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Some questions may have been altered or removed compared to the version of this paper used during the competition period. This is a download of an online, interactive paper, so the formatting is also sub-optimal.

Answers are not provided.

Students are not expected to have memorised all the facts assessed, or be familiar with all the topics presented. Their biological intuition and problem solving is being assessed.

British Biology Olympiad 2023

This was split into 2 papers of 45 minutes each.

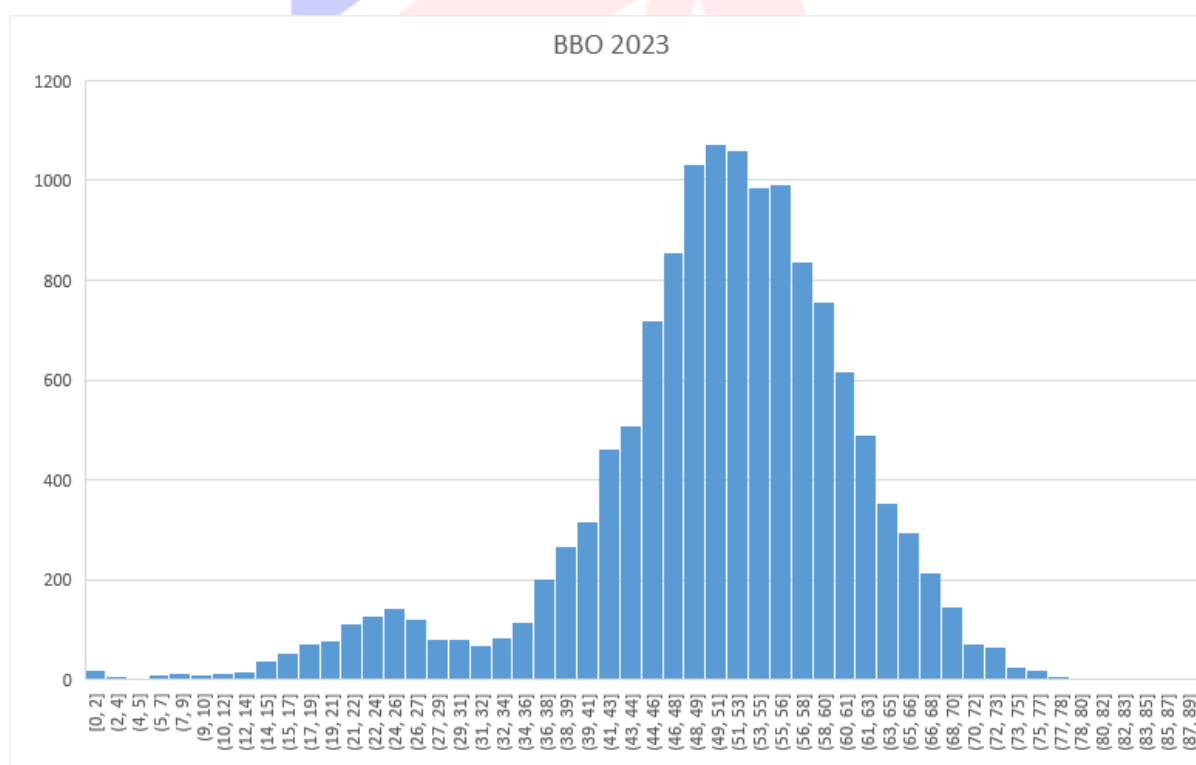
You may use a calculator.

It is recommended that you have pen and paper to hand for rough work.

No marks are subtracted for incorrect answers.

Some questions have more than one answer you need to choose. For some questions, you need to put the answers in the correct order.

Award	Percentage score	Percentage of students who took part in the British Biology Olympiad 2023
Gold	65.81%	5%
Silver	60.76%	10%
Bronze	56.62%	15%
Highly Commended	53.51%	15%
Commended	50.59%	15%



British Biology Olympiad 2023

Paper 1

Duration: 45 minutes

Total marks: 81

Question 1

Part 1 of 5

Cockatoos in Sydney have begun to open suburban rubbish bins.



Sulphur-crested cockatoo opening a household bin (Barbara Klump/Max Planck Institute of Animal Behavior)

Part 2 of 5

What type of behaviour causes cockatoos to search for food?

1 mark

Choose *ONE*

- a) Reasoning
- b) Instinct
- c) Social Learning
- d) Habituation
- e) Reflex
- f) Imprinting

Part 3 of 5

Humans have started protecting their bins from the cockatoos.



Running shoes wedged into the hinge of the bin lid (Barbara Klump/Current Biology)

Part 4 of 5

What type of learning is this?

1 mark

Choose *ONE*

- a) Reasoning
- b) Instinct
- c) Social Learning
- d) Habituation
- e) Reflex
- f) Imprinting

Part 5 of 5

Some cockatoos figured out how to overcome the bin protections. They then shared this knowledge with other cockatoos in their neighbourhood. What type of learning is this?

1 mark

Choose *ONE*

- a) Reasoning
- b) Instinct
- c) Social Learning
- d) Habituation
- e) Reflex
- f) Imprinting

Question 2

Part 1 of 2

Are these true or false?

3 marks

Mark the following as *TRUE* or *FALSE*

a) Phototropism in plants involves the bending of plant organs towards, or away from, sources of light

TRUE FALSE

b) Plants require symbiotic bacteria to fix inorganic nitrogen from the atmosphere

TRUE FALSE

c) CAM photosynthesis involves the opening of stomata at night

TRUE FALSE

d) Apomixis (the generation of seeds without fertilisation) results in offspring that are genetically identical to the parent plant

TRUE FALSE

Part 2 of 2

Are these true or false?

3 marks

Mark the following as *TRUE* or *FALSE*

a) The process of digestion in animals involves the breakdown of food into smaller molecules that can be absorbed and used by the body

TRUE FALSE

b) All animals have a closed circulatory system for transporting blood

TRUE FALSE

c) Animals always reproduce sexually

TRUE FALSE

d) Thermoregulation involves a negative feedback loop to maintain body temperature

TRUE FALSE

e) Animal behaviours are always learnt

TRUE FALSE

Question 3

Part 1 of 4

Which of the following polymerisation reactions release H_2O ?

2 marks

Choose as many as appropriate

- a) Nucleotides to DNA
- b) Glucose to starch
- c) Amino acids to proteins
- d) Triglycerides to fatty acids

Part 2 of 4

Which of the following bonds break when heated to $100^{\circ}C$?

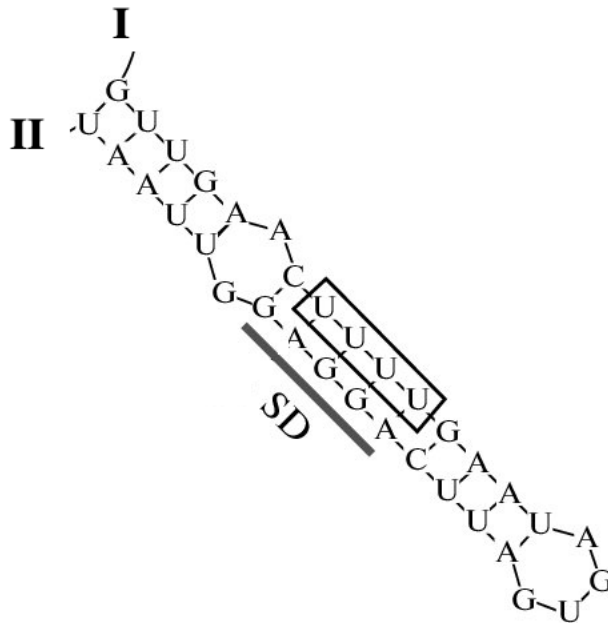
2 marks

Choose as many as appropriate

- a) Ionic
- b) Covalent
- c) Hydrogen
- d) Disulphide bridges
- e) Hydrophobic interactions

Part 3 of 4

Single-stranded mRNA can form secondary structures. One example of this is the 4U sequence in bacteria. The 4 uracils bind the Shine-Dalgarno sequence (AGGAGG) of mRNA. Usually, bacterial ribosomes bind to the Shine-Dalgarno sequence. This mRNA secondary structure is stable at 20°C but not at 40°C.



4U RNA secondary structure

Part 4 of 4

Are these true or false?

4 marks

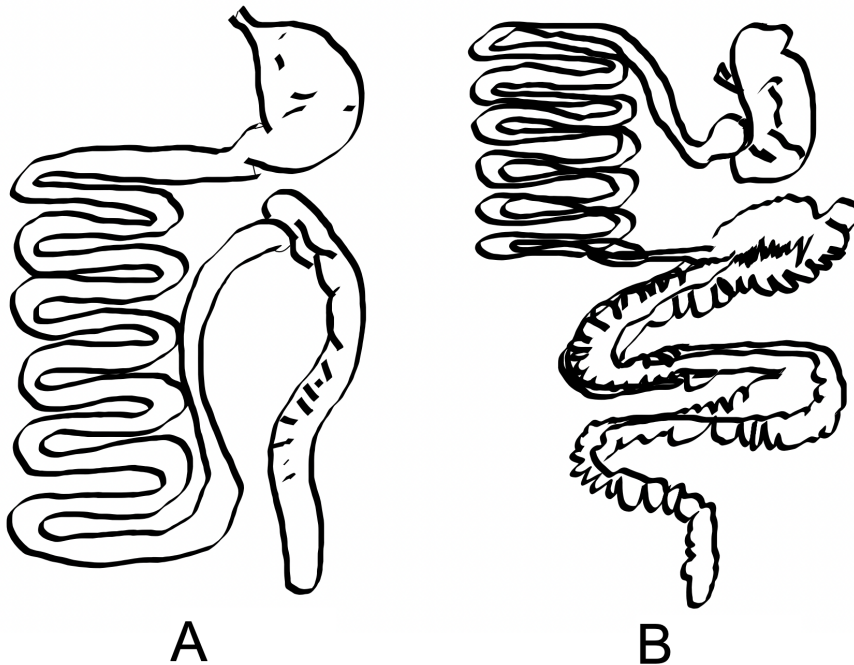
Mark the following as TRUE or FALSE

- a) RNA with a secondary structure is less likely to be damaged and broken down
- TRUE FALSE
- b) The 4U secondary structure acts as an RNA thermometer which prevents translation at low temperatures
- TRUE FALSE
- c) It is likely this mRNA codes for a heat shock protein
- TRUE FALSE
- d) Position I is 3' and position II is 5'
- TRUE FALSE
- e) Mutating the fourth U to a G would make the secondary structure more stable
- TRUE FALSE
- f) Mutating the Shine-Dalgarno sequence would strongly reduce translation
- TRUE FALSE
- g) Other RNA switches could form secondary structures which bind to particular metabolites
- TRUE FALSE

Question 4

Part 1 of 4

An animal's anatomy is closely linked with its lifestyle. For example, cows eat only poor-quality grass. Therefore, it has a large stomach to house bacteria to break down the grass.



Schematics of the digestive tract of two animal species

Part 2 of 4

Which of the following lifestyles are associated with A and B?

2 marks

Groups

Foregut-fermenter

Hindgut-fermenter

Carnivore

Put into the groups above

a) A

b) B

Part 3 of 4

Animal A, B, and a cow, each eat a sugar cube. Which animals would be able to absorb all the sugar into their blood? *Check all that apply*



By Michael Gäbler, CC BY 3.0, <https://commons.wikimedia.org/w/index.php?curid=9875161>

1 mark

Choose as many as appropriate

- a) A
- b) B
- c) Cow

Part 4 of 4

Are these true or false?

2 marks

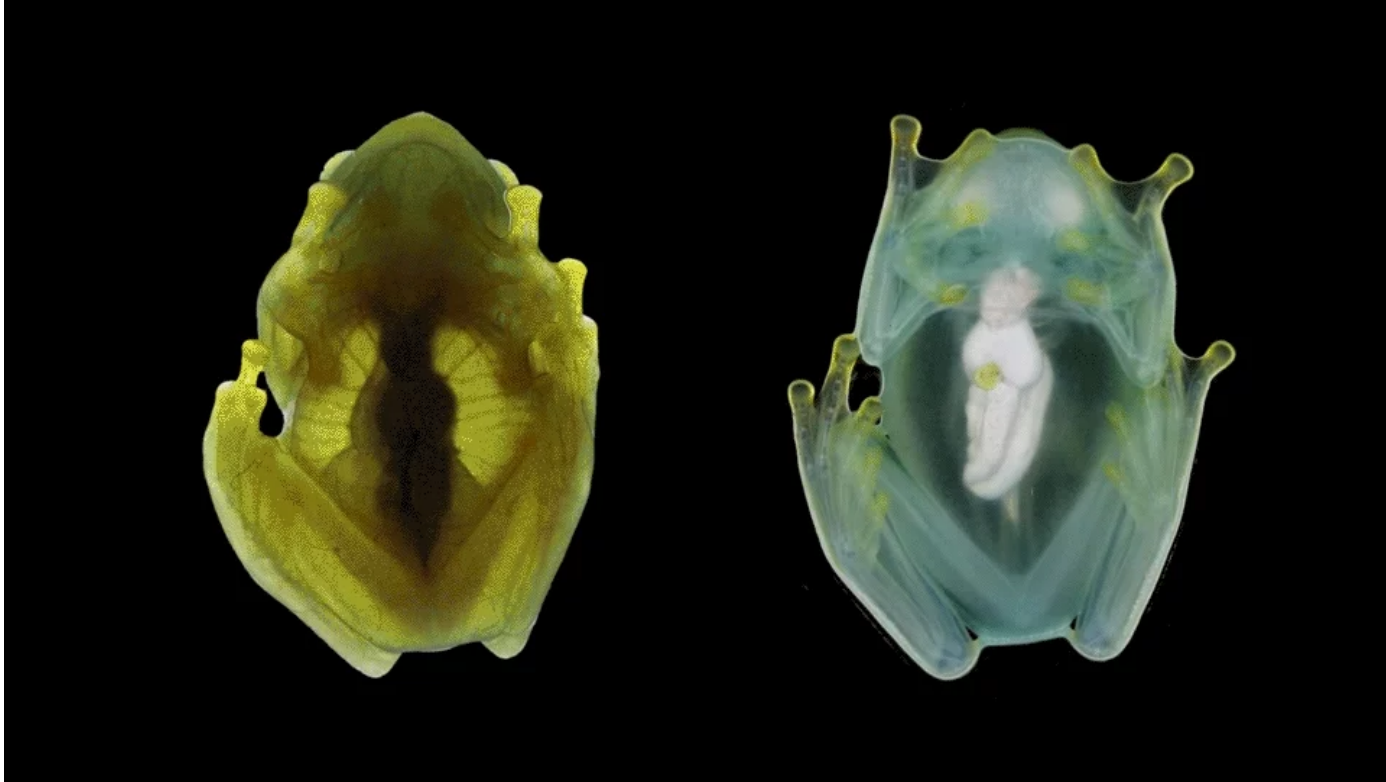
Mark the following as TRUE or FALSE

- a) Animal A would extract more nutrition from cooked food over uncooked food
TRUE FALSE
- b) Animal A may eat its faeces to gain extra nutrients
TRUE FALSE
- c) Animal B may eat its faeces to gain extra nutrients
TRUE FALSE
- d) Animal B prefers new plant shoots and buds to tough old leaves
TRUE FALSE

Question 5

Part 1 of 3

Glass frogs are famous for their ability to appear almost transparent, especially when sleeping. The recordings show a glass frog from underneath when it's awake (left) and asleep (right).



The Atlantic; Jesse Delia / American Museum of Natural History

Part 2 of 3

As frogs fall asleep, they condense almost all of their red blood cells into their liver, and coat their liver with a layer of shiny reflective crystals.

Part 3 of 3

Are these likely true or false?

3 marks

Mark the following as TRUE or FALSE

- a) Glass frogs probably sleep during the daytime.
TRUE FALSE
- b) Glass frog organs can probably survive prolonged periods without oxygen.
TRUE FALSE
- c) Glass frogs are probably warm blooded.
TRUE FALSE
- d) Glass frog blood is probably less able to clot than human blood.
TRUE FALSE
- e) The main reason glass frogs go transparent is probably to hide from predators.
TRUE FALSE

Question 6

Part 1 of 1

The proportion of each base in 5 different genome sequences (*i-v*) are given in the table.

	Proportion of sequence				
Base	A	T	C	G	U
i	0.22	0.28	0.18	0.32	0
ii	0.29	0.29	0.21	0.21	0
iii	0.32	0	0.26	0.12	0.3
iv	0.15	0.31	0.12	0.35	0.07
v	0	0	0.46	0.54	0

Which sequences are certainly from a virus (as opposed to another type of organism or a mistake)? 2 marks

Choose as many as appropriate

- a) i
- b) ii
- c) iii
- d) iv
- e) v

Question 7

Part 1 of 2

Equal lengths of three different blood vessels were threaded onto the horizontal arm of a retort stand. Weights were then hooked on the vessels until they broke.

Part 2 of 2

Predict the results of the experiment. *Match the vessel to the maximum weight it bore before snapping*

2 marks

Groups

800 g

3500 g

5000 g

Put into the groups above

- a) Vena Cava
- b) Aorta
- c) Pulmonary Artery



Question 8

Part 1 of 7

The following logic puzzles are based on **defining characteristics** and **shared traits** of branches of the tree of life. For example, vertebrate animals share many characteristics (pairs of appendages, spinal cords, digestive tract below backbone), some of which may be unique to them, but they are *defined* by having a backbone divided into jointed vertebrae.

Part 2 of 7

Mitochondria are to Eukaryotes as X are to plants. What is X?

1 mark

Choose *ONE*

- a) Cell walls
- b) Leaves
- c) Plastids (e.g. chloroplasts)
- d) Vacuoles
- e) Nuclei

Part 3 of 7

Milk glands are to mammals as X are to birds. What is X?

1 mark

Choose *ONE*

- a) Eggs
- b) Beaks
- c) Feathers
- d) Wings
- e) Warm bloodedness

Part 4 of 7

Mushrooms are to fungi as X are to plants. What is X?

1 mark

Choose *ONE*

- a) Roots
- b) Seed pods
- c) Flowers
- d) Leaves
- e) Chloroplasts

Part 5 of 7

Complete these analogies.

Part 6 of 7

Whales are to fish as X are to birds. What is X?

1 mark

Choose *ONE*

- a) Parrots
- b) Reptiles
- c) Eggs
- d) Bats
- e) Snakes

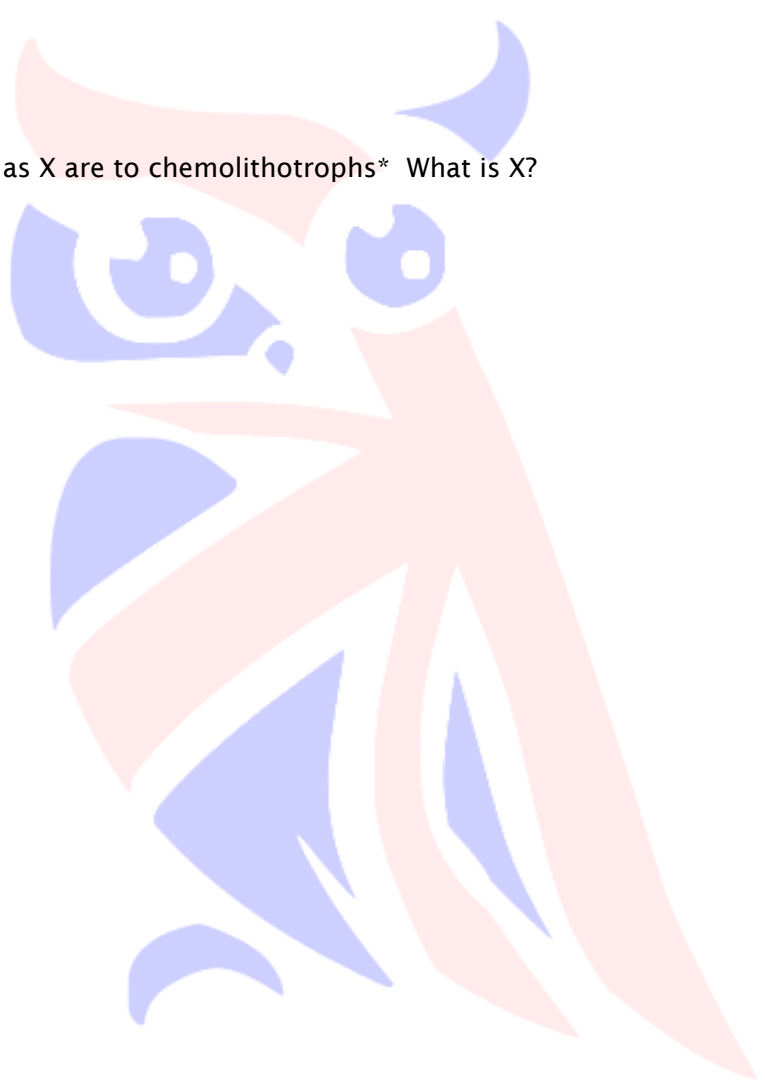
Part 7 of 7

Light is to plants as X are to chemolithotrophs What is X?

1 mark

Choose *ONE*

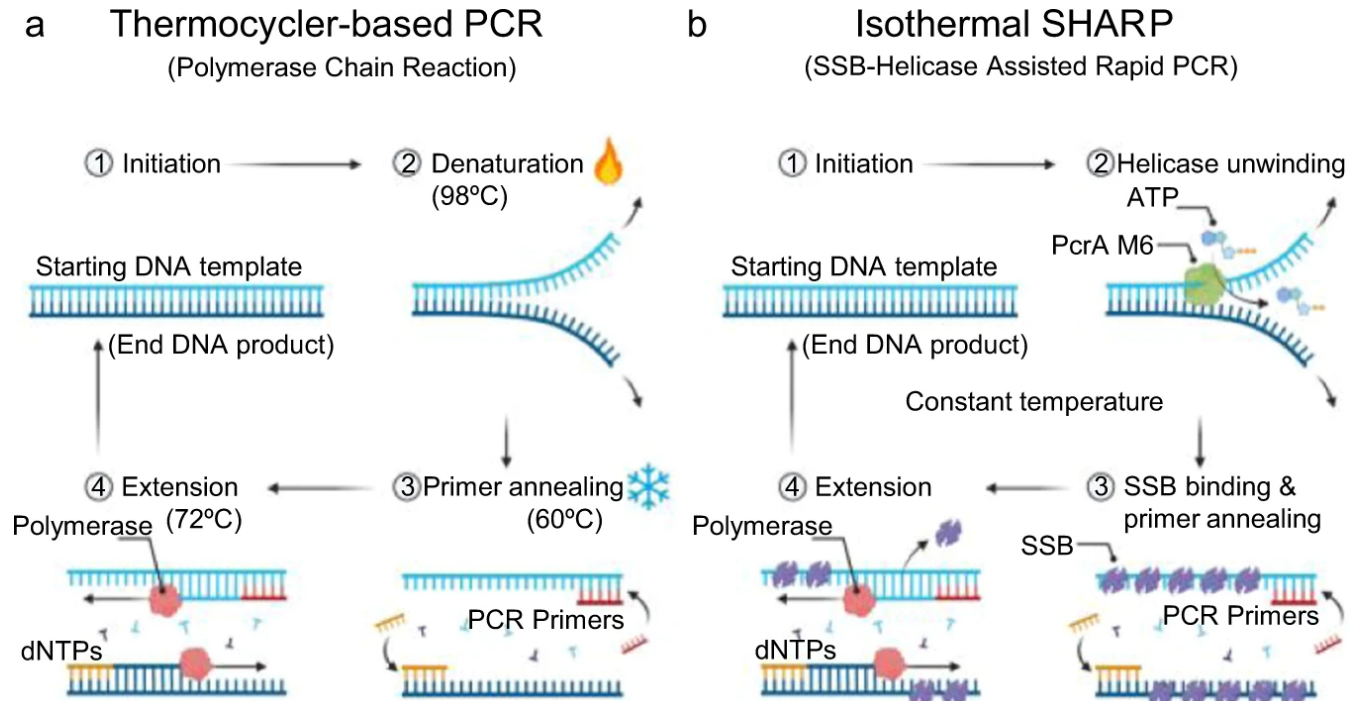
- a) Prey
- b) Water
- c) Heat
- d) Plants
- e) Rocks



Question 9

Part 1 of 2

PCR is a staple laboratory technique for the amplification of DNA. Recently, a new method for the amplification of DNA was invented which can be done at constant temperature in a single test tube. *Helicase is an enzyme, and SSB is 'single strand binding protein'.*



CC BY 4.0 Gavrilov et al 2022 <https://doi.org/10.1038/s41467-022-34076-0> Created with BioRender.com.

Part 2 of 2

3 marks

Groups

Traditional PCR

SHARP PCR

Both

Neither

Put into the groups above

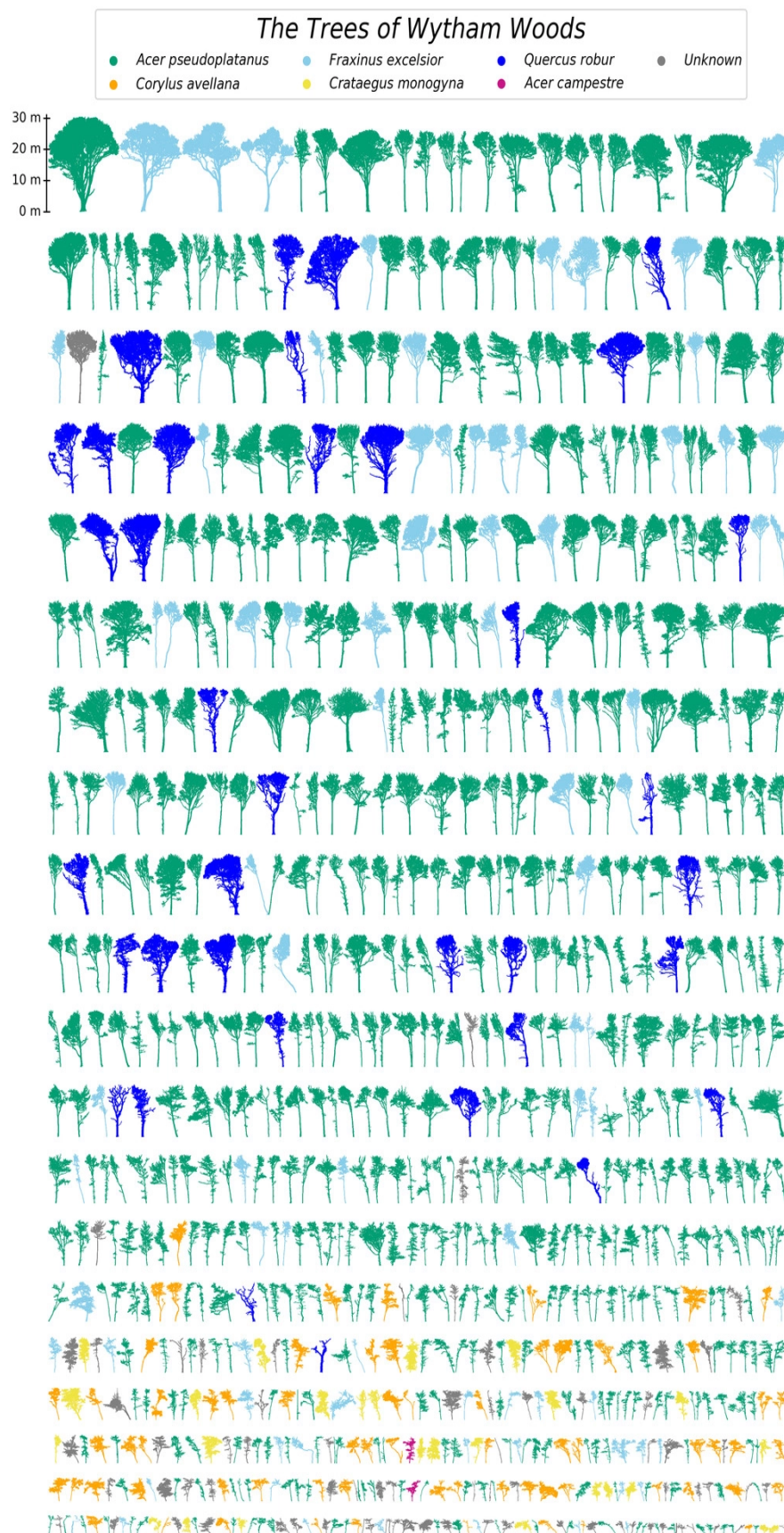
- Temperature is lowered to allow primer binding
- Requires ATP
- Amplification is semi-exponential
- Requires reverse- transcriptase
- Heat is used to separate double- stranded DNA
- SSB is used to keep DNA strands separated

Question 10

Part 1 of 11

Ecologists used laser scanning and 3D reconstruction (LIDAR) to non-destructively measure the size of every tree in an Wytham Woods, Oxford. Overall, they found 815 trees within the 1.4 ha study area.





CC BY 4.0 Calders et al 2022 <https://doi.org/10.1002/2688-8319.12197>

Part 2 of 11

Which species has the tallest tree?

1 mark

Choose *ONE*

- a) Acer pseudoplatanus (Sycamore)
- b) Fraxinus excelsior (Ash)
- c) Corylus avellana (Hazel)
- d) Quercus robur (Oak)
- e) Crataegus monogyna (Hawthorn)
- f) Acer campestre (Field maple)

Part 3 of 11

Which species is most likely to be shade tolerant?

1 mark

Choose *ONE*

- a) Acer pseudoplatanus (Sycamore)
- b) Fraxinus excelsior (Ash)
- c) Quercus robur (Oak)
- d) Crataegus monogyna (Hawthorn)

Part 4 of 11

Which species is most likely to be a main source of food for deer?

1 mark

Choose *ONE*

- a) Acer pseudoplatanus (Sycamore)
- b) Fraxinus excelsior (Ash)
- c) Quercus robur (Oak)
- d) Crataegus monogyna (Hawthorn)

Part 5 of 11

Which species is likely to be the main food source for caterpillars?

1 mark

Choose *ONE*

- a) Acer pseudoplatanus (Sycamore)
- b) Fraxinus excelsior (Ash)
- c) Corylus avellana (Hazel)
- d) Quercus robur (Oak)
- e) Crataegus monogyna (Hawthorn)
- f) Acer campestre (Field maple)

Part 6 of 11

Does *Fraxinus excelsior* or *Quercus robur* have a greater **range** in height?

1 mark

Choose **ONE**

- a) *Fraxinus excelsior*
- b) *Quercus robur*

Part 7 of 11

The data in the graphic can also be displayed as a table.

```
**Species**|**Count**  
:-----|:-----:  
Acer pseudoplatanus |532  
Fraxinus excelsior |84  
Corylus avellana |67  
Quercus robur |35  
Crataegus monogyna |24  
Acer campestre |2  
Unknown|71
```

This data can be used to calculate the Simpson's Diversity Index. Simpson's

Diversity is a measure of diversity within an ecosystem which takes into account both richness and evenness.

Simpson's Diversity is calculated as

$$\text{Simpson's Diversity Index} = \sum (n/N)^2$$

Simpson's Diversity Index

Part 8 of 11

where n is the number of individuals in a species, and N is the total number of individuals.
Treat unknown as a single species for this particular example

Part 9 of 11

What is the Simpson's Diversity Index of Wytham Woods to **three significant figures**?

3 marks

Write something below

Part 10 of 11

Would the Simpson's Diversity Index increase or decrease, if unknown was composed of two species not one?

1 mark

Choose **ONE**

- a) Increase
- b) Decrease
- c) Depends on the ratio of individuals in the two species

Part 11 of 11

What would Simpson's Diversity Index tend to when the number of different species becomes extremely large? *Type a number*

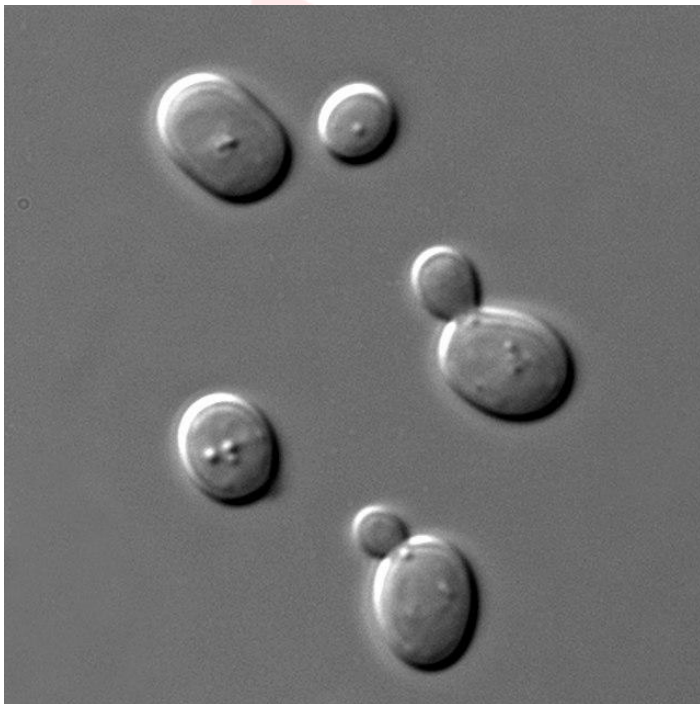
1 mark

Write something below

Question 11

Part 1 of 9

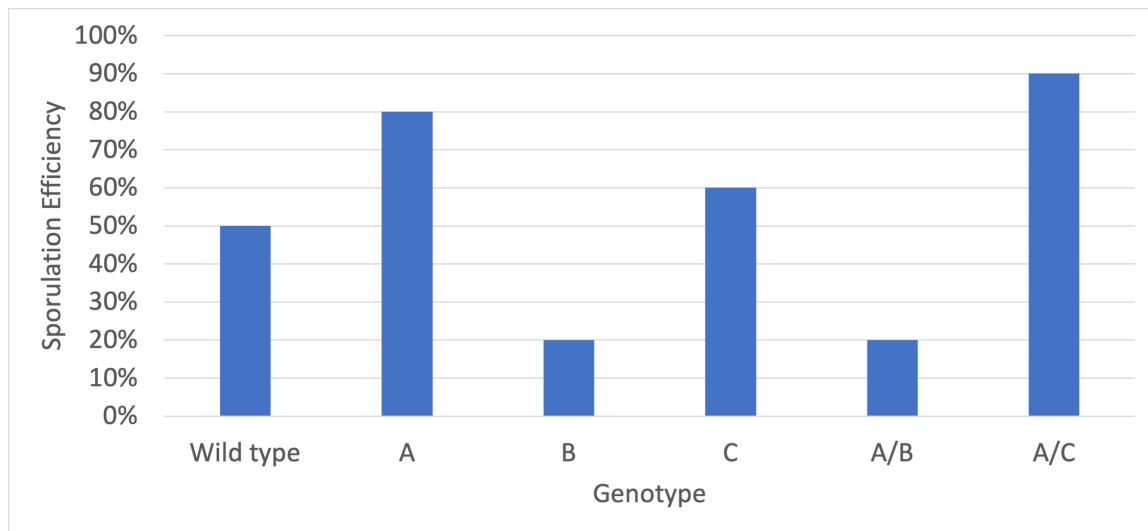
Baker's yeast (*Saccharomyces cerevisiae*) sporulates in response to nutrient deprivation. The fraction of cells that sporulate in a culture, called the sporulation efficiency, varies heritably among yeast strains. For example, the best-studied laboratory strain, S288c, is a notoriously poor sporulator, so most studies of sporulation employ the efficient sporulator, SK1.



Saccharomyces cerevisiae

Part 2 of 9

Scientists found three mutations which affected sporulation efficiency. One mutant (A) stopped the production of the protein RME1, and two mutations (B & C) affected IME1. A - RME1 Knockout B - IME1 Knockout C - IME1 Protein structural change



Sporulation efficiency for mutant yeast and some combinations

Part 3 of 9

For each mutation, decide whether the mutation increased, decreased or had no effect on sporulation

1 mark

Groups

Increased

Decreased

Had no effect

Put into the groups above

- a) C
- b) A
- c) B

Part 4 of 9

Which unmutated proteins increase, decrease or have no effect on sporulation?

1 mark

Groups

Increase

Decrease

No effect

Put into the groups above

- a) RME1
- b) IME1

Part 5 of 9

Does RME1 work upstream, downstream or in a different pathway to IME1?

1 mark

Choose ONE

- a) Upstream
- b) Downstream
- c) In a different pathway

Part 6 of 9

What do you expect the sporulation efficiency of a combined B/C mutant plant to be? *Give an answer in numerals. The unit is % (it doesn't matter whether you type the unit)*

1 mark

Write something below

Part 7 of 9

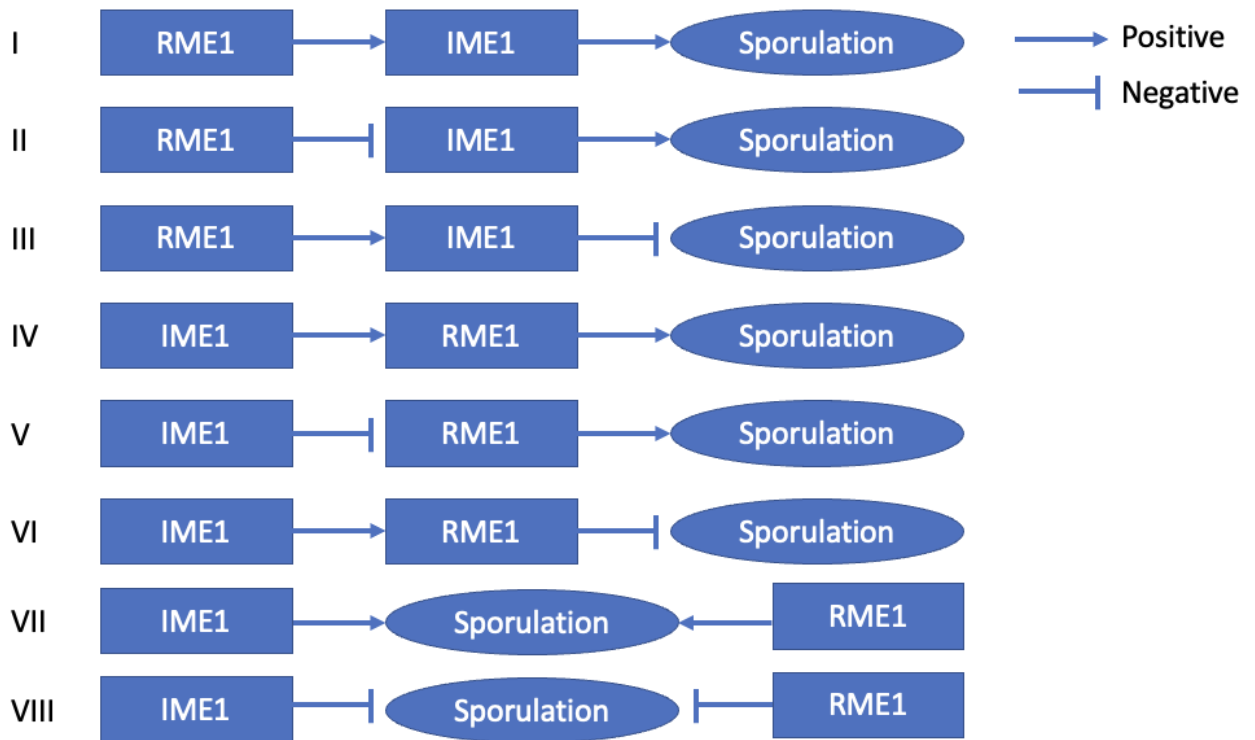
What do you expect the sporulation efficiency of a combined A/B/C mutant to be? *Give an answer in numerals. The unit is % (it doesn't matter whether you type the unit)*

2 marks

Write something below

Part 8 of 9

Which of the following genetic diagrams show the pathway of sporulation?



1 mark

Choose *ONE*

- a) I
- b) II
- c) III
- d) IV
- e) V
- f) VI
- g) VII
- h) VIII

Part 9 of 9

Which of the following is the most likely genotype of S288c?

1 mark

Choose *ONE*

- a) Wild type
- b) A/B
- c) C

Question 12

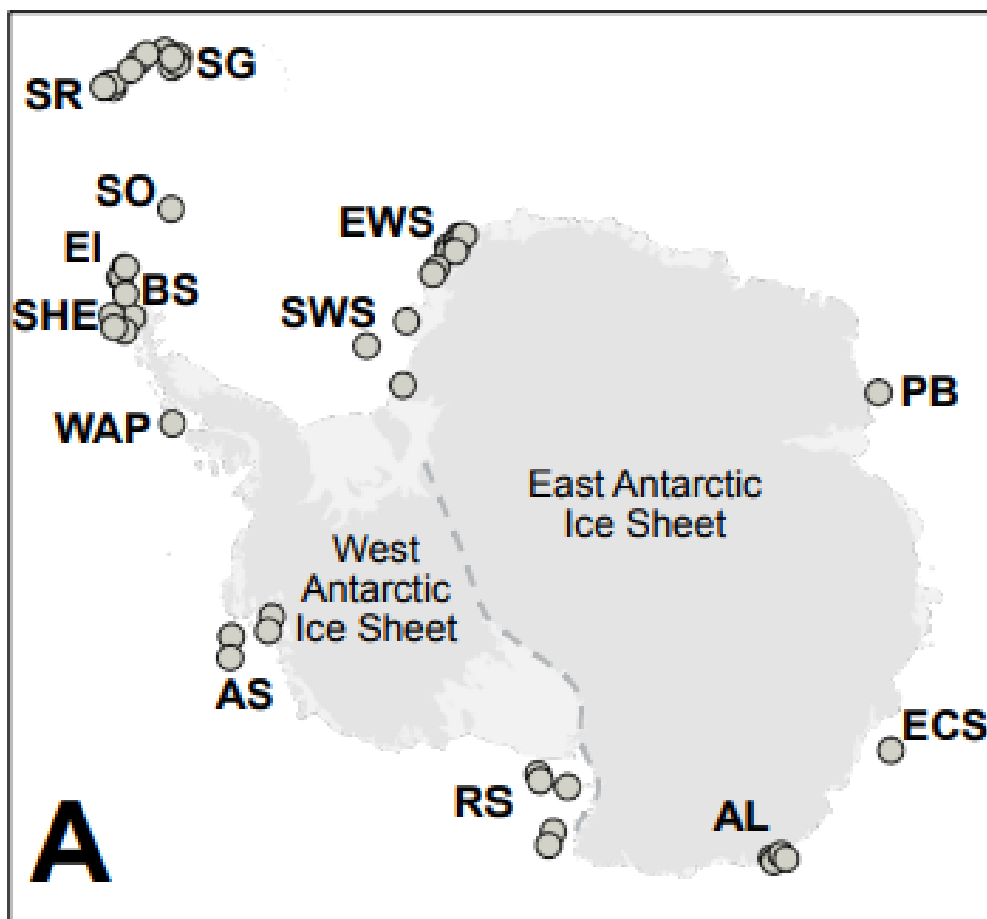
Part 1 of 7

The Royal Research Ship (submarine) *Boaty McBoatface* is exploring the underside of Thwaites glacier in Amundsen Sea in West Antarctica. This 'doomsday glacier' has become highly unstable, and the focus of global concern. The collapse of Thwaites glacier would raise sea-levels 0.9 m within decades, devastating coastal ecosystems. However, it also braces the entire West Antarctic ice sheet against flowing into the sea.

Following the loss of Thwaites glacier, it would take centuries for the West Antarctic ice sheet itself to collapse into the sea, but the process would be irreversible and raise sea levels by >3 m. Scientists are debating whether the West Antarctic ice sheet collapsed 125000 years ago when temperatures were last as hot as they are today. The enormous weight of ice in Antarctica pushes the ground below sea level, so if the ice melts, channels of water can link distant parts of the continent. Turquet's Octopus (*Pareledone turqueti*) has populations scattered around the coastline of Antarctica. Scientists collected genome sequences of octopi from each population and produced a statistical model of the size of each population through time, and the rate of interbreeding between each population.

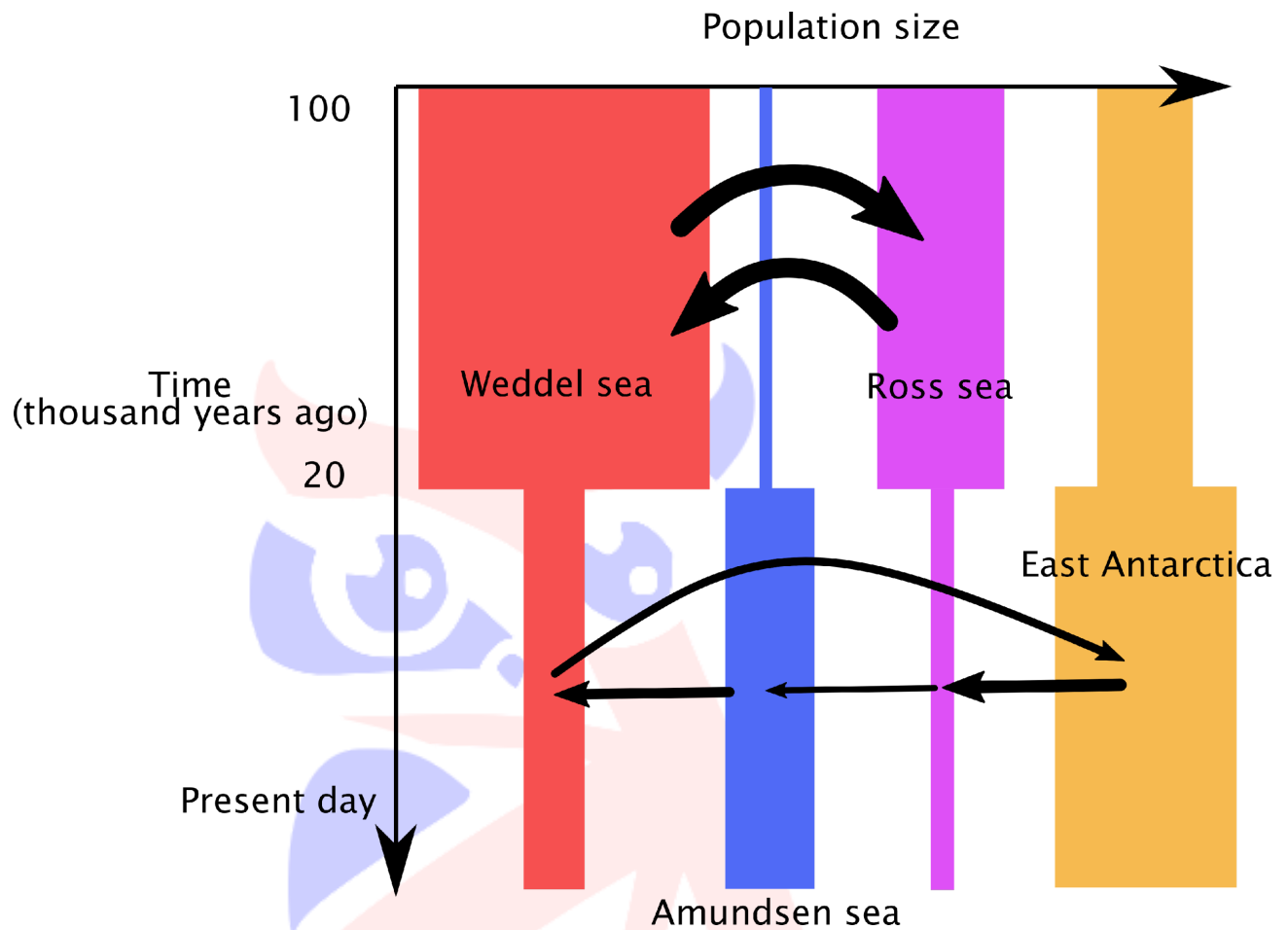
Part 2 of 7

Dots show Octopi populations SWS = South Weddel Sea AS = Amundsen Sea RS = Ross Sea



Part 3 of 7

The output of the model is shown below. Arrows show the direction of allele flow. Arrow thickness shows the rate of allele flow.



Part 4 of 7

2 marks

Mark the following as *TRUE* or *FALSE*

- The West Antarctic ice sheet was likely melted ~100,000 years ago.
TRUE FALSE
- Currents currently circulate mostly anticlockwise around the Antarctic coast.
TRUE FALSE
- The octopi prefer to travel through very deep oceanic water than shallow costal water.
TRUE FALSE
- The octopi are better adapted to the warmer oceans of the past.
TRUE FALSE
- Octopi in the Weddel Sea and Ross Sea are likely to look more similar today than they did in the past.
TRUE FALSE

Part 5 of 7

Scientists discovered bacteria and animals living on rocks under 1 km ice floating on 500 m ocean, and ~150 miles from the edge of the ice shelf.

Part 6 of 7

What are the organisms in this food chain likely to be? *Check all that apply*

1 mark

Choose as many as appropriate

- a) Primary producers
- b) Detritivores
- c) Herbivores
- d) Carnivores
- e) Warm blooded (endotherms)

Part 7 of 7

What adaptations do animals adapted to extreme-cold tend to have, compared to animals in tropical climates? *Sort them into those associated with warm-blooded or cold-blooded animals, or neither*

3 marks

Groups

Warm-blooded

Cold-blooded

Neither

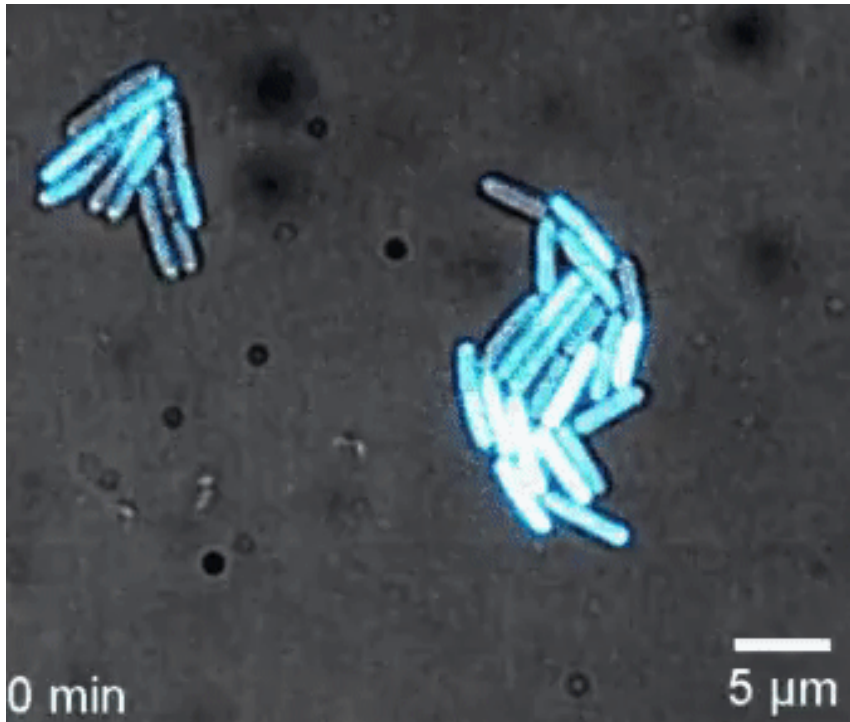
Put into the groups above

- a) Travelling long distances for food
- b) Lower oxygen carrying capacity of blood
- c) Huddling
- d) Lower metabolic rate
- e) Hibernation
- f) Thick fur / blubber
- g) Faster generation times

Question 13

Part 1 of 10

Bacteria (*Bacillus subtilis*) were treated with a chemical which changes their membrane properties when stimulated with laser light. When pulsed with light, the membrane rapidly depolarises (as seen with blue colouring in the video). The membrane then rapidly repolarises. *B. subtilis* normally lives in the soil and guts of mammals.



CC BY 4.0 de Souza Guerreiro et al 2023 <https://doi.org/10.1002/advs.202205007>

Part 2 of 10

How frequently was the light pulsed?

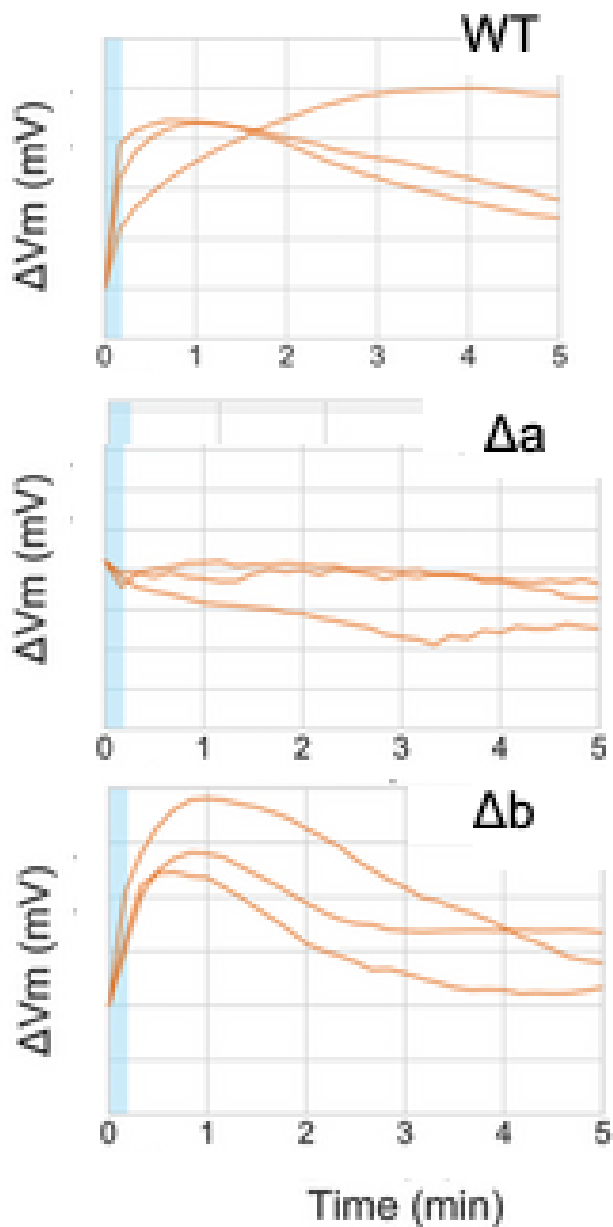
1 mark

Choose *ONE*

- a) 1 minute
- b) 5 minutes
- c) 10 minutes
- d) 20 minutes
- e) 30 minutes
- f) 60 minutes

Part 3 of 10

The scientists wanted to see which channels were important for response to light stimulation. They looked at two mutant bacteria which had Gene A (Δa) or Gene B (Δb) deleted.



CC BY 4.0 de Souza Guerreiro et al 2023 <https://doi.org/10.1002/adv.202205007>

Part 4 of 10

Which genes were required for response to light?

1 mark

Choose as many as appropriate

a) ☐ a

b) ☐ b

Part 5 of 10

Roughly how long does it take for *Bacillus subtilis* to divide?

3 marks

Choose ONE

a) ☐ 15 minutes

- b) 30 minutes
- c) 45 minutes
- d) 60 minutes
- e) 75 minutes
- f) 90 minutes

Part 6 of 10

This experiment was carried out at room temperature (22°C). What effect would repeating it at 37°C have?

1 mark

Choose ONE

- a) Faster cell division
- b) Slower cell division
- c) No change on cell division
- d) No cell division

Part 7 of 10

This experiment was carried out at room temperature (22°C). What effect would repeating it at 70°C have?

1 mark

Choose ONE

- a) Faster cell division
- b) Slower cell division
- c) No change on cell division
- d) No cell division

Part 8 of 10

This experiment was carried out at room temperature (22°C). What effect would repeating it at 37°C have?

1 mark

Choose ONE

- a) Faster repolarisation
- b) Slower repolarisation
- c) No change on polarisation

Part 9 of 10

Assume membrane polarisation in *B. subtilis* is controlled similarly to human neurons.

1 mark

Choose ONE

- a) The light pulses cause sodium ion channels to briefly open quickly
- b) The light pulses cause sodium ion channels to briefly open slowly
- c) The light pulses cause sodium ion channels to briefly shut

- d) The light pulses cause sodium/potassium ATPase to turn on

Part 10 of 10

Assume membrane polarisation in *B. subtilis* is controlled similarly to human neurons.

1 mark

Choose *ONE*

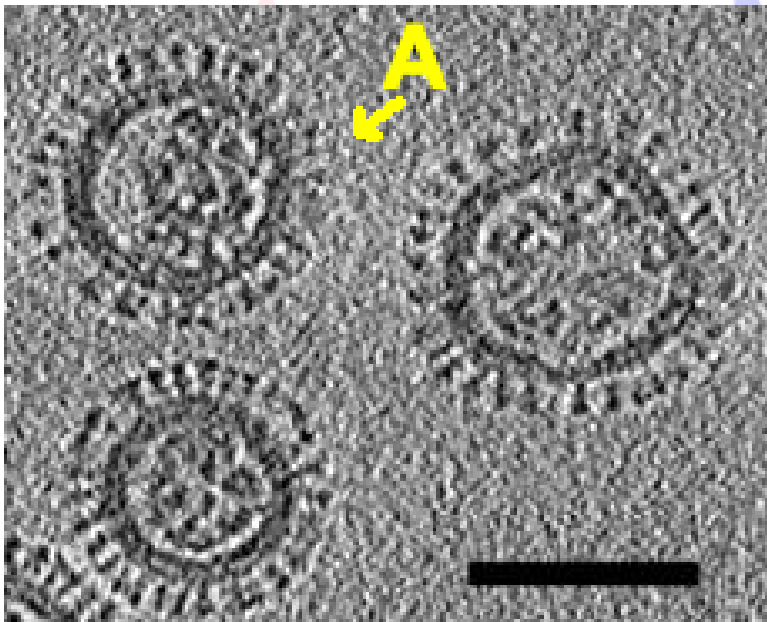
- a) The light pulses cause potassium ion channels to briefly open quickly
- b) The light pulses cause potassium ion channels to briefly open slowly
- c) The light pulses cause potassium ion channels to briefly shut
- d) The light pulses cause sodium/potassium ATPase to turn **off**



Question 14

Part 1 of 7

Pandemic flus are frequently caused by the recombination of human and avian strains of flu. Flu can be classified by the hemagglutinin (H) and neuraminidase (N) proteins. For example, two human flus are: H1N1 and H3N1. * Hemagglutinin binds to receptors on host cells. It is the spikes on the image below. * Neuraminidase is an enzyme which helps viral entry and allows daughter virus to be released by cutting the receptors hemagglutinin binds to. Generally, bird flu cannot infect humans and vice versa. This is fortunate, as a pandemic bird flu is currently devastating many species of birds. Up to 2/3 of British seabirds have died over the past year, and poultry has been in a strict lockdown for months. Flu virions contain 8 genetic strands, each encoding different proteins. When a cell is infected with two strains, these are combined into daughter virions randomly. Below is an electron micrograph of influenza virion (scale bar: 100 nm).



Scale bar: 100 nm. Influenza virions from Harris et al 2006

Part 2 of 7

What is the diameter of the flu viron labelled A?

1 mark

Choose *ONE*

- a) 10 nm
- b) 50 nm
- c) 100 nm
- d) 150 nm
- e) 200 nm
- f) 100 μ m

Part 3 of 7

There are 18 types of Hemagglutinin and 11 types of Neuraminidase. How many different H/N combinations can there be? *Type an answer in Arabic numerals*

2 marks

Write something below

Part 4 of 7

Two flu virions which share none of the same genetic strands invade the same cell. How many different genotypes can the daughter virions have? Assume there is no 'crossing over'.
Type an answer in Arabic numerals

2 marks

Write something below

Part 5 of 7

Flu receptor proteins are glycosylated (have sugars attached). * Human viruses bind to SA α 2,6-Gal linked receptors. * Avian viruses tend to bind to SA α 2,3-Gal linked receptors. * Mink, ferrets and pigs can be infected by both human and avian viruses



A National Trust ranger in the UK clears dead puffins

Part 6 of 7

Sort the animals into the receptor groups

2 marks

Groups

Only SA α 2,6-Gal

Only SA α 2,3-Gal

Both SA α 2,6-Gal and SA α 2,3-Gal

Neither

Put into the groups above

a) Pig

b) Ferret

- c) Humans
- d) Mink
- e) Birds

Part 7 of 7

Are these true or false?



3 marks

Mark the following as TRUE or FALSE

- a) Bird flu pandemics are more likely to spread directly into humans than via intermediate animals (such as mink)
 - TRUE
 - FALSE
- b) Bird flu adaptation to humans requires adaptation of hemagglutinin
 - TRUE
 - FALSE
- c) Bird flu adaptation to humans requires adaptation of neuraminidase
 - TRUE
 - FALSE
- d) Hemagglutinin is the best target for antibodies which 'neutralise' flu particles
 - TRUE
 - FALSE
- e) Neuraminidase is a good target for drugs against flu
 - TRUE
 - FALSE

British Biology Olympiad 2023

Paper 2

Duration: 45 minutes

Total marks: 84

Question 1

Part 1 of 2

In a healthy person, when glucose levels are high, what are the levels of each of these factors?

2 marks

Groups

High

Low

Put into the groups above

- a) Glycogen synthase activity
- b) Insulin
- c) Glucagon levels
- d) Lipase activity
- e) Glycogen phosphorylase activity

Part 2 of 2

Some people have tumours made of pancreatic beta cells. In these patients, what are the levels of each of these factors?

3 marks

Groups

High

Low

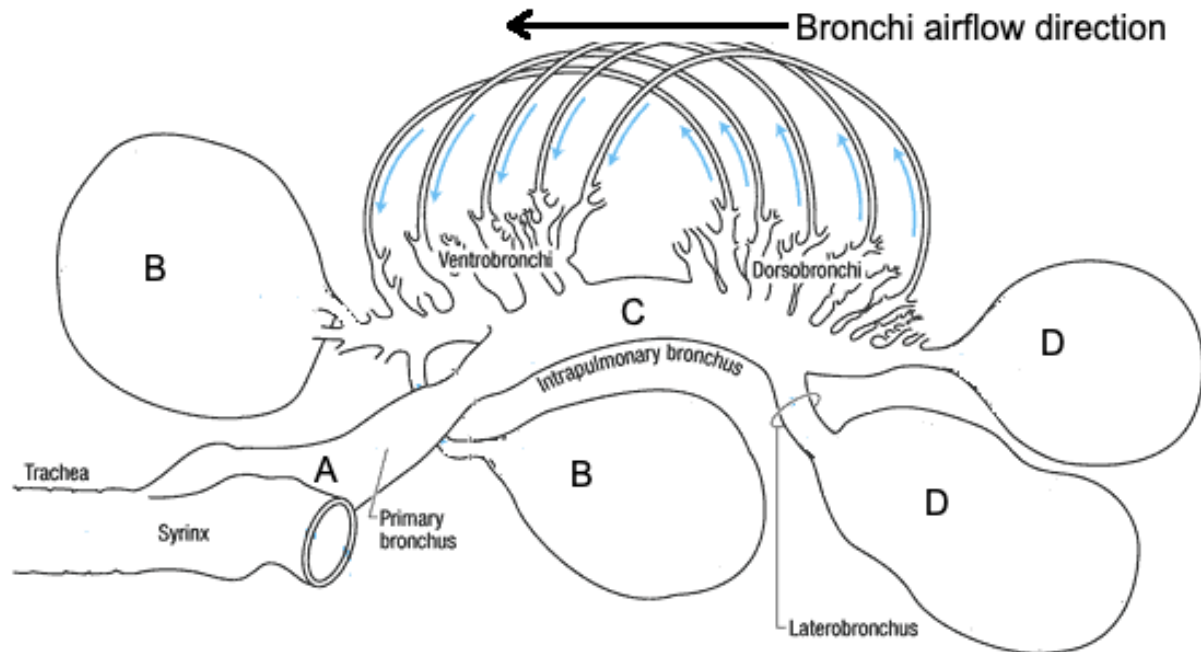
Put into the groups above

- a) Glucose levels
- b) Glucagon levels
- c) Glycogen phosphorylase activity
- d) Lipase activity
- e) Glycogen synthase activity
- f) Insulin

Question 2

Part 1 of 3

The anatomy of bird lungs is very different to that of mammals. Birds have unidirectional flow of air through the bronchi. Similar to humans, birds have a two-step breathing (in through the beak and then out through the beak).



Gary Ritchison, Eastern Kentucky University

Part 2 of 3

For each position in the diagram, sort them into the appropriate group.

3 marks

Groups

Only fresh air

Only 'spent' air

A mix of air

Put into the groups above

- a) B
- b) D
- c) A
- d) Human alveoli

Part 3 of 3

Are these true or false?

2 marks

Mark the following as TRUE or FALSE

- a) Birds can extract more oxygen for each ml of air inhaled than mammals

TRUE FALSE

- b) Birds require valves to control the direction of airflow within their lungs

TRUE FALSE

c) The direction of blood flow alongside the bronchi will be in the same direction as the air

TRUE FALSE



Question 3

Part 1 of 7

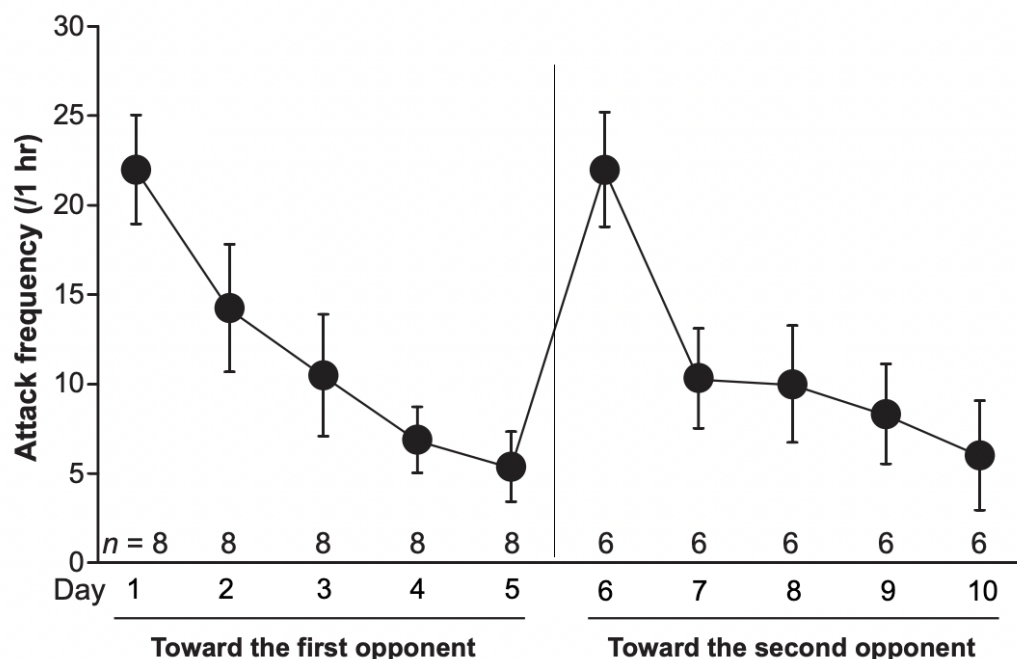
The cleaner fish, **Labroides dimidiatus**, uses visual cues to identify between different individual members within social groups. Kohda and colleagues looked at aggressive fish behaviours (rushing, bumping and biting) with other fish and images of themselves with and without mirrors.



CC BY 4.0 Kohda et al 2023 <https://doi.org/10.1073/pnas.2208420120>

Part 2 of 7

First, the scientists carried out a "dear enemy experiment" to see whether a cleaner fish habituated to a neighbour.



Cleaner fish aggression to a neighbour over time (CC BY 4.0 Kohda et al 2023
<https://doi.org/10.1073/pnas.2208420120>)

Part 3 of 7

3 marks

Mark the following as *TRUE* or *FALSE*

a) Cleaner fish can recognise their neighbour

TRUE FALSE

b) Cleaner fish become less aggressive to their neighbour when they get used to their company

TRUE FALSE

c) Cleaner fish become less aggressive to all other fish when they get used to company

TRUE FALSE

d) Cleaner fish get less aggressive as they get older

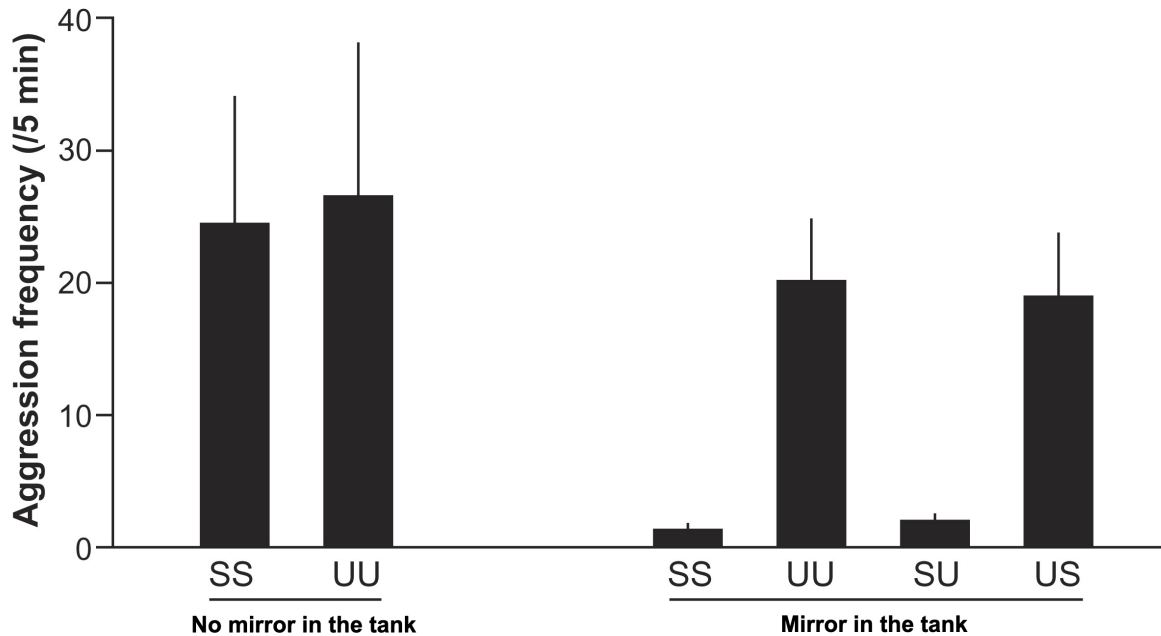
TRUE FALSE

e) Cleaner fish adapt to having a new neighbour more quickly after having had one before

TRUE FALSE

Part 4 of 7

Next, the scientists wanted to know if the cleaner fish could recognise themselves. They showed the fish pictures of themselves and counted the aggressive behaviours shown (if any). The pictures were made up of two halves (head and body) and each half could either be of themselves or an unknown fish: | Key | Head | Body | -- | ----- | ----- | SS | Self | Self | SU | Self | Unknown | US | Unknown | Self | UU | Unknown | Unknown | Finally, they looked at two sets of fish, those who had a mirror in their tank and those who did not.



Cleaner fish aggression to a photo (CC BY 4.0 Kohda et al 2023
<https://doi.org/10.1073/pnas.2208420120>)

Part 5 of 7

What can we ascertain for certain from the data above only?

4 marks

Mark the following as *TRUE* or *FALSE*

a) Cleaner fish attack unknown fish

TRUE FALSE

b) Cleaner fish know what they look like without a mirror

TRUE FALSE

c) With a mirror, cleaner fish recognise themselves as familiar

TRUE FALSE

d) With a mirror, cleaner fish recognise themselves as themselves

TRUE FALSE

e) Cleaner fish can recognise their own body

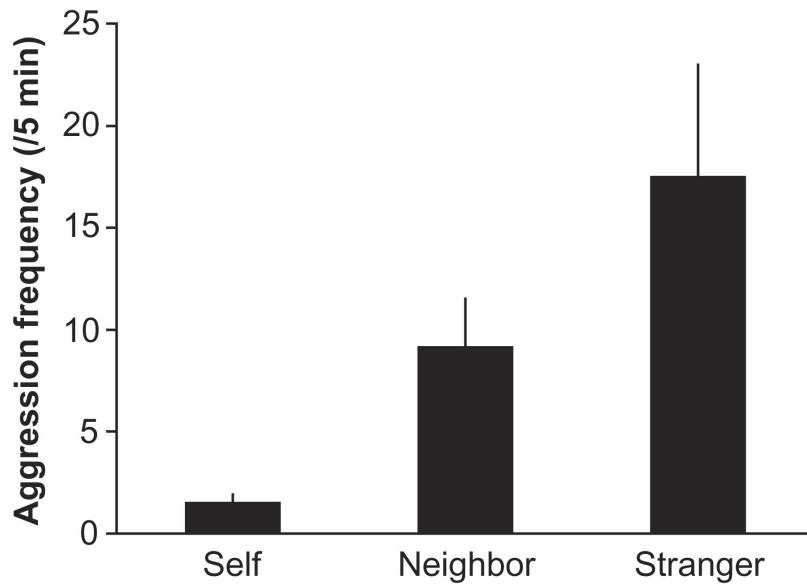
TRUE FALSE

f) Cleaner fish use facial features for recognition

TRUE FALSE

Part 6 of 7

Finally, the scientists wanted to know whether the cleaner fish could tell themselves in the mirror apart from familiar neighbours. They presented fish with mirrors in their tanks three photos: one of themselves, one of a neighbour and one of an unknown fish (stranger).



Cleaner fish aggression to photos (CC BY 4.0 Kohda et al 2023
<https://doi.org/10.1073/pnas.2208420120>)

Part 7 of 7

Do cleaner fish have self-recognition or do they think the fish in the mirror is just a neighbour?

1 mark

Choose ONE

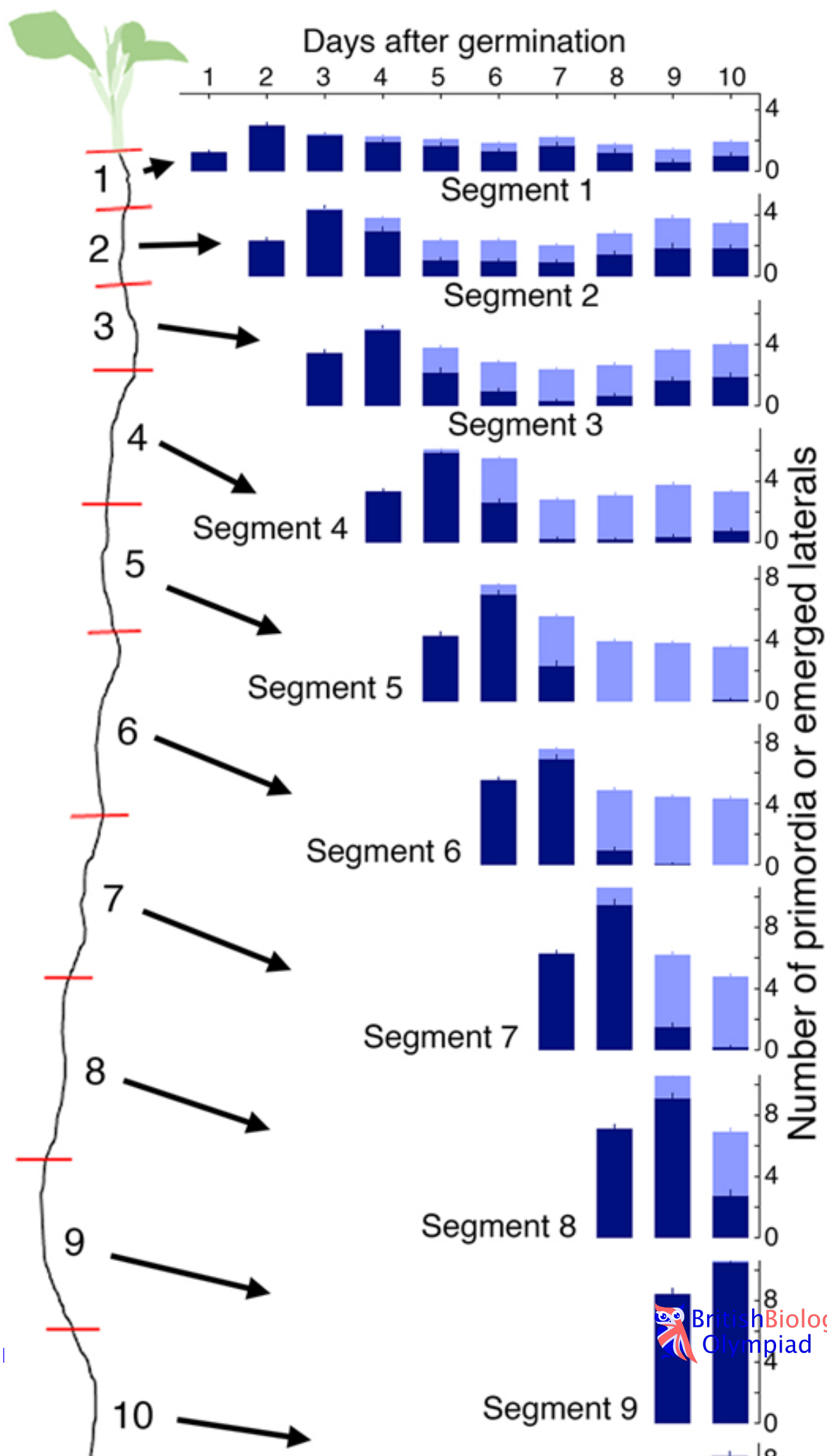
- a) Self-recognition
- b) Neighbour

Question 4

Part 1 of 5

Root anatomy changes as plants mature. As roots grow, lateral roots grow from the primary (roots). Many lateral roots can grow from one primary root, and each lateral root grows from a single primordium. A primordium can be thought of as a lateral root bud. To study plant root growth, scientists grew *Arabidopsis thaliana* plants for 10 days. Each day they marked how far the root grew, and how many root primordia there were within each days' growth. Every day they checked whether or not the primordia had developed into lateral roots.





Part 2 of 5

At the end of the experiment, how old were the cells found in segment 7 of the root?(Give your answer in Arabic numerals)

1 mark

Write something below

Part 3 of 5

Are these true or false?

4 marks

Mark the following as TRUE or FALSE

a) The root grew quicker on day 9 than it did on day 2

TRUE FALSE

b) Root primordia can only be created and not destroyed

TRUE FALSE

c) Root primordia are guaranteed to eventually become lateral roots

TRUE FALSE

d) Lateral roots require at least 24h to emerge from primordia

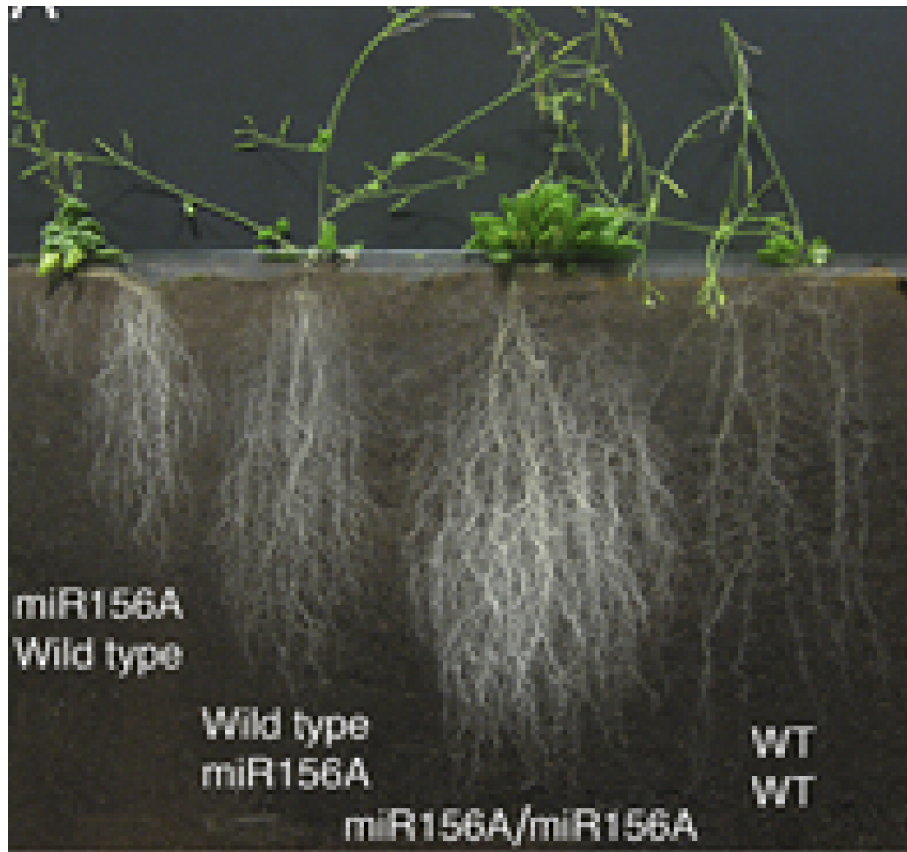
TRUE FALSE

e) At the end of the experiment, there were more lateral roots in segment 6 than segment 4

TRUE FALSE

Part 4 of 5

To study how a gene **miR156A** affects plant development, scientists then created an **Arabidopsis** plant which did not contain the **miR156A** gene. In a technique called grafting, plants are cut in half and different genotypes are re-attached between roots (stock) and shoots (scion). In the figure below, the first name describes the scion and the second name describes the stock. WT are wild-type plants, and *miR156A* are **miR156A** mutant plants.



CC BY 4.0 Laskowski et al 2022 <https://doi.org/10.1242/dev.199871>

Part 5 of 5

Are these true or false?

3 marks

Mark the following as *TRUE* or *FALSE*

a) The miR156A gene increases root growth

TRUE FALSE

b) miR156A must be expressed in the roots to change root development

TRUE FALSE

c) The severity of the effect of *miR156A* mutations varies with the amount of miR156A made

TRUE FALSE

d) miR156A is also involved in leaf development

TRUE FALSE

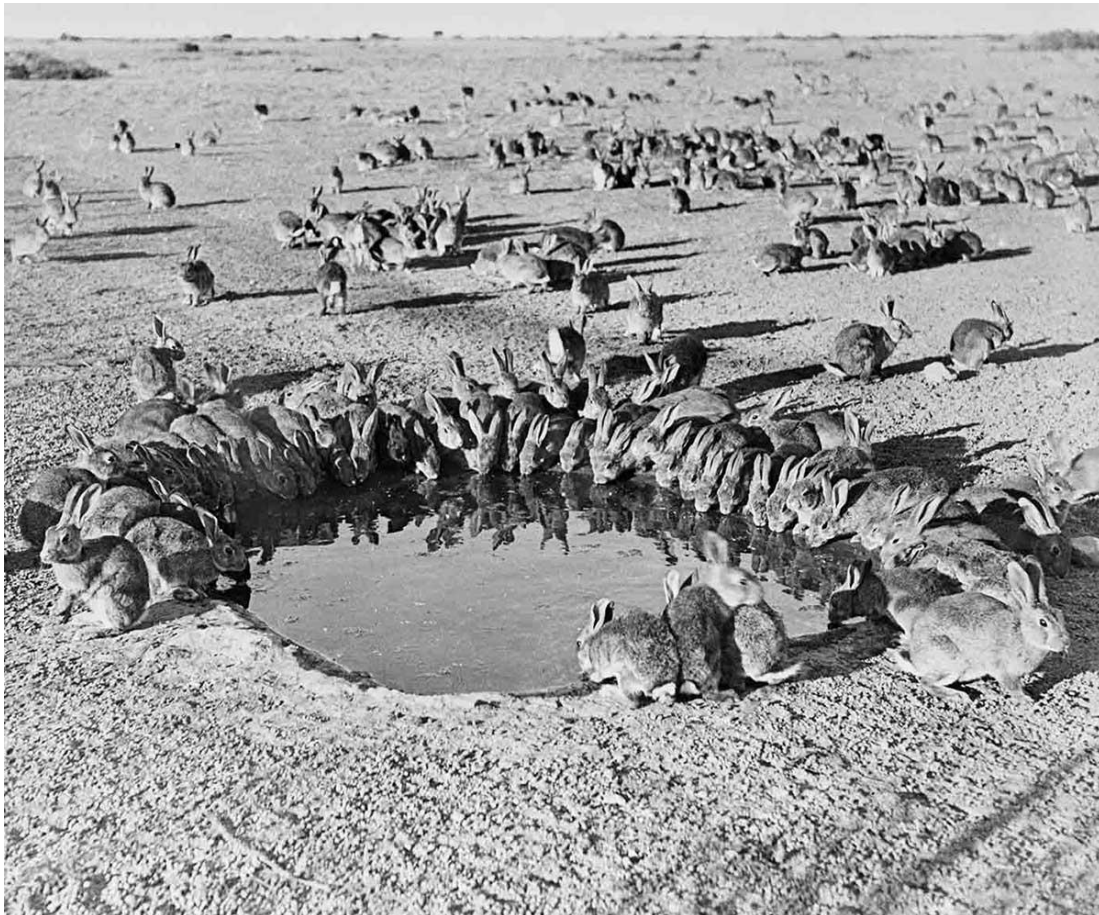
e) Plants with no miR156A could have more lateral root primordia

TRUE FALSE

Question 5

Part 1 of 10

Rabbits were originally only wild in Spain and France. The Romans domesticated French rabbits, and introduced them to Britain (and the rest of Europe). During the Imperial era, rabbits were introduced to Australia. Rabbits spread across Australia explosively, causing catastrophic damage to Australian habitats. Scientists in Cambridge investigated where feral Australian rabbits came from.



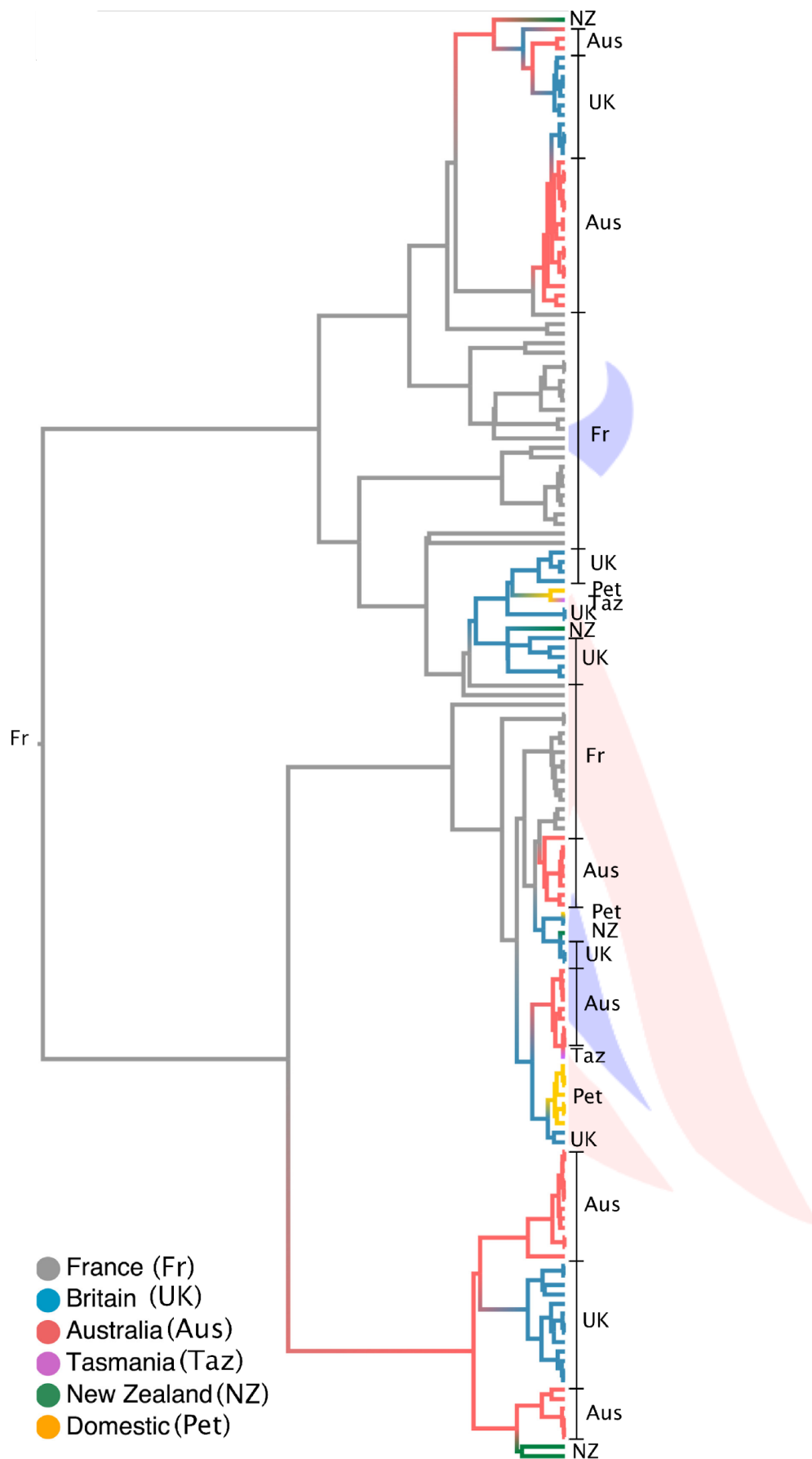
Rabbits around a waterhole during myxomatosis trials, Wardang Island, South Australia, 1938

Part 2 of 10

Historical records show: * A ship carried 5 domestic rabbits from Britain and released them in Sydney in 1788. * Between 1788 and 1850, at least 90 different ships carried domestic rabbits into Australia from Europe. * Tasmania (an island just off the Australian coast) was full of feral rabbits from 1810 onwards. * New Zealand was full of feral rabbits from 1820 onwards. * In 1859, an Englishman transported 24 wild rabbits, collected across England, to Melbourne for sport hunting. * By 1870, South Western Australia (including Melbourne and Sydney) were full of feral rabbits. * By 1880, feral rabbits had reached Eastern Australia.

Part 3 of 10

To work out where Australian feral rabbits came from, a genetic tree of the different rabbit populations was constructed. The length of each branch is proportional to the number of genetic changes.



Part 4 of 10

Where did Australian feral rabbits come from?

2 marks

Choose ONE

- a) French wild rabbits
- b) British wild rabbits
- c) Domestic rabbits
- d) New Zealand
- e) Tasmania
- f) Inconclusive / other

Part 5 of 10

Does this tree prove feral rabbits in Australia came from multiple different shippings?

1 mark

Choose ONE

- a) Yes
- b) No

Part 6 of 10

List the following populations in terms of how genetically diverse you expect them to be.*Put the most diverse population at the top, and the least diverse at the bottom.*

2 marks

Put into the correct order

- a) Feral rabbits in South Western Australia
- b) British wild rabbits
- c) Domestic rabbits
- d) French wild rabbits
- e) Feral rabbits in Eastern Australia

Part 7 of 10

In the case of rabbits invading Australia, which factor was most important for the success of the invading population?

2 marks

Choose ONE

- a) The number of animals in the initial population
- b) Whether the initial population was released in a hospitable location
- c) The genetic fitness of the initial population
- d) Whether the initial population was the first to arrive in Australia
- e) Repeated re-invasion to top-up the initial population

Part 8 of 10

Australian governments have tried many ways to control the rabbit population. In 1950, they released an extremely lethal strain of myxomatosis virus, which killed >99.8% of infected

rabbits within a few days. However, over many years, the lethality of this strain on Australian rabbits was found to decrease, and Australian strains of myxomatosis were also found to be less lethal than the original strain. In the 1990s, the Australian government was testing the safety of *rabbit haemorrhagic disease virus*. In 1995, the virus escaped quarantine and killed >10 million rabbits within 8 weeks. Now, the Australian government periodically re-introduces rabbit haemorrhagic disease viruses.



Releasing infected rabbits. By CSIRO, CC BY 3.0, <https://commons.wikimedia.org/w/index.php?curid=35461394>

Part 9 of 10

Which of these factors help prevent the eradication of rabbits via viruses?

2 marks

Choose as many as appropriate

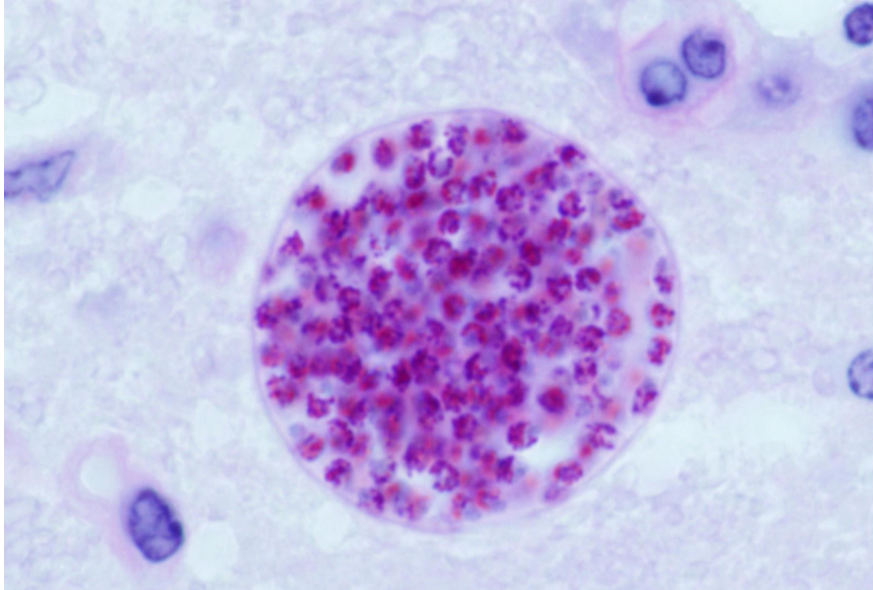
- a) High genetic diversity of Australian rabbits
- b) New mutations arising in a very large population of Australian rabbits
- c) Natural (/ artificial) selection by the viruses acting on rabbits
- d) Viruses which are **more** lethal tend to be fitter than viruses which are less lethal
- e) Viruses usually go extinct within a few decades
- f) Viruses do badly in the Australian climate

Part 10 of 10

Question 6

Part 1 of 10

Toxoplasma gondii is a single-celled organism which lives within mammals. *T. gondii* is spread by eating infected meat. It can spread asexually within infected mammals, but tends to form permanent semi-dormant cysts, except in the severely immunocompromised. *T. gondii* can **only** reproduce sexually in cats (domestic cats, lions, cougars etc). Therefore, semi-dormant *T. gondii* manipulates the behaviour of infected cat prey-animals (e.g. mice, rats) to make them unafraid of cats; infected mice will run repeatedly toward cats. In humans, and other non-prey mammals, *T. gondii* has less obvious and more controversial effects, but is widely reported to increase recklessness, road-rage etc. Up to 1/3 of humans are infected with *T. gondii*, especially where rare meat is eaten.



Toxoplasma cyst in mouse brain

Part 2 of 10

Which terms describe the relationship between *T. gondii* and mammals?

2 marks

Choose as many as appropriate

- a) Symbiosis
- b) Mutualism
- c) Altruism
- d) Parasitism
- e) Commensalism
- f) Endosymbiosis
- g) Mimicry

Part 3 of 10

Yellowstone National Park contains very well studied wolf packs. Some wolves live near cougars and steal their prey, or even eat cougars. The wolves in Yellowstone are monitored throughout their lives, and their location and status within pack hierarchies is recorded. 228 random wolves also had blood taken to test whether they were infected with *T. gondii*. 8 male wolves were infected with *T. gondii*. 92 male wolves were not infected with *T.*

gondii*. * 7 wolf-pack leaders were infected with *T. gondii*. * 8 wolf-pack leaders were not infected with *T. gondii*.

Part 4 of 10

How many fold does *T. gondii* increase the probability of becoming a pack leader? *Give your answer (in Arabic numerals) to the nearest whole number*

2 marks

Write something below

Part 5 of 10

Calculate the Chi-square statistic to test whether pack-leader status is independent of *T. gondii* infection. *Type a number (in Arabic numerals) to the nearest whole number*

3 marks

Write something below

Part 6 of 10

Wolves infected with *T. gondii* were found to be 3-fold (on average) more likely to leave their pack and disperse across Yellowstone, than uninfected wolves.

Part 7 of 10

In this study, the Chi-square statistic was calculated to be 6.467. The critical value for 1 degree of freedom and 95% confidence is 3.841. Are wolves infected with *T. gondii* significantly more likely to disperse?

1 mark

Choose ONE

- a) Yes
- b) No
- c) Undetermined

Part 8 of 10

Statistics *can* tell you whether an observation is due to random chance, but they *cannot* tell you what causes that observation. *Only* a well-designed scientific study can tell you what causes an effect. What factors should the ecologists control for when determining whether *T. gondii* infection makes wolves more likely to be **pack leaders**?

2 marks

Choose as many as appropriate

- a) Differences in infection rates in wolves of different ages
- b) Differences in infection rates in wolves of different sexes
- c) Differences in infection rates between packs in different locations
- d) Whether wolves with bolder behaviour are more likely to become infected
- e) Whether cougars are more likely to hunt pack leaders

Part 9 of 10

Recently, ecologists have realised that apex predators are overwhelmingly important for the proper functioning of ecosystems. For example, the loss of whales severely reduces nutrient circulation in the oceans, leading to large declines in plankton and fish. The loss of wolves from Scotland has contributed to the highlands becoming a barren wilderness. In 1970, 40

wolves were re-introduced to Yellowstone, after being hunted to near-extinction across the USA.



Part 10 of 10

Put the following *trophic cascade* in order, from re-introduction of wolves at the top, to the present day at the bottom.

2 marks

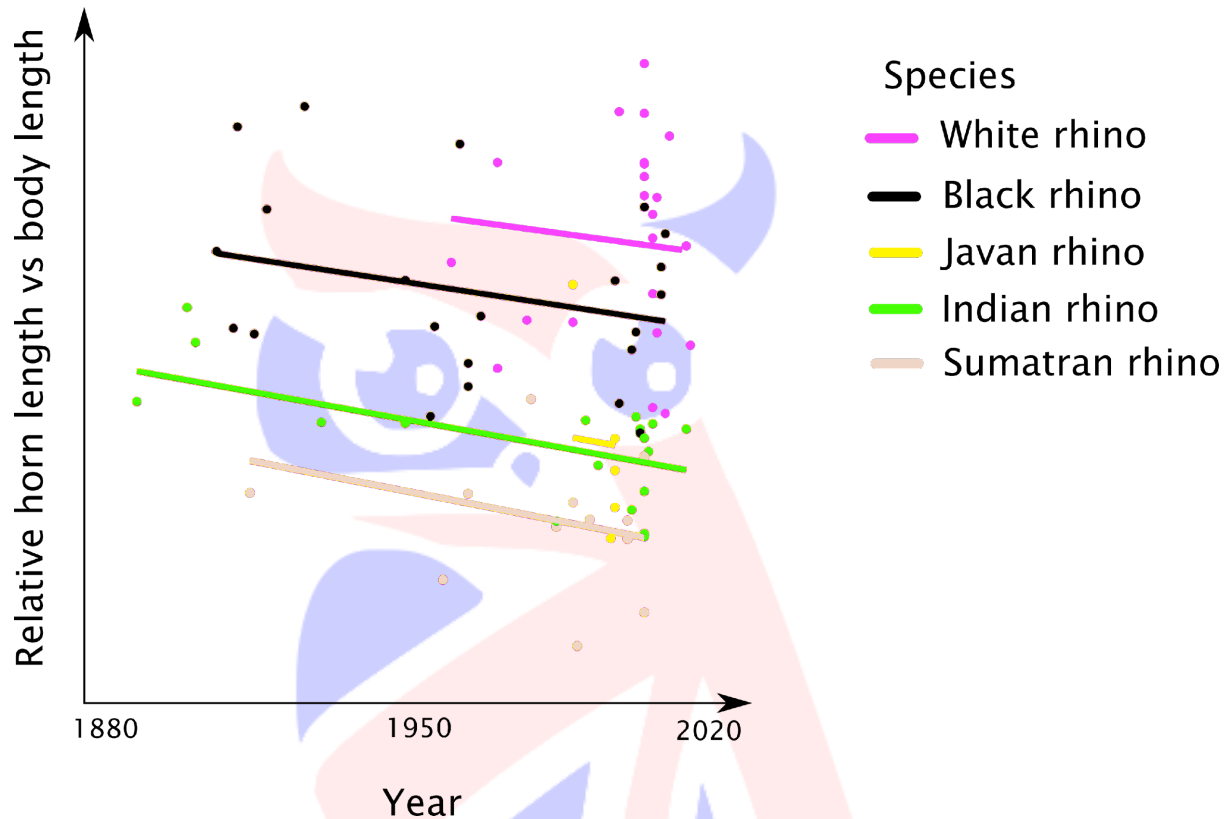
Put into the correct order

- a) Ecosystem becomes more robust to perturbations (e.g. extreme weather or invasive species)
- b) Population of ungulates (elk, deer etc) shrinks and becomes fitter
- c) River beds stabilise, deepen and pools form
- d) Diversity of fish, insects, birds and mammals increases
- e) Ungulates primarily graze inaccessible slopes rather than open planes and valleys
- f) Diversity of plants increases and trees grow along river banks

Question 7

Part 1 of 3

Scientists collected illustrations and photographs of rhinoceros species from museums. In side-on images, they measured the length of the rhino's horn compared to its body length. The relative length of the rhino horn has been plotted against the date when the image was produced. **Note: rhinos reach adulthood at around 4 years old, and live for approximately 50 years. Poachers receive much more money for larger rhino horns than smaller horns.**



Part 2 of 3

Think about the patterns in this data, how the data was produced, and how it could be interpreted. Are these statements more likely to be true, or false?

7 marks

Mark the following as *TRUE* or *FALSE*

a) Rhino horns have tended to increase in size, relative to body length, over the past 100 years

TRUE FALSE

b) White rhinos have larger horns, relative to body length, than other rhino species

TRUE FALSE

c) The trend in horn length is more certain for Indian rhinos compared to white rhinos

TRUE FALSE

d) The trend in horn length is more certain for Javan rhinos compared to white rhinos

TRUE FALSE

e) Artificial selection could explain the trends

TRUE FALSE

f) Habitat degradation, leading to malnutrition, could explain the trends

TRUE FALSE

g) If rhino body mass has stayed constant over the past 100 years, this supports the hypothesis that the trend in horn length is genetic, rather than environmental

TRUE FALSE

h) If rhinos only reached adulthood at 30 years old, and lived for 100 years, this would support the hypothesis that the trend in horn length is genetic, rather than environmental

TRUE FALSE

i) If all of the pre-1950 images are illustrations, and all of the post-1950 images are photographs, this increases our confidence that the trend is real

TRUE FALSE

j) If a mix of captive and wild rhinos were measured, this increases our confidence that the trend is real

TRUE FALSE

Part 3 of 3



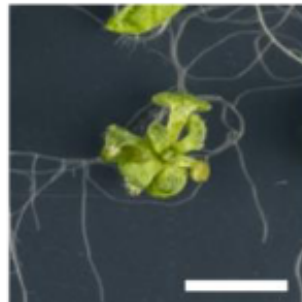
Question 8

Part 1 of 8

PDLP1 is a protein found in the plasmodesmata (membrane lined inter-cellular channels) in plants. Over-expression of PDLP1 causes dwarfism. In addition, it also causes an overaccumulation of callose (similar to starch) within the plasmodesmata, blocking the channel.



Wild type



PDLP1
Over-expression

Scale = 0.5 cm. The Proteins Found at Plasmodesmata and the Interactions Between Them (M Johnston, 2021)

Part 2 of 8

Which of the following are reasonable ****hypotheses**** from the data?

2 marks

Choose as many as appropriate

- a) The overaccumulation of callose causes dwarfism
- b) PDLP1 is a negative regulator of plant growth
- c) PDLP1 is a positive regulator of plant growth
- d) PDLP1 is required for normal plant development

Part 3 of 8

Which of the following are reasonable ****conclusions**** from the data?

2 marks

Choose as many as appropriate

- a) The overaccumulation of callose causes dwarfism
- b) PDLP1 is a negative regulator of plant growth
- c) PDLP1 is a positive regulator of plant growth
- d) PDLP1 is required for normal plant development

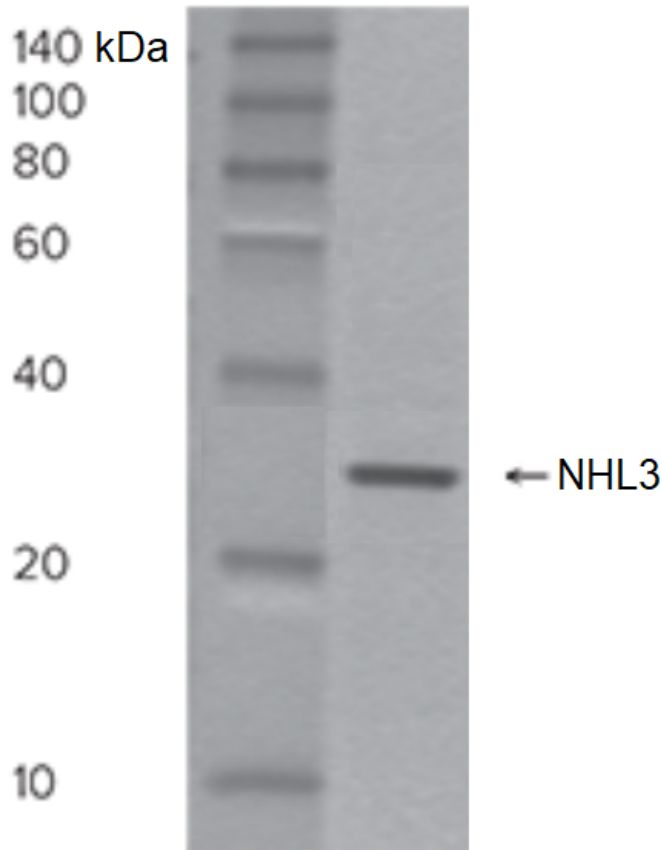
Part 4 of 8

To find out how PDLP1 over-expression leads to callose deposition, Scientist searched for proteins which interact with PDLP1. They found NHL3 interacts with PDLP1. NHL3 is a short

protein with no catalytic domains. NHL3 was run on a Western blot gel against a ladder, shown below.

Part 5 of 8

How large is NHL3 to the nearest 10 kDa? *Type an answer in numerals*



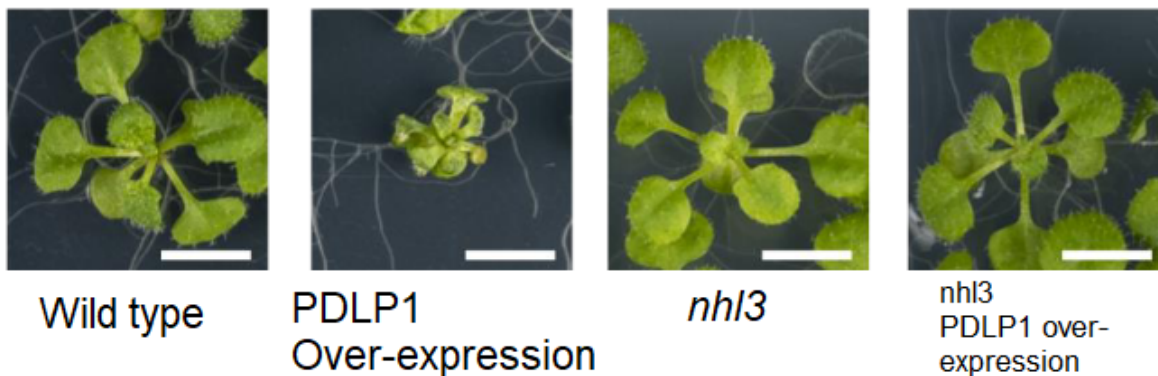
NHL3 run on a Western blot against a ladder

1 mark

Write something below

Part 6 of 8

Plants with no functioning NHL3 (*nhl3*) are normal size with normal callose levels. Plants both over-expressing PDL1, and with no functioning NHL3 (*nhl3*), are also normal size with normal callose levels.



Scale = 0.5 cm. The Proteins Found at Plasmodesmata and the Interactions Between Them (M Johnston, 2021)

Part 7 of 8

Which of the following are reasonable ****hypotheses**** from the data?

3 marks

Choose as many as appropriate

- a) The overaccumulation of callose causes dwarfism
- b) NHL3 is required for callose deposition
- c) NHL3 is required for PDLP-mediated callose deposition
- d) Overexpression of NHL3 would lead to the overaccumulation of callose
- e) PDLP1 acts upstream of NHL3
- f) PDLP1 acts downstream of NHL3
- g) NHL3 produces callose

Part 8 of 8

Which of the following are reasonable ****conclusions**** from the data?

2 marks

Choose as many as appropriate

- a) The overaccumulation of callose causes dwarfism
- b) NHL3 is required for callose deposition
- c) NHL3 is required for PDLP-mediated callose deposition
- d) The overexpression of NHL3 would lead to the overaccumulation of callose
- e) PDLP1 acts upstream of NHL3
- f) PDLP1 acts downstream of NHL3
- g) NHL3 produces callose

Question 9

Part 1 of 4

Order the steps of protein synthesis from DNA (at the top) to protein (at the bottom).

1 mark

Put into the correct order

- a) mRNA processing
- b) Transcription
- c) Translation
- d) Protein folding and modification

Part 2 of 4

Order the levels of organisation in living systems from smallest (at the top) to largest (at the bottom).

1 mark

Put into the correct order

- a) Cells
- b) Ecosystems
- c) Populations
- d) Tissues
- e) Habitats
- f) Organelles
- g) Organisms
- h) Organs

Part 3 of 4

Order the types of immune responses from earliest (top) to most prolonged (bottom)

3 marks

Put into the correct order

- a) Production of potent cell-killing adaptive immune cells
- b) Production of low-affinity antibodies
- c) Production of memory T and B cells
- d) Activation of complement system of innate immunity
- e) Activation of naive (never used before) adaptive immune cells
- f) Killing and internalisation by innate immune cells

Part 4 of 4

Order the steps of blood clotting from injury (top) to healing (bottom).

3 marks

Put into the correct order

- a) Exposure of components of tissue and blood vessel walls

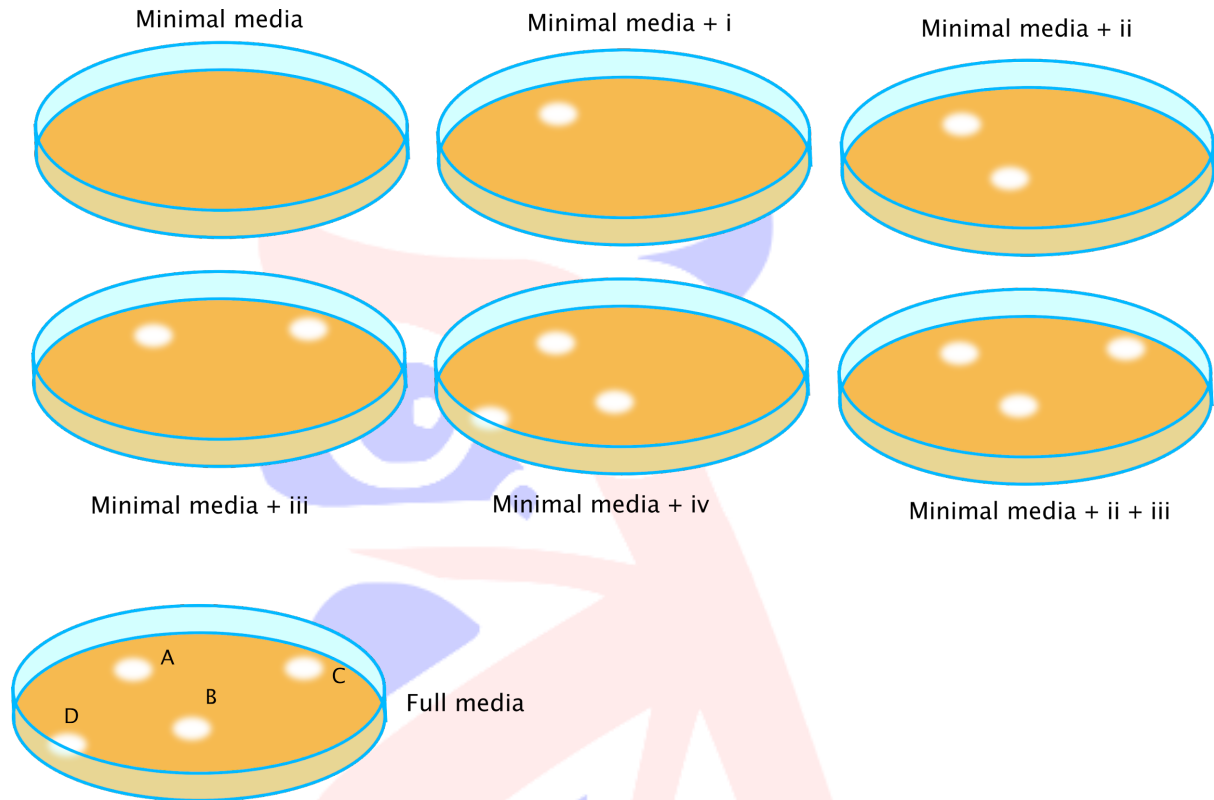
- b) Activation of stem cells and remodelling (cell growth, movement, death and phagocytosis)
- c) Platelet aggregation and formation of fibrin network
- d) Recruitment of immune cells and chondrocytes (collagen producing cells)
- e) Platelet activation and activation of clotting factors



Question 10

Part 1 of 9

E. coli can normally grow on minimal media. You expose some *E. coli* to UV light which creates a single point mutation in each bacterium. You dilute the *E. coli* and grow it on full media so all colonies can grow. You 'stamp' replica plates onto plates containing minimal media, or minimal media containing supplements *i-iv*. Only some colonies can grow on each plate.



Part 2 of 9

This type of genetic analysis can be used to dissect the steps in a biosynthesis pathway. For example, here it can be seen that the gene product (enzyme) lost in colony A is involved in the synthesis of compound *i*, and all compounds *ii-iv* are made from *i*.

Part 3 of 9

Sketch a pathway for the synthesis of compounds *i-iv*. Label the steps with enzymes *A-D*.
Note, the pathway may have branches. Are the following true or false?

5 marks

Mark the following as *TRUE* or *FALSE*

a) *B* synthesises *ii* from *i*.

TRUE FALSE

b) *B* synthesises *iv*.

TRUE FALSE

c) *D* synthesises *iv* from *i*.

TRUE FALSE

d) *D* synthesises *iv* from *ii*.

TRUE FALSE

e) *D* synthesises *iv* from *iii*.

TRUE FALSE

f) *C* synthesises *iii*.

TRUE FALSE

g) *C* synthesises *ii*.

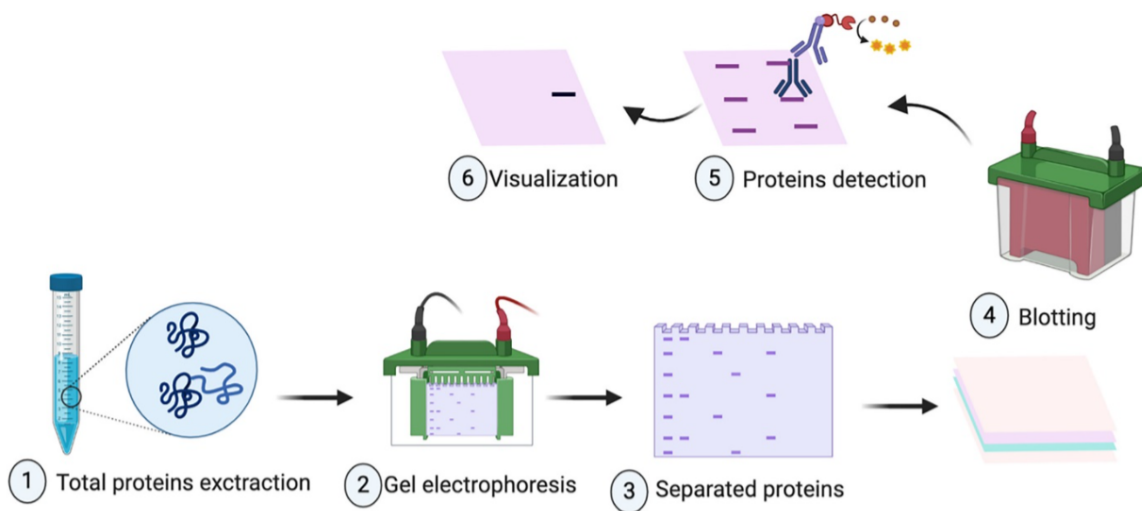
TRUE FALSE

h) *i* is the substrate for *C*.

TRUE FALSE

Part 4 of 9

A similar experiment identified that *E. coli* mutants *x*, *y* and *z* have one mutation in the α or β subunits of tryptophan synthase. You carry out a western blot to visualise tryptophan synthase in these mutants, and wildtype (WT; not mutated) *E. coli*.



Part 5 of 9

Part 6 of 9

1 mark

Mark the following as TRUE or FALSE

a) Unmutated tryptophan synthase α is a longer gene than unmutated tryptophan synthase β .

TRUE FALSE

Part 7 of 9

Check all the types of mutation which *X* could likely have according to these data.

2 marks

Choose as many as appropriate

- a) Frameshift (deletion or insertion of one base)
- b) Nonsense (creation of Stop codon)
- c) Missense (swapping one amino acid for another)
- d) Mutation in regulatory region (e.g. promoter)
- e) No mutation

Part 8 of 9

Check all the types of mutation which *Y* could likely have according to these data.

2 marks

Choose as many as appropriate

- a) Frameshift (deletion or insertion of one base)
- b) Nonsense (creation of Stop codon)
- c) Missense (swapping one amino acid for another)
- d) Mutation in regulatory region (e.g. promoter)
- e) No mutation

Part 9 of 9

Check all the types of mutation which *Z* could likely have according to these data.

2 marks

Choose as many as appropriate

- a) Frameshift (deletion or insertion of one base)
- b) Nonsense (creation of Stop codon)
- c) No mutation

BBO 2023: Checked Reference Answers

Matches the UKBC public edition, Papers 1 and 2. T = true; F = false. Letters follow the printed choices. Source-page numbers refer to the question PDF.

Independent reference key, not a UKBC mark scheme. Missing evidence is marked unresolved; conditional answers state their assumptions. The original question pages are preserved. Checked revision: 2026-10-13.

Paper 1

Question	Reference answer and reasoning
Q1 Part 2 p. 3	B Food-seeking motivation is an innate behaviour.
Q1 Part 4 p. 4	A People reason about how to block access to the bin.
Q1 Part 5 p. 4	C The new technique spreads by social learning.
Q2 Part 1 p. 5	a T; b F as a universal assertion; c T; d T Plants themselves cannot fix atmospheric N ₂ , but many obtain inorganic soil nitrogen produced by free-living microbes rather than requiring a symbiotic association. The familiar legume-bacterium relationship is a particular symbiosis, not a requirement of all plants.
Q2 Part 2 p. 5	a T; b F; c F; d T; e F Many animals have open circulation and some reproduce asexually; innate behaviours exist.
Q3 Part 1 p. 6	A, B, C in the formal condensation model Joining unactivated monomers is formally represented as a dehydration reaction. Actual cellular synthesis uses activated precursors: DNA polymerisation releases pyrophosphate, starch elongation releases ADP, and ribosomal peptide formation releases deacylated tRNA. The question does not distinguish formal reaction accounting from those cellular routes; D is breakdown, not polymerisation.
Q3 Part 2 p. 6	A, C, E in protein-denaturation context Heating disrupts noncovalent interactions; it does not normally hydrolyse peptide bonds or reduce disulphides. Exact disruption depends on the chemical environment.
Q3 Part 4 p. 7	a T; b T; c T; d T; e F; f T; g T The exposed SD sequence binds ribosomes; changing U to G opposite A creates a mismatch. I/II orientation follows the stated SD sequence.

Question	Reference answer and reasoning
Q4 Part 2 p. 8	A: carnivore; B: hindgut fermenter B has an expanded fermentative hindgut; A has a simpler large intestine.
Q4 Part 3 p. 9	A, B Sugar can be absorbed before hindgut fermentation; rumen microbes consume sugar before a cow can absorb it as sugar.
Q4 Part 4 p. 9	a T; b F; c T; d T Cooking aids digestion; a hindgut fermenter may recover microbial nutrients through caecotrophy and select nutrient-rich shoots.
Q5 Part 3 p. 10	a T; b T as a hypothesis; c F; d T as a local-storage hypothesis; e T RBC sequestration reduces oxygen transport and requires protection against clotting. The stem does not establish that systemic clotting ability is lower than human blood.
Q6 Part 1 p. 11	A, C (i, iii) in the intended genome model i violates $A=T/C=G$ and is consistent with a single-stranded DNA viral genome; iii is an RNA genome. iv mixes U and T and v lacks A/T while C differs from G, so neither is secure evidence rather than a measurement mistake. Composition alone does not independently verify a viral source.
Q7 Part 2 p. 12	Vena cava: 800 g; pulmonary artery: 3500 g; aorta: 5000 g This is a wall-strength prediction, not measured data.
Q8 Part 2 p. 13	C Plastids are the analogous endosymbiotic organelles of plants.
Q8 Part 3 p. 13	C Feathers define living birds; wings, beaks and eggs are not exclusive.
Q8 Part 4 p. 13	C Mushrooms and flowers are specialised reproductive structures.
Q8 Part 6 p. 14	D Whales resemble fish in lifestyle but are mammals; bats similarly resemble birds in flight.
Q8 Part 7 p. 14	E Reduced inorganic compounds in rocks can provide chemical energy; heat alone is not a metabolic electron donor.

Question	Reference answer and reasoning
Q9 Part 2 p. 15	Traditional: A, E; SHARP: B, F; both: C; neither: D SHARP helicase consumes ATP; DNA amplification here does not need reverse transcription.
Q10 Part 2 p. 18	A The tallest silhouette is sycamore, about 30 m.
Q10 Part 3 p. 18	A as a graph-based prediction Sycamore is abundant across height classes. Shade tolerance itself is not measured by the plot.
Q10 Part 4 p. 18	D as a height-based prediction Hawthorn foliage lies low enough for deer to reach; food preference is not measured.
Q10 Part 5 p. 18	A as a total-foliage prediction Sycamore dominates the displayed population. Caterpillar abundance or host preference is not given, so this cannot be a definitive species ranking.
Q10 Part 6 p. 18	A Ash spans a larger height range than oak in the graphic.
Q10 Part 9 p. 19	0.454 Use the printed $\sum(n/N)^2$, not 1 minus that sum: $301415/815^2 = 0.4537845$.
Q10 Part 10 p. 19	B Splitting a group into two nonempty groups lowers the sum of squared proportions.
Q10 Part 11 p. 19	0 if no species retains a dominant fraction For an increasingly even community, $\sum(p_i^2)$ tends to zero; species number alone does not guarantee this.
Q11 Part 3 p. 21	Increased: A, C; decreased: B; no effect: none Read 80%, 60% and 20% against WT 50%.
Q11 Part 4 p. 21	RME1: decreases; IME1: increases Knocking out a repressor increases the response; knocking out an activator decreases it.
Q11 Part 5 p. 22	A IME1 knockout masks the RME1 knockout effect.

Question	Reference answer and reasoning
Q11 Part 6 p. 22	20 Knockout B eliminates the protein that structural mutation C affects.
Q11 Part 7 p. 22	20 IME1 knockout remains epistatic.
Q11 Part 8 p. 22	B (II) RME1 inhibits IME1, which promotes sporulation.
Q11 Part 9 p. 23	B (A/B), among the offered choices A/B gives the lowest displayed sporulation efficiency; this is an inference from the simplified graph.
Q12 Part 4 p. 25	a T; b F; c F; d not established; e F Old direct Weddell-Ross gene flow supports a former connection. The modern coastal flow on the supplied map is clockwise. Historical population size alone does not prove thermal adaptation; reduced direct flow does not predict increased similarity.
Q12 Part 6 p. 26	B, D; A possible if chemosynthetic producers are present Detritus can be imported beneath the shelf; absence of sunlight alone does not establish chemoautotrophy. Endothermy or herbivory cannot be inferred from the stated discovery.
Q12 Part 7 p. 26	Warm-blooded: A, C, E, F; cold-blooded: B, D; neither: G These are broad tendencies. Low haemoglobin is a special cold-water adaptation, not universal; true hibernation differs from ectotherm brumation.
Q13 Part 2 p. 27	C (10 minutes) The cited primary study reports 10-second light stimulation every 10 minutes; the PDF contains only a still of the video.
Q13 Part 4 p. 28	A only Deleting a removes the response; deleting b retains it.
Q13 Part 5 p. 28	Unresolved: the division time requires the missing movie Figure 5 in the primary study confirms 10-minute light pulses over a 100-minute recording, but its 5-30-minute snapshots do not establish a full division interval. None of A-F can be selected reliably from the public PDF; a generic species doubling time is not a substitute.
Q13 Part 6 p. 29	A as the mesophile prediction 37 C is closer to suitable growth conditions than 22 C in the question's comparison.

Question	Reference answer and reasoning
Q13 Part 7 p. 29	D 70 C does not support ordinary vegetative <i>B. subtilis</i> division; surviving spores are a different issue.
Q13 Part 8 p. 29	A as a temperature-rate prediction Within a viable temperature range, channel/enzyme processes can proceed faster.
Q13 Part 9 p. 29	A under the explicit neuron analogy Rapid sodium-channel opening depolarises a neuron. The cited bacterial study actually reports hyperpolarisation, so do not generalise this hypothetical answer to its actual mechanism.
Q13 Part 10 p. 30	A under the explicit neuron analogy Rapid potassium-channel opening repolarises a neuron; the sodium-potassium pump is not the immediate repolarising mechanism.
Q14 Part 2 p. 31	C (100 nm) The labelled virion is roughly one scale-bar length across.
Q14 Part 3 p. 31	198 $18 \times 11 = 198$ theoretical subtype combinations.
Q14 Part 4 p. 32	256 Two choices for each of eight segments: 2^8 .
Q14 Part 6 p. 32	Humans: alpha2,6; birds: alpha2,3; pig/ferret/mink: both This follows the simplified supplied host model; real tissues may contain both receptor linkages.
Q14 Part 7 p. 33	a F; b T; c T for HA-NA functional balance; d T; e T These are the intended host-adaptation comparisons. Adaptation of HA/NA is not by itself sufficient for efficient human transmission; NA-specific antibodies can also be protective.

Paper 2

Question	Reference answer and reasoning
Q1 Part 1 p. 34	High: A, B; low: C, D, E Insulin promotes storage and suppresses glucagon-driven mobilisation.
Q1 Part 2 p. 34	High: E, F; low: A; B, C, D conditional A functioning insulinoma causes excess insulin and hypoglycaemia. Insulin suppresses glucagon/lipolysis/glycogenolysis, but hypoglycaemia triggers opposing counter-regulation. The stem does not uniquely determine B/C/D; the simple insulin-only model puts them low.
Q2 Part 2 p. 35	B: spent; D: fresh; A and human alveoli: mixed B/D are anterior/posterior air sacs in the simplified airflow model.
Q2 Part 3 p. 35	a T; b F; c F Aerodynamic valving need not involve physical valves; avian exchange uses cross-current geometry.
Q3 Part 3 p. 38	a T; b T; c F; d F; e T as a trend Aggression returns with a new neighbour; acclimation to the second appears faster. E lacks a formal significance test in the displayed graph.
Q3 Part 5 p. 39	a T; b F; c T; d F; e F; f T The composite-image test identifies familiar faces, but alone does not separate self-recognition from familiarity.
Q3 Part 7 p. 40	A The additional experiment separates the self photograph from neighbour and stranger photographs; it supports the self-recognition interpretation.
Q4 Part 2 p. 43	3 days Day 10 minus the formation day 7; cells formed during day 7 span roughly 3-4 days.
Q4 Part 3 p. 43	a T; b F; c F; d T; e T Read root-segment lengths and dark/light primordium/lateral-root bars; disappearing primordia need not all become laterals.
Q4 Part 5 p. 44	Corrected overexpression model: a T; b F; c conditional T; d T; e possible T The printed deletion stem conflicts with the cited experiment. Read miR156A as overexpression, retaining the source pages unchanged. A concerns lateral-root density, not faster primary-root elongation. B is false because an overexpressing scion affects WT roots. C is compatible with the intermediate graft phenotypes but miRNA amount was not quantified here. D follows the altered leaf phenotype. E is a plausible slower-primordium-emergence hypothesis, not an observed knockout result. There is no valid deletion-based key as printed.

Question	Reference answer and reasoning
Q5 Part 4 p. 47	B Australian feral samples cluster with British wild rabbits.
Q5 Part 5 p. 47	B Several source lineages can arrive in one mixed shipment; the tree cannot prove separate shipments.
Q5 Part 6 p. 47	D, B, A, E; C cannot be uniquely inserted Serial founder effects predict France > Britain > south-west > east. The relative diversity of independently bred domestic rabbits versus each feral population is not determined by this tree alone.
Q5 Part 7 p. 47	C Wild-source genetic fitness explains establishment better than introduction order or repeated domestic shipments.
Q5 Part 9 p. 48	A, B, C Variation, mutation and selection can produce resistant rabbits; greater lethality is not universally greater viral fitness.
Q6 Part 2 p. 49	A, D, F Symbiosis is the broad association; this intracellular association is parasitic endosymbiosis, not mutualistic endosymbiosis.
Q6 Part 4 p. 50	10 only if leader counts refer to the 100 males Relative risk = $(7/8)/(8/92) = 10.0625$. If the leader counts include both sexes, the total infected/uninfected counts for all 228 wolves are missing; the risk ratio is then not determined. Association does not establish causation.
Q6 Part 5 p. 50	36 only under the same male-count assumption The table $[[7,1],[8,84]]$ gives Pearson chi-square = 35.8483. One expected cell is 1.2, so an exact test would be preferable to a chi-square approximation.
Q6 Part 7 p. 50	A $6.467 > 3.841$; this rejects independence at the stated threshold, not proof of causation.
Q6 Part 8 p. 50	A, B, C, D, E as possible confounders/reverse-causality routes Age, sex, location, prior boldness and exposure via cougar interactions may relate to both infection and leadership. E needs evidence rather than assuming cougars actually target leaders.
Q6 Part 10 p. 51	B, E, F, C, D, A A simplified cascade from reduced/redistributed grazing through vegetation and river recovery to diversity and resilience; ecological processes overlap.

Question	Reference answer and reasoning
Q7 Part 2 p. 52	a F; b T; c T; d F; e T; f T; g T; h F; i F; j F unless sampling is stratified Use declining fitted trends, sampling span/scatter and potential confounding. Hunting is human-mediated selection; mixing captive and wild samples without controls can bias a time trend.
Q8 Part 2 p. 54	A, B, D as hypotheses Callose may mediate dwarfing; necessity of PDL1 remains a hypothesis without loss-of-function evidence.
Q8 Part 3 p. 54	B only Overexpression limits growth; correlation alone does not establish callose as the cause or normal-development necessity.
Q8 Part 5 p. 55	30 kDa The band lies between 20 and 40 kDa, close to 30.
Q8 Part 7 p. 56	A, C, D, E as hypotheses NHL3 is a noncatalytic component of the PDL1-linked response. It is not required for all basal callose and is not shown to synthesise callose itself. Linear order E is only a hypothesis because a complex can give the same genetic result.
Q8 Part 8 p. 56	C only Loss of NHL3 suppresses PDL1-induced excess callose; it does not prove a unique upstream/downstream order.
Q9 Part 1 p. 57	B, A, C, D Transcription -> RNA processing -> translation -> folding/modification.
Q9 Part 2 p. 57	F, A, D, H, G, C, E, B as an intended scale ordering Habitats and populations are not strict nested organisational levels; the last three positions require the simplified meaning used in the exercise.
Q9 Part 3 p. 57	D, F, E, B, A, C Innate complement/phagocytes precede adaptive activation, early antibodies, expanded cytotoxic cells and long-lived memory; stages overlap.
Q9 Part 4 p. 57	A, E, C, D, B Wall exposure -> platelet/coagulation activation -> clot -> repair-cell recruitment -> remodelling. The printed 'chondrocytes (collagen producing cells)' likely intends fibroblasts in ordinary wound repair.
Q10 Part 3 p. 59	a T; b F as the immediate product; c F; d T; e F; f T; g F; h T The simplest branched pathway is A -> i; i --B--> ii --D--> iv; i --C--> iii. Growth requires iii and iv; rescue of A by individual later metabolites implies reversible steps or additional routes not drawn in the stem.

Question	Reference answer and reasoning
Q10 Part 6 p. 60	F (verified against the E. coli K-12 reference sequences) UniProt P0A877 alpha has 268 amino acids, versus 397 for P0A879 beta: 804 versus 1191 coding nucleotides excluding the stop codon. Thus the alpha coding sequence is shorter. This uses an external reviewed reference; the source blot itself is missing and the strain is not specified.
Q10 Part 7 p. 61	Unresolved: mutant X result is absent Conditional guide: a shortened subunit can fit A (frameshift) or B (nonsense); a same-size inactive protein can fit C (missense); altered abundance can fit D (regulatory), although coding mutations can also affect stability. E contradicts the stated mutant premise. Without the X band pattern, no specific selection is defensible.
Q10 Part 8 p. 61	Unresolved: mutant Y result is absent Apply the same guide as for X. Band size and abundance, together with the mutant premise, constrain the selection; protein size alone cannot distinguish every mutation class. Do not assign X and Y arbitrarily to the shortened or altered-expression patterns.
Q10 Part 9 p. 61	Unresolved: mutant Z result is absent Among these choices, a longer protein can fit A (frameshift with a later stop); a shorter one can fit A or B. A nonsense mutation does not lengthen a protein, and C contradicts the stated mutant premise. The absent Z band prevents a unique answer.

Source references

The questions and figures in the unchanged UKBC source edition are the basis of this key. The following primary or official sources support the research-specific checks and notes. Links are clickable.

Exam scope

UK Biology Competitions: British Biology Olympiad

<https://ukbiologycompetitions.org/british-biology-olympiad/>

Question edition

UKBC public paper, 2023

<https://ukbiologycompetitions.org/wp-content/uploads/2023/08/British-Biology-Olympiad-2023-Paper-1-and-2.pdf>

SHARP; Paper 1 Q9

Gavrilov et al. (2022), Nature Communications

<https://doi.org/10.1038/s41467-022-34076-0>

Forest inventory; Paper 1 Q10

Calders et al., Wytham Woods dataset

<https://doi.org/10.1002/2688-8319.12197>

Light pulses and membrane hyperpolarisation; Paper 1 Q13

de Souza Guerreiro et al. (2023), primary article

<https://doi.org/10.1002/advs.202205007>

Primary article manuscript, including movie timing

University of Warwick repository

<https://wrap.warwick.ac.uk/id/eprint/173206/1/WRAP-Membrane-targeted-azobenzene-drives-optical-modulation-bacterial-23.pdf>

Cleaner-fish recognition; Paper 2 Q3

Kohda et al. (2023), PNAS

<https://doi.org/10.1073/pnas.2208420120>

miR156 overexpression, not deletion; Paper 2 Q4

Laskowski et al. (2022), Development 149, dev199871

<https://doi.org/10.1242/dev.199871>

Toxoplasma and wolf behaviour; Paper 2 Q6

Meyer et al. (2022), Communications Biology

<https://doi.org/10.1038/s42003-022-04122-0>

NHL3 / PDLF response; Paper 2 Q8

Primary study, PMID 37068237

<https://pubmed.ncbi.nlm.nih.gov/37068237/>

Alpha coding sequence; Paper 2 Q10

UniProtKB reviewed P0A877, E. coli K-12, 268 aa

<https://www.uniprot.org/uniprotkb/P0A877/entry>

Beta coding sequence; Paper 2 Q10

UniProtKB reviewed P0A879, E. coli K-12, 397 aa

<https://www.uniprot.org/uniprotkb/P0A879/entry>