

Victorian Certificate of Education  
2022

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

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**BIOLOGY**  
**Written examination**

Friday 28 October 2022

Reading time: 9.00 am to 9.15 am (15 minutes)

Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

**QUESTION AND ANSWER BOOK****Structure of book**

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	40	40	40
B	11	11	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 of 42 pages
- 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** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- 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.

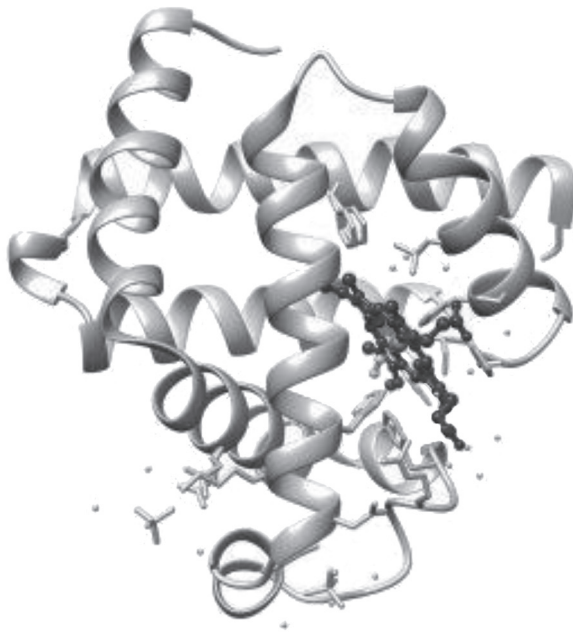
Marks will **not** be deducted for incorrect answers.

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**

In the 1950s, scientist John Kendrew determined the structure of myoglobin. Myoglobin was found to be a single polypeptide chain with one heme group, as shown below.



Source: Tuscany Diet, 'Definition, composition, and structure of the proteins',  
<[www.tuscany-diet.net/proteins/definition-composition-structure/](http://www.tuscany-diet.net/proteins/definition-composition-structure/)>

The protein structure shown above would best be described as myoglobin's

- A. primary structure.
- B. secondary structure.
- C. tertiary structure.
- D. quaternary structure.

Use the following information to answer Questions 2–4.

A scientist identified a single-stranded molecule with the structure shown below.

exon	intron	exon	intron	exon	intron
50 bases	150 bases	70 bases	80 bases	120 bases	40 bases

**Question 2**

It would be reasonable for the scientist to conclude that this molecule is

- A. mature mRNA.
- B. pre-mRNA.
- C. copy DNA.
- D. DNA.

**Question 3**

In which part of a cell would this molecule be found?

- A. nucleus
- B. ribosome
- C. Golgi apparatus
- D. endoplasmic reticulum

**Question 4**

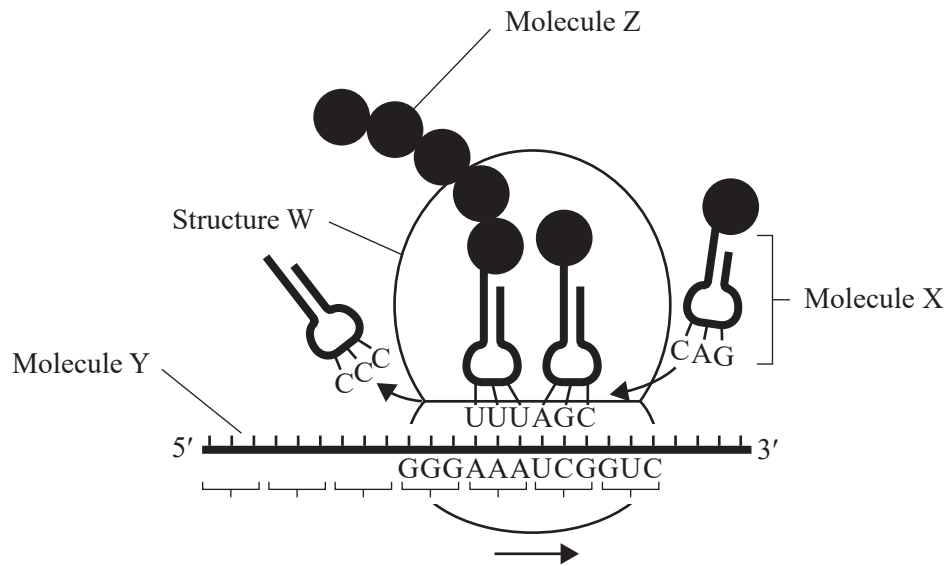
The scientist would expect the length of the molecule that is translated into a protein to be

- A. 240 bases.
- B. 270 bases.
- C. 480 bases.
- D. 510 bases.

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**Question 5**

Consider the diagram shown below, with molecules X, Y and Z, and Structure W labelled. All arrows depict the movement of molecules or structures.



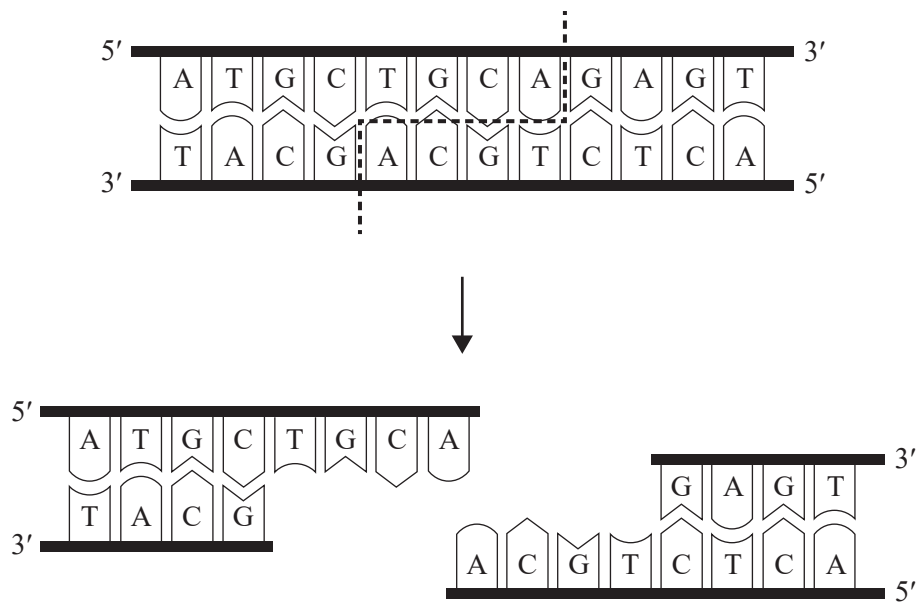
Source: adapted from H Lodish, A Berk, P Matsudaira et al.,  
*Molecular Cell Biology*, 5th edition, WH Freeman and Company, New York, 2003, p. 119

Which one of the following is a correct statement about the diagram above?

- A. Structure W is a copy of template DNA found in the nucleus.
- B. Molecule X carries an amino acid that will be added to the growing polypeptide.
- C. Molecule Y is being read in the 3' to 5' direction.
- D. Molecule Z contains a codon.

**Question 6**

An enzyme is used to manipulate DNA as shown in the diagram below.



Source: adapted from Ali DM/Shutterstock.com

Which one of the following is a correct statement about this enzyme?

- A. This enzyme is an endonuclease.
- B. This enzyme could be used to join two DNA fragments together.
- C. The action of this enzyme produces blunt ends on the two new fragments.
- D. This enzyme breaks only hydrogen bonds between complementary base pairs.

**Question 7**

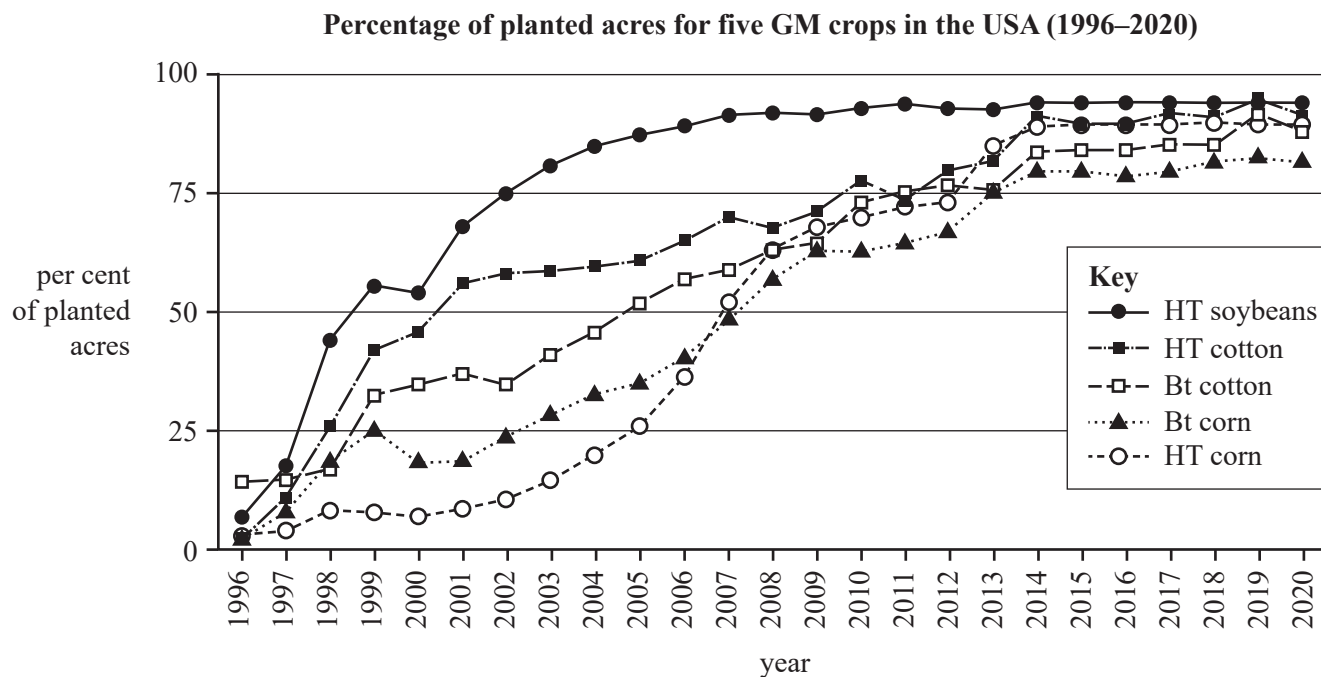
Genetically modified (GM) crops are engineered to introduce a new trait into a species. Traits chosen by scientists are ones that will benefit people either directly or indirectly.

An example of such a trait is one that

- A. decreases the nutritional value of a crop.
- B. improves environmental conditions for crops.
- C. increases resistance to toxins produced by fungi.
- D. develops potential allergens that trigger a vigorous immune response.

**Question 8**

The extent to which GM crops were planted in the United States of America (USA) between 1996 and 2020 was investigated. The percentage of planted acres of GM crops out of the total planted acres of crops for five different types of crops – HT soybeans, HT cotton, Bt cotton, Bt corn and HT corn – is presented in the graph below. ‘HT’ indicates herbicide-tolerant varieties and ‘Bt’ indicates insect-resistant varieties.



Source: adapted from USDA, Economic Research Service using data from the 2002 ERS report ‘Adoption of Bioengineered Crops’ (AER-810) for the years 1996–1999 and National Agricultural Statistics Service, (annual) June Agricultural Survey for the years 2000–2020, <[www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx](http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx)>

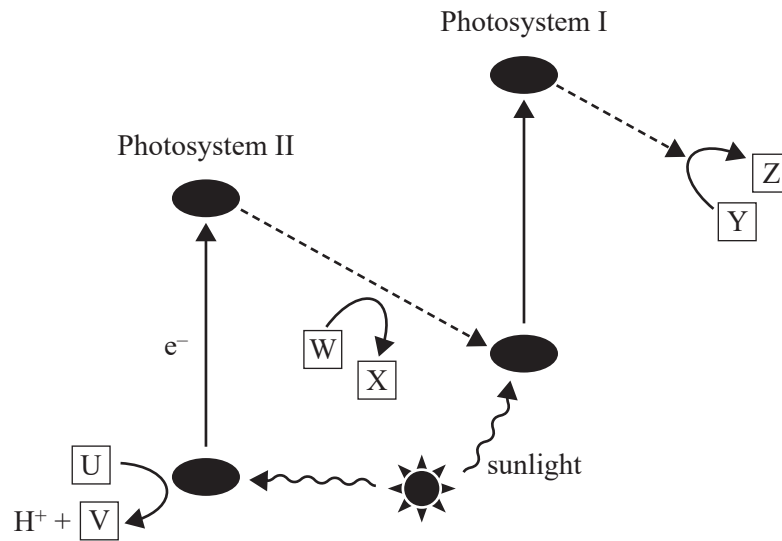
From the graph above, it can be concluded that

- in 1996, the percentage of planted acres of HT cotton crops was greater than 10 per cent.
- in 2007, the percentage of planted acres of Bt corn crops was greater than the percentage of planted acres of HT corn crops.
- in 2013, the percentage of planted acres of Bt cotton crops and the percentage of planted acres of Bt corn crops were similar.
- in 2020, the percentage of planted acres of HT soybean crops was the lowest that it had been for the duration of the investigation.

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Use the following information to answer Questions 9 and 10.

Photosynthesis is an important process that occurs in plants and in some bacteria. The diagram below represents one of the stages that occurs in the photosynthetic process.



Source: adapted from Arif Majid, SlideShare,  
<<https://pt.slideshare.net/ArifMajid/light-reaction-of-photosynthesis/17>>

**Question 9**

Where in a plant cell would the stage of the photosynthetic process shown above be located?

- A. mitochondria
- B. thylakoid membrane
- C. chloroplast inner membrane
- D. chloroplast outer membrane

**Question 10**

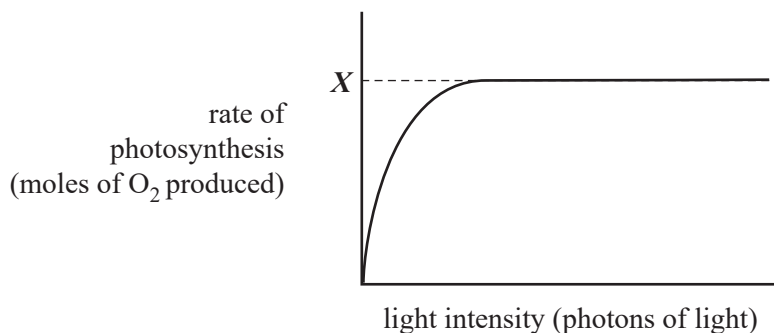
In the diagram shown above, what do V, W and Z represent respectively?

- A. water, ATP and  $NADP^+$
- B. oxygen, ATP and NADPH
- C. oxygen, ADP and NADPH
- D. carbon dioxide, ADP and  $NADP^+$

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**Question 11**

A student shone a light on a green leaf and measured the rate of photosynthesis. The student varied the intensity of the light and graphed the findings as shown below.  $X$  was the maximum rate of photosynthesis detected by the student.



Which one of the following conditions will increase the value of  $X$ ?

- A. adding a filter to the light used
- B. using a leaf that contains more chloroplasts
- C. moving the light further away from the leaf
- D. decreasing the temperature of the leaf's environment

**Question 12**

A plant specialist was investigating the viability of producing a new plant variety. The plant specialist investigated the optimum time to grow the new plant variety in Brisbane, Queensland. This plant flourishes when the temperature is above 20 °C, the precipitation is less than 50 mm per month and the number of daylight hours exceeds eight hours per day.

An example of qualitative data that the plant specialist may collect to assist their investigation of the viability of producing the new plant variety would be

- A. recording the number of days per year that the temperature falls below 20 °C in Queensland.
- B. determining the average number of hours of sunlight per day in Queensland.
- C. obtaining a list of the plant preferences from people living in Brisbane.
- D. calculating the mean monthly precipitation in Brisbane.



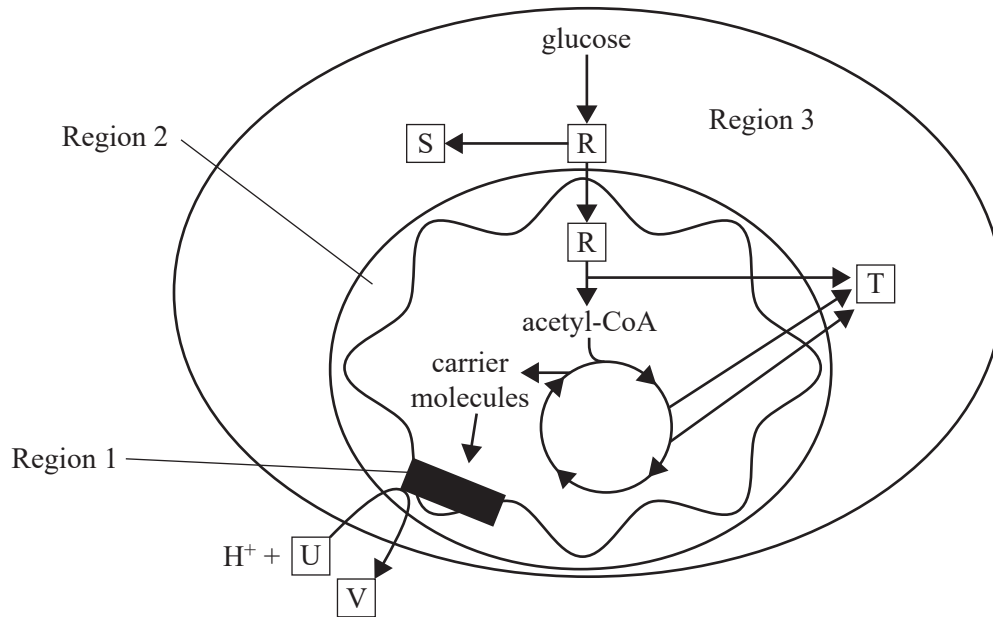
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**SECTION A – continued  
TURN OVER**

Use the following information to answer Questions 13–16.

There are a number of ways in which an animal cell is able to use compounds such as glucose to produce the energy that it needs to be able to function. The diagram below outlines the general metabolic pathways for cellular respiration in an animal cell.



**Question 13**

Which metabolic pathway is found in Region 3 of the cell?

- A. electron transport chain
- B. Calvin cycle
- C. Krebs cycle
- D. glycolysis

**Question 14**

Which of the following gives the names of compounds R, T and V, shown in the diagram above?

	R	T	V
A.	lactic acid	carbon dioxide	oxygen
B.	lactic acid	carbon dioxide	NAD <sup>+</sup>
C.	pyruvate	carbon dioxide	water
D.	pyruvate	NADH	oxygen

DO NOT WRITE IN THIS AREA

**Question 15**

The carrier molecules represented in the diagram on page 10 are

- A.  $\text{NAD}^+$  and water.
- B.  $\text{FAD}^+$  and oxygen.
- C.  $\text{NADH}$  and  $\text{FADH}_2$ .
- D.  $\text{NAD}^+$ , carbon dioxide and  $\text{FADH}_2$ .

**Question 16**

The last electron acceptor in cellular respiration is

- A. water.
- B. oxygen.
- C.  $\text{NADH}$ .
- D. carbon dioxide.

**Question 17**

Enzymes play an important role in metabolic pathways.

Which one of the following statements about enzymes is **incorrect**?

- A. All enzymes are affected by changes in pH.
- B. Most enzymes have a limited number of substrates.
- C. Enzymes increase the average energy of reactant molecules.
- D. Enzymes lower the activation energy of the reactions they catalyse.

**Question 18**

A student investigated the effect of temperature and oxygen on the production of lactic acid by cultured human skin cells. At the start of this experiment, each test tube contained the same number of skin cells and the same concentration of glucose. The temperature of each test tube and the amount of oxygen supplied to each test tube are given in the table below. After 24 hours, the student measured the amount of lactic acid in the test tubes.

**Temperature and oxygen content of each test tube in the experiment**

Test tube	Temperature ( $^{\circ}\text{C}$ )	Oxygen content (%)
1	20	20
2	37	20
3	37	5
4	75	5

Which test tube would be expected to contain the highest concentration of lactic acid?

- A. Test tube 1
- B. Test tube 2
- C. Test tube 3
- D. Test tube 4

**Question 19**

Enzymes are associated with the biochemical pathways of cellular respiration and photosynthesis.

Consider a cell that carries out both cellular respiration and photosynthesis.

Which one of the following is a correct statement about the enzymes associated with these pathways?

- A. Both pathways are catalysed by the same enzymes.
- B. An increase in pH above the optimal pH for cellular respiration may cause the enzymes to denature.
- C. The rates of these biochemical pathway reactions are not affected by changes in the concentrations of the enzymes.
- D. A decrease in temperature below the optimal temperature for photosynthesis will cause the enzymes to denature.

**Question 20**

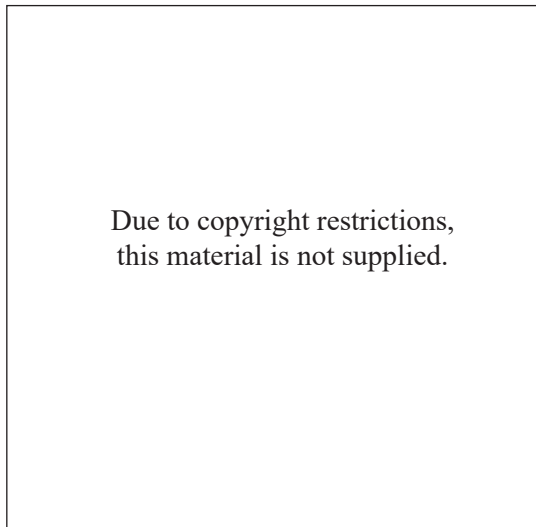
During their lifetime, plants are exposed to both pathogenic and beneficial microorganisms. Some plants provide shelter within their bodies for beneficial microorganisms. These beneficial microorganisms help plants that have not been genetically modified to resist pathogenic microorganisms.

The beneficial microorganisms may be providing protection by

- A. synthesising toxins that kill pathogenic microorganisms.
- B. providing a permeable physical barrier to pathogenic microorganisms.
- C. stimulating the production of antibodies against pathogenic microorganisms.
- D. mobilising the cells of the third line of defence against pathogenic microorganisms.

**Question 21**

The diagrams below illustrate the inflammatory response that may occur when a pathogen enters the human body.

**Diagram 1****Diagram 2**

Source: adapted from NA Campbell, JB Reece et al., *Biology*, 8th edition, Pearson Education Australia, 2009, p. 949

Which of the following correctly identifies one of the cells labelled 1 to 4 in the diagrams above and their role in the inflammatory response?

	Cell number	Name of cell	Role
A.	①	T cell	releases cytokines
B.	②	dendritic cell	presents antigens to helper T cells
C.	③	mast cell	releases histamines
D.	④	neutrophil	acts as a phagocyte

**Question 22**

The human body does not normally produce an immune response against self cells.


Cells in the human immune system can distinguish self cells from non-self cells


- A. because non-self cells have a faster reproduction rate.
- B. due to the presence of different antigens on non-self cells.
- C. only when antibodies are attached to the surface of non-self cells.
- D. because non-self cells are always smaller in size than self cells.


Use the following information to answer Questions 23–27.


# MEASLES:

## Important considerations

  
suspect

  
report

  
confirm

  
prevent

- In 2019, outbreaks of measles have occurred across the United States, with over 1,000 cases reported from 30 states.
- In 2018, Europe experienced a large measles outbreak with over 69,000 cases reported.
- The last case of measles reported in Montana was in 1990.

### WHO'S AT RISK →

- Babies who are too young for vaccine (< 12 months)
- Immunocompromised
- Pregnant women
- Unvaccinated

### INCUBATION →

**Average: 14 days**  
(range 7-21 days)


### SYMPTOMS


- High fever
- Runny nose
- Cough
- Red, watery eyes
- Rash (spreads from head to toe)
- Koplik spots (sometimes)


**Measles complications can include: pneumonia, encephalitis, and/or death**


**How infectious is measles? → One person can infect 12-18 susceptible people**





### RISK FACTORS

  
Travel to a place where measles is endemic


  
Contact with someone who has measles

  
Not receiving a measles vaccine (MMR)

  
Visitors from areas where measles is occurring

SUSPECT	REPORT	CONFIRM	PREVENT
			
Evaluate signs and symptoms and risk factors to determine if measles is high on the suspicion list.	Measles is immediately reportable to local public health. Reporting should not wait until lab results are available. If you suspect measles, report it ASAP.	A diagnosis of measles is confirmed by prompt laboratory testing. The gold standard is PCR and can be performed as soon as possible following rash onset. Blood tests for IgM and IgG antibody production may also be helpful.	The measles vaccine (MMR) is extremely effective against preventing the disease in those who are >12 months of age. <b>Two doses of MMR are 97% effective.</b>

**For more information, contact your local health department**



Source: adapted from Montana Official State Website, measles infographic, <<https://dphhs.mt.gov/assets/publichealth/CDEpi/Infographics/measles2019ADA.pdf>>

### Question 23

There are many countries where measles is endemic and the vaccination rate for measles is low.

Assuming that an unvaccinated person from the state of Montana, USA, travelled home by plane from one of these countries, what is the minimum number of days that this person should be kept in quarantine so that they are not at risk of spreading the disease if they were infected?

- A. 30
- B. 21
- C. 14
- D. 7

**Question 24**

Testing a traveller for IgM antibodies would let a health official know if the traveller

- A. is no longer infectious.
- B. has had red, watery eyes.
- C. has recovered from measles.
- D. has been infected with the measles virus.

**Question 25**

The  $R_0$  is defined as the average number of secondary cases of an infectious disease arising from one case.

According to the infographic provided, what is the  $R_0$  for measles?

- A. 0–7
- B. 3–97
- C. 7–21
- D. 12–18

**Question 26**

There are 200 people aged more than 12 months old in a population. This population is exposed to the measles virus.

If the population was fully vaccinated, how many of these 200 people could be expected to be infected with the measles virus?

- A. 0
- B. 3
- C. 6
- D. 9

**Question 27**

Which of the following cells responds first when a person receives the MMR vaccination?

- A. helper T cells
- B. memory T cells
- C. cytotoxic T cells
- D. antigen-presenting cells

**Question 28**

Hendra virus is a disease that can affect horses and human beings. Available evidence implicates fruit bats as the natural reservoir of the Hendra virus, which is transmitted in bodily fluids.

One practical way of controlling the spread of the Hendra virus to horses is to

- A. stop horses from eating fruit.
- B. cover the feed and water containers for horses.
- C. inject all fruit bats with a vaccine against the virus.
- D. minimise the number of fruit trees that bats rely on for food.

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 29–31.

Populations of the koala (*Phascolarctos cinereus*) can be found along the eastern coast of Australia. In the late 1800s, habitat destruction and hunting reduced the number of koalas dramatically. In an effort to save the koala from extinction, a small number of individual koalas were introduced to French Island, Victoria. The number of koalas on the island quickly grew. Scientists measured the genetic diversity within the island population and found it to be low when compared to populations of koalas in New South Wales and Queensland.

**Question 29**

The low genetic diversity within the French Island koala population can be explained by

- A. the bottleneck event.
- B. the founder effect.
- C. gene flow.
- D. mutations.

**Question 30**

The population of koalas on French Island

- A. will show more variation in traits than the populations in New South Wales.
- B. will have the same number of alleles per trait as the populations in Queensland.
- C. may be vulnerable to future changes in selective pressures acting on the population.
- D. will have more harmful mutations than the populations in New South Wales and Queensland.

**Question 31**

When completing the research on the French Island koalas, the scientists would have needed to take into account bioethical issues. The scientists were aware that they would need to communicate all results, whether favourable or unfavourable.

Which one of the following principles of bioethics would the scientists be addressing?

- A. non-maleficence
- B. beneficence
- C. integrity
- D. respect



Use the following information to answer Questions 32 and 33.



Source: chrisdorney/Shutterstock.com

Victoria's fossil emblem *Koolasuchus cleelandi*, shown on the stamp above, was chosen in January 2022. *K. cleelandi* fossils have been found in Boonwurrung country in Gippsland. Studies of *K. cleelandi* fossils have revealed many interesting findings. Several of these findings are summarised below.

***K. cleelandi* findings**

1. It was an amphibian that lived 125 million years ago.
2. It had a jaw, a skull, vertebrae and ribs made of bone.
3. It was covered in scales and had fangs on the roof of its mouth.
4. It lived in rivers carrying many sediments.
5. It lived in Victoria for 50 million years after its closest relatives in the rest of the world became extinct.
6. It fed on small dinosaurs, turtles and fish.
7. It was the size of a small car, 4 m long and weighed 500 kg.

**Question 32**

Which combination of findings from the list above is most likely to be associated with an increased chance of formation of *K. cleelandi* fossils?

- A. findings 1 and 6
- B. findings 2 and 4
- C. findings 3 and 5
- D. findings 2 and 7

**Question 33**

It is most likely that scientists determined the absolute age of *K. cleelandi* fossils

- A. through mtDNA analysis of *K. cleelandi* scales and fangs.
- B. through carbon-14 dating of jaw bones, skull, vertebrae and ribs.
- C. by finding index fossils nearby, such as those of small dinosaurs and turtles.
- D. through radioisotope dating of rock surrounding the fossils.

**Question 34**

Consider a hypothetical animal species, Species X, that can neither fly nor swim. Separate populations of Species X live in the same geographical area and often interbreed. After a period of time, a new species, Species Z, arises from Species X. The following list describes some barriers that may have contributed to the formation of Species Z:

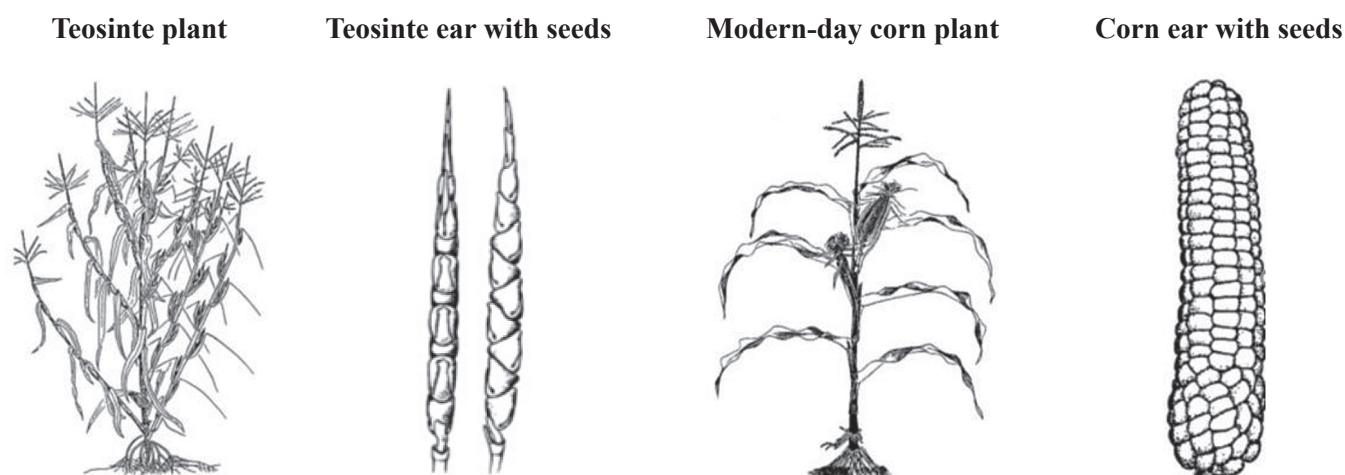
1. A newly formed river separated one population of Species X from the other populations.
2. One population of Species X developed a new mating ritual that was not recognised by members of the other populations of Species X.
3. One population of Species X began to breed several weeks later than the other populations of Species X.
4. A volcanic eruption created a mountain that separated one population of Species X from the other populations of Species X.

The barrier(s) that could have led to the formation of Species Z by sympatric speciation is

- A. either barrier 1 or barrier 4.
- B. either barrier 2 or barrier 3.
- C. barrier 1 only.
- D. barrier 2 only.

**Question 35**

Corn (*Zea mays* subsp. *mays*) is a crop grown in Australia. The direct ancestor of corn is widely believed to be a wild grass known as teosinte (*Zea mays* subsp. *parviglumis*). Approximately 9000 years ago, farmers in Mexico began selecting for more favourable traits in teosinte. Further selective breeding has resulted in the current form of the corn plant. Some of the traits of both the ancestral teosinte plant and the modern-day corn plant are shown below.



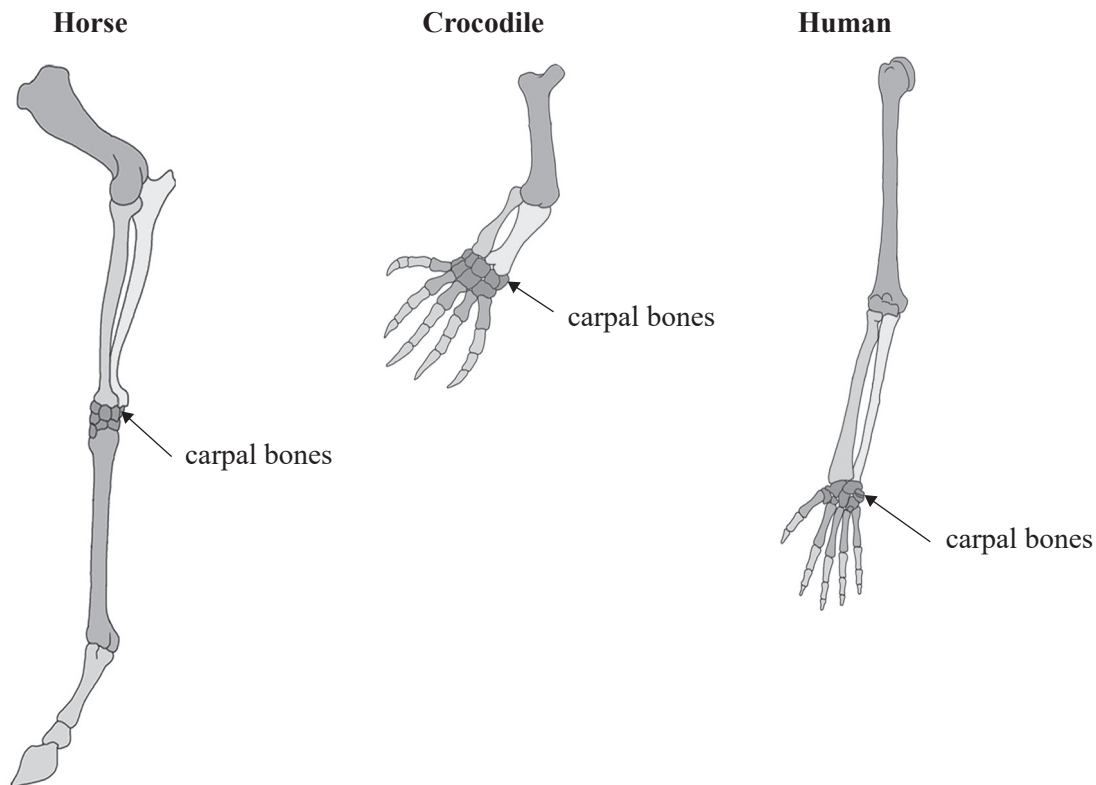
Source: adapted from CJ Yang, LF Samayoa, PJ Bradbury et al., 'The genetic architecture of teosinte catalyzed and constrained maize domestication', *Proceedings of the National Academy of Sciences (PNAS)*, vol. 116, no. 12, 19 March 2019, <<https://doi.org/10.1073/pnas.1820997116>>; licensed CC BY-NC-ND 4.0, <<https://creativecommons.org/licenses/by-nc-nd/4.0/>>

In the selective breeding to produce modern-day corn, a trait that has been selected for is an increase in the number of

- A. branches per plant.
- B. leaves on the plant.
- C. seeds in the ear.
- D. ears per plant.

Use the following information to answer Questions 36 and 37.

The images below show the bones in the forelimbs of three vertebrates. The carpal bones of a human are located in the wrist. Note that the three images are not shown at the same scale.



Source: adapted from Amadeu Blasco/Shutterstock.com

**Question 36**

The arrangement of bones in the forelimbs of these vertebrates can be described as

- A. putative.
- B. vestigial.
- C. analogous.
- D. homologous.

**Question 37**

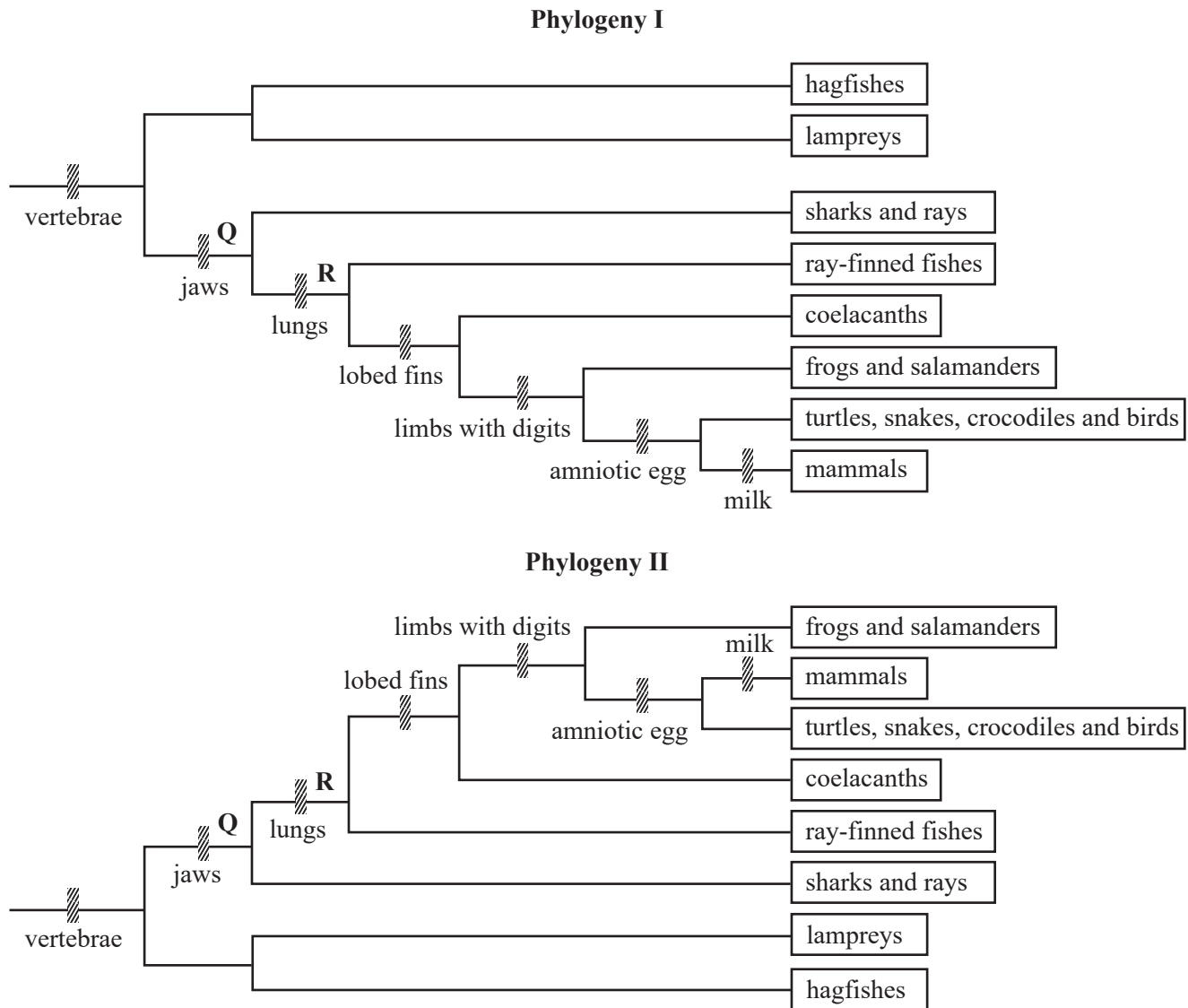
Based on your knowledge of evolution and the images above, which one of the following is a reasonable conclusion?

- A. The earliest ancestors of horses had only one digit on their forelimbs.
- B. The crocodile is a transitional form between horses and humans.
- C. Humans are more closely related to crocodiles than to horses.
- D. Humans, crocodiles and horses share a common ancestor.

Use the following information to answer Questions 38 and 39.

The two phylogenetic trees below depict evolutionary relationships between major vertebrate animal groups. The short, striped, vertical bars along the branches represent the features either found in the adult or the embryos of present-day species, or in the fossils of species that are now extinct.

Points Q and R represent animals that were alive just before an evolutionary branch split.



Source: adapted from LA Urry, N Meyers, ML Cain et al., *Campbell Biology*, 11th edition, Pearson Australia, 2018, p. 739

**Question 38**

Which one of the following statements is correct?

- A. Phylogeny I shows the evolutionary relationships between groups of vertebrates more accurately than Phylogeny II.
- B. Phylogeny I and Phylogeny II use different features of vertebrates as evidence to draw evolutionary relationships.
- C. Phylogeny II shows the same evolutionary relationships between groups of vertebrates as Phylogeny I.
- D. The most advanced groups in Phylogeny II are the hagfishes and lampreys.

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**Question 39**

Which one of the following is a correct conclusion from Phylogeny I?

- A. Frogs arose more recently than coelacanths.
- B. The common ancestor of all vertebrates is animal Q.
- C. The most closely related groups are lampreys and hagfishes.
- D. Animal R is the most recent common ancestor of ray-finned fishes and sharks.

**Question 40**

Scientists are investigating the mitochondrial genomes of different Aboriginal Australian populations. A purpose of these investigations is to reveal the pathways of migration of Aboriginal Australians who arrived from Sahul.

Mitochondrial DNA can be used for this purpose because it

- A. contains genes that code for enzymes.
- B. is always the same in specific populations.
- C. is conserved through the maternal lineage.
- D. is more structurally stable than nuclear DNA.

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**END OF SECTION A  
TURN OVER**

## 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 (7 marks)

Tryptophan (trp) is the least abundant amino acid in eukaryotic cells.

Consider the genetic code below.

		Second letter				
		U	C	A	G	
First letter U	UUU } phe	UCU } ser	UAU } tyr	UGU } cys	U	
	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	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	

- a. In terms of the genetic code, what feature shared by trp and met is not common to the other 18 amino acids?

1 mark

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DO NOT WRITE IN THIS AREA

b. Using the genetic code on page 22:

- write the next triplet in the sequence so that trp will be the next amino acid added to the polypeptide chain
- provide the corresponding mRNA strand
- provide the translated amino acid sequence.

3 marks

DNA template strand T A C T T C G G C T C A G T A \_\_\_\_\_  
└──────────┘  
|  
next triplet

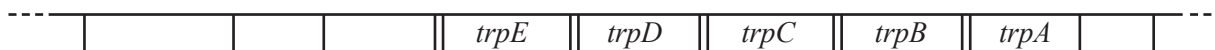
mRNA strand \_\_\_\_\_

Amino acid sequence \_\_\_\_\_

c. Unlike humans, the bacterium *Escherichia coli* does not need to rely on consuming tryptophan from the environment as these bacteria can synthesise their own. The *trp* operon regulates the production of tryptophan in *E. coli*. The diagram below shows the position of the five genes in the *trp* operon.

Annotate the diagram below to show how *E. coli* regulates the expression of genes through repression when tryptophan levels are high in the cell.

3 marks

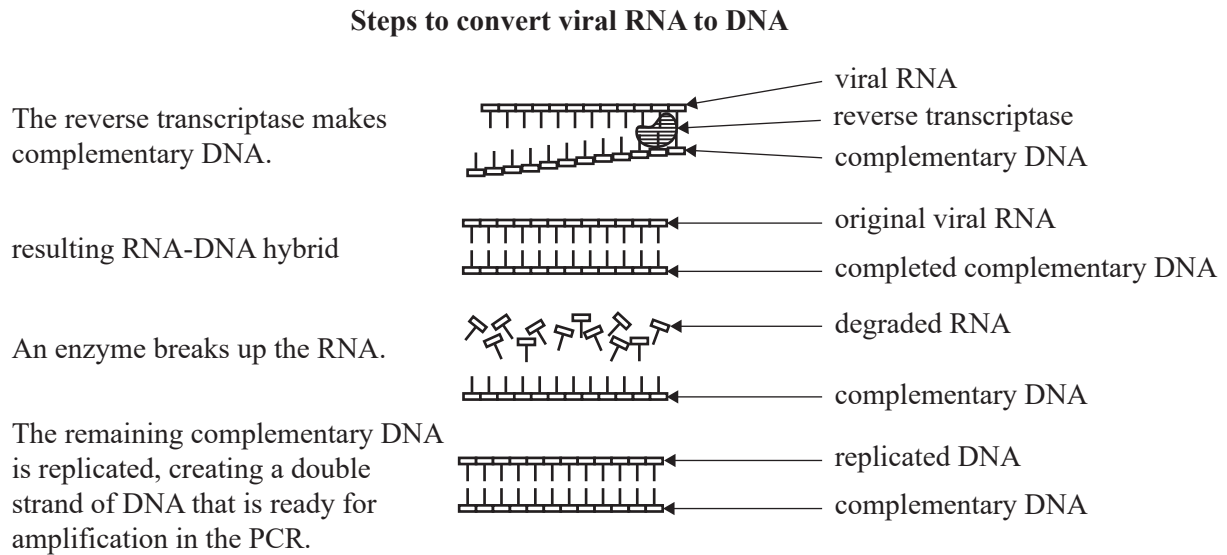
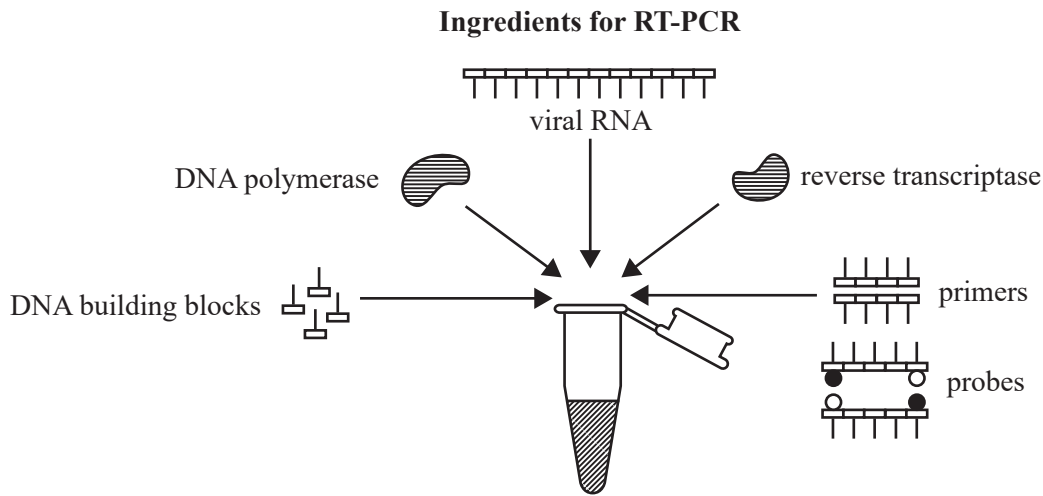


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SECTION B – continued  
 TURN OVER

**Question 2 (7 marks)**

The polymerase chain reaction (PCR) can be used to determine if a person is infected with a particular virus. Viral RNA must be converted to DNA before the PCR can occur. The process by which this occurs is called reverse transcription PCR (RT-PCR). The diagram below shows the ingredients required and the steps that must be taken for viral RNA to be converted to DNA.



Source: adapted from S Tiner, 'The science behind the test for the COVID-19 virus', *Discovery's Edge* (Mayo Clinic's research magazine), 27 March 2020, <<https://discoverysedge.mayo.edu/2020/03/27/the-science-behind-the-test-for-the-covid-19-virus/>>

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- a. i. Explain why RNA must be converted to DNA in RT-PCR. 1 mark

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- ii. What is the purpose of DNA amplification in the PCR? 1 mark

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- b. There are different stages in the PCR and each requires a different temperature.

Explain why each stage requires a different temperature.

3 marks

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- c. The probes shown in the diagram titled 'Ingredients for RT-PCR' on page 24 fluoresce (glow). They attach to complementary sequences only found in a particular virus.

State **two** reasons why virus identification using RT-PCR cannot be used for all viruses.

2 marks

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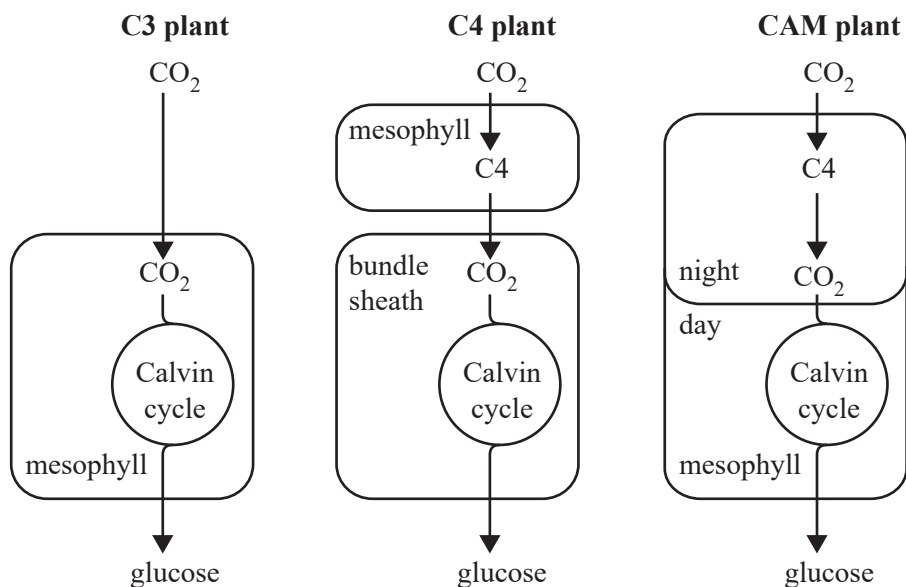
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SECTION B – continued  
TURN OVER

**Question 3** (8 marks)

Plants have the unique ability to photosynthesise and utilise sunlight. They are able to produce high-energy-containing molecules that fix carbon dioxide ( $\text{CO}_2$ ) into forms of carbohydrates that can be stored or used by plant cells. Most plants use the C3 pathway to fix  $\text{CO}_2$  and some use the C4 pathway. A small group of plants use a combination of both pathways. This smaller number of plants are called the CAM plants.



Source: adapted from H Kheyrodin and S Kheyrodin, 'CO<sub>2</sub> gas exchange in Crassulacean acid metabolism and C3 and C4 plants', *International Journal of Advanced Research in Biological Sciences*, vol. 4, issue 10, 2017, <<http://dx.doi.org/10.22192/ijarbs.2017.04.10.007>>

As part of their VCE Biology practical investigation, a group of students collected plant samples from their school grounds. While the students were able to identify most of the plants they collected, there was one they had not seen before. They performed a series of experiments with this plant in the laboratory. The observations they made, as well as documented information for C3, C4 and CAM plants, are shown in the table below.

**Comparison of the characteristics of the unknown plant with C3, C4 and CAM plants**

Plant characteristic	Unknown plant	C3 plant	C4 plant	CAM plant
ideal temperature for photosynthesis	25–35 °C	15–25 °C	30–40 °C	> 40 °C
pathway to fix $\text{CO}_2$	C4 pathway and Calvin cycle	only Calvin cycle	C4 pathway and Calvin cycle	C4 pathway and Calvin cycle
stomata open during the day	yes	yes	yes	no
photorespiration occurring	moderate to low	high	low	only observed in the middle of the day
water loss during the day	moderate	high	moderate	low
plant growth rate	moderate	moderate	fast	very slow



**Question 4 (7 marks)**

Increased protein consumption is a global trend. Chicken eggs are a good source of protein.

Ovalbumin (egg white protein) is formed from chicken cells during egg production.

- a. Describe the role of organelles in the export of ovalbumin from a chicken’s cells into an egg. 3 marks

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- b. To meet the growing demand for ovalbumin, more chickens are being bred for egg production using intensive farming methods. Animal welfare concerns have been raised, so alternative processes for making ovalbumin are being explored. Currently, recombinant technology can use a fungus to produce large quantities of ovalbumin. It has been suggested that scientists explore the option of using recombinant plasmids to transform bacterial cells for ovalbumin production.

Discuss an ethical concern that could be raised about intensive farming methods or the use of recombinant technology to produce protein. Propose a feasible solution to this ethical concern. State the ethical concept or approach that has been addressed in your discussion.

4 marks

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**Question 5** (8 marks)

Wheat is a cereal crop grown extensively in Australia. The starch found within the wheat grain is used to produce wheat flour. Wheat flour is used to make a variety of foods.

Scientists are investigating ways to improve wheat crop yields. It is known that both the weight and protein content of a wheat grain are under genetic control. The scientists designed a single guide RNA (sgRNA) molecule and used CRISPR-Cas9 technology to edit the gene associated with grain weight. After editing, the gene was not expressed. When grown, the gene-edited wheat plants showed both an increase in grain weight and an increase in protein content.

- a. Explain how the scientists would have designed the sgRNA molecule and outline the function of sgRNA in the editing of the gene.

3 marks

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- b. The scientists noted that the lack of gene expression could have resulted from either the insertion of a nucleotide into the gene or the deletion of seven nucleotides from the gene.

Explain how each of these two different gene edits could have caused the lack of gene expression.

3 marks

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- c. Starch from the wheat grain can be used to manufacture bioethanol. In this process, *Zymomonas mobilis* bacteria and enzymes that break down starch into monosaccharides are added to the starch. *Z. mobilis* is a facultative anaerobic bacterium.

Explain how *Z. mobilis* is used in the manufacture of bioethanol.

2 marks

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**Question 6 (7 marks)**

Influenza is an infectious respiratory disease. In humans, it can be caused by the influenza A or influenza B viruses.

- a. Natural killer cells and cytotoxic T cells both play an important part in the human immune response to the virus causing influenza.

Compare the roles played by each of these two types of cells in the immune response to the influenza virus.

4 marks

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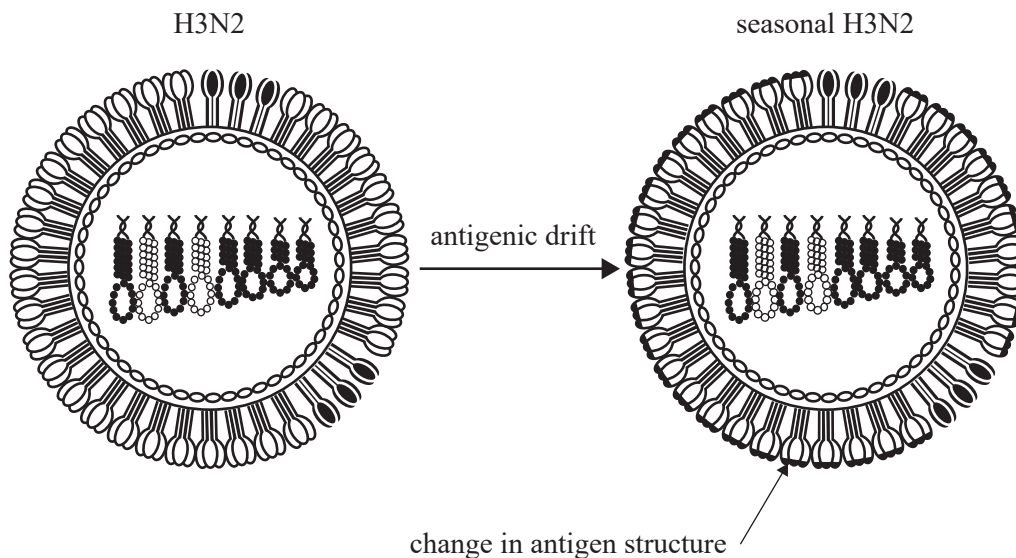
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Antigenic drift can result in small changes to the structure of the antigens on the surface of the influenza virus, as shown in the diagram below.



Source: adapted from F Krammer, GJD Smith, RAM Fouchier et al., 'Influenza', *Nature Reviews Disease Primers*, 4:3 (2018), <<https://doi.org/10.1038/s41572-018-0002-y>>; reproduced with permission of Springer Nature; via CCC-Rightslink USA

- b. i. What change would have occurred within the virus to bring about the change in the structure of the antigen?

1 mark

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- ii. Vaccines against influenza are available and it is recommended that people are vaccinated each year.

Explain, in terms of antigenic drift, why vaccinations are recommended yearly for influenza rather than once every few years.

2 marks

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**Question 7** (6 marks)

Before the chickenpox vaccine was developed, many people used ‘chickenpox parties’ as a way to infect their children with the virus. The idea was to enable the children to become immune to the virus before reaching adulthood, when the symptoms of the infection can be more severe. Some people continue to hold ‘chickenpox parties’ as an alternative to receiving the vaccine. However, the Centers for Disease Control and Prevention (CDC) in the United States of America (USA) warns against this practice, saying that chickenpox can have severe and sometimes unpredictable or life-threatening consequences. The CDC recommends vaccination as a safe way to develop immunity to chickenpox.

- a. What is the name given to the type of immunity that would develop in children who became infected at the ‘chickenpox parties’? 1 mark

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- b. A summary of case-control studies conducted from 1997 to 2003 and analysed by the Australian National University showed that a single dose of varicella (chickenpox) vaccine was 97% effective in the first year after vaccination and 86% effective in the second year. From the second to eighth year after vaccination, the vaccine’s effectiveness remained stable at 81% to 86%. Most vaccinated children who developed chickenpox during the eight years after vaccination had a mild case of the disease.

Why do most vaccinated individuals, if they are infected, show only a mild case of the disease? 2 marks

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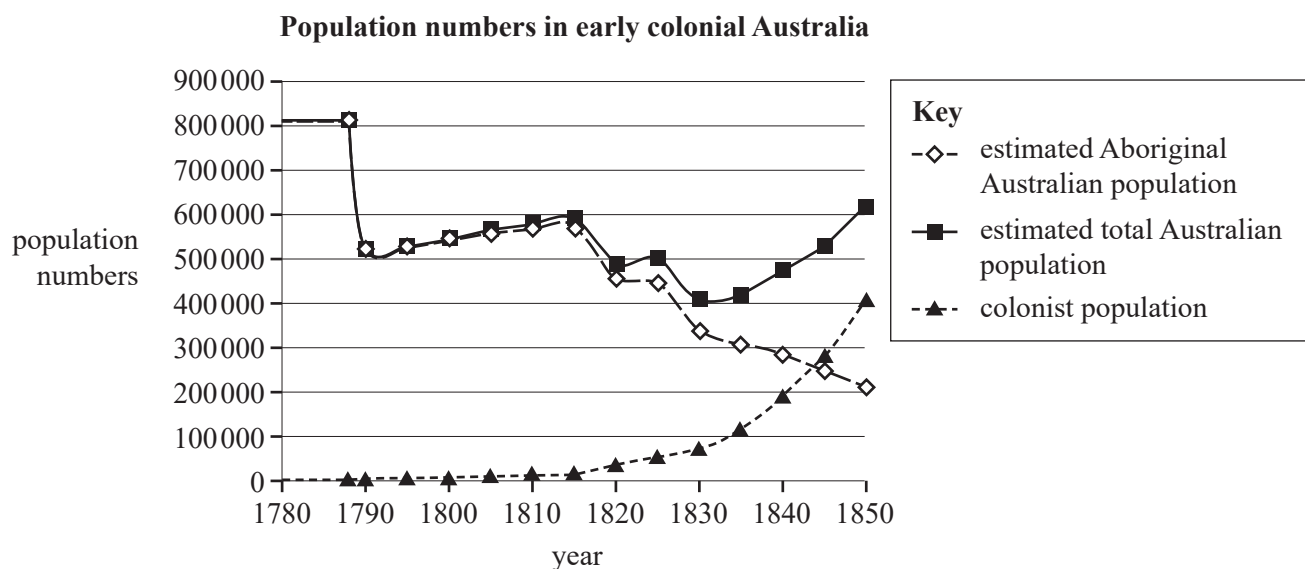
DO NOT WRITE IN THIS AREA



- c. Smallpox is widely believed to be the cause of the significant population decline in Indigenous populations during early European arrival in Australia. Recent research suggests that it may have been chickenpox that caused the change in population numbers rather than smallpox. It is thought that chickenpox did not exist in Aboriginal and Torres Strait Islander communities before European arrival. Chickenpox is fairly mild in young children and is easily transmitted. It can be a fatal disease in adults who were not infected as children.

The graph below shows population numbers during the period 1780–1850:

- the estimated Aboriginal Australian population
- the colonist population
- the estimated total Australian population



Source: adapted from BH Hunter and J Carmody, 'Estimating the Aboriginal population in early colonial Australia: The role of chickenpox reconsidered', *Australian Economic History Review*, vol. 55, no. 2, July 2015, <<https://doi.org/10.1111/aehr.12068>>; reproduced with permission from John Wiley & Sons Co.; via CCC-Rightslink USA

With reference to chickenpox, explain how infection may have caused such a large impact on the Aboriginal Australian population and yet did not affect the population numbers of the colonists significantly, and why the Aboriginal population increased from 1790 to 1810.

3 marks

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**Question 8** (9 marks)

There are 13 species of small birds commonly known as Darwin’s finches, found only on the Galápagos Islands in the Pacific Ocean, 1000 km west of South America. Their closest living relative is the dull-coloured grassquit, *Aemospiza obscura*, which is found on mainland South America. It is believed that Darwin’s finches evolved from *A. obscura* or from its ancestor on the mainland.

The different finch species are similar in colour but vary in beak size and shape, habitat and diet.

- a. Discuss how the different species of Darwin’s finches arose from an ancestral population on the mainland. In your response, name the type of speciation that occurred, identify the main selection pressure that has acted on finch populations and explain how the Galápagos Islands enabled rapid speciation.

6 marks

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The table below shows the distribution of Darwin's finch species on the Galápagos Islands.

**The species of Darwin's finches found on each island of the Galápagos**

Species	Abbreviated name of island															
	Esp.	Fern.	Flor.	D. Maj.	Gen.	Isa.	Pint.	Mar.	N. Sey.	Pinz.	Rab.	S. Cris.	S. Cruz	S. Fe	Santi.	W. & Dar.
<i>Certhidea olivacea</i>	✓	✓	✓		✓	✓			✓	✓	✓		✓		✓	
<i>Certhidea fusca</i>	✓		✓		✓		✓	✓				✓		✓		
<i>Geospiza scandens</i>			✓	✓	✓	✓	✓		✓	?	✓	✓	✓	✓	✓	
<i>Geospiza conirostris</i>	✓															
<i>Geospiza magnirostris</i>		✓	extinct	✓	✓	✓	✓	✓		✓	✓	extinct	✓	extinct	✓	
<i>Geospiza psittacula</i>		✓	extinct			✓	✓	✓		extinct	✓		✓	✓	✓	
<i>Geospiza heliobates</i>						✓										
<i>Geospiza fortis</i>		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
<i>Geospiza pauper</i>			✓													
<i>Geospiza difficilis</i>		✓	extinct				✓						extinct			✓
<i>Geospiza fuliginosa</i>	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
<i>Geospiza parvula</i>		✓	✓	✓		✓			✓	✓	✓	✓	✓	✓	✓	
<i>Geospiza pallida</i>		?				✓				?		✓	✓		✓	

Source: Galapagos Conservation Trust, 'Darwin's finches', <<https://galapagosconservation.org.uk/wildlife/darwins-finches/>>

- b. Using the table above, identify the species of Darwin's finches that is currently the most widely distributed.

1 mark

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- c. The species *G. magnirostris*, *G. psittacula* and *G. difficilis* are listed as 'extinct' on several islands.

Describe **two** types of evidence that would allow biologists to classify a species as extinct on a particular island.

2 marks

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\_\_\_\_\_

**Question 9** (6 marks)

*Homo sapiens* are the only species of hominin alive today. The table below gives estimated ranges of existence for several hominin species, based on fossil evidence.

Species name	Earliest date found (number of years ago)	Latest date found (number of years ago)	Location
<i>Australopithecus anamensis</i>	4 200 000	3 800 000	East Africa
<i>Australopithecus afarensis</i>	3 850 000	2 950 000	East Africa
<i>Australopithecus africanus</i>	3 300 000	2 100 000	South Africa
<i>Homo habilis</i>	2 400 000	1 400 000	East and South Africa
<i>Homo rudolfensis</i>	1 900 000	1 800 000	East Africa
<i>Homo erectus</i>	1 890 000	110 000	North, East and South Africa West and East Asia
<i>Homo floresiensis</i>	700 000	50 000	South-East Asia (Indonesia)
<i>Homo neanderthalensis</i>	400 000	40 000	Europe South-West and Central Asia
<i>Homo sapiens</i>	300 000	present	earliest in North Africa, now worldwide

Data: Smithsonian National Museum of Natural History, 'What does it mean to be human',  
<<https://humanorigins.si.edu/evidence/human-evolution-interactive-timeline>>

- a. Describe **two** trends that would be observed in fossils of these hominin species, with respect to brain size and limb structure, from the most ancient to the most recent species.

2 marks

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b. Several times during hominin evolution, different hominin species lived in the same locations and it is possible that they interbred. There is evidence to support the theory that *H. sapiens* and *H. neanderthalensis* interbred in some parts of Europe.

i. Using the table on page 36, apart from interbreeding between *H. sapiens* and *H. neanderthalensis*, identify **two** other occasions when interbreeding may have occurred between two different species of hominin and name the species involved.

2 marks

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ii. Discuss the limitations of the evidence that supports your response to **part b.i.**

2 marks

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SECTION B – continued  
TURN OVER

**Question 10** (8 marks)**A vaccine for cancer**

Scientists are investigating whether it is possible to produce a vaccine that will work against cancer cells.

Currently there are vaccines available against certain viruses that are known to cause cancer. For example, the human papillomavirus vaccine is highly effective in preventing cervical cancer. The vaccine contains virus-like particles that have antigens that are found on the surface of the human papillomavirus. These antigens stimulate an immune response when injected into the individual but do not cause disease. The vaccine is very effective as the immune response produces high levels of antibodies.

This example is considered a conventional vaccine. Conventional vaccines contain either a dead or inactivated version of a pathogen, or a protein from that pathogen. Conventional vaccines can take many months to produce.

As most cancers are not caused by viruses, scientists investigated whether a non-conventional vaccine could be developed. A vaccine containing mRNA was produced. mRNA codes for the production of a protein that must be produced by the cells of the individual injected with the vaccine. This protein manufactured by the cells acts as an antigen and, when released from the cells, results in an immune response within the individual.

The scientists determined the genetic code of an antigen found on the surface of a particular cancer cell. They assembled a molecule of mRNA that would code for this antigen. Many copies of this mRNA molecule were then incorporated into a vaccine. In December 2019, a clinical trial to test for a new type of vaccine took place. Individuals injected with the mRNA vaccine produced an immune response that resulted in antibodies that acted against the antigen found on the surface of the cancer cells.

Scientists realised that they could potentially quickly produce vaccines for many different cancers by changing the nucleotide sequence of the mRNA molecule. However, designing vaccines for cancers is not that simple. Cancer cells can easily evade immune cells and continue to reproduce. Mutations can cause changes to the target antigens on the surface of cancer cells. A vaccine designed for one person may not work for another person as their cancers have different mutations.

Reference: N Pardi, MJ Hogan, FW Porter and D Weissman, 'mRNA vaccines – A new era in vaccinology', *Nature Reviews Drug Discovery*, vol. 17, April 2018, <<https://doi.org/10.1038/nrd.2017.243>>

- a. i. According to the article, what are the contents of conventional vaccines and how do they lead to an improved immune response when a person encounters a pathogen? 2 marks

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- ii. Explain how mRNA vaccines are different from conventional vaccines. 2 marks

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- b. Using the information in the article on page 38, identify the advantages of developing mRNA vaccines for the treatment of cancer. Outline an ethical concept that should be taken into account when developing mRNA vaccines.

4 marks

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**SECTION B – continued**  
**TURN OVER**

**Question 11** (7 marks)

A researcher was testing compounds for their effects on the activity of malate dehydrogenase (MDH), an enzyme in the Krebs cycle. One of the compounds the researcher tested, Compound A, yielded interesting results when the experiment was performed using malate as the substrate.

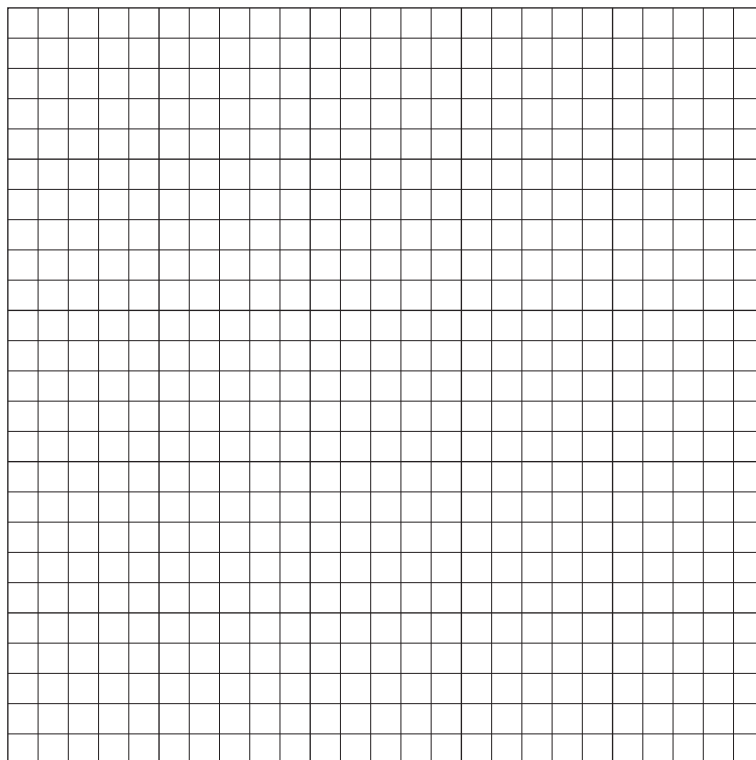
In the experiment, two sets of five test tubes were set up containing different amounts of malate, as shown in the table below. The same amount of enzyme was added to all the test tubes, but Compound A was added to only the experimental set of test tubes. The experiment was performed for one minute at 37 °C. The researcher found the rate at which the product formed, in millimoles per minute, and the results are shown in the table below.

**Effect of Compound A on MDH activity**

Amount of malate added (mmoles)	Rate of product formation (millimoles per minute)	
	Without Compound A	With Compound A
0	0.00	0.00
5	3.30	1.00
10	3.80	2.00
15	3.90	3.00
25	4.00	3.80

- a. On the grid provided below, plot a graph representing the results and provide appropriate labels for the axes.

3 marks





- b. Compound A was found to be a competitive inhibitor.

Briefly explain how competitive inhibitors affect the activity of an enzyme.

2 marks

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- c. The researcher repeated this experiment. However, when the researcher plotted the data, they noticed that while the shapes of the curves were similar, the results were different. On re-examination of the experimental set-up, the researcher noticed that the repeat experiment had been carried out at 20 °C.

State the effect that this temperature change would have had on these results and explain the cause of this difference.

2 marks

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