Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A400U20-1

S23-A400U20-1

FRIDAY, 16 JUNE 2023 – MORNING

BIOLOGY – A level component 2

Continuity of Life

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**6**	
2.	**6**	
3.	**13**	
4.	**22**	
5.	**12**	
6.	**14**	
7.	**18**	
8.	**9**	
Total	**100**	

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ADDITIONAL MATERIALS

In addition to this paper you may 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.

Answer **all** questions.

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

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 **8**.

The quality of written communication will affect the awarding of marks.

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Answer **all** questions.

1. (a) Restriction endonucleases are found in bacterial cells. They are used by these cells to cut the DNA of viruses that infect the bacteria. These viruses are called bacteriophages.

(i) State the name given to enzymes which work inside cells. [1]

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(ii) The cutting of the viral DNA prevents the bacteriophage viral proteins being synthesised in the bacterium.

Apart from enzymes, state which other part of the virus is formed of protein. [1]

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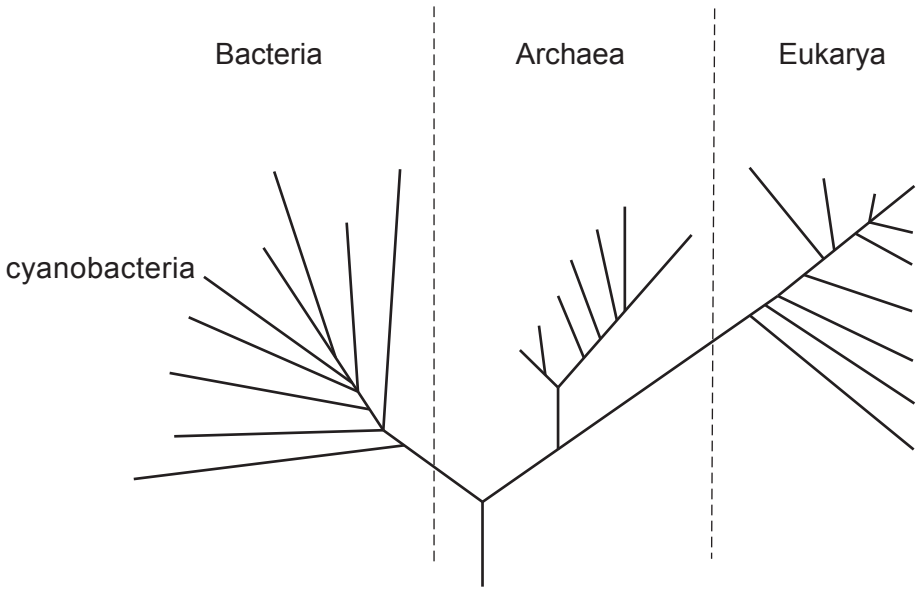
The Three Domain system, developed by Carl Woese in 1990, is a system for classifying biological organisms. It replaced the Five Kingdom classification system.

The phylogenetic tree in **Image 1.1** is a simplified version of his work.

Image 1.1

Phylogenetic Tree of Life



(iii) One type of endonuclease is Cas9. It has not yet been found in any of the Archaea.
Using this information, **write a letter X** on the tree in **Image 1.1** to show the most recent common ancestor of organisms containing Cas9. [1]

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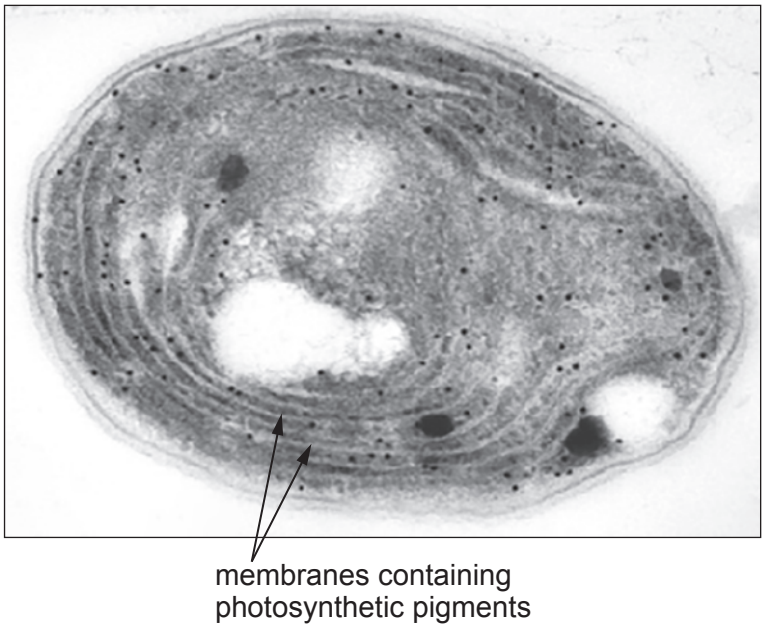
(b) A labelled branch on **Image 1.1** represents a group called the cyanobacteria. **Image 1.2** shows one of these organisms.

Image 1.2



Some bacteria contain an enzyme called nitrogenase. This enzyme is used in nitrogen fixation. It does not function in the presence of oxygen.

(i) Describe and explain the evidence from **Image 1.2** that shows that nitrogen fixation is not taking place in this cyanobacterium. [2]

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(ii) Scientists used to classify cyanobacteria in the Kingdom Protoctista. With reference to their cell structure, suggest why they have been reclassified as bacteria. [1]

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2. Scientists studied the changes associated with growth occurring in the root tip region of wheat plants. They measured the dry mass of cells and the volume of cells at different distances from the root tip.

The results are shown in **Table 2.1**.

Table 2.1

Distance from end of root tip / mm	Mean dry mass of cells / pg	Mean volume of cells / μm^3
1	2.5	20
2	2.5	25
3	2.5	35
4	3.5	45
5	4.5	55
6	5.5	65

(a) Suggest why there is an increase in the volume of the cells between 1 and 3 mm from the end of the root tip, even though the dry mass remains constant. [2]

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(b) A student made a root tip squash to observe mitosis. They used hydrochloric acid to separate the cells by breaking down the chemicals which bind cells together.

The instructions they followed then stated:

'Make sure that the slide is on a flat surface and squash down on the coverslip with a strong vertical pressure using your thumb. Do not twist or roll the thumb from side to side.'

(i) Explain why the student is told to 'squash down with strong vertical pressure' **and** not to 'twist or roll the thumb from side to side'. [2]

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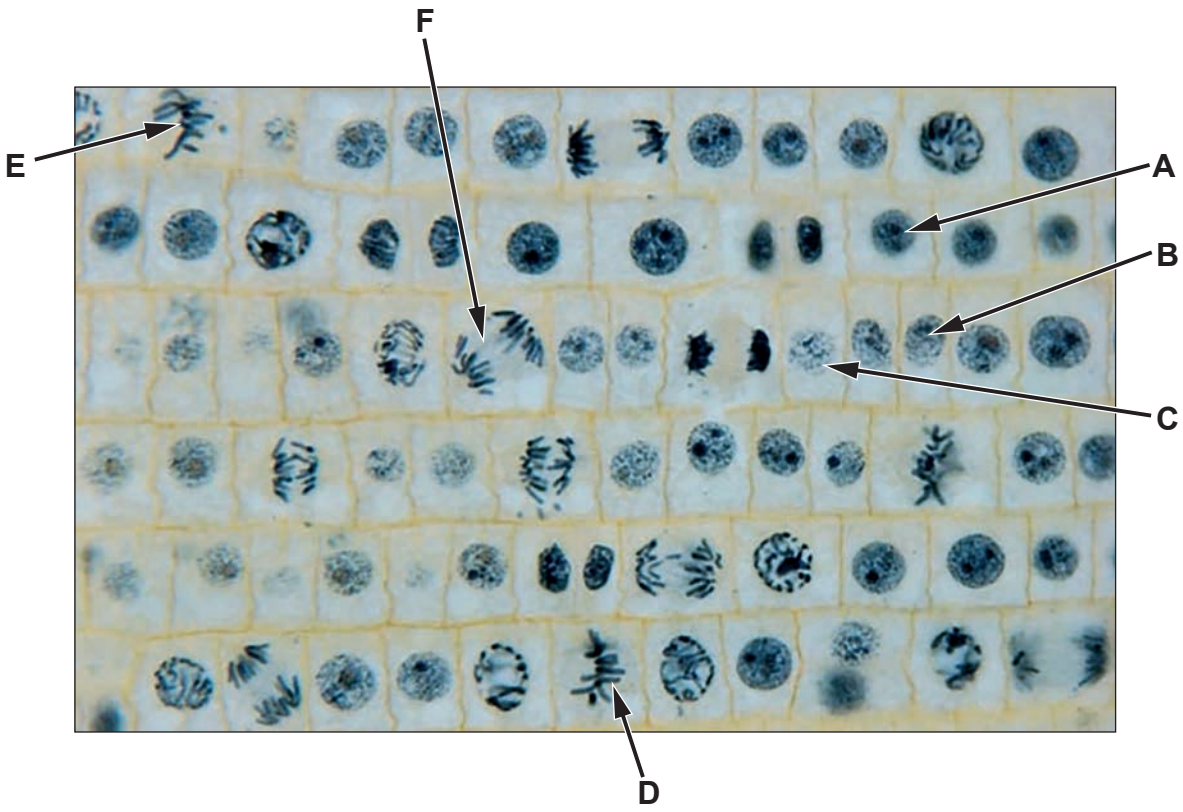
The photograph in **Image 2.2** has been taken from the root tip.

Image 2.2



(ii) Use **Image 2.2** to describe the evidence that interphase is the longest stage of the cell cycle. [1]

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(iii) State which of the cells **A** to **F** contains spindle fibres that are shortening. Explain your answer. [1]

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3. *Colchicum autumnale* is a flowering plant found in many countries.

(a) In the UK, *Colchicum autumnale* is known as autumn crocus, as well as meadow saffron or naked ladies. In India it is commonly known as 'gowri gedde'.

Use this information to explain why the binomial scientific name provides more reliable information to scientists than the common name. [2]

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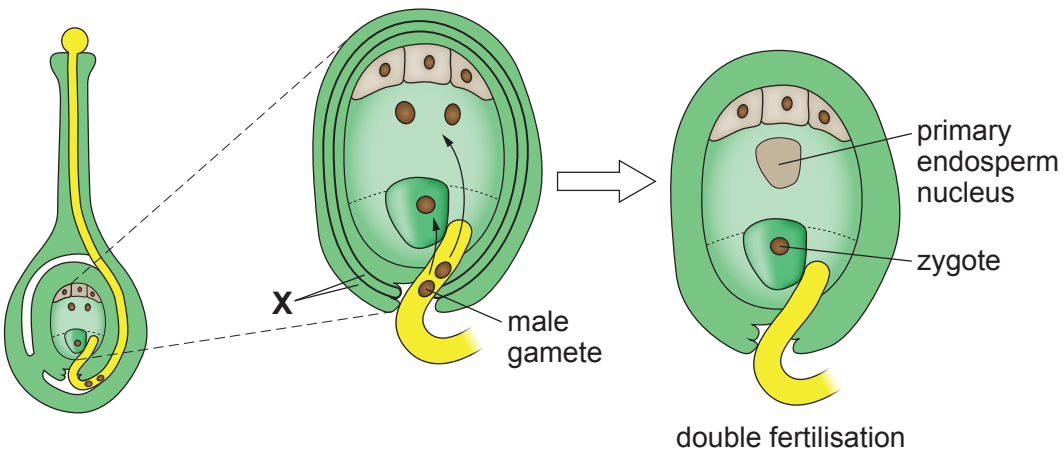
(b) **Image 3.1** shows specimens of *Colchicum autumnale*.

Image 3.1

Image 3.2 is a drawing of a section through a carpel of *Colchicum autumnale* undergoing double fertilisation. The diploid chromosome number of *Colchicum autumnale* is 16.

Image 3.2



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(i) Complete **Table 3.3** to state how many chromosomes are present in the following structures shown in **Image 3.2** and explain how the structures are formed. [6]

Table 3.3

Structure	Number of chromosomes	Explanation of how the structure is formed
male gamete	.....	....
primary endosperm nucleus	.....	....
zygote	.....	....

(ii) During development, the ovule is supplied with sugar by phloem sieve tubes. State how many chromosomes there would be in a phloem sieve tube element and explain your answer. [2]

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(iii) Describe what happens to the structures labelled **X** in **Image 3.2** after fertilisation. [1]

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(c) *Colchicum autumnale* plants release a chemical called colchicine into the soil. Colchicine inhibits the production of spindles in cells. Suggest an advantage to the plant of doing this. [2]

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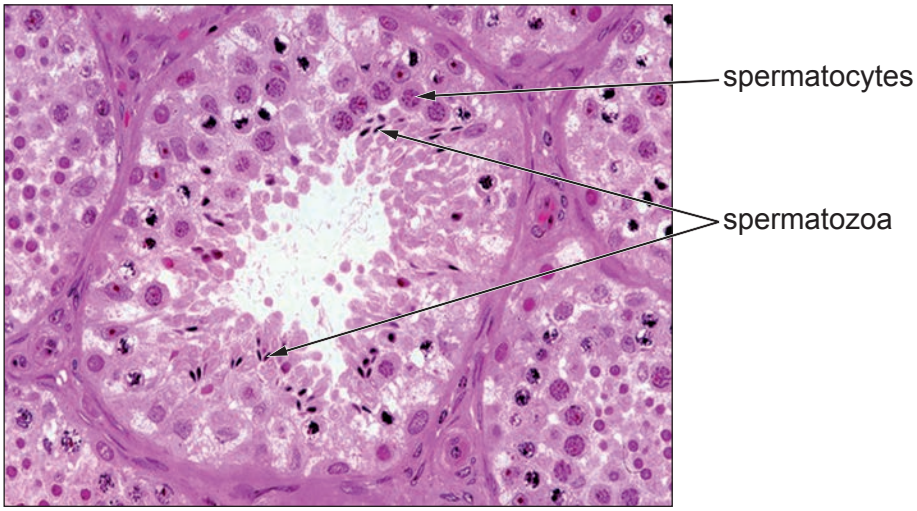
4. The process of spermatogenesis takes place in the seminiferous tubules, as shown in **Image 4.1.**

Image 4.1



(a) (i) The heads of the spermatozoa are clustered around specific cells. Name the cells that the spermatozoa are clustered around and state their function. [2]

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(ii) Explain why both mitosis and meiosis are involved in the production of spermatozoa. [3]

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(b) (i) State the name of the cells in the testes that secrete testosterone. [1]

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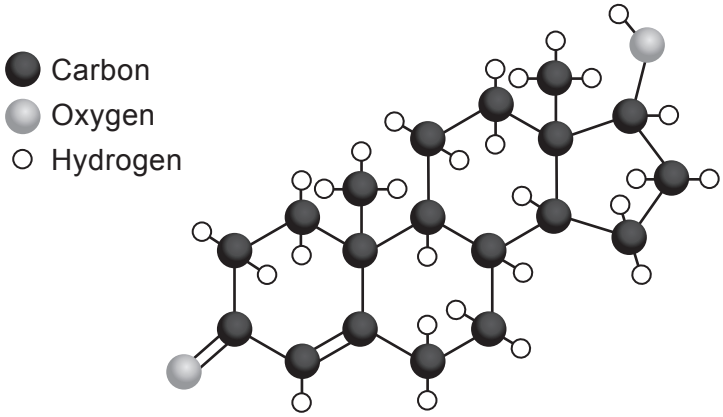
Testosterone is a steroid hormone. Its formula is $C_{19}\ H_{28}\ O_2$. Its structure is shown in **Image 4.2**.

Image 4.2



(ii) Testosterone is classified as a lipid.

Use **Image 4.2** and the information given to explain why testosterone is not classified as a:

I. carbohydrate; [1]

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II. protein. [1]

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(c) It is estimated that one gram of testis tissue produces 400 000 sperm every hour. If a man has 2 500 000 sperm in 1cm^3 of his ejaculate and his testes have a total mass of 24 g, calculate how long it will take to produce the sperm for 1 cm^3 of ejaculate.
Give your answer to the nearest minute. [3]

Time = ... minutes

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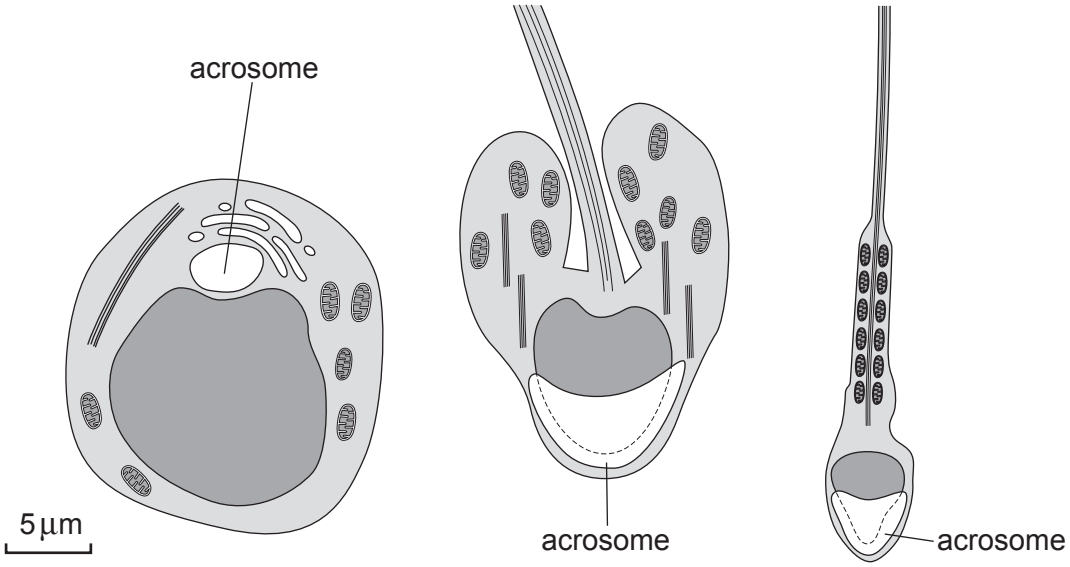
(d) **Image 4.3** shows the maturation of a spermatid to form a spermatozoon. All the diagrams are to the same scale.

Image 4.3



The acrosome labelled on each diagram is a large lysosome.

(i) State the name of the organelle that produces the acrosome. [1]

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(ii) Use **Image 4.3** to describe what happens to the volume of the nucleus and the cytoplasm during maturation and suggest why this occurs. [2]

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(iii) On contact with the zona pellucida, the acrosome reaction occurs. One of the hydrolytic enzymes released from the acrosome is acrosin. It is stored in the acrosome in a non-hydrolytic form that only becomes active when it is released from the sperm.

Suggest a reason for it being stored in a non-active form. [1]

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(e) A group of scientists used golden hamsters (*Mesocricetus auratus*) to study the acrosome reaction.

Two groups of male hamsters were used.

Group 1: produced normal sperm.

Group 2: genetically modified to produce sperm that did not carry out acrosin production.

Two sets of ova were then taken from female hamsters. These were treated in two different ways.

Set A: Ova were left complete.

Set B: The zona pellucida were removed from around the ova.

The sperm from both groups were then mixed with the ova from each set in vitro.

The percentage of the oocytes that were fertilised was calculated and the results are shown in **Table 4.4**.

Table 4.4

Sperm and ova types	% of oocytes fertilised
Group 1 (normal) sperm with Set A (normal) ova	89
Group 1 (normal) sperm with Set B (no zona pellucida) ova	100
Group 2 (no acrosin) sperm with Set A (normal) ova	0
Group 2 (no acrosin) sperm with Set B (no zona pellucida) ova	100

(i) Use the information given in **Table 4.4** to suggest what conclusions could be made about the role of acrosin. Explain your answer. [3]

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This experiment was performed in vitro.

(ii) State where fertilisation normally occurs in a mammal. [1]

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(iii) An acrosin inhibitor has been suggested as a form of contraception. Explain how a non-competitive inhibitor could act on acrosin to prevent fertilisation. [3]

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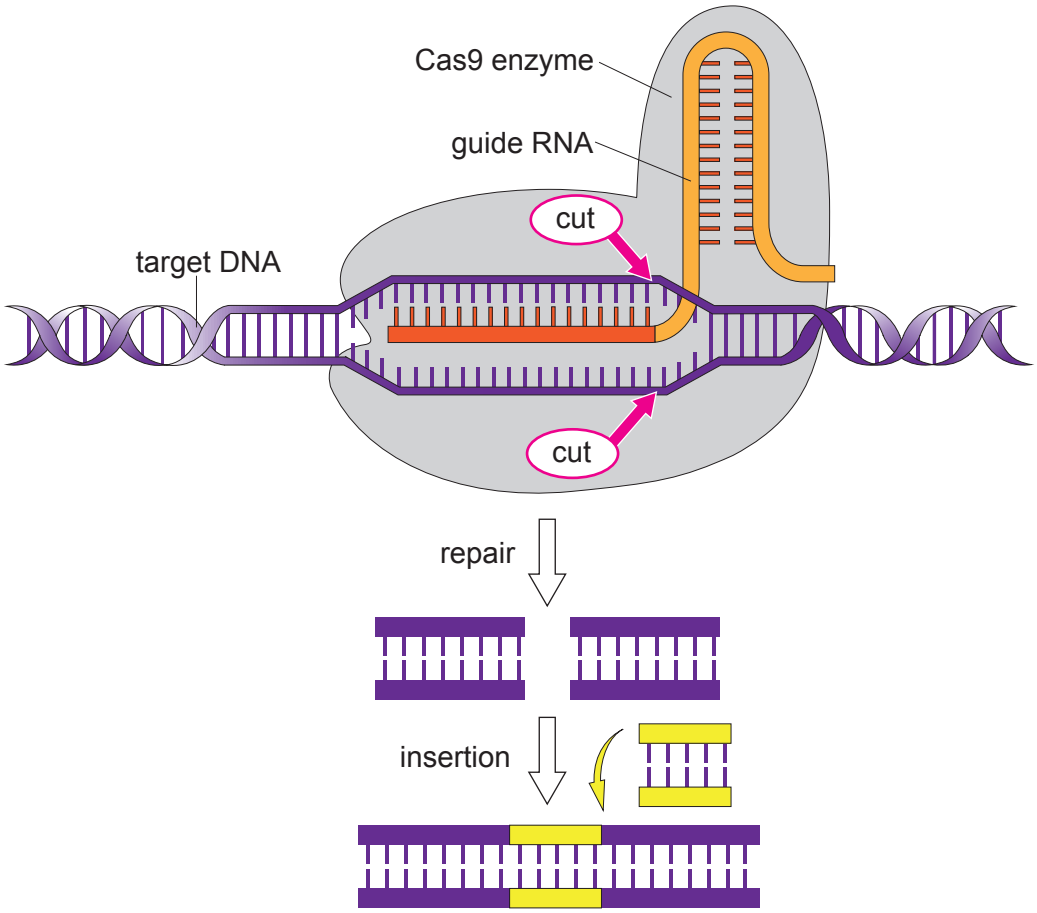
5. Cas9 is a DNA endonuclease that is associated with a strand of guide RNA (gRNA). The enzyme unwinds DNA and breaks the hydrogen bonds between the DNA strands. The base sequence on part of the gRNA then aligns next to a specific target sequence on the DNA. The endonuclease then makes a double stranded cut at this target sequence. During the repair of the DNA molecule a double-stranded length of DNA can be inserted. This is shown in **Image 5**.

Image 5



(a) (i) State **two** differences between nucleotides of RNA and nucleotides of DNA. [2]

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(ii) Cas9 can be used to inactivate specific human genes by cutting them. The section of gRNA used to locate the gene is usually only 20 bases long. Suggest why using gRNA, which is only 20 bases long, may affect other parts of the genome. [1]

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(iii) Artificial gRNA molecules can be made that have specific base sequences. Double stranded DNA containing functional alleles of genes associated with recessive genetic disorders can also be produced. These functional alleles can be inserted into human DNA as shown in **Image 5** using an enzyme.

It has been suggested that the Duchenne Muscular Dystrophy (DMD) allele could be replaced with a functioning allele in germ-line therapy.

Suggest how Cas9 and these functional alleles could be used to alter an embryo's genotype so that it no longer has DMD. [3]

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(iv) Suggest **two** advantages of germ-line therapy. [2]

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(b) The size of a DNA fragment can be measured using the kilobase (1 kilobase = 1000 base pairs).

The length of 1 kilobase is 0.34 µm.

The DNA in a nucleus of a cell from a male with DMD is 2.95×10^6 kilobases in total.

(i) Calculate the length of DNA in the nucleus of the cell from a male with DMD in millimetres (mm). **Give your answer in standard form**. Show your working. [3]

Length = ... mm

(ii) When the **total length** of DNA from a human male cell with DMD is calculated it is longer than 2.95×10^6 kilobases. Explain why. [1]

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6. The leaves of maize have characteristics that are controlled by genes. The leaves can be glossy or rough. They can also be green or green with white stripes.

Pollen from a pure-bred plant with glossy green leaves was transferred to the stigma of a pure-bred plant with rough striped leaves. All of the F1 generation had glossy green leaves.

(a) Give **three** practical precautions that should be taken to ensure that the offspring produced are only from the desired cross. [3]

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(b) Pollen from the F1 generation was transferred to the stigma of pure-bred plants with rough striped leaves. The expected ratio of the phenotypes of the offspring from this cross is 1:1:1:1.

Seeds from this cross were grown and the following phenotypes were seen.

Glossy green leaves	64
Glossy striped leaves	12
Rough green leaves	11
Rough striped leaves	73

A null hypothesis was proposed that there was 'no significant difference between the observed and expected numbers of each phenotype in the offspring'.

A χ^2 (chi-squared) test can be carried out to find the probability of the results being significantly different from the expected ratio.

The χ^2 calculation is shown below.

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Where O = observed results
E = expected results
$\sum$ = sum of

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(i) Use the information given to complete **Table 6.1** and calculate χ^2 for these results. [3]

Table 6.1

Phenotype	Observed number (O)	Expected number (E)	$O-E$	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Glossy green leaves	64	.....	.....	.....	.....
Glossy striped leaves	12	.....	.....	.....	.....
Rough green leaves	11	.....	.....	.....	.....
Rough striped leaves	73	.....	.....	.....	.....

χ^2 = ...

(ii) State the number of degrees of freedom for these results. [1]

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Table 6.2

Degrees of freedom	Probability								
	0.9	0.8	0.7	0.5	0.2	0.1	0.05	0.02	0.01
1	0.016	0.064	0.15	0.46	1.64	2.71	3.84	5.41	6.64
2	0.21	0.45	0.71	1.39	3.22	4.60	5.99	7.82	9.21
3	0.58	1.00	1.42	2.37	4.64	6.25	7.82	9.84	11.34
4	1.06	1.65	2.20	3.36	5.99	7.78	9.49	11.67	13.28

(iii) Use the calculated value of χ^2 and the table of probabilities in **Table 6.2** to find the probability of the results being significantly different from the expected ratio. [1]

Probability = ...

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(iv) State what conclusion can be made from these results and explain your answer. [2]

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(v) With reference to the results of the cross, explain why the actual ratio of phenotypes obtained was different from the expected ratio. [4]

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7. Scientists studied the diet and length of jaws of tiger snakes (*Notechi scutatus*) on the mainland of Australia and an island 5 km off its coast.

When captured and handled, some of the snakes regurgitated their prey. This allowed the scientists to identify the diet of the snakes. The results are shown in **Table 7.1**.

Table 7.1

Area snake found	Prey	Mass of prey / g	Circumference of prey / mm	Number of snakes in which prey item found
Island	Seagull chick	133.10	155.00	1
Island	Silver gull chick	39.70	121.80	10
Island	Skink (lizard)	26.43	58.42	21
Island and mainland	Mouse	19.28	55.82	28
Mainland	Tree frog (type 1)	18.64	58.85	21
Mainland	*Ctenotus* (lizard)	9.85	33.45	40
Mainland	Tree frog (type 2)	1.00	21.55	20
Mainland	Tree frog (type 3)	0.88	21.76	33
				TOTAL 174

(a) (i) In total, 168 snakes were studied. Suggest why the total for the number of snakes in which the prey items were found was 174. [1]

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(ii) Evaluate the method by which the scientists gathered the data on the diet of the snakes. [3]

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(iii) Use **Table 7.1** to compare the diet of the snakes on the island and on the mainland. [3]

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The scientists wanted to investigate the effect of prey size on jaw development in snakes.

- They used newly hatched snakes from both locations; 123 snakes were measured from the island and 129 from the mainland.
- The snakes were fed either large or small mice over several months until they reached maturity.
- The jaw length of each snake was measured from the tip of the nose to the point of articulation of the upper jaw using digital callipers with a precision of 0.01 mm.

The results are shown in **Table 7.2**.

Table 7.2

	Experiment 1		Experiment 2	
	Mainland snakes		Island snakes	
	Group A – fed small mice	Group B – fed large mice	Group C – fed small mice	Group D – fed large mice
Mean length of snakes' jaws at hatching / mm	13.26	13.28	13.85	13.79
Mean length of snakes' jaws at maturity / mm	26.37	26.64	29.20	33.83

(iv) The scientists thought the data produced by their investigation was accurate and reliable. State what is meant by accuracy and reliability. [2]

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(v) State the independent variable in **Experiment 2** shown in **Table 7.2**. [1]

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(vi) The scientists could express the results as percentage change in length of jaw. Explain why this may be a better way of expressing the results. [2]

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(vii) The scientists concluded that the island snakes:

- may carry genes that determine a larger relative jaw size
- jaw sizes increase if fed larger prey.

Use the results shown in **Table 7.2** to explain the evidence that suggests the size of the tiger snakes' jaws at maturity is:

I. a genetically inherited trait; [1]

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II. affected by environmental factors. [1]

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(b) It has been proposed that the two populations of snakes may eventually evolve into two separate species.

(i) With reference to all the information about the snakes in the two populations, outline how the two separate species may evolve. [3]

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(ii) Explain how the scientists would know that the two populations were separate species. [1]

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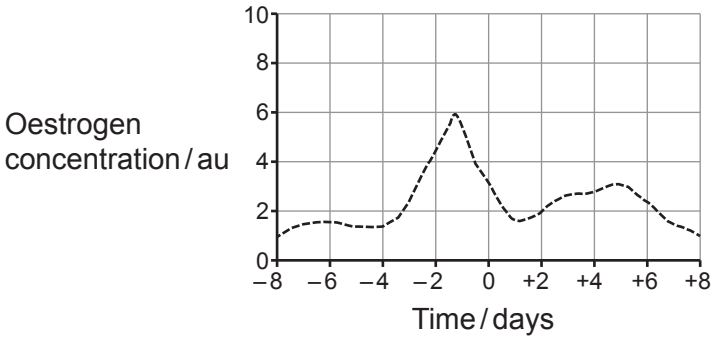
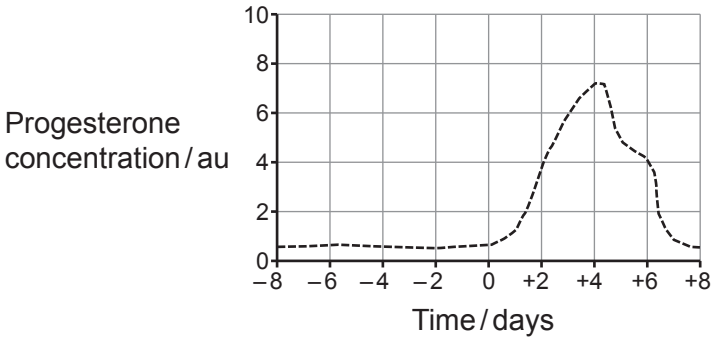
8. **Graphs 8.1–8.4** show the concentrations of four hormones found in the plasma of a mature ewe (female sheep). The hormone concentrations are plotted over a time period of 16 days. The days are numbered either side of the peak concentration of LH secretion.

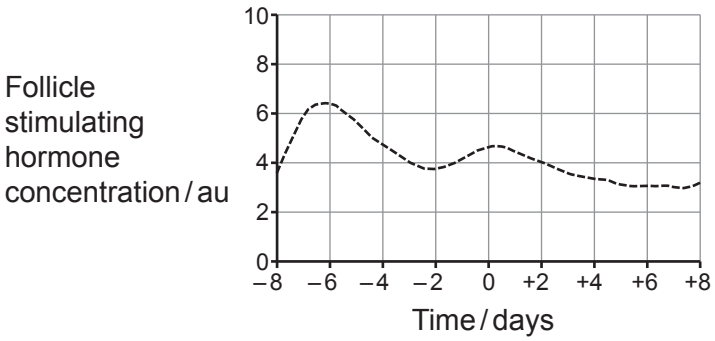
Graph 8.1



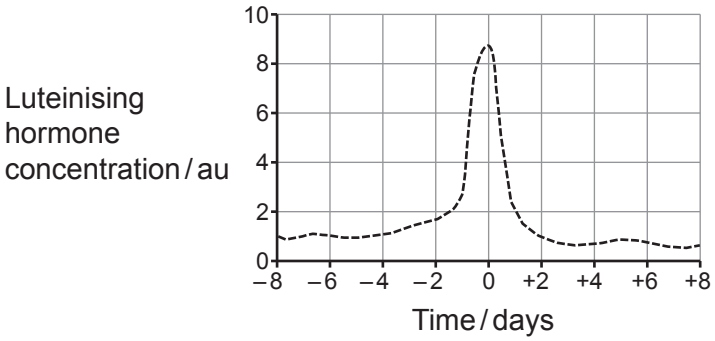
Graph 8.2



Graph 8.3



Graph 8.4



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If sheep are given progesterone for eight days and then the treatment is stopped, they will ovulate eight to twelve days later. In this way, the oestrus cycle of a flock of sheep can be synchronised.

Use **Graphs 8.1**, **8.2**, **8.3** and **8.4** to explain the role of oestrogen in the control of the timing of ovulation in the sheep.

Explain why the sheep will ovulate after the doses of progesterone are stopped.

Suggest why is it useful for a farmer to be able to determine when ovulation will occur and suggest why some people are against injecting reproductive hormones into sheep that are used for food. [9 QER]

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