GCE A LEVEL

1400U40-1

THURSDAY, 13 JUNE 2019 – MORNING

BIOLOGY – A2 unit 4

Variation, Inheritance and Options

2 hours plus your additional time allowance

Surname _____

Other Names _____

Centre Number _____

Candidate Number 2 _____

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
Section A	1.	15	
	2.	13	
	3.	8	
	4.	12	
	5.	5	
	6.	8	
	7.	9	
Section B	Option	20	
	Total	90	

ADDITIONAL MATERIALS

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

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball-point pen or your usual method.

Write your name, centre number and candidate number in the spaces provided on the front cover.

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

INFORMATION FOR CANDIDATES

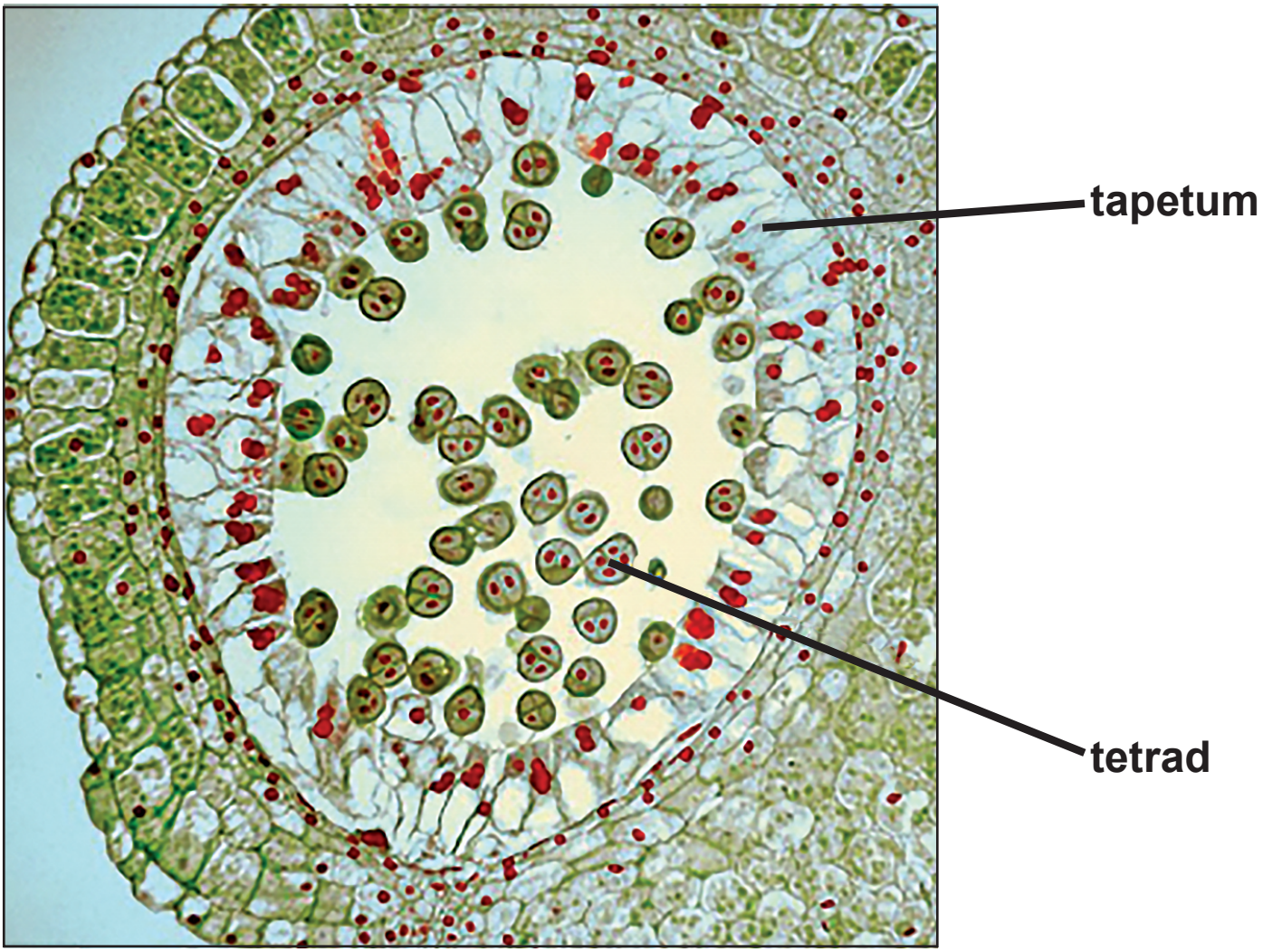
This paper is in 2 sections, A and B.

Section A: 70 marks. Answer all questions. You are advised to spend about 1 hour 35 minutes plus your additional time allowance on this section.

Section B: 20 marks; Options. Answer ONE OPTION ONLY. You are advised to spend 25 minutes plus your additional time allowance on this section.

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

The assessment of quality of extended response (QER) will take place in question 7. The quality of written communication will affect the awarding of marks.


tapetum
tetrad

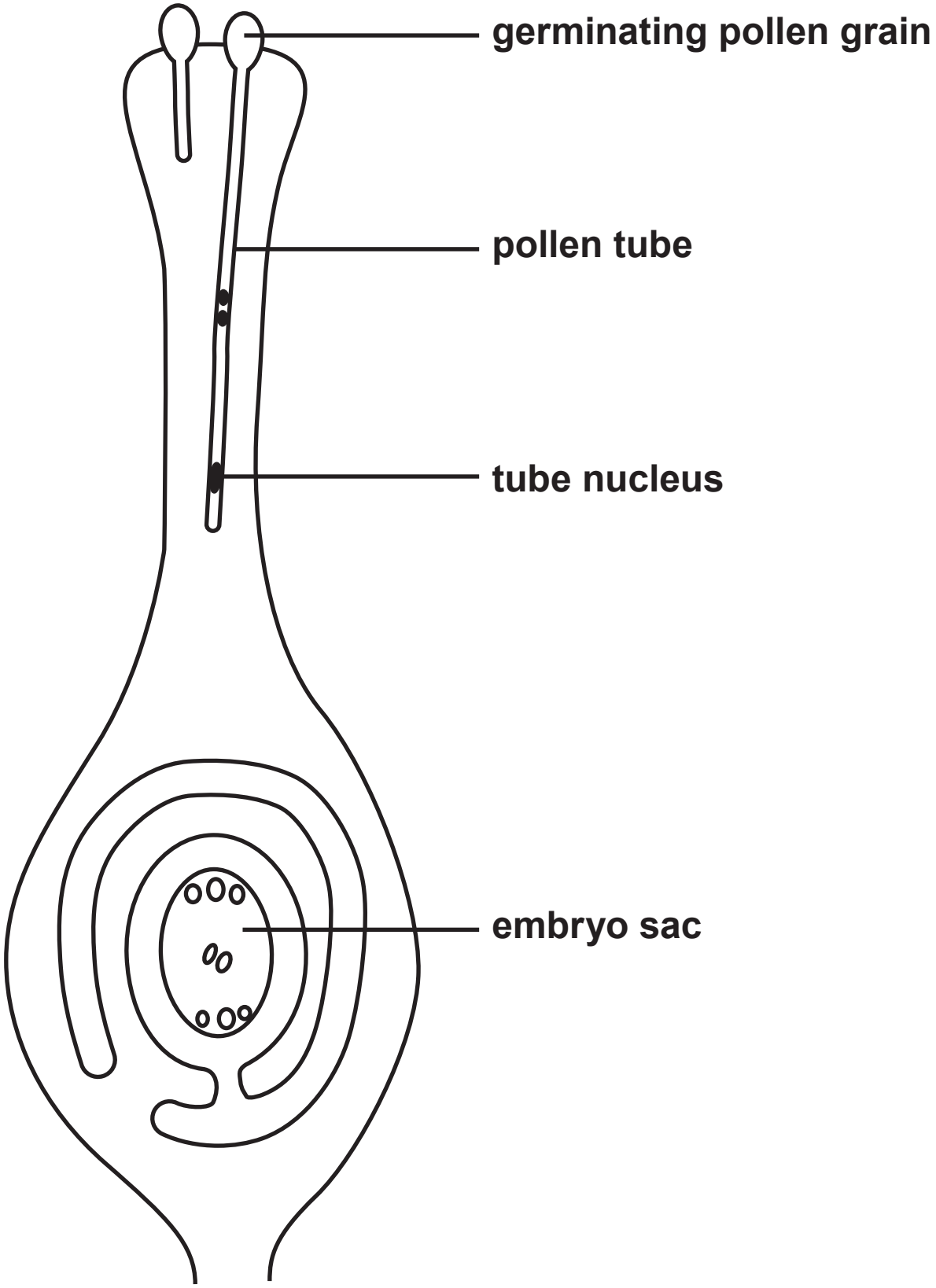
SECTION A

Answer ALL questions.

1(a) The photomicrograph opposite shows a section through part of an anther.

(i) State the function of the tapetum. [1]

(ii) Explain the appearance of the tetrad. [2]

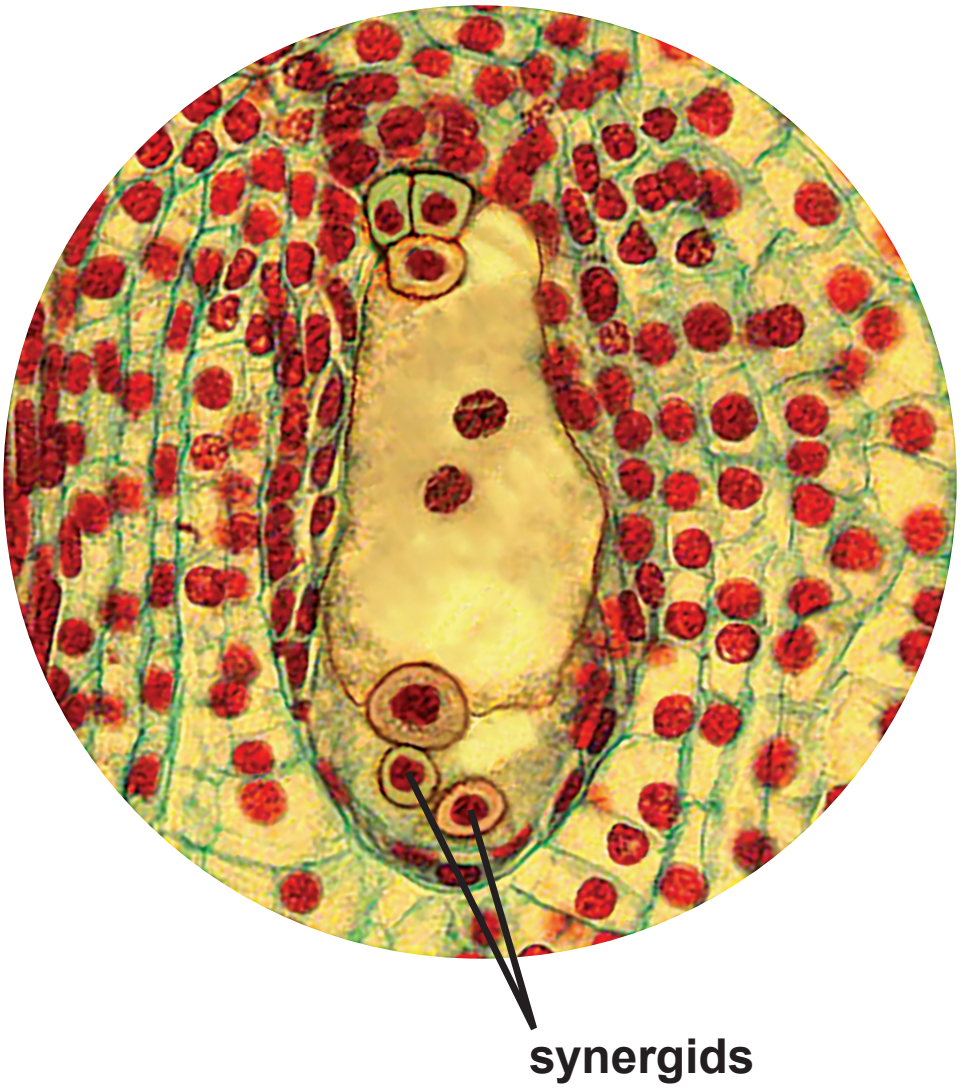

germinating pollen grain
pollen tube
tube nucleus
embryo sac

1(b) The diagram opposite shows a carpel following pollination.

(i) Describe the function of the tube nucleus in the growth of the pollen tube. [2]

1(b) (ii) **In maize, the distance between the stigma and the micropyle is 20 cm. It takes 20 hours for the pollen tube to grow and reach the micropyle. Calculate the rate of growth of the pollen tube. Give your answer to one decimal place. [3]**

Rate of growth = _____ mm minute^{-1}


synergids

The photomicrograph opposite shows an embryo sac in the carpel.

1(b) (iii) **Use clearly drawn label lines to show the following:**

A = Female gamete.
B = Polar nuclei. [1]

(iv) **Describe the role of mitosis and meiosis in the formation of the female gamete. [3]**

1(b) (v) **With reference to the photomicrograph opposite page 8, explain why fertilisation in plants is referred to as double fertilisation. [3]**

15

Genotype	Description
HbA HbA	Haemoglobin does not cause red blood cells to sickle.
HbA HbS	Codominant alleles producing 50% normal haemoglobin and 50% mutated. Sickling of red blood cells can take place at low partial pressures of oxygen. This is called sickle cell trait.
HbS HbS	All haemoglobin is affected which results in severe sickling of red blood cells. Red blood cells only live for 10 – 20 days causing severe anaemia (sickle cell anaemia). Without treatment, it is rare for individuals homozygous for this condition to live to reproductive age.

2. **Human haemoglobin has a quaternary structure consisting of 2 alpha and 2 beta polypeptide chains. A mutation can result in the production of a beta chain which causes a red blood cell to become distorted into a sickle shape at low partial pressures of oxygen.**

The table opposite shows the genotypes present in a population, where the allele for normal haemoglobin is HbA and for the abnormal haemoglobin is HbS.

2(a) **Using the equations below, calculate the frequency of alleles HbA and HbS in African-Americans living in America where 1 in 625 suffers from sickle cell anaemia.**

Use these values to calculate the percentage frequency of heterozygotes in the population. [4]

p = frequency of HbA

q = frequency of HbS

$p + q = 1$

$p^2 + 2pq + q^2 = 1$

frequency of HbA = _____

frequency of HbS = _____

frequency of heterozygotes = _____

% frequency of heterozygotes = _____

2(b) **Malaria is the most serious and wide-spread parasitic disease in humans; the vast majority of global malaria cases are in Africa.**

Sickle red blood cells are less likely to be infected by the malarial parasite.

The frequency of heterozygotes (HbA HbS) in some parts of Africa is approximately 42%.

The frequency of heterozygotes in African-Americans is lower than in native African populations.

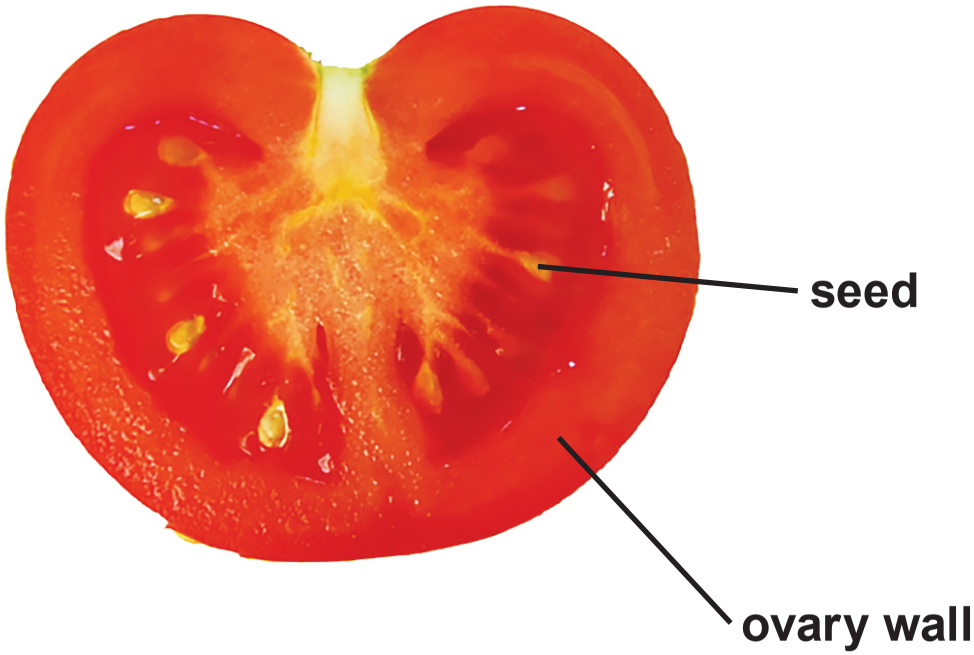
Using the information provided and your own knowledge, explain the differences in the percentage frequency of African-American heterozygotes compared to those in Africa. [5]

2(c) **Malaria is caused by a parasite of the genus *Plasmodium* and it is transmitted from one person to another by *Anopheles* mosquitoes. In 2002, after seven years, the Plasmodium Genome Project and the Anopheles Genome Project were both completed.**

(i) **State what information has been obtained from the Anopheles and Plasmodium Genome Projects. [2]**

2(c) (ii) State TWO uses of the information obtained from these genome projects in the control of malaria. [2]

13


seed
ovary wall

3. **Flowers may be insect or wind-pollinated. After pollination, plants produce seeds. The photographs opposite show a tomato flower, which is insect-pollinated, and a vertical section through a tomato fruit.**

(a) **State how the appearance of the flower would be different if the tomato flower was wind-pollinated.**

[2]

_____

_____

_____

_____

3(b) The ovary wall of the tomato fruit produces chemicals that inhibit germination of seeds before they are dispersed.

An experiment was carried out to compare the concentration of inhibitor in two varieties of tomato. Germination inhibitors were extracted from the ovary wall as follows:

- grind up tissue in solvent using a pestle and mortar
- filter the extract
- place extract on filter paper
- allow solvent to evaporate

(i) State THREE ways in which you would ensure that the extracts from both varieties of tomato were comparable. [2]

To compare the concentration of inhibitor the following procedure was followed:

- **wash seeds in distilled water**
- **place seeds on filter paper containing extract**
- **provide the conditions required for germination**
- **calculate the percentage of seeds germinated after three days**

3(b) (ii) Explain why the seeds need to be washed before placing on the filter paper. [1]

(iii) Explain why the extracts from both varieties of tomato were tested on seeds from both varieties. [1]

3(b) (iv) Describe and explain a suitable control for this experiment. [2]

8

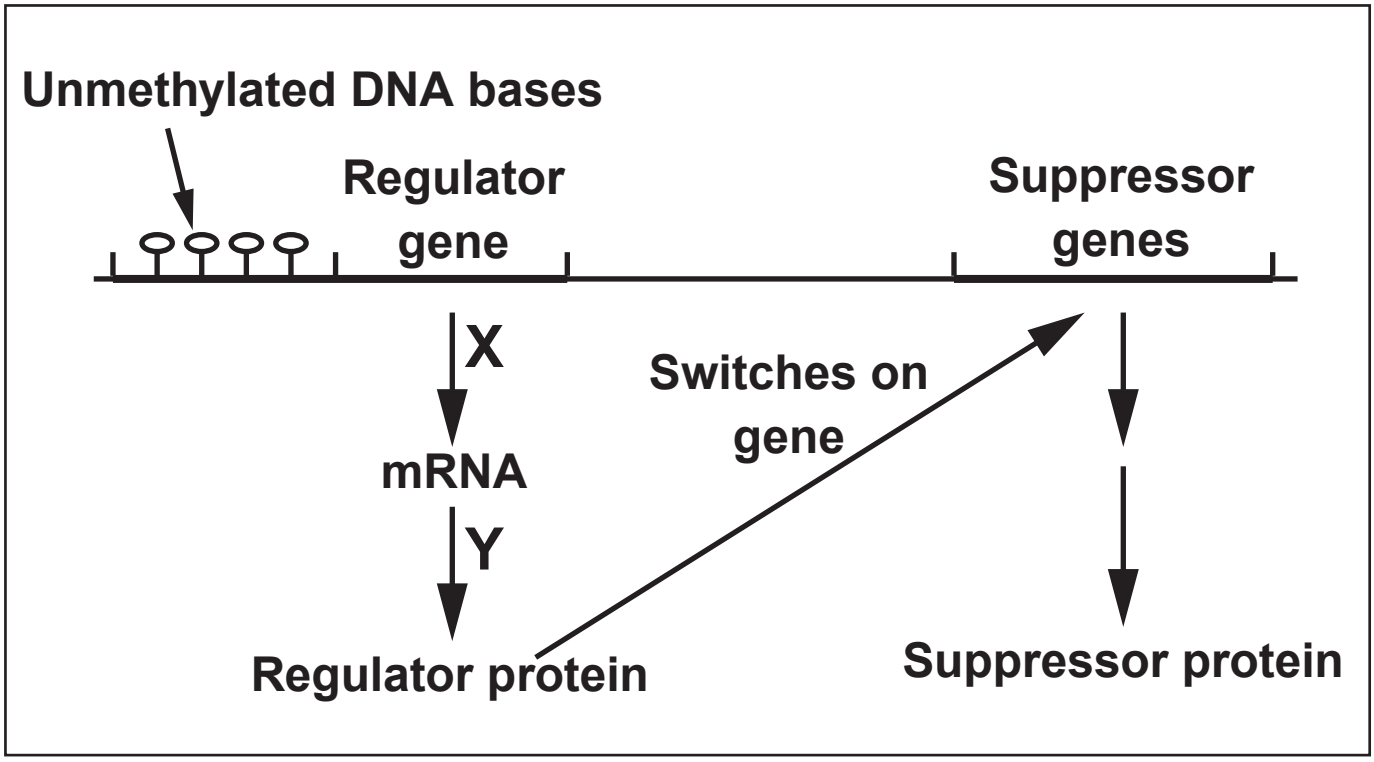
4. Cancers are caused by disruption of the normal cell cycle and can involve proto-oncogenes and epigenetic factors. Some cancers can be treated using chemotherapy which also kills some of the non-cancerous body cells. After treatment the tissues can be repopulated using stem cells.

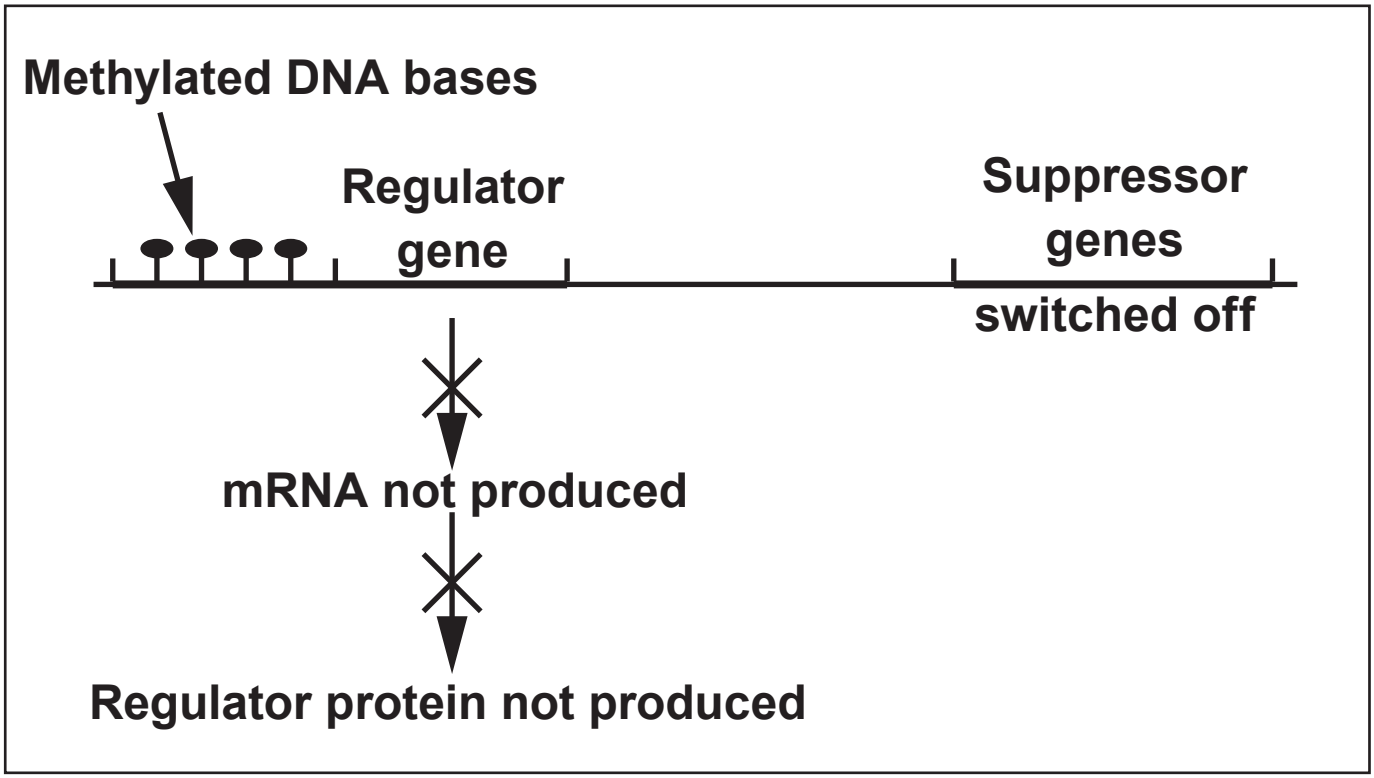
(a) Define what is meant by the following terms: [3]

(i) Proto-oncogene

(ii) Epigenetics

4(a) (iii) Stem cell


Unmethylated DNA bases
Regulator gene
Suppressor genes
X
mRNA
Y
Switches on gene
Regulator protein
Suppressor protein


Methylated DNA bases
Regulator gene
Suppressor genes
switched off
mRNA not produced
Regulator protein not produced

4(b) **In the human genome there are suppressor genes which regulate cell division and growth. These genes can be switched off (silenced) to increase cell division or growth, and switched on to suppress division and growth.**

Two molecular processes are vital in the silencing of genes, DNA methylation and histone modification.

The diagram opposite shows the effect of DNA methylation.

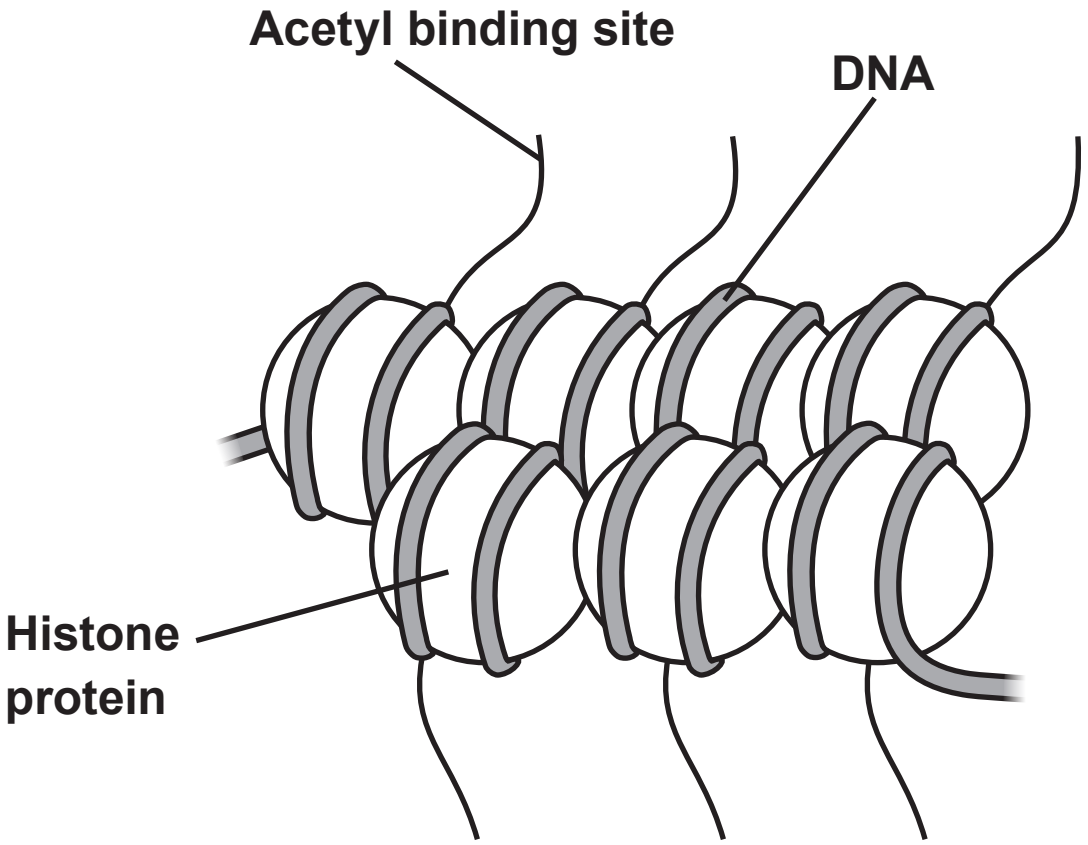
(i) **Name the processes labelled X and Y on the diagram. [1]**

X _____

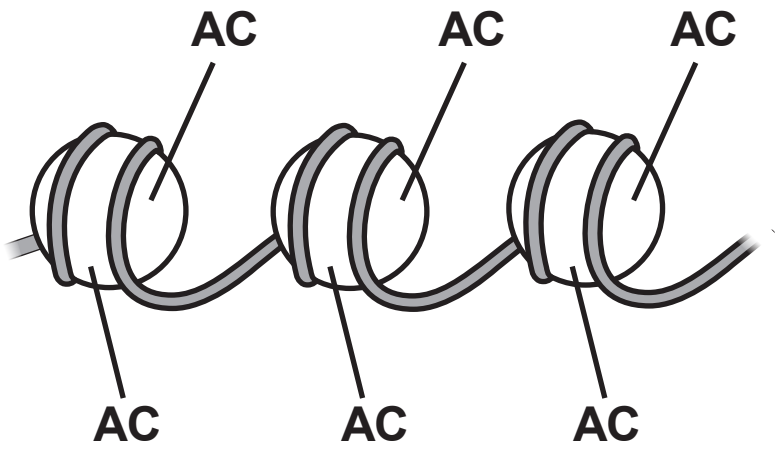
Y _____

4(b) (ii) **Cancer cells can cause DNA methylation in non-cancerous cells. With reference to the diagram explain how DNA methylation results in tumour growth. [3]**

Genes switched off



Genes switched on



AC = acetyl group

Histones are proteins which have DNA wrapped around them as shown in the diagram opposite. The histones can be acetylated by having an acetyl group added to them by an enzyme. Acetylated histones have an open structure which allows RNA polymerase to have access to the DNA and the genes are switched on.

4(b) (iii) In relation to the diagram opposite, suggest how cancer cells switch the suppressor genes off. [3]

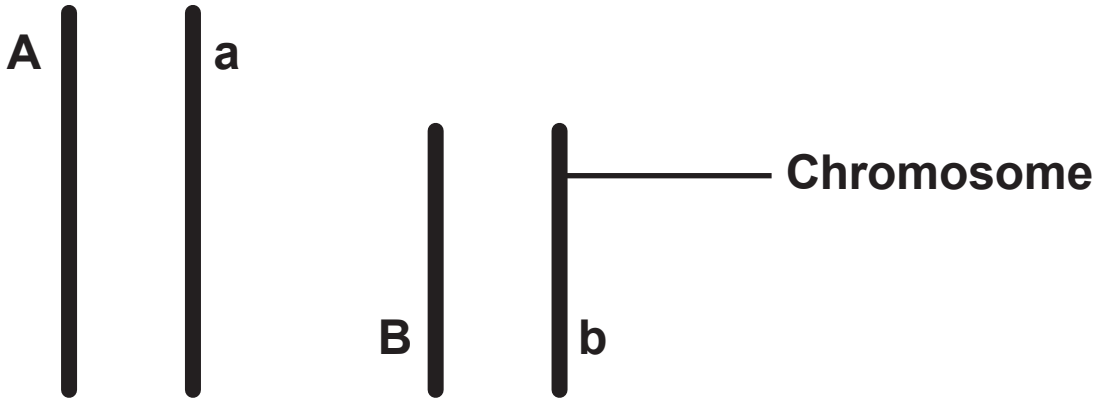
4(b) (iv) **In some humans, tumour suppressor genes can become permanently switched off in ALL CELLS in the body. Explain the consequences of such a change. [2]**

12

5(a) **An organism heterozygous for two genes, A and B, has the genotype AaBb.**

(i) **The alleles are arranged as shown in the diagram below. State the genotypes of the gametes produced and the expected phenotype ratio of the offspring in the F_1 following a cross between AaBb and AaBb.**

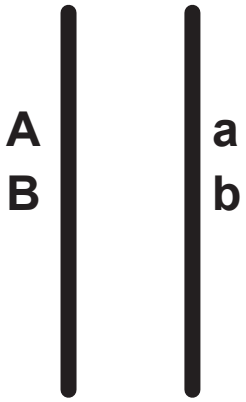
[2]



Gamete genotypes: _____

F_1 phenotype ratio: _____

5(a) (ii) **The alleles could be arranged as shown below.**



Explain why a cross between AaBb and AaBb in the above could produce a phenotype ratio of 3:1. [2]

5(b) Explain why two individuals, both with genotype AaBb, may not be phenotypically identical for these characteristics. [1]

5

6. The human reproductive cycle is controlled by several hormones.

(a) Clomifene is a medication used to treat some forms of infertility. It leads to increased release of FSH and LH. Suggest how clomifene increases the chance of conception. [2]

6(b) Prolactin and oxytocin are hormones which play a role in birth and feeding of the child after birth.

(i) Prolactin concentrations stay higher in women who are breastfeeding.
Prolactin inhibits the production of FSH.

Describe the role of prolactin in women who are breastfeeding and explain why they have a reduced chance of conception.
[3]

6(b) (ii) Explain why oxytocin production during birth is an example of positive feedback. [3]

8

7. Plants, such as maize (*Zea sp.*), can be genetically modified to provide resistance to insect pests. The bacterium, *Bacillus thuringiensis*, naturally produces a protein toxic to insects. The Bt gene that codes for this protein can be introduced into plant cells using a genetically engineered plasmid. One way of achieving this is to prepare a cDNA fragment containing the Bt gene and then incorporating it into a suitable plasmid.

Describe how a cDNA fragment containing the Bt gene can be prepared and the processes by which genetically engineered plasmids can be produced. Explain why there are concerns over the use of such a technique to increase resistance to insect pests in crop plants. [9 QER]

9

SECTION B: OPTIONAL TOPICS

Option A: IMMUNOLOGY AND DISEASE ☐

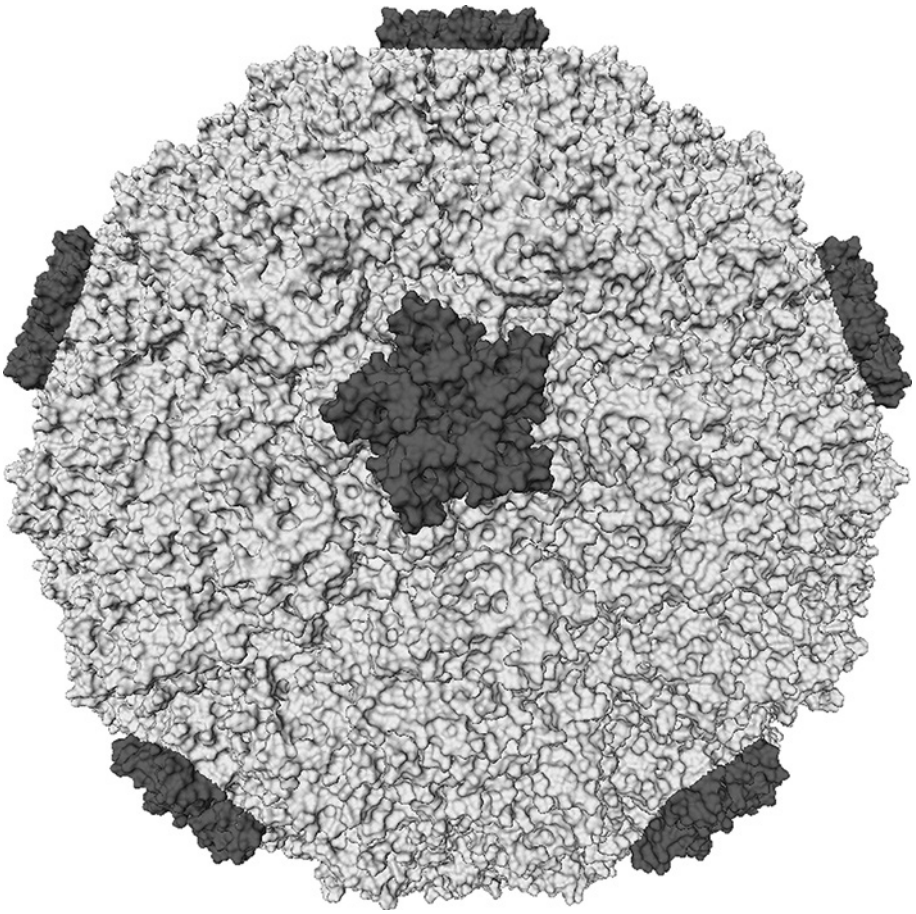
Option B: HUMAN MUSCULOSKELETAL ANATOMY ☐

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 PLUS YOUR ADDITIONAL TIME ALLOWANCE ON THIS SECTION.



Rhinovirus

OPTION A: IMMUNOLOGY AND DISEASE

8. **The common cold is caused by a rhinovirus such as shown opposite which infects the cells of the nasal epithelium.**

Symptoms of this infection include a runny nose, sneezing, cough and sore throat. The nasal epithelium contains ciliated mucous membranes which usually act as a natural barrier to infection by trapping microbes entering in inhaled air.

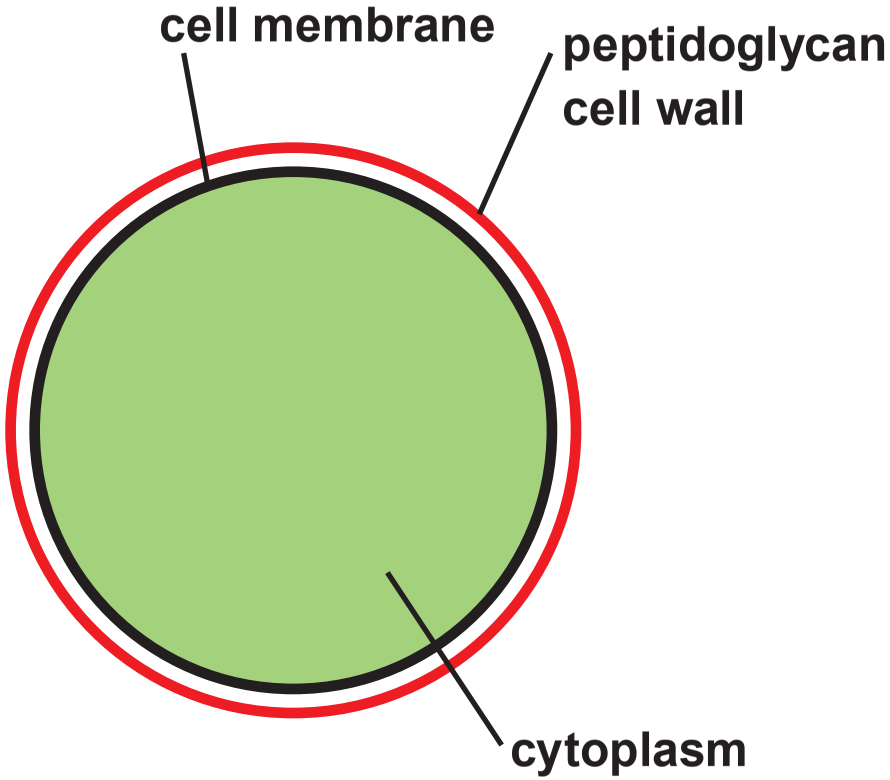
(a) **(i)** **State THREE OTHER natural barriers to infection in the body. [1]**

8(a) (ii) **Explain why the body is sometimes described as a host to other living organisms. [1]**

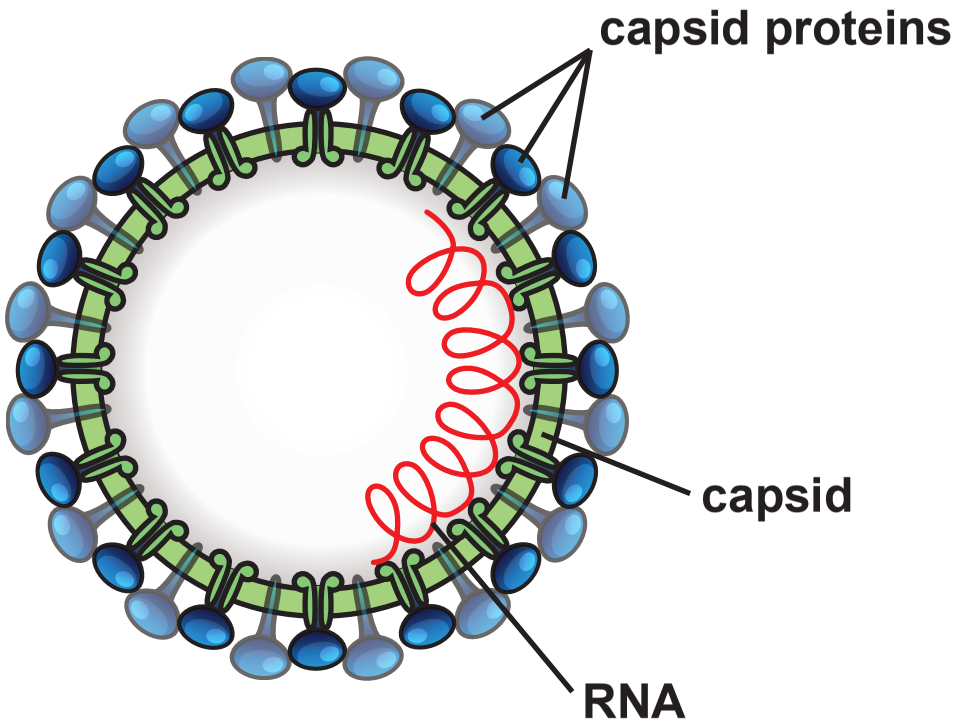
(iii) **Rhinovirus uses the metabolic pathways of a host cell to produce many copies of the virus. Explain how infection with rhinovirus could cause cell death. [1]**

8(a) (iv) **In cells infected with rhinovirus, the cell-mediated immune response involves the activation of B and T lymphocytes, and phagocytes.**
Explain how phagocytes and T lymphocytes bring about the cell-mediated response against rhinovirus. [3]

S. PYOGENES



RHINOVIRUS

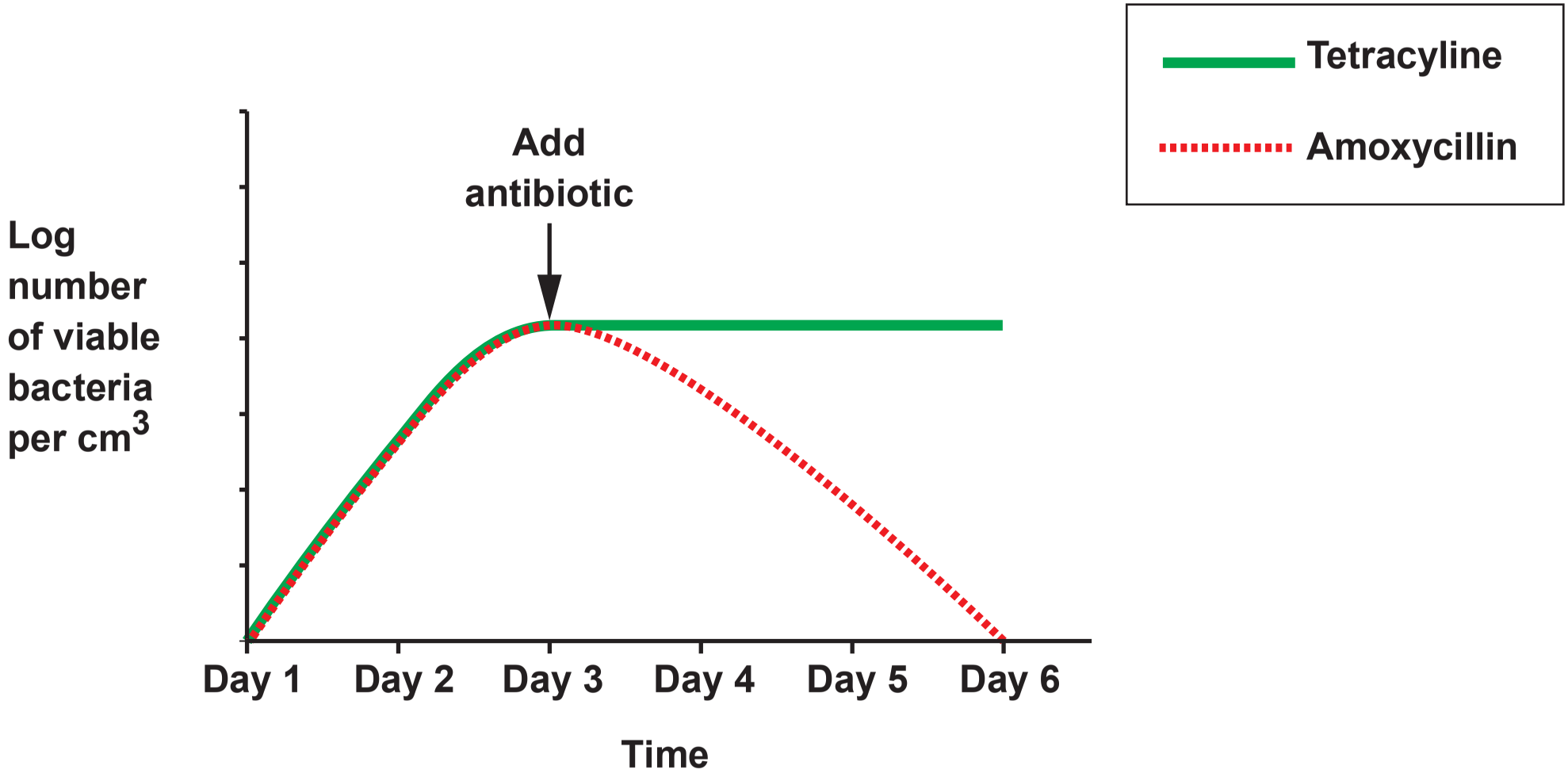


8(b) Symptoms of a cold can also be caused by other viruses and bacterial infections. **Streptococcus pyogenes** is a species of Gram-positive bacteria which produces similar symptoms. These symptoms can be treated with antibiotics. The diagrams opposite show simplified structures of a coccus bacterium (such as **S. pyogenes**) and a virus (such as rhinovirus).

(i) With reference to the diagram opposite, explain why antibiotics can be used to treat colds caused by **S. pyogenes** but not those caused by rhinovirus. [3]

8(b) (ii) Patients infected with *S. pyogenes* can be treated with the antibiotic amoxycillin which has a similar mode of action to penicillin. The recommended dosage is at 25 mg kg^{-1} twice a day for 10 days. Calculate the total dosage over the 10 days for a child weighing 14.5 kg. [2]

Total dosage = _____ mg


Tetracyline
Amoxycillin
Add
antibiotic
Log
number
of viable
bacteria
per cm3
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Time

Scientists studied the effect of tetracycline and amoxycillin on *S. pyogenes*.

The same number of bacteria were inoculated into the same type of nutrient medium and cultured for 6 days at 35 °C in aerobic conditions. Amoxycillin was added to one culture and tetracycline was added to the other at day 3. The graph below shows how the number of viable bacteria change during the course of the experiment.

8(b) (iii) Using the graph opposite, identify the mode of action of these two antibiotics and explain how you reached this conclusion. [2]

8(b) (iv) **State TWO factors that would need to be controlled to increase confidence in the results. [2]**

(v) **Explain why *S. pyogenes* was cultured at 35 °C. [1]**

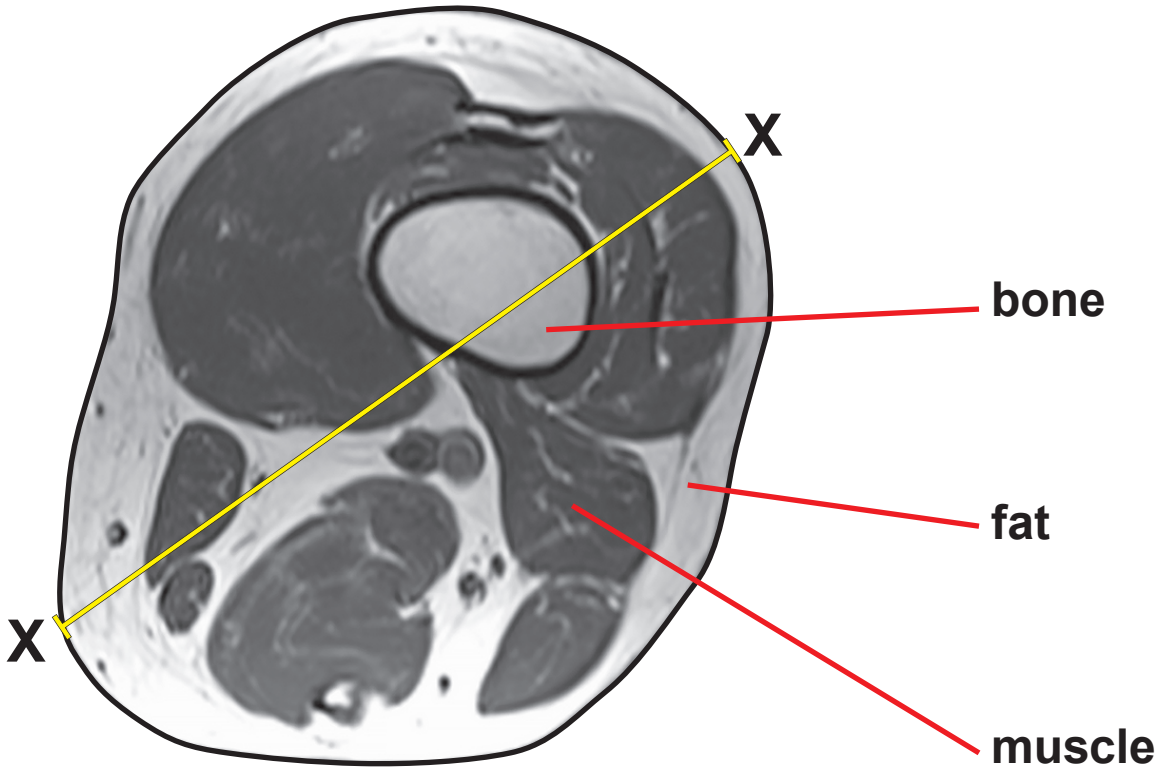
8(c) Vaccination programmes for the common cold caused by rhinovirus have so far proved unsuccessful.

(i) Using your own knowledge of immunisation, suggest and explain why it is unlikely that a vaccine for the common cold will ever be developed. [3]

8(c) (ii) **The flu virus causes many similar symptoms to the common cold. There is a vaccine against the flu virus which can provide protection. It is offered to certain 'at-risk' groups. These immunisations are not compulsory.**

Suggest why it would be considered unethical to make the flu vaccine compulsory for all. [1]

20


X
X
bone
fat
muscle

OPTION B: HUMAN MUSCULOSKELETAL ANATOMY

9. The image opposite shows a transverse section through the human thigh using an imaging technique called magnetic resonance imaging (MRI). The image shows bone, fat and muscle.

(a) (i) Name the bone shown within the thigh. [1]

_____

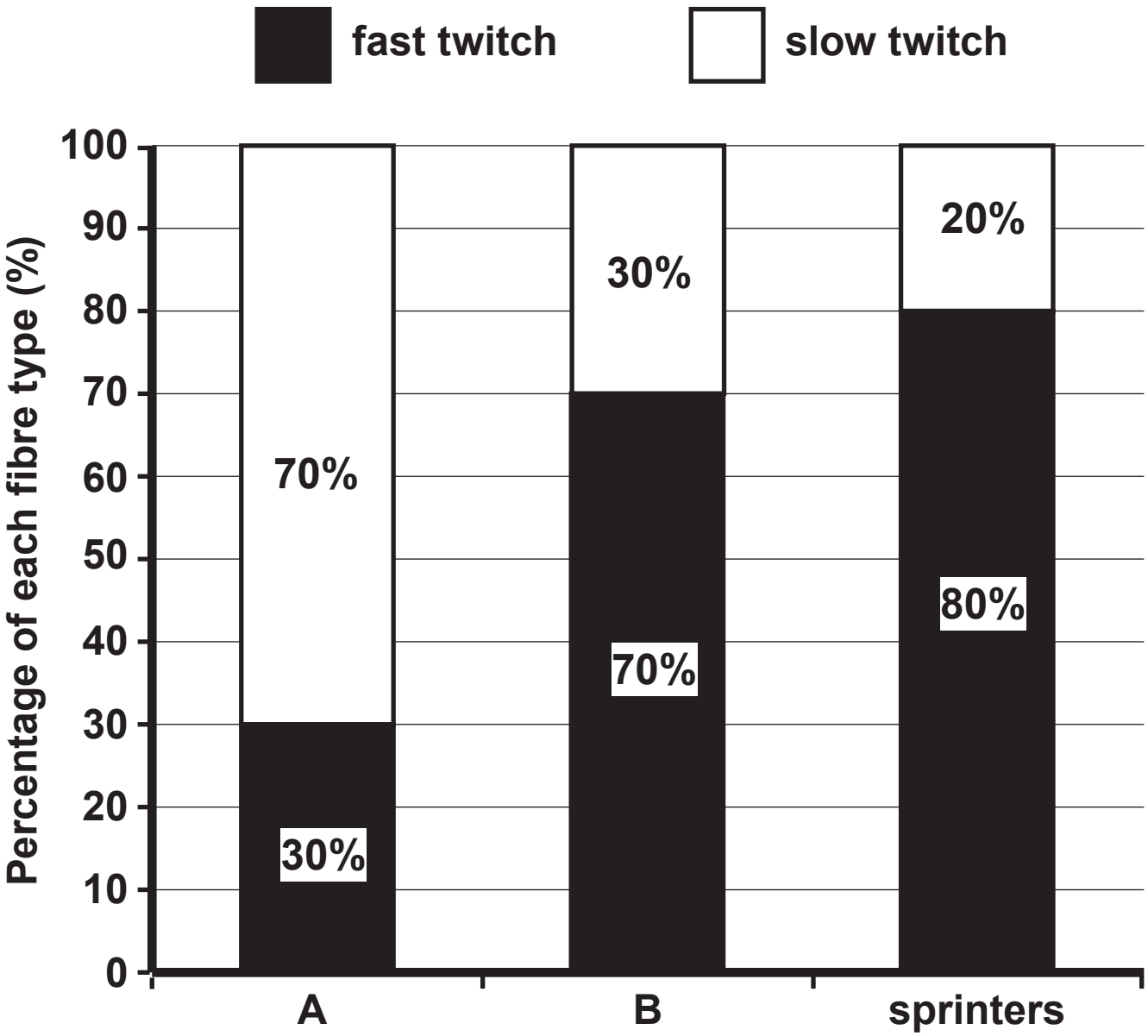
_____

(ii) At point X-X on the image the thigh has an actual width of 150 mm.
Calculate the magnification of the image.
[2]

magnification = _____

9(a) (iii) **Bones have an outer layer of compact bone. State which inorganic components strengthen the bone. [1]**

(iv) **Explain how the structure of the thigh bone enables nutrients to be supplied to the osteoblasts and osteoclasts. [2]**


fast twitch
slow twitch
Percentage of each fibre type (%)
100
90
80
70
60
50
40
30
20
10
0
70%
30%
30%
70%
20%
80%
A
B
sprinters

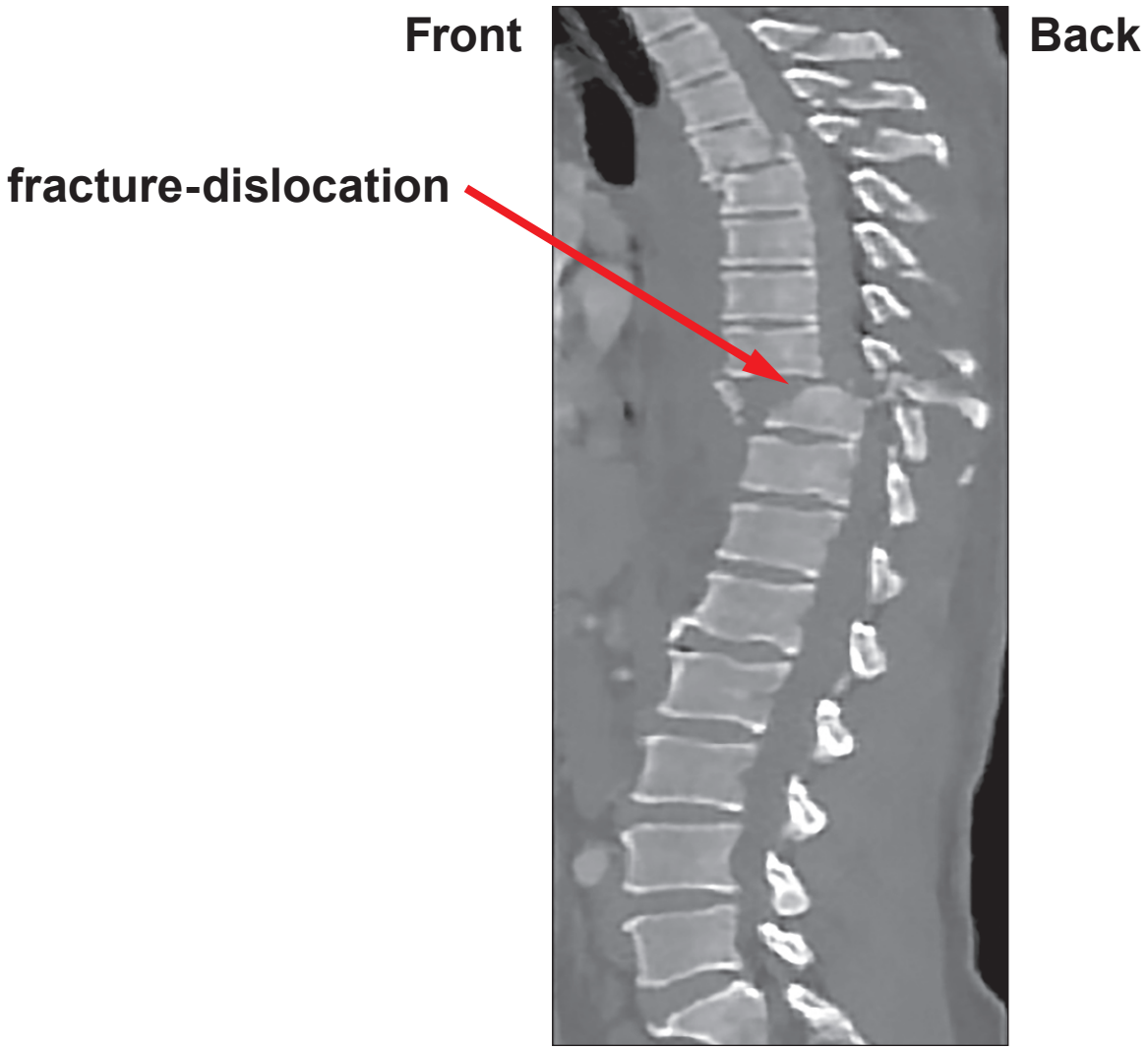
The proportion of fast and slow twitch muscle fibres was investigated in the muscles of the thigh in a range of athletes. The graph opposite shows the percentage of slow and fast twitch fibres in the muscle samples.

9(a) (v) Investigators observed a difference in colour between fast and slow twitch fibres. Suggest what this difference may be and explain your answer. [2]

9(a) (vi) **Explain why the percentage of fibres was calculated rather than using the total number of each fibre type. [2]**

(vii) **Explain why the athletes chosen were of the same age, gender and ethnicity. [1]**

9(a) (viii) **It was concluded that Athlete B was a weightlifter as further analysis of the tissue found high lactate levels. With reference to the graph and your own knowledge explain how they reached this conclusion. [3]**

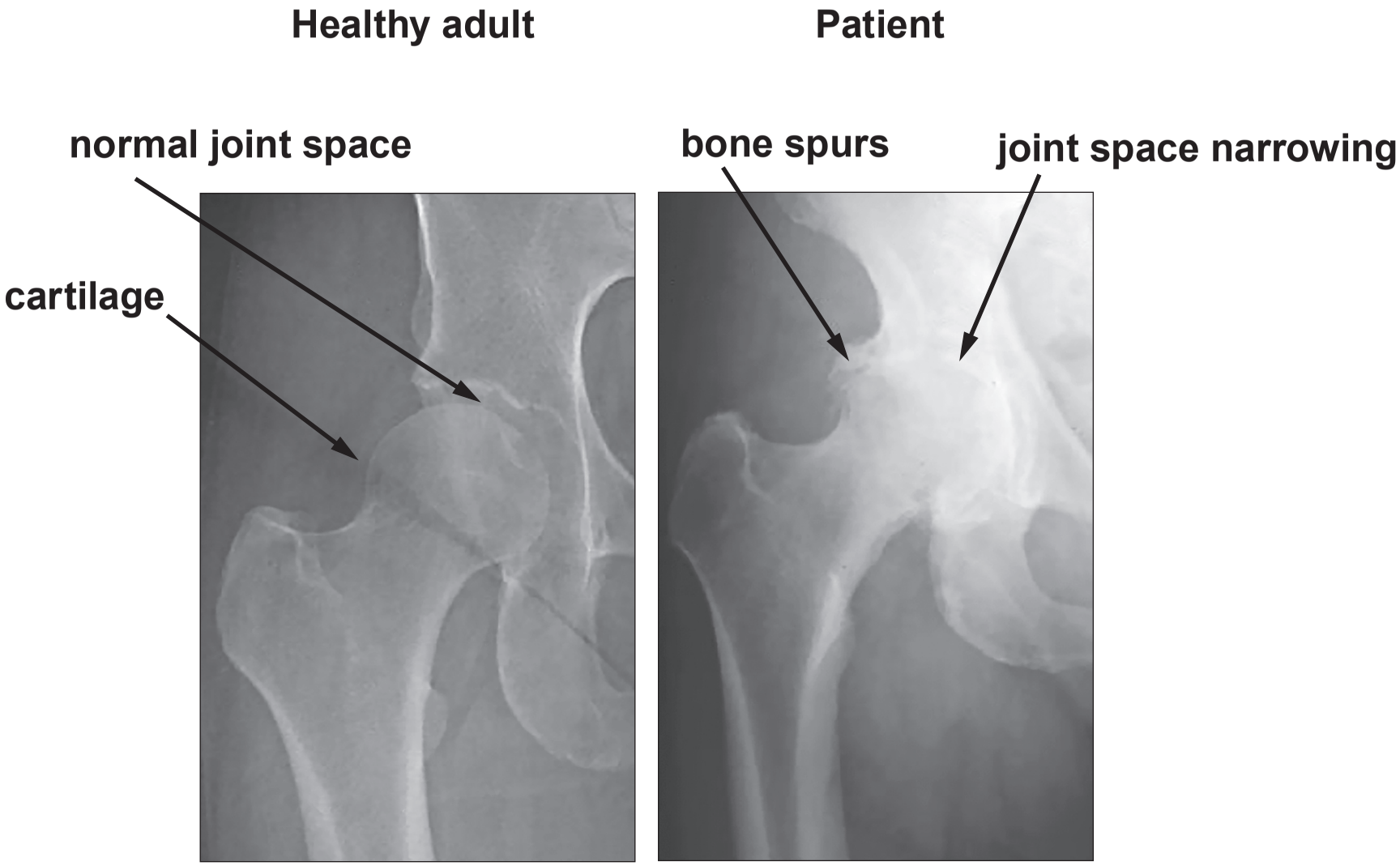

Front
Back
fracture-dislocation

9(b) **The image opposite shows an X-ray of a human vertebral column showing a fracture to the axial skeleton.**

(i) **State TWO functions of this part of the skeleton. [1]**

(ii) **With reference to the X-ray, state which region of the vertebral column contains a fracture. [1]**

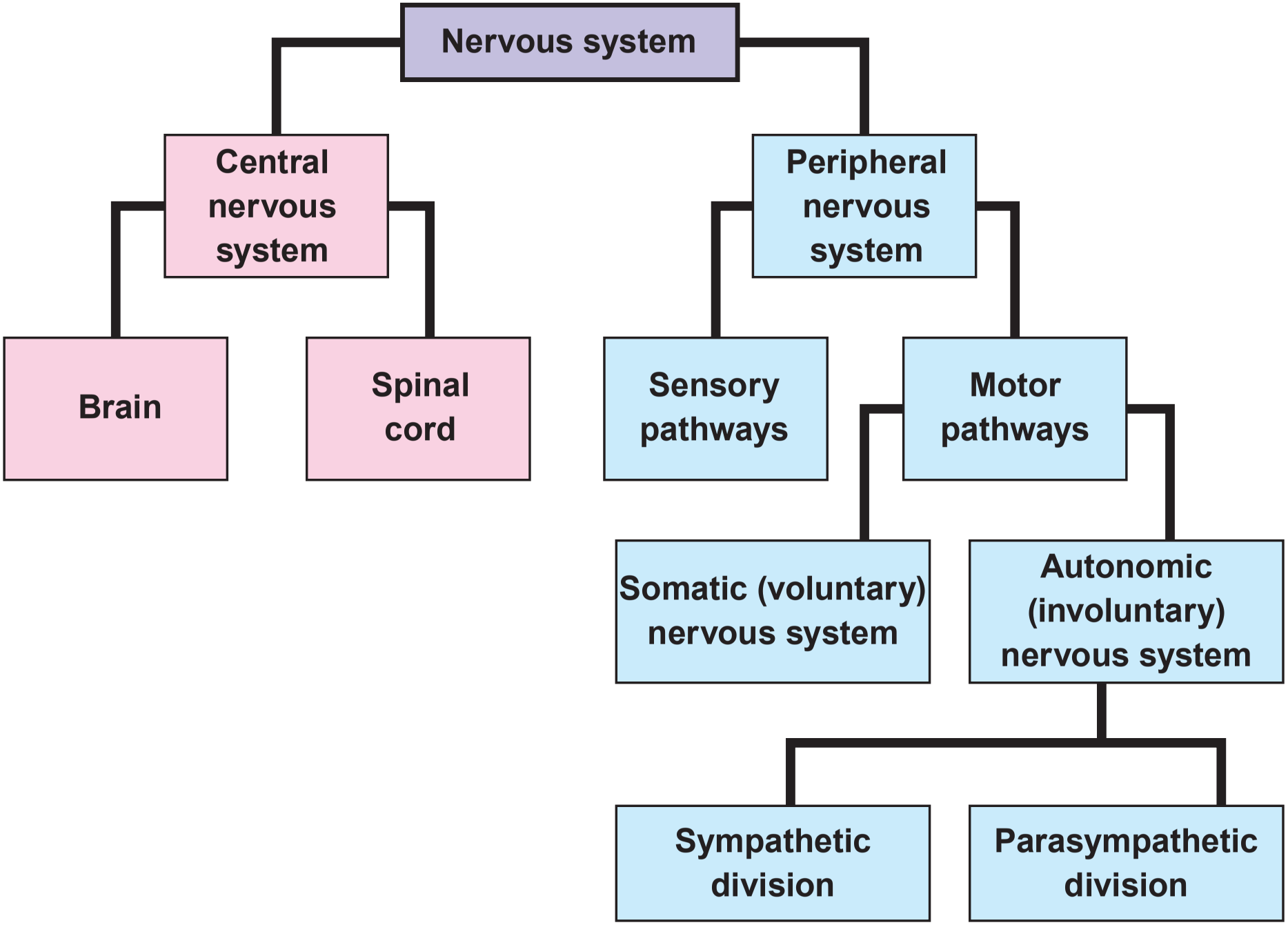
(iii) **If fractures of the vertebral column are not treated correctly they can lead to problems with posture. Apart from surgery, suggest ONE other type of treatment that could be offered to a patient to avoid posture issues. [1]**


Healthy adult
Patient
normal joint space
cartilage
bone spurs
joint space narrowing

9(c) **Two X-ray images of the hip joint are shown opposite. The X-ray image on the right, shows the hip joint of a patient aged 56 who was overweight. The patient was in a lot of pain and had difficulty walking but had previously played a lot of sport.**

(i) **State the type of joint shown. [1]**

(ii) **Using all the information provided, conclude what type of degenerative disease is affecting the patient. Describe the evidence that supports your diagnosis. [2]**

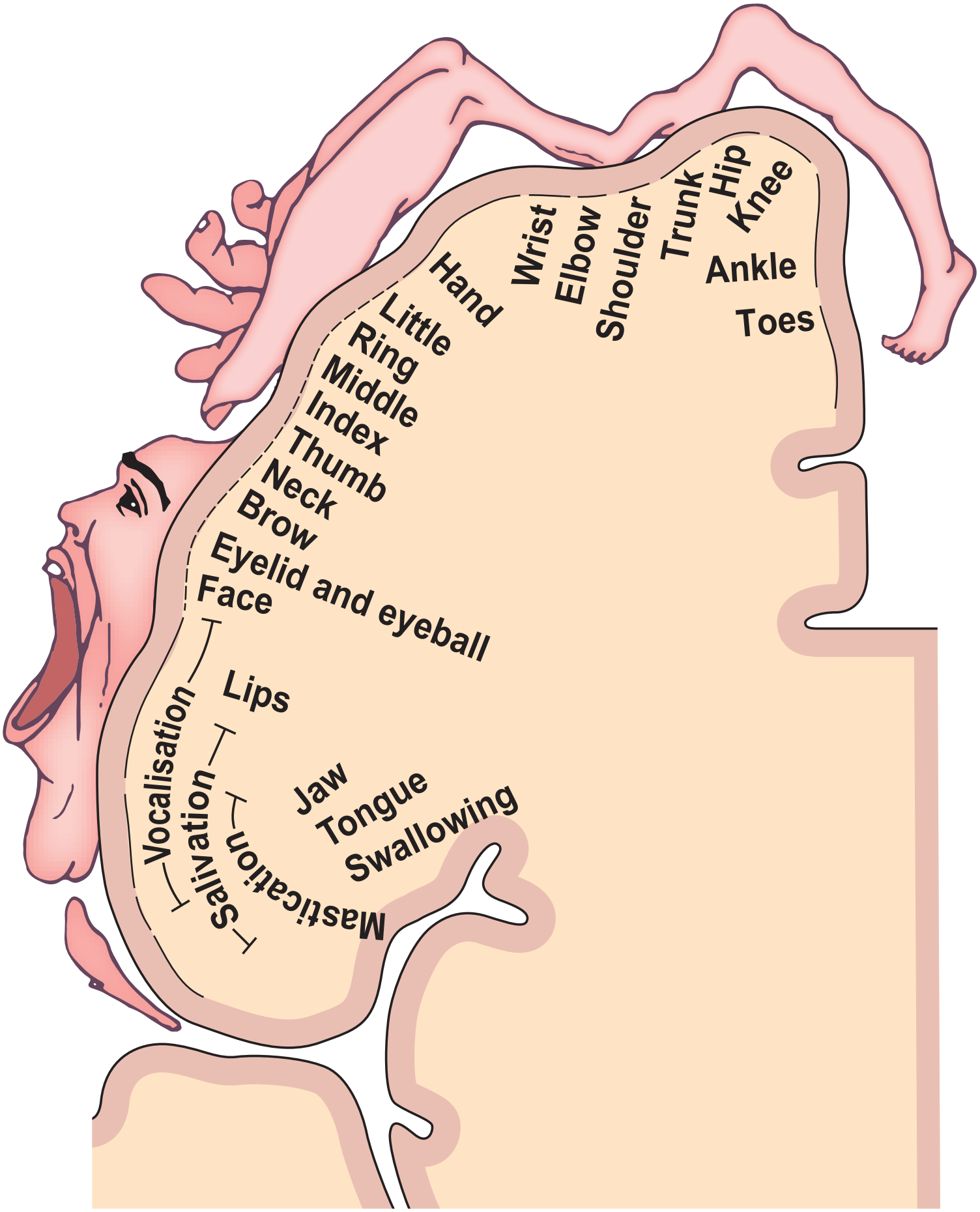

Nervous system
Central nervous system
Peripheral nervous system
Brain
Spinal cord
Sensory pathways
Motor pathways
Somatic (voluntary) nervous system
Autonomic (involuntary) nervous system
Sympathetic division
Parasympathetic division

OPTION C: NEUROBIOLOGY AND BEHAVIOUR

10(a) The diagram opposite shows the organisation of the human nervous system.

(i) Complete the table below to show the differences between the divisions of the autonomic nervous system. [3]

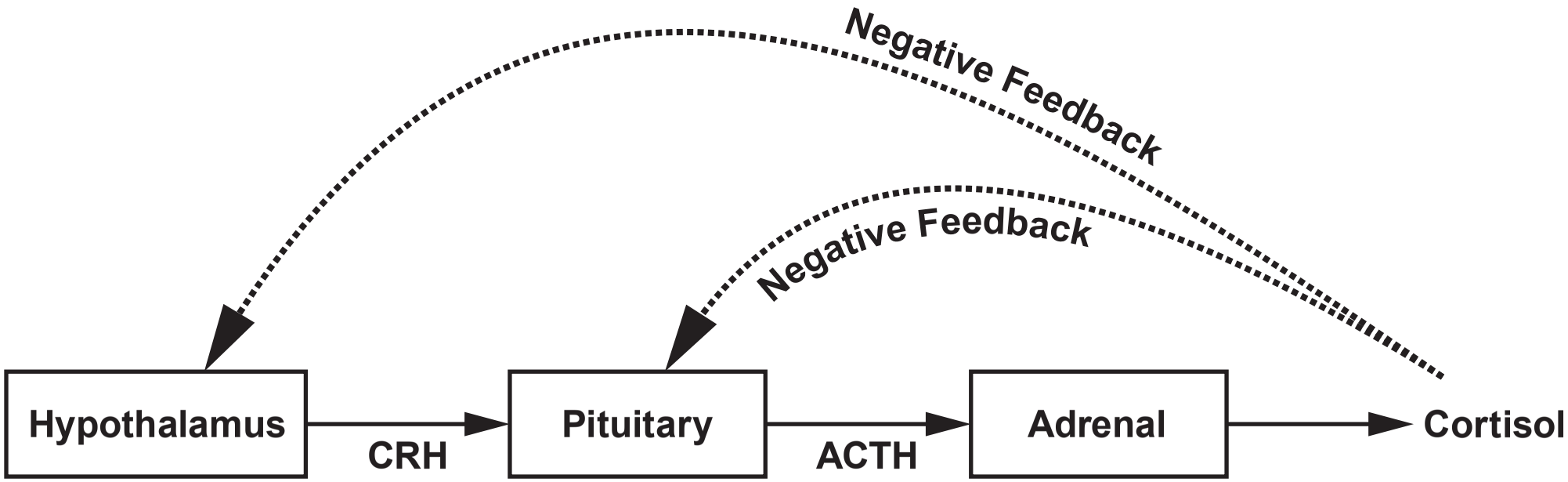
	Sympathetic	Parasympathetic
Neurotransmitter		
General effect		
Effect on heart rate		


Hip
Knee
Trunk
Shoulder
Elbow
Wrist
Hand
Ankle
Toes
Little
Ring
Middle
Index
Thumb
Neck
Brow
Eyelid and eyeball
Face
Lips
Jaw
Tongue
Swallowing
Mastication
Salivation
Vocalisation

The somatic nervous system is involved in controlling voluntary movements via motor neurones, and sensory information via sensory neurones. This links to the motor and sensory cortex of the cerebrum of the brain. The diagram opposite shows a motor homunculus.

10(a) (ii) Explain what the motor homunculus represents. [1]

(iii) Suggest why the sensory homunculus would differ from the motor homunculus. [1]


Negative Feedback
Negative Feedback
Hypothalamus
CRH
Pituitary
ACTH
Adrenal
Cortisol

10(b) **The hypothalamus is the link between the nervous system and the endocrine system, and is found in the brain. It is closely associated with the pituitary gland.**

Cortisol is a hormone produced by the adrenal glands and is involved in the body's response to stress. The normal release of cortisol is controlled by the hypothalamus as shown in the diagram opposite.

High levels of cortisol could be a cause of mental illness. Cushing's disease can be caused by a tumour on the pituitary gland, which causes an abnormally high level of ACTH to be released.

(i) **Using the information above, and your own knowledge, suggest why mental illness has been linked with Cushing's disease. [3]**

10(b) (ii) **The gene for cortisol is expressed in the cells of the adrenal gland.**
Suggest how the expression of this gene could be affected in children who have experienced trauma. [2]

10(c) **Behaviour describes many actions by living organisms in relation to other organisms or the environment they inhabit. Behaviours can be highly complex or seem quite simple.**

Ants are social insects which live in large colonies.

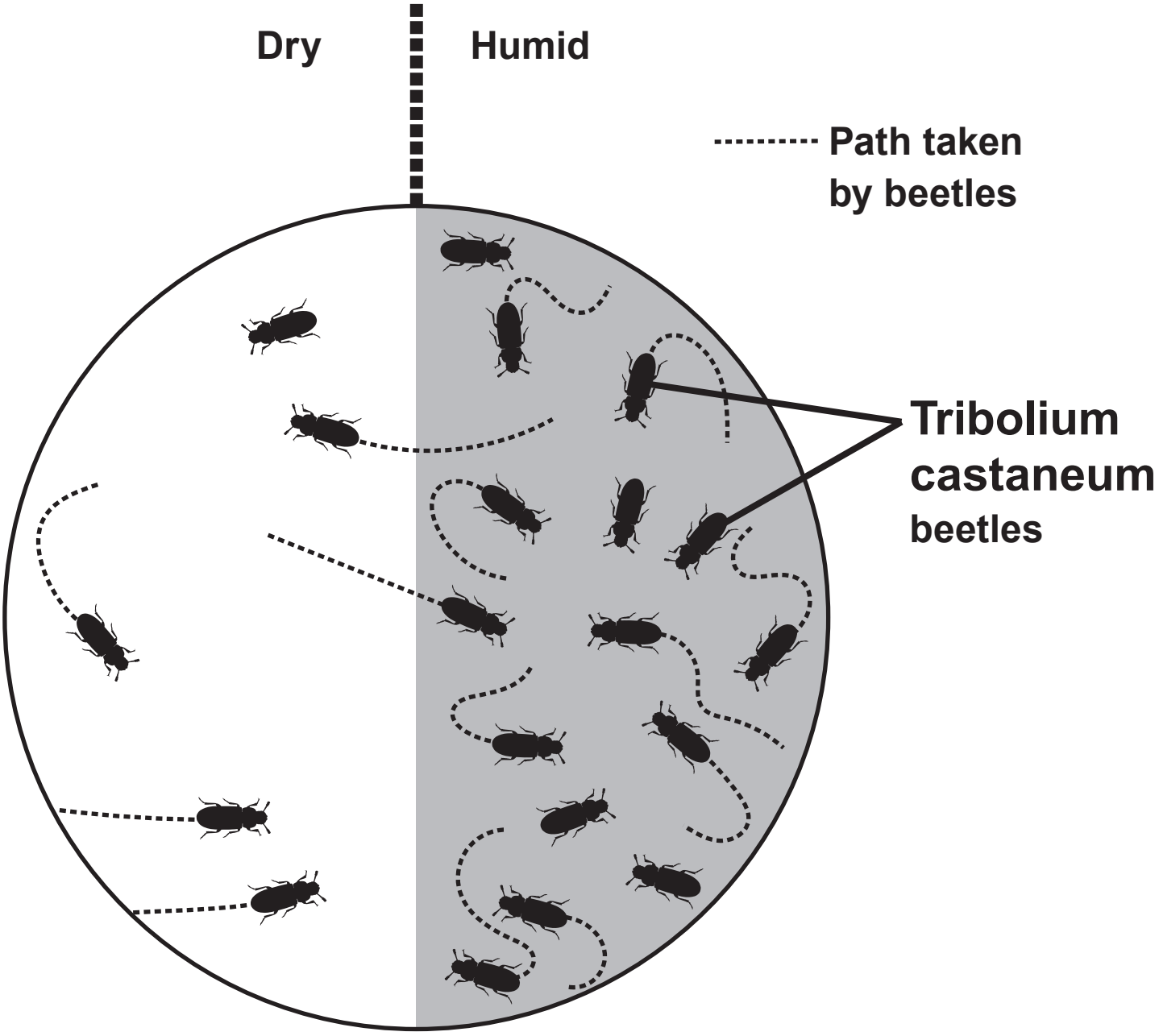
(i) **State the advantages to the ants of living in a colony. [2]**

(ii) **Suggest how ants may communicate with each other. [1]**

Sexual selection has played a role in the evolution of courtship behaviours in vertebrates. Male elephant seals fight with other males for breeding rights, often with fatal consequences.

The photograph opposite shows two male elephant seals fighting.

10(c) (iii) **State the type of sexual selection displayed by the male elephant seals. Explain the consequence of this type of selection. [2]**


Dry
Humid
Path taken by beetles
Tribolium castaneum beetles

10(c) (iv) **Students carried out the following experiment to investigate behaviour in insects. Twenty *Tribolium castaneum* beetles were placed in a Petri dish which had dry and humid areas as shown opposite. The number of beetles found in each area was recorded every 30 seconds for 3 minutes.**

State the type of innate behaviour exhibited by the beetles in response to the environment they are placed in. [1]

_____

_____

Degree of freedom	p = 0.1	p = 0.05	p = 0.02	p = 0.01
1	2.705	3.841	5.024	6.635
2	4.605	5.991	7.378	9.210
3	6.251	7.815	9.348	11.345
4	7.779	9.488	11.143	13.277
5	9.236	11.070	12.832	15.086

10(c) (v) **The null hypothesis for this experiment was that there was no significant difference between the observed and expected number of *Tribolium* beetles found in the dry and humid areas. A Chi-squared test was then performed on the data to test the null hypothesis.**

The calculated value of Chi-squared for these data was 5.00 with one degree of freedom. Use this information to reach a conclusion for this experiment at a suitable level of significance. [4]

20

END OF PAPER

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

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

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

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