



NSW Education Standards Authority

**2021** HIGHER SCHOOL CERTIFICATE EXAMINATION

# Biology

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## General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used

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## Total marks: 100

### Section I – 20 marks (pages 2–11)

- Attempt Questions 1–20
- Allow about 35 minutes for this section

### Section II – 80 marks (pages 13–36)

- Attempt Questions 21–33
- Allow about 2 hours and 25 minutes for this section

## Section I

20 marks

Attempt Questions 1–20

Allow about 35 minutes for this section

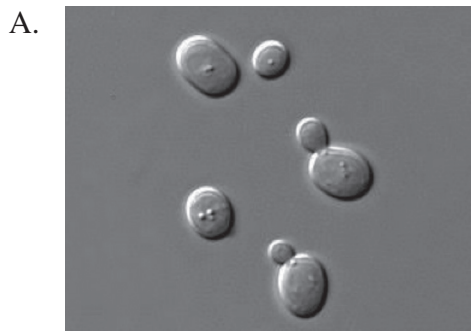
Use the multiple-choice answer sheet for Questions 1–20.

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- 1 A patient felt tired, weak and had a swollen neck. After following the doctor's advice to eat more foods containing iodised salt, her symptoms disappeared.

What was the most likely cause of the patient's symptoms?

- A. Cancer
  - B. Genetic disorder
  - C. Nutritional deficiency
  - D. Environmental exposure
- 2 Which of the following photographs shows an example of sexual reproduction?



Yeast budding

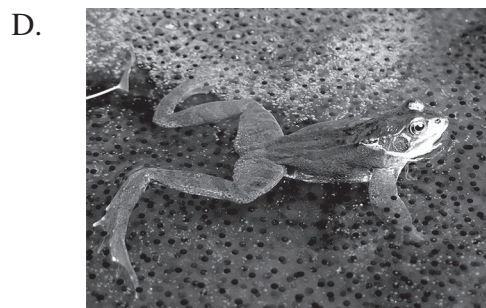


Bacteria – binary fission



Strawberry runners

Stack overflow



Frog spawning

Photo by Salimfadhley

- 3** A scientist transferred male gametes from one plant to another to achieve a desired characteristic in the offspring.

Which genetic technology was the scientist using?

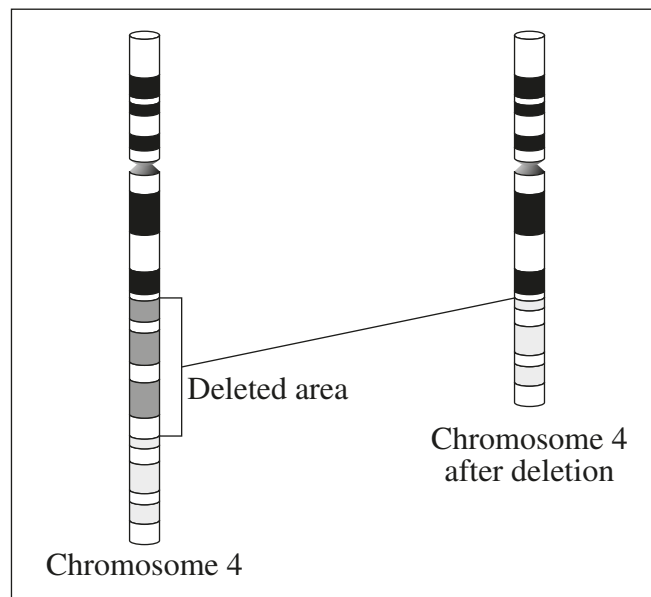
- A. Gene cloning
  - B. Artificial pollination
  - C. Artificial insemination
  - D. Whole organism cloning
- 4** Which is the most effective strategy for treating non-infectious diseases?
- A. Hygiene
  - B. Pharmaceuticals
  - C. Quarantine
  - D. Vaccination

- 5** Glucose levels are maintained by the hormones insulin and glucagon.

Which statement best describes the changes in hormone levels of a healthy human soon after a high glucose meal?

- A. Insulin levels fall and glucagon levels rise.
- B. Insulin levels fall and glucagon levels fall.
- C. Insulin levels rise and glucagon levels fall.
- D. Insulin levels rise and glucagon levels rise.

- 6 A mutation involving a DNA deletion is illustrated.



Courtesy of the National Human Genome Research Institute.  
<https://www.genome.gov/genetics-glossary/deletion>

Which statement about the mutation is correct?

- A. It will have an effect on many genes.
  - B. It will have an effect on only one codon.
  - C. It may be the result of an error during translation.
  - D. It may be the result of an error during transcription.
- 7 Which of the following shows correct base pairing in DNA replication?

- A. A A T G T G C C A  
U U A C A C G G U
- B. A A T G T G C C A  
G G C A C A T T G
- C. A A T G T G C C A  
T T A C A C G G T
- D. A A T G T G C C A  
T T U C U C G G T

- 8 Howard Florey conducted a breakthrough experiment in the development and use of antibiotics. He infected eight mice with *Streptococcus* bacteria. Four mice were given penicillin and survived while the four untreated mice died.

What conclusion could be drawn from the data obtained?

- A. The experiment should be repeated with more mice.
  - B. The use of penicillin causes antibiotic resistance in mice.
  - C. Penicillin may be used on humans safely to treat bacterial infections.
  - D. Penicillin may have played a role in the survival of the four treated mice.
- 9 Streptomycin is an antibiotic that kills bacteria by interfering with the function of their ribosomes.

The primary effect of the antibiotic is that it prevents the bacteria from producing

- A. tRNA.
  - B. mRNA.
  - C. amino acids.
  - D. polypeptides.
- 10 Cystic fibrosis is an autosomal recessive disorder caused by mutations in the *CFTR* gene. Many different recessive alleles cause cystic fibrosis.

The four most common alleles of the *CFTR* gene and their frequencies in the Australian population are shown in the table.

<i>Allele</i>	<i>Frequency of allele (%)</i>
A	98.33
a1	1.13
a2	0.08
a3	0.07

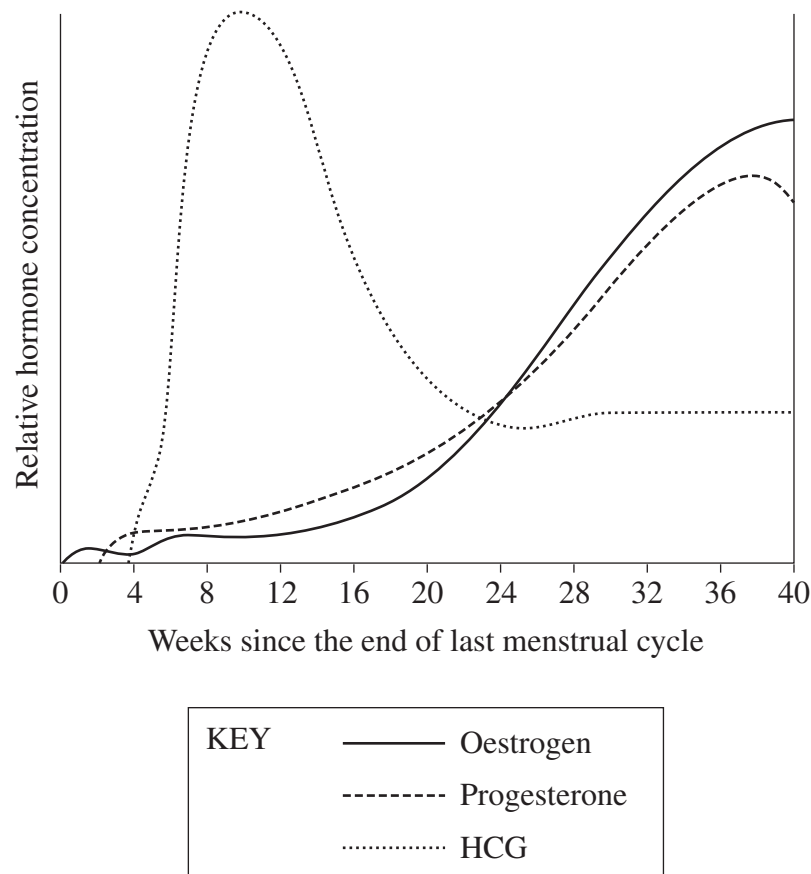
What will be the most common genotype of cystic fibrosis patients in Australia?

- A. a1/a1
- B. a1/a2
- C. A/a1
- D. A/A

- 11 Many transgenic crops have been genetically engineered to have traits such as herbicide resistance. In at least four different crops the transgene has been found in nearby wild plant relatives of the cultivated crops.

What is the most likely reason for this observation?

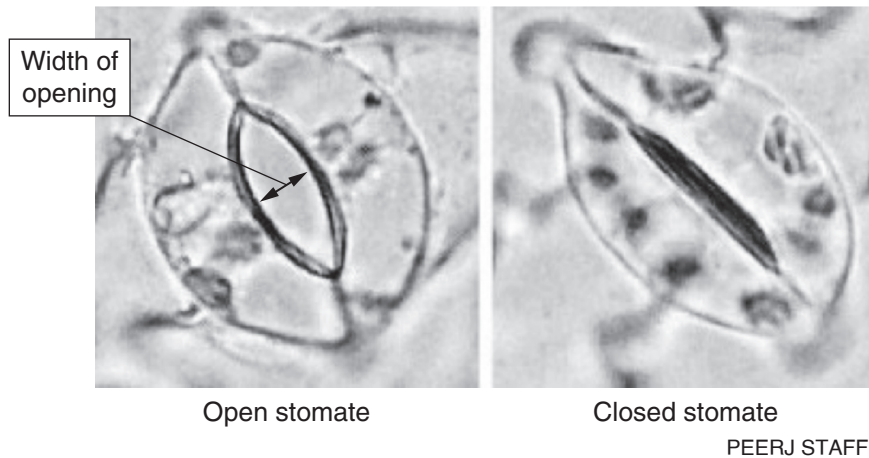
- A. Crossing over in the wild plants
  - B. Gene flow from the crops to the wild plants
  - C. Genetic drift from the crops to the wild plants
  - D. Mutations in the wild plants that match the transgenes
- 12 The graph shows the levels of three hormones, oestrogen, progesterone and human chorionic gonadotrophin (HCG), measured in the blood of a woman during her pregnancy.



Which statement can be inferred from the graph?

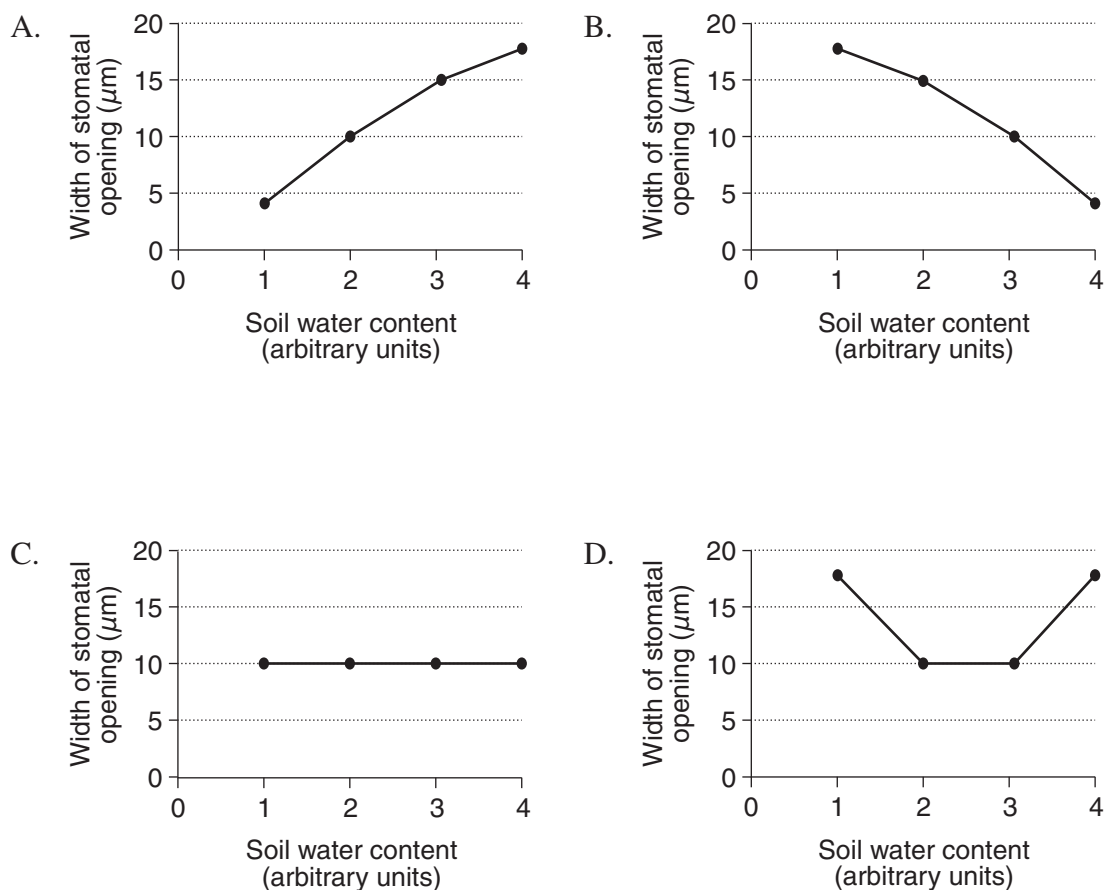
- A. Birth occurred about week 36.
- B. Fertilisation occurred at day 0.
- C. Implantation occurred about week 4.
- D. The placenta was formed about week 24.

- 13 The photographs show an open and a closed stoma on a leaf surface. When open, stomates allow water vapour to pass out of the leaf.



Regulating stomates is a mechanism by which plants maintain water balance.

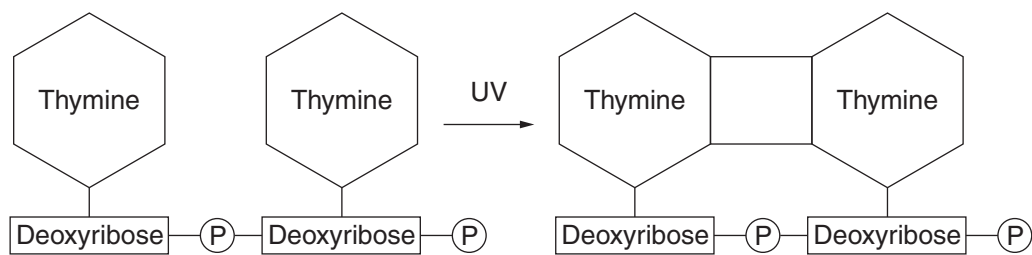
Which of the following graphs best illustrates this homeostatic mechanism?



- 14** The human *PRNP* gene codes for the prion protein. Misfolding of this protein may be the result of ingesting tissue that contains misfolded prion protein or a mutation. Accumulation of misfolded prion protein causes serious diseases such as Creutzfeldt–Jakob disease (CJD).

Which of the following statements best classifies CJD?

- A. It is both a genetic disease and an infectious disease.
  - B. It is a genetic disease only, since it is encoded by a gene.
  - C. It is not an infectious disease because the prion is non-cellular.
  - D. It is an infectious disease and the normal prion protein is the pathogen.
- 15** An example of the mutagenic effect of ultraviolet radiation (UV) on DNA is shown in the diagram.



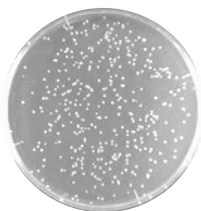
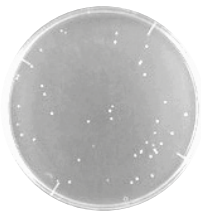
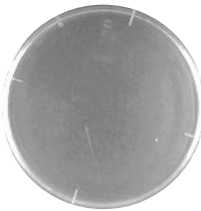
What is the mutagenic effect that is modelled?

- A. Thymine is duplicated.
- B. Bonds are formed between adjacent bases.
- C. Nucleotides form bonds in the backbone of DNA.
- D. Thymines on the two strands of DNA form bonds.



- 16 Scientists conducted an experiment to investigate the effectiveness of treating water from storage dams with UV radiation.

The experiment was conducted more than three times. The results are shown in the table.

<i>UV dose (mJ/cm<sup>2</sup>)</i>	<i>Agar plates after being inoculated with 5 mL of water and incubated at 25°C for 24 hours</i>	
	<i>Photo of agar plate</i>	<i>Average number of bacterial colonies counted</i>
0		365
1		55
6		2

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What conclusion may be drawn from the data obtained?

- A. The control plates are contaminated.
- B. High doses of UV eliminate all pathogens.
- C. Exposure to UV inhibits reproduction of bacteria.
- D. The presence of bacteria reduces the amount of UV.

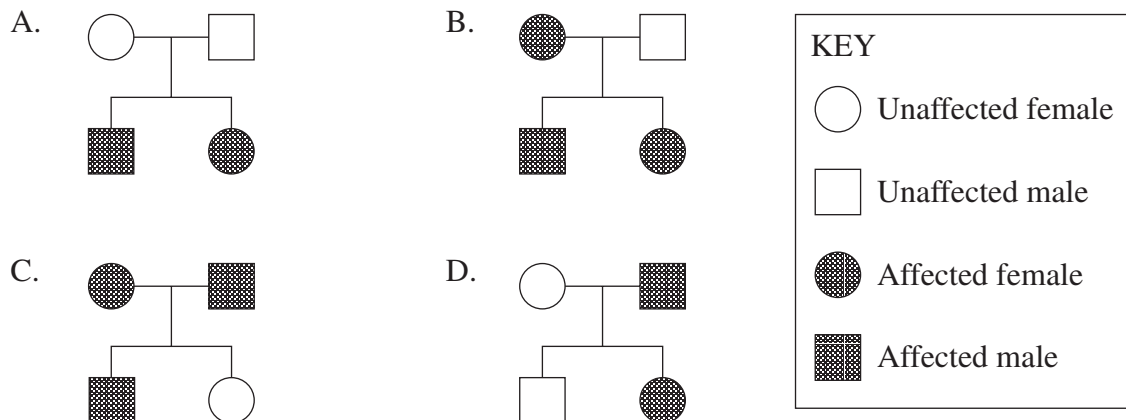
- 17 The images show the sequence of changes in the chromosomes (stained black) during mitosis in plant cells.

Due to copyright restrictions, this material cannot be displayed until permission has been obtained.

Which statement is true for mitosis?

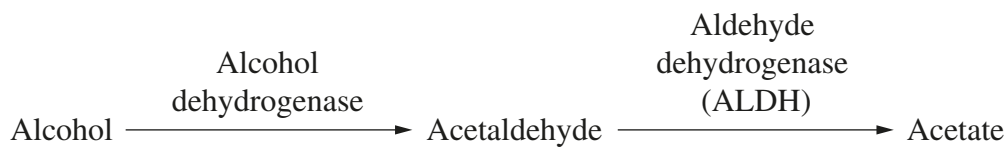
- A. Crossing over occurs during prophase.
- B. Sister chromatids separate during anaphase.
- C. Two daughter cells are produced during telophase.
- D. Homologous pairs of chromosomes line up in metaphase.

- 18 Which human pedigree shows inheritance of a recessive, sex-linked characteristic?



Use the following information to answer Questions 19–20.

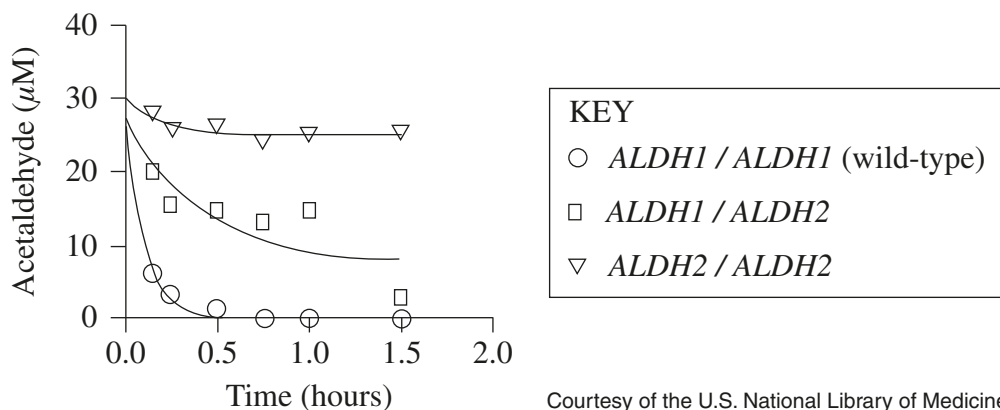
Alcohol that is consumed is broken down by the following pathway.



ALDH is the product of the *ALDH* gene. The normal allele is *ALDH1* but many people have the *ALDH2* allele, which is associated with an increased risk of cancer.

Scientists have used mouse models to study the effects of *ALDH2*. They used wild-type mice with *ALDH1* alleles and genetically-engineered mice with one or two copies of the *ALDH2* allele.

The mice were given a dose of alcohol and the response was measured. The results are shown.



**19** The *ALDH* alleles differ in their

- A. genome location.
- B. location in gametes.
- C. effect on phenotype.
- D. amino acid composition.

**20** What do the data show about the effect of the *ALDH2* allele?

- A. Enzyme activity is highest in homozygous mice.
- B. Enzyme activity decreases if *ALDH2* is present.
- C. Enzyme activity increases if *ALDH2* is present.
- D. Enzyme activity is lowest in wild-type mice.

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Centre Number

**Biology**

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Student Number

**Section II Answer Booklet**

**80 marks**

**Attempt Questions 21–33**

**Allow about 2 hours and 25 minutes for this section**

**Instructions**

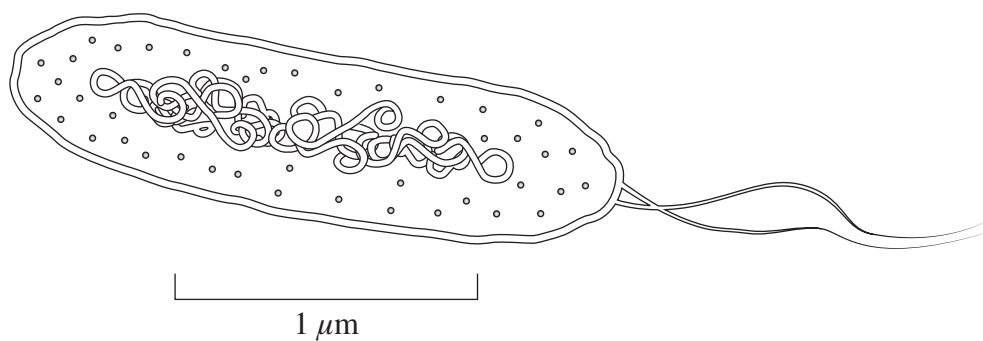
- Write your Centre Number and Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

**Please turn over**

**Question 21** (7 marks)

- (a) Label TWO features on the diagram below that would help to classify this pathogen as a bacterium.

2



**Question 21 continues on page 15**

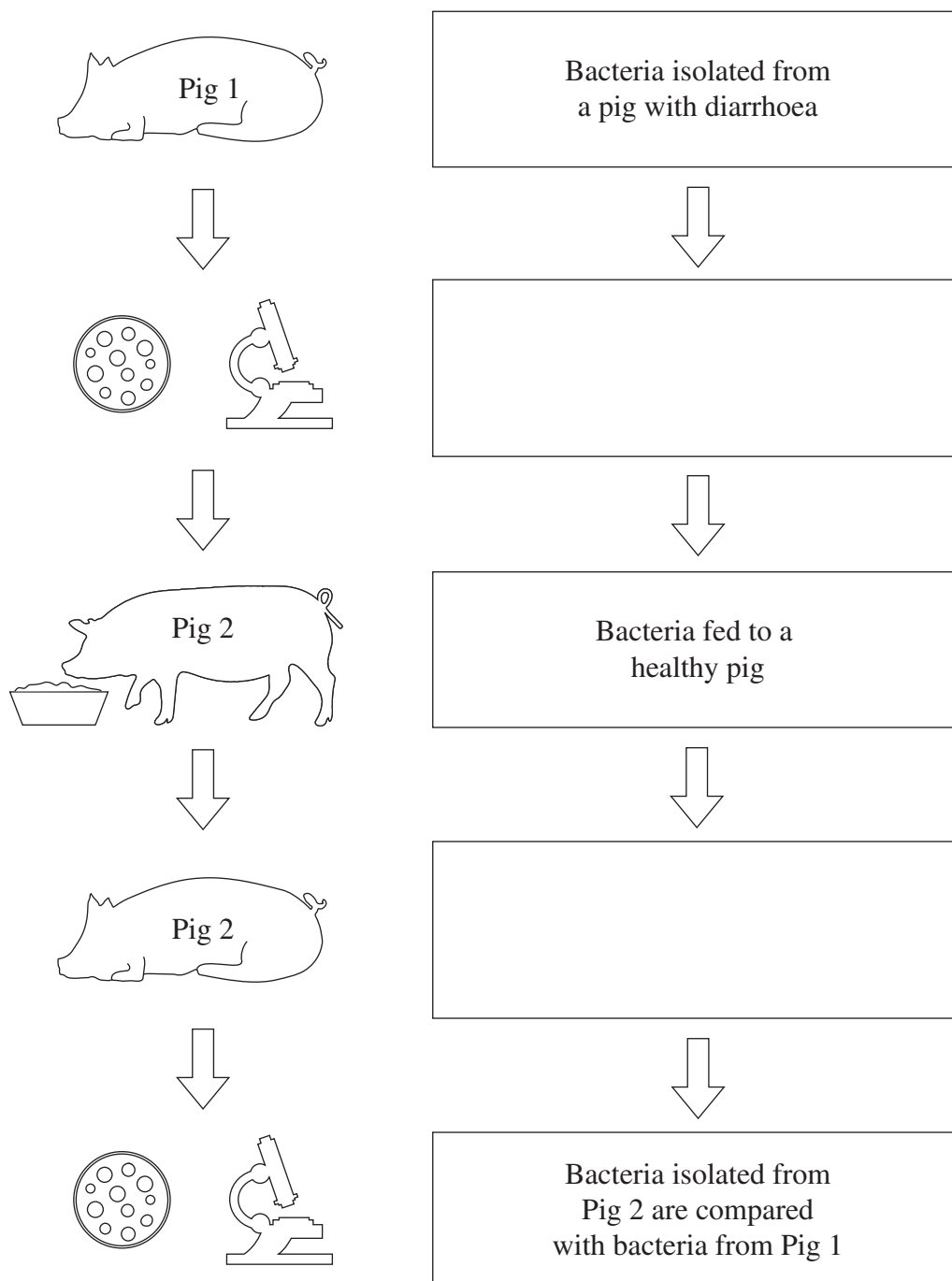
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Question 21 (continued)

- (b) A scientist followed Koch's postulates to confirm that this bacterium was causing diarrhoea in pigs on a local farm.

2

Complete the boxes in the flowchart provided to show the steps taken by the scientist.



Question 21 continues on page 16

Question 21 (continued)

- (c) Two pig farmers on neighbouring farms noticed that their pigs were suffering from diarrhoea and gradually losing weight. The farmers each adopted a different strategy to deal with this disease, as shown in the table.

3

<i>Farm</i>	<i>Strategy</i>	<i>Result</i>
1	Treatment with antibiotics	All pigs recovered after two weeks
2	Elimination of rats and mice from pig sheds to improve hygiene	Decrease in number of sick animals over three months

Outline ONE benefit and ONE limitation of the strategies used on each farm.

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Question 22 (3 marks)

In a population of rabbits, black fur colour is dominant over white fur. A black rabbit, whose mother has white fur, mates with a white rabbit.

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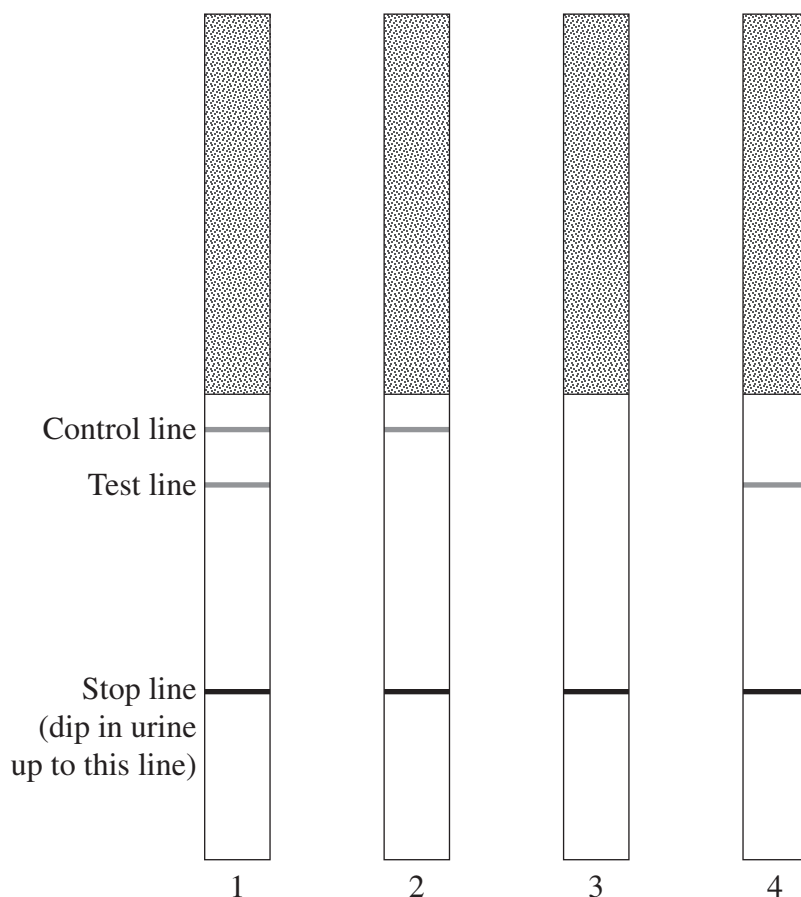
Predict the phenotypic ratio for the offspring of this cross. Show your working.



**Question 23** (3 marks)

**3**

Ovulation in women is associated with a rapid increase in luteinising hormone (LH). Test strips can be used to detect high levels of LH in urine. Once a test strip is used, a control line should appear and the presence of a test line indicates high levels of LH in urine. The image below represents four different results that were obtained.



Which of the results indicates a valid test which shows that ovulation is NOT occurring? Justify your answer.

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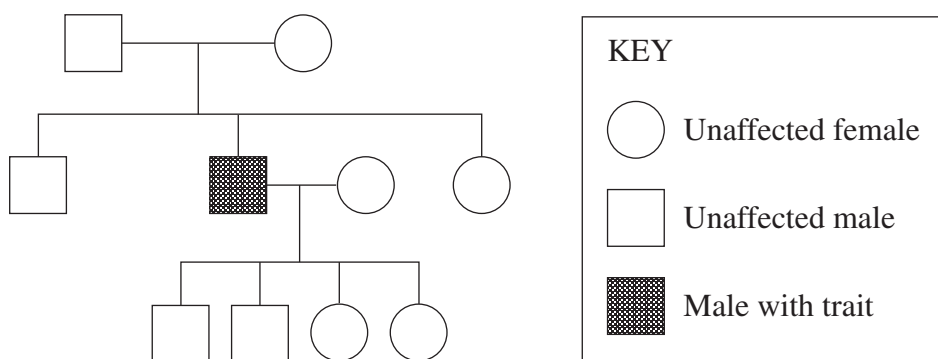
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**Question 24** (7 marks)

An incidence of an autosomal dominant trait is shown in the pedigree.



- (a) Is this trait likely to be the result of a somatic or a germ-line mutation? Justify your answer.

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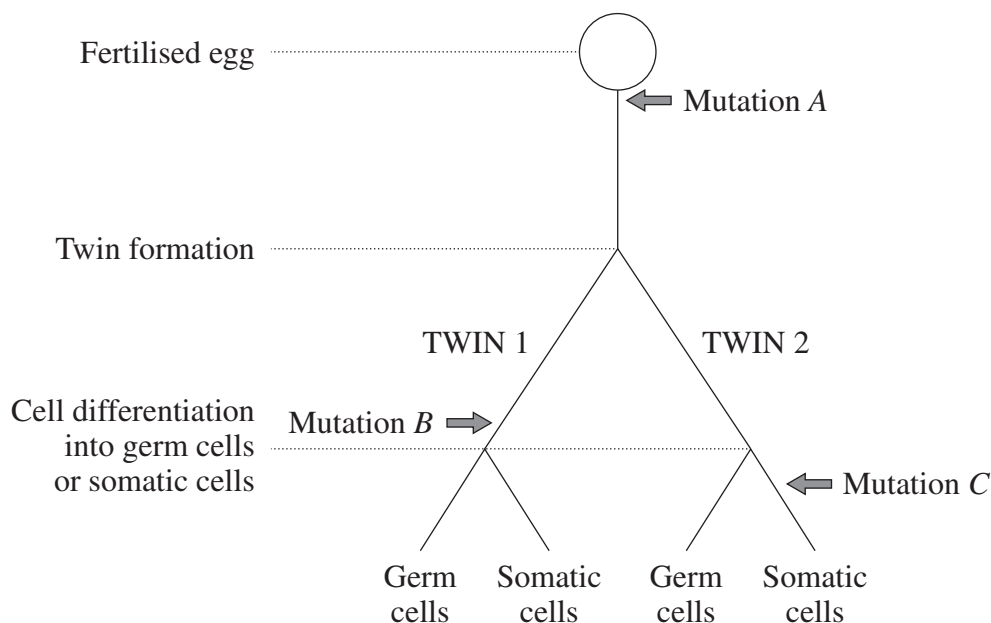
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**Question 24 continues on page 19**

Question 24 (continued)

- (b) The diagram shows the early stages of embryonic development from a fertilised egg. The developing ball of cells has split and monozygotic (identical) twins have formed. Mutations can occur at different times during embryonic development, for example Mutation A would result in both twins having the mutation in all their cells.

4



Explain the effects of Mutation B and Mutation C on each twin and on any offspring that they may have.

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**End of Question 24**

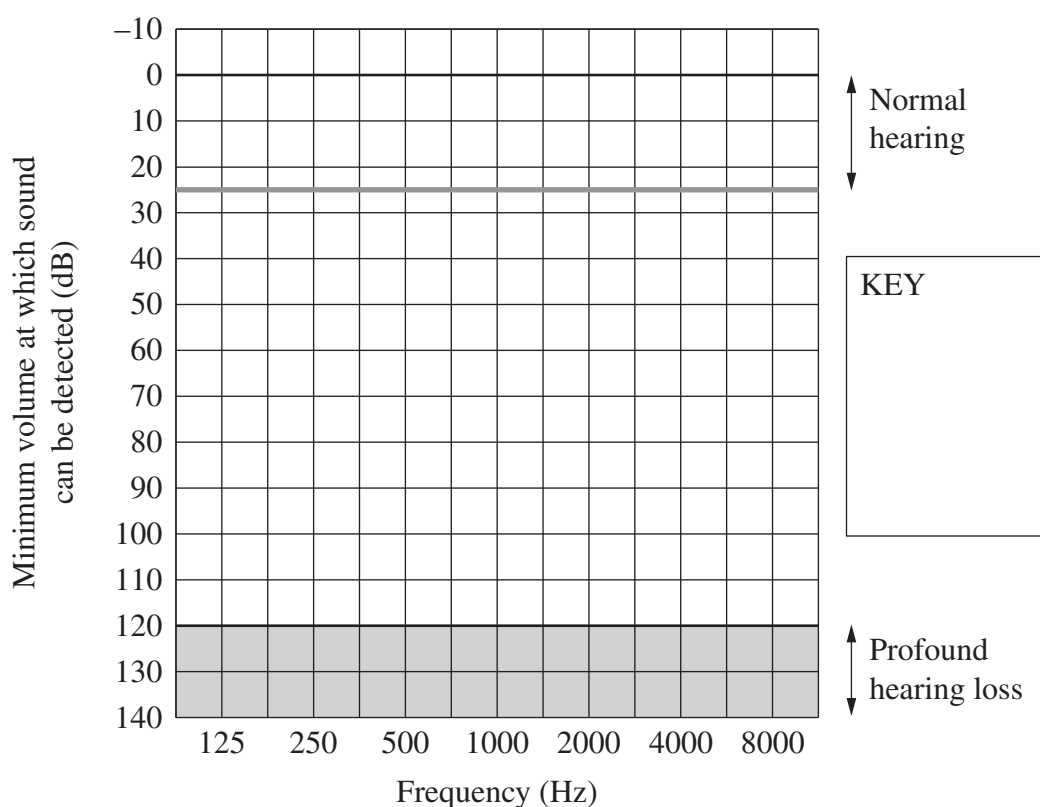
**Question 25** (8 marks)

A patient visited an audiologist for a hearing test. The audiologist tested both ears at specific frequencies. The volumes at which each frequency could be heard are shown.

Frequency (Hz)	Minimum volume at which sound could be detected (dB)	
	Right ear	Left ear
250	5	55
500	9	60
1000	9	75
2000	5	75
4000	9	80
8000	20	100

- (a) Plot the data on the grid provided and include a key.

3



**Question 25 continues on page 21**

Question 25 (continued)

- (b) What conclusions can be drawn about the patient's hearing? 2

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- (c) It is discovered that there is a complete and permanent blockage of the outer ear, 3  
but the cochlea is still fully functional.

Justify the use of a suitable technology to assist the patient's hearing.

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**End of Question 25**

**Question 26** (4 marks)

Zebra populations are suffering from a reduction in their gene pools due to habitat destruction and increasing isolation. This has led to an increase in the number of offspring born with coat patterns different to that of their parents. An example is shown.

4

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Explain possible reasons for the increase in these offspring.

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**Question 27** (3 marks)

Sickle cell anaemia is a genetic disorder. In a family, the parents are both known to be heterozygous for the mutation that causes sickle cell anaemia. The couple has two unaffected children and is now expecting a third child. They have had an allele screening test to determine whether the child will have sickle cell anaemia.

3

A part of the DNA profile is shown. It shows the alleles present.

<i>Mother</i>	<i>Father</i>	<i>Child 1</i>	<i>Child 2</i>	<i>Child 3</i>
████████	████████		████████	████████
████████	████████	████████	████████	

Use the DNA profile provided to justify whether Child 3 will have sickle cell anaemia.

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**Question 28** (8 marks)

- (a) Describe the role of mRNA in human cells.

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**Question 28 continues on page 25**

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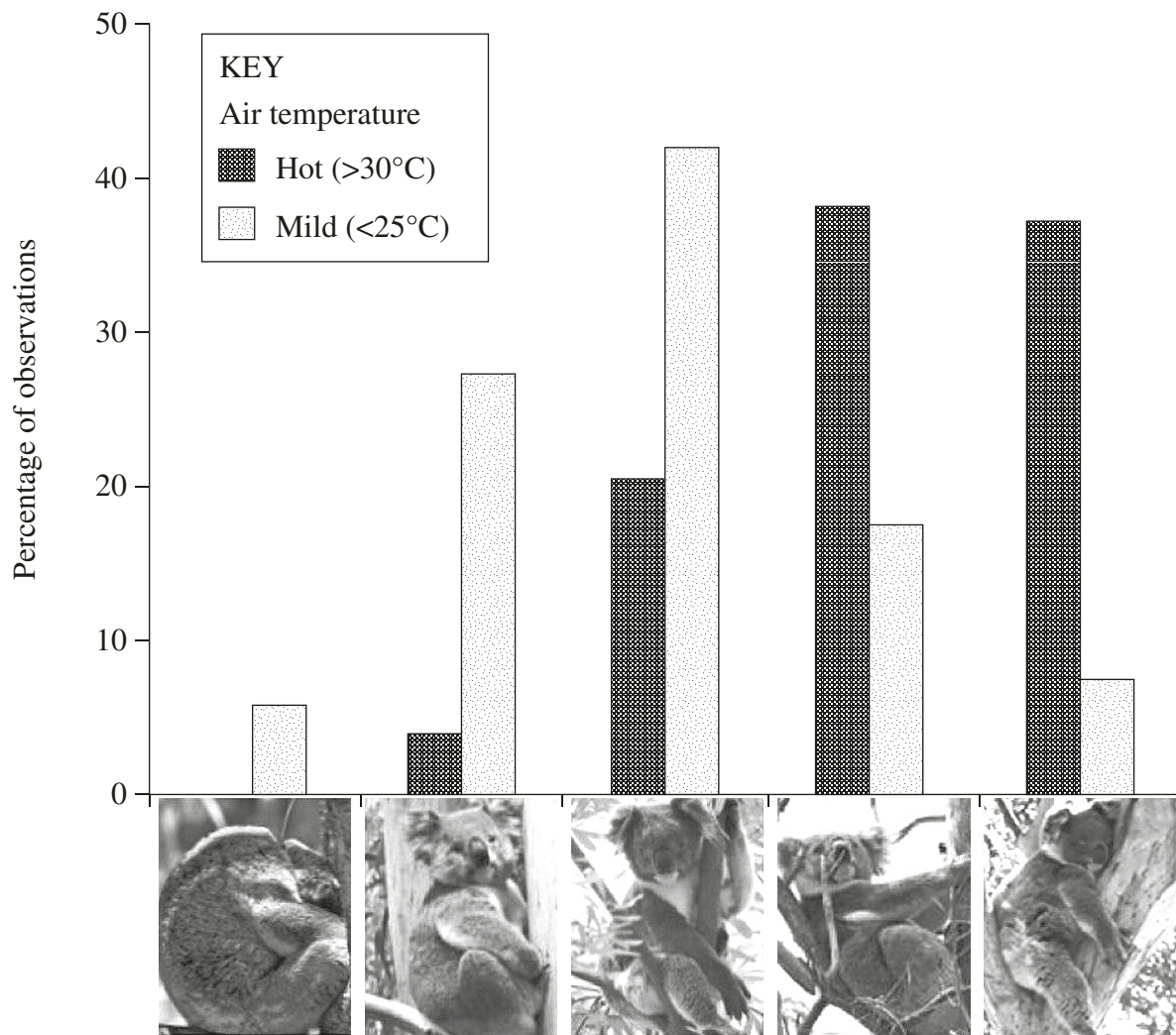
**Question 29** (4 marks)

The koala is a mammal that maintains a stable body temperature of close to 36.6°C.

4

A study was conducted. Koalas were observed in natural forests in south-eastern Australia. Their posture in the tree and the ambient temperature were recorded. Ambient temperatures were divided into two categories, hot and mild.

The graph shows the posture of koalas observed.



Koala posture

By Briscoe N, Handasyde K, Griffiths S, Porter W, Krockenberger A, and Kearney M  
Reproduced with permission of the Licensor through PLSclear

Additional data showed that the temperature of some tree trunks and large branches was up to 9°C cooler than air temperature during hot conditions.

**Question 29 continues on page 27**

Question 29 (continued)

Explain the adaptations used by the koalas in this study to maintain a stable body temperature. Make reference to the stimulus provided.

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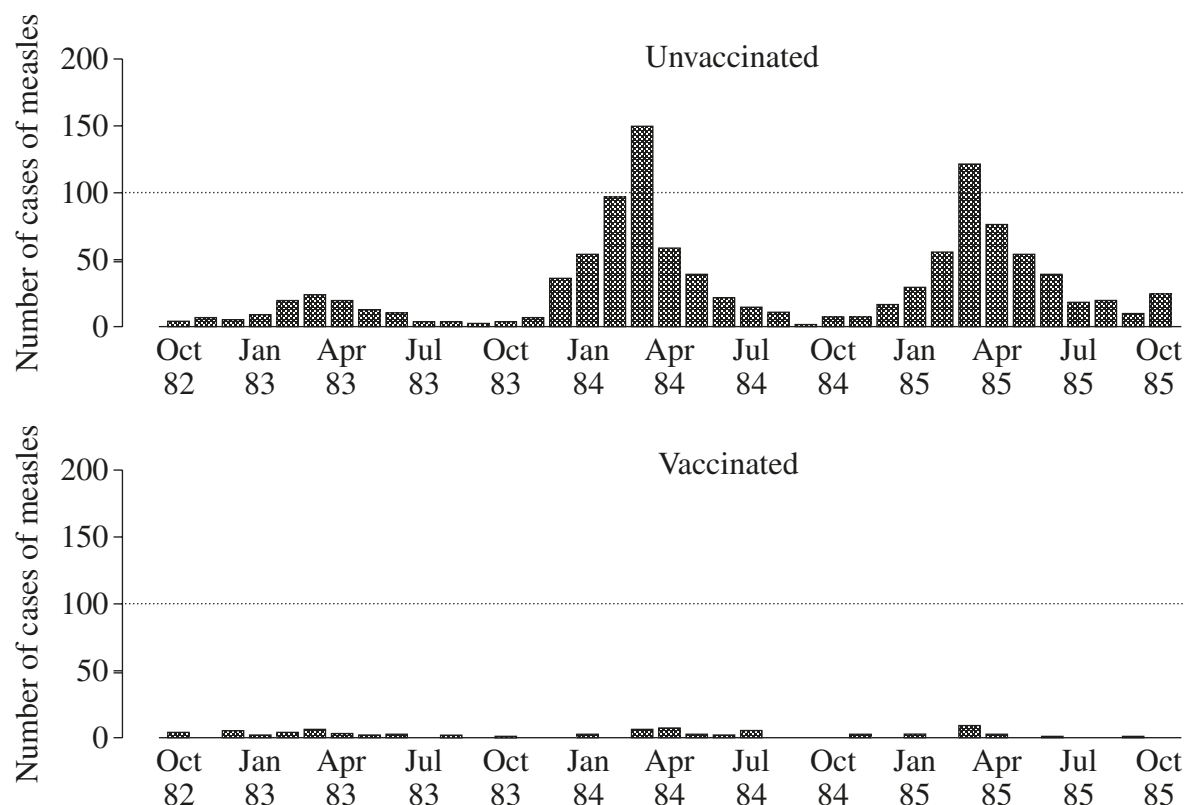
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**End of Question 29**

**Question 30** (7 marks)

A study compared the incidence of disease and survival of 8134 children who had received the measles vaccine with 8134 children from a neighbouring area who remained unvaccinated against measles. Children in each group were matched for age, sex, size of dwelling, number of siblings and maternal education. The graphs show the number of measles cases among the two groups over three years.

7



Aaby, P, Bhuiya, A, Nahar, L, Knudsen, K, de Francisco, A & Strong, M 2003, 'The survival benefit of measles immunization may not be explained entirely by the prevention of measles disease: a community study from rural Bangladesh', International Journal of Epidemiology, vol. 32. Reproduced by permission of Oxford University Press on behalf of the International Epidemiological Association.

The table compares the cause of death and number of deaths of the two groups over the same three years.

Cause of death	Number of deaths	
	Children vaccinated against measles	Children unvaccinated against measles
Measles	2	40
Diarrhoea and dysentery	85	156
Oedema (swelling due to fluid in the tissues)	6	21
Fever	22	25
<b>Total</b>	<b>115</b>	<b>242</b>

**Question 30 continues on page 29**

‘A vaccine only protects the community against a specific disease.’

[illegible]

– 29 –

**Question 31** (6 marks)

6

Millions of people around the world take drugs known as statins, which have been shown to reduce the incidence of heart attacks and strokes in vulnerable patients. However, up to 20% of people stop taking statins due to side-effects such as muscle aches, fatigue, feeling sick and joint pain.

A recent study at a public hospital focused on 60 patients who had all stopped taking statins in the past due to severe side-effects. Patients took statin tablets for four months, placebo tablets for four months and no tablets for four months.

Every day for the year the patients scored, from zero to 100, how bad their symptoms were. The results are shown.

<i>Four month treatment</i>	<i>Average score symptoms / 100</i>
Statin tablets	16.3
Placebo tablets	15.4
No tablets	8.0

Evaluate this study and its results.

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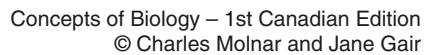
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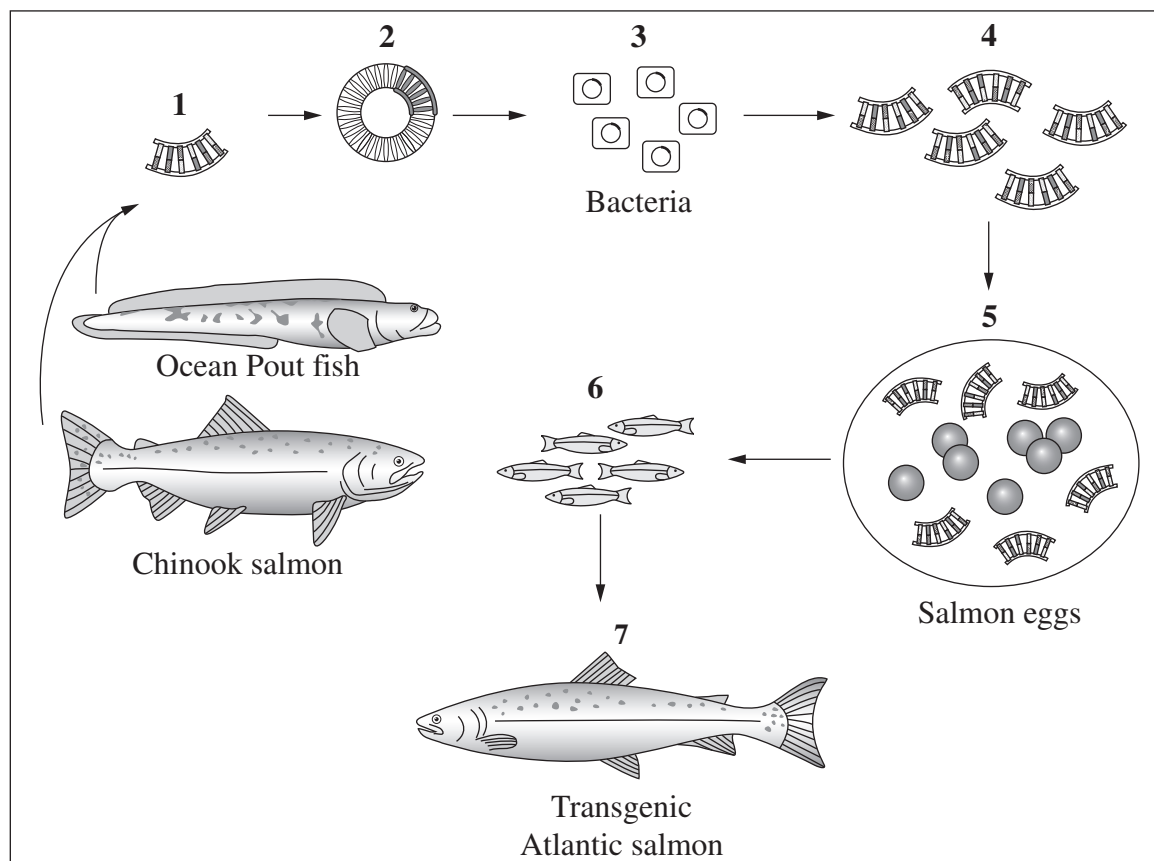


Explain the changes that would occur in the testes of a male athlete continuously taking anabolic steroids. Support your answer with reference to the flow chart.

[illegible]

**Question 33** (15 marks)

Genetically engineered Atlantic salmon have been produced and approved for aquaculture in the US. These salmon have a transgene that includes a protein-coding sequence from a Chinook salmon's growth hormone gene and the promoter region of an Ocean Pout's antifreeze protein gene. The following diagram provides an overview of the production of the transgenic salmon.



- (a) Explain the processes shown in steps 1–4.

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**Question 33 continues on page 33**



Question 33 (continued)

- (b) The graph summarises the growth of standard salmon and transgenic salmon.

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Explain ONE potential benefit of using transgenic salmon in aquaculture. Support your answer with data from the graph.

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Question 33 continues on page 34

Question 33 (continued)

- (c) Transgenic fish can reproduce and pass on the dominant transgene (T).

9

Reproduction for aquaculture is strictly controlled using a variety of techniques in order to protect and preserve biodiversity.

Some of these techniques are outlined below.

1. Homozygous (TT) female (XX) breeding stock are kept in quarantine.
2. The female fish undergo hormone treatment that results in sex reversal and the development of male sex organs and sperm.
3. The sperm produced is collected and used to fertilise eggs obtained from wild-type, non-transgenic salmon.
4. The eggs are treated with pressure shock to prevent the completion of meiosis II. As a result, offspring are triploid (three copies of each chromosome).

All offspring are transgenic female fish and have XXX (XXX fish cannot develop sex organs).

5. Offspring are transported to inland aquaculture tanks to be grown to market size.

Analyse how these techniques protect and preserve biodiversity.

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Question 33 continues on page 35

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– 35 –

**Section II extra writing space**

**If you use this space, clearly indicate which question you are answering.**

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