineral density (BMD) is a useful measure of bone health. Bones undergo continuous remodelling; through the daily removal of small amounts of bone mineral, and equal deposition of new mineral. This process must be balanced if bone strength is to be preserved.

As we age, the bone mineral balance tips toward excessive removal and bones weaken. Over time they can become brittle and prone to fracture, leading to a disease called osteoporosis.

The table below shows the effect of four osteoporosis treatments.

Drugs	Bone mineral density gain (%)	Fracture reduction (%)
Bisphosphonate	**3-5**	**30-45**
Denosumab	**3-6**	**55-70**
Oestrogen	**3-5**	**35**
Calcitonin	**1-1.5**	**20-30**

Data adapted from Department of Pharmacology, Al-Ameen College of Pharmacy, Bangalore-560027, India.

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(b) Denosumab is a drug that binds to receptors on osteoclasts and inhibits their activity. With reference to the mineral composition of compact bone and the cells found in the lacunae, describe how bone remodelling takes place in a healthy adult and suggest how Denosumab can be used as a treatment for osteoporosis. [4]

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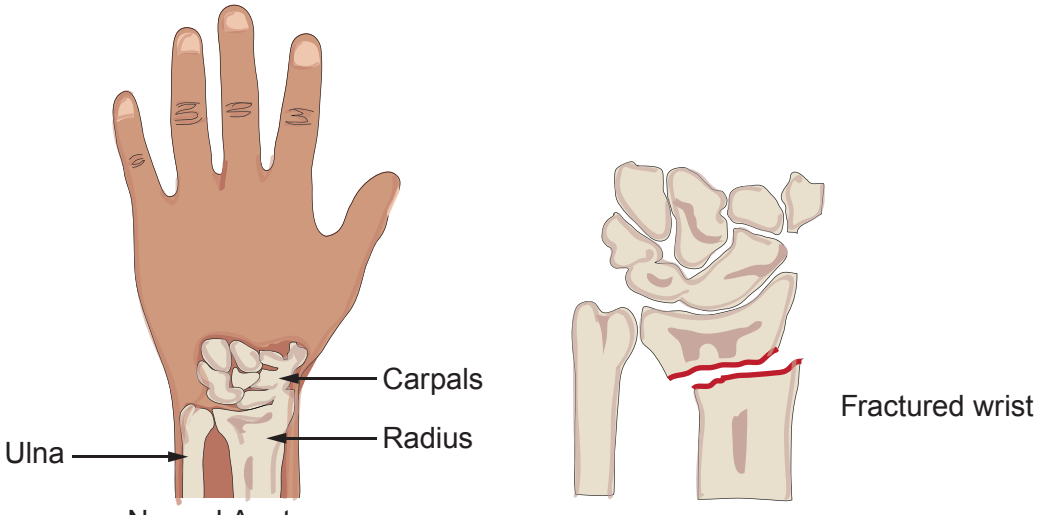
(c) With reference to data provided, conclude whether Denosumab or oestrogen is the most effective treatment for osteoporosis. Give a reason for your answer. [2]

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(d) Wrist fractures are very common in women in their 50s, typically after a fall onto an outstretched arm. This can be the first sign of underlying osteoporosis.



(i) The image above depicts a displaced fracture of the wrist. Suggest **one** possible treatment for this. [1]

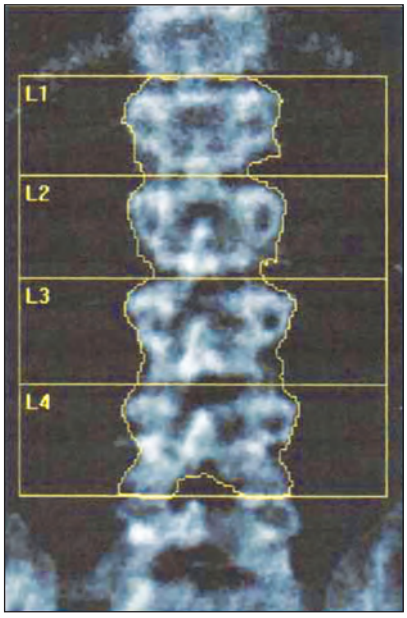
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(ii) Ideally, doctors need to identify and treat patients with osteoporosis before a fracture occurs. A radiograph of the vertebral column can be used to diagnose osteoporosis. A scan identifies the bone area, bone mineral composition (BMC) and bone mineral density (BMD). The results are then compared to the mean results for young adults to calculate a *T- score*, which can then be used to predict fracture risk.
The lumbar spine scan of a 60 year old woman is shown below.



Scan Report:

Scan Date: July 30, 2015

Scan Type: Lumbar Spine

Region	Area (cm^2)	BMC (g)	BMD (g/cm^2)	Young adult BMD Mean (g/cm^2)	Young adult BMD Standard deviation (g/cm^2)
L1	11.54	7.41	0.642	1.0	0.1
L2	12.14	9.28	0.765		
L3	12.21	9.93	0.813		
L4	14.80	12.09	0.817		
Mean	12.67	9.68	0.759		

The T score is calculated as:

$$\text{T Score} = \frac{\text{Patient mean BMD} - \text{Young Adult mean BMD}}{\text{Standard Deviation Young Adult BMD}}$$

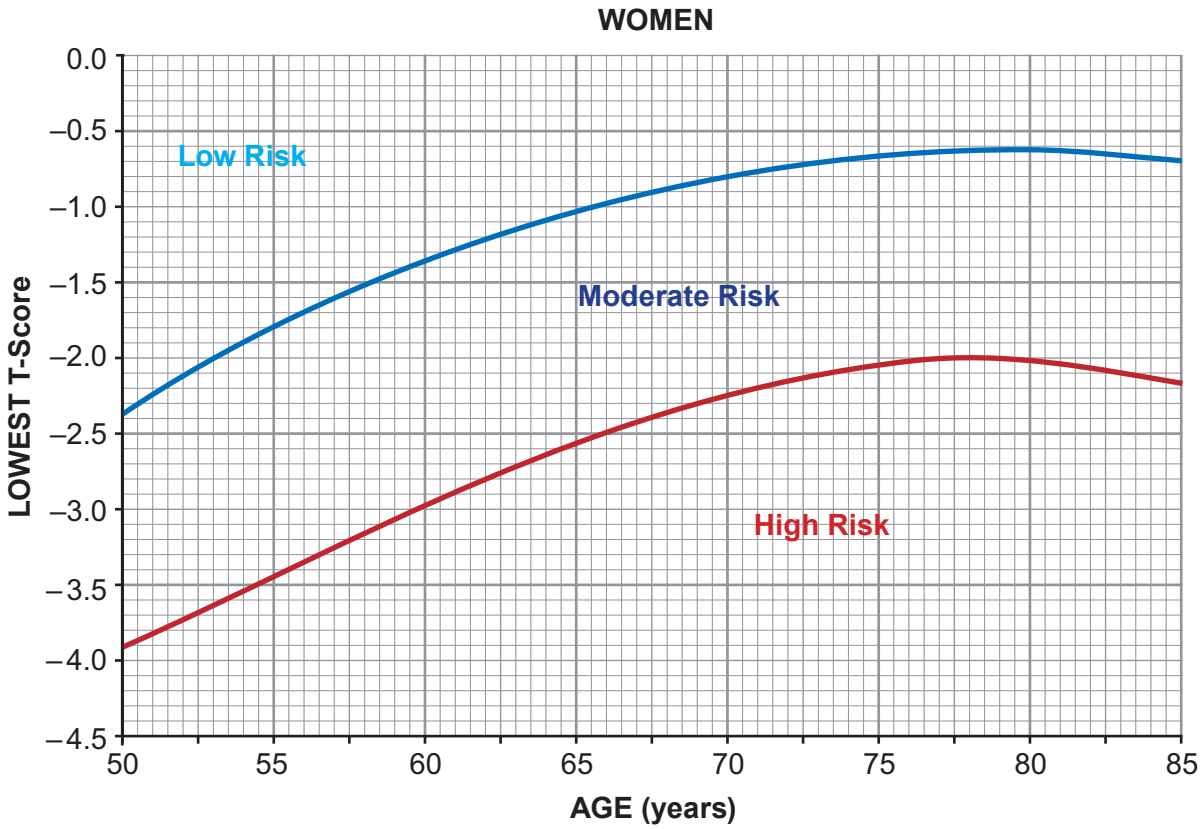
Calculate the T score for the patient. [1]

T score = ...

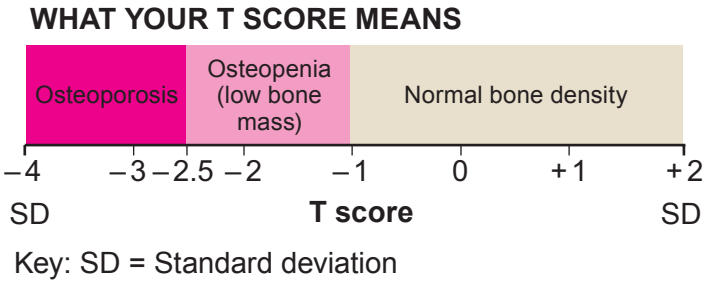
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The graph below can be used to estimate the future fracture risk in women.



The scale below can be used to interpret the T score.



Key: SD = Standard deviation

(iii) Use the T score and the information provided to diagnose her condition and fracture risk. [2]

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(e) Arthritis affects joints, particularly those in the hands and wrists.



Finger Joint Arthritis

(i) Compare and contrast the structure and movement of the wrist joint with those found in the fingers. [4]

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(ii) A patient presents symptoms of pain, stiffness and swelling in their joints. Physical examination reveals an increase in temperature at the swollen areas. Is this patient likely to be suffering from osteoarthritis or rheumatoid arthritis? Explain your conclusion. [3]

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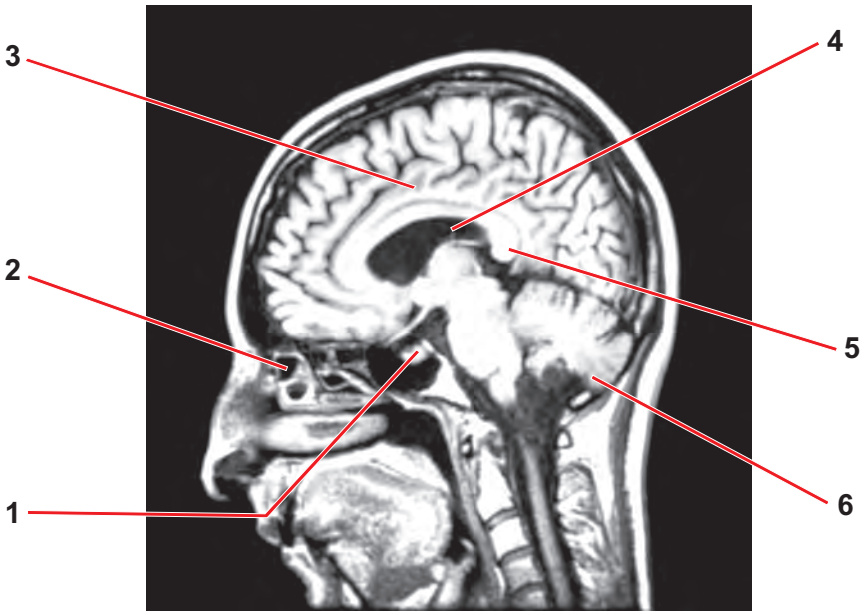
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OPTION C: NEUROBIOLOGY AND BEHAVIOUR

9. Scientists carried out research into possible changes that occur in the brains of taxi drivers, as a result of learning. To qualify as a London taxi driver, they have to learn every street name, landmark and direction of traffic flow. MRI images can be analysed to measure the volume of specific brain structures.

(a) (i) The following image depicts an MRI scan of a human brain. Which number **(1-6)** shows the hippocampus? [1]

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(ii) Suggest why the scientist studied the hippocampus region of the brain. Give reasons for your answer. [2]

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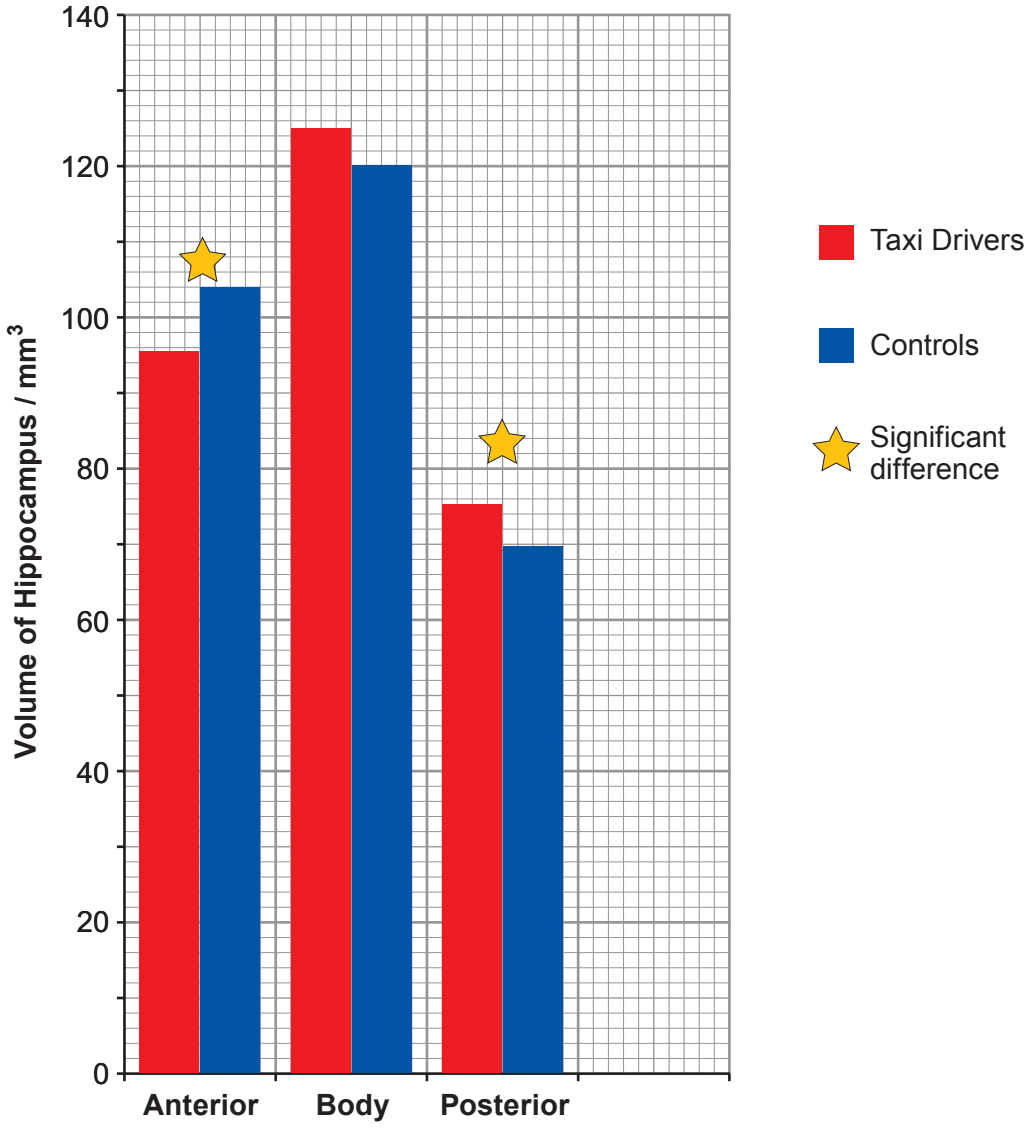
(iii) The independent variable in this research was being a male taxi driver. The dependent variable was the volume of the hippocampus as seen using MRI. Male non-taxi drivers were used as controls in this study. Suggest **two** *other* factors regarding these individuals that should be controlled. [1]

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(b) The MRI scanned the anterior, body (middle) and the posterior regions of the hippocampus. The results from the research are shown below.



(i) The scientist's hypothesis stated, "the regions of hippocampi in London taxi drivers will be structurally different to the hippocampi in non-taxi drivers".
Using the results given, can the hypothesis be accepted? Justify your conclusion.
[4]

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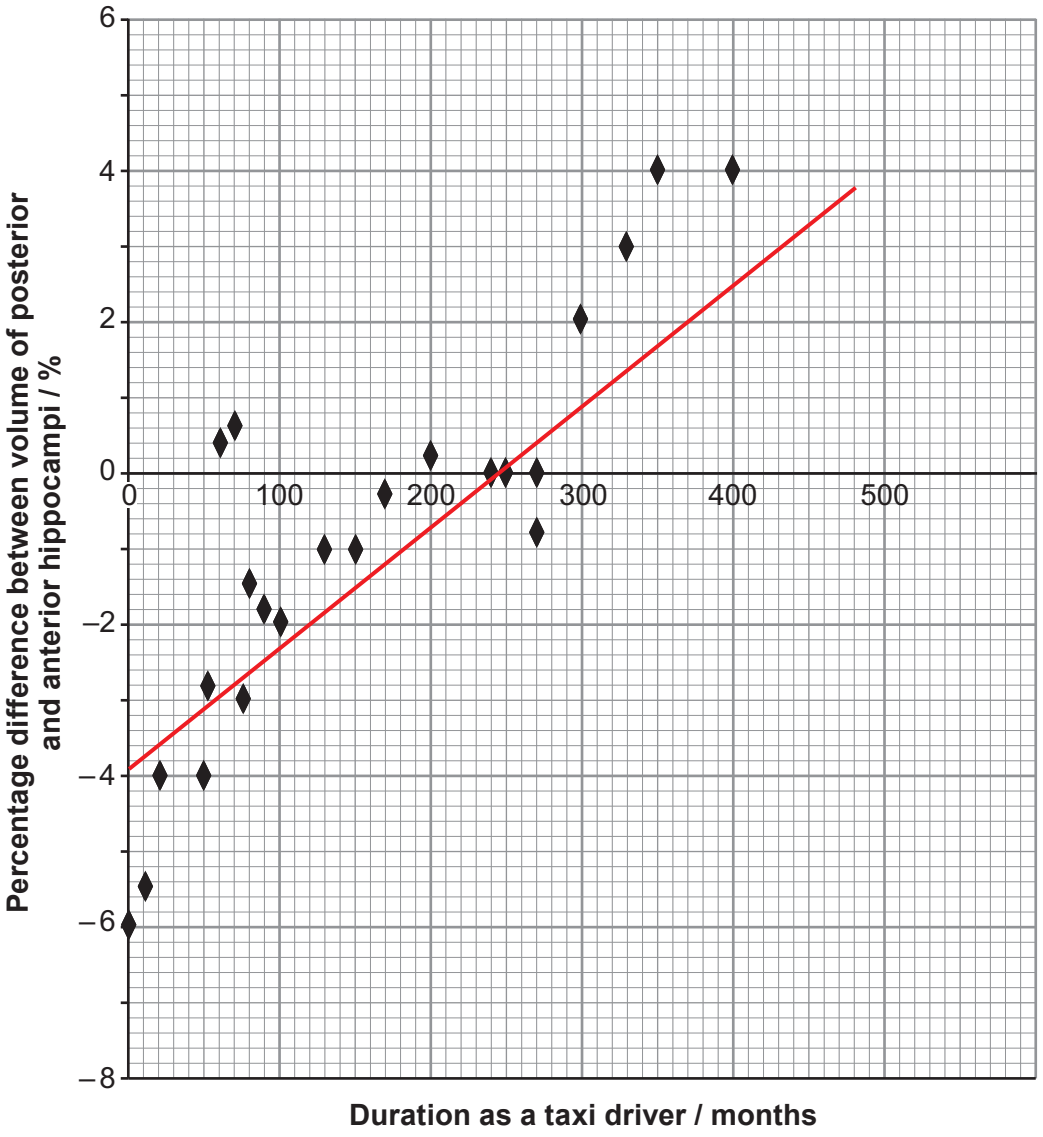
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The percentage differences between the volumes of the posterior and anterior hippocampi were plotted against the duration of time spent as a taxi driver.



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(ii) The line shown on the graph is a correlation line. Using the trend shown and your knowledge of brain structure and neuroplasticity, what conclusions can be drawn? [4]

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(iii) A further investigation is to be carried out to look at changes in brain activity during a map reading exercise whilst driving the taxi. Suggest a brain imaging technique that could be used and explain why it would be more suitable than MRI. [2]

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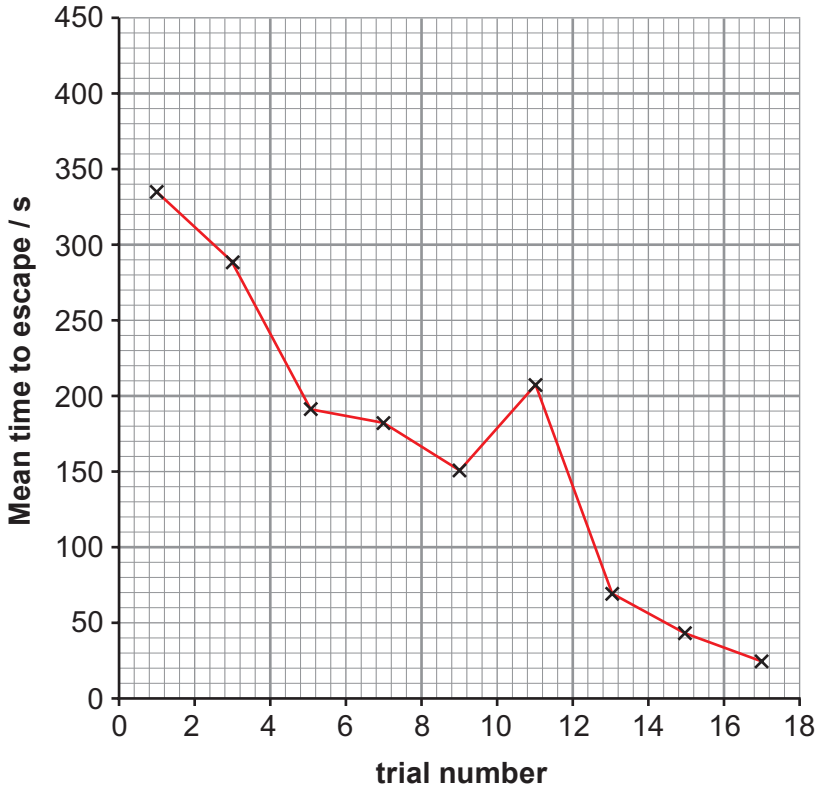
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(c) In order to better understand learning in animals, researchers presented spotted hyenas *(Crocuta crocuta)* with a problem-solving task. Hyenas were placed in a puzzle box and were encouraged to escape to reach food placed outside. Researchers timed how long it took the hyenas to escape. The experiment was repeated several times.



(i) Calculate the percentage change in mean time to escape between the start and end of the trials. [2]

percentage change in mean time = ...

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(ii) State and explain the type of behaviour exhibited by the hyenas. [2]

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(iii) Explain why the time taken to escape from the box decreases. [1]

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(iv) Suggest how the experiment could be modified to improve the reliability of the conclusion. [1]

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