



Victorian Certificate of Education
2023

Name: _____

Teacher's name: _____

STUDENT NUMBER

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Letter

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UNITS 3&4 BIOLOGY

Written examination

2023

Reading time: 15 minutes

Writing time: 2 hours 30 minutes

QUESTION AND ANSWER BOOK

Structure of book

Section	Number of questions	Number of questions to be answered	Number of marks
A	40	40	40
B	12	12	80
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, and rulers.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.
- No calculator is allowed in this examination.

Materials supplied

- Question and answer book.
- Answer sheet for multiple-choice questions.
- Additional space is available at the end of the book if you need extra space to complete an answer.

Instructions

- Write your student number in the space provided above on this page.
- Check that your name on your answer sheet for multiple-choice questions is correct.
- All written responses must be in English.

At the end of the examination

- Place the answer sheet for multiple-choice questions inside the front cover of this book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Multiple-choice questions**Instructions for Section A**

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

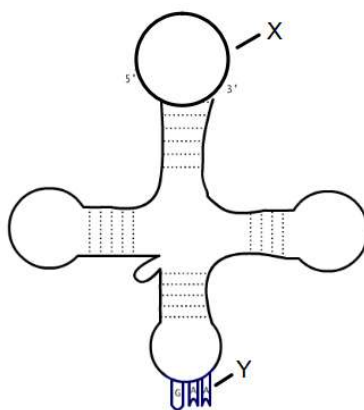
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

There are 20 amino acids that are used to make proteins. Which part of the structure varies between each of these amino acids?

- A. the amino group
- B. the carboxyl group
- C. the R group
- D. hydrogen

Use the following diagram to answer Questions 2 and 3.



Adapted from: <https://commons.wikimedia.org/wiki/File:.png>

Question 2

The molecule shown in the diagram above does not contain which of the following nitrogenous bases?

- A. uracil
- B. thymine
- C. cytosine
- D. adenine

Question 3

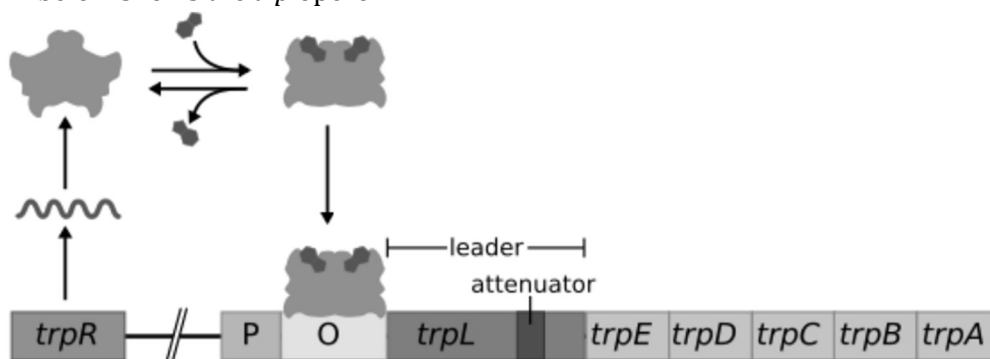
What do the structures labelled X and Y represent respectively?

- A. amino acid and anti-codon
- B. anti-codon and amino acid
- C. codon and anti-codon
- D. amino acid and codon

DO NOT WRITE IN THIS AREA

Question 4

The diagram below shows the *trp* operon.



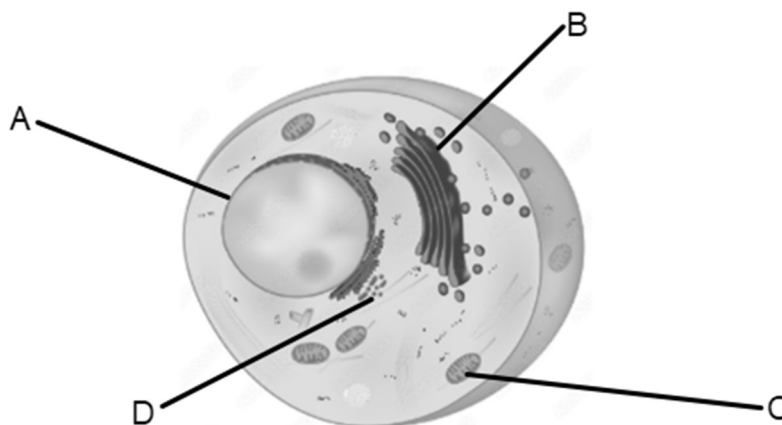
Adapted from: https://en.wikipedia.org/wiki/Trp_operon#/media/File:Trpoperon.svg

Which statement below is correct when describing what is occurring in the diagram?

- A. an inactive repressor is unable to bind to the operator
- B. RNA polymerase is binding to the promoter to begin transcription
- C. the repressor undergoes a conformational change to become active
- D. tryptophan is unable to bind to the repressor

Use the following information to answer Questions 5 and 6.

Consider the diagram of the eukaryotic cell shown below.



Adapted from: <https://stock.adobe.com/images/components-of-a-typical-animal-cell-unlabeled/168443766>

Question 5

The correct sequence of organelles that are involved in the protein secretory pathway is

- A. vesicle, Golgi body, endoplasmic reticulum and structure A.
- B. structure C, ribosome, vesicle and structure B.
- C. rough endoplasmic reticulum, vesicle, structure B and vesicle.
- D. nucleus, structure D, vesicle and cell membrane.

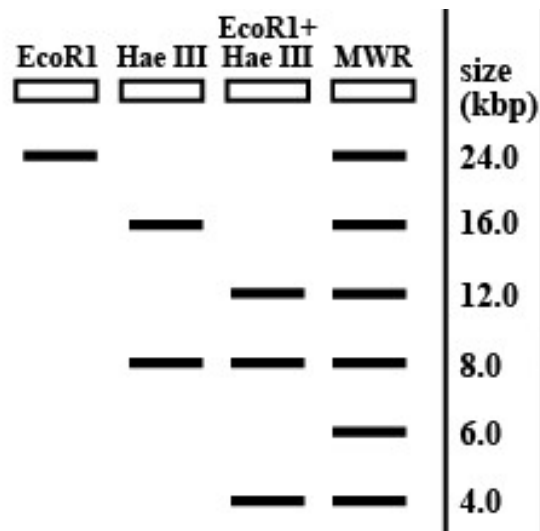
Question 6

Which statement below best describes the role of structure C?

- A. site of photosynthesis
- B. site of aerobic respiration
- C. site of anaerobic respiration
- D. the only site where ATP is produced in a cell

DO NOT WRITE IN THIS AREA

Question 7



Source: <https://www.toppr.com/ask/question/a-gel-electrophoresis-was-run-to-show-the-fragments-produced-by-restriction-digests-with-different/>

When a bacterial plasmid is cut by both EcoR1 and Hae III enzymes, how many restriction sites are needed to produce the fragments that are shown in the above gel electrophoresis?

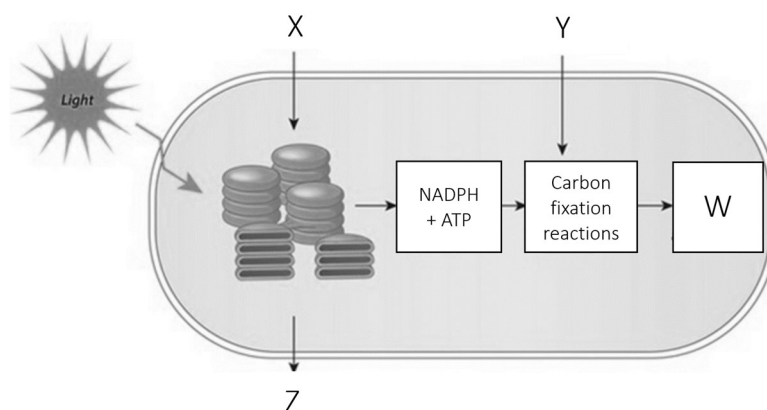
- A.** one
B. two
C. three
D. four

Question 8

Which of the following is the best explanation for why two genetically different primers are used during PCR?

- A.** because DNA is an anti-parallel double-stranded molecule
B. because two new copies of DNA will be produced per single strand
C. so that *Taq* polymerase can anneal to the primers
D. so that genetically varied DNA copies can be made

Question 9



Source: <https://www.nature.com/scitable/topicpage/photosynthetic-cells-14025371/>

Refer to the diagram to identify the molecule/s that are the outputs of light independent reactions of photosynthesis.

- A.** X and Y
B. W and Z
C. Z only
D. W and NADP

Question 10

Which of the following is NOT a strategy that is used by CAM plants to avoid photorespiration?

- A. closing stomata during the day
- B. absorbing CO₂ at night
- C. completing most of the Calvin cycle in bundle sheath cells
- D. starting the Calvin cycle in mesophyll cells

Question 11

When the amount of glucose increases in a yeast cell, it would be expected that the amount of CO₂ that is produced

- A. decreases.
- B. increases.
- C. stays the same.
- D. decreases first then rapidly increases.

Question 12

CRISPR-Cas9 can be applied to change gene expression in the thylakoid membranes of chloroplasts.

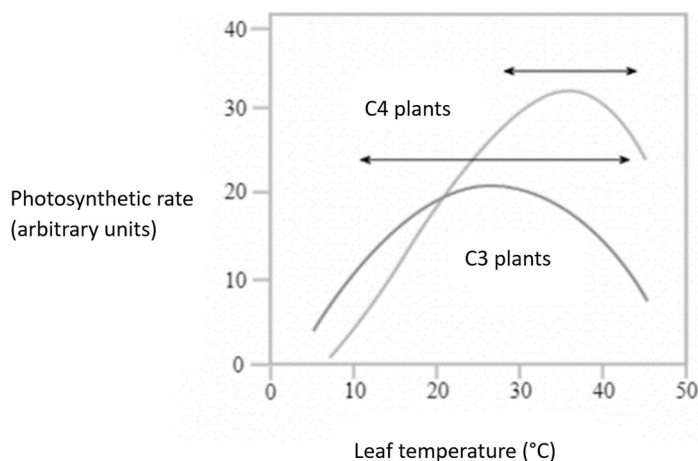
What is the benefit of using CRISPR-Cas9 to edit the genes of photosynthesising plant cells?

- A. it is easy and cost-effective
- B. it edits Rubisco to have an affinity to bind with O₂
- C. it increases the photorespiration rate
- D. all of the above

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 13 – 15.

The graph below shows the results of an experiment that investigated the relationship between temperature and the photosynthetic rate of C3 and C4 plants.



Source: <https://www.aakash.ac.in/important-concepts/biology/photosynthesis>

Question 13

Which of the following statements is true regarding the graph above?

- A. the enzymes in C3 and C4 plants denature at 10°C
- B. at 20°C, the photosynthetic rate for C3 plants is lower than C4 plants
- C. at 40°C, the photosynthetic rate for C3 plants is 25 arbitrary units
- D. C4 plants have a higher optimal temperature than C3 plants

Question 14

Which of the following explains the results that were obtained at 10°C for both plants?

- A. the enzyme activity was reduced due to the action of competitive inhibitors
- B. the low pH had begun to denature the enzymes
- C. the kinetic energy is reduced compared to other temperatures
- D. the activation energy is too low

Question 15

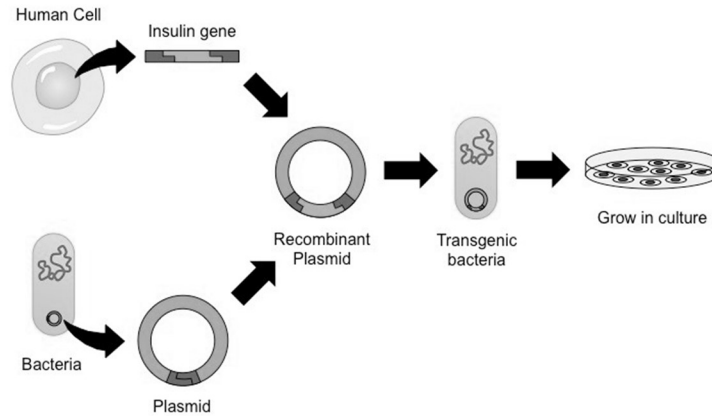
A controlled variable that would be included when collecting the data for this experiment would be

- A. leaf temperature.
- B. the photosynthetic rate.
- C. repeating the experiment in the absence of light.
- D. the CO₂ concentration.

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 16 and 17.

The following diagram shows how recombinant technology is used to produce human insulin.



Source: <https://ib.bioninja.com.au/standard-level/topic-3-genetics/35-genetic-modification-and/gene-transfer.html>

Question 16

Which of the following is the vector in the process that is depicted in the image?

- A. insulin gene
- B. bacteria
- C. recombinant plasmid
- D. human cell

Question 17

Why are the bacteria referred to as 'transgenic' after the insertion of the recombinant plasmid?

- A. it has non-bacterial DNA
- B. it is antibiotic resistant
- C. it is a GMO
- D. the genes have been silenced

Question 18

A Year 12 biology class carried out an experiment testing the effect of glucose concentration on the rate of ethanol production by yeast cells. They ensured that all variables besides glucose concentration were controlled. This was done to ensure that the results were more

- A. precise.
- B. reproducible.
- C. valid.
- D. repeatable.

Question 19

Pyruvate is used by yeast cells to make ethanol, which is then converted to biofuel. The process in yeast cells that produces ethanol

- A. is aerobic fermentation.
- B. is carried out in mitochondria.
- C. requires more energy than it releases.
- D. is carried out in the absence of oxygen.

Question 20

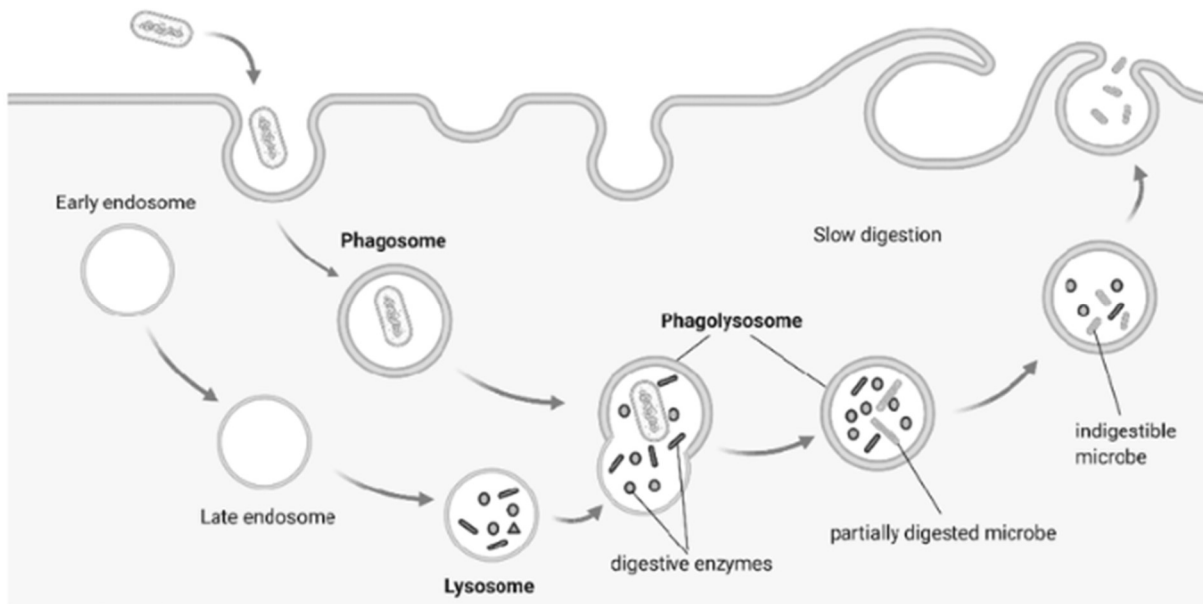
A chemical barrier of plants against pathogens is/are

- A. thick waxy cuticles.
- B. oxalic acid.
- C. the formation of galls.
- D. interferon.

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 21 and 22.

This diagram shows the action of macrophages in response to invading pathogenic bacteria.



Source: https://www.researchgate.net/figure/Schema-of-phagocytosis-performed-by-macrophages-Macrophages-are-professional-phagocytes_fig1_360073222

Question 21

The action of macrophages as shown in the diagram is an example of a

- A. first-line of defence and specific immunity.
- B. second-line of defence and adaptive immunity.
- C. first-line of defence and passive immunity.
- D. second-line of defence and innate immunity.

Question 22

Once macrophages digest the pathogenic bacteria, they travel to the lymph nodes. Which is the most correct description of what occurs here?

- A. macrophages display antigens on their MHC II markers
- B. macrophages attract Tc cells
- C. macrophages secrete antibodies
- D. macrophages respond to cytokines, causing apoptosis of the affected cells

Question 23

A child was bitten by a venomous snake; she was taken to the hospital immediately, where anti-venom was administered. The type of immunity that is provided by the anti-venom is

- A. artificial and active.
- B. natural and active.
- C. artificial and passive.
- D. natural and passive.

Question 24

Which of the following statements is an accurate description of something that may occur during the humoral response?

- A. cytotoxic T cells release perforin
- B. NK cells destroy infected cells
- C. antibodies bind to pathogens and activate complement proteins
- D. mast cells release histamine

DO NOT WRITE IN THIS AREA

Question 25

Adalimumab is a monoclonal antibody that is used in the treatment of rheumatoid arthritis, which is an autoimmune disease.

Source: <https://arthritisaustralia.com.au/medication-search/adalimumab/>

Adalimumab is likely to be an effective treatment for an autoimmune disease because

- A. of its ability to block the release of cytokines.
- B. it activates the immune system.
- C. it triggers apoptosis.
- D. it allows NK cells to kill infected cells.

Use the following information to answer Questions 26 and 27.

Ross River virus is spread by infected mosquitoes when they bite through the skin. People are at increased risk of infection if they spend a lot of time near bodies of water, such as wetlands or rivers. It is not spread from person to person and a vaccine is not currently available in Australia.

Source: <https://www.health.nsw.gov.au/Infectious/factsheets/Pages/ross-river-fever.aspx>

Question 26

Ross River virus

- A. is spread through physical contact.
- B. can be prevented with the use of hand sanitizer.
- C. can only be controlled by killing mosquitoes.
- D. involves vectors.

Question 27

Australia does not have herd immunity to the Ross River virus because

- A. you cannot have vaccines for viruses.
- B. there is no available vaccine.
- C. a majority of the population has already been infected.
- D. it is spread by mosquitoes.

DO NOT WRITE IN THIS AREA

Question 28

Refer to the following codon table to answer the question.

		Second Base					
		U	C	A	G		
First Base	U	UUU } Phe	UCU } Ser	UAU } Tyr	UGU } Cys	U	Third Base
		UUC } Phe	UCC } Ser	UAC } Tyr	UGC } Cys	C	
		UUA } Leu	UCA } Ser	UAA } STOP	UGA } STOP	A	
		UUG } Leu	UCG } Ser	UAG } STOP	UGG } Trp	G	
	C	CUU } Leu	CCU } Pro	CAU } His	CGU } Arg	U	
		CUC } Leu	CCC } Pro	CAC } His	CGC } Arg	C	
		CUA } Leu	CCA } Pro	CAA } Gln	CGA } Arg	A	
		CUG } Leu	CCG } Pro	CAG } Gln	CGG } Arg	G	
	A	AUU } Ile	ACU } Thr	AAU } Asn	AGU } Ser	U	
		AUC } Ile	ACC } Thr	AAC } Asn	AGC } Ser	C	
		AUA } Ile	ACA } Thr	AAA } Lys	AGA } Arg	A	
		AUG } Met or Start	ACG } Thr	AAG } Lys	AGG } Arg	G	
	G	GUU } Val	GCU } Ala	GAU } Asp	GGU } Gly	U	
		GUC } Val	GCC } Ala	GAC } Asp	GGC } Gly	C	
		GUA } Val	GCA } Ala	GAA } Glu	GGA } Gly	A	
		GUG } Val	GCG } Ala	GAG } Glu	GGG } Gly	G	

Source: https://commons.wikimedia.org/wiki/File:Genetic_Code.png

Which of the following sequences would result in a nonsense mutation?

- A. ACT
- B. UAA
- C. UAG
- D. ACU

Question 29

A population will likely have low genetic diversity if

- A. random mating occurs.
- B. there is gene flow.
- C. there are high levels of inbreeding.
- D. there is a very high mutation rate.

Question 30

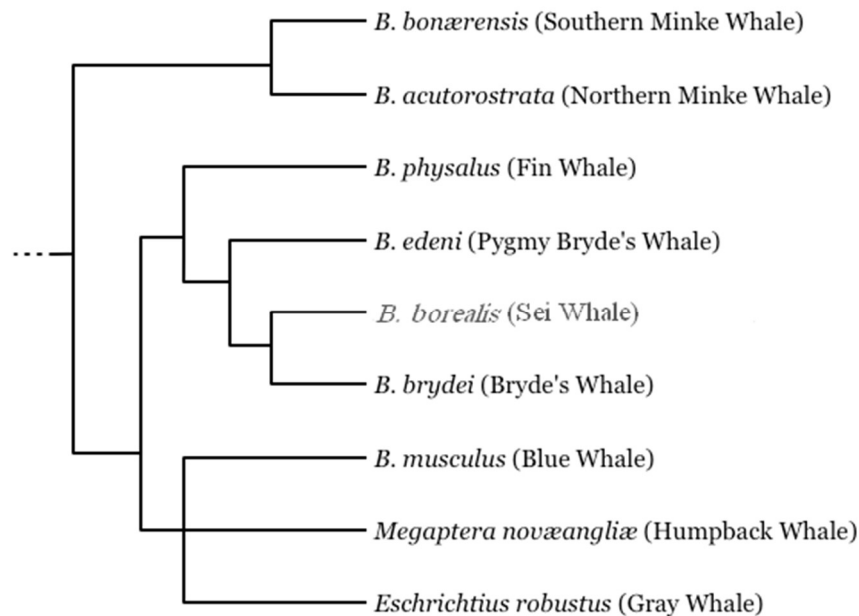
Which of the following is the most likely reason for selectively breeding sheep in Australia?

- A. to increase genetic diversity
- B. to increase wool quality
- C. to allow for more gene flow
- D. to allow natural selection to occur

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 31 – 33.

The diagram below shows the evolutionary relationship between different species of whale.



Source: https://upload.wikimedia.org/wikipedia/commons/a/a1/Sei_Whale_Cladogram.PNG

Question 31

Which of the following statements is correct?

- A. the blue whale is more closely related to the sei whale than the Bryde's whale
- B. the southern minke whale and the northern minke whale would have more DNA in common with each other than with the other whales
- C. the pygmy Bryde's Whale shares a more recent common ancestor with the fin whale than the sei whale
- D. the humpback whale is the least closely related to the fin whale

Question 32

The diagram above is referred to as a

- A. pedigree.
- B. evolutionary time scale.
- C. family tree.
- D. phylogenetic tree.

Question 33

Which statement is correct about the structural characteristics of the whales?

- A. the pelvic bone in whales is likely to be an example of a vestigial organ that demonstrates the ancestors of whales walked on land
- B. whales do not share any homologous structures
- C. structures that increase the chance of survival would be selected against
- D. structures that allow swimming are not inherited

Question 34

Which of the following is not necessary for fossilisation to occur?

- A. a low oxygen environment
- B. low pressure
- C. a lack of decomposers
- D. protection from scavengers

DO NOT WRITE IN THIS AREA

Question 35

Which of the following gives the most accurate information when analysing the relatedness between species?

- A. comparative anatomy
- B. vestigial structures
- C. amino acids sequencing
- D. DNA sequencing

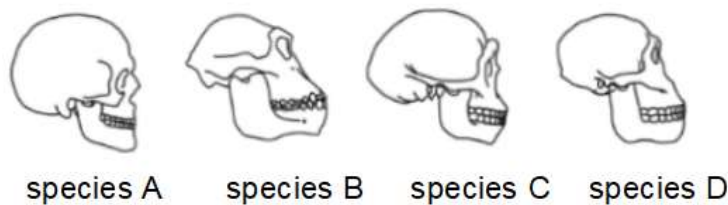
Question 36

Primates

- A. have a small cranium-to-body ratio.
- B. have sensitive touch receptors in their fingers.
- C. carry out bi-pedal locomotion.
- D. lack a tail.

Use the following information to answer Questions 37 and 38.

The diagram below shows a selection of skulls of various extinct and living human species.



Source: https://commons.wikimedia.org/wiki/File:Skull_evolution.png#/media/File:Skull_evolution.png

Question 37

Which of the skulls above has the most central foramen magnum?

- A. species A
- B. species B
- C. species C
- D. species D

Question 38

From oldest to most recent, which is the correct order of the four species that are shown in the diagram?

- A. B, D, C, A
- B. A, B, C, D
- C. B, D, A, C
- D. A, C, D, B

DO NOT WRITE IN THIS AREA

Please note: the following question refers to research collecting the DNA of Indigenous Australians who have died.

Question 39

Studies of Indigenous Australian mtDNA have found a high amount of genetic diversity and estimate the age of the genetic haplogroups, a combination of alleles that are closely linked and that tend to be inherited together, to be over 40,000 years old.

Source: <https://www.latrobe.edu.au/news/articles/2017/release/dna-study-of-indigenous-australians>

This supports the suggestion that

- A. Indigenous Australians migrated to Australia from Sahul.
- B. Indigenous Australians interbred with Denisovans in Asia.
- C. there was a low mutation rate in the DNA of Indigenous Australians.
- D. Indigenous Australians have one of the oldest continuous cultures in the world.

Question 40

When conducting a scientific experiment that involves human test subjects, scientists are required to

- 1) honestly report findings;
- 2) receive consent from the participants; and
- 3) reduce the possibility of any harm to the participants.

Match the requirement with the correct ethical concept.

	Requirement 1	Requirement 2	Requirement 3
A.	integrity	respect	non-maleficence
B.	beneficence	respect	non-maleficence
C.	justice	justice	beneficence
D.	integrity	justice	beneficence

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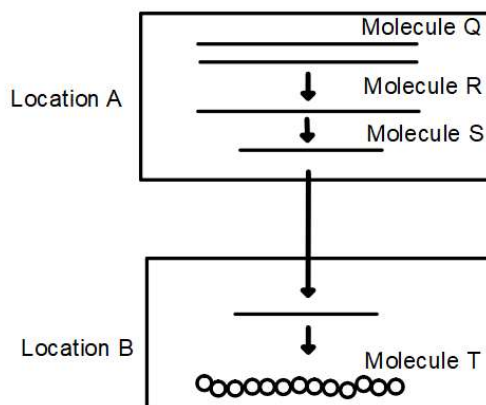
SECTION B**Instructions for Section B**

Answer **all** questions in the spaces provided.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (8 marks)

The following diagram shows the steps involved in the processes of gene expression.



- a. Identify Molecule Q and Molecule S. State two differences between these two molecules.

3 marks

- b. Justify why the length of Molecule S is shorter than that of Molecule R.

1 mark

DO NOT WRITE IN THIS AREA

- c. Outline the steps of the process that occurs in Location B that leads to the formation of Molecule T. 4 marks

In your answer, identify the organelle that Location B represents and state the biological molecule that Molecule T represents.

Question 2 (4 marks)

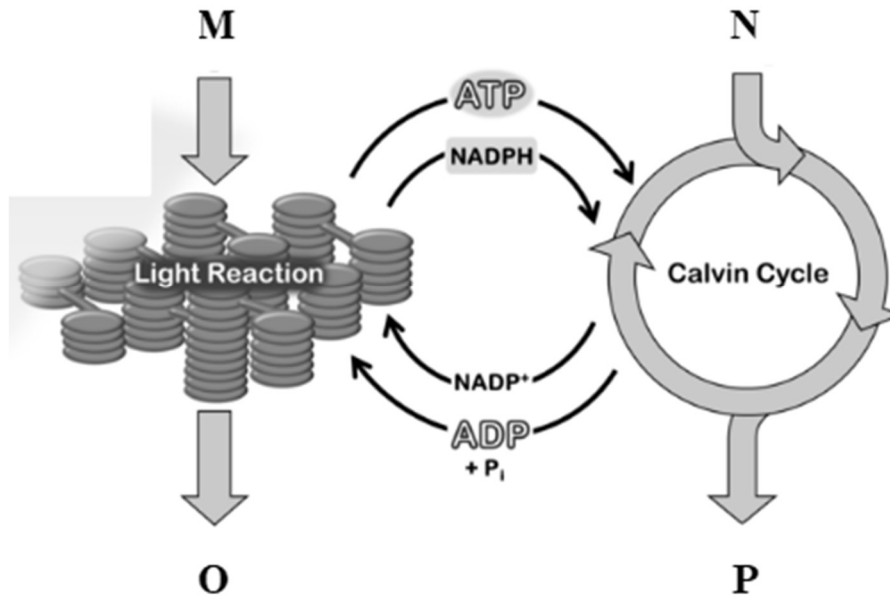
CRISPR-Cas9 is a gene-editing technique that can be used to alter the genome of plants to improve crops for human benefit. The CRISPR-Cas9 system is one way of editing a plant's genome to increase the rates of photosynthesis.

- a. What type of enzyme is Cas9 and what is the role of Cas9 in the CRISPR-Cas9 complex? 2 marks

- b. Explain how CRISPR-Cas9 technology could edit genes to change the rate of photosynthesis in plants. 2 marks

Question 3 (7 marks)

The diagram below represents the process of photosynthesis.



Source: https://commons.wikimedia.org/wiki/File:Photosynthesis_overview.png

- a. Name the input molecules M and N and describe how they react to produce the output molecules O and P. 3 marks

- b. Identify the structure where the light-dependent reaction of photosynthesis occurs. 1 mark

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- c. Sugarcane plants are adapted to hot, sunny conditions and are an example of C4 plants. These adaptations change how the Calvin cycle of photosynthesis is carried out. Most plants are examples of C3 plants and carry out the Calvin cycle differently to C4 plants.

3 marks

Explain the differences in the adaptations that affect the process of photosynthesis between sugarcane plants and C3 plants.

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Question 4 (9 marks)

Duckweed is a fast-growing aquatic plant that is being studied as an option to use in the production of biodiesel; currently, soybeans are the most commonly used plant to produce biodiesel.

In a new study in the *Plant Biotechnology Journal*, researchers found that genetically modifying duckweed plants could lead to the production of seven times more oil when compared with using soybeans. CRISPR-Cas9 technology was one of the techniques that was used to edit the duckweed genome. Bacterial transformation was also utilised to insert foreign genes into the duckweed plant genome to test its potential for biofuel production.

Source: <https://onlinelibrary.wiley.com/doi/full/10.1111/pbi.13943>

- a.** Identify the input molecule that produces bioethanol. 1 mark

- b.** Would genetically modified duckweed plants be considered transgenic? Justify your response. 2 marks

- c.** Agrobacterium bacterial cells were used in the bacterial transformation process. 2 marks

State the structure in the agrobacterial cells that allows it to be used in the bacterial transformation process and describe its role.

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- d.** Enzymes play an important role in the bacterial transformation process.

3 marks

In the table, identify two enzymes that are involved in bacterial transformation and state their respective roles.

Enzyme	Role
1.	<hr/> <hr/> <hr/> <hr/> <hr/>
2.	<hr/> <hr/> <hr/> <hr/> <hr/>

- e.** Using CRISPR-Cas9 technology to edit the duckweed plant genome to produce large amounts of biodiesel was a breakthrough in plant biology research.

1 mark

List another possible application of CRISPR-Cas9 technology on plants.

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Question 5 (13 marks)

Measles is a highly contagious viral disease that is spread primarily through coughing and sneezing. It can also be passed on by touching contaminated surfaces.

Source: <https://www.abc.net.au/news/health/2019-04-10/measles-spikes-prompts-immunisation-warning-are-you-at-risk/10986172>

- a.** Identify whether measles is caused by a cellular or non-cellular pathogen, and provide one piece of information to support your answer. 2 marks

- b.** Referring to the modes of transmission of measles, describe one physical and one chemical first line of defence. 2 marks

- c.** MMR (measles-mumps-rubella) is the vaccine that is available to protect people from measles. In Australia, children receive two doses of the MMR vaccine – the first when they are 12 months old and the second when they are 18 months old. 90% of those who are not immunised against measles catch the disease after an exposure event. 4 marks

Source: <https://www.abc.net.au/news/health/2019-04-10/measles-spikes-prompts-immunisation-warning-are-you-at-risk/10986172>

Outline how the MMR vaccine works to provide protection against measles.

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DO NOT WRITE IN THIS AREA

- d.** Justify whether MMR vaccination is an example of active or passive immunity. 2 marks

- e.** The MMR vaccine is important for two reasons. It allows individuals immunised to both protect themselves and the wider population by enabling herd immunity to be achieved. 3 marks

Explain the importance of herd immunity for containing an outbreak of a contagious disease such as measles, and protecting the community.

Question 6 (5 marks)

Galápagos Island Tortoises on the slopes of the Alcedo volcano, referred to as the Alcedo Volcano Tortoise population, have comparatively lower genetic diversity than compared with other Galápagos Island tortoise populations. Evidence of volcanic eruptions burying areas of the Alcedo Volcano Tortoise population habitat in pumice and ash have been found.

Source: https://en.wikipedia.org/wiki/Population_bottleneck

- a. Identify the process that most likely resulted in a reduced population size of the Alcedo Volcano Tortoise population, following the volcanic eruptions. 1 mark

- b. Provide two reasons why the process that was identified in Question 6a could contribute to the lower genetic diversity in the Alcedo Volcano Tortoise population. 2 marks

- c. A different population of Galápagos Island Tortoises, the Giant Tortoise species, have seen a reduction in their population numbers over time in the Galápagos Islands. 2 marks

Scientists have observed, that in the first five years in the wild, Giant Tortoise mortality rates are at their highest due to a lack of food and water, as well as the predation of hatchlings.

Today, there are conservation programs to revive Giant Tortoise populations.

Adapted From: <https://www.galapagos.org/conservation/giant-tortoise-restoration/>

Suggest one action that conservationists can take to protect Giant Tortoise species and outline how this may increase population size.

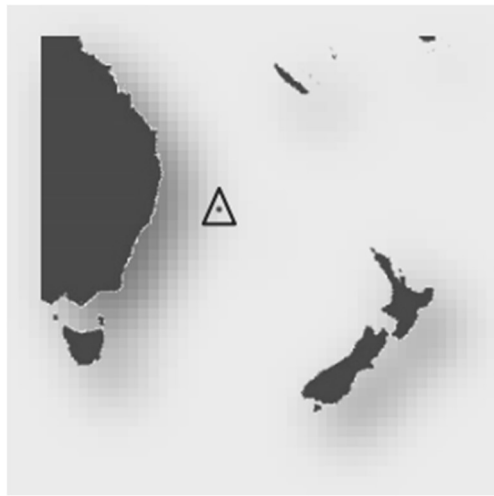
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Question 7 (6 marks)

Lord Howe Island, found 600km from Australia's mainland, is a very small, isolated subtropical island that was formed from volcanic remains. It is shown in reference to Australia's east coast on the map below, in the centre of the triangle.



There are two *Howea* palm plant species on Lord Howe Island and they survive in close proximity to one another; these palms do not rely on insects for pollination but on wind dispersal of pollen instead.

Adapted From: https://www.mq.edu.au/_data/assets/pdf_file/0007/1217293/Plant-of-the-week-Lord-Howe-Island-Palms-Howea-spp.pdf

- a. State the type of speciation of which *Howea* palms are an example. Justify your answer. 2 marks

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- b.** The two *Howea* palm species are called 'Belmore palms' and 'Kentia palms.'

2 marks

Belmore palms grow on volcanic soils, whereas Kentia palms grow on calcareous soil, which is composed mostly of calcium carbonate. The soil type also seems to affect the flowering times of the two different plants. Calcareous soils, where Kentia palms successfully grow, are low in nutrients, causing flower production to occur six weeks before the Belmore palms, which grow on nutrient-rich volcanic soils.

Given that both species are wind-pollinated, biologists believe that there is enough evidence that speciation has occurred.

Adapted From: https://www.mq.edu.au/_data/assets/pdf_file/0007/1217293/Plant-of-the-week-Lord-Howe-Island-Palms-Howea-spp.pdf

Describe the term selection pressure. Using the provided information about the two *Howea* palm species, identify the selection pressure that was involved in this example.

- c.** Biologists have sequenced the DNA of various Kentia palms and Belmore palms. They found that there were a small number of genetic differences between different palms of the same species; they also found that there was a significant amount of shared DNA between the two different species of palms.

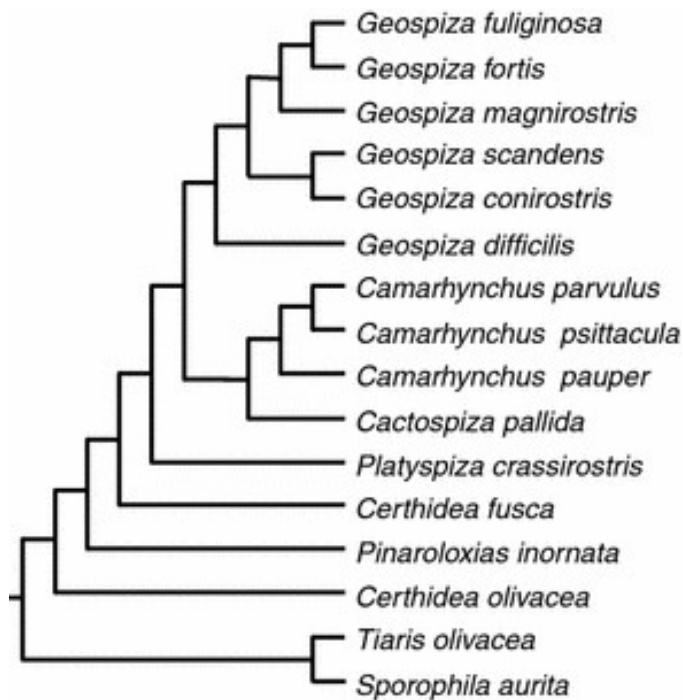
2 marks

Explain the biological reasons for both of these findings.

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Question 8 (4 marks)

The diagram below shows the evolutionary relationship between different finches in the Galapagos Islands.



Source: <https://link.springer.com/article/10.1007/s10682-008-9257-1/figures/1>

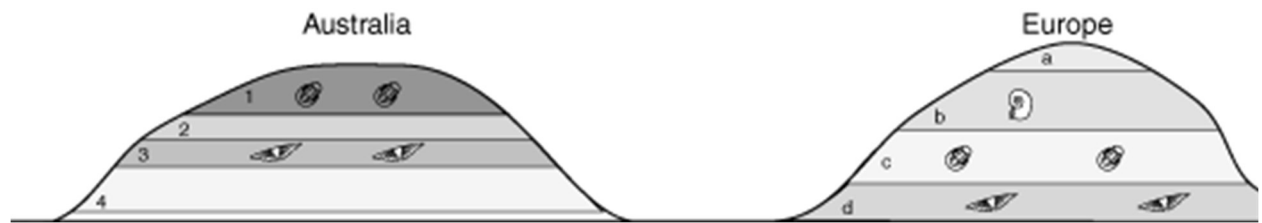
- a. Identify a molecule other than DNA that can be used to construct a diagram such as the one above. 1 mark

- b. Explain which species you would expect *Geospiza scandens* to share the most DNA in common with. 3 marks

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Question 9 (7 marks)

Study the following diagram comparing fossils that are found in Australia and Europe.



Source: <https://www.geol.umd.edu/~jmerck/geol342/lectures/18.html>

- a.** Identify the oldest fossil layers for both Australia and Europe. 2 marks

- b.** Name the dating technique that is depicted in the diagrams. Identify one limitation of this technique. 2 marks

- c.** The fossils in the top layer of the Australian rock strata are found in the second-last layer (c) in the European example. 3 marks

Identify this type of fossil and how it is useful in this example of relative dating between areas in Australia and Europe.

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Question 10 (5 marks)**How do you make a universal flu vaccine? A microbiologist explains the challenges, and how mRNA could offer a promising solution.***Published in The Conversation: February 8, 2023*

The recent success of mRNA vaccines for COVID-19 shows promise for their use in achieving the vision of an effective universal influenza vaccine.

There are 20 known subtypes of influenza. Prior to the development of mRNA vaccines, it wasn't feasible to make a single flu vaccine against all 20 subtypes due to the complexities and costs in manufacturing. Unlike traditional vaccines, constructing and producing mRNA vaccines is rapid and simple because manufacturers don't have to produce and purify the protein directly. Instead, mRNA vaccines provide the genetic sequence of the protein and then use the body's own cells to generate that protein in its natural structure. This makes it relatively easy to incorporate any antigen or many antigens.

Recently, a team of researchers designed a mosaic mRNA vaccine with sequences from multiple versions of the haemagglutinin protein, each representing one of the 20 influenza subtypes. This vaccine induced broad immunity against each variant in mice and ferrets.

There are still several challenges before a universal influenza mRNA vaccine can be made available.

For one, it is not clear which conserved antigens provide the broadest protection and some don't naturally induce strong immune responses; so, mRNA vaccines may need improvements, like additional components that help activate immune cells. One such addition could include using mRNA to express nanoparticles that stimulate stronger immune responses against the conserved antigens that are presented by the vaccine.

The mosaic approach is also limited by the maximum dose possible for mRNA vaccines because higher doses could cause increased adverse reactions to the vaccine. When that dose gets divided into 20 or more antigens, the dose of one or more of those antigens may drop below the threshold that is needed for protection.

Scientists are working on these challenges, including by developing new mRNA technologies that work with a much lower dose. If mRNA vaccines work for universal protection from influenza, the same strategies could also apply to other frequently mutating viruses, such as the virus that causes COVID-19 and maybe even HIV.

Adapted From: <https://theconversation.com/how-do-you-make-a-universal-flu-vaccine-a-microbiologist-explains-the-challenges-and-how-mrna-could-offer-a-promising-solution-195807>

- a. The article states that there are 20 influenza subtypes. Identify and describe the biological process that causes this to occur. 2 marks

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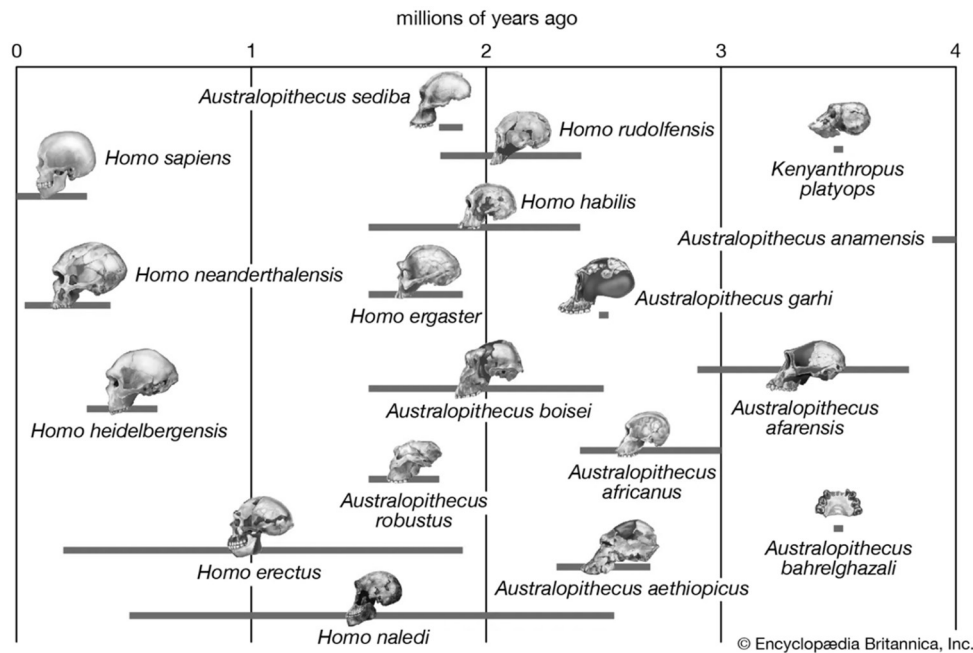
- b.** Referring to the information in the article, discuss one social and one biological implication of designing mosaic mRNA vaccines. 2 marks

- c.** Human clinical trials, where vaccines are tested on people to see if they are safe and effective, must be carried out before a vaccine is made available to the broader population. 1 mark

Outline one ethical consideration scientists conducting the trials would need to address.

Question 11 (5 marks)

The diagram below provides simple estimated time ranges for different hominin species.



Source: <https://www.britannica.com/topic/Homo-sapiens>

- a. Which species is the oldest species that is depicted on the diagram? 1 mark

- b. List two structural trends in the evolution of hominins from the *Australopithecus* genus to the *Homo* genus. 2 marks

- c. The diagram shows that *Homo sapiens* and *Homo neanderthalensis* have overlapping times of existence. Modern humans who live outside of Africa have been shown to have 1 – 4% Neanderthal DNA in their genome. This has led to a debate in the scientific community about whether to classify *Homo sapiens* and *Homo neanderthalensis* as separate species or as sub-species. 2 marks

Adapted From: <https://humanorigins.si.edu/evidence/genetics/ancient-dna-and-neanderthals>

Provide two reasons which explain how there can be disagreement between scientists when classifying different human species using the same fossil record.

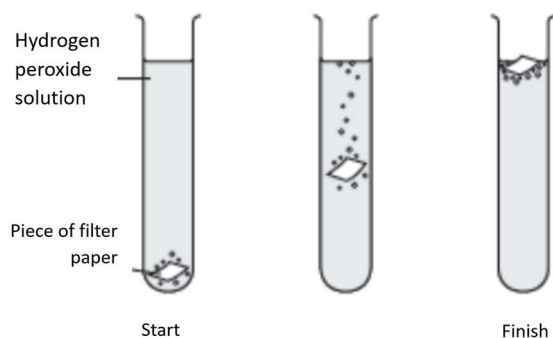
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Question 12 (7 marks)

Students were testing the effect of temperature on the ability of catalase enzyme to break down hydrogen peroxide into oxygen gas. Each group of students completed three trials per temperature and measured the time that it took for paper soaked in catalase to rise when placed in a hydrogen peroxide solution.

Source: <https://qrpastpapers.com/exam/1184>**Table 1: Student Group 1 Results**

Temperature (°C)	Trial 1	Trial 2	Trial 3
5	70 seconds	77 seconds	100 seconds
25	55 seconds	60 seconds	52 seconds
40	30 seconds	33 seconds	30 seconds
60	300 seconds	280 seconds	302 seconds

- a. Identify two controlled variables that could be introduced to this experiment. 1 mark

- b. Identify the optimal temperature for catalase. Justify your answer by referring to the data that was collected by Student Group 1. 2 marks

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- c. Below are the results for another group of students.

2 marks

Table 2: Student Group 2 Results

Temperature (°C)	Trial 1	Trial 2	Trial 3
5	72 seconds	75 seconds	71 seconds
25	55 seconds	56 seconds	51 seconds
40	40 seconds	35 seconds	41 seconds
60	150 seconds	155 seconds	146 seconds

Analyse the results in Table 2 and justify which of the temperature measurements are the least precise.

- d. Compare the results from Table 1 and Table 2 and identify which results could have resulted from a possible systematic error. Suggest a cause of that error.

2 marks

END OF QUESTION AND ANSWER BOOK

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Clearly number all responses in this space.

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VCE BIOLOGY
Written Examination
ANSWER SHEET – 2023

Student
name:

Use a **PENCIL** for **ALL** entries. For each question, shade the box which indicates your answer.

Marks will **NOT** be deducted for incorrect answers.

NO MARK will be given if more than **ONE** answer is completed for any question.

If you make a mistake, **ERASE** the incorrect answer – **DO NOT** cross it out.

1	A	B	C	D
2	A	B	C	D
3	A	B	C	D
4	A	B	C	D
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39	A	B	C	D
40	A	B	C	D