

STUDENT NUMBER

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# BIOLOGY

## Written examination

Monday 30 May 2022

Reading time: 10.00 am to 10.15 am (15 minutes)

Writing time: 10.15 am to 12.45 pm (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 40 pages
- Answer sheet for multiple-choice questions

#### 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.

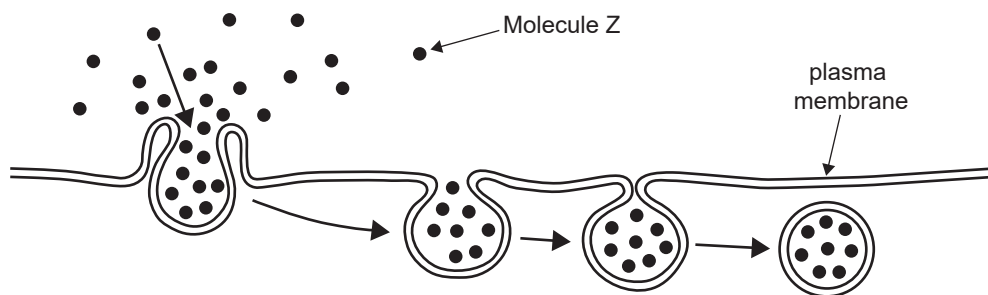
Marks will **not** be deducted for incorrect answers.

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**

Consider the movement of Molecule Z into a cell, as shown below.



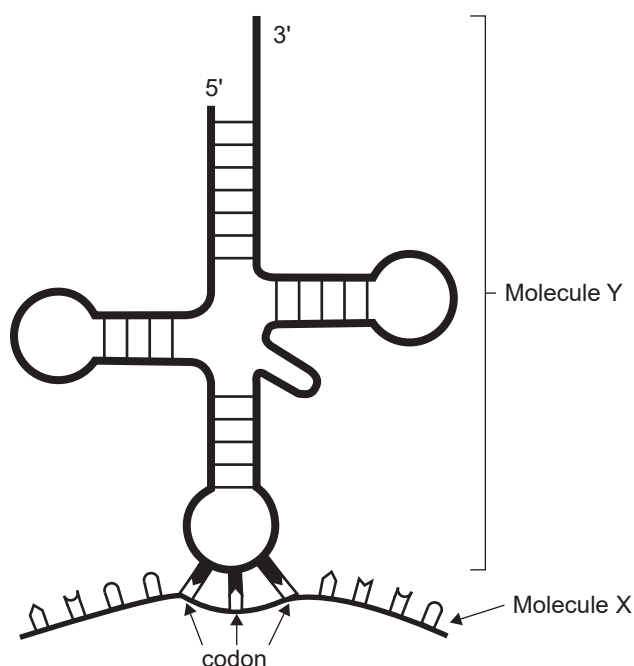
Source: adapted from Aldona Griskeviciene/Shutterstock.com

Based on the information above, it can be concluded that Molecule Z

- A. is hydrophobic.
- B. is a lipid-based hormone.
- C. is a small non-polar molecule.
- D. enters the cell by endocytosis.

Use the following information to answer Questions 2 and 3.

The diagram below shows the positions of two cellular molecules: Molecule X and Molecule Y.



Source: adapted from Designua/Shutterstock.com

### Question 2

Based on the diagram above, on which organelle in a cell would these two molecules be found in the position shown?

- A. nucleus
- B. ribosome
- C. Golgi apparatus
- D. secretory vesicle

### Question 3

Which one of the following statements is correct for Molecule X?

- A. It is composed of monomers called amino acids.
- B. It contains thymine as a nitrogen base.
- C. It is a single strand of nucleotides.
- D. It contains introns.

**Question 4**

The table below shows all mRNA codons and the amino acid coded for by each codon.

|              |   | Second letter                            |                                      |  |   |                  |
|--------------|---|--|--------------------------------------|--|---|------------------|
|              |   | U  | C                                    | A  | G   |                  |
| First letter | U | UUU } phe<br>UUC }<br>UUA } leu<br>UUG } | UCU }<br>UCC } ser<br>UCA }<br>UCG } | UAU } tyr<br>UAC }<br>UAA STOP<br>UAG STOP | UGU } cys<br>UGC }<br>UGA STOP<br>UGG trp | U<br>C<br>A<br>G |
|              | C | CUU }<br>CUC } leu<br>CUA }<br>CUG }     | CCU }<br>CCC } pro<br>CCA }<br>CCG } | CAU } his<br>CAC }<br>CAA } gln<br>CAG }   | CGU }<br>CGC } arg<br>CGA }<br>CGG }      | U<br>C<br>A<br>G |
|              | A | AUU }<br>AUC } ile<br>AUA }<br>AUG met   | ACU }<br>ACC } thr<br>ACA }<br>ACG } | AAU } asn<br>AAC }<br>AAA } lys<br>AAG }   | AGU } ser<br>AGC }<br>AGA } arg<br>AGG }  | U<br>C<br>A<br>G |
|              | G | GUU }<br>GUC } val<br>GUA }<br>GUG }     | GCU }<br>GCC } ala<br>GCA }<br>GCG } | GAU } asp<br>GAC }<br>GAA } glu<br>GAG }   | GGU }<br>GGC } gly<br>GGA }<br>GGG }      | U<br>C<br>A<br>G |

The sequence of nucleotides in the template strand of a DNA fragment is as follows.

3' A A T T C G G C C A T T 5'

Transcription and translation of this DNA fragment would produce an amino acid chain of

- two identical amino acids.
- three different amino acids.
- four different amino acids.
- four amino acids, of which two are identical amino acids.

**Question 5**

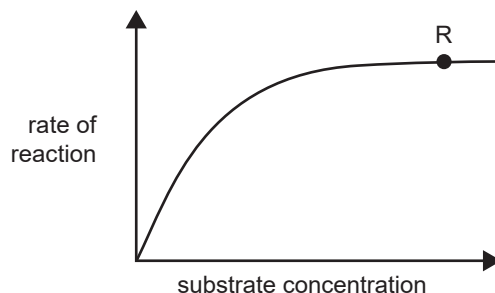
The proteome of a muscle cell

- will be identical to the proteome of a nerve cell.
- refers to the number of nucleic acid molecules within the cell.
- changes in response to differing internal or external conditions of the cell.
- refers to the packaging of protein by the Golgi apparatus for export from the cell.

**Question 6**

The rate of a chemical reaction catalysed by an enzyme found in human cells was investigated for a range of substrate concentrations. The results of the investigation are shown in the graph below.

**Rate of a chemical reaction catalysed by an enzyme with increasing substrate concentration**



One way in which the rate of the reaction at point R on the graph could be increased is to

- A. introduce a reversible inhibitor.
- B. heat the solution to 50 °C.
- C. add more substrate.
- D. add more enzyme.

**Question 7**

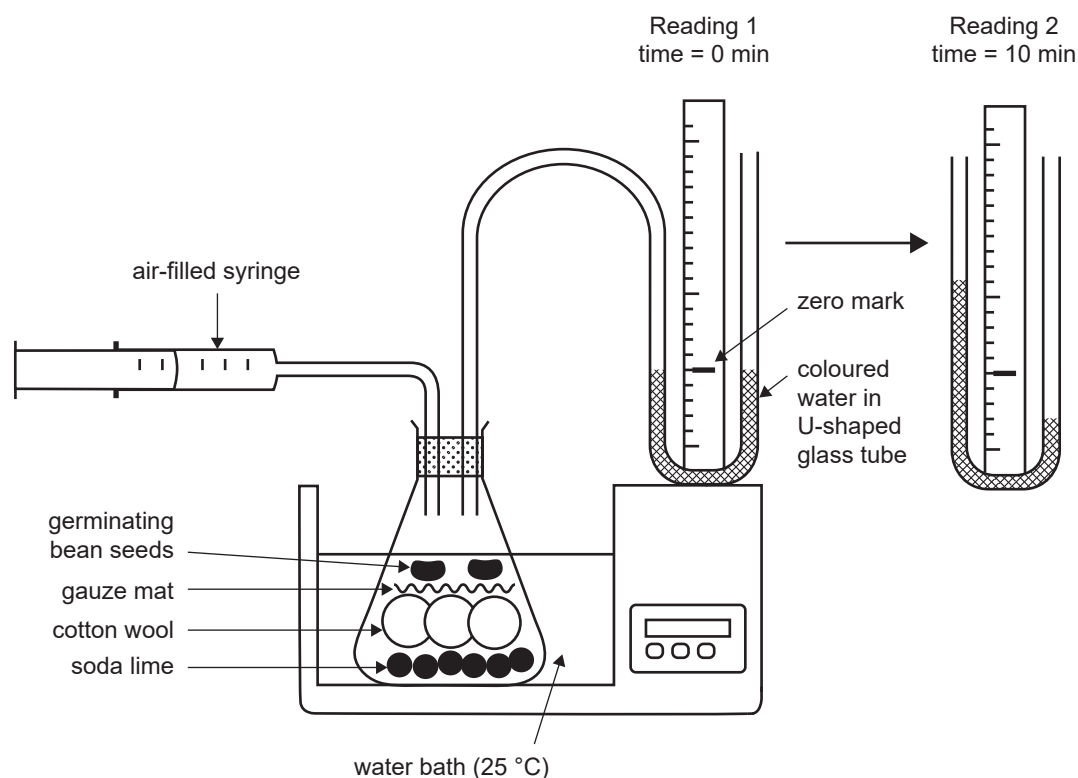
Consider both mitochondria and chloroplasts.

Which of the following features provide evidence of their bacterial origins?

- A. matrix, ATP synthase, cristae
- B. circular DNA, double membrane, ribosomes
- C. electron transport chain, cell wall, similar size to bacteria
- D. ability to self-replicate, plasmids, high surface-area-to-volume ratio

Use the following information to answer Questions 8–11.

A Biology class set up the apparatus shown in the diagram below to compare the rate of cellular respiration in organisms such as germinating bean seeds and blowfly larvae. The system was airtight. Soda lime was used to absorb carbon dioxide. A black cover (not shown) was placed over the water bath to block out light. Tests were performed on a number of organisms and materials. At the start of each test, the coloured water in the U-shaped glass tube was level with the zero mark on the left side of a ruler fixed on the tube. After each 10-minute test period, the change in the level of the coloured water in the left side of the tube was measured with the ruler. The water level was then adjusted back to the zero mark by pushing air into the flask via the syringe.



### Question 8

In the first test, germinating bean seeds were placed on the gauze mat. At the start of the test, the coloured water in the U-shaped glass tube was level with the zero mark, as shown at Reading 1. After 10 minutes, the water level moved up the left side of the U-shaped glass tube, as shown at Reading 2.

What is the best explanation for the movement of the water in the U-shaped glass tube during the 10-minute test period?

- The volume of carbon dioxide in the flask increased because it was released during the Krebs cycle by the germinating bean seeds.
- The volume of carbon dioxide in the flask decreased because it was used during glycolysis by the germinating bean seeds.
- The volume of oxygen in the flask decreased because it was used during the electron transport stage of cellular respiration in the germinating bean seeds.
- Air was removed from the flask using the syringe, triggering anaerobic respiration.

**Question 9**

The table below shows the results obtained from several organisms and materials tested by the class.

| Organism/Material      | Mass of organism/material (g) | Distance water moved in 10 min (cm) | Distance water moved per gram (cm/g) |
|------------------------|-------------------------------|-------------------------------------|--------------------------------------|
| blowfly larvae         | 6.23                          | 10.1                                | 1.62                                 |
| germinating bean seeds | 15.7                          | 10.5                                | 0.67                                 |
| boiled bean seeds      | 11.5                          | 0.1                                 | 0.01                                 |
| bean leaves            | 7.8                           | 3.5                                 | 0.45                                 |
| glass beads (control)  | 15.52                         | 0.1                                 | 0.01                                 |

Consider the results and the information provided on page 6.

Which one of the following is the most reasonable conclusion?

- A. The glass beads removed some air from the flask.
- B. Cells in the germinating bean seeds were photosynthesising during the 10-minute test period.
- C. Some of the boiled bean seeds were still alive and able to conduct cellular respiration.
- D. Germinating bean seeds have a lower rate of cellular respiration per gram than blowfly larvae.

**Question 10**

In the test on the blowfly larvae, it was noted that the rate of movement of water in the U-shaped tube began to slow down after eight minutes.

This was most likely due to

- A. insufficient food supplied to the larvae.
- B. a shortage of oxygen in the flask.
- C. an insufficient supply of ATP.
- D. the larvae falling asleep.

**Question 11**

To increase the precision of the distance measurements recorded in this investigation, the Biology class should

- A. measure the change in water level with a U-shaped tube that has an uncertainty of  $\pm 1\%$  rather than  $\pm 5\%$ .
- B. repeat the experiment the next day under the same conditions.
- C. make sure that the same mass of material is used in each test.
- D. subtract 0.1 cm from each of the measurements obtained.

Use the following information to answer Questions 12–14.

When a rat is injured, the behaviour of other nearby rats changes. Scientists discovered that, following an injury to a rat, two odorous substances, 4-methylpentanal and hexanal, were present in very small amounts in the air. They performed four follow-up experiments that involved exposing different combinations of these substances to one rat and observing the rat's behavioural responses to them. The following results were obtained.

| Substance present            | Behavioural response                     |
|------------------------------|--|
| 4-methylpentanal             | no change                                |
| hexanal                      | no change                                |
| 4-methylpentanal and hexanal | repeated scratching and whiskers shaking |
| no chemical                  | no change                                |

Reference: H Inagaki, Y Kiyokawa, S Tamogami, H Watanabe, Y Takeuchi and Y Mori, 'Identification of ... that increases anxiety in rats', *Proceedings of the National Academy of Sciences (PNAS)*, vol. 111, no. 52, 30 December 2014, <<https://doi.org/10.1073/pnas.1414710112>>

### Question 12

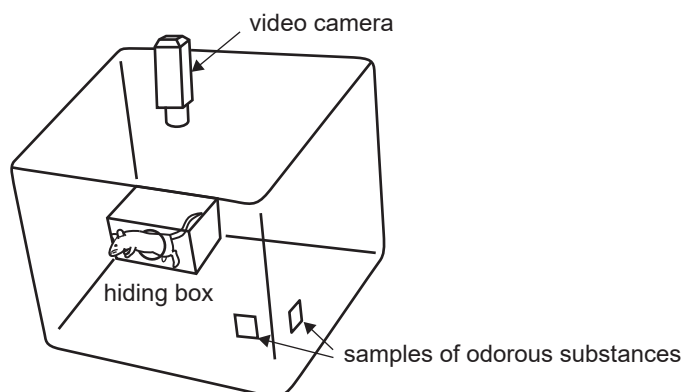
From the results, it can be concluded that the odorous substances may be acting like

- A. hormones.
- B. allomones.
- C. pheromones.
- D. neurotransmitters.

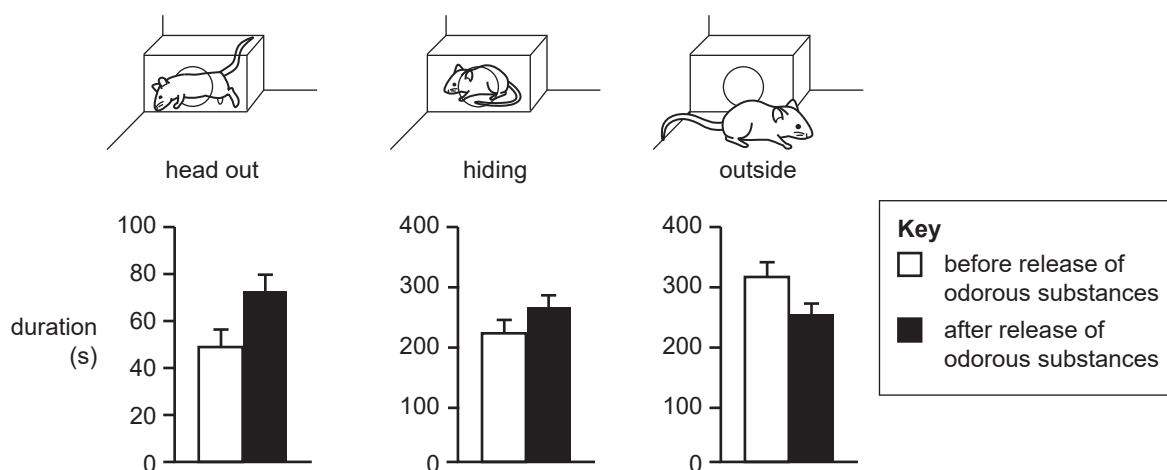


Use the following **additional** information to answer Questions 13 and 14.

The scientists further studied the effects of the odorous substances on the rat by placing it in a container in which the rat could choose between moving to an open area or staying in a hiding box, as shown in the diagram below. The rat's movements were recorded by a video camera.



The time spent, in seconds, in each position was recorded. The results are graphed below.



Source: diagram and graph adapted from H Inagaki, Y Kiyokawa, S Tamogami, H Watanabe, Y Takeuchi and Y Mori, 'Identification of ... that increases anxiety in rats', *Proceedings of the National Academy of Sciences (PNAS)*, vol. 111, no. 52, 30 December 2014, <<https://doi.org/10.1073/pnas.1414710112>>

### Question 13

From the information provided in the graphs, it can be concluded that exposure to the odorous substances

- decreased the time the rat spent hiding in the box or had their head outside of the box.
- increased the time the rat spent outside of the box and decreased the time the rat spent hiding.
- increased the time the rat spent hiding in the box and decreased the time the rat spent outside of the box, both by approximately 25%.
- decreased the time the rat spent outside of the box by approximately 40% and increased the time the rat spent with its head out of the box by 10%.

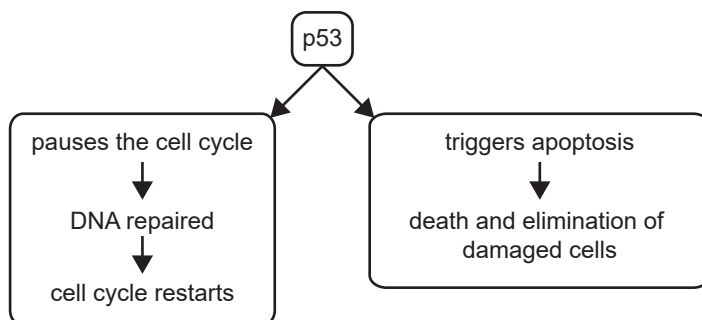
### Question 14

In this experiment, where the rat's movements were recorded by a video camera, the independent variable was the

- specific behaviour exhibited by the rat.
- change in duration of the specific behaviour.
- location of the hiding box within the container.
- presence of the odorous substances 4-methylpentanal and hexanal.

**Question 15**

There is a tumour suppressor protein, p53, that has roles in two important processes, as shown in the diagram below.



Source: adapted from Thierry Soussi, 'Pathways of the p53 protein', March 2007, <[https://commons.wikimedia.org/wiki/File:P53\\_pathways.jpg](https://commons.wikimedia.org/wiki/File:P53_pathways.jpg)>

In many patients with cancers, the structure of p53 is altered so much that the protein is inactive. This would lead to

- A. activation of the proteins involved in DNA repair.
- B. an uncontrolled increase in the number of cells.
- C. cell blebbing and fragmentation.
- D. a pause in the cell cycle.

**Question 16**

Which one of the following is an example of self-antigens in a human?

- A. pathogenic bacteria replicating in an open wound
- B. malaria protozoa infecting red blood cells
- C. pollen inhaled on a windy day
- D. receptors found on liver cells

**Question 17**

T helper cells encounter an antigen-presenting dendritic cell.

The two types of cells will be able to bind if the

- A. receptor on the T helper cell is complementary in shape to the presented antigen.
- B. dendritic cell begins to divide after activation from the T helper cell.
- C. antigen matches the antibody found on the T helper cell.
- D. T helper cell receives a signal to form a plasma cell.

**Question 18**

Which one of the following best describes the innate immune response?

- A. the production of antibodies against pathogens
- B. a targeted, specific reaction to a single pathogen
- C. a generalised set of defences against a range of pathogens
- D. specialised cells that remain after repeated exposure to a certain pathogen

**Question 19**

What is the role of lymph nodes in an immune response?

- A. to produce mature neutrophils
- B. a site of B cell and T cell activation
- C. a microbiological barrier found in animals
- D. the main component of complement proteins

**Question 20**

The population of a Victorian town has herd immunity to measles, a contagious disease.

The effect of herd immunity on this population will be that

- A. people will have increasing levels of antibodies to measles over time.
- B. the transmission of measles from person to person is unlikely.
- C. each individual is equally protected against measles.
- D. only unvaccinated children will get measles.

**Question 21**

In 2019, the first vaccine was approved for use against *Zaire ebolavirus*, which causes Ebola virus disease. The vaccine contains a live, attenuated virus that has been genetically altered to express a glycoprotein from *Z. ebolavirus*.

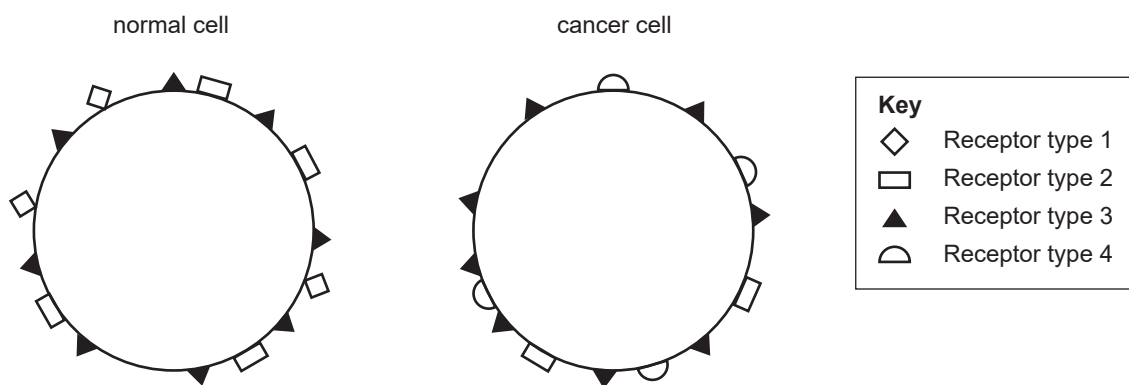
After injection of the vaccine, a person would

- A. produce antibodies to the *Z. ebolavirus* glycoprotein.
- B. become ill from the live, attenuated virus.
- C. be protected from all species of *Ebolavirus*.
- D. have passive immunity.

**Question 22**

Cells contain many receptors on their plasma membranes.

Consider the diagram below, which shows some of the receptors on both a normal cell and a cancer cell.



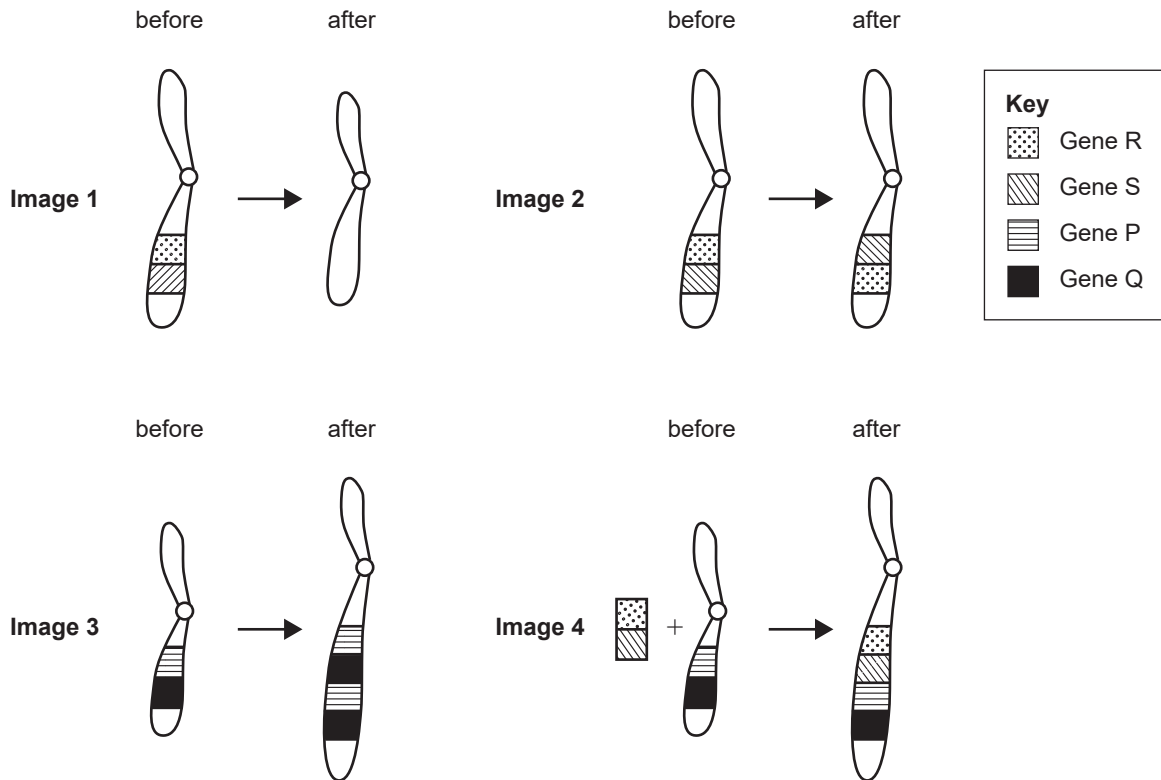
Scientists wish to target the cancer cell.

Which of the following would be the best choice to specifically target the cancer cell?

- A. polyclonal antibodies
- B. a Receptor type 3 antigen
- C. a virus targeting Receptor type 1
- D. a monoclonal antibody to Receptor type 4

**Question 23**

Consider the genes R, S, P and Q on the chromosomes represented in the images below, both before and after four different block mutations have occurred.



Source: adapted from Designua/Shutterstock.com

Which one of the images above shows an inversion?

- A. Image 1
- B. Image 2
- C. Image 3
- D. Image 4

**Question 24**

The following statements describe the processes involved in the formation of certain fossils:

1. decomposition of soft tissue
2. mineralisation occurs to hard parts
3. rapid burial beneath a blanket of sediment
4. pressure turning layers of sediment into rock

Which one of the following gives the order in which these processes occur?

- A. 1, 2, 3, 4
- B. 2, 3, 4, 1
- C. 3, 1, 2, 4
- D. 3, 2, 4, 1

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**Question 25**

Bats and whales are mammals that are distantly related. Some species of both bats and whales use echolocation to find food.

This is an example of

- A. selective breeding.
- B. divergent evolution.
- C. allopatric speciation.
- D. convergent evolution.

*Use the following information to answer Questions 26–28.*

In 1965, about 400 human footprints were discovered in a cave in Romania. These footprints may be the oldest human impressions in Europe. At the time, scientists attributed the footprints to a man, woman and child from a population that lived 10 000 to 15 000 years ago. Recently, two fossilised bones from a bear were unearthed just below the footprints. The age of the bones from the bear indicated that the people who made the footprints actually lived in the Stone Age, around 36 500 years ago.

**Question 26**

What is the name given to fossils such as the footprints mentioned above?

- A. cast
- B. trace
- C. index
- D. mineralised

**Question 27**

Which absolute dating technique was most likely used to date the fossilised bones from the bear?

- A. DNA hybridisation
- B. carbon-14 to nitrogen-14
- C. potassium-40 to argon-40
- D. uranium-238 to lead-206

**Question 28**

The age of the human footprints could not be determined directly.

The footprints were dated using

- A. relative dating.
- B. comparative dating.
- C. structural morphology.
- D. biogeographical dating.

Use the following information to answer Questions 29–31.

In humans, rhesus monkeys and gibbons, the  $\beta$ -polypeptide chain of haemoglobin ( $\beta$ -globin) contains 146 amino acids. Scientists compared the amino acid sequences in each species. The table below summarises their findings and shows only the positions in the  $\beta$ -globin sequence where differences were present between the three species.

|   | Amino acid present |     |     |     |     |     |     |
|---|--------------------|-----|-----|-----|-----|-----|-----|
| <b>Human</b>  | ser                | ala | val | thr | ala | thr | pro |
| <b>Rhesus monkey</b>                                  | asn                | thr | leu | ser | asn | gln | gln |
| <b>Gibbon</b>   | ser                | ala | val | thr | ala | gln | gln |
| <b>Position in <math>\beta</math>-globin sequence</b> | 9                  | 13  | 33  | 49  | 76  | 87  | 125 |

### Question 29

It can be deduced from the data above that

- A. there are 21 differences between the  $\beta$ -globin amino acid sequences of humans and rhesus monkeys.
- B. identical mutations resulted in gln at positions 87 and 125 in the  $\beta$ -globin of rhesus monkeys and gibbons.
- C. the  $\beta$ -globin sequences of humans and gibbons have 144 identical amino acids.
- D. gibbons are more closely related to rhesus monkeys than they are to humans.

### Question 30

Comparisons of the amino acid sequences in each species give a measure of

- A. molecular homology.
- B. structural differences.
- C. biogeographical distance.
- D. DNA hybridisation.

### Question 31

Conclusions about the evolutionary relationships between the three species can be drawn because

- A. the genetic code is redundant and non-overlapping.
- B. changes in amino acid sequences will alter DNA sequences.
- C. similar amino acid sequences are a consequence of convergent evolution.
- D. the more time that has passed since divergence from a common ancestor, the greater the chance of changes having occurred in the DNA sequence.

### Question 32

The human fossil record is often contested, refined and revised because

- A. sometimes new fossils are found that do not fit into current phylogenetic models.
- B. cognitive changes in hominins enabled diverse changes in culture and technology.
- C. many human fossils have been destroyed in ritual burials performed by ancient hominins.
- D. *Homo sapiens* and *Homo neanderthalensis* possibly interbred to produce *Homo denisovans*.

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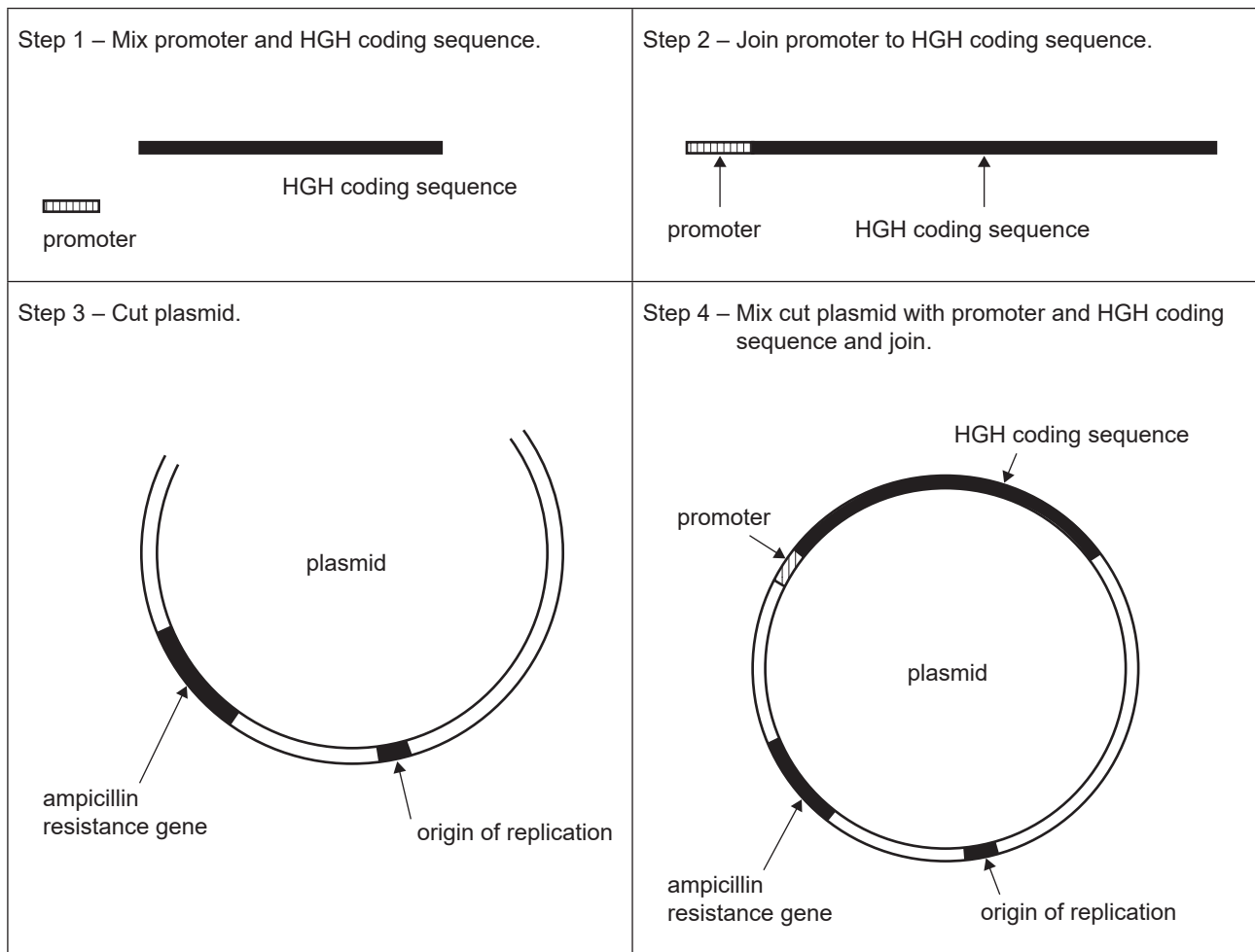
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**SECTION A – continued  
TURN OVER**

Use the following information to answer Questions 33–35.

Transformed cells of *Escherichia coli* can be used to produce human growth hormone (HGH).

Recombinant plasmids are often used to transform bacterial cells. Some of the steps required to produce the plasmids that are used to transform bacterial cells are shown below.



### Question 33

Which of the following identifies the most likely enzymes acting at Step 2, Step 3 and Step 4 in the gene-cloning process?

|    | Step 2         | Step 3         | Step 4         |
|----|----------------|----------------|----------------|
| A. | endonuclease   | DNA ligase     | DNA polymerase |
| B. | DNA ligase     | endonuclease   | DNA ligase     |
| C. | DNA polymerase | endonuclease   | DNA ligase     |
| D. | DNA ligase     | DNA polymerase | endonuclease   |



**Question 34**

The role of the promoter in the plasmid is to

- A. join the HGH coding sequence to the nucleotide sequence of the plasmid.
- B. allow the plasmid to reproduce itself inside the bacteria.
- C. turn on expression of the HGH coding sequence.
- D. cut the nucleotide sequence at a recognition site.

**Question 35**

*E. coli* cells can be stimulated to take up the plasmid by a treatment called heat shock. In this treatment, a suspension containing *E. coli* cells and recombinant plasmids is placed on ice, then heated to 42 °C and quickly cooled.

To identify transformed *E. coli* cells, the suspension is spread onto a culture plate

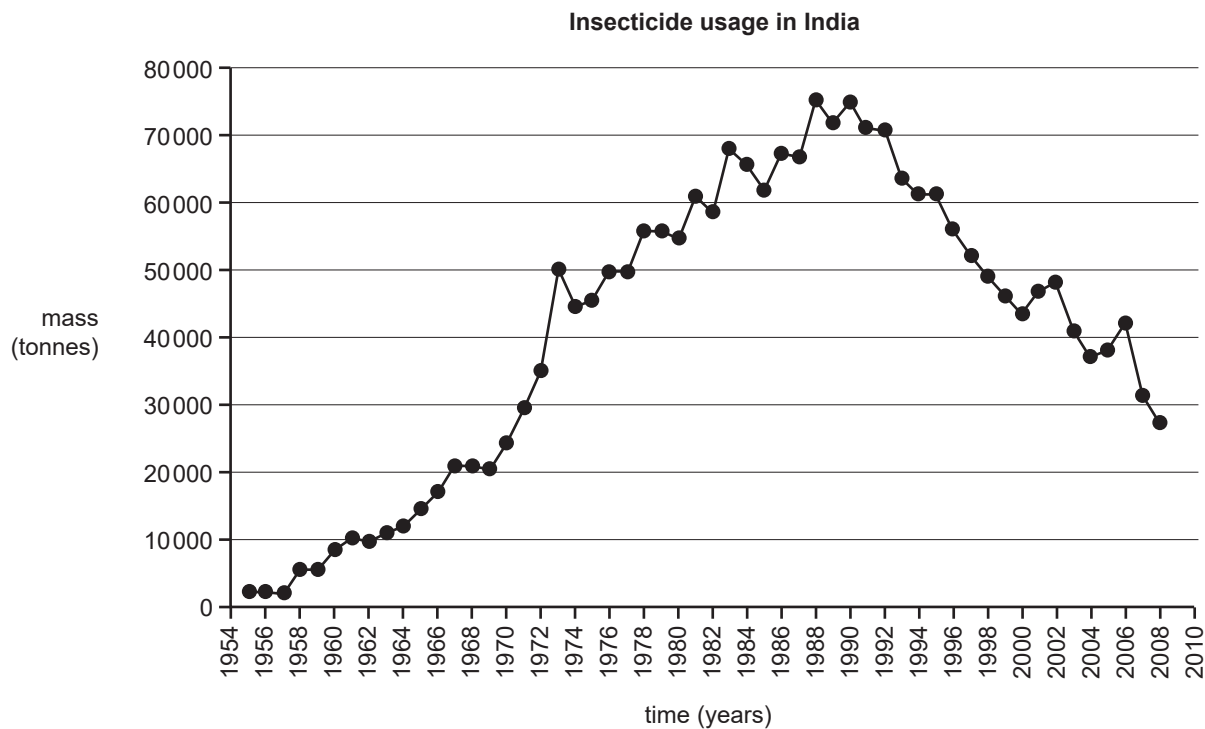
- A. and reheated to 42 °C.
- B. and exposed to ultraviolet light.
- C. with a pH of 3 and a temperature of 37 °C.
- D. containing ampicillin and given time to grow.

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Use the following information to answer Questions 36 and 37.

Following concerns about insecticide resistance in insects, scientists have developed insect-resistant corn and cotton crops. This has reduced the need for insecticides in many countries. Despite safety testing confirming there are no health risks to organisms consuming genetically modified (GM) crops, there have been claims of GM crops having an impact on public health.

The graph below shows the changes in insecticide usage in India from 1954 to 2010.



Source: adapted from 'GMO FAQ: Do GMO Bt (insect-resistant) crops pose a threat to human health or the environment?', Genetic Literacy Project, <<https://geneticliteracyproject.org>>

### Question 36

The graph above shows the changes in insecticide usage in India.

Which one of the following is the most likely year in which GM crops were introduced into this country?

- A. 1960
- B. 1972
- C. 1980
- D. 1992

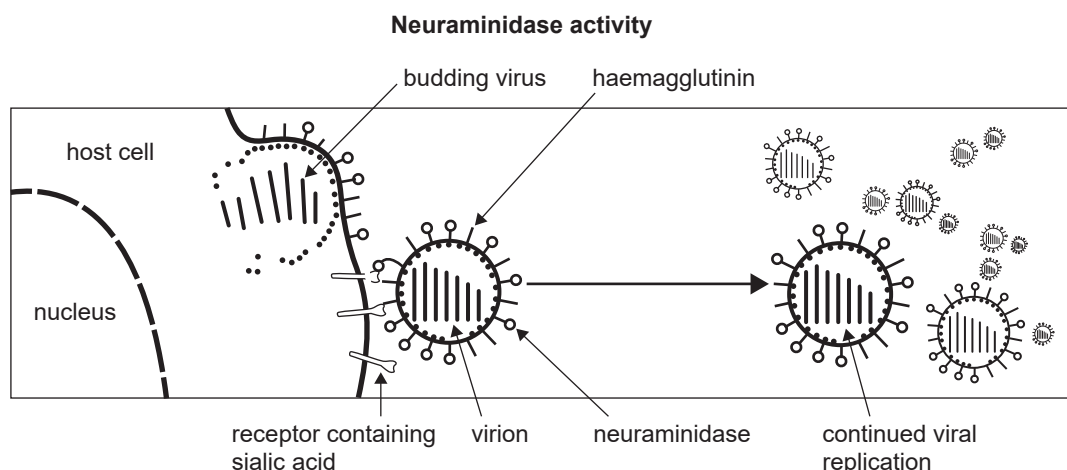
**Question 37**

With reference to the information provided, which of the following correctly identifies a biological implication and an ethical implication of the use of GM crops?

|           | <b>Biological implication</b>   | <b>Ethical implication</b>   |
|-----------|---|--|
| <b>A.</b> | more aquatic organisms affected in streams and rivers near where GM crops are planted             | decrease in cost of insecticide prohibits some farmers or countries from using these           |
| <b>B.</b> | more insects are present, resulting in more crop predation and, consequently, smaller crop yields | modification of crops is unnatural and some people argue that it is not right                  |
| <b>C.</b> | an increase in the genetic diversity of GM crops compared to natural, non-GM crops                | farmers' non-GM crops could become genetically modified due to cross-pollination with GM crops |
| <b>D.</b> | use of only GM crops may reduce diversity and increase crop susceptibility to disease             | large companies may control seed prices, restricting GM crops to wealthier farmers             |

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## Question 38



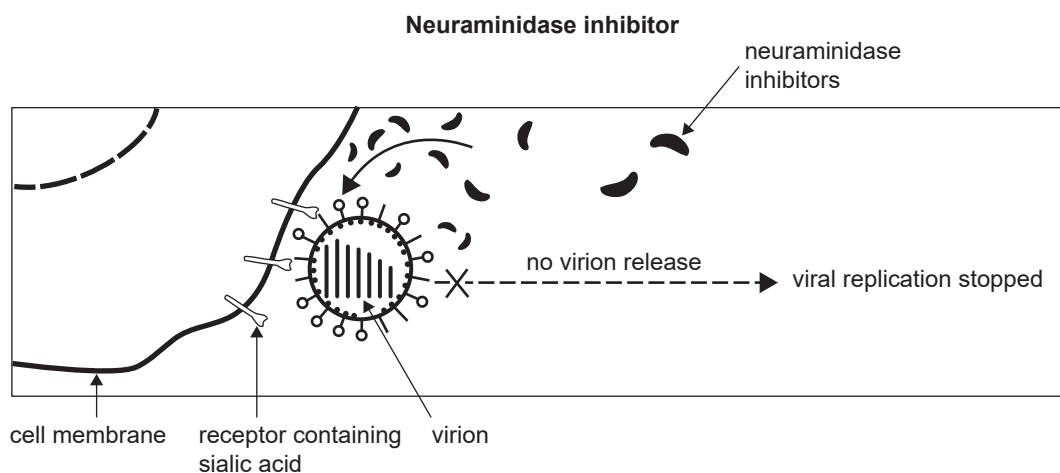
Source: adapted from A Moscona, 'Neuraminidase inhibitors for influenza',  
*The New England Journal of Medicine*, 29 September 2005,  
 <[www.nejm.org/doi/full/10.1056/NEJMra050740](http://www.nejm.org/doi/full/10.1056/NEJMra050740)>

The diagram above illustrates the action of neuraminidase on virus replication.

Neuraminidase aids the reproduction of viruses by

- increasing protein production.
- allowing the virus to bud.
- allowing the virion to separate from the infected cell.
- having a complementary shape to the sialic acid receptor.

## Question 39



Source: adapted from A Moscona, 'Neuraminidase inhibitors for influenza',  
*The New England Journal of Medicine*, 29 September 2005,  
 <[www.nejm.org/doi/full/10.1056/NEJMra050740](http://www.nejm.org/doi/full/10.1056/NEJMra050740)>

The diagram above illustrates the action of a neuraminidase inhibitor.

What two properties must the inhibitor have to affect the action of neuraminidase?

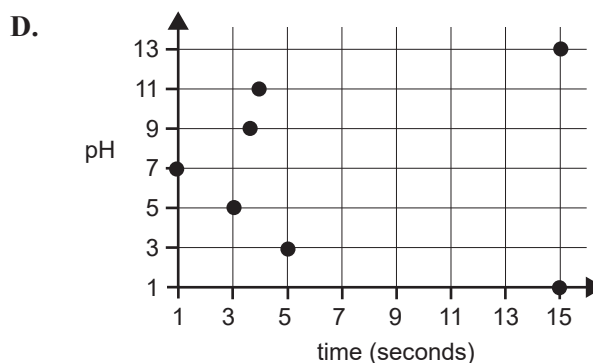
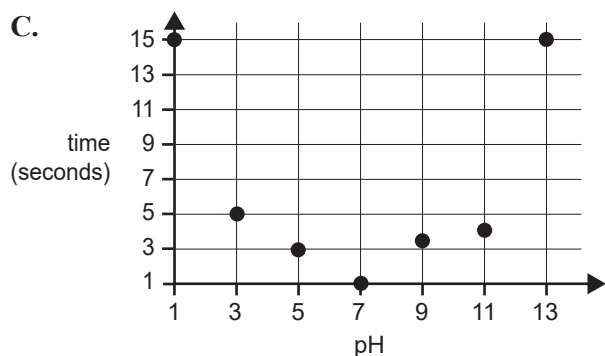
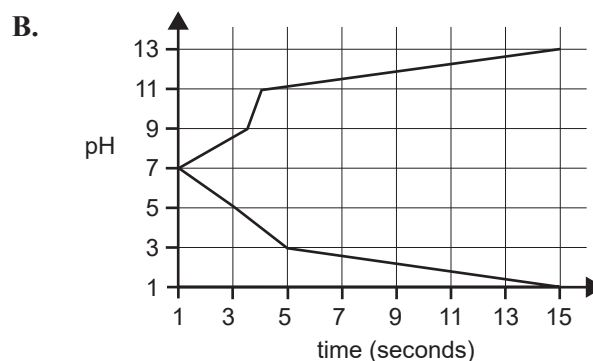
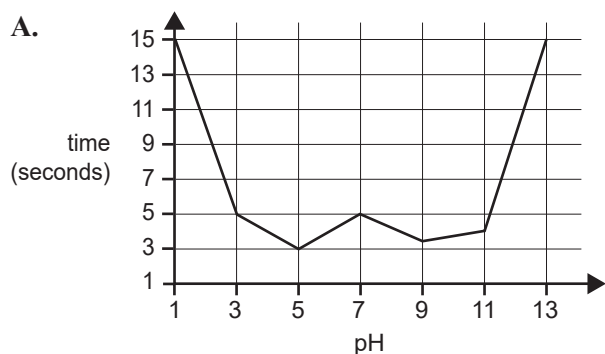
- complementary shape and charge to enzyme active site
- complementary shape to sialic acid and complementary charge to neuraminidase
- complementary shape to virion and complementary charge to sialic acid receptor
- competitive shape and charge to enzyme binding site

**Question 40**

The table below shows the results of an experiment that investigated the effect of pH on an enzyme breaking down a substrate. The time it took the substrate to completely break down was recorded. A maximum time of 60 seconds was allowed before timing was stopped. The same volumes and concentrations of enzyme and substrate were added to each pH buffer solution.

| pH   | 1  | 3 | 5 | 7 | 9   | 11 | 13 |
|--|----|---|---|---|-----|----|----|
| Time taken for substrate to break down (seconds) | 15 | 5 | 3 | 1 | 3.5 | 4  | 15 |

Which graph best represents the data presented in the table?



**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** (6 marks)

Genomic DNA contains both structural genes and regulatory genes.

- a. Describe the differences in the functions of these two types of genes. 2 marks

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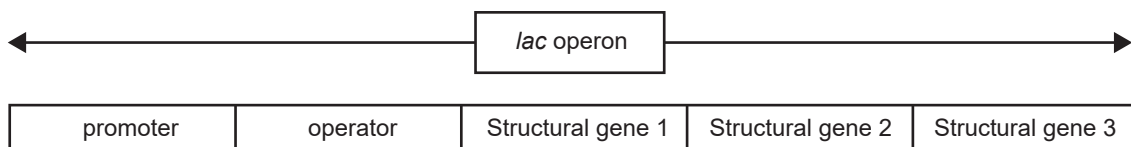


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- b. In the bacteria *Escherichia coli*, the *lac* operon contains three structural genes adjacent to each other, as shown in the diagram below.



- i. State **one** advantage for the *E. coli* bacteria of having the three structural genes under the control of a single promoter. 1 mark

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- ii. The activity of the proteins expressed by these three structural genes is affected by the temperature of the bacterial cells.

If the temperature of the bacterial cells was increased above the optimal temperature for cellular activity, would the activity of the proteins of the gene expression increase, decrease or stay the same? Justify your response. 3 marks

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**Question 2** (7 marks)

- a. Photosynthesis occurs in many plant cells.

Explain the function of photosynthesis in plant cells.

2 marks

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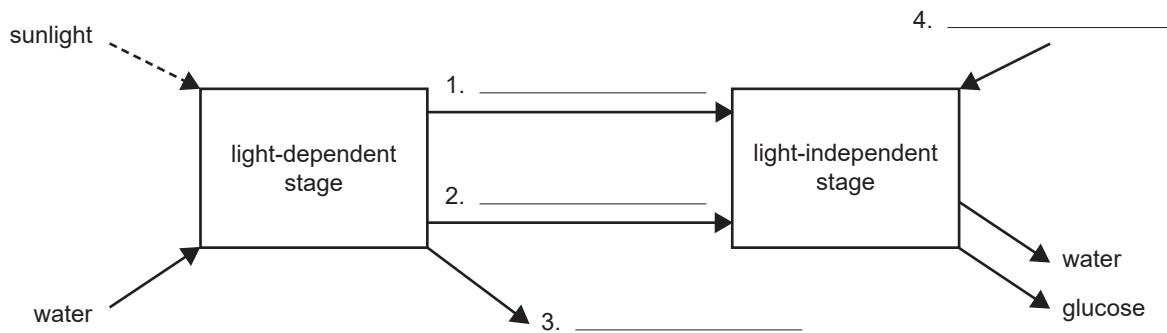


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- b. Photosynthesis has two stages: the light-dependent stage and the light-independent stage. A pair of Biology students created a diagram of the two stages of photosynthesis, shown below. The students labelled several arrows that show some of the inputs and outputs of each stage, but they omitted the labels on four of the arrows, labelled 1–4.

Write correct labels for the four remaining arrows on the lines provided.

3 marks



- c. Create two additional annotations that could be added to the students' diagram, which show a deeper understanding of the stages of photosynthesis.

2 marks

Annotation 1 \_\_\_\_\_

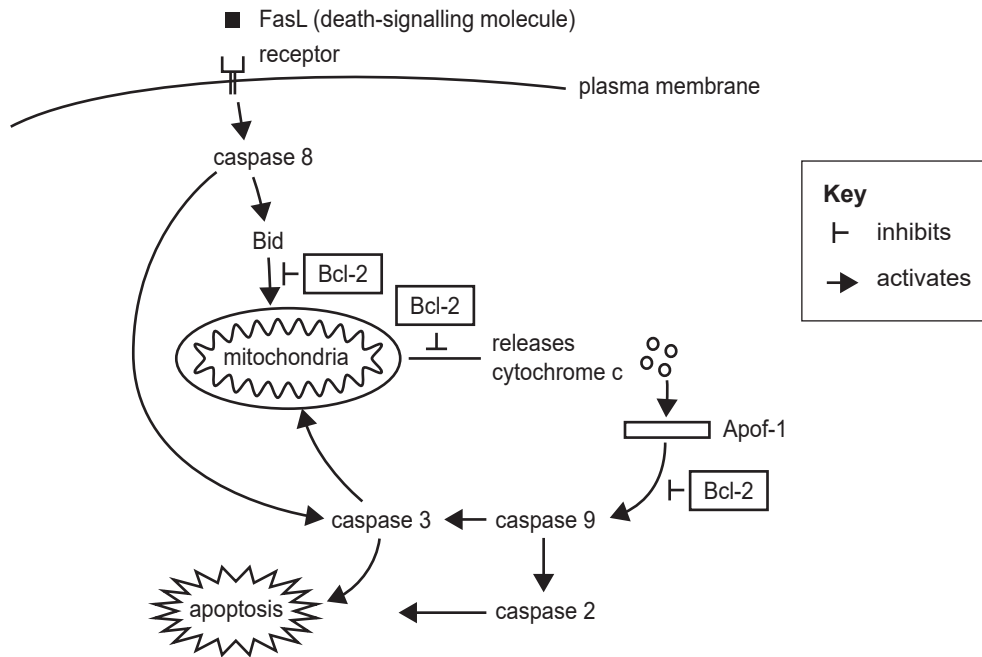
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Annotation 2 \_\_\_\_\_

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**Question 3** (8 marks)

When a human T helper cell is identified for death, FasL, a death-signalling molecule, attaches to the cell and initiates a response within the cell, as shown in the diagram below.



Bcl-2 is a protein that inhibits both the release of cytochrome c from the mitochondria and the production of other proteins needed for apoptosis.

Caspases are enzymes that break down proteins within a cell.

- a. Is FasL a peptide-based or a fatty-acid-based signalling molecule? Justify your response with reference to the diagram. 2 marks

Type of signalling molecule \_\_\_\_\_

Justification \_\_\_\_\_

\_\_\_\_\_

DO NOT WRITE IN THIS AREA



- b. A person who has been infected with the human immunodeficiency virus (HIV) has fewer T helper cells than a person who has not been infected with HIV. The virus contains enzymes that deactivate Bcl-2.

Describe how the presence of HIV enzymes would influence the apoptosis pathway shown in the diagram on page 24.

2 marks

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- c. Scientists hope to design a molecule that will specifically inhibit HIV enzymes. Once this molecule has been created, they plan to test it on patients infected with HIV.

Identify **four** requirements or aspects of the experimental design that would need to be considered when the scientists are planning their trial of this molecule.

4 marks

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**Question 4** (10 marks)

Over the weekend, Morgan went to the movies with Alex and Pat. They all sat together and shared a drink. The next day, Morgan had symptoms of the flu virus and the doctor told Morgan that Morgan had been infectious when at the movies.

- a. Describe **two** components of the immune system's first line of defence that the virus overcame to infect Morgan. 2 marks

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Alex wakes up a few days later with a sore, inflamed throat.

- b. Using your knowledge of the immune response, suggest what is happening to cause Alex's sore, inflamed throat. 2 marks

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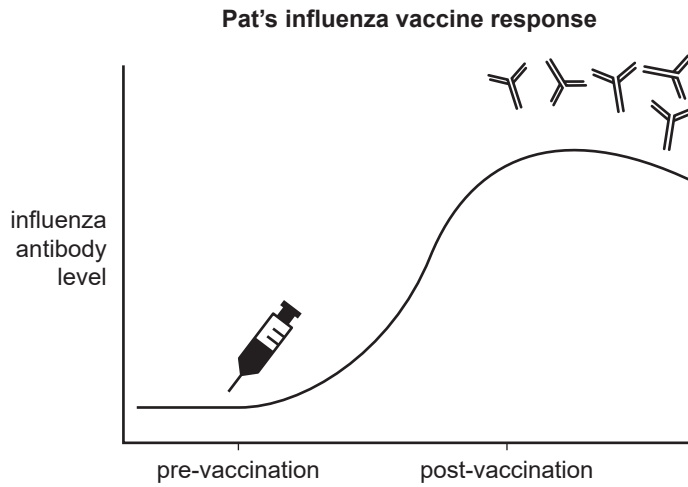
- c. Other than by sharing a drink, how could the virus have been transmitted from Morgan to Alex? Provide **one** measure that could have been taken to prevent this transmission. 2 marks

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- d. Pat does not develop symptoms of the flu after Pat’s contact with Morgan, who was infectious. Pat had the influenza vaccination this season. The graph below shows Pat’s influenza virus antibody levels before and after vaccination.



Source: adapted from SPH van den Berg et al, ‘Effect of latent cytomegalovirus infection on the antibody response to influenza vaccination: a systematic review and meta-analysis’, *Medical Microbiology and Immunology*, vol. 208, 4 April 2019, <<https://doi.org/10.1007/s00430-019-00602-z>>

Explain Pat’s immune response after contact with Morgan, which prevented Pat from developing the flu.

4 marks

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**Question 5** (10 marks)

Many Amazon rainforest bird species are evolving in response to climate change. A study examined four decades' worth of data on bird species and found that, as the average temperature of the region increased, some bird species appeared to be changing physically.

Another study of 77 non-migratory Amazon rainforest bird species conducted from 1979 to 2019 found that the average weight of all individual birds had decreased at the end of the study. The individuals in a third of the bird species had increased average wing lengths.

- a. Outline how the environmental change could have brought about the decrease in average weight of the birds. 2 marks

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During 40 years of field work in the Amazon rainforest, more than 15 000 individual birds were captured, measured, weighed, tagged with a leg band and released. The scientists are confident that the data from this study is reliable.

- b. Do you agree or disagree about the reliability of the study? Explain your response. 1 mark

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- c. The validity of the study was enhanced by gathering data from non-migratory birds. Explain the benefit of using non-migratory birds with reference to the impact on the gene pool of the population of birds studied. 3 marks

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- d. Using your knowledge, explain how a species of bird would 'evolve' to either weigh less or have longer wings. 4 marks

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**Question 6** (4 marks)

Using the example of African cichlid fish, explain the role of the BMP4 gene during embryonic development and explain how mutations in the BMP4 gene have led to the evolution of new phenotypes in this animal group.

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**Question 7** (7 marks)

Hominins are the only primate groups that contain species that evolved to become fully bipedal.

- a. State **two** advantages of bipedalism for ancient hominins.

2 marks

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- b. A hominoid fossil was found in East Africa. It was a partial skeleton dated at about 4 million years old. The skull was not present.

To determine whether the fossilised skeleton belonged to a hominin or an ape-like hominoid, scientists studied its structural features.

Complete the table below by listing three structural differences between the skeletons of hominins and the skeletons of ape-like hominoids that would help to place the fossil into the correct group. The first difference has been provided as an example.

3 marks

| Skeletal feature of hominin | Skeletal feature of ape-like hominoid |
|-----------------------------|---------------------------------------|
| <i>arched foot</i>          | <i>flat foot</i>                      |
|                             |                                       |
|                             |                                       |
|                             |                                       |

- c. Examine the images of the two fossilised skulls below. They are not to scale. Both fossils were found in Africa, but at different sites and in different years. Palaeontologists have classified these two fossils as belonging to two different species of hominin.

Image A



Image B



Source: Danny Ye/Shutterstock.com (Image A); WH\_Pics/Shutterstock.com (Image B)

Which of the two fossils most likely represents the more ancient hominin species? Justify your response using **two** observations from the images. 2 marks

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**Question 8** (4 marks)

An early investigation by scientists has shown that it is possible to produce only female offspring when breeding mice. Embryos can be stopped from developing by deactivating a gene called *TOP1*. When *TOP1* is deactivated, the embryos do not progress beyond a very early stage of development – around four to 16 cells. The gene can be deactivated using a gene-editing molecule.

This gene-editing molecule consists of two parts. Each part is coded for by its own gene. These genes are not normally found in mice.

The scientists placed the gene coding for one part of the editing molecule into the genome of female mice and placed the gene coding for the second part of the editing molecule into the genome of male mice. Breeding with these gene-edited mice resulted in offspring that were all female. No male mice were born as the *TOP1* gene was deactivated in the male embryos.

The government of the United Kingdom is considering allowing the use of gene editing to produce only female chickens and, in doing so, prevent the killing of thousands of young male chickens, which do not lay eggs, each year.

Scientists hope to be able to use this gene-editing technology to prevent the birth of male chickens.

- a. Outline an ethical implication that justifies why scientists have developed this gene-editing technology. 2 marks

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- b. Explain whether the young mice containing the two genes for the gene-editing molecule would be considered transgenic or genetically modified. 2 marks

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

**Question 9** (7 marks)

Tuberculosis (TB) is a disease resulting from an infection by *Mycobacterium tuberculosis*. TB typically affects an individual's lungs and throat and, in some cases, can cause serious illness. It is transmitted between individuals when an infected person coughs, sneezes or speaks. However, in most cases, the bacteria remain inactive in the body and only become active in approximately 10% of those infected.

- a. People with HIV, cancer patients, the elderly and newborn babies are more likely to fall ill than the general population.

Select one of these groups and explain why people in this group are more vulnerable to infections such as TB.

2 marks

Group selected \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

- b. State whether a doctor would prescribe antibiotics or antiviral medication to patients suffering from TB. Justify your response.

1 mark

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

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The World Health Organization (WHO) released a report containing the following statistics about TB:

- In 2020, TB infected approximately 10 million people globally. Of these, 5.6 million were men, 3.3 million were women and 1.1 million were children.
- Eight countries (India, China, Indonesia, the Philippines, Pakistan, Nigeria, Bangladesh and South Africa) accounted for 67% of new TB cases in 2020.
- 1.5 million people (or 15%) died from TB in 2020. Of these, 214 000 were also people with HIV.
- The incidence of TB cases globally decreased by approximately 2% per year from 2015 to 2020.

The following quote also appeared in the WHO report relating to TB infection: ‘Ending the TB epidemic by 2030 is among the health targets of the United Nations Sustainable Development Goals (SDGs).’

Source: data and quote from World Health Organization, ‘Tuberculosis’, fact sheet, 14 October 2021, <[www.who.int/news-room/fact-sheets/detail/tuberculosis](http://www.who.int/news-room/fact-sheets/detail/tuberculosis)>

- c. Explain the term ‘epidemic’ and whether it has been used correctly in the quote. 2 marks

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- d. Based on the data above, does the United Nations’ goal to end the ‘TB epidemic by 2030’ seem achievable? Justify your response. 2 marks

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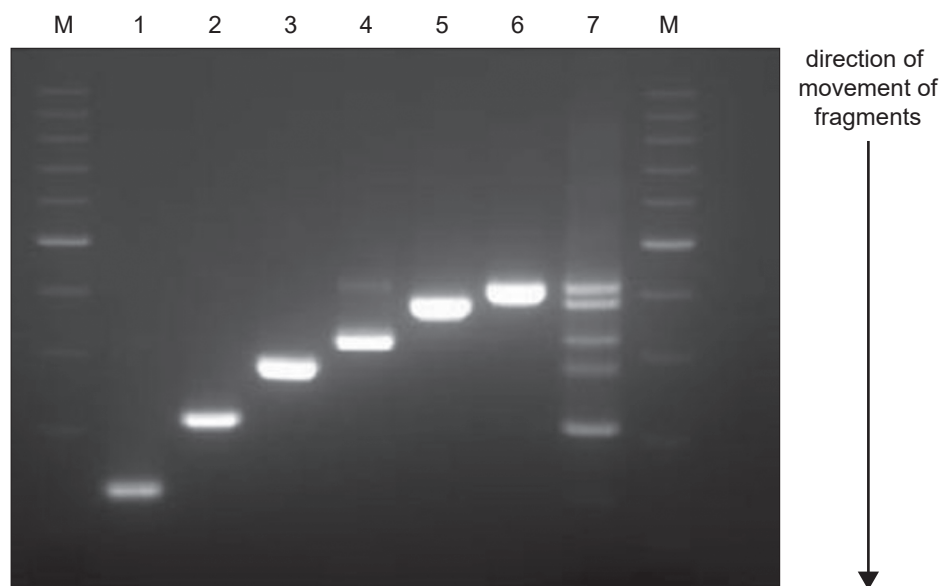
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**Question 10** (11 marks)**How reliable are PCR tests?**

PCR is a common laboratory technique that is used in molecular biology, genetics and medical diagnostics.

PCR is used to detect the presence of viral or bacterial pathogens in samples taken from people with infections. PCR is used to amplify a section of the DNA or RNA in a sample. After completion of the PCR, the DNA can be separated using gel electrophoresis.

The image below shows the results obtained when six different but known viral pathogens were tested. The lanes labelled M contain fragments of known sizes. The lanes labelled 1 to 6 contain DNA from six different viruses. Lane 7 contains DNA from all of the six different viruses. A fluorescent dye has been added to help visualise the position of the DNA. The gel was made using 3% agarose. Scientists run many experimental trials to test for the right conditions to separate the DNA fragments.



In additional trials, the scientists determine the optimal temperature and timing to carry out each of the stages of PCR. Each stage has an optimal temperature and an optimal length of time over which it should run. The scientists design primers to identify particular pathogens.

After many trials, a strict protocol is determined. If the protocol is followed by laboratory technicians when performing the pathogen identification tests, the results have been shown to be very accurate and reliable. However, incorrect temperatures or timing of each stage may result in a gel that has missing or lighter bands. The sample is retested when a band is very faint.

Some people refer to the PCR test as the ‘gold standard’ test for pathogen identification. Occasionally, a PCR test will produce incorrect results. This is rare and often related to the age or quality of the sample. Laboratory technicians can visually identify low-quality samples and can request that a new sample be provided. Old samples need to be discarded. One study has shown that incorrect results occur in less than 0.0001% of PCR tests and these incorrect results are usually related to the collection of the sample rather than the PCR test.

Reference: D Devis, ‘Ask Cosmos: How reliable are PCR tests?’, *Cosmos*, 6 September 2021, <<https://cosmosmagazine.com/health/ask-cosmos-how-reliable-are-pcr-tests/>>

Source: image from Ji Wang et al, ‘A two-tube multiplex reverse transcription PCR assay for simultaneous detection of viral and bacterial pathogens of infectious diarrhea’, *BioMed Research International*, vol. 2014, 10 March 2014, <<https://doi.org/10.1155/2014/648520>>

- a. What does 'PCR' stand for? 1 mark

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- b. Scientists design primers for a particular target DNA sequence.

Explain how a scientist would design primers for a target DNA sequence that allow amplification of that DNA sequence and no other DNA sequences.

4 marks

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- c. Consider lanes 1 to 7 in the image on page 36.

Which lane shows the shortest DNA sample? Justify your response.

2 marks

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- d. The article refers to possible errors that may appear in the gel electrophoresis result due to problems with the PCR process.

Using the information in the article, identify two factors that may alter the result seen on the gel and explain how each factor might have an impact on the result.

4 marks

Factor 1 \_\_\_\_\_

Explanation \_\_\_\_\_

Factor 2 \_\_\_\_\_

Explanation \_\_\_\_\_

**Question 11** (6 marks)

A researcher wanted to investigate the effect of different antibiotics on two species of bacteria: *Bacillus cereus* and *Serratia marcescens*. The researcher obtained three identical nutrient agar plates and used a sterilised spreader to spread a drop of the *B. cereus* bacterial culture over the surface of each of the three plates. The researcher repeated this step using three more identical nutrient agar plates, spreading a drop of *S. marcescens* bacterial culture on each. The researcher then soaked six small, round filter paper discs in distilled water, the antibiotic chloramphenicol or the antibiotic sulphatriad. The researcher firmly pressed one filter paper disc onto the centre of each nutrient agar plate.

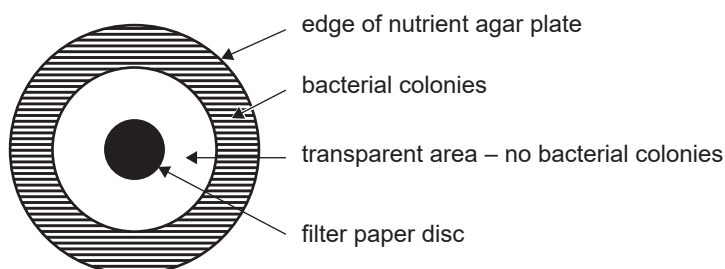
The table below summarises the researcher's set up.

| Nutrient agar plate | Bacterial species present | Chemical in filter paper disc |
|---------------------|---------------------------|-------------------------------|
| 1                   | <i>B. cereus</i>          | distilled water               |
| 2                   | <i>B. cereus</i>          | chloramphenicol               |
| 3                   | <i>B. cereus</i>          | sulphatriad                   |
| 4                   | <i>S. marcescens</i>      | distilled water               |
| 5                   | <i>S. marcescens</i>      | chloramphenicol               |
| 6                   | <i>S. marcescens</i>      | sulphatriad                   |

After the filter paper discs were pressed onto each nutrient agar plate, lids were placed on the plates and sealed with sticky tape.

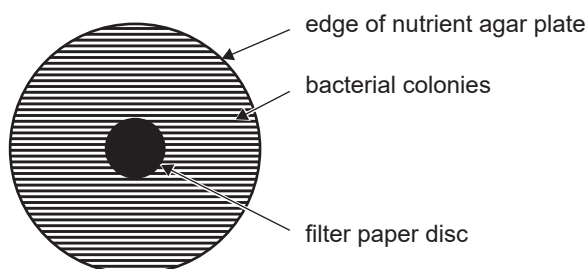
The plates were put into an incubator at 37 °C and left overnight.

The next day, the researcher noted that on some plates there was a transparent area around the filter paper disc, which indicated that bacteria were not growing in this area. The diagram below illustrates what the researcher could see.



The researcher measured the diameter of each transparent area.

On other plates there was no transparent area, indicating bacterial colonies growing all over the plate. The diagram below illustrates what the researcher could see.

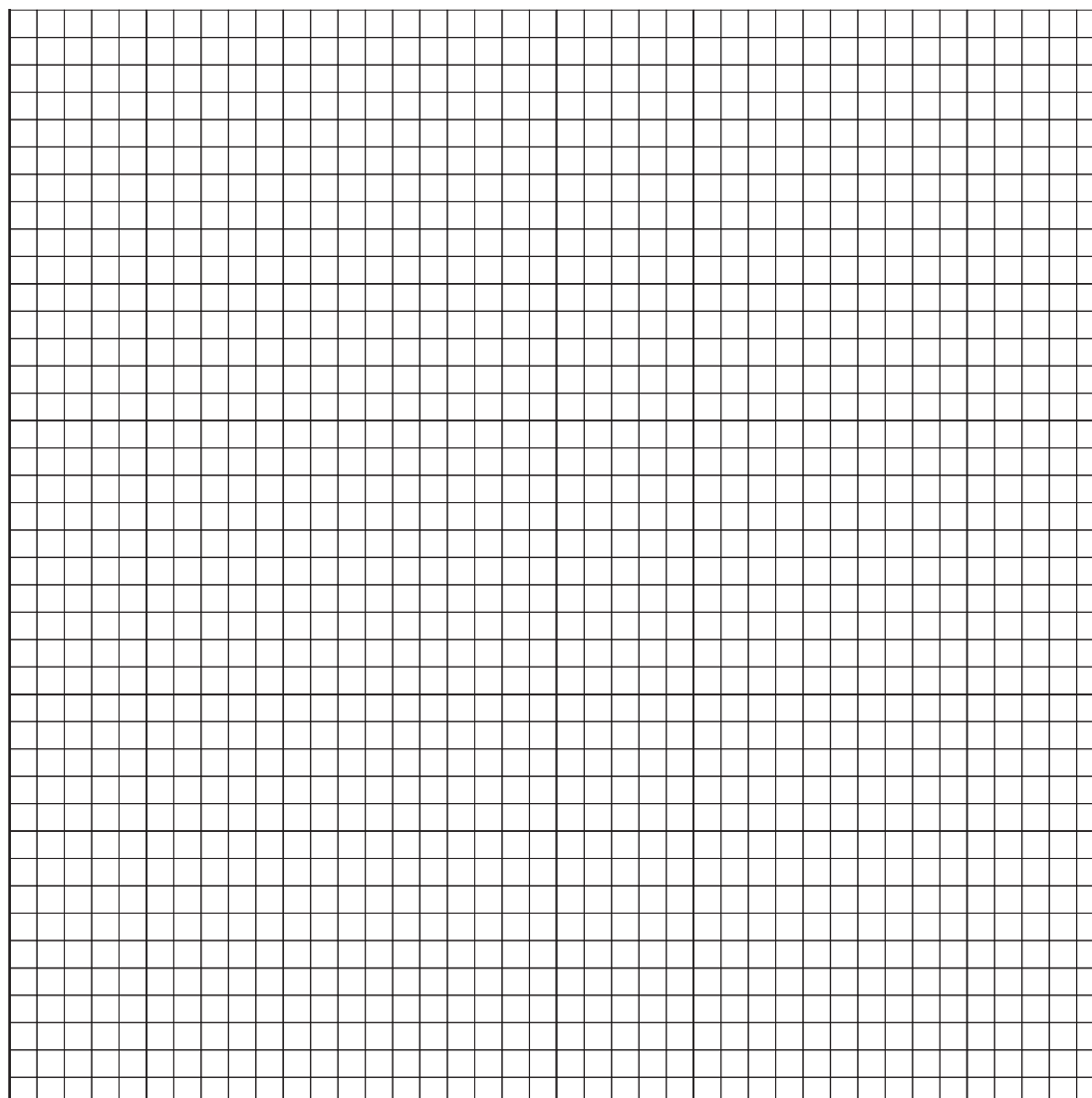


The researcher's results are shown in the table below. A result of 0 mm indicates the absence of a transparent area.

| Nutrient agar plate | Bacterial species present | Chemical in filter paper disc | Size of transparent area (mm) |
|---------------------|---------------------------|-------------------------------|-------------------------------|
| 1                   | <i>B. cereus</i>          | distilled water               | 0                             |
| 2                   | <i>B. cereus</i>          | chloramphenicol               | 40                            |
| 3                   | <i>B. cereus</i>          | sulphatriad                   | 0                             |
| 4                   | <i>S. marcescens</i>      | distilled water               | 0                             |
| 5                   | <i>S. marcescens</i>      | chloramphenicol               | 21                            |
| 6                   | <i>S. marcescens</i>      | sulphatriad                   | 35                            |

- a. Draw and label an appropriate graph to illustrate the results obtained for both species of bacteria.

3 marks



- b.** After analysing the data from the investigation, what are **two** conclusions that the researcher could make about the effects of these two antibiotics on the two species of bacteria? 2 marks

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- c.** State a source of random error that may be present in the researcher's experiment. 1 mark

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