GCE Biology

S21-A400U30-1

Assessment Resource 27

Requirements for Life- Options Resource I

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 30 minutes on this section.

Option A: Immunology and Disease

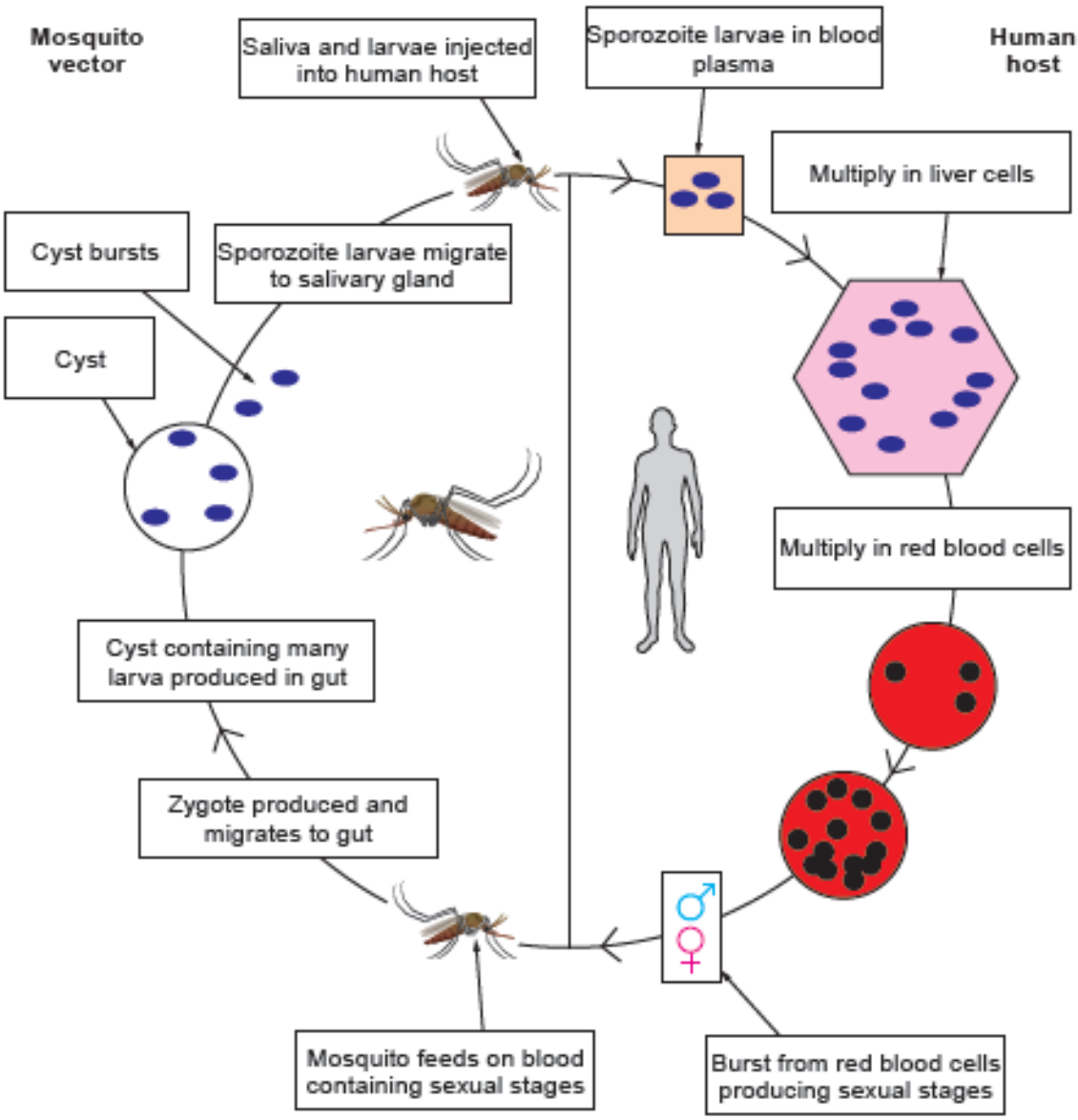
1. Malaria is a disease caused by the parasitic protoctist, *Plasmodium* and carried by a vector, the *Anopheles* mosquito.

Malaria is endemic in many tropical countries. A large proportion of the 1 million people who die from malaria each year are children under five years of age and 90% of cases occur in sub-Saharan Africa.

There are many stages in the life cycle. A larval form of the parasite is passed into human blood plasma when a mosquito feeds on blood. The parasite reproduces rapidly in the liver and erythrocytes (red blood cells) of a human host.

A summary of the life cycle of *Plasmodium falciparum* is shown in **image 1.1**.

Image 1.1



(a) State the meaning of the word 'endemic'. [1]

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In 2015, 'Mosquirix' (trade name) was the first vaccine licensed for use against malaria.

A clinical trial of the vaccine involved 1000 healthy infants under 3 months old and 1000 healthy children aged 3 months to 5 years across Africa. The trial included a control group.
Infants and children in the trial were injected with an antigen, a protein called CSP, found on the plasma membrane of the sporozoite stage of the life cycle.

Scientists measured the immune response to the antigen by recording the concentration of anti-CSP antibody in the blood of individuals in each age group.

(b) (i) Using the information in **image 1.1** together with your own knowledge, suggest **two** reasons for developing a vaccine that targets the sporozoite stage of the life cycle. [2]

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(ii) State **one** reason why a vaccine for malaria has proved difficult to produce. [1]

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(iii) Suggest a suitable control that could have been used in this trial. [1]

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A summary of the results of the trial is shown in **table 1.2**.

Table 1.2

Age Group	Mean anti-CSP antibody concentration / a.u.
< 3 months (infants)	333
3 months – 5 years (children)	465

The concentration of anti-CSP antibody was lower in infants than in children. Despite this, the infant group did **not** show a higher frequency of cases of malaria.

Most infants in the trial were breast fed. Infants produced even lower concentrations of the anti-CSP antibody if their mother lived in an area which had a higher incidence of malaria cases.

(iv) Use your knowledge of immunity to suggest an explanation for:

I. the infants' lower antibody production; [1]

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II. the infants' lower susceptibility to malaria. [2]

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(c) The puff adder is a venomous snake that lives in parts of Africa.

Victims of puff adder bites may be given an injection of anti-venom containing antibodies specific to a toxin found in the puff adder's venom.

Anti-venom is produced by injecting very small volumes of the toxin (the antigen) into a mammal such as a sheep. The sheep produces specific antibodies that are purified from blood taken from the sheep.

(i) The sheep's immune system produces specific B lymphocytes in response to the antigen. The B lymphocytes then increase their numbers rapidly. Explain how the formation of B lymphocytes leads to the production of antibodies, which can be used as anti-venom. [2]

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(ii) Suggest why anti-venom is administered to a person bitten by a puff adder even though they would produce their own antibodies to the toxin in the venom. [1]

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Anti-venom containing the purified antibodies is frozen or refrigerated to protect antibody proteins from heat damage while in storage until it is needed.

Scientists in Dubai have carried out research into the use of camels to produce anti-venom.

Camels are very large mammals that are able to tolerate body temperatures up to 41°C, several degrees higher than that of a sheep.

(iii) Giving a reason for your answer, suggest **one** advantage of using camels rather than sheep to produce puff adder anti-venom. [2]

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(d) Diphtheria is a potentially fatal bacterial disease caused by the Gram positive bacteria, *Corynebacteria diphtheria*.

Parts of South Africa have seen a rise in the number of cases of diphtheria due to a decrease in the number of children vaccinated.

Patients suffering from diphtheria are treated with antibiotics such as penicillin.

Penicillin inhibits an enzyme that is involved in the formation of the bacterial cell wall.

(i) Explain how inhibition of the enzyme described above causes bacterial cells to die. [2]

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(ii) Explain why penicillin is more effective against *Corynebacteria diphtheria* than it is against Gram negative bacteria. [2]

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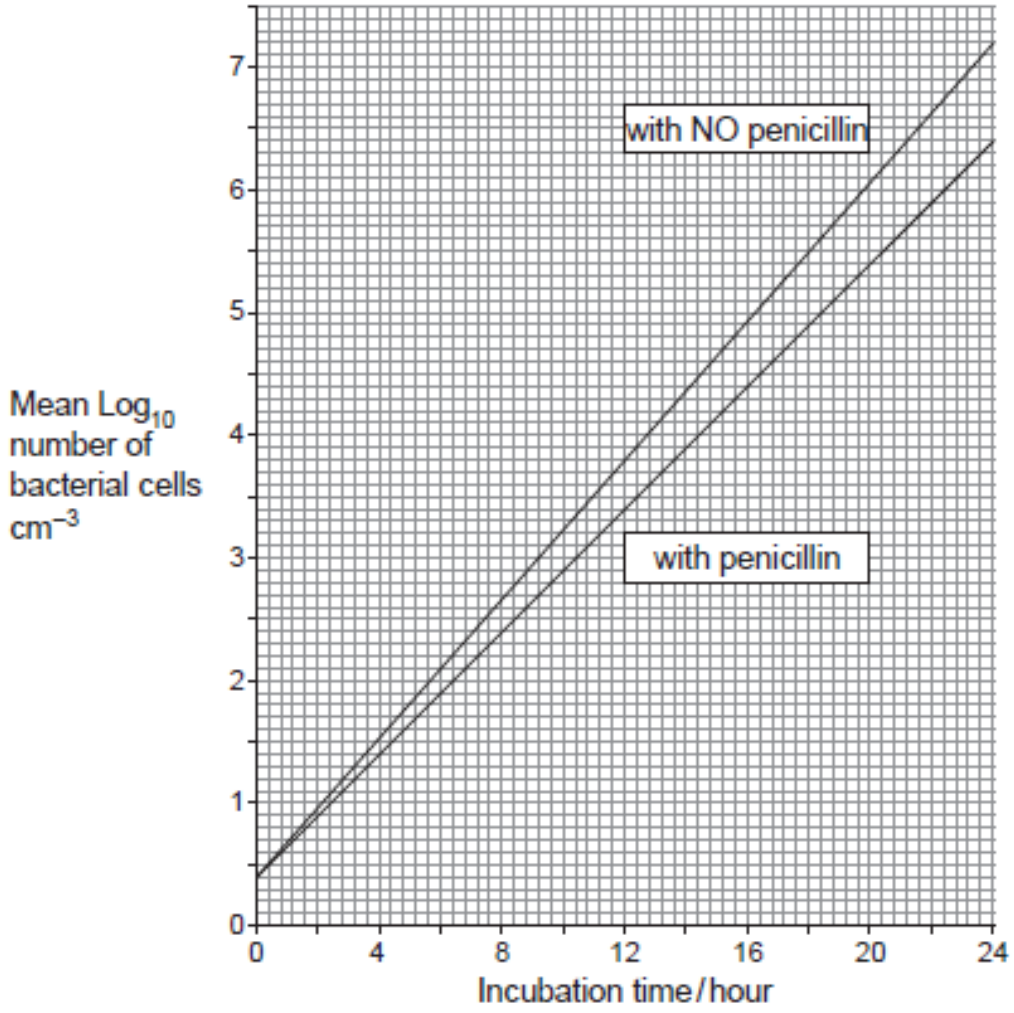
(e) Scientists investigated the effect of penicillin on the number of *C.diphtheria* cells growing in a nutrient broth in a laboratory.

A culture of *C. diphtheria* was incubated at 37°C in nutrient broth containing penicillin. A second culture was incubated at the same temperature in the same volume of nutrient broth containing no penicillin. Samples were taken from each culture at hourly intervals and the number of bacteria counted.

The mean $\log_{10}$ numbers of bacterial cells were plotted on a graph as shown in **graph 1.4**.

Graph 1.4



After 24 hours incubation with **no** penicillin, a $\log_{10}$ value of 7.2 on the graph indicated that the actual number of bacteria was 15848932 cm^{-3}

(i) Calculate the **actual** number of bacteria after 24 hours incubation with penicillin. [2]

Actual number of bacteria = ... cm^{-3}

(ii) The nutrient broth used to grow each *C.diphtheria* population contained compounds called peptones which provide a source of organic nitrogen. Explain why a source of nitrogen is included in the nutrient broth. [1]

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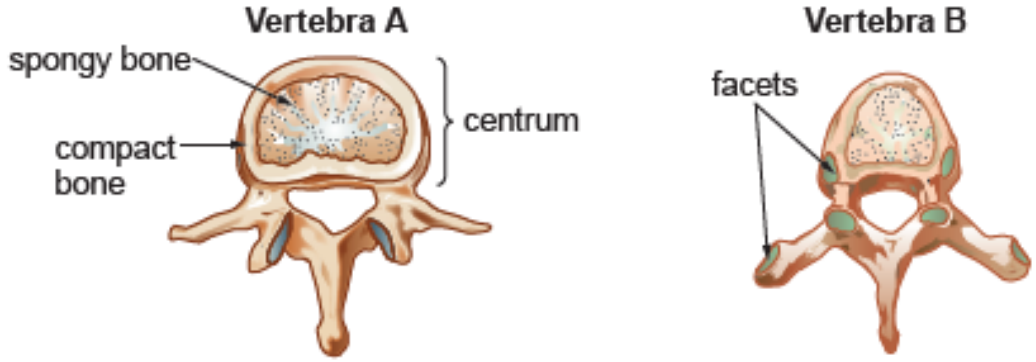
Option B: Human Musculoskeletal Anatomy

2. *(a)* **Image 2.1** shows two different vertebrae.

Image 2.1



(i) Vertebra **A** is found in the lumbar region of the vertebral column.
Identify the region of the vertebral column where vertebra B is found and state the specific function of the facets labelled on the image. [2]

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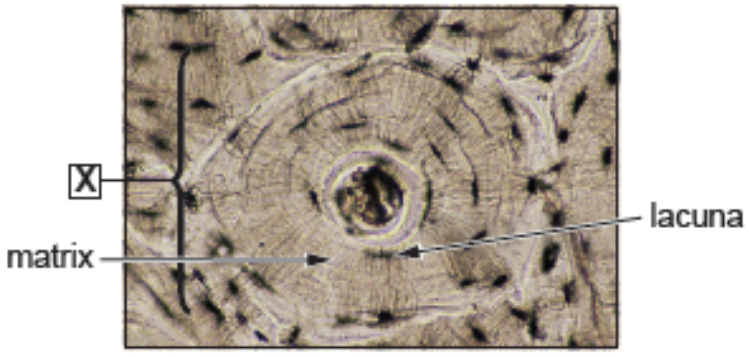
The centrum is formed from spongy (cancellous) bone and compact bone.

Image 2.2 hows a transverse section through an area of compact bone.

Image 2.2



(ii) Identify structure **X**. [1]

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In the matrix, organic and inorganic compounds contribute to bone density and hardness.

(iii) Name **one** organic and **one** inorganic compound found in the matrix. [2]

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

(b) The centrum plays a role in supporting body weight when upright. Bone should have a high enough density to carry out this function.

A bone density loss of 25% results in a condition called osteoporosis which carries a greater risk of fractures.

Bone density loss is a problem for astronauts on long duration space flights.

In 1989, American and Russian scientists investigated bone density changes in astronauts before and after space flights lasting 4–14 months.

Eighteen crew members underwent spine, pelvis and wrist bone density scans.

A baseline reading was taken from a scan 30 days before flight.

All astronauts carried out regular exercise, such as running on a treadmill, during flights. The space station was at 0.6 of the Earth's gravity.

A summary of the results is shown in **table 2.3**.

Table 2.3

Region of skeleton	Mean loss of bone density / % month^{-1}	Standard deviation (sd)
Spine (L1–L4) Lumbar		0.63
Spine Cervical	–1.15	0.84
Pelvis	–1.56	0.54
Wrist	–0.04	0.88

(i) The mean baseline total mass of four lumbar vertebrae (L1–L4) was 59.74 g.
At the end of a flight this had decreased to 52.14 g.
Calculate the percentage loss of bone density in these vertebrae during the entire flight. [2]

Percentage loss of bone density = ...

(ii) State the region of the skeleton that provides the greatest confidence in the data.
Give a reason for your answer. [1]

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(iii) Suggest a reason why the scientists chose to measure the bone density of lumbar vertebrae and the wrist as part of their study. [2]

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(iv) Describe why running on a treadmill might be expected to increase bone density or reduce bone density loss in parts of bones such as the centrum of the vertebrae. Explain how osteocytes (bone cells) in the lacunae of compact bone reduce bone density loss as a result of an activity such as running. [3]

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(c) Arthritis is a disease that causes inflammation and pain at joints.
Image 2.4 is an X-ray photograph showing osteoarthritis in part of the spine.

Image 2.4

(i) The position of inflammation is highlighted by the red areas. From the image, identify the tissue most likely to be affected in those areas. Explain how pain and further damage to the joint is likely to be the result. [2]

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(ii) Rheumatoid arthritis is an autoimmune disease that results in joint inflammation. Explain the cause of inflammation in this form of arthritis. [1]

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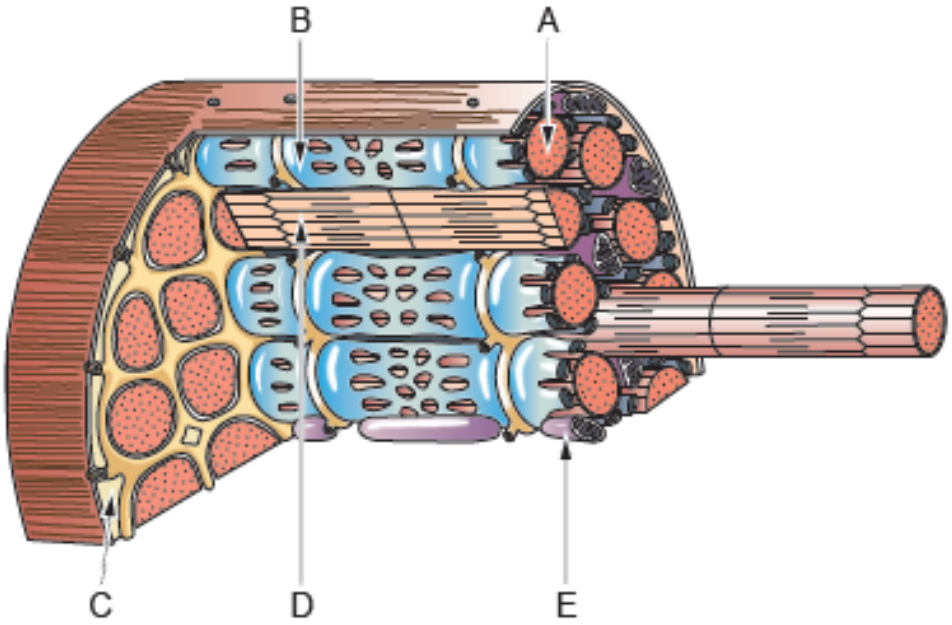
The spine provides a means of attachment for the spinal extensor muscles which contract to hold the body upright.

Strengthening bones and muscles can reduce the risk of back pain in non-arthritic joints.

Calcium in the diet can increase bone density in the vertebrae and is needed for normal muscle contraction. **Image 2.5** shows part of a striated muscle fibre.

Image 2.5



(iii) State the letter and name the component of the muscle fibre where calcium ions are stored. [1]

Letter .....

Name .....

Image 2.6 shows a representation of the arrangement of proteins of an actin filament in a myofibril.

Image 2.6

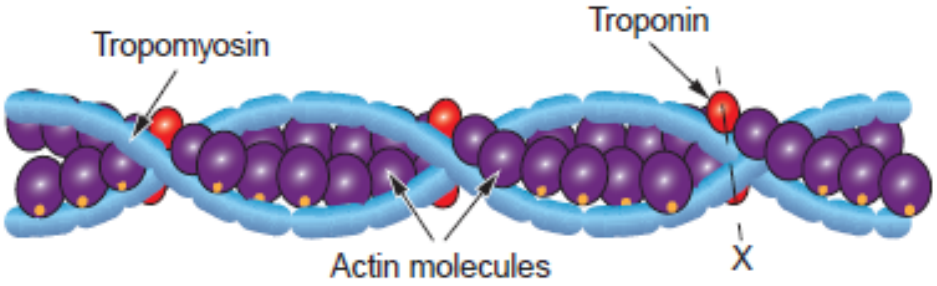


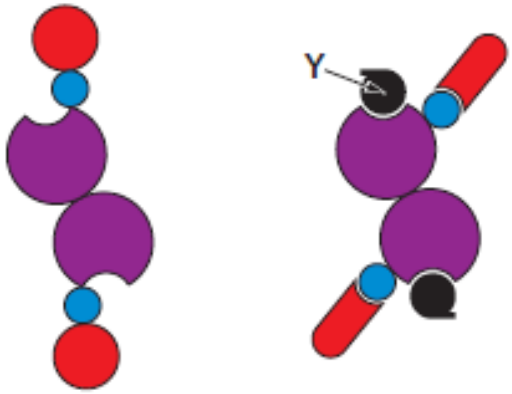
Image 2.7 shows a cross section through the structures of **Image 2.6** at the point marked **X**.

I. Represents their position when calcium ions are absent and

II. Represents their position when calcium ions are present.

Image 2.7

I. Calcium ions absent II. Calcium Ions present



(iv) With reference to structures represented in **image 2.7** and using your knowledge of proteins in the myofibril, explain the relationship between the presence of calcium ions and the position of structure **Y** in the process of muscle contraction. [3]

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Option C: Neurobiology and Behaviour

3. Many animals exhibit simple forms of innate behaviour.

(a) (i) Explain what is meant by innate behaviour. [1]

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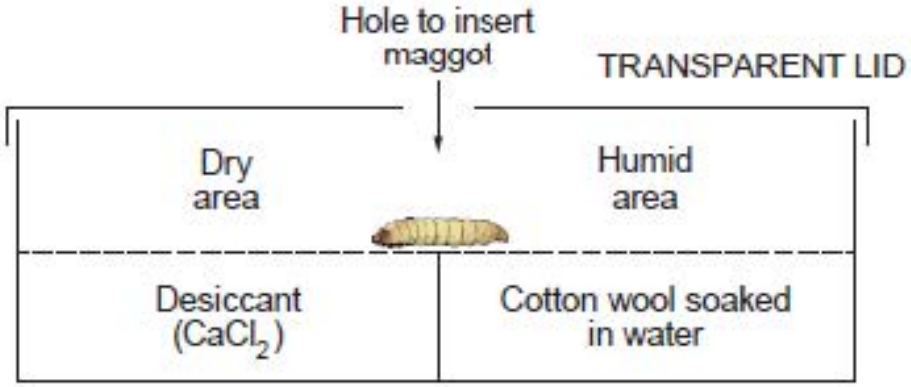
Blowflies *(Calliphora spp)* are insects that lay eggs on recently dead animals. Eggs hatch into larvae called maggots that feed inside the dead animal.

A student investigated the effect of humidity on the movement of maggots. The apparatus is shown in **image 3.1**.

Image 3.1



The student set up a choice chamber as shown in **image 3.1**.

- The base was separated into two compartments.
- Cotton wool soaked with water was placed in one compartment and calcium chloride granules were placed in the other ($CaCl_2$ is a desiccant or drying agent).
- A grid was placed above the compartments and the lid replaced.
- The air above each compartment became humid or dry depending on the content of the compartment.
- One maggot selected randomly from a large sample group, was placed carefully in the centre of the grid through a hole in the lid.
- At 10 second intervals, the position of the head of the maggot was marked by a numbered dot on the transparent lid.

(ii) Before use in the experiment, the maggots were kept at room temperature for 10 minutes to allow them to equilibrate. Explain why this was necessary. [1]

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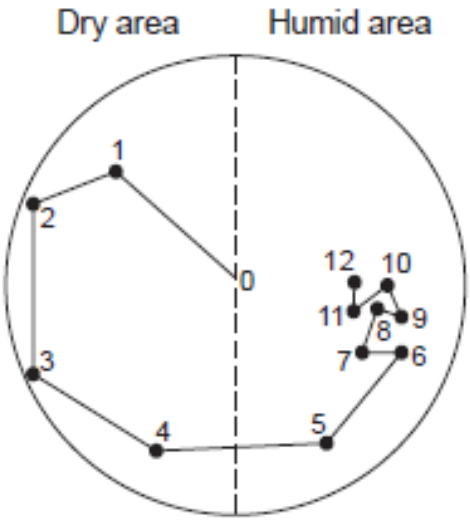
After 2 minutes, the student removed the maggot then joined the dots on the lid. The pathway of the maggot over 2 minutes showing its position at 10 second intervals is shown in **image 3.2**.

Image 3.2.



The procedure was repeated several times using a different maggot each time.

(iii) Identify the type of innate behaviour shown by the maggot in this experiment and describe **one** feature of the pattern of movement that supports your conclusion. [2]

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(iv) Suggest how this behaviour would be an advantage to the maggot in its natural environment. [2]

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(v) The rate of movement during the first minute was calculated by measuring the total length of the lines drawn on the lid from 0 to 6 and dividing by 60 seconds. Suggest why calculating the rate of movement from this data is likely to be inaccurate. [1]

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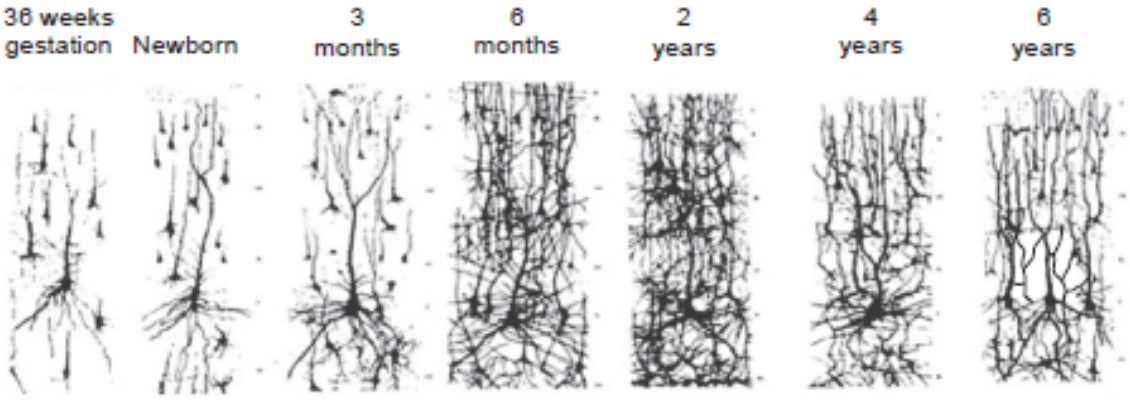
(b) Mammals exhibit innate and learned behaviour.

Young mammals need sensory input during a critical receptive stage of early development. This enables them to develop learned behaviour that also uses motor areas of the brain.

Image 3.3 shows the developmental changes in the neurones of a human cerebral cortex before, during and after this critical time period.

Image 3.3



(i) State the name that describes the changes in the development of neurones illustrated in **image 3.3**. [1]

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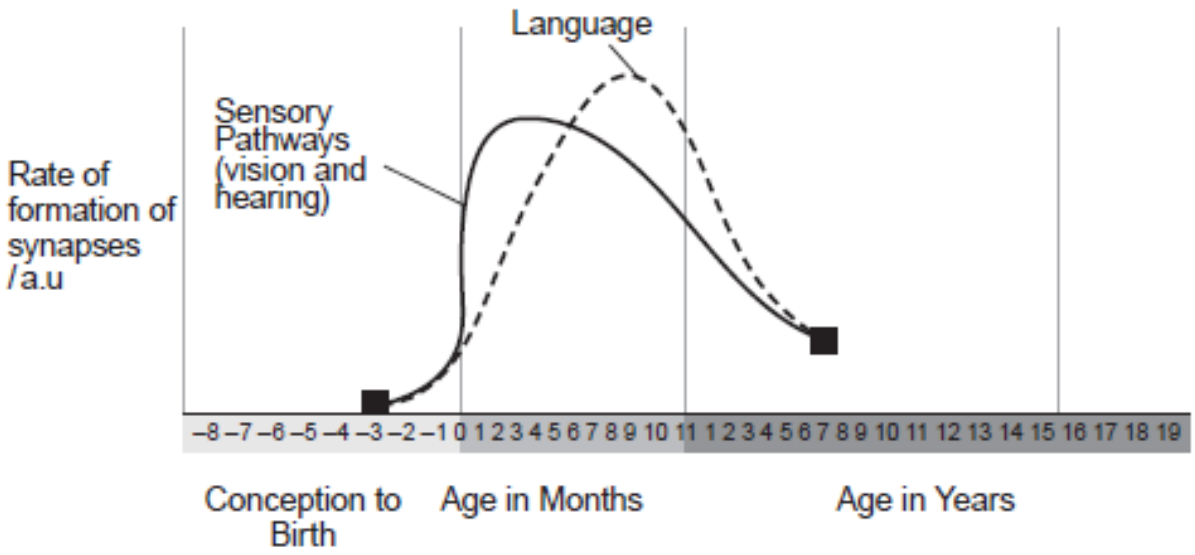
Graph 3.4 shows the rate of formation of synapses involved in sensory pathways and language development in early childhood.

Graph 3.4



(ii) Using information from **graph 3.4**, together with your own knowledge, explain why hearing deficiency during the critical period for the formation of sensory pathways can result in poor speech and language development. [3]

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(iii) With reference to the neurones of a 4 year old and 6 year old (photographs 6 and 7), suggest why speech and language does not improve significantly if hearing is restored after the critical period. [1]

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(iv) State the names of the **two** areas of the cerebral cortex associated with the development of speech and language. [1]

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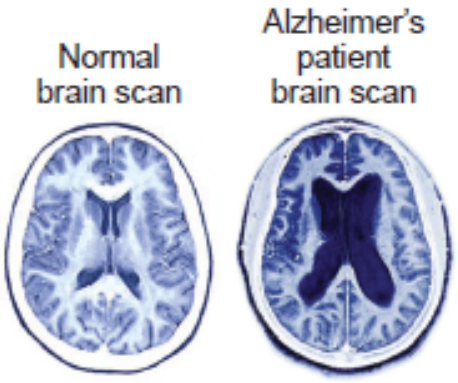
(c) Alzheimer's disease is a condition that causes gradual deterioration of tissue in the brain over several years. The onset of Alzheimer's disease is associated with increasing age.

Patients suffering from Alzheimer's disease show varying degrees of atrophy (brain shrinkage) as shown in the CT scan in **image 3.5**.

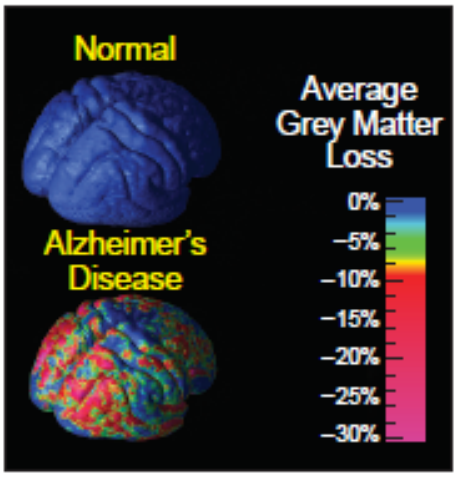
Image 3.5



The degree of atrophy can also be measured using an MRI scan such as the one shown in **image 3.6**.

Image 3.6

MRI comparison of a normal brain and the brain of a patient with Alzheimer's disease.



(i) Compare the way that a CT and MRI scan image is produced and suggest two advantages of using an MRI scan for monitoring the progression of Alzheimer's disease. [3]

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(ii) State **one** factor that should be considered in order to make a valid comparison between the brain of an Alzheimer's patient and a normal brain. [1]

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Memory loss can be a symptom of Alzheimer's disease.

The hippocampus is one area of the brain where memory is processed. The position and relative size of the hippocampus is shown in **image 3.7**.

Image 3.7

hippocampus

Scientists suspected that loss of volume of the hippocampus may account for some memory loss. MRI scans were used to measure the volume of the hippocampus and the total brain volume in several Alzheimer's patients with degrees of memory loss over a 12 month period.

A summary of the results is shown in **table 3.8**.

Table 3.8

Component/portion of the brain	Mean volume/mm^3	
	At Start	After 12 months
Hippocampus	4065	3537
Total Brain	1.534×10^6	1.453×10^6

(iii) The ratio of the total brain volume to hippocampus volume at the start of the 12 month period was 377 : 1.

I. Calculate the ratio of the total brain volume to hippocampus volume after 12 months. [2]

Ratio = ... : .....

II. Explain what the difference between these two ratios indicates about the size of the brain and the hippocampus. [1]

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END OF PAPER