Biology

2023 examination

Section 1: **Multiple-choice questions** (Questions 1 to 15) 15 marks
Answer **all** questions in Section 1
Allow approximately 25 minutes

Section 2: (Questions 16 to 24) 105 marks
Answer **all** questions in Section 2
Allow approximately 105 minutes

Approved calculators may be used

Total time: 130 minutes

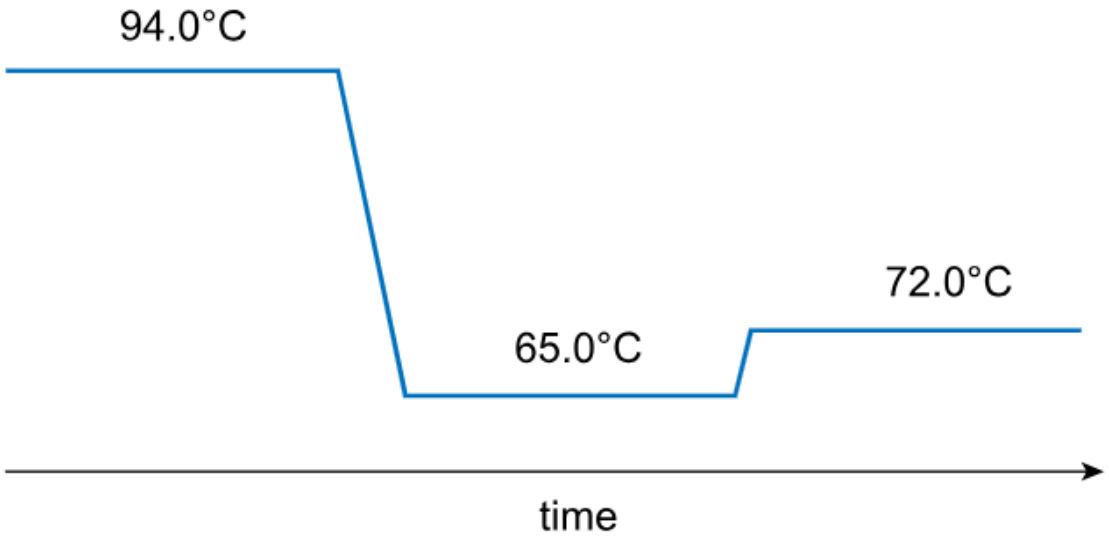
Total marks: 120

© SACE Board of South Australia 2023

Source 1

Information for Question 2

The diagram below shows the sequence of steps for part of one cycle in a polymerase chain reaction (PCR).



Source 2

Information for Question 3

Table 1: The mRNA codons for selected amino acids

Amino acid	*mRNA codon(s)*
phenylalanine (Phe)	UUU, UUC
serine (Ser)	UCU, UCC, UCA, UCG, AGU, AGC
leucine (Leu)	UUA, UUG, CUU, CUC, CUA, CUG
isoleucine (Ile)	AUU, AUC, AUA
methionine (Met)	AUG

Table 2: The base sequences of an original and a mutated DNA template strand

original	TAC AAC TAG AAG
mutated	TAC AAT TAT AAA

Table 3: Effect of the mutations listed in Table 2 on the second, third, and fourth amino acid, and the likely effect on the function of the resulting protein

	Second amino acid	*Third amino acid*	*Fourth amino acid*	*Function of resulting protein*
J	changed	unchanged	unchanged	unchanged
K	unchanged	unchanged	unchanged	unchanged
L	unchanged	changed	changed	changed
M	changed	changed	changed	changed

Source 3

Information for Question 5

The table below describes a cell before and after process A, B, C, or D.

Process	*Cell before process*	*Cell after process*
A	haploid	haploid
B	diploid	diploid
C	haploid	diploid
D	diploid	haploid

*Questions 1 to 15 are multiple-choice questions. For each multiple-choice question, indicate the **one** alternative that you consider best answers the question by clicking on the bubble beside it.*

Each question is worth 1 mark.

Questions 1 to 5

1. Which one of the following processes is **not** used to transfer genes between species?

- Introduction of DNA into a fungal cell using high-voltage electric shocks.
- Transformation of bacteria using plasmids.
- Microinjection of DNA molecules into the nucleus of an animal cell.
- Changes to plant DNA through exposure to UV light.

Refer to Source 1 when answering Question 2.

2. The step in the cycle at 65.0°C in Source 1 is required for

- the separation of the double-stranded DNA templates into two single strands.
- the formation of bonds between the primers and the DNA templates.
- the addition of nucleotides to the new DNA strands by DNA polymerase.
- transcription from the DNA template.

Refer to Source 2 when answering Question 3.

3. Which one of the combinations in Table 3 in Source 2 is consistent with the information in Table 1 and Table 2?

- J
- K
- L
- M

4. Fungal cells

- are prokaryotic and do not have a nucleus.
- are eukaryotic and have chloroplasts.
- have a cell wall but do not have chloroplasts.
- have a cell membrane and chloroplasts.

Refer to Source 3 when answering Question 5.

5. Which one of the following statements is consistent with the information in the table in Source 3?

- Process A could be mitosis.
- Process B could be meiosis or mitosis.
- Process C could be meiosis.
- Process D could be fertilisation.

Source 1

Information for Question 6

The fennec fox (*Vulpes zerda*) is a small mammal native to North Africa. Each **gamete** of the fennec fox has 32 chromosomes.

Fennec fox



Source: adapted from © Catherine Downie | Dreamstime.com

Source 2

Information for Question 8

Acetylcholine is a neurotransmitter required for the functioning of most muscles in the human body.

Some poisonous plants can cause life-threatening paralysis. The toxins from these plants prevent acetylcholine from binding to receptors.

The toxin botulinum from the bacterium *Clostridium botulinum* can cause temporary paralysis by preventing the release of acetylcholine from vesicles into the synapse.

The table below lists combinations of toxin source, mechanism of toxin action, and effector.

	Toxin source	***Mechanism of toxin action***	***Effector***
J	plant	prevents acetycholine from binding to receptors on muscle cells	neuron
K	bacterium	prevents exocytosis	muscle
L	plant	prevents acetylcholine from binding to receptors on neurons	synapse
M	bacterium	prevents the uptake of vesicles by neurons from the synapse	muscle

Source 3

Information for Question 10

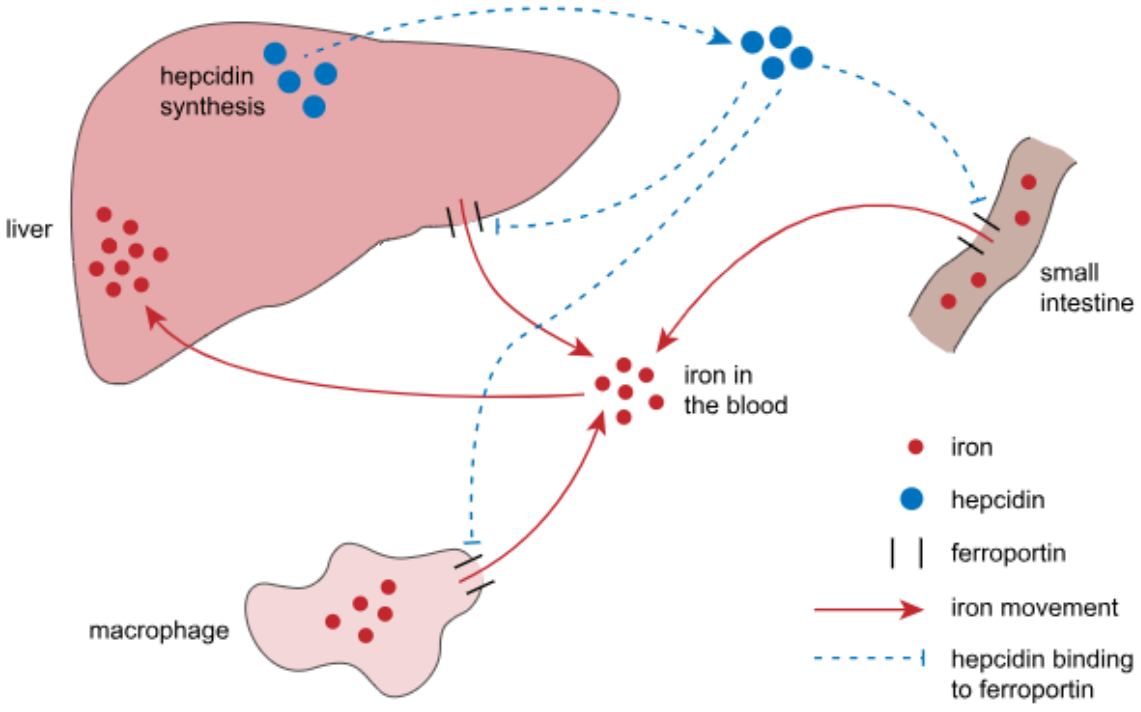
Iron is an essential nutrient for humans, but it is toxic if the concentration is too high.

One of the body's mechanisms for regulating the concentration of iron in the blood involves ferroportin and hepcidin.

Ferroportin is a cellular iron-export protein. Hepcidin is a peptide hormone that controls the amount of iron exported from specific cells by binding to the ferroportin in their cell membranes.

A high concentration of iron in the blood results in the synthesis of more hepcidin, which reduces iron absorption from the small intestine into the blood. Hepcidin also prevents the export of iron from the liver, and from cells such as macrophages. As a result, more iron remains in storage.

The diagram below summarises the hepcidin–ferroportin mechanism.



[This diagram is not drawn to scale]

Questions 6 to 10

Refer to Source 1 when answering Question 6.

6. Cells of the fennec fox undergoing a normal meiotic division contain

- 16 pairs of homologous chromosomes at the start of prophase II.
- 32 chromosomes at the end of telophase I.
- 64 chromosomes at the start of metaphase II.
- 64 chromatids at the end of prophase I.

7. Which one of the following processes is **not** an example of homeostasis?

- Synthesis of neurotransmitters in a neuron.
- Restoration of blood glucose level to normal.
- Decrease in body temperature after vigorous exercise.
- Reabsorption of water from the tubule of a nephron into the blood.

Refer to Source 2 when answering Question 8.

8. In the table in Source 2, which one of the combinations of toxin source, mechanism of toxin action, and effector is correct?

- J
- K
- L
- M

9. If the solute concentration of the blood decreases, the tubule of the nephron will be

- less permeable to water and the urine will be more concentrated.
- less affected by ADH, resulting in a decrease in the excretion of water.
- affected by adrenaline, causing a decrease in the reabsorption of water.
- less permeable to water and more urine will be produced.

Refer to Source 3 when answering Question 10.

10. Which one of the following statements is consistent with the information provided about the hepcidin–ferroportin mechanism?

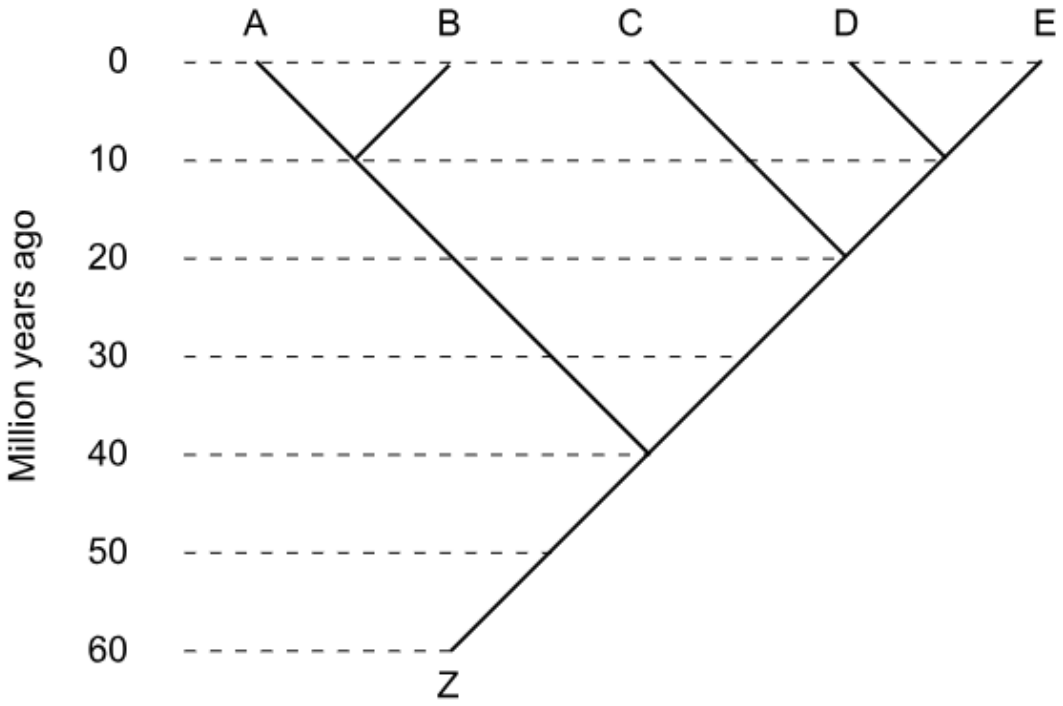
- An increase in hepcidin will lead to an increase in the level of iron in the blood.
- An inhibitor that stops the synthesis of hepcidin will block the absorption of iron from the small intestine.
- Ferroportin controls the export of iron into the blood by negative feedback.
- A low level of iron in the blood will result in less hepcidin being synthesised and more iron being released from storage into the blood.

Source 1

Information for Question 14

The diagram below represents the evolutionary relationships between five species — A, B, C, D, and E — and their common ancestor, species Z.

The relationships are based on the similarity in the sequence of DNA bases found in genes common to these five species.



Source 2

Information for Question 15

Five 1 cm cubes were cut from a potato for an investigation, and their masses were measured using two balances, A and B, shown below. The measurements are given in the table below.

The true average density of potato is 1.067 g/cm^3.

Balance A (±0.001 g)	*Balance B (±0.01 g)*
	

Potato cube	*Mass of potato cube (g)*	
	Balance A	*Balance B*
1	1.023	1.03
2	1.109	1.10
3	1.041	1.05
4	1.078	1.08
5	1.044	1.05
Average	**1.059**	**1.06**

Questions 11 to 15

11. Which one of the following features of two individual organisms would be of **least** use when deciding whether they belong to the same species?

- They show similar morphology.
- They share a common gene pool.
- They have biochemical similarity.
- They exhibit the same behaviours.

12. The Tasmanian devil (*Sarcophilus harrisii*) is an endangered species of carnivorous marsupial. It is estimated that about 25 000 Tasmanian devils live in the wild.

    Such a relatively small population is a cause for concern because

- reduced genetic diversity in a species increases its risk of extinction.
- there is a shortage of breeding pairs of Tasmanian devils.
- a smaller gene pool will result in greater genetic diversity in the species.
- this could lead to an increase in the mutation rate in Tasmanian devils.

13. Convergent evolution of two unrelated species results from

- successful breeding to form a viable hybrid.
- evolution to resemble a common ancestor.
- being subjected to similar selection pressures.
- exploiting a range of new habitats.

Refer to Source 1 when answering Question 14.

14. Based on the information in Source 1, it is reasonable to assume that

- the DNA sequence in species E has not changed in 60 million years.
- species A is more closely related to species B than species D is to species E.
- species C is more closely related to species E than it is to species B.
- species A is more closely related to species C than it is to species E.

Refer to Source 2 when answering Question 15.

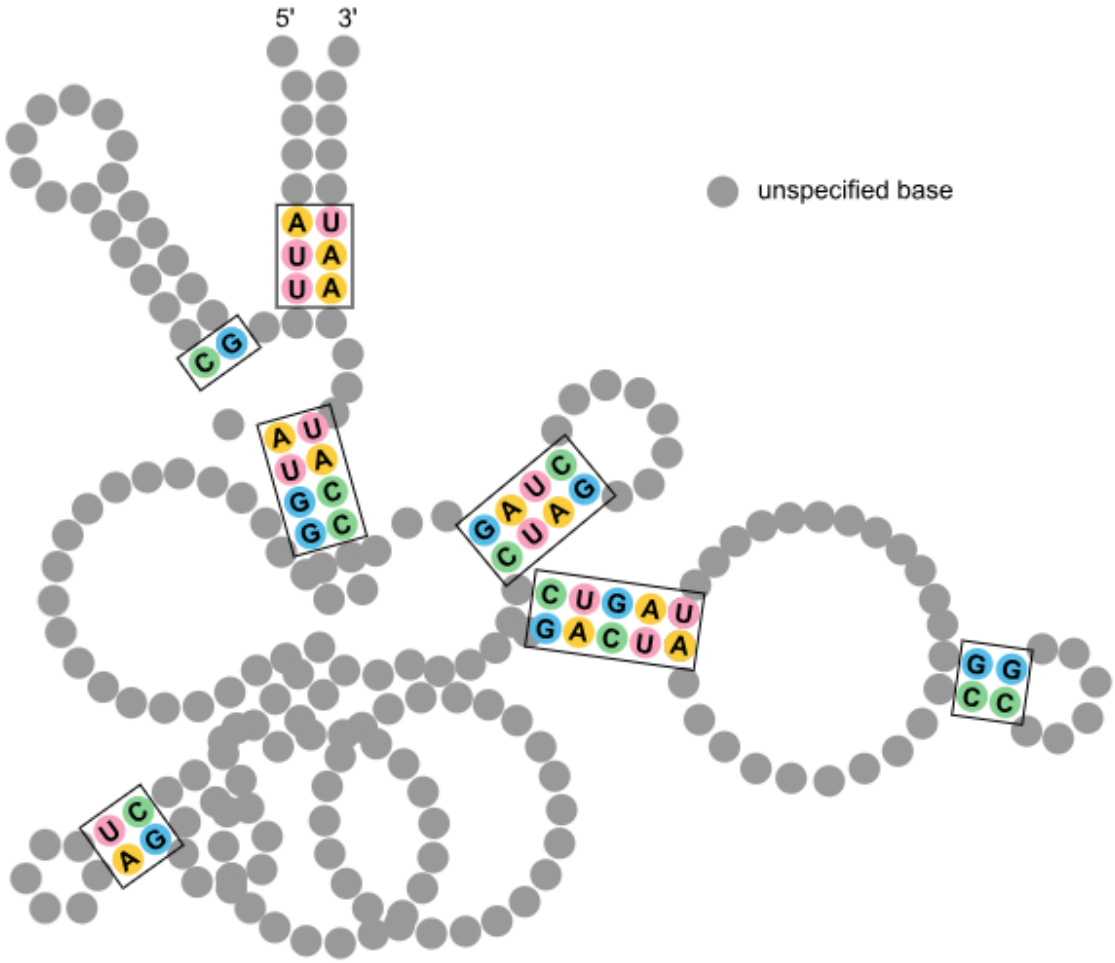
15. Compared with Balance B, Balance A

- had greater resolution, but less precise data.
- gave a more accurate average, but less precise data.
- gave a less accurate average, but more precise data.
- had greater resolution and gave a more accurate average.

Source

Information for Question 16

GIR1 is a naturally occurring RNA molecule, which can fold into the unique three-dimensional shape represented below.



Source: adapted from the Rfam database under CC0 1.0, viewed 26 June 2023, rfam.org

Question 16 (a) to (f)

Refer to the source when answering Question 16.

(a) GIR1 has the ability to cut other RNA molecules.

State the name given to RNA molecules that are able to catalyse chemical reactions.

(1 mark)

(b) Some bases in the diagram are outlined by boxes.

State a property of RNA that enables GIR1 to fold into this unique three-dimensional shape.

(1 mark)

(c) Explain the likely effect of high temperatures on the function of this molecule.

(3 marks)

(d) Describe **one** difference between the structure of RNA and DNA.

(2 marks)

(e) State **one** function of RNA, other than catalysing chemical reactions, that would enable the first simple cells to survive without DNA and proteins.

(1 mark)

(f) Explain **one** piece of evidence that supports the idea that eukaryotic cells probably evolved **from** prokaryotic cells.

(3 marks)

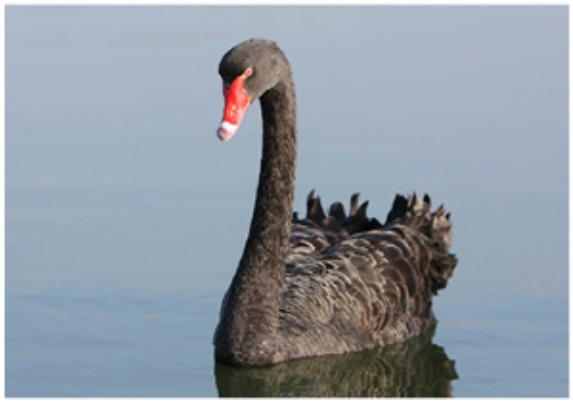
Source

Information for Question 17

The black swan (*Cygnus atratus*) is native to Australia. A detailed study of its genome was published in January 2023. One gene identified was *TLR7*, which codes for the toll-like receptor 7 protein (TLR7). The TLR7 protein is produced when the *TLR7* gene is expressed. The TLR7 protein detects the presence of the highly pathogenic avian influenza (HPAI) virus inside a host cell.

As part of an investigation, cells from a range of bird species were cultured and infected with the HPAI virus. This investigation included the mute swan (*Cygnus olor*), which is closely related to the black swan and is native to the Northern Hemisphere. The *TLR7* gene was present in all species that were tested, and no structural difference between the genes was identified. Although the *TLR7* gene was present in the cells of the black swan, it was not transcribed.

Black swan (left) and mute swan (right)





Source: black swan adapted from © CraigRJD | iStockphoto.com; mute swan adapted from © HeckiMG | Pixabay.com

Question 17 (a) to (e)

Refer to the source when answering Question 17.

(a) Describe the first step that occurs in the nucleus of a cell to enable the expression of the *TLR7* gene.

(3 marks)

(b) State the consequence of the absence of the TLR7 protein in a black swan.

(1 mark)

(c) Explain why the TLR7 protein would probably not detect other pathogens, such as bacteria.

(2 marks)

(d) Explain **one** reason for sequencing the genome of the black swan.

(2 marks)

(e) The HPAI virus has not yet been detected in black swan populations in Australia. The virus has the potential to infect other bird species, including poultry. Measures have been adopted to protect black swans from HPAI.

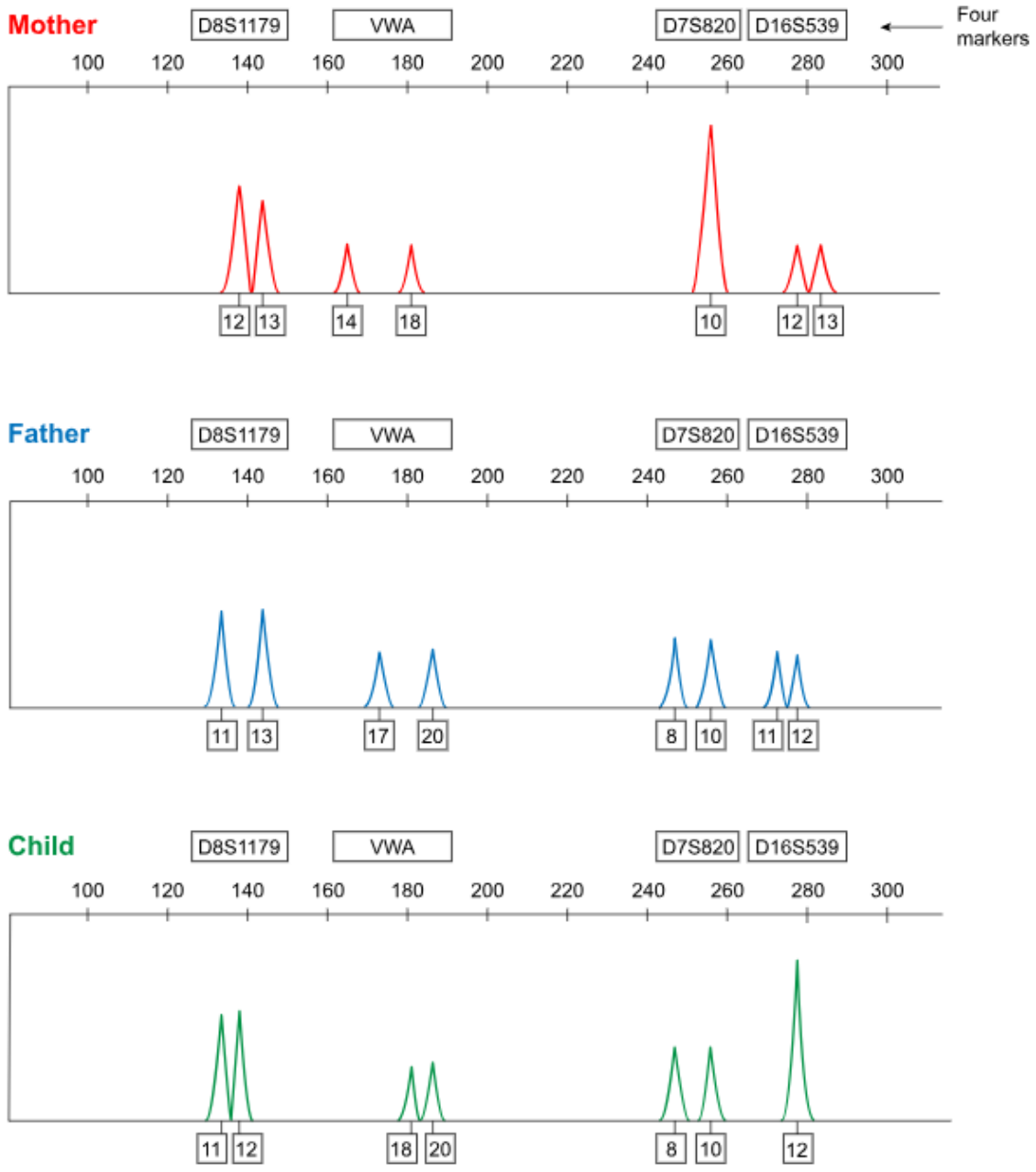
Discuss how the adoption of measures to protect Australian populations of black swans from HPAI demonstrates 'Influence', one of the key concepts of science as a human endeavour.

(4 marks)

Source

Information for parts (a) and (b)

The electropherograms below show the same four markers of the DNA profile for a mother, a father, and a child.



Question 18 (a) to (d)

Refer to the source when answering parts (a) and (b).

To produce DNA profiles, forensic scientists target short tandem repeats (STRs). These are highly variable regions of the genome in which 1 to 6 bases are repeated.

(a) At the D7S820 marker, the mother has only one peak, labelled 10, but the father has two peaks, labelled 8 and 10.

Explain the significance of these observations.

(2 marks)

(b) A lawyer claimed that, according to the information in the DNA profiles, this mother and father could not be the biological parents of this child.

By referring to the profiles, explain whether or not you agree with the lawyer.

(3 marks)

(c) Describe **one** limitation of DNA profiles being used as evidence in a court of law.

(2 marks)

(d) Identify **one** ethical issue that needs to be considered when collecting human DNA samples.

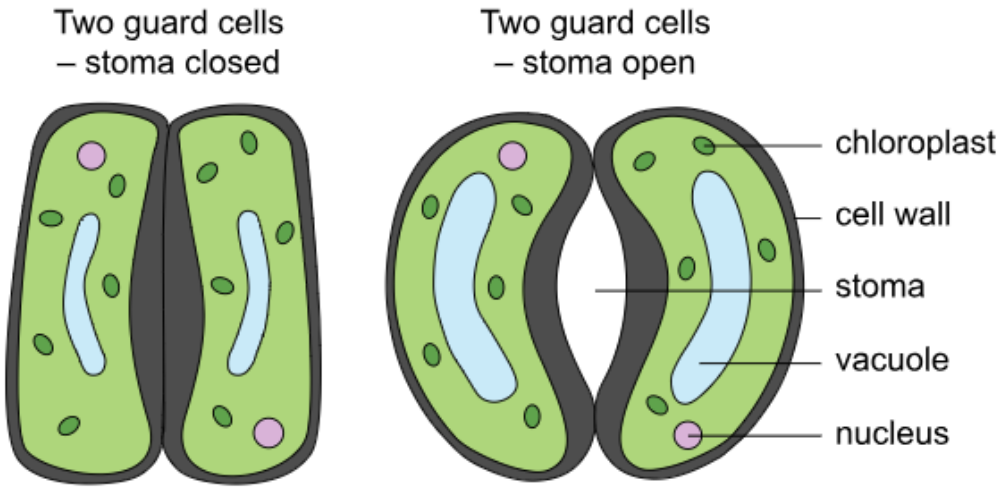
(1 mark)

Source 1

Information for parts (a) to (c)

In plants, stomata (singular: stoma) are pores in the leaves that control gas exchange between a leaf and its external environment.

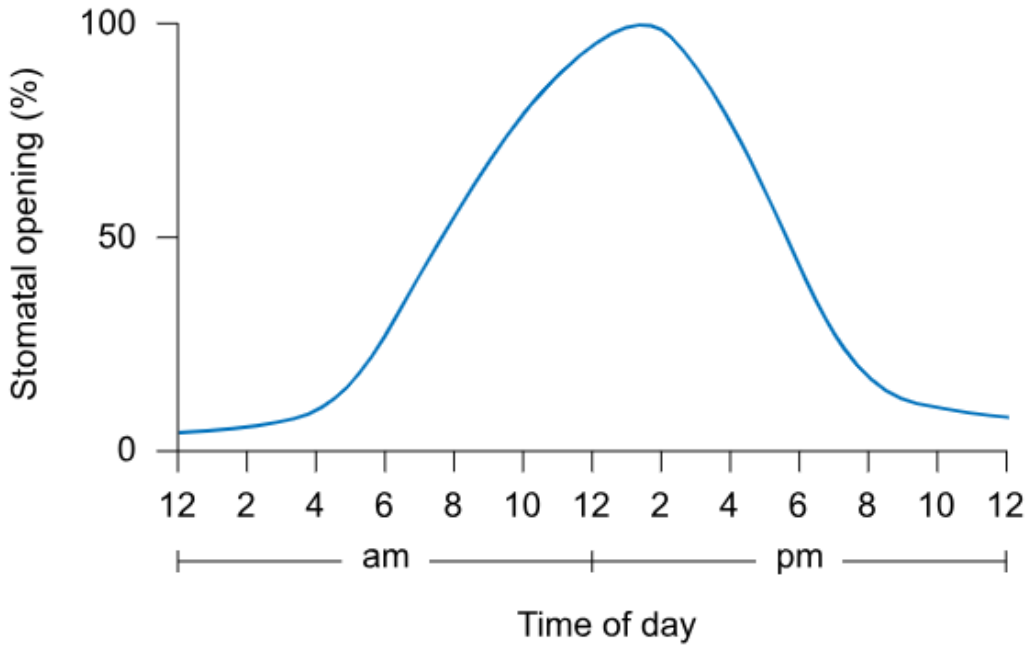
Plants control the rate of gas exchange by altering the size of their stomata. Each stoma is formed by a pair of guard cells. The uptake of ions into guard cells triggers the uptake of water into the cells, increasing cell volume. As the inner wall of a guard cell is thicker than its outer wall, this uptake of water causes the guard cell to bend outwards, opening the stoma, as illustrated in the diagram below.



Source 2

Information for parts (d) to (f)

An investigation was conducted on a rice plant (*Oryza sativa*) to determine if there is a relationship between the time of day and the extent of stomatal opening, expressed as a percentage. The results are represented in the graph below.



Source 3

Information for parts (g) and (h)

Many people rely on rice as a major source of food. Due to climate change, approximately half of the global rice crop is predicted to experience decreased water availability and increased frequency of extreme drought and high temperatures.

Recently, scientists have developed rice crops with lower stomatal density that require significantly less water than unaltered rice. Stomatal density is the number of stomata per unit area of leaf surface. The altered rice crops thrive, as they use 40% less water than unaltered rice crops. When grown at elevated atmospheric carbon dioxide levels, these altered rice crops were able to survive drought and high temperature (40°C) for longer than unaltered rice.

Question 19 (a) to (h)

Refer to Source 1 when answering parts (a) to (c).

(a) State the name of the protein through which water moves across the cell membrane into a guard cell.

(1 mark)

(b) Explain why the uptake of ions into guard cells causes the uptake of water into the cells.

(3 marks)

(c) Guard cells contain chloroplasts, as shown in the diagram.

Explain how the structure of the internal membranes of chloroplasts facilitates some biochemical processes.

(3 marks)

Refer to Source 2 when answering parts (d) to (f).

(d) (i) State the dependent variable in this investigation.

(1 mark)

(ii) State **one** limitation of a conclusion drawn from the results of this investigation.

(1 mark)

(iii) Explain how the reliability of an investigation such as this could be increased.

(2 marks)

(e) Explain how a plant would benefit by having its stomata open wider as the light intensity increases.

(2 marks)

(f) Explain why a net release of oxygen from stomata would occur when the light intensity is at its maximum.

(3 marks)

Refer to Source 3 when answering parts (g) and (h).

(g) Stomatal density varies between plant species.

State **one** advantage to a plant of having a low stomatal density.

(1 mark)

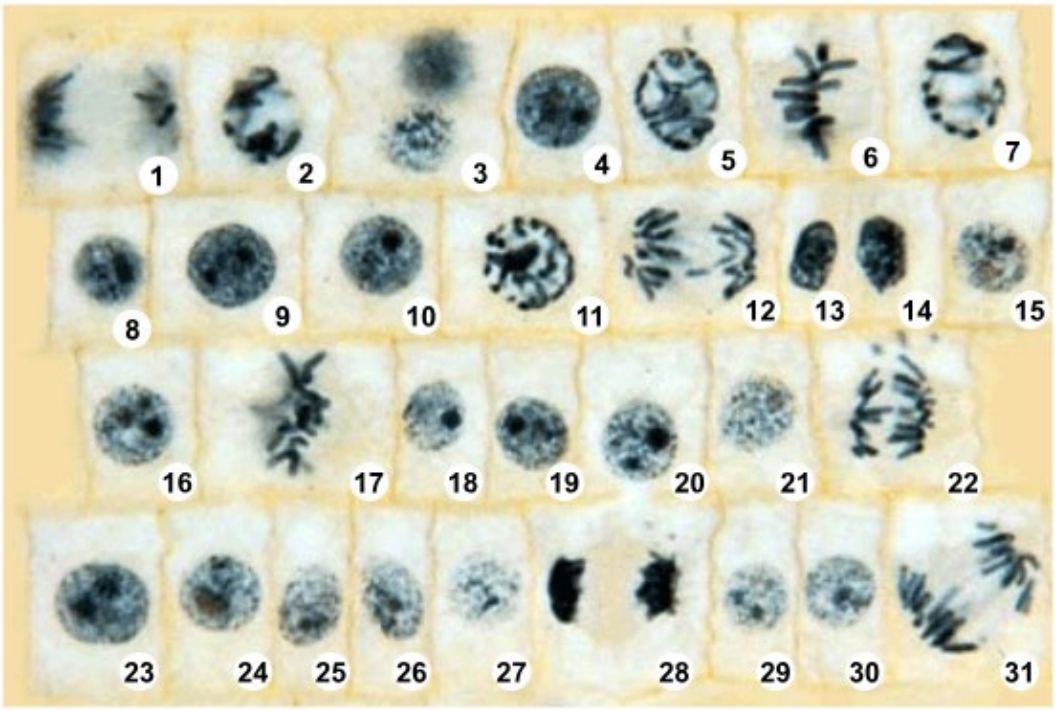
(h) Discuss how Source 3 illustrates the interaction between science and society.

(4 marks)

Source

Information for Question 20

The photomicrograph below shows a group of stained cells.



Source: adapted from © 2008 Pearson Education Inc.

Question 20 (a) to (e)

Refer to the source when answering Question 20.

(a) State the name of the phase of mitosis shown in cell 6.

(1 mark)

(b) Describe **one** source of genetic variation that could occur in a group of cells produced by mitosis.

(2 marks)

The mitotic index is a measure of cell proliferation and is calculated using the equation below.

$$\text{mitotic index} = \frac{\text{number of cells in sample undergoing mitosis}}{\text{total number of cells in sample}}$$

(c) The mitotic index for the group of cells shown in the photomicrograph is closest to:

- 0.2
- 0.4
- 0.6
- 0.8

(1 mark)

(d) State the highest theoretical mitotic index for a group of cells.

(1 mark)

(e) Explain why the mitotic index in cancer tissues would differ from the mitotic index of most non-cancer tissues.

(2 marks)

Question 21 (a) to (d)(ii)

Pyrogens are chemicals that can induce a fever in humans by binding to receptors in the hypothalamus. This increases the thermostat setting for body temperature from approximately 37°C to approximately 40°C.

Pyrogens are produced by human cells following an infection, and are also produced by some bacteria that infect humans.

(a) State **one** reason that a specific temperature is required for cells to function efficiently.

(1 mark)

(b) Explain **one** way in which a person's body would respond to a temperature of 38°C brought on by these pyrogens.

(3 marks)

Once the immune system has started to control the infection, the thermostat setting in the hypothalamus will be restored to normal body temperature, approximately 37°C.

(c) **Other than sweating**, state **one** response involving the nervous system that occurs when human body temperature rises above 37°C, and explain its effect.

(3 marks)

Excessive sweating may alter blood osmolarity (the concentration of solutes in the blood), which then affects the volume of urine produced.

(d) (i) State the name of the main hormone that affects the volume of urine produced.

(1 mark)

(ii) With reference to blood osmolarity and the role of a hormone, explain the effect that excessive sweating may have on the production of urine.

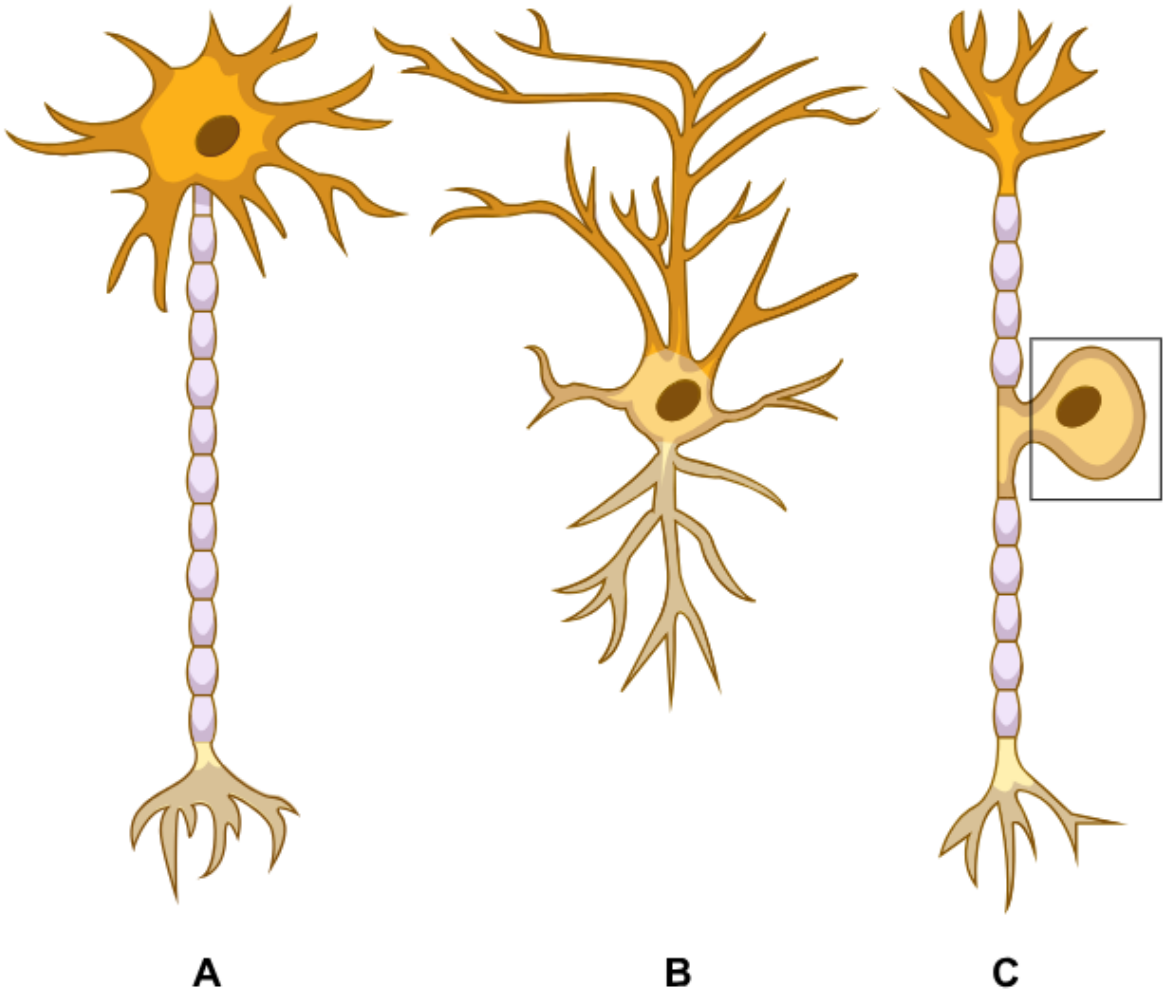
(4 marks)

Source

Information for Question 22

Motor neuron disease (MND) refers to a range of progressive neurological disorders in which the number of motor neurons is reduced, resulting in the loss of control of skeletal muscles. Activities such as walking and breathing are affected.

The diagrams below represent three different types of neuron.



Source: adapted from © Mari-Leaf | Shutterstock.com

Question 22 (a) to (g)(ii)

Refer to the source when answering Question 22.

(a) Which diagram represents a typical motor neuron?

- Diagram A
- Diagram B
- Diagram C

(1 mark)

(b) Name the boxed structure in Diagram C.

(1 mark)

The cause of MND is unknown. However, in some forms of the disease, inherited mutations are thought to account for between 5% and 40% of cases. Environmental factors are also thought to play a role in some cases.

(c) State **one** factor that can increase the rate of mutation.

(1 mark)

Scientists have tried to establish if any environmental factors can be linked to the onset of MND. One technique is to ask people diagnosed with MND to try to remember if they have been exposed to potential environmental risks.

(d) Explain why asking people with MND **after** their diagnosis about potential earlier exposures reduces the validity of the data.

(2 marks)

It is possible that the expression of certain genes in people with MND can be altered by histone modification.

(e) Describe how histone modification can alter gene expression.

(2 marks)

Due to the loss of control of skeletal muscles, people with MND often experience adverse respiratory symptoms, such as shortness of breath and inability to exchange oxygen and carbon dioxide effectively.

(f) Explain how shortness of breath in people who do **not** have MND would affect the composition of their blood, and describe their body's response.

(3 marks)

Studies have shown that people with type 1 diabetes have an increased risk of developing certain types of MND.

(g) (i) Name the hormones involved in the regulation of the level of glucose in the blood.

(2 marks)

(ii) Select **one** of the hormones that you stated in part (g)(i) and describe its action when the concentration of glucose in the blood falls below the normal level.

(3 marks)

Source

Information for Question 23

Macquarie Island is an isolated island in the Southern Ocean, about 1500 km south-east of Tasmania.

The island is an important breeding site for many seabirds, including the Macquarie shag (*Leucocarbo purpurascens*). Biologists have suggested that this population of birds may have been affected by genetic drift, due to its isolation.

Macquarie shag



Source: adapted from © Hullwarren 1996, 'Close-up of a Macquarie shag *Leucocarbo purpurascens*, on Macquarie Island', viewed 26 June 2023, en.wikipedia.org, licensed under CC BY-SA 3.0

Question 23 (a) to (c)

Refer to the source when answering Question 23.

(a) Describe the effect that genetic drift may have on the gene pool of a small, isolated population such as the Macquarie shag.

(2 marks)

Although similar to other shags of the Southern Ocean, the Macquarie shag is considered to be a separate species. One technique that can be used to confirm that birds of similar appearance are distinct species is DNA–DNA hybridisation.

(b) Explain how this technique may be used to establish whether birds of similar appearance belong to different species.

(4 marks)

Between 2000 and 2003, the population of the Macquarie shag on Macquarie Island decreased by about 30% to only 460 breeding pairs.

(c) State **one** human activity and explain how it may have contributed to a change in the size of the population of Macquarie shags.

(3 marks)

Source 1

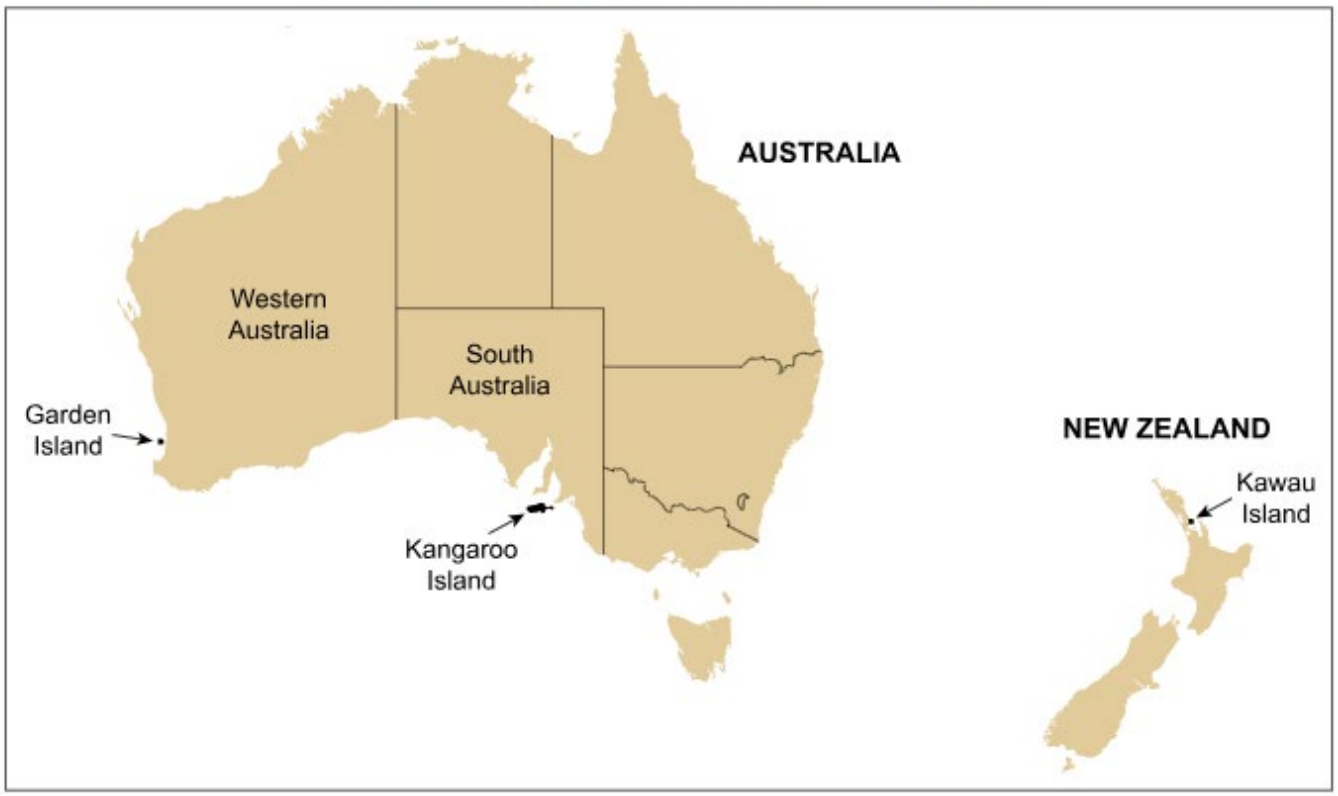
Information for parts (a) and (b)

Tammar wallaby



Source: adapted from © Isaac Beneshed | Unsplash.com

Map showing locations for relevant tammar wallaby populations



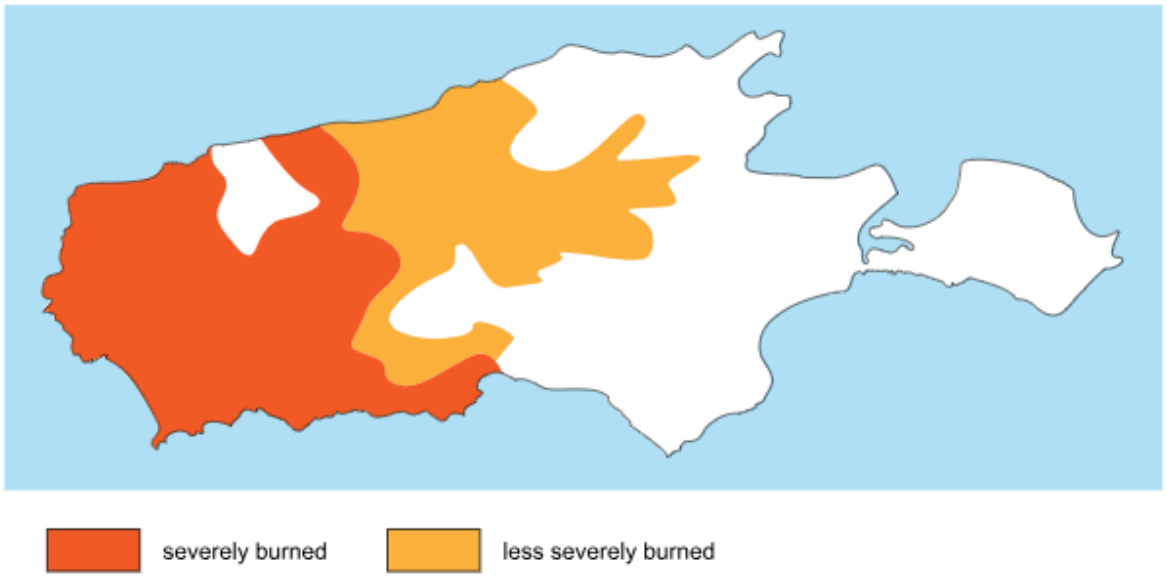
Source: based on © Ruslan Maiborodin | Vecteezy.com

Source 2

Information for part (d)

In early 2020, bushfires destroyed more than 200 000 hectares of vegetation on Kangaroo Island, as shown in the map below. The photos below show one area of bushland before and immediately after the bushfires. Since 2020, the vegetation in affected areas has been regenerating and is expected to become stable within about 15 years.

Map of Kangaroo Island showing areas affected by the 2020 bushfires



Source: based on Department of Climate Change, Energy, the Environment and Water 2022, 'Kangaroo Island', https://www.dcceew.gov.au/environment/biodiversity/bushfire-recovery/regional-delivery-program/kangaroo-island, viewed 21 June 2023

Views along a road on Kangaroo Island showing bushland before (left) and after (right) the 2020 bushfires



Source: (left) © AAP; (right) © Alamy

Question 24 (a) to (d)

Refer to Source 1 when answering parts (a) and (b).

Separate populations of tammar wallabies (*Notamacropus eugenii*), from Garden Island in Western Australia and Kangaroo Island in South Australia, have significant differences in their mitochondrial DNA (mtDNA). The number of differences would normally be sufficient to consider the populations as different species. However, when placed in captivity, individuals from these two populations can breed to produce fertile offspring.

(a) Explain **one** reason why the use of mtDNA instead of nuclear DNA, when comparing the genetic similarity of populations, reduces the need for PCR.

(2 marks)

About 150 years ago, tammar wallabies were transported to Kawau Island, off the coast of New Zealand. In 2017, when their mtDNA was compared with the mtDNA of the Kangaroo Island tammar wallabies, very little difference was observed.

(b) State **one** reason for there being very little difference in the mtDNA between these two populations.

(1 mark)

The eastern grey kangaroo (*Macropus giganteus*) and western grey kangaroo (*Macropus fuliginosus*) usually do not interbreed to produce fertile offspring.

(c) (i) State **one** reproductive isolating mechanism, **other than geographical separation**, that may maintain separate species, such as the eastern and western grey kangaroos.

(1 mark)

(ii) Explain how the mechanism that you stated in part (c)(i) maintains separate species.

(2 marks)

Refer to Source 2 when answering part (d).

(d) Name and describe the process of gradual change in the mix of species in an area after a significant bushfire.

(4 marks)

Final checklist

- [ ] I have reviewed my work
- [ ] I understand that by selecting 'Next' I cannot return to the examination

Next