Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

S23-1400U40-1

1400U40-1

FRIDAY, 16 JUNE 2023 – MORNING

BIOLOGY – A2 unit 4
Variation, Inheritance and Options

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**15**	
	2.	**9**	
	3.	**13**	
	4.	**11**	
	5.	**13**	
	6.	**9**	
Section B	**Option**	**20**	
	Total	**90**	

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ADDITIONAL MATERIALS

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

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) 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 on this section.

Section **B**: 20 marks; Options. Answer **one option only**. You are advised to spend 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 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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Answer **all** questions.

1. **Image 1.1** shows a section of human ovary.

Image 1.1

Following ovulation, structure **A** performs an endocrine function, secreting a hormone which reaches a maximum concentration about 6 days later. Active growth of blood vessels occurs in the ovary after ovulation.

(a) (i) Name structure **A** and state its function. [2]

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(ii) Suggest **one** reason why it is important that the number of blood vessels in the ovary increase after ovulation. [1]

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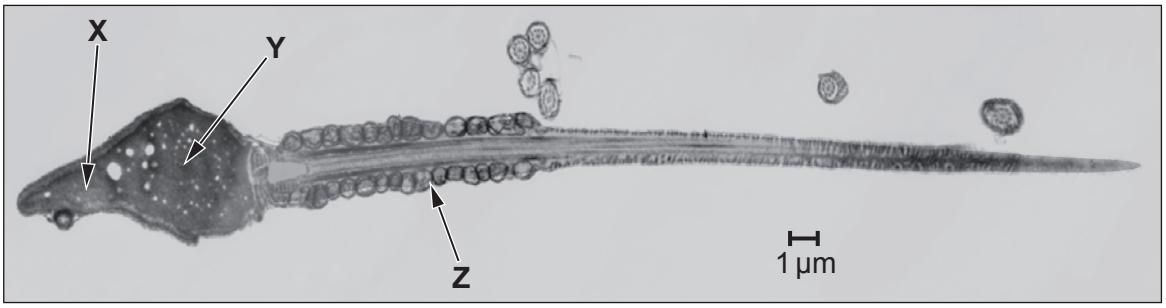
Image 1.2 shows a single human spermatozoon.

Image 1.2



(b) (i) Calculate the actual length of the spermatozoon shown in **Image 1.2**. **Give your answer in mm**. [2]

Length = ... mm

(ii) Structure **A** in **Image 1.1** has a mean diameter of 16 mm. Calculate the number of times larger structure **A** is than the human spermatozoon. [1]

Structure **A** is ..... times larger than the human spermatozoon.

(c) (i) Complete **Table 1.3** by identifying structures **X**, **Y** and **Z** on **Image 1.2**, describing their function during fertilisation. [3]

Table 1.3

Letter	Name of structure	Function during fertilisation
X	.....	....
Y	.....	....
Z	.....	....

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(ii) Humans normally have a diploid number 2n = 46. Occasionally a secondary oocyte is fertilised by two sperm. The embryo formed develops abnormally and will not survive.
State the number of chromosomes this embryo would have and the term used to describe the number of sets of chromosomes. [2]

Number of chromosomes = ...

Term used .....

(iii) This number of sets of chromosomes also occurs naturally in a certain plant tissue. State the name of this plant tissue and state its function. [2]

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Image 1.4 shows a human placenta, following delivery, after the baby is born.

Image 1.4

(d) Use **Image 1.4** to state **two** features of a placenta and describe how they are important to the survival of the embryo. [2]

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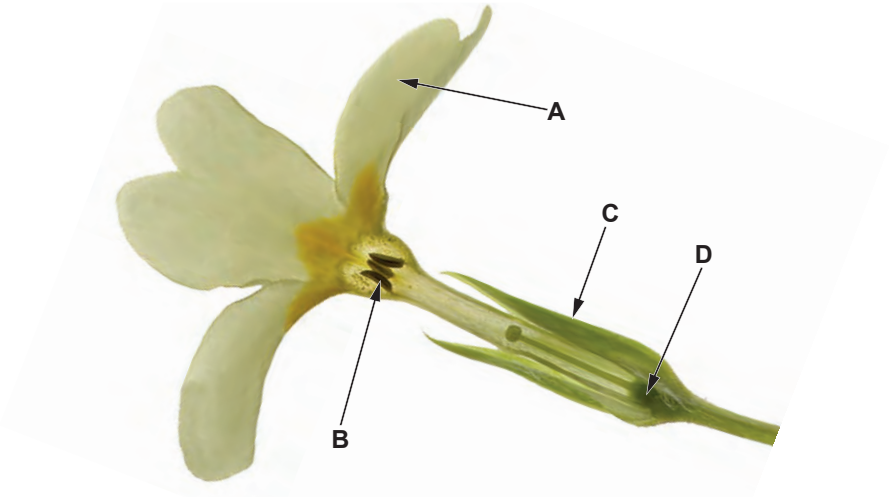
2. An investigation was carried out to determine the flower structure of a primrose.

The flower was dissected as shown in **Image 2.1**.

Image 2.1



(a) The technician requested a materials list prior to the investigation.

Apart from safety glasses, list **three** items of apparatus which would be needed to carry out this investigation. [1]

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(b) Identify structures **A** to **D** on the flower in **Image 2.1** and describe their functions. [4]

	Structure	Function
A	.....	....
B	.....	....
C	.....	....
D	.....	....

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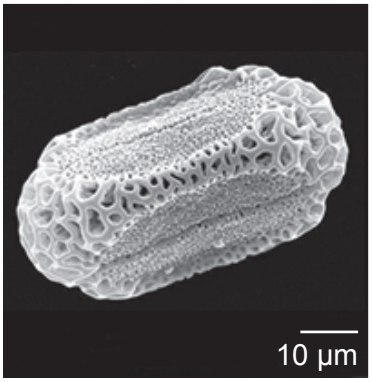
(c) Further research was carried out to determine how pollen from different species varied. Photomicrographs of two types of pollen from different species are shown in **Image 2.2**.

Image 2.2

E

F



Using your own knowledge of pollination and the photographs shown, conclude how each of the pollen samples, **E** and **F**, are transferred from one flower to another. Explain how you came to your conclusions. [4]

Pollen E .....

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Pollen F .....

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3. Co-dominance and certain homozygous genotypes can give unusual ratios in the resulting offspring. **Image 3.1** shows some phenotypes of Camellia plants.

Image 3.1

Variegated leaves (green and white)

Green leaves

Red flower

Red and white flower

Horticulturalists crossed plants which had red flowers and variegated leaves with plants which had red and white flowers and variegated leaves.

(a) (i) Using the symbols below show this cross and the resulting offspring by:

- completing the parental genotypes and gametes;
- drawing a genetic diagram. [2]

RR red flower
RW red and white flower
WW white flower

GG green leaves
GA variegated leaves
AA white leaves

Parental phenotype red flower, variegated leaves

Parental genotype .....

Gametes .....

Parental phenotype red and white flower variegated leaves

Parental genotype .....

Gametes .....

Genetic Diagram

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(ii) Use the genetic diagram drawn in (a)(i) to complete **Table 3.2**. [3]

Table 3.2

Genotypes		.....	.....	.....	.....	.....	.....
Expected phenotypes	Flower colour	.....	.....	.....	.....	.....	.....
	Leaf type	.....	.....	.....	.....	.....	.....
Expected ratio		.....	.....	.....	.....	.....	.....

(b) The resulting 420 seeds from the above cross were planted and the phenotypes of all the **mature** plants were counted and the following results observed.

56 red flowers, green leaves
102 red flowers, variegated leaves
49 red and white flowers, green leaves
110 red and white flowers, variegated leaves

The following observation was made:

'Of the 420 seeds produced in the above cross, all the seeds germinated but 103 did not grow and so a different phenotypic ratio was observed than expected.'

Explain this observation. Your answer should include reference to:
- germination;
- plant leaf cell structure;
- observed and expected phenotypic ratios. [5]

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(c) The production of seeds requires sexual reproduction which involves meiosis. One way for a plant grower to produce plants with the same phenotype as the parent plant is to take cuttings. Using your knowledge of cell division explain why the same phenotype would be retained. [3]

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4. A large research project was carried out to investigate the effect of the environment on the shell length of common European limpet shells *(Patella vulgata)*. These molluscs live on rock surfaces and remain clamped to the rock with a muscular foot when they are exposed at low tide and only move for feeding when they are covered at high tide as shown in **Image 4.1**. They graze algae from the rock surface and always return to the same home position as the tide goes out.

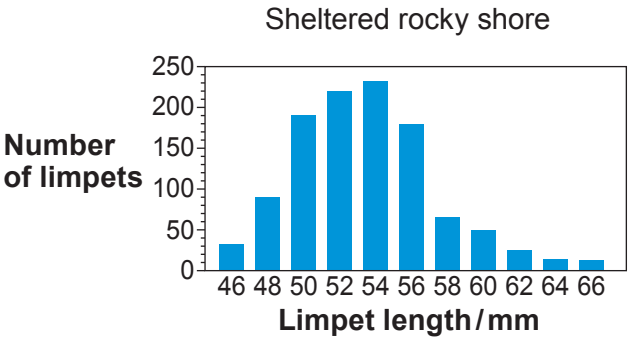
Image 4.1

Patella vulgata clamped to rock

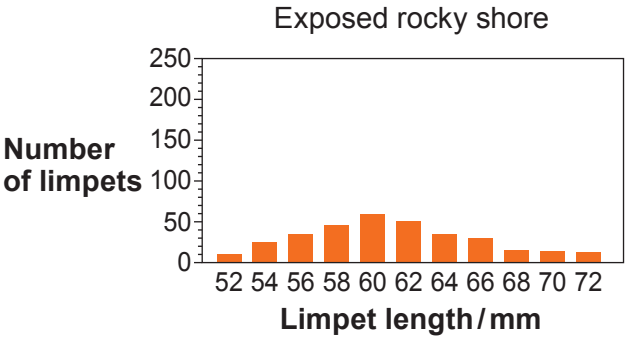
Showing muscular foot

The results from two sites, sheltered and exposed rocky shores, are shown on **Graphs 4.2A** and **4.2B**. The same size area was investigated at both sites.

Graph 4.2A



Graph 4.2B



(a) (i) State **two** conclusions that you could draw from the data in **Graph 4.2A** and **Graph 4.2B**. [2]

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(ii) State the modes for the two sets of data. [1]

Sheltered rocky shore mode = ...

Exposed rocky shore mode = ...

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Two groups of A level students carried out the same type of investigation on the two types of rocky shore. They measured the shell length in mm of 20 mature *Patella vulgata* at each site. They recorded their data in a results table and used an on-line calculator which calculated the t value.

Group 1: exposed rocky shore, Cemlyn Bay, Anglesey

Group 2: sheltered rocky shore, Menai Strait

The online results are shown in **Image 4.3**.

Image 4.3

Result

You entered the following data:

Group 1	Group 2
72 68 59 69 58 58 49 59	68 47 45 60 59 49 51 67
61 69 75 80 49 68 70 71	58 59 49 67 63 66 61 58
67 58 60 71	55 60 59 62

Summary

	Group 1	Group 2
Mean	64.55	58.15
Variance	68.05	47.1868
Standard deviation	8.2492	6.8693
n	20	20
t	**2.6662**	

The t value was calculated as 2.6662

(b) (i) State the null hypothesis for this experiment. [1]

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(ii) State the degrees of freedom which should be used. [1]

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Table 4.4 shows the critical values for a two-tailed test.

Table 4.4

	Probability				
Degrees of freedom	**0.1**	**0.05**	**0.01**	**0.005**	**0.001**
30	1.697	2.042	2.75	3.030	3.646
31	1.696	2.040	2.744	3.022	3.633
32	1.693	2.037	2.738	3.015	3.622
33	1.692	2.035	2.733	3.008	3.611
34	1.691	2.032	2.728	3.002	3.601
35	1.690	2.030	2.724	2.996	3.591
36	1.684	2.028	2.719	2.991	3.582
37	1.683	2.026	2.715	2.985	3.574
38	1.682	2.024	2.712	2.980	3.566
39	1.681	2.023	2.708	2.976	3.558
40	1.680	2.021	2.704	2.971	3.551

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(iii) Use **Table 4.4** to determine whether you would accept or reject the null hypothesis. Explain how you have come to this conclusion. [3]

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(c) Suggest **one** density-independent and **two** density-dependent factors which could account for the difference in shell length. [3]

Density-independent factor

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Density-dependent factors

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5. The international trade of ivory has been banned since 1989. However, as many as 50 000 African elephants are killed each year for their ivory tusks out of a population of less than 400 000.

Researchers created a map of genetic profiles of different elephant populations across Africa using dung samples containing DNA from epithelial cells.

Polymerase Chain Reaction (PCR) was carried out to amplify the DNA and after 40 cycles over a billion copies of the target sequence was produced.

(a) (i) Explain the following processes during the PCR: [3]

I. a single stranded DNA primer is added;

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II. the DNA is heated to 95°C at the start of a cycle;

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III. the DNA is then cooled to 50–60°C.

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(ii) Explain why a certain type of polymerase, called Taq polymerase, is necessary in the final extension stage of the cycle at 70°C. [1]

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Examiner only

The researchers collected elephant dung samples from many locations to analyze the DNA. **Image 5** shows the distribution of these locations (⋆▪•) . Each location was known to contain one population of elephants.

Image 5

(b) The different patterned dots (⋆▪•) on **Image 5** indicate where closely matching genetic profiles were found by the researchers.
Explain the distribution of the genetic profiles of the different elephant populations shown on **Image 5**. [2]

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Most female African elephants have tusks, but typically about 6% of females in a population will never grow tusks.

However, in Gorongosa National Park in Mozambique:

- elephants with large tusks are targeted and killed by poachers for the illegal ivory trade;
- 33% of females between 10 and 20 years old do not have tusks;
- 50% of females over 20 years old do not have tusks.

(c) Using your knowledge of evolution, explain the high incidence of elephants without tusks in the Gorongosa elephant population. [3]

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(d) Suggest how the trend toward **increased lack of tusks** in a population with **heavy poaching** will affect African elephant population sizes in the future. Explain your answer. [2]

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(e) Ivory from elephant tusks contains DNA. Suggest how the data on the DNA profiles of populations could help with combatting poaching. [2]

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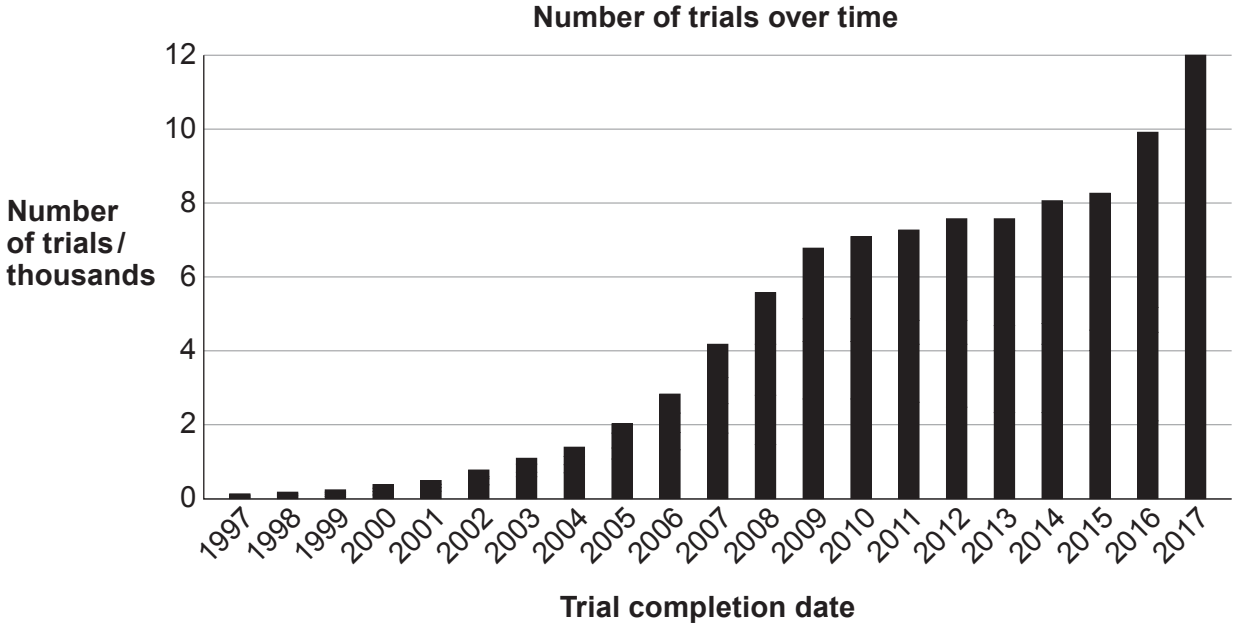
Examiner only

6. The Human Genome Project was completed in April 2003 when an accurate and complete human genome sequence was made available to scientists and researchers.

As a result of this research, more gene therapy drug trials have taken place.
Graph 6 shows the number of gene therapy drug trials between 1997 and 2017.

Graph 6



Explain what is meant by gene therapy and outline **one** of the techniques involved.
Describe how the data in **Graph 6** supports a link between the completion of the sequencing of the human genome and the number of gene therapy trials. Use your knowledge of the aims of the Human Genome Project to explain your answer.
Describe the use of exon skipping gene therapy for the treatment of muscular dystrophy.

[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. Insect bites can cause infection of the deeper layers of the skin. This infection is called cellulitis and is caused by bacteria such as *Streptococcus* and *Staphylococcus* that usually live harmlessly on the surface of the skin. These bacteria are introduced into the wound when the bite is scratched. Flucloxacillin is a bactericidal antibiotic, similar to penicillin, which is used to treat insect bite infections.

(a) (i) State what is meant by the term bactericidal. [1]

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(ii) *Streptococcus* and *Staphylococcus* are types of Gram-positive bacteria. Suggest how and why flucloxacillin has a bactericidal effect on these types of bacteria. [4]

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(iii) Flucloxacillin has become ineffective against some species of *Staphylococcus*. Suggest why. [3]

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(iv) Suggest how infection following the insect bite could be prevented. [1]

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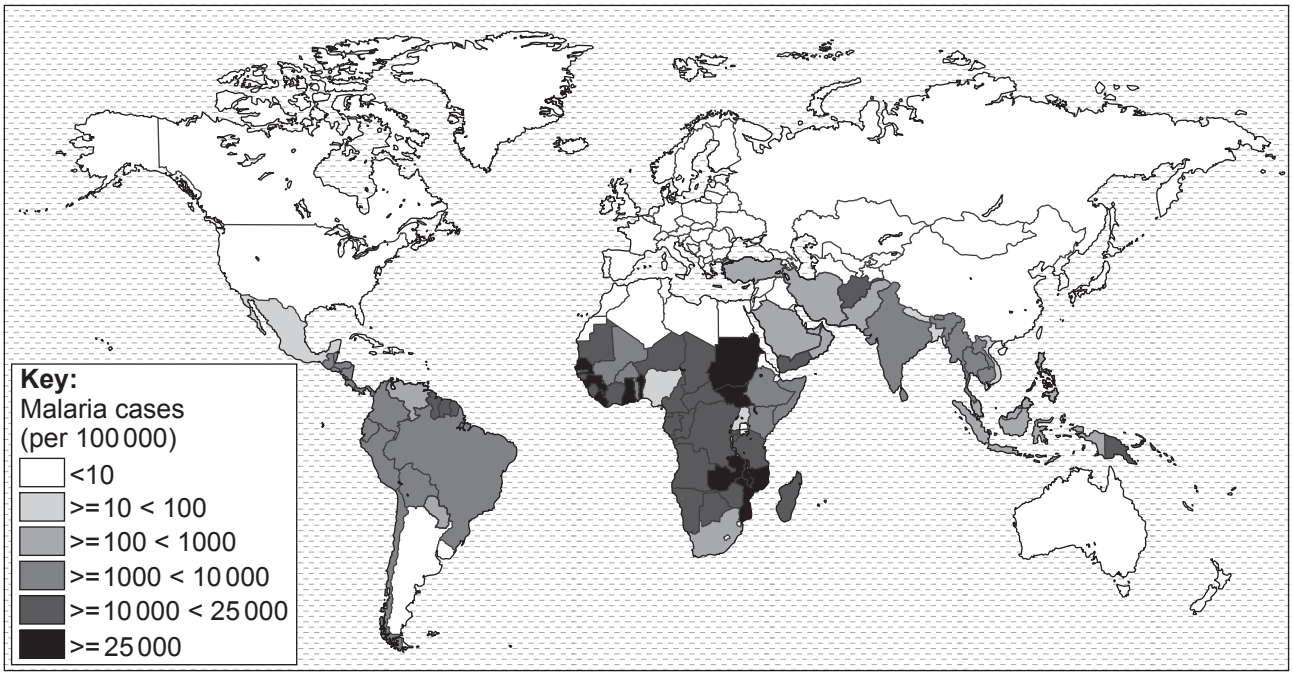
Examiner only

(b) Malaria is a disease spread by insect bites from some mosquitoes. They carry the protoctistan parasite *Plasmodium*, which causes the disease. Malaria is endemic in some sub-tropical areas, can become epidemic during wet seasons and could also be regarded as pandemic. **Image 7.1** shows the distribution of malaria.

Image 7.1

Malaria cases (per 100 000) by country



(i) Describe the difference between the terms endemic and epidemic. Suggest why malaria could be considered pandemic. [2]

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(ii) State why there is no current effective vaccine against *Plasmodium*. [2]

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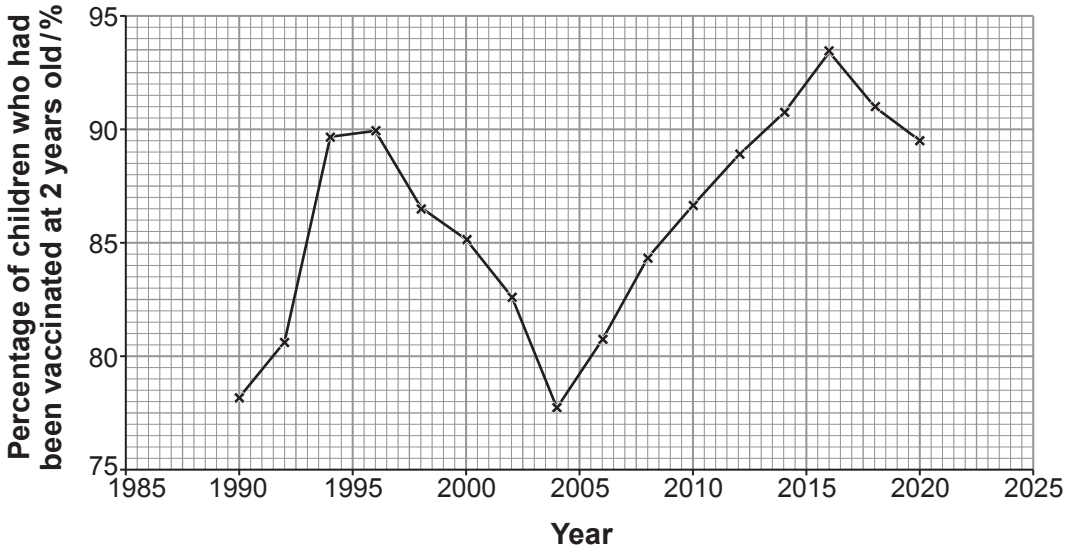
Examiner only

(c) The aim of vaccination is to develop humoral and cell-mediated responses against a number of potentially fatal diseases. In 2019, the UK lost its World Health Organisation (WHO) measles-free status as the number of cases of measles was rising. The MMR vaccine provides immunity for measles, mumps and rubella. **Graph 7.2** shows the results of a study into the percentage uptake of the vaccine in children.

Graph 7.2



(i) Conclude why the number of cases of measles increased between 2016 and 2020. [1]

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(ii) In 2018 there were 700 000 children born. Calculate the number of children that had not been vaccinated by the time they were **two years old**. [2]

Number of children = ...

Examiner only

(iii) The MMR vaccine contains antigens of the three pathogens. Explain why a child who is exposed to the measles virus after being vaccinated does not develop the measles disease. [3]

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The MMR vaccine was linked to autism developing in children in a report that has since been disproven. However, some people still associate this condition with the combined MMR vaccine.

(iv) Use **Graph 7.2** to suggest which year the report was published. [1]

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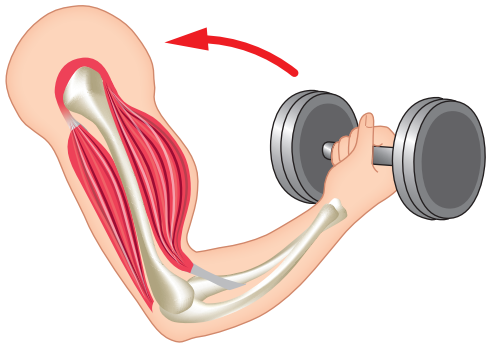
Option B: Human Musculoskeletal Anatomy

8. **Image 8.1** shows a weight being lifted by a human forelimb.

Image 8.1



(a) (i) With reference to the names of the muscles involved, state how the muscles work together to lift the weight. [1]

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(ii) **Image 8.1** represents a third order lever. Use **Image 8.1** and your knowledge of levers to identify the effort, load and fulcrum and explain why it is a third order lever. [2]

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Another experiment was carried out into the rate of muscle fatigue when the weight was held in the position as shown in **Image 8.1**.

(b) (i) Suggest what causes the muscle to fatigue. [2]

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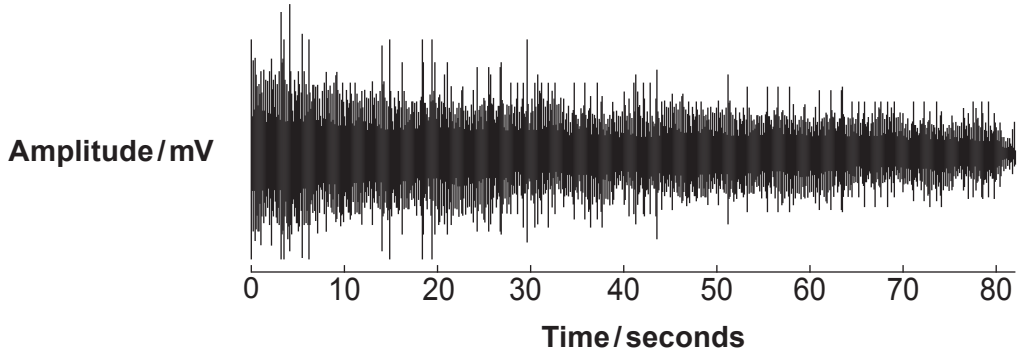
Examiner only

Image 8.2 shows an electromyogram (EMG) which is used to measure fatigue over time. The amplitude (mV) of the signal indicates the force the muscle is generating.

Image 8.2



An EMG was produced for three males and three females. The total time they could hold the weight and the mean amplitude for the first 5 seconds and last 5 seconds of the trace was recorded for each person. The results are shown in **Table 8.3**.

Table 8.3

Gender	Name	Total time / s	Mean amplitude for first five seconds / mV	Mean amplitude for last five seconds / mV	Rate of fatigue
male	Robert	85	26.85	17.20	–0.11
	George	135	29.13	5.03	–0.18
	Gabriel	90	6.83	2.10	.....
female	Mary	230	9.32	3.48	–0.03
	Elizabeth	120	14.31	4.09	–0.09
	Alexandra	135	12.11	3.55	–0.06

The rate of fatigue is measured using the equation:

$$\text{Rate of fatigue} = \frac{\text{mean amplitude for last five seconds} - \text{mean amplitude for first five seconds}}{\text{time}}$$

(ii) Use the equation to calculate the rate of fatigue for **Gabriel**. Suggest a unit for rate of fatigue. [3]

Rate of fatigue = ...

Unit = ...

Examiner only

(iii) It was concluded that females had better endurance than males. With reference to the data in **Table 8.3** comment on the validity of this conclusion. [3]

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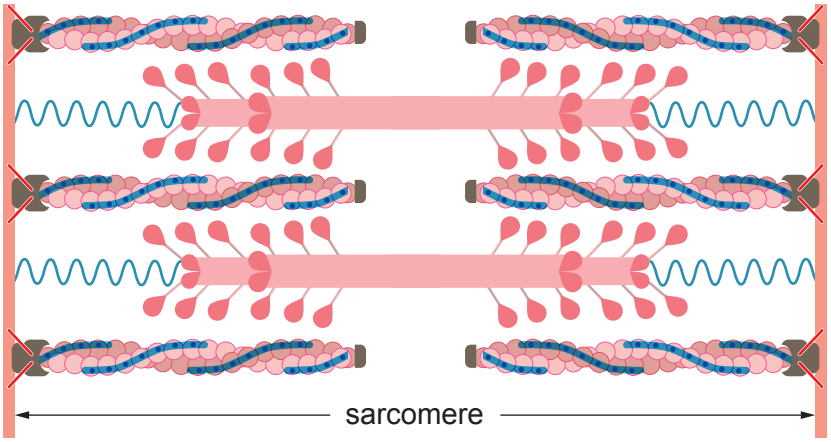
(c) **Image 8.4** shows a sarcomere.

Image 8.4



(i) Use the letters **X**, **Y** and **Z** to label the following proteins on the sarcomere in **Image 8.4**. [1]

X actin
Y myosin
Z tropomyosin

Examiner only

(ii) Low blood calcium increased the rate of muscle fatigue. Use your knowledge of sliding filament theory to explain the reason for this. [4]

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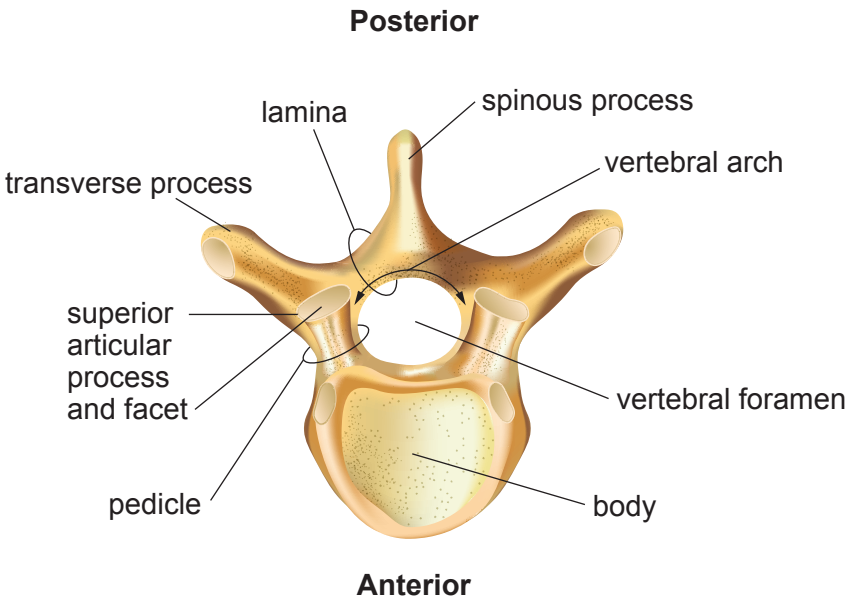
(d) **Image 8.5** shows a vertebra.

Image 8.5



(i) State what spinal region the vertebra in **Image 8.5** is from and explain your answer. [2]

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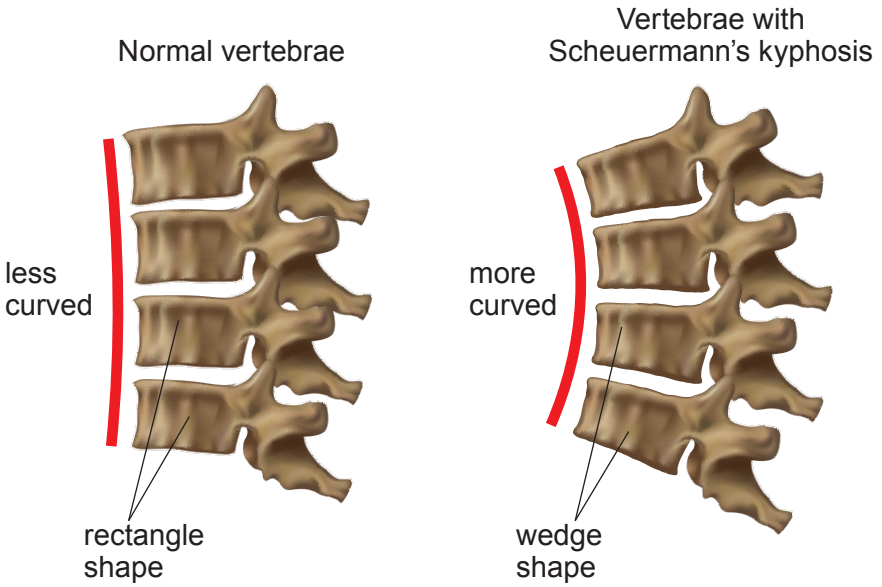
Scheuermann's kyphosis is a medical condition similar to scoliosis which causes curvature of the spine due to vertebrae being wedge-shaped as shown in **Image 8.6**.

Image 8.6



(ii) Suggest which way the spine would curve in the body of a person with Scheuermann's kyphosis. [1]

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(iii) Suggest a possible treatment for Scheuermann's kyphosis. [1]

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Option C: Neurobiology and Behaviour

9. Chacma baboons *(Papio ursinus)* are the largest members of the monkey family and are a highly social species that live in groups of up to 200 individuals. Within a group, adult males form a dominance hierarchy that is established and maintained by fighting and aggressive displays.

(a) (i) State the meaning of the term 'dominance hierarchy'. [1]

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(ii) State and explain an advantage of dominance hierarchy in chacma baboons. [2]

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(iii) Suggest an advantage of maintaining hierarchy by aggressive displays rather than fighting. [1]

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Examiner only

(iv) With reference to the appropriate branches of the nervous system, explain how the hypothalamus prepares the baboons for the 'fight or flight response' during these aggressive displays. [4]

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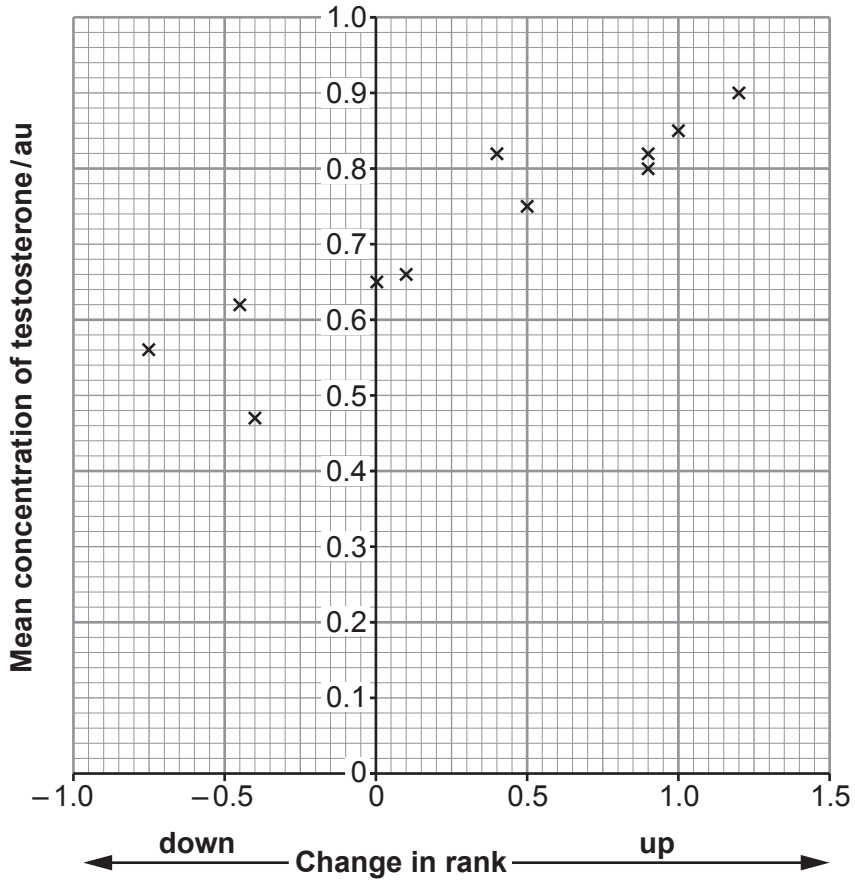
Examiner only

(b) Male ranking is unstable and changes every 6–12 months. This is because young males tend to migrate between groups and high-ranking males frequently lose their status to younger, immigrant males.
Male testosterone levels were measured using faecal samples in a group of chacma baboons. **Graph 9.1** shows the relationship between change in male ranking and mean testosterone levels.

Graph 9.1



(i) Calculate the percentage change in mean testosterone levels when the chacma baboon moves up one rank from 0 to 1. [2]

Percentage change = ...

(ii) Suggest an advantage for the change in testosterone levels. [1]

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Examiner only

(c) Courtship behaviour, as shown by the Indian peafowl *(Pavo cristatus)* in **Image 9.2**, is an example of innate behaviour.

Image 9.2

Female (peahen)

Male (peacock)

(i) State the meaning of the term innate behaviour. [1]

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(ii) Courtship behaviour, as seen in peafowl, is an example of the male handicap model. With reference to **Image 9.2**, state the evidence that this is an example of the male handicap model and conclude how courtship behaviour provides both an advantage and a disadvantage in this species. [3]

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(d) Scientists carried out research into possible changes that occur in the brains of squirrels as a result of learning how to get nuts out of a bird feeder. MRI images can be analysed to measure the volume of the different parts of the hippocampus.

(i) State **two** reasons why the scientists studied the hippocampus region of the brain in this research. [2]

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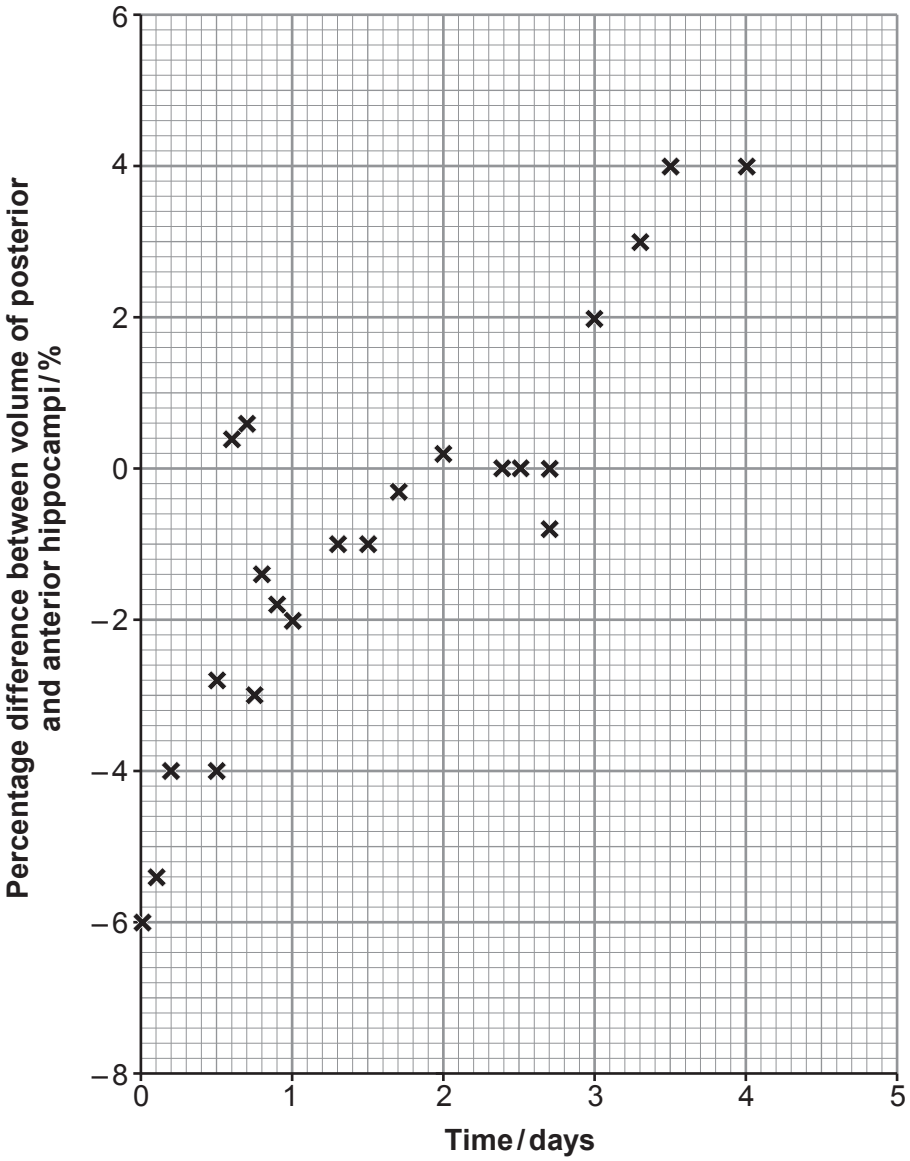
Graph 9.3 shows the percentage differences between the volumes of the posterior and anterior hippocampi against the duration of time spent with the bird feeder.

Graph 9.3



Examiner only

(ii) State the trend shown in **Graph 9.3** and use your knowledge of brain structure and neuroplasticity to state **two** conclusions that can be drawn. [3]

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END OF PAPER

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

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

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