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Write your **student number** in the boxes above.

Letter

Biology

Question and Answer Book

VCE (NHT) Examination – Tuesday 21 May 2024

- Reading time is **15 minutes**: 10.30 am to 10.45 am
- Writing time is **2 hours 30 minutes**: 10.45 am to 1.15 pm

Materials supplied

- Question and Answer Book of 44 pages
- Multiple-Choice Answer Sheet

Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.

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

Contents	pages
Section A (40 questions, 40 marks) _____	2–23
Section B (11 questions, 80 marks) _____	24–41

Section A – Multiple-choice questions

Instructions

- Answer **all** questions in pencil on the Multiple-Choice Answer Sheet.
 - 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.
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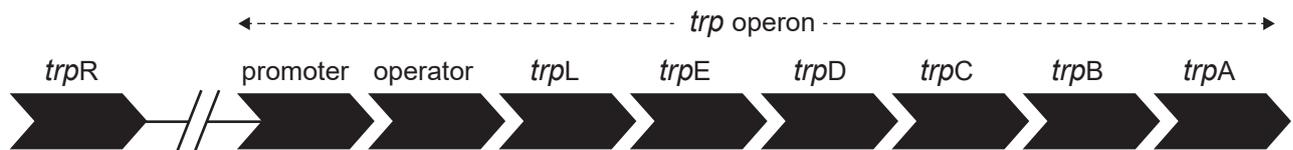
Question 1

Which one of the following molecules consists of one or more polypeptide chains?

- A. DNA polymerase
- B. NADH
- C. RNA
- D. ATP

Use the following information to answer Questions 2 and 3.

The production of tryptophan in a bacterial cell is regulated via the *trp* operon.

**Question 2**

Which of the following correctly matches the region with its function in the production of tryptophan?

	Region	Function
A.	<i>trpR</i>	site for RNA polymerase attachment
B.	promoter	prevents the production of tryptophan
C.	operator	binding site for a repressor protein
D.	<i>trpE</i>	codes for the production of a repressor protein

Question 3

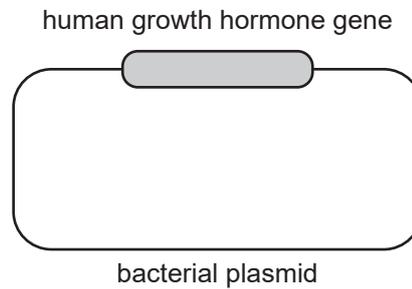
In the production of tryptophan in bacterial cells, the attenuation mechanism is different from the repression mechanism.

One of these differences is that, in attenuation

- A. hairpin loops are not formed in the transcribed mRNA.
- B. only two of the five structural genes are expressed.
- C. RNA polymerase does not bind to the promoter.
- D. transcription of mRNA begins and then stops.

Use the following information to answer Questions 4 and 5.

Human growth hormone can be produced using bacteria. The human growth hormone gene is first synthesised, and then many copies of the gene are mixed with cut bacterial plasmids. Under the right conditions, one copy of the gene will join with one cut plasmid, as shown in the diagram below.

**Question 4**

The gene is joined with the bacterial plasmid, assisted by

- A. Cas9.
- B. ligase.
- C. polymerase.
- D. PAM sequence.

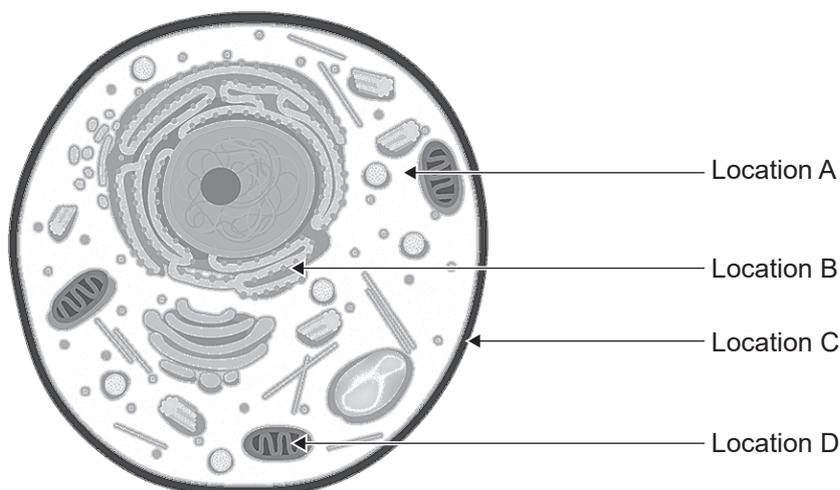
Question 5

When plasmids containing the human growth hormone gene are taken up by the bacteria, the bacteria are

- A. transferred.
- B. synthesised.
- C. fragmented.
- D. transformed.

Question 6

Consider the following diagram of an animal cell.



Source: adapted from Achiichiii/Shutterstock.com

Which of the following correctly matches the location A, B, C or D with the function of that location within the cell?

A.	Location A	contains the enzymes for glycolysis
B.	Location B	contains the enzymes for Krebs cycle
C.	Location C	site of protein synthesis
D.	Location D	site of anaerobic respiration

Question 7

What is the main function of enzymes found in a cell?

- A. They provide amino acids as building blocks for reactions.
- B. They provide energy for reactions to occur.
- C. They combine products to form reactants.
- D. They speed up chemical reactions.

Question 8

Which one of the following groups of molecules transfers energy to the electron transport chain?

- A. ATP and FADH_2
- B. ADP and FADH_2
- C. NADH and ADP
- D. NADH and FADH_2

Question 9

A scientist was growing some cells in culture and noticed a 'baked bread' smell in the incubator coming from the cells. Chemical analysis of the tissue culture medium revealed the presence of ethanol.

What conditions would most likely have caused this?

- A. yeast cells respiring in the presence of oxygen
- B. yeast cells respiring in the absence of oxygen
- C. bacteria respiring in the presence of oxygen
- D. bacteria respiring in the absence of oxygen

Question 10

Farmers in cold climates often use greenhouses to encourage the faster growth of crops.

This increases photosynthesis by increasing the

- A. chlorophyll concentration.
- B. oxygen levels.
- C. temperature.
- D. pH.

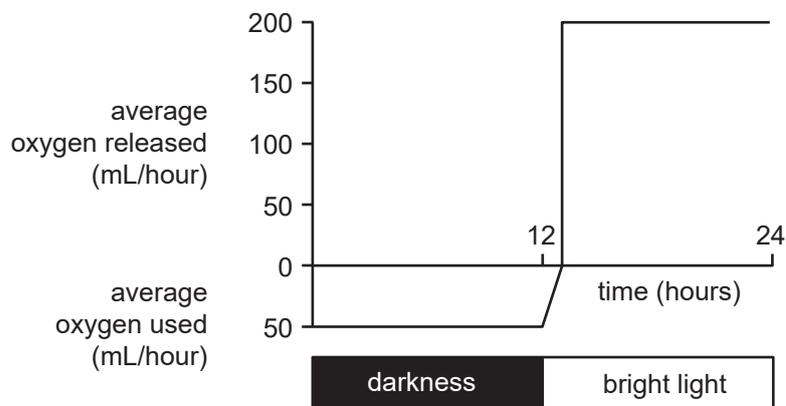
Question 11

What molecules are required for the light-independent stage of photosynthesis to function?

- A. ATP, carbon dioxide and NADPH
- B. ATP, carbon dioxide and NADH
- C. ADP, oxygen and NADPH
- D. ATP, oxygen and NADH

Use the following information to answer Questions 12–14.

The average amount of oxygen used and released over a 24-hour period (12 hours of light and 12 hours of darkness) for a group of plants was measured and the results shown in the graph below.

**Question 12**

According to the graph above, what is the total amount of oxygen produced per hour at 16 hours?

- A. -50 mL/hour
- B. 150 mL/hour
- C. 200 mL/hour
- D. 250 mL/hour

Question 13

What would most likely occur if the light intensity was reduced from bright light to dim light for the next 24-hour period?

- A. The rate of oxygen released from the plants would decrease.
- B. The rate of water taken up by the plants would increase.
- C. Glucose production inside the plants would increase.
- D. Photosynthesis would completely stop.

Question 14

To show that the results were repeatable, the experiment should be continued

- A. in darkness for the next 24 hours.
- B. on the same day in the following week.
- C. using a different plant species.
- D. for another 12-hour period in darkness, followed by 12 hours in bright light.

Question 15

Research has been conducted into the fermentation of different sources for the production of ethanol. This ethanol will be used to produce biofuel.

The table below shows ethanol yield, measured in litres per hectare (L/hectare) of land used to grow each biofuel source.

Source	Ethanol yield (L/hectare)
corn stalks	1050–1400
wheat	2590
cassava	3310
sweet sorghum	3050–4070
corn kernels	3460–4020
sugar beet	5010–6680
switch grass	10 760
algae grown in lakes	46 760–140 290

Source: <https://www.intechopen.com/chapters/47886>

Which of the following is a correct statement about the data in the table above?

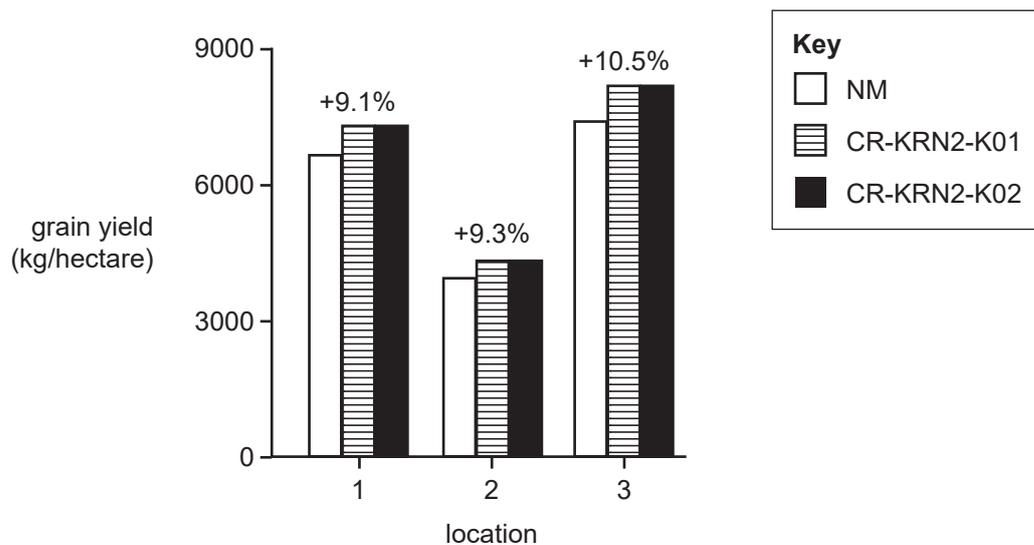
- A. Wheat would require a higher yeast concentration to produce the same ethanol yield as cassava.
- B. Of all the sources listed, algae would require the smallest area of land to produce 10 000 litres (L) of ethanol.
- C. A fermentation temperature of 100 °C would increase the ethanol yields of each source.
- D. Increasing the oxygen levels during fermentation of sugar beet would increase the ethanol yield.

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Use the following information to answer Questions 16–18.

The gene kernel row number 2 (*KRN2*) has been shown to play a role in the production of kernels in corn plants. Scientists investigated the gene by carrying out the following steps:

1. CRISPR-Cas9 was used to knock out *KRN2* in two types of corn plants (CR-KRN2-K01 and CR-KRN2-K02).
2. Large numbers of identical offspring of each corn type were produced.
3. CR-KRN2-K01, CR-KRN2-K02 and non-modified (NM) corn plants were planted in separate fields at each of three locations.
4. After several weeks, the corn was harvested from each field and the grain yield (kg/hectare) was recorded. A graph of the results is shown below. The percentages above the bars indicate the difference in grain yield between the NM corn plants and the modified corn plants.



Source: adapted from Wenkang Chen et al, *Science*, Vol. 375, issue 6587, 25 March 2022, p. 5

Question 16

The dependent variable for this investigation would be the

- A. number of repeats.
- B. growing time.
- C. grain yield.
- D. location.

Question 17

Scientists in a different country repeated the experiment and obtained very similar results.

This demonstrates that the data is

- A. reproducible.
- B. quantitative.
- C. qualitative.
- D. precise.

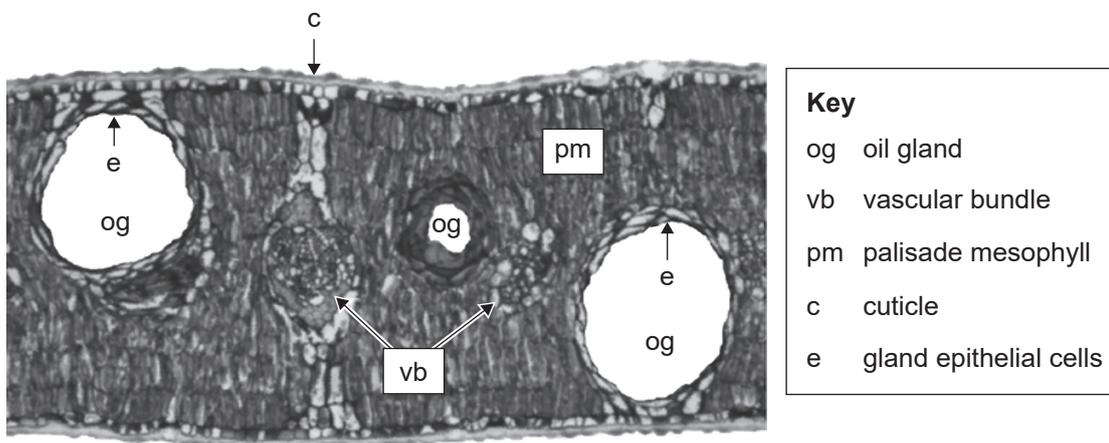
Question 18

Which one of the following is an appropriate conclusion that could be drawn from the data in the graph on page 10?

- A. The use of CRISPR-Cas9 increased the crop yield of the plants in each location.
- B. All the data from Location 2 should be disregarded because it contains outliers.
- C. CR-KRN2-K02 in Location 3 produced a grain yield of less than 6000 kg per hectare.
- D. The modified corn plants in Location 1 produced larger percentage increases in grain yield compared with the modified corn plants in Location 2.

Question 19

Australian native *Eucalyptus polybractea* trees have leaves containing oil glands that release eucalyptol. Eucalyptol has antimicrobial properties. Below is a cross-section of an *E. polybractea* leaf, showing the positions of the oil glands.



Source: King, DJ, Gleadow, RM, & Woodrow, IE, 'Regulation of oil accumulation in single glands of *Eucalyptus polybractea*', *New Phytologist*, 172(3), 2006, pp. 440–451

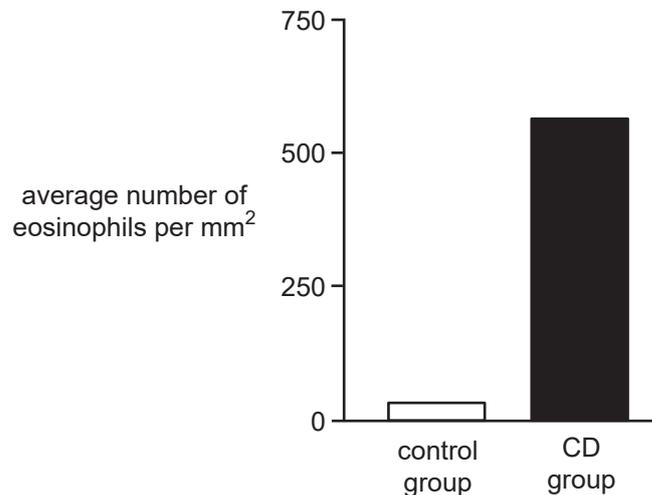
Eucalyptol forms part of the tree's

- A. adaptive immune system.
- B. chemical barriers.
- C. waxy cuticle.
- D. microbiota.

Use the following information to answer Questions 20–22.

Crohn's disease (CD) is a type of inflammatory bowel disease. A study compared sections of intestinal wall from people diagnosed with CD with sections of intestinal wall of people in the control group, not diagnosed with CD. There were eight participants in each group, with ages ranging from 17 to 76 years.

The average number of eosinophils per square millimetre (mm^2) in each intestinal wall section from the control group was compared with the intestinal wall sections from the CD group.



Source: Smyth, CM et al., 'Activated eosinophils in association with enteric nerves in inflammatory bowel disease', *PLOS ONE*, 8(5), 2013, e64216

Question 20

Eosinophils, along with many other immune cells, are involved in the inflammatory response to CD.

Eosinophils are part of the

- A. adaptive immune response.
- B. cellular immune response.
- C. innate immune response.
- D. T cell immune response.

Question 21

Based on the information presented above, it is reasonable to suggest that the average number of eosinophils is

- A. higher in Crohn's participants, as they are older than the control group.
- B. lower in the control group, as they have natural immunity.
- C. due to autoimmune diseases in the control group.
- D. contributing to the symptoms of people with CD.

Question 22

The scientific investigation methodology of this study is

- A. a case study.
- B. a correlational study.
- C. a controlled experiment.
- D. classification and identification.

Question 23

Lysozymes are proteins important in innate immunity.

Lysozymes are found in

- A. interferon.
- B. antibodies.
- C. macrophages.
- D. proteins.

Question 24

Beak and feather disease is widespread and occurs naturally in Australia. It affects parrots and cockatoos. The pathogen that causes beak and feather disease contains single-stranded circular DNA. It multiplies in the liver cells of affected birds and can be transmitted orally, in faeces or on feathers.

The pathogen that causes this disease may be classified as a

- A. virus.
- B. prion.
- C. fungus.
- D. bacterium.

Question 25

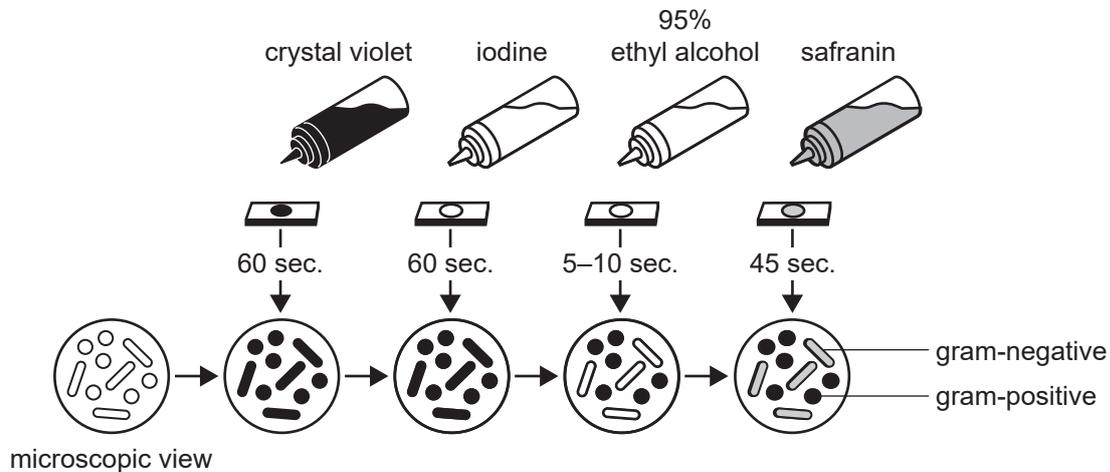
During an allergic reaction, activated mast cells release histamine.

Histamine causes symptoms of allergies, including

- A. vasoconstriction.
- B. increased allergens.
- C. increased microbiota.
- D. increased inflammation.

Use the following information to answer Questions 26–28.

Not all bacteria have a cell wall, but those that do can be classified as either gram-positive or gram-negative after undergoing the gram staining technique. The steps of this technique are summarised below.



Source: <https://theory.labster.com/reagents>

1. Crystal violet is added to the bacteria to stain them.
2. Iodine is used to stabilise the stain.
3. Ethyl alcohol is used to decolourise the gram-negative bacteria.
4. Safranin stains gram-negative bacteria pink. Gram-positive bacteria remain purple.

Pertussis is a highly infectious disease, caused by the gram-negative bacteria *Bordetella pertussis*, which is transmitted through respiratory droplets when people cough and sneeze. Individuals with suspected pertussis infection can have their throats swabbed. The swab will contain all the types of bacteria present from that region of their throat. Gram staining can then be performed on these bacteria.

Question 26

An individual who is infected with *B. pertussis* has their throat swabbed and the swab is then processed and gram stained.

Which one of the following statements is correct?

- A. Without the addition of ethyl alcohol or safranin, all bacteria with a cell wall would appear gram-positive.
- B. All purple bacteria at the end of the gram staining process would be *B. pertussis*.
- C. *B. pertussis* would be stained pink, since it lacks a cell wall.
- D. Gram staining would amplify the bacterial DNA.

Question 27

Compared to people not infected with *B. pertussis* bacteria, individuals infected with the bacteria would have

- A. specific helper T cells that activate the innate immune response.
- B. dendritic cells, which present *B. pertussis* antigen in the lymph nodes.
- C. antibodies against *B. pertussis*, each containing four heavy chains and two light chains.
- D. high concentrations of cytotoxic T cells, which present *B. pertussis* antigen to helper T cells.

Question 28

Which one of the following would be a suitable method to limit the spread of the *B. pertussis* bacteria within Australia?

- A. Provide free genetic testing kits to determine which members of society have a particular genetic mutation.
- B. Start a government education program to encourage people with symptoms to take antiviral medication.
- C. Spray lakes and waterholes with mosquito-killing insecticides.
- D. Achieve herd immunity through an available vaccination.

Use the following information to answer Questions 29–31.

In Australia, the spread of cane toads (*Rhinella marina*) has brought about a rapid decline in the number of northern quolls (*Dasyurus hallucatus*), a native ground-dwelling marsupial predator. Northern quolls die when they prey on the cane toads. Northern quolls are themselves preyed on by feral cats and dingoes.



Source: John Carnemolla/Shutterstock.com

Question 29

Since the introduction of cane toads, many northern quoll populations are now smaller in size and more isolated.

Smaller and more isolated quoll populations may result in

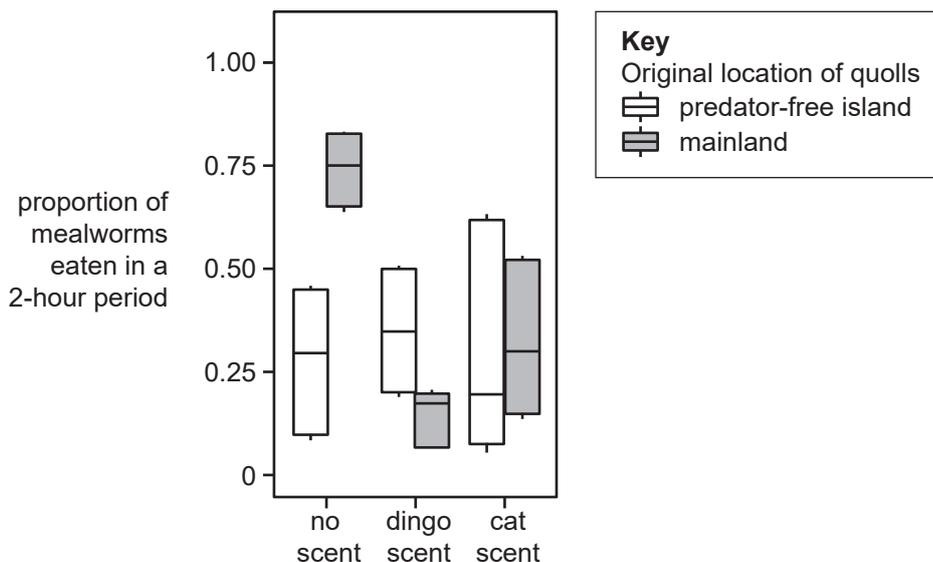
- A. increased numbers of feral cats and dingoes.
- B. increased genetic diversity in dingo populations.
- C. decreased genetic diversity in the cane toad populations.
- D. reduced movement of alleles between northern quoll populations.

Question 30

Between 2003 and 2017, populations of northern quolls were established on two predator-free islands, that also have no cane toads, off the coast of the Northern Territory. In the years that followed, northern quoll populations increased on the islands from a total of 64 to 5600 individuals.

In 2016, a reintroduction of northern quolls from one of the islands to the mainland was trialled. The quolls did not survive long term. Scientists investigated reasons for the failure of the quolls to survive. Each quoll was independently offered mealworms in three separate boxes. The first box contained no scent, the second box contained dingo scent, and the final box contained cat scent. The proportion of mealworms eaten in all boxes by each quoll in a two-hour period was calculated.

The results are shown in the graph below. The dark line within each box is the middle score. The spread of the middle half of the results is shown as a box.



Source: Jolly, CJ, Webb, JK, Phillips, BL, *Biol. Lett.* 14:20180222, 2018

From the results of the experiment, the scientists had evidence to support which one of the following statements?

- The eating behaviour of quolls from the mainland is less affected by the presence of a predator scent than the eating behaviour of quolls from the predator-free islands.
- Quolls from the predator-free islands may not survive when reintroduced onto the mainland, as they are less likely to identify the presence of predators.
- Quolls from the predator-free islands behave identically to the quolls on the mainland in the presence of different predator scents.
- Quolls from the mainland ate fewer mealworms in the presence of cat scent than in the presence of dingo scent.

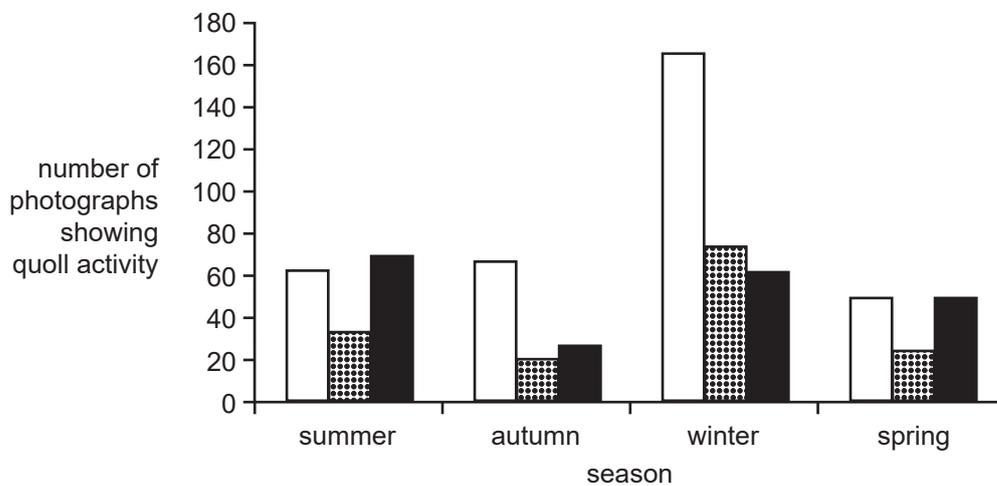
Question 31

Which one of the following actions are the scientists likely to have included in this controlled experiment?

- A. Allow cats and dingoes to interact with the quolls.
- B. Use different sized boxes depending upon the scent being placed in the box.
- C. Ensure that the quolls were not distressed or harmed when placed near the boxes.
- D. Feed the quolls on mealworms just before introducing the quolls to the three boxes.

Use the following information to answer Questions 32 and 33.

In another unrelated quoll study, scientists recorded the seasonal activity of a population of a different species of quolls (*Dasyurus maculatus*) in the Illawarra highlands in NSW. The activity of the quolls was recorded by taking photographs. The number of photographs taken was recorded at three different times each day throughout the study. Data from the study was arranged by season.

**Key**

- night: from 7.30 pm to 5.30 am the next day
- morning/dusk: from 5.30 am to 7.30 am and from 5.30 pm to 7.30 pm
- day: from 7.30 am to 5.30 pm

Source: Nicholson, J, 'Spot the difference: Using camera-traps to analyse the Spotted-tailed Quoll population in the Illawarra Highlands, NSW Australia', BEnviSci Hons, School of Earth & Environmental Sciences, University of Wollongong, 2018. <<https://ro.uow.edu.au/thsci/164>>

Question 32

From the results of this experiment, which one of the following could the scientists conclude?

- A. The activity of the quolls is identical in both summer and autumn.
- B. The activity of the quolls is independent of the time of the day.
- C. In spring, the quolls are least active during the day.
- D. The quolls are more active during winter.

Question 33

The scientists carried out fieldwork in their study of the quoll population in the Illawarra highlands.

This study allowed the scientists to

- A. carry out the quoll data collection in a semi-controlled environment within a laboratory.
- B. use a method that was easier for other scientists to replicate in exactly the same way.
- C. collect data that will more likely reflect quoll behaviour in their natural environment.
- D. analyse secondary data on quoll behaviour collected by other scientists.

Question 34

The *Aedes aegypti* mosquito species transmits three human viral diseases. People are simultaneously at risk for all three diseases if living in a place that contains all three viruses as well as the mosquito.

It has been suggested that scientists develop a selective breeding program for a desired trait that reduces, in wild populations, the number of mosquitoes capable of carrying the three viruses.

For this selective breeding program to be successful, there must be

- A. no change in the gene pool of the wild populations of *A. aegypti* mosquitoes after the program is completed.
- B. initial genetic variation in wild populations of the *A. aegypti* mosquitoes in their ability to carry the viral pathogens.
- C. *A. aegypti* mosquitoes released into the wild that are unable to pass the desired trait to the next generation of mosquitoes.
- D. *A. aegypti* mosquitoes bred in the laboratory with the desired trait that are likely to die when released into the wild populations.

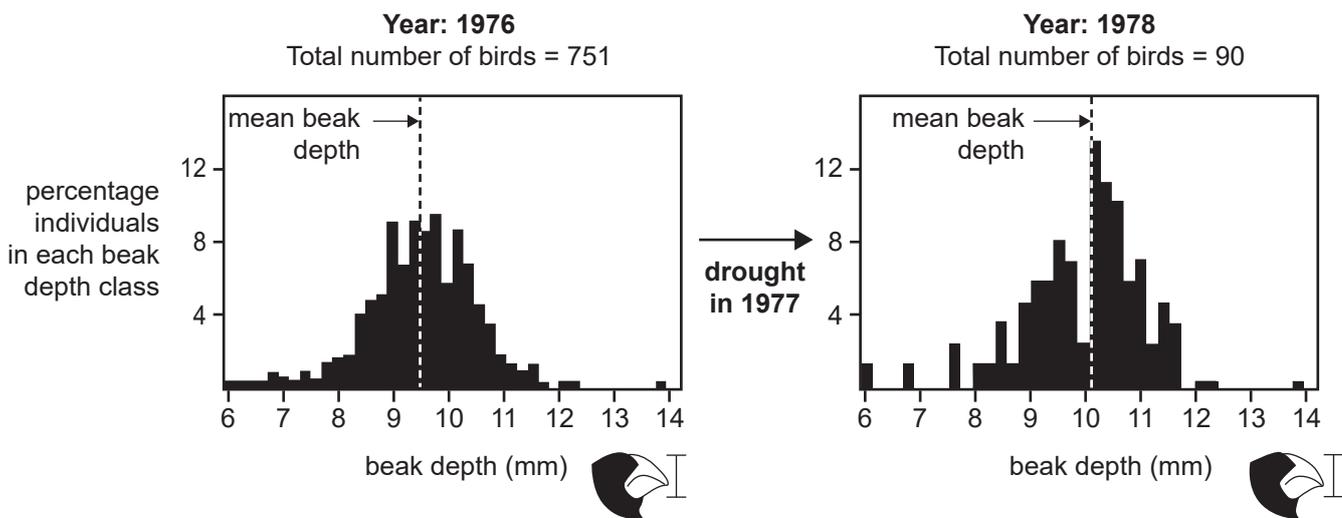
Use the following information to answer Questions 35 and 36.

The medium ground finch (*Geospiza fortis*) can be found on the Galapagos Island of Daphne Major. The medium ground finch has a small beak and eats mostly seeds. There are very few predators or competitors to medium ground finches on Daphne Major.

In 1977, the island experienced a severe drought, which finished in 1978. Small, soft seeds that were eaten by medium ground finches became very scarce. Numerous larger, harder seeds could still be found.

The graphs below show the beak depths of medium ground finches on Daphne Major, before (left) and after (right) the drought.

Beak size of medium ground finches on Daphne Major



Question 35

Based on the data presented above, what is the correct interpretation of the changes seen in the finch population?

- A. The total number of medium ground finches increased between 1976 and 1978.
- B. The mean beak depth of the population increased after the drought.
- C. The most common beak depth before the drought was 8 mm.
- D. The total number of birds after the drought was 751.

Question 36

Based only on the information above, the most likely reason for the observed changes after the drought was that

- A. finches with larger beaks could access a wider range of available seeds.
- B. female small-beaked finches were more likely to breed.
- C. there was more competition from other finch species.
- D. a disease affected small-beaked finches.

Question 37

Cytochrome c is a small protein found in mitochondria. It is useful in the study of evolutionary relationships.

There are amino acid differences in cytochrome c between humans and other animals. The table below shows how many of these differences exist between humans and seven other animals.

Animal	Number of cytochrome c amino acid differences compared with humans
horse	5
chicken	7
tuna	10
frog	11
shark	12
monkey	1
rabbit	4

Using the information shown in the table, identify which one of the following shows the correct evolutionary relationship between humans and the listed animals.

	Most distant common ancestor to human		→	Closest common ancestor to human	
A.	tuna	horse		chicken	monkey
B.	shark	frog		horse	tuna
C.	monkey	rabbit		horse	chicken
D.	shark	chicken		rabbit	monkey

Question 38

The table below shows four dating techniques.

Dating technique	Useful age range (years)	Materials dated
potassium–argon	200 000 to >4 billion	volcanic rocks and minerals
carbon 14	60 000 or less	organic remains
stratigraphy	0 to >4 billion	fossils and other objects found in sedimentary rock
index fossils	0.5 to 600 million	fossils

Each dating technique can be classified as either an absolute or a relative dating method.

Which one of the following correctly classifies the selected techniques from the table above?

	Absolute technique	Relative technique
A.	index fossils	stratigraphy
B.	potassium–argon	carbon 14
C.	carbon 14	index fossils
D.	stratigraphy	potassium–argon

Use the following information to answer Questions 39 and 40.

Achondroplasia is the most common cause of dwarfism. It is caused by overactivity of the FGFR3 receptor. A new drug, vosoritide, blocks the activity of the FGFR3 receptor, and allows for normal bone growth. Trials have confirmed that vosoritide is safe to give to young people with achondroplasia. To have the greatest effect, vosoritide is given as a daily injection from birth. The Australian Government has subsidised the cost of the drug so that it is more easily available for those who choose to use it.

Question 39

The aim of achieving maximum positive outcomes with minimum negative effects when administering vosoritide is considered when using which of the following ethical approaches?

- A. consequences-based approach
- B. virtues-based approach
- C. duty-based approach
- D. rule-based approach

Question 40

When completing their research, the scientists who developed vosoritide honestly reported all sources of information and communicated both favourable and unfavourable results.

Which of the following best describes the ethical concept that the scientists applied?

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

Section B

Instructions

- Answer **all** questions in the spaces provided.
 - Write your responses in English.
 - Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
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Question 1 (8 marks)

- a. DNA contains the genetic code for the production of proteins within a cell.

Outline the features of the code that make it both a universal code and a degenerate code.

2 marks

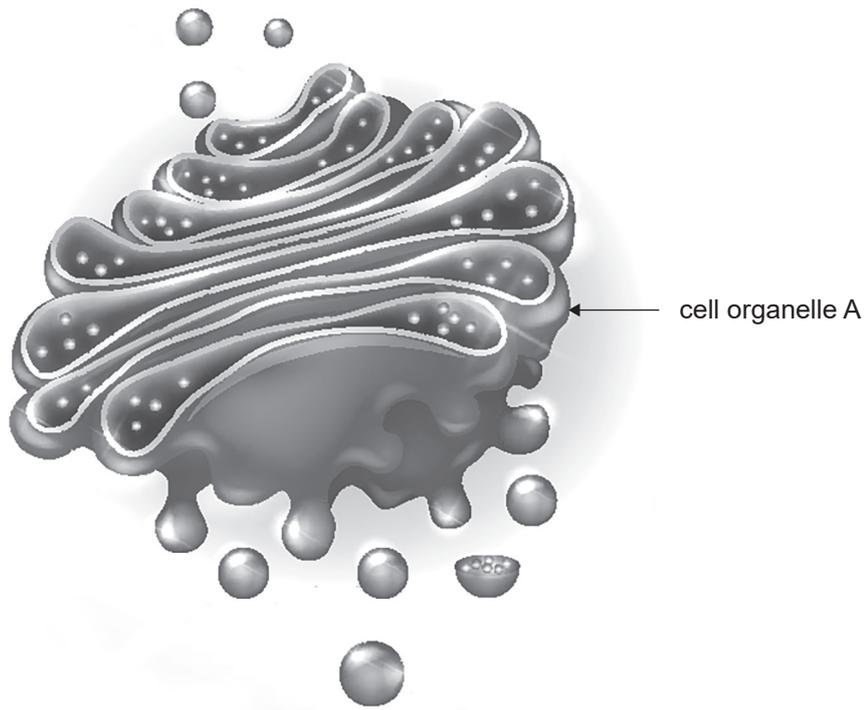
- b. The production of a protein within a cell requires several steps. One of these steps is translation.

Name two nucleic acid molecules that play an important role in translation, and outline the role played by each molecule.

4 marks

- c. Identify cell organelle A, below, and outline the role it would play in the transport of a protein for export from the cell.

2 marks



Source: adapted from TimeLineArtist/Shutterstock.com

T H N

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Question 2 (8 marks)

Malnutrition, including iron deficiency, is a global human health problem. In response to this issue, scientists developed transgenic wheat seeds with increased iron content. More recently, CRISPR-Cas9 has been used to edit the genome of wheat seeds and remove a specific gene, resulting in increased iron content of wheat seeds.

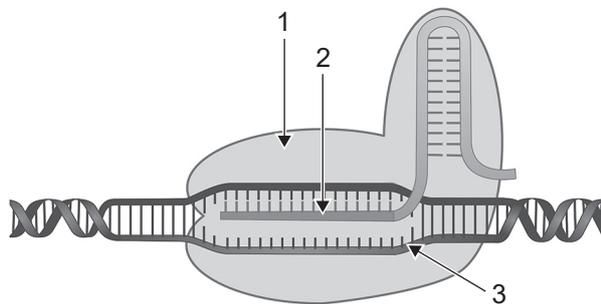
- a. Explain why wheat seeds that have been edited using CRISPR-Cas9 may be advantageous over transgenic wheat seeds. 2 marks

Use the following information to answer part b and part c.

Wheat seeds are deficient in iron due to the presence of phytic acid (PA). PA is synthesised from pre-phytic acid by an enzyme coded for by the *IPK1* gene.

The CRISPR-Cas9 complex can be used to knock out the *IPK1* gene and produce genome edited (GE) wheat seeds.

- b. Refer to the diagram of the CRISPR-Cas9 complex below.

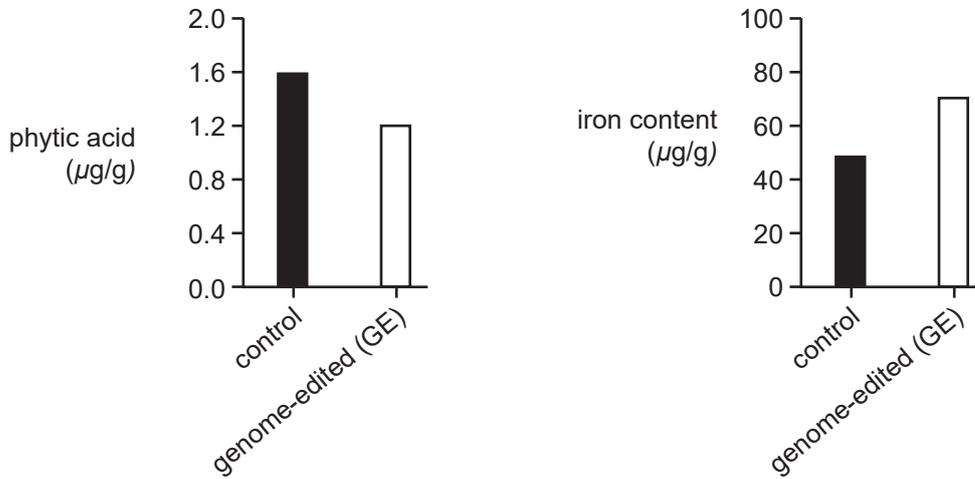


Source: adapted from Soleil Nordic/Shutterstock.com

- i. Which arrow, 1, 2 or 3, correctly points to the position of the sgRNA? 1 mark

- ii. Describe the function of sgRNA. 2 marks

c. A controlled experiment was undertaken to determine the effectiveness of using the CRISPR-Cas9 complex to knock out the *IPK1* gene of wheat seeds. In the experiment, wheat seeds were grown to maturity and measured for total PA content (microgram/gram) and iron content (microgram/gram). The results are displayed in the graphs below.



Source: Ibrahim, S, Saleem, B, Rehman, N, Zafar, SA, Naeem, MK, & Khan, MR, *Journal of Advanced Research*, vol. 37, 2022, pp. 33–41

i. Using the data from the graph above, compare the levels of phytic acid and iron content in the control and GE wheat seeds.

2 marks

ii. Apart from experimental errors, give one reason why GE wheat seeds continued to synthesise phytic acid.

1 mark

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Question 3 (9 marks)

Rosiglitazone inhibits the uptake of pyruvate into the mitochondria of the cell. A scientist investigated the effect of rosiglitazone on glucose metabolism in actively growing human liver cells over a 24-hour period. The cells were grown under similar conditions in two Petri dishes. One of the Petri dishes was given 5 micromoles of rosiglitazone while the other one was not. The results of the investigation are shown in the table below.

Effect of rosiglitazone on glucose metabolism in cultured human liver cells

Rosiglitazone (micromoles)	Glucose consumed (micromoles/10 ⁶ cells)	Lactate produced (micromoles/10 ⁶ cells)
0	12.36	5.68
5	27.40	52.05

- a. Explain why both the consumption of glucose and production of lactate change when the cells are given 5 micromoles of rosiglitazone.

2 marks

- b. Consider the cells that were not given 5 micromoles of rosiglitazone.

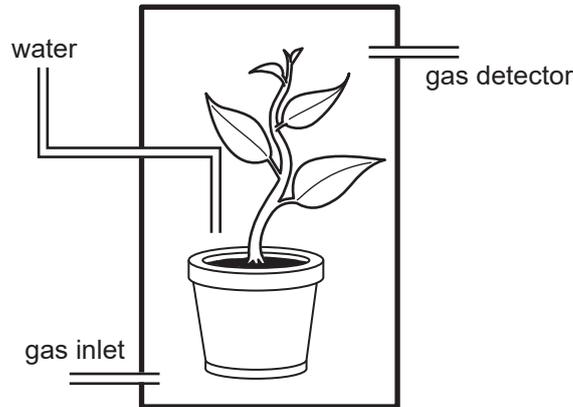
From which metabolic pathways would cells be obtaining most of their energy and where are these metabolic pathways found in the cell?

2 marks

Question 4 (7 marks)

A student investigated how different coloured light affects plant growth. The student placed a number of identical plant seedlings into individual glass containers and monitored gas and water levels. The seedlings were kept in the dark for two days before the start of the experiment.

The diagram below shows the setup for one of these seedlings.



Source: <https://www.drawingtutorials101.com/how-to-draw-plant-in-pot>

- a. The student placed an equal number of seedlings into four groups, which were all given the same amount of both water and fertiliser. The plants in the first group were exposed to white light, the plants in the second group were exposed to red light, the plants in the third group were exposed to blue light and the plants in the fourth group were exposed to green light. After seven days the height of the plants was measured.

The average height increase was calculated for each group and is shown in the table below.

Experimental group	Light source	Average height increase
1	white light	3.6 cm
2	red light	3.4 cm
3	blue light	3.5 cm
4	green light	0.8 cm

Explain why the group exposed to green light failed to grow as well as plants exposed to the other types of light.

2 marks

- b. It is hoped that one day scientists will be able to insert a gene to enhance the growth of seedlings exposed to light of any colour.

What might this gene code for, and how could it increase the formation of glucose in plants exposed to any type of light?

2 marks

- c. The student set up another experiment. This time they used seedlings from C3, C4 and CAM plants. These seedlings were all exposed to white light, but the concentration of carbon dioxide was varied, as shown in the table below.

There was the same number of plants in each group.

Group	Plant type	Percentage CO ₂	Percentage O ₂	Percentage of other gases
1	C3	5	5	90
2	C4	5	5	90
3	CAM	5	5	90
4	C3	0.5	5	94.5
5	C4	0.5	5	94.5
6	CAM	0.5	5	94.5

After seven days, the student measured the height of the seedlings. They noticed that one of the groups exposed to low carbon dioxide grew the least. Identify which group of plants would not have grown well when exposed to low carbon dioxide levels, and explain why this would have occurred.

3 marks

Question 5 (7 marks)

Multiple sclerosis (MS) is a disease in which the immune system damages nerve cells in the brain and spinal cord. Alemtuzumab is a monoclonal antibody that has been shown to be effective in delaying the progression of the disease in some people. It is thought that alemtuzumab binds to a protein known as CD52, which is present on the membranes of B cells. This leads to B cell destruction by activating complement proteins.

- a. Describe how complement proteins could destroy B cells. 3 marks

- b. Explain how the destruction of B cells could lead to a reduction in symptoms of MS. 2 marks

- c. Alemtuzumab can also be used to help treat the cancer, T cell prolymphocytic leukaemia (T-PLL). In sufferers of T-PLL, the body makes too many T cells. Alemtuzumab can bind to both T cells in sufferers of T-PLL and B cells in people with MS.

With reference to the structure of alemtuzumab, explain how alemtuzumab can bind to both T cells and B cells. 2 marks

Do not write in this area.

Question 6 (7 marks)

Rabies is a serious viral disease that is usually spread through the infected saliva of dogs, bats and foxes, but all mammals are capable of contracting and spreading the virus.

Treatments for rabies in humans include:

Treatment 1: A vaccine that contains the inactivated rabies virus.

Treatment 2: Injection of specific antibodies directed against human rabies.

- a. A person who has been bitten by a dog with rabies is given both treatments 1 and 2.

What are the benefits of administering both treatments?

4 marks

- b. Suggest why it is advised that people who have received the vaccine and who often travel to rabies-infected areas have a booster after three years.

3 marks

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Question 7 (7 marks)

For almost a century, Europe has been free of diseases carried by mosquitoes. Recently, mosquito species that can cause disease are becoming increasingly common in Europe.

Of particular concern is the Asian tiger mosquito (*Aedes albopictus*), which can transmit deadly viruses such as dengue, chikungunya and Zika.

With global warming leading to warmer temperatures and higher rainfall in Europe, it is predicted that these mosquitoes will continue to move further north every year.

- a. Suppose that a group of people in Europe were infected with chikungunya virus.

Describe two approaches that could help to reduce or control the spread of the chikungunya virus from infected people to other people in the same country.

2 marks

- b. There is currently a vaccine available for people who live in areas where dengue disease is endemic.

How do endemic diseases differ from epidemic diseases?

2 marks

- c. Until recently, there was no vaccine for Zika virus. This virus can have severe effects on the unborn babies of infected mothers. It has been found that monoclonal antibodies (mAbs) help reduce the viral infection in pregnant women and lessen the effects on their unborn children. These mAbs bind with proteins found on the outside of the virus.

Describe the process of producing mAbs against Zika virus.

3 marks

Do not write in this area.

Question 8 (6 marks)

Influenza viruses can cause acute respiratory illnesses.

The surface antigens of the influenza viruses can change through either antigenic drift or antigenic shift.

- a. Compare antigenic drift and antigenic shift.

3 marks

- b. A person who has had influenza may lose immunity to influenza as a result of changes in the surface antigens of the virus.

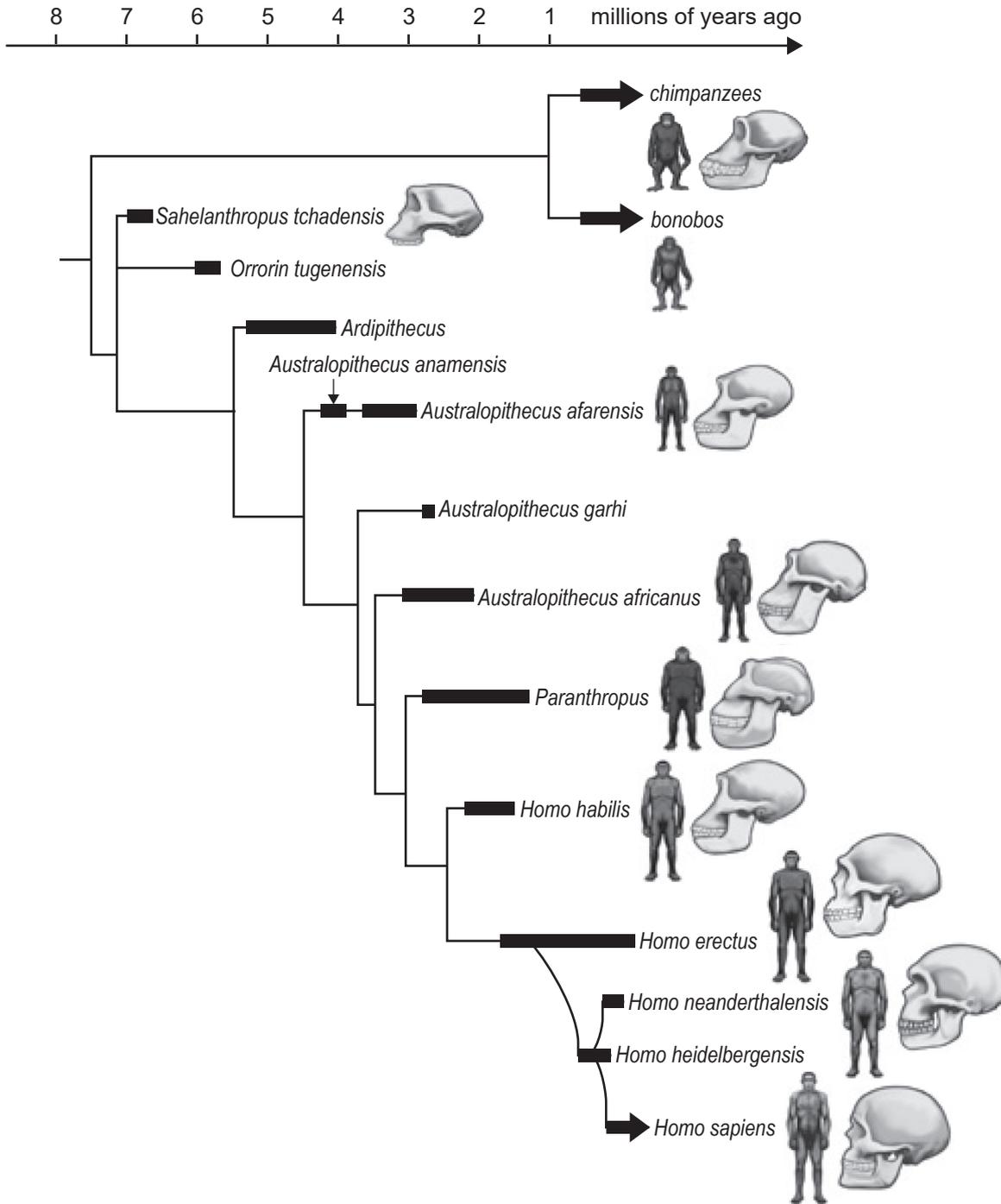
Explain how changes to the surface antigens can result in the loss of immunity to a virus.

3 marks

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Question 9 (6 marks)

The diagram below represents an interpretation of human evolution based on the current fossil record.



Source: adapted from work by Carl Zimmer, <<https://evolution.berkeley.edu/what-are-evograms/the-emergence-of-humans/>>

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- a.** Using information from the diagram on page 36, describe the relationship between *Australopithecus anamensis* and *Australopithecus afarensis*. 1 mark

- b.** The interpretation of human evolution shown in the diagram is mostly made through evidence of fossilised remains and includes a relatively small number of *Homo* species.
- Explain why fossilised remains may not give scientists a more detailed understanding of the relatedness of *Homo* species. 3 marks

- c.** Using evidence from the diagram, identify two major trends in evolution from the genus *Australopithecus* to the genus *Homo*. 2 marks

Question 10 (8 marks)

There is evidence that Denisovans and Neanderthals interbred. DNA evidence also shows that *Homo sapiens* interbred with Neanderthals in Europe, and with Denisovans in Asia and New Guinea. Scientists who have mapped the genomes of people of the islands of South-East Asia have found that 3%–5% of their DNA can be traced to Denisovan ancestors.

Based on differences in their genomic DNA, three separate populations of Denisovans have been identified. The first Denisovan population (D0) was first discovered in fossils found in Siberia. The second Denisovan population (D1) is thought to have split from the D0 population around 283 000 years ago. The third Denisovan population (D2) split from the D0 population around 363 000 years ago.

The D1 genome is distinctly different from the D0 genome. The D1 population genome sequences are especially common in the indigenous people (Papuan) of the island of New Guinea.

Both Papuans and Aboriginal and Torres Strait Islander Peoples have relatively high levels of Denisovan DNA in their genomes compared to other *H. sapiens* populations. Current evidence suggests that Aboriginal and Torres Strait Islander Peoples have been living in Australia for around 65 000 years. There is no current evidence of Denisovans having lived in Australia. Up until 10 000 years ago, Australia was joined by a land bridge to New Guinea and known as Sahul.

A group of scientists hypothesised that the Denisovan population had been living in New Guinea and, isolated from other Denisovans, had reproduced with *H. sapiens* sometime between 15 000 and 30 000 years ago. A second group of scientists challenged this hypothesis. This group of scientists suggests that Denisovans reproduced with *H. sapiens* much earlier than 30 000 years ago.

Source: adapted from <<https://www.science.org/>>; <<https://australian.museum/>>

- a. Using supporting evidence from the article above, explain how modern *H. sapiens* genomes can be used to show the past relationships between Neanderthal and Denisovan populations.

2 marks

- b.** The article states that the D1 population genome appears to be quite different from the genomes of both the D0 and D2 populations.

Considering mechanisms for speciation, describe two possible explanations for this.

2 marks

- c.** Outline the reasoning for the second group of scientists' hypothesis that people in New Guinea must have interbred with Denisovans much earlier than 30 000 years ago.

2 marks

- d.** Explain why it is likely that the scientific understanding of the history of the migration of Aboriginal and Torres Strait Islander Peoples will change.

2 marks

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Question 11 (7 marks)

Tasmanian devils (*Sarcophilus harrisii*) are marsupial carnivores endemic to Tasmania. The species is affected by two cancers, known as devil facial tumour 1 (D1) and devil facial tumour 2 (D2). The facial tumours are transmitted between animals by the direct transfer of living cancer cells, probably by biting.

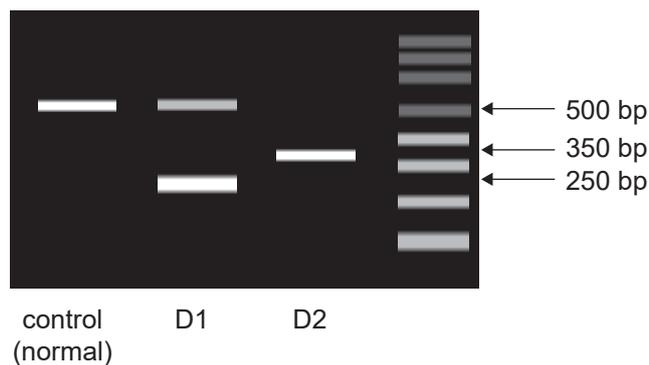
D1 and D2 have similar physical characteristics and are identified in Tasmanian devils using polymerase chain reaction (PCR) followed by gel electrophoresis.

- a. In order to identify D1 and D2, a PCR was performed under the following conditions: heating to 94 °C, followed by reducing temperature to 60 °C and then increasing temperature to 72 °C. This was repeated for 30 cycles.

Explain why 30 cycles are required.

2 marks

- b. The PCR products then undergo gel electrophoresis. The following results show the fragments that are separated for the control (normal), D1 and D2 samples.



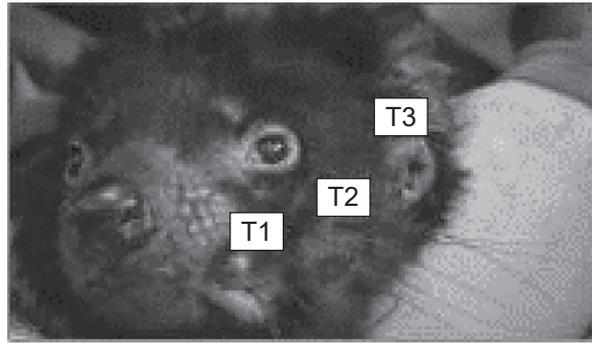
Name the molecule found within the bands on the gel electrophoresis shown above.

1 mark

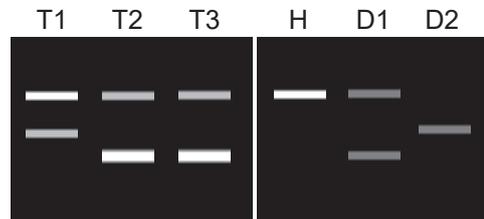


Source: Julie Gaia/Shutterstock.com

c. A Tasmanian devil was found to have three tumours: T1, T2 and T3.



The tumours were identified using PCR and gel electrophoresis. The three tumours were compared to normal, non-tumour (host, H), known D1 and known D2. The results are shown below.



i. Identify two variables the scientists would control when completing gel electrophoresis.

2 marks

ii. Analysing the results of the gel electrophoresis, identify T1, T2 and T3 as either D1 or D2 and complete the following table.

1 mark

Tumour	Tumour identification (D1 or D2)
T1	
T2	
T3	

iii. How was the validity of results maintained?

1 mark

Source of all other images for Question 11: Kwon, YM et al., 'Tasman-PCR: a genetic diagnostic assay for Tasmanian devil facial tumour diseases', *Royal Society open science*, 5(10), 180870, 2018

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