Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

1400U40-1

Z22-1400U40-1

FRIDAY, 17 JUNE 2022 – MORNING

BIOLOGY – A2 unit 4
Variation and Inheritance

1 hour 35 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**13**	
	2.	**16**	
	3.	**11**	
	4.	**10**	
	5.	**11**	
	6.	**9**	
	Total	**70**	

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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

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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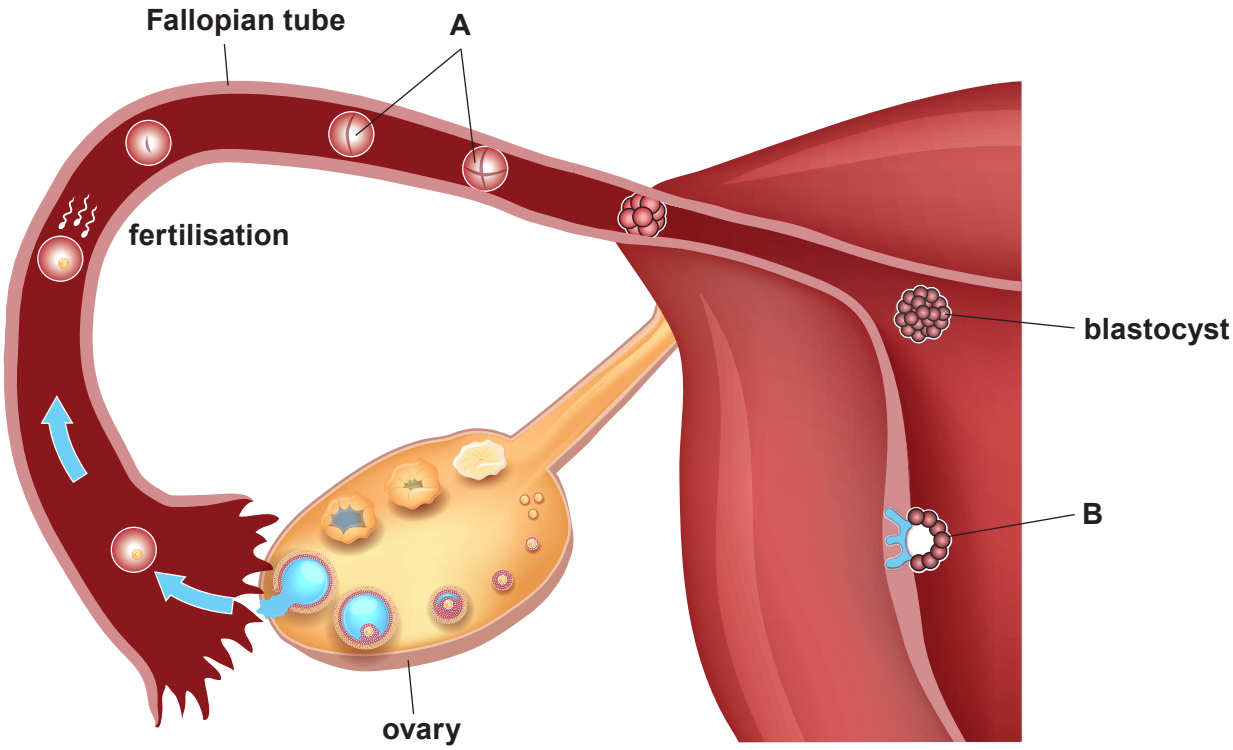
Answer **all** questions.

1. **Image 1.1** shows the sequence of events which occur in the fallopian tube and uterus before and after fertilisation.

Image 1.1



(a) (i) State the process which has recently occurred in the ovary in **Image 1.1**. [1]

Process .....

(ii) Briefly describe the process of fertilisation in humans. [4]

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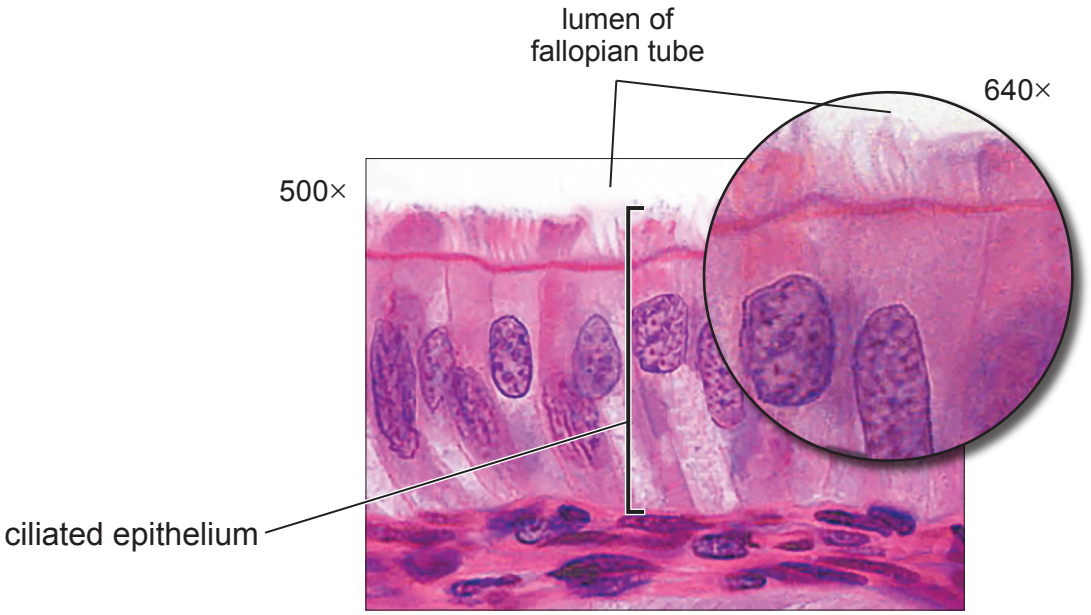
(iii) State the type of cell division involved in the production of structure **B** and the term given to the events shown at **A**. [1]

Type of cell division .....

Term given to events shown at **A** .....

Image 1.2 shows ciliated epithelium, which is found lining the fallopian tube, as seen with a light microscope.

Image 1.2



(b) Explain why ciliated epithelium is important in the sequence of events shown in **Image 1.1**. [3]

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(c) In mammals, other than humans, the menstrual cycle is known as the oestrous cycle. During the oestrous cycle most female mammals are receptive to mating for only a limited period of time. This varies between mammals. The timing of ovulation also varies.
Table 1.3 shows information about the oestrous cycle of three different mammals.

Table 1.3

Average Reproductive Cycles				
Mammal	Length of oestrous cycle	Length of time receptive to male (oestrus)	Ovulation	(approx) Length of Pregnancy
cow	21 days (all year)	18 hr	11 hr after end of oestrus	9 months
sheep	17 days seasonal (autumn)	29 hr	near end of oestrus	5 months
horse	21 days seasonal (spring)	4–8 days	1–2 days before end of oestrus	12 months

(i) Using the data shown in **Table 1.3**, explain why having a seasonal oestrous cycle is the best way to ensure offspring survival for animals such as sheep and horses. [2]

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(ii) Explain why ovulation in the three species shown in **Table 1.3** occurs towards the end of oestrus (when the female is receptive to the male). [2]

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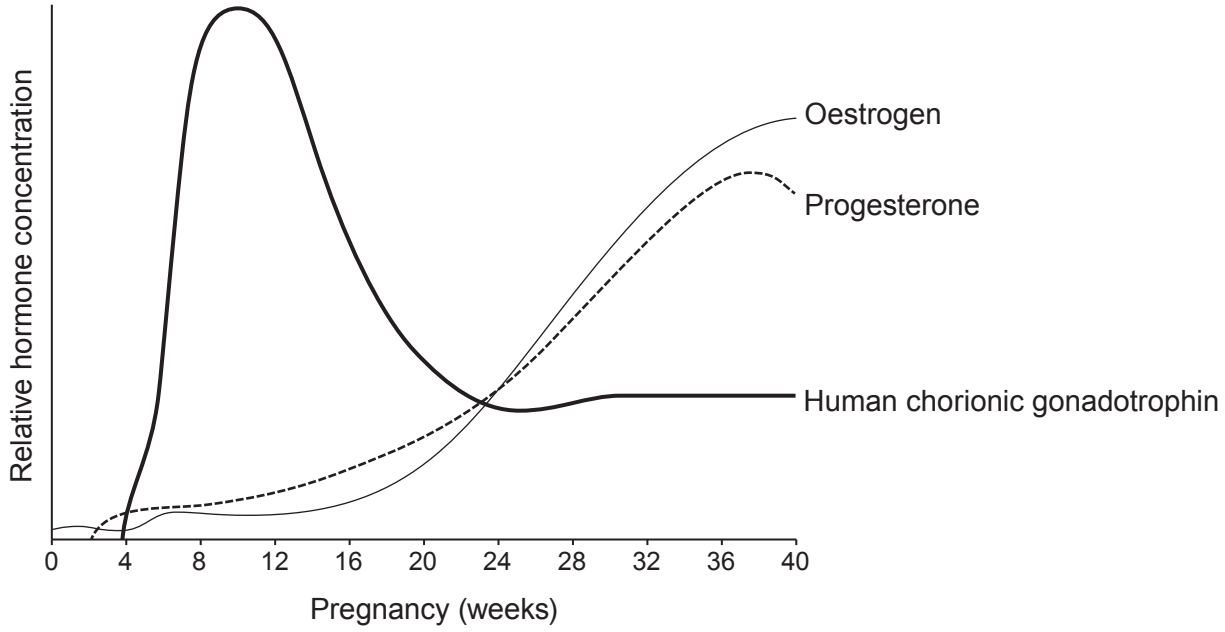
2. Human chorionic gonadotrophin (hCG) is secreted by the developing embryo and is crucial in maintaining early pregnancy. **Graph 2.1** shows how levels of hCG change over time, together with two other hormones which have important roles in pregnancy.

Graph 2.1



(a) With reference to **Graph 2.1**, explain why hCG levels are used in pregnancy tests to determine if a woman is pregnant. [2]

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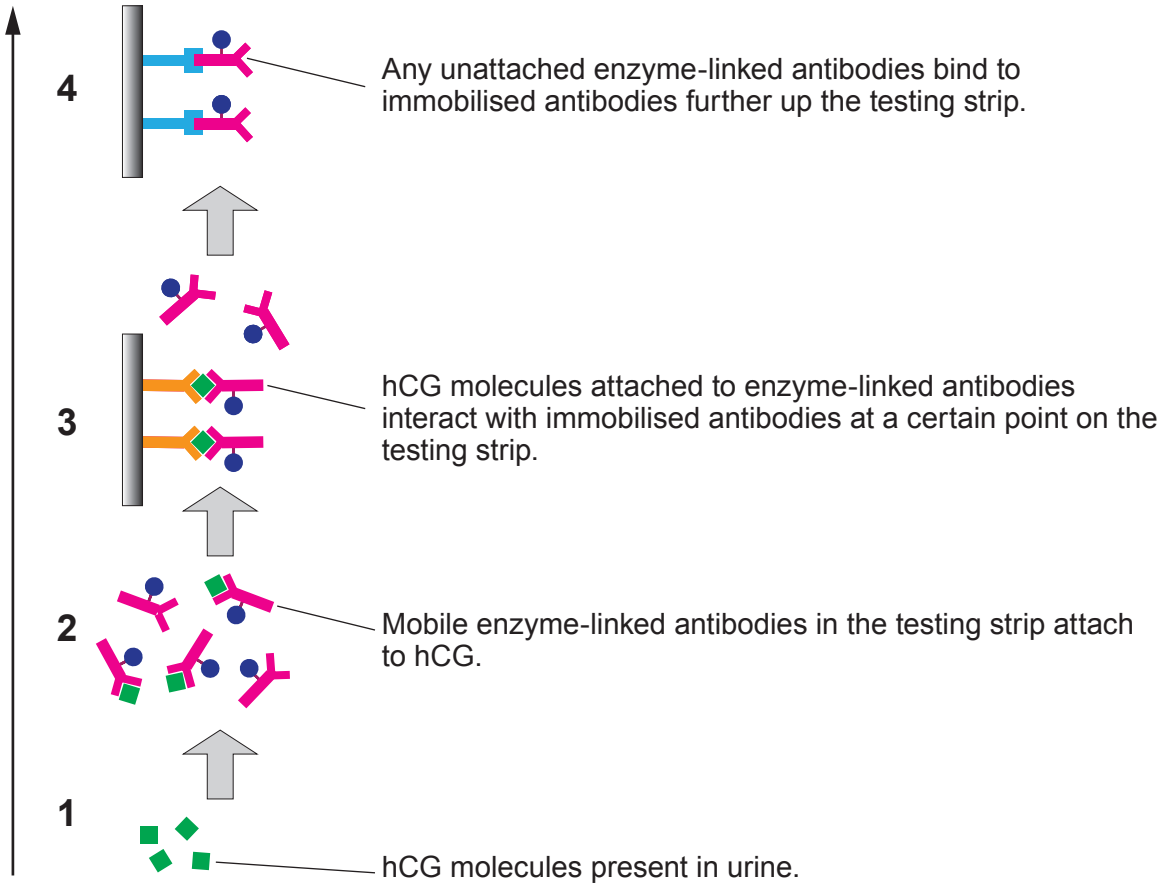
(b) One type of pregnancy test uses mobile proteins, called antibodies, which attach to hCG. These in turn are attached to an enzyme that changes the colour of a dye in an absorbent testing strip.

Another set of antibodies specific to hCG are immobilised to the colourless dye in the strip. If hCG is present in urine, it will interact with both sets of antibodies (forming an antibody sandwich). When both sets of antibody are bound to hCG, the enzyme can bind with the dye, changing its colour.

Immobilised antibodies further up the testing strip will bind any unattached enzyme-linked antibodies, changing their colour, functioning as a control.

This is summarised in **Image 2.2**.

Image 2.2



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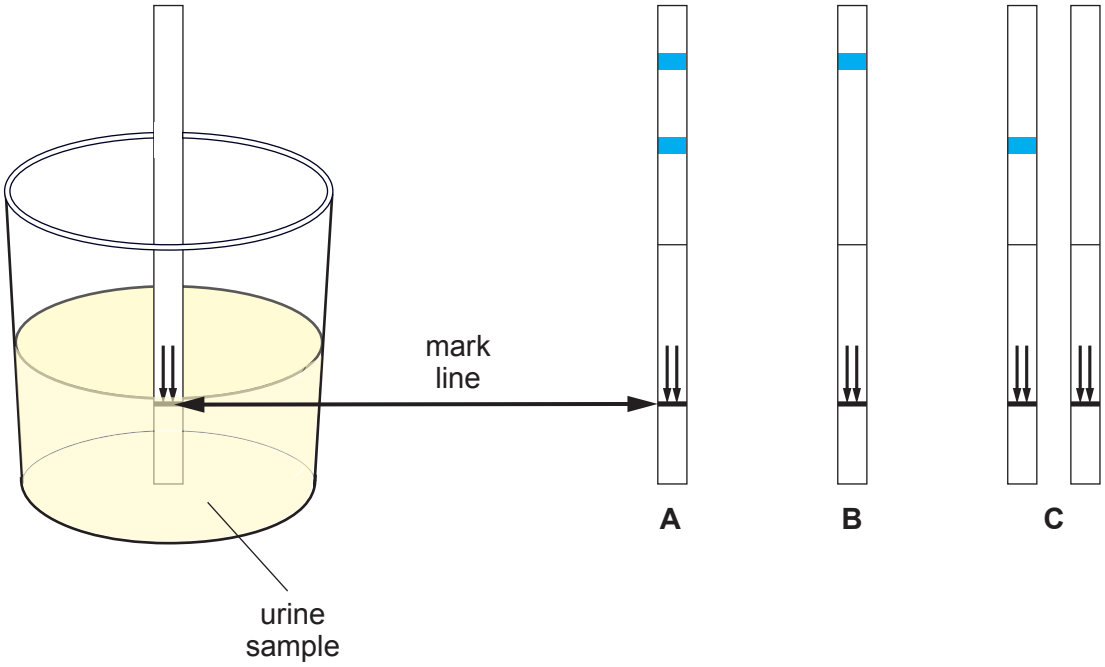
The set of testing strips in **Image 2.3** show a number of different possibilities.

Image 2.3



(i) Determine which of the tests **A** or **B** is positive for a pregnancy and explain your reasoning. [3]

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(ii) Explain why both of tests **C** are invalid. [2]

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(c) State the function of hCG in pregnancy and what happens if levels of hCG fall or are too low at the start of the pregnancy. [3]

(d) hCG is a protein coded for by two genes. Sometimes mutations occur which may affect the structure and functionality of the hormone. Explain why mutations in the hCG genes may or may not effect pregnancy. [2]

(e) With reference to **Graph 2.1**, explain the functions of the hormones oestrogen **and** progesterone during pregnancy. [4]

16

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3. Beta thalassemia is a fairly common blood disorder worldwide. Beta thalassemia occurs frequently in people from Mediterranean and African countries. Normal homozygous individuals (**TT**) have normal red blood cells that are easily infected with the malarial parasite. Thus in the past many of these individuals became very ill from the parasite and died.

Individuals who are homozygous (**tt**) often die because of the complications of anaemia.

Individuals with the heterozygous condition (**Tt**) have mutant haemoglobin that means the malaria parasite cannot survive well in their red blood cells.

(a) (i) The frequency of the **t** allele is 2% in a population.

Using the formulae given, calculate the **percentage** of the population that will be heterozygous (**Tt**) for the thalassemia gene. [3]

$p + q = 1.0$

$p^2 + 2pq + q^2 = 1.0$

Percentage of population that are heterozygous = ...

(ii) Suggest the advantage of being a **Tt** individual in a region where malaria is present. [2]

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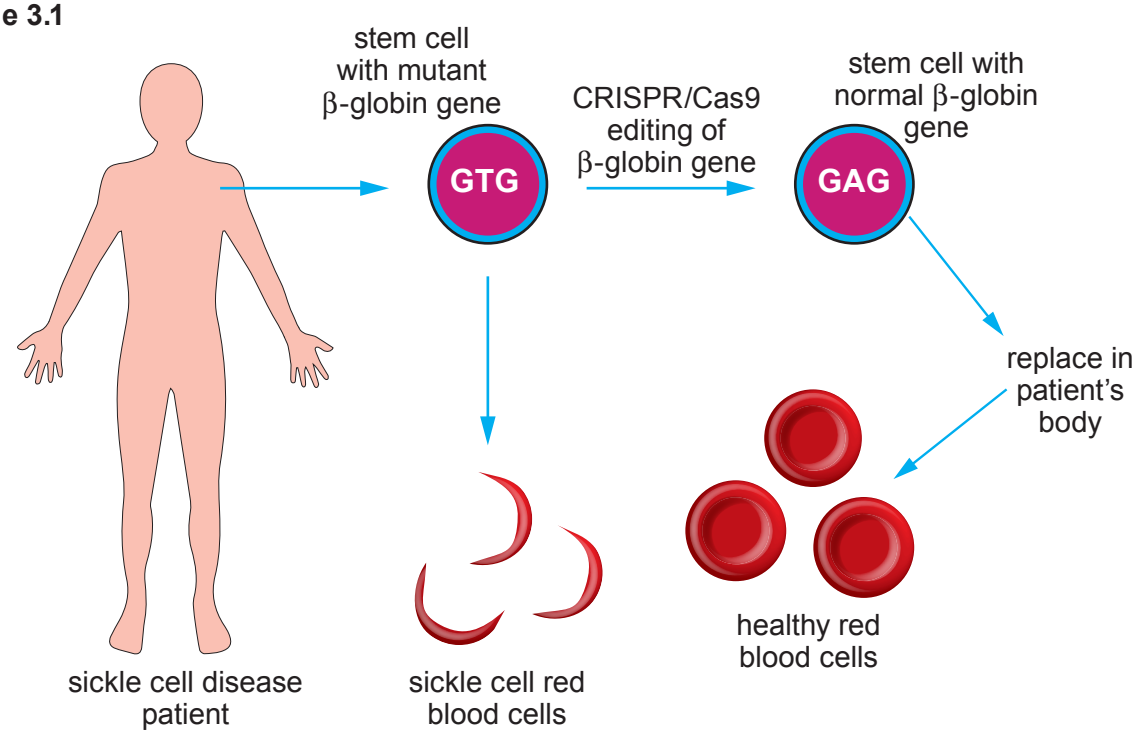
A different form of anaemia is sickle cell disease (SCD). SCD is caused by a point mutation in the β-globin gene. A single nucleotide substitution from A to T in the codon for the sixth amino acid in the β-globin protein converts a glutamic acid to a valine that leads to the production of sickle haemoglobin.

(b) One possible way of treating sickle cell disease is using gene therapy and stem cells as shown in **Image 3.1**. Stem cells are removed from the patient and treated with a gene editing technique called CRISPR/Cas9. The repaired gene can then function normally and the treated stem cells are replaced in the patient.

Image 3.1



(i) State why stem cells must be used in this technique. [2]

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(ii) Describe **two** advantages of using this type of stem cell treatment over using embryonic stem cells. [2]

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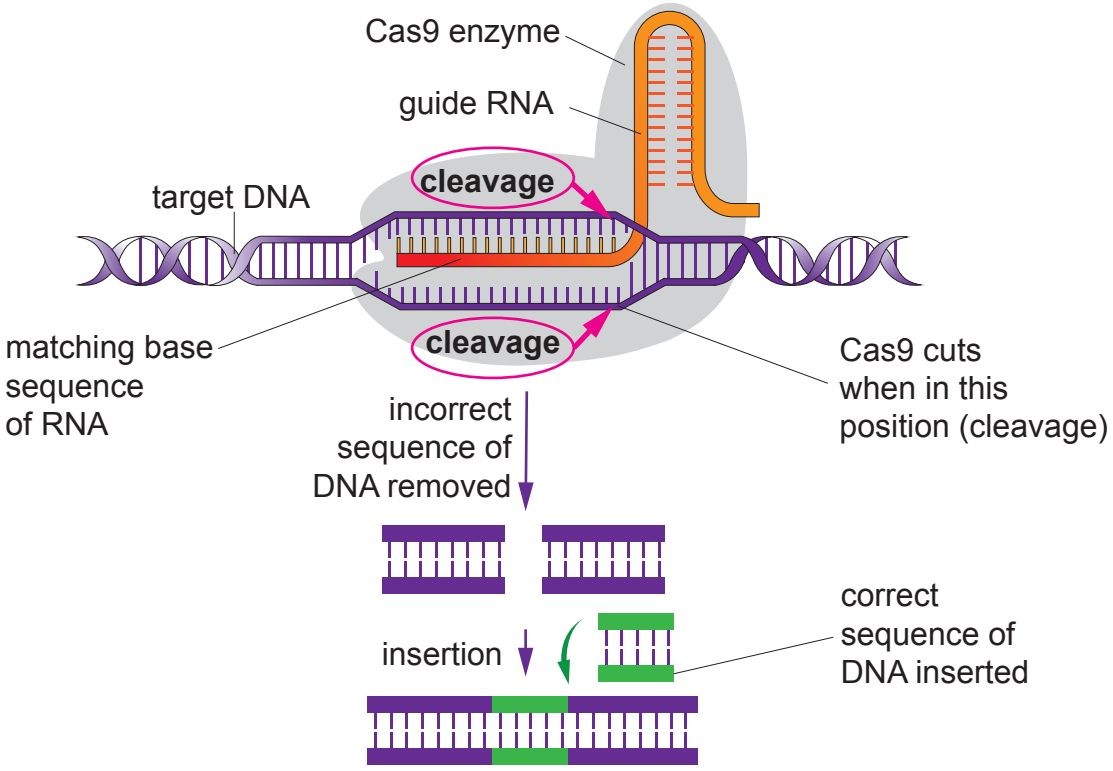
The gene editing relies on the RNA guide recognising a target sequence of DNA so that the editing can be carried out on the correct section of DNA as shown in **Image 3.2**. This RNA is synthesised in laboratories from a template so that it matches the target sequence.

Image 3.2



(iii) Suggest how the results of the Human Genome Project has made the use of this gene editing technique possible. [2]

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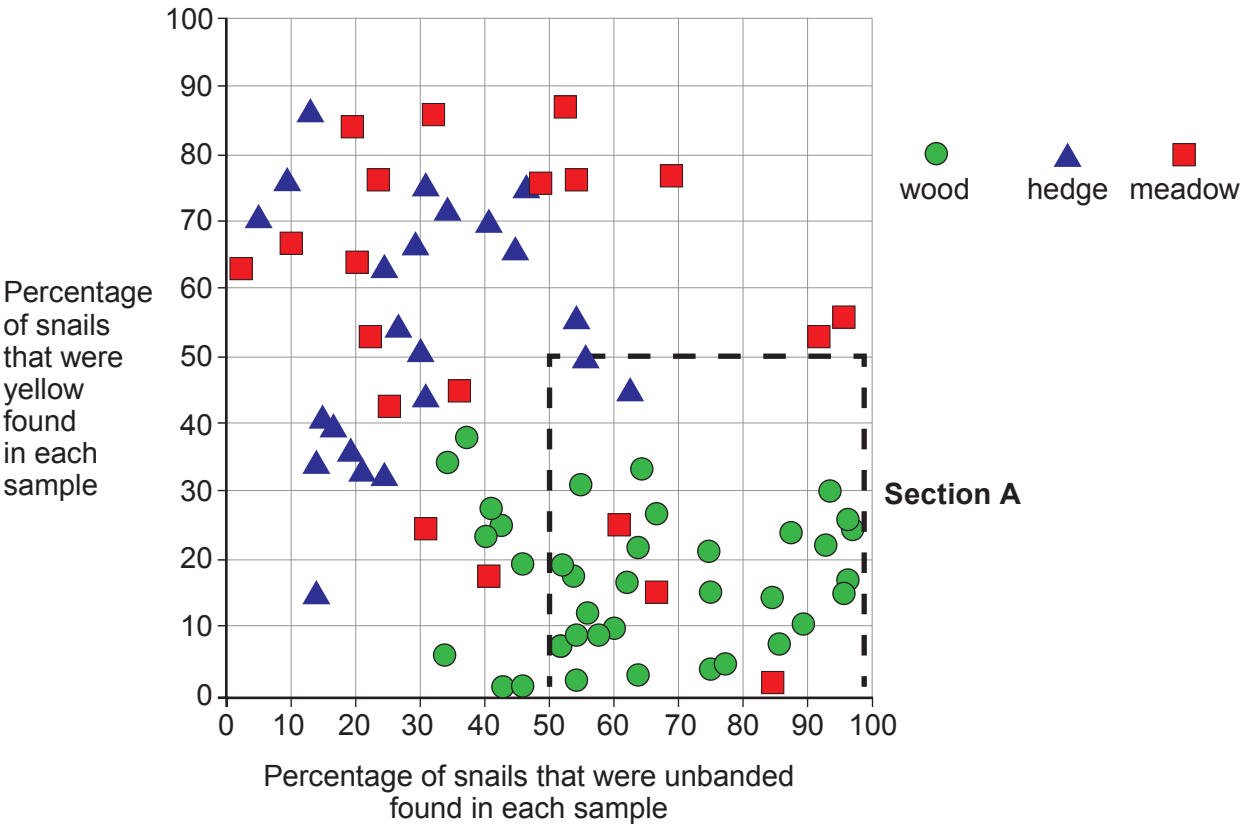
4. *Cepaea nemoralis* is a common British snail which is found in a variety of habitats. The shells of this species of snail vary in the pattern of dark bands found on their surface and their colours. They are either yellow or brown and banded or unbanded. The four phenotypes are shown in **Image 4.1**.

Image 4.1

An investigation was carried out to determine the phenotypes of the snails in a number of different habitats (woodland, hedge and meadow). Snails were collected from a number of different sample areas in each habitat and the percentage of each phenotype was determined. The results are shown in **Graph 4.2**. The different habitats are shown in the key. Each shape on the graph represents the results for one sample area.

Graph 4.2



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(a) (i) Using data from **Graph 4.2**, state the conclusions you could draw about the distribution of the phenotypes in each of the **three** habitats. [3]

Wood

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Meadow

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Hedge

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(ii) Explain why the snails might be distributed in the three habitats in such a way. [1]

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(b) The snails collected from the sample areas shown in **Section A** of **Graph 4.2** were mainly brown and unbanded. The data suggests that there is an uneven distribution of this phenotype between the three habitats.

To statistically test this correlation, a Chi-squared (χ^2) statistical test was applied to the data. The null hypothesis was that 'There is no statistically significant difference in the percentage of brown unbanded snails in the three different habitats'.

Calculate the value of Chi-squared (χ^2) by completing the table and using the formula below. [3]

Habitat	Observed (O)	Expected (E)	$O - E$	$(O - E)^2$	$\frac{(O - E)^2}{E}$
Wood	28				
Hedge	2				
Meadow	3				
	Total = 33				$\sum$ =

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

χ^2 = ...

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Table 4.3

Chi-squared value

Degrees of freedom	Probability (p)									
	0.95	**0.90**	**0.80**	**0.70**	**0.50**	**0.30**	**0.20**	**0.10**	**0.05**	**0.01**
1	0.004	0.02	0.06	0.15	0.46	1.07	1.64	2.71	3.84	6.64
2	0.10	0.21	0.45	0.71	1.39	2.41	3.22	4.60	5.99	9.21
3	0.35	0.58	1.01	1.42	2.37	3.66	4.64	6.25	7.82	11.34
4	0.71	1.06	1.65	2.20	3.36	4.88	5.99	7.78	9.49	13.28

(c) **Table 4.3** shows a range of Chi-squared values. Using two degrees of freedom and the Chi-squared values shown in **Table 4.3**, state whether you would accept or reject the null hypothesis stated in (b). Explain your answer. [3]

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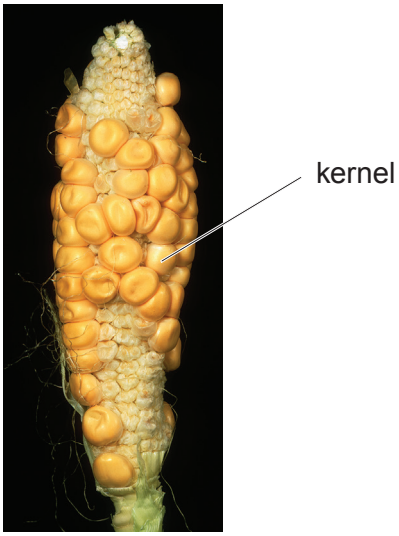
5. Angiosperms are the most successful plant group on earth, in part due to their reproductive strategies.

Following fertilisation in maize, fruits form which are called kernels. **Image 5.1** shows a poorly fertilised maize or corn cob with missing kernels.

Image 5.1



(a) (i) Describe double fertilisation in plants. [2]

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(ii) Explain why **only** the fertilised ovules develop into kernels.
State the advantage to the plant of this. [2]

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(b) Using **Images 5.2** and **5.3**, briefly describe how the following seeds are dispersed. [2]

Image 5.2

Dandelion

Image 5.3

Cocklebur

Dandelion

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Cocklebur

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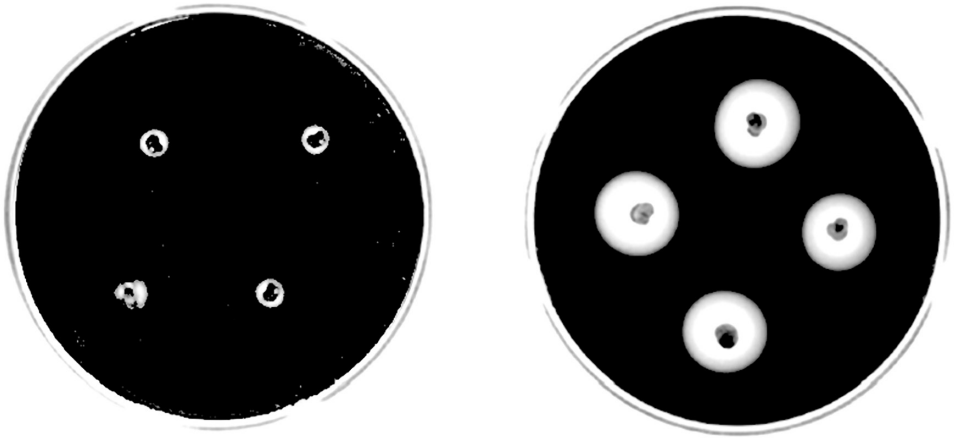
(c) An experiment was carried out to investigate the effect of the embryo on controlling germination in barley grains. The method is given below.

- Half-grains were incubated on the surface of starch-agar gel.
- After 48 hours, the gel was washed with iodine-potassium iodide which reacts with starch to form a blue-black colour.
- A clear circle, or halo, surrounding the half-grain indicates the digestion of starch by α-amylase.
- The results are shown in **Image 5.4**. The control plate (left) contained four half-grains with no embryo present. The plate on the right contained half-grains with embryo intact.

Image 5.4



Control plate: no embryos present **Embryos present**

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(i) State the following variables in this experiment: [2]

Independent variable .....

Dependent variable .....

(ii) State the conclusion you can draw from the experimental results shown in **Image 5.4**. Use your knowledge of plant hormones to explain your answer. [3]

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6. "Call it a 'pizzly' or a 'grolar bear', this new hybrid may be here to stay, say scientists. But is this the end to the polar bear as we know it or the start of a new bear species?"

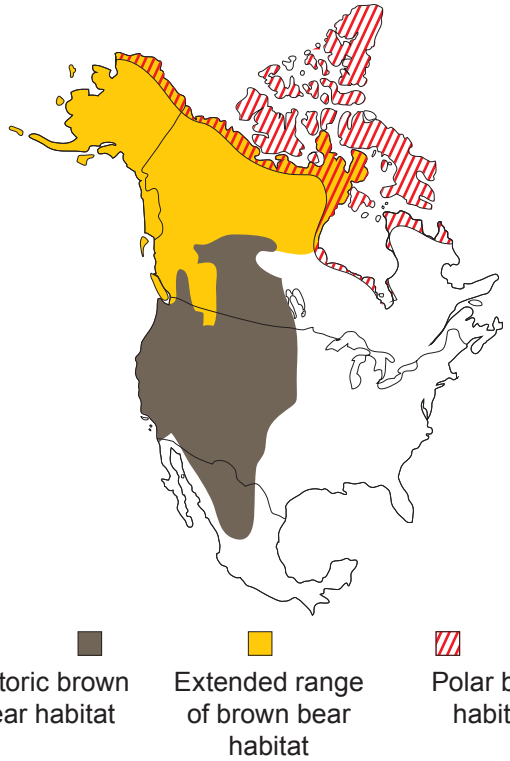
This is the title of a recent scientific report stating that there is an increase in numbers of hybrid bears which are polar bear and brown (grizzly) bear hybrids and subsequent offspring which are ¾ brown bear and ¼ polar bear. The three types of bear are shown in **Image 6.1**.

Image 6.1

polar bear | brown bear | hybrid bear

The map shown in **Image 6.2** is the recently extended geographical range of the brown bear.

Image 6.2



At the start of the last ice age, a population of brown bears in the north became geographically isolated when increased ice stopped the free movement of the brown bears. Following their isolation, these brown bears evolved to become polar bears.

Brown bears eat tubers, berries and fish. Polar bears rapidly evolved a metabolism that let them live off a blubber-rich diet, which would be unhealthy for most mammals. Polar bears have genes related to fat transport, fatty acid metabolism, and cardiovascular function – all of which helps them survive on a diet of mostly fatty marine mammals like seals. Polar bears adjusted to this ultra-high-fat diet in less than 20 500 generations.

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Since 2008, brown bears have been spotted further north than their historic range, a possible consequence of climate change. As a result, the brown bear habitat now overlaps the polar bear habitat. The two kinds of bears, which are capable of mating and producing viable offspring, are considered to be separate species.

Describe how the process of geographical isolation has resulted in the evolution of polar bears from the brown bear.

Explain how the polar bear has adapted to live in its habitat.

Suggest how the existence of hybrid bears affects scientists' confidence that they are two different species. [9 QER]

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9

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