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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.

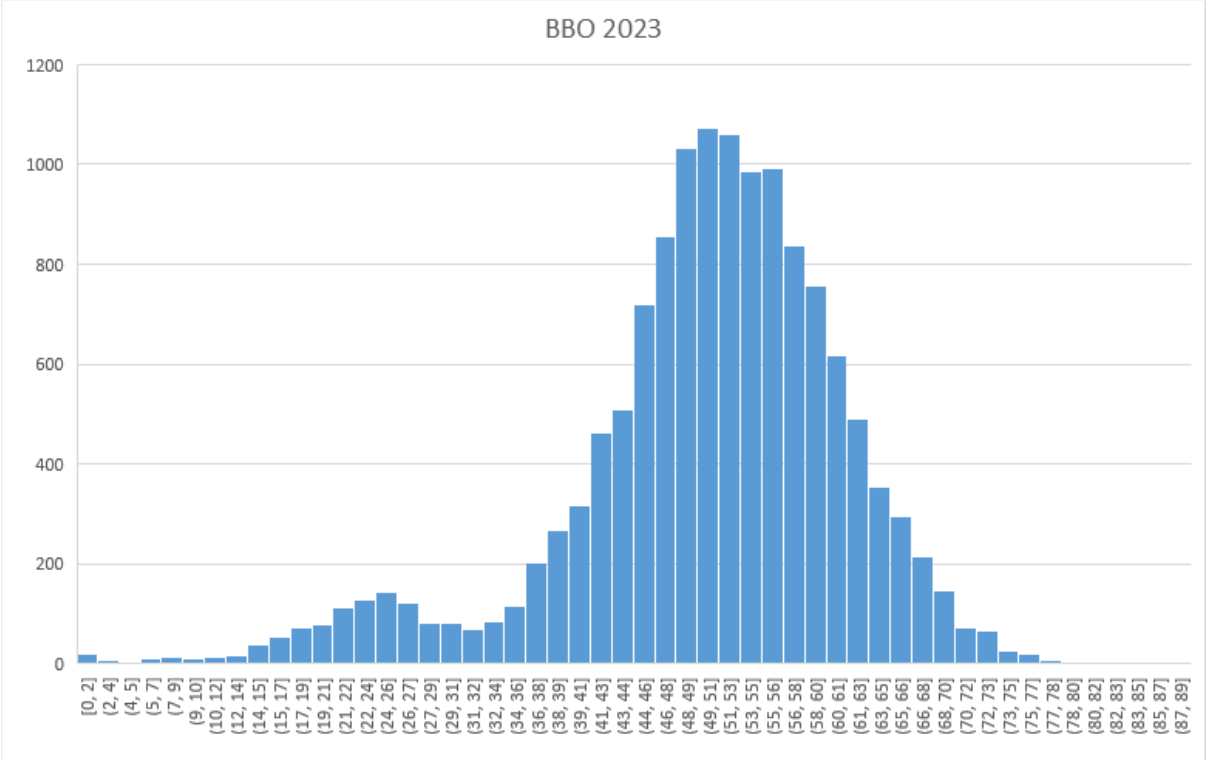
You may use a calculator.

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˚C?

2 marks

Choose as many as appropriate

a) Ionic

b) Covalent

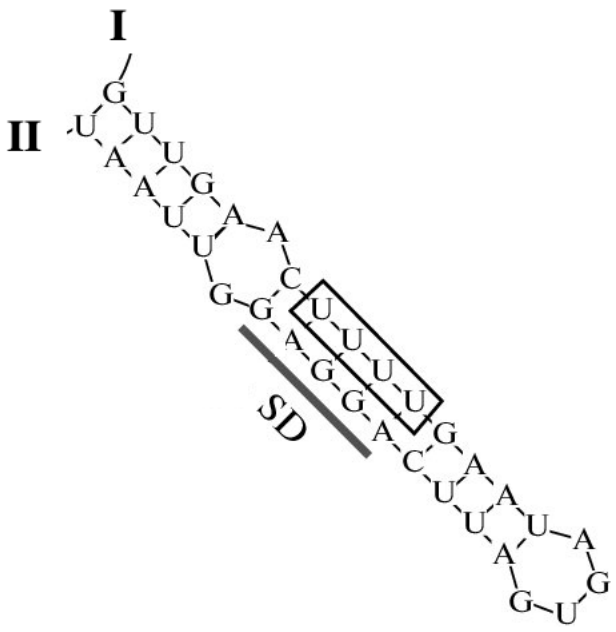
c) Hydrogen

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-Delgarno sequence would strongly reduce translation

TRUE FALSE

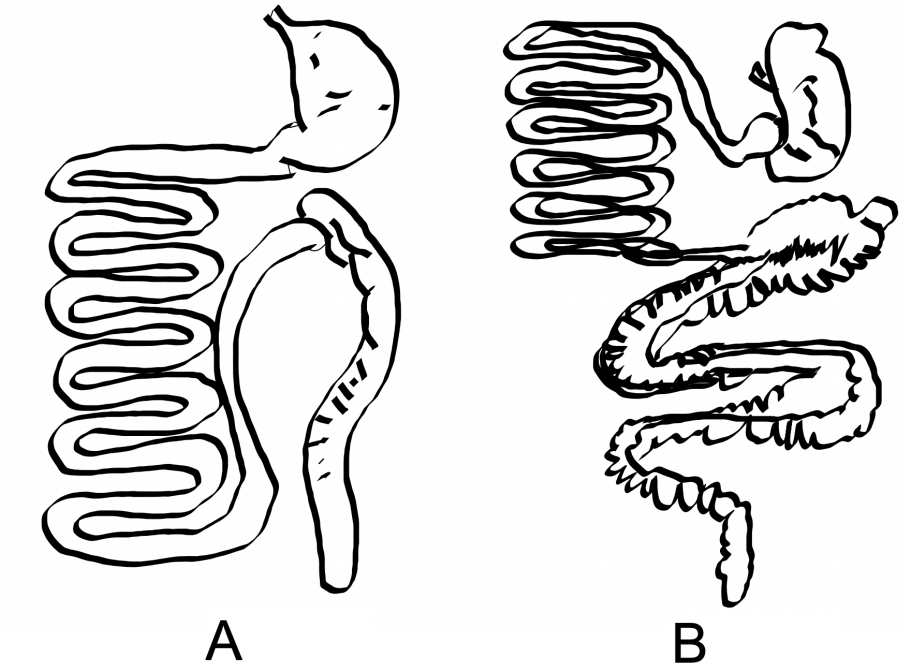
g) Other RNA switches could form secondary structures which bind to particular metabolites

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

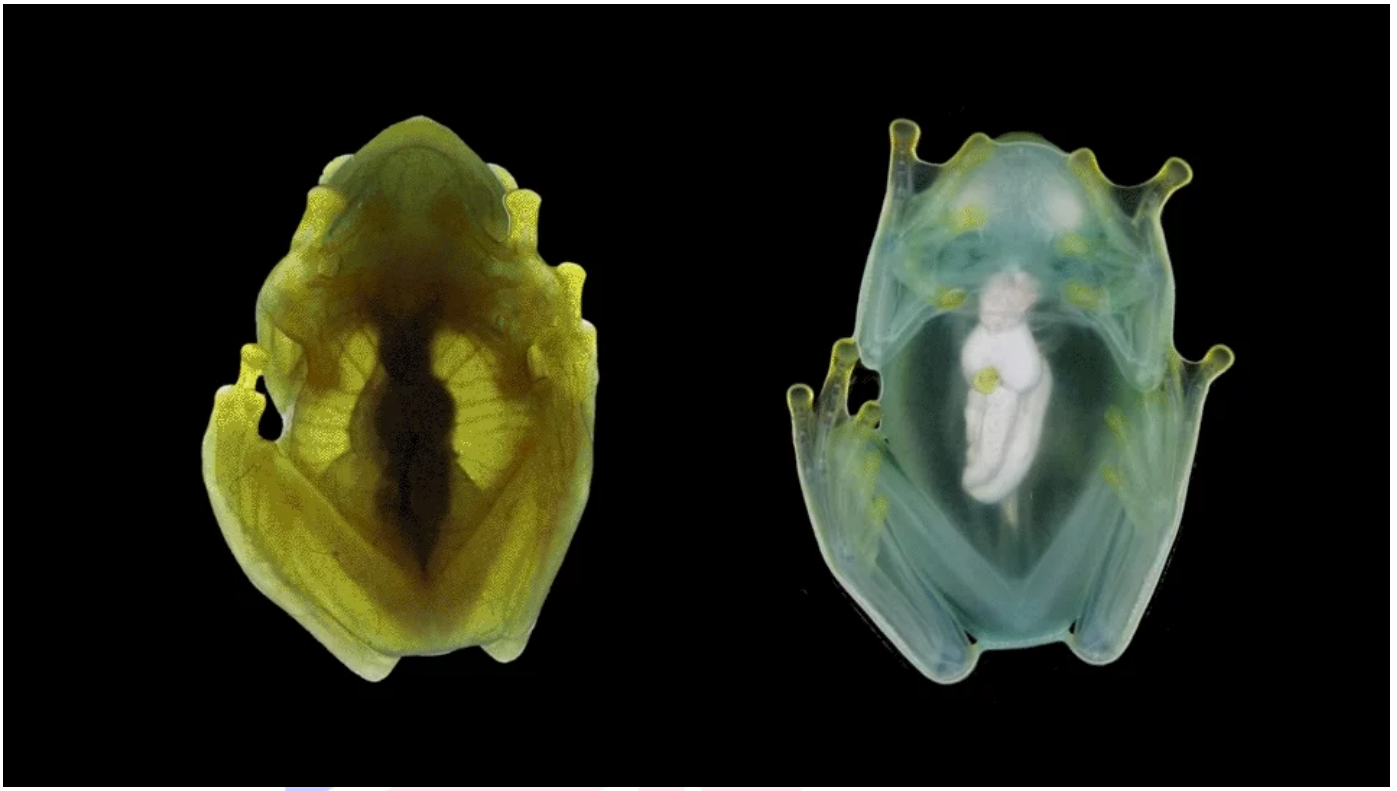
TRUE FALSE

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

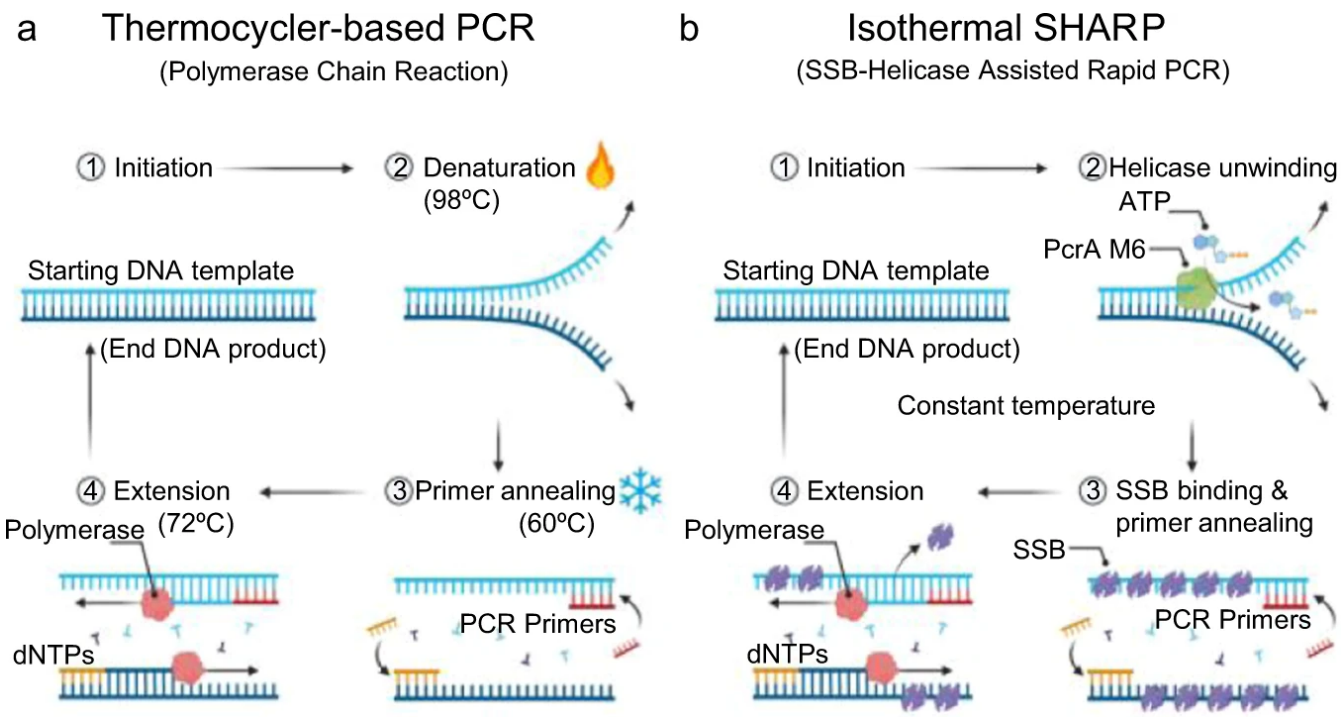
d) Plants

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

a) Temperature is lowered to allow primer binding

b) Requires ATP

c) Amplification is semi-exponential

d) Requires reverse- transcriptase

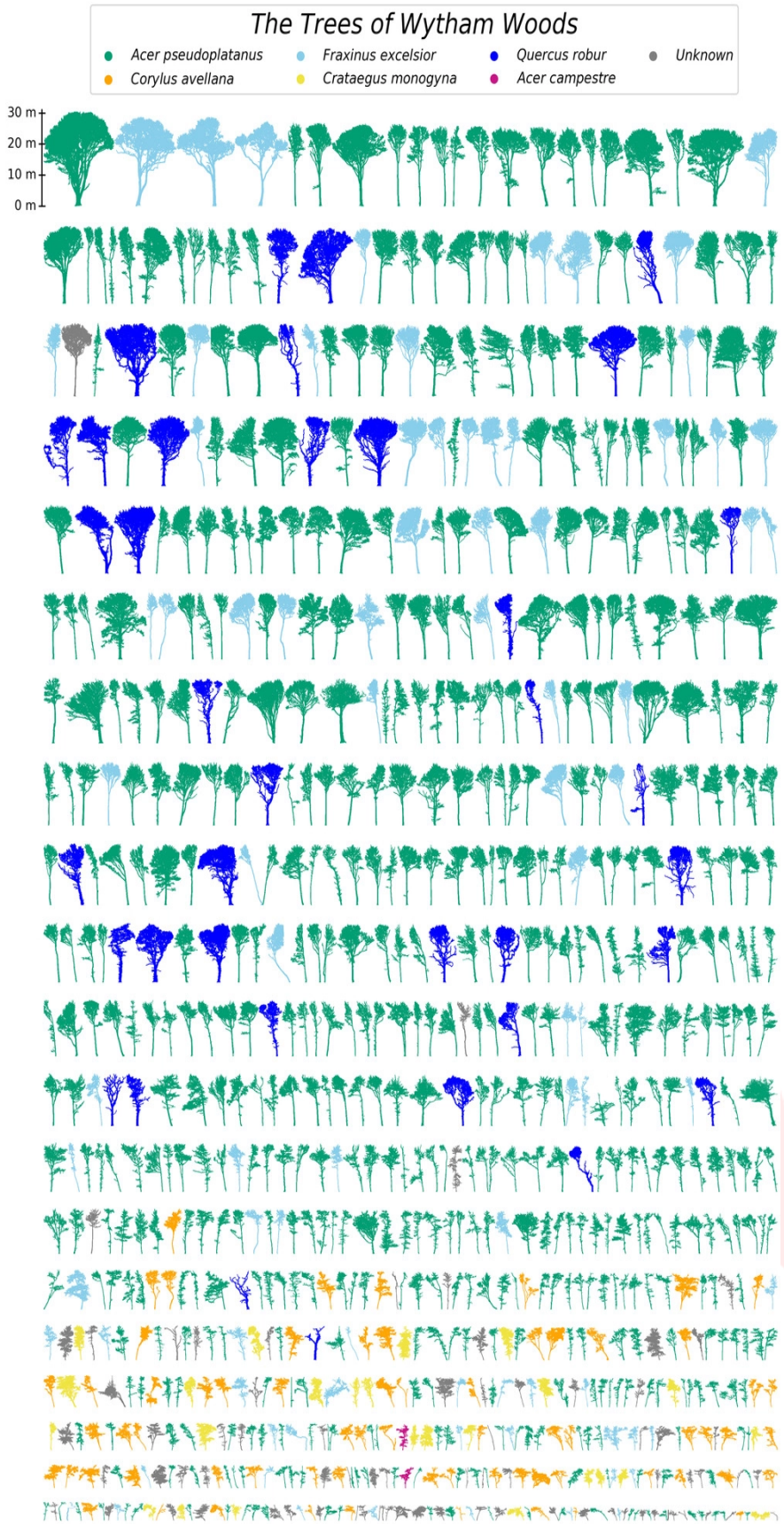
e) Heat is used to separate double- stranded DNA

f) 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

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

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*

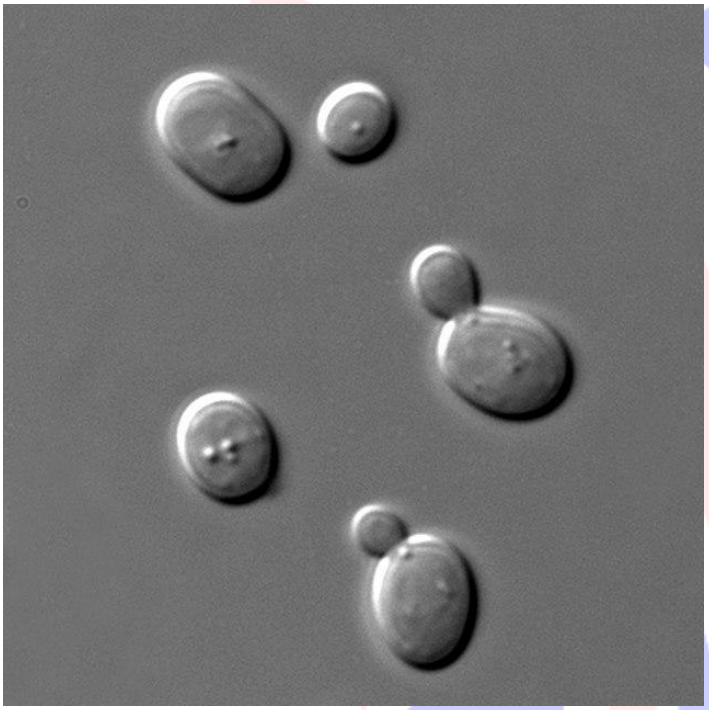
1 mark

Write something below

Question 11

Part 1 of 9

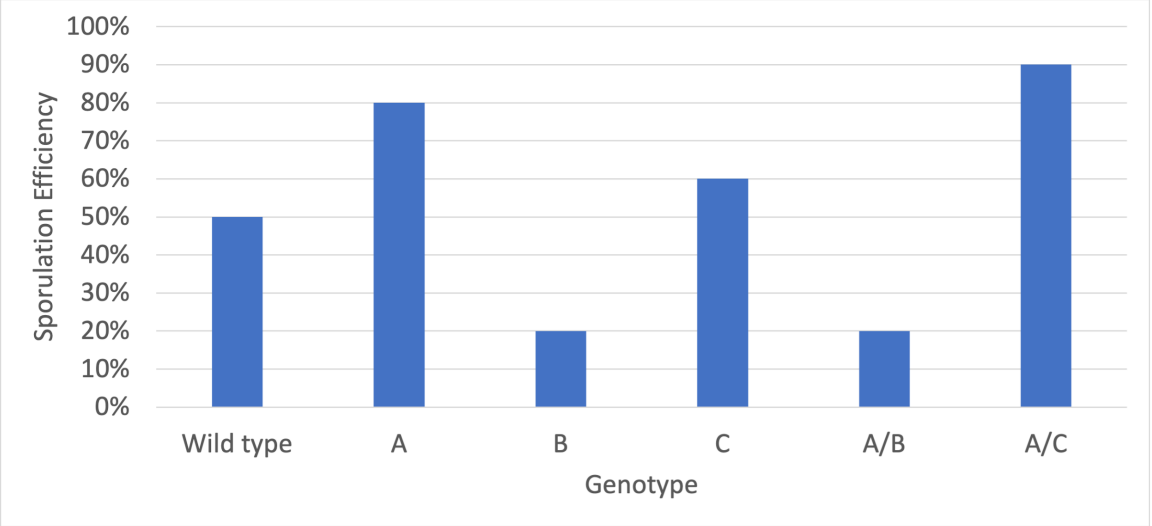
Baker's yeast (*Saccharomyces cerevisiae*) sporulates in response to nutrient deprivation. The fraction of cells that sporulate in a culture, called the sporulation efficiency, varies heritably among yeast strains. For example, the best-studied laboratory strain, S288c, is a notoriously poor sporulator,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

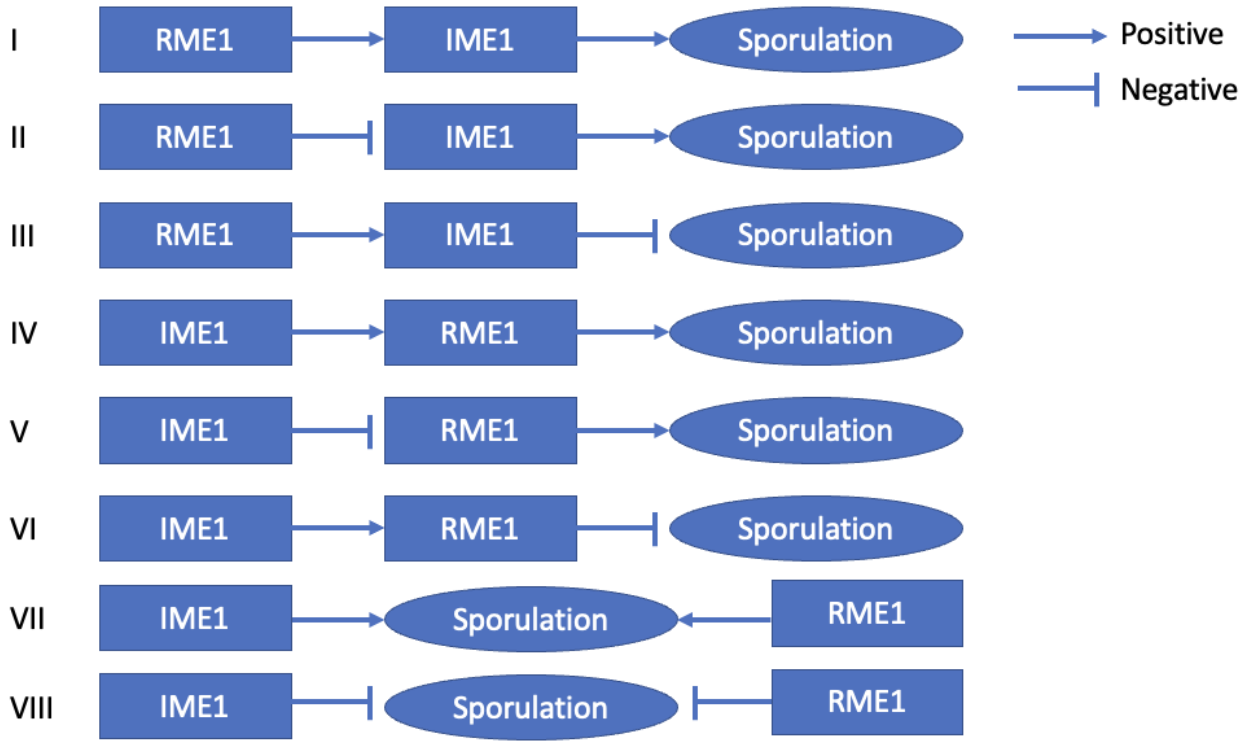
Part 6 of 9
What do you expect the sporulation efficiency of a combined B/C mutant plant to be? *Give an answer in numerals. The unit is % (it doesn't matter whether you type the unit)*

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

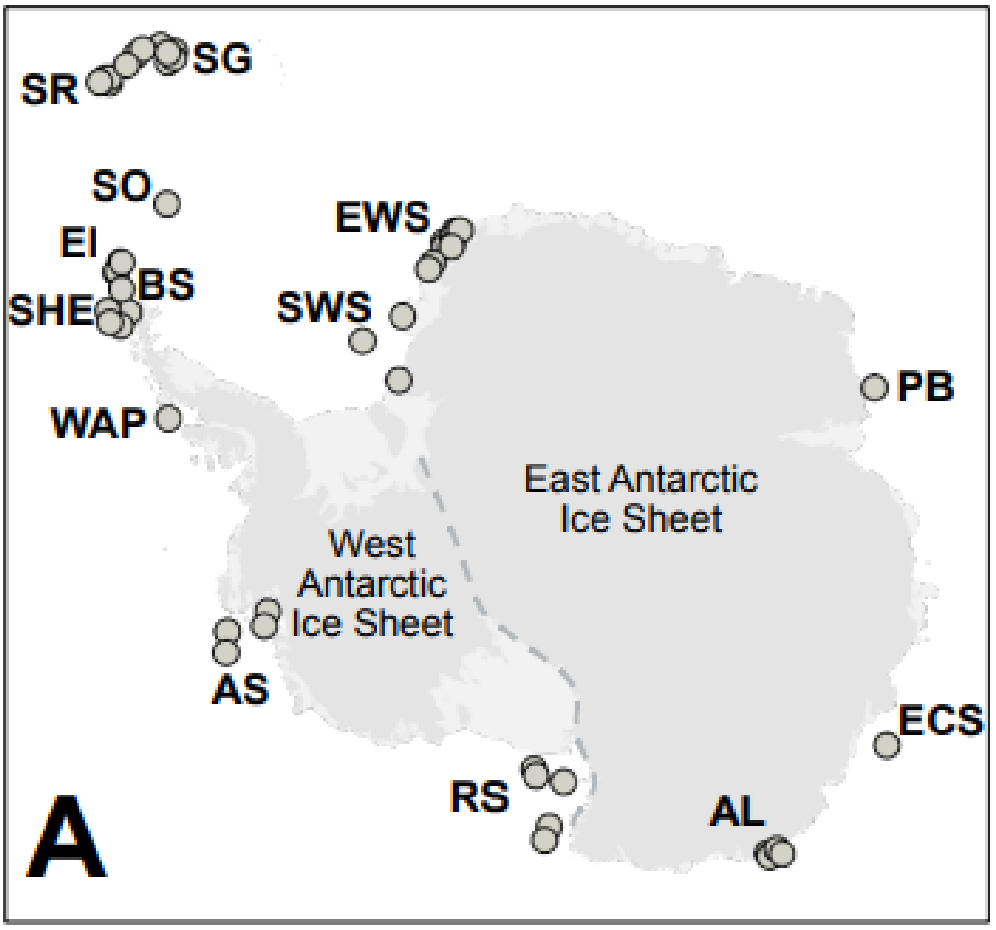
Part 1 of 7

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 costal 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.

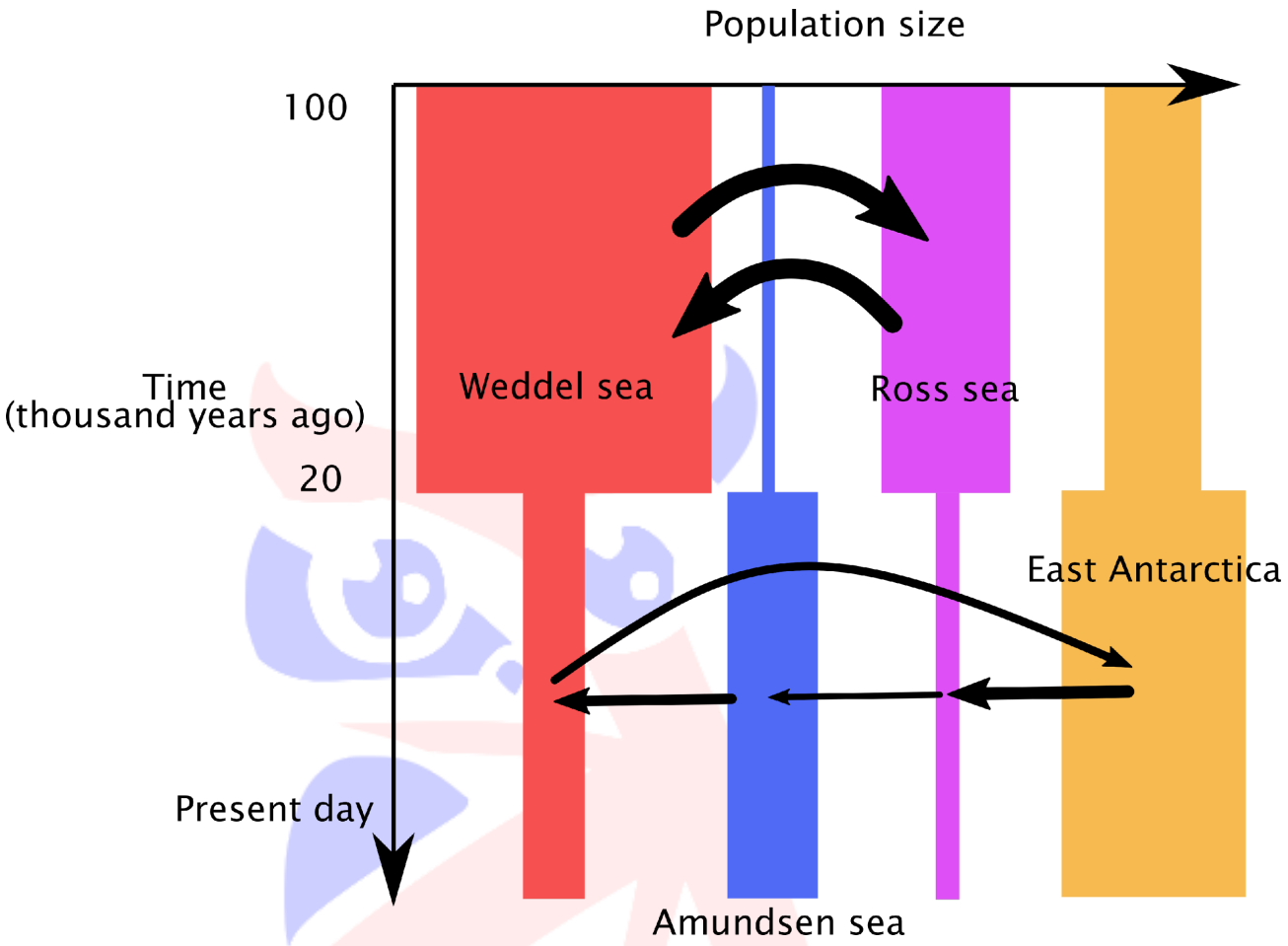
Part 2 of 7

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

a) The West Antarctic ice sheet was likely melted ~100,000 years ago.

TRUE FALSE

b) Currents currently circulate mostly anticlockwise around the Antarctic coast.

TRUE FALSE

c) The octopi prefer to travel through very deep oceanic water than shallow costal water.

TRUE FALSE

d) The octopi are better adapted to the warmer oceans of the past.

TRUE FALSE

e) 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

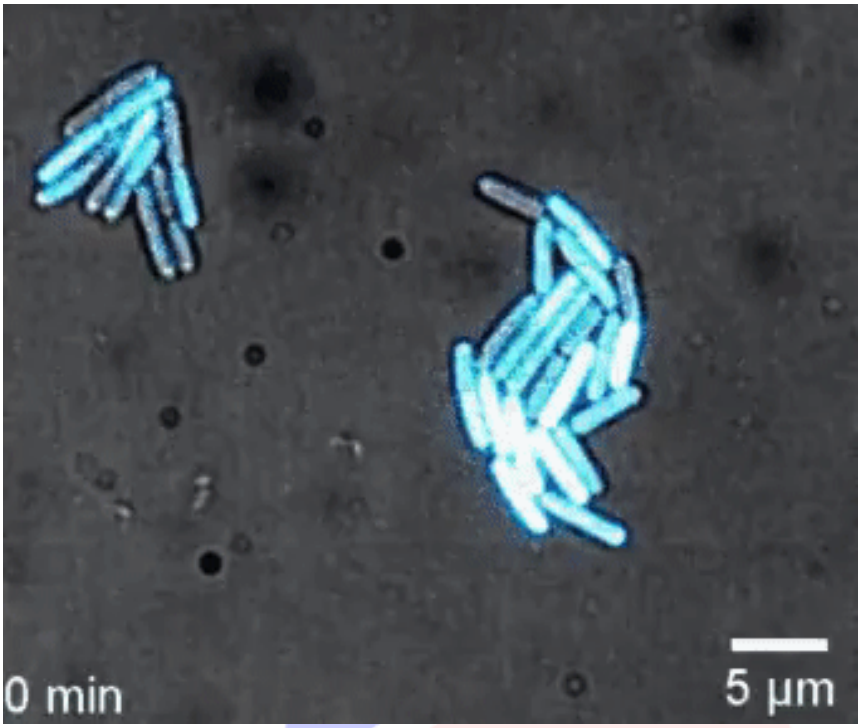
f) Thick fur / blubber

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

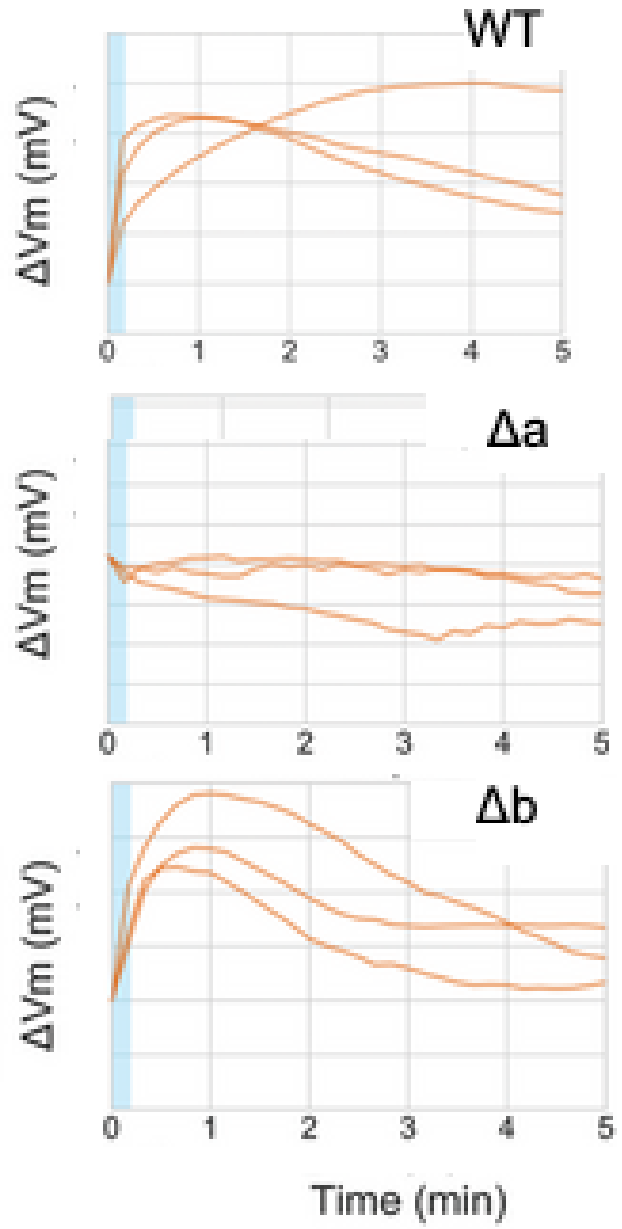
d) 20 minutes

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.



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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

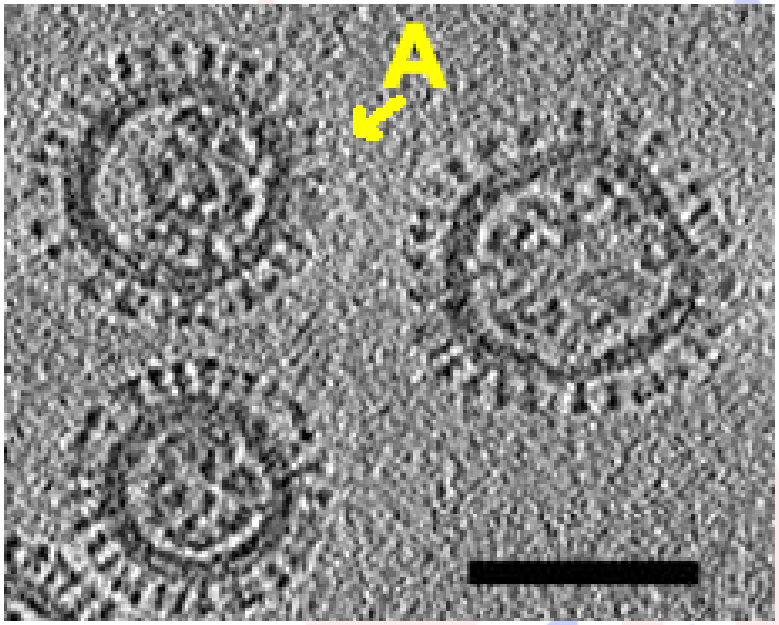
c) The light pulses cause potassium ion channels to briefly shut

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 flus 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 viron (scale bar: 100 nm).



Scale bar: 100 nm. Influenza virons 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 µm

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 SAα2,6-Gal linked receptors. * Avian viruses tend to bind to SAα2,3-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 SAα2,6-Gal

Only SAα2,3-Gal

Both SAα2,6-Gal and SAα2,3-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

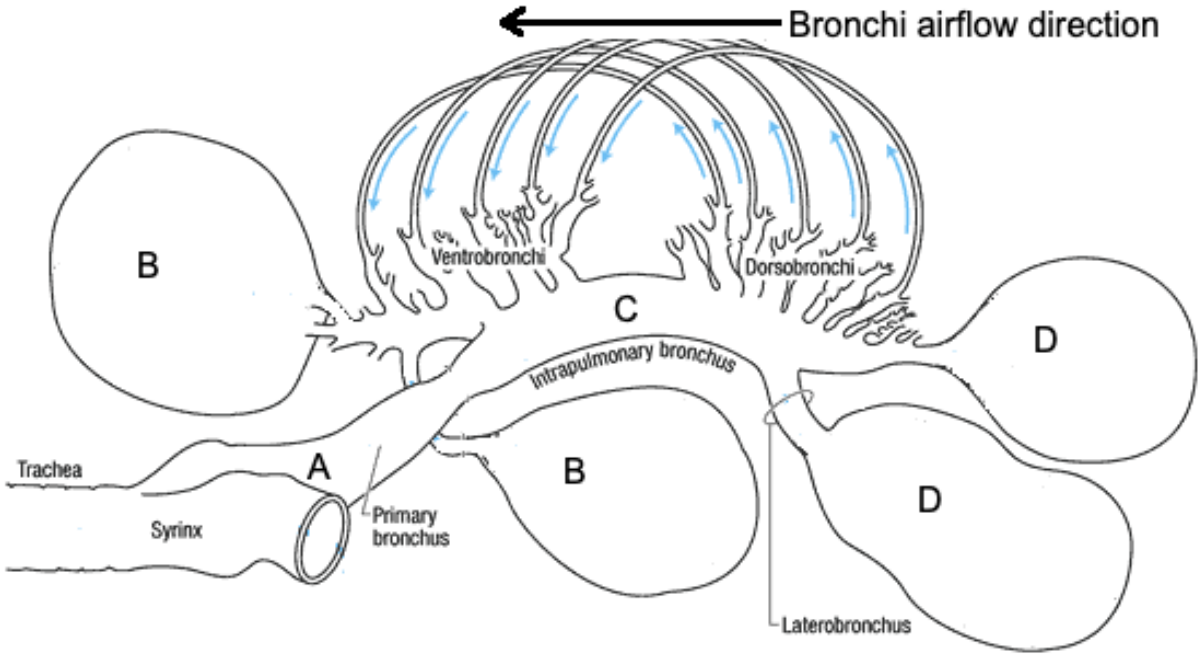
e) Glycogen synthase activity

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

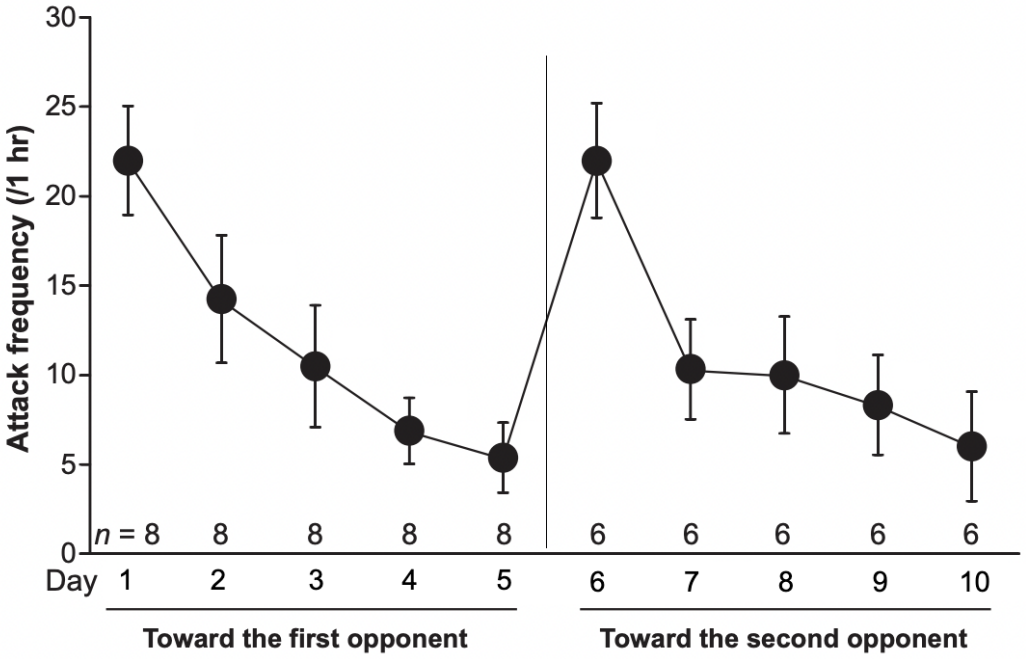
The cleaner fish, *Labroides dimidiatus*, uses visual cues to identify between different individual members within social groups.Kohda and colleagues looked at aggressive fish behaviours (rushing, bumping and biting) with other fish and images of themselves with and without mirrors.



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

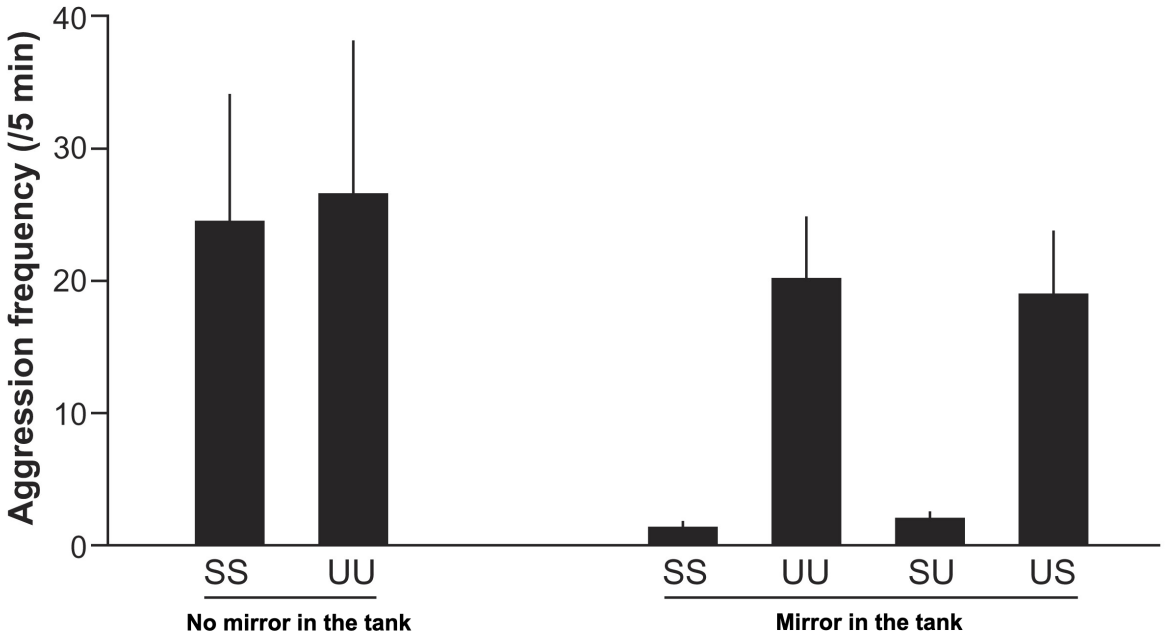
TRUE FALSE

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

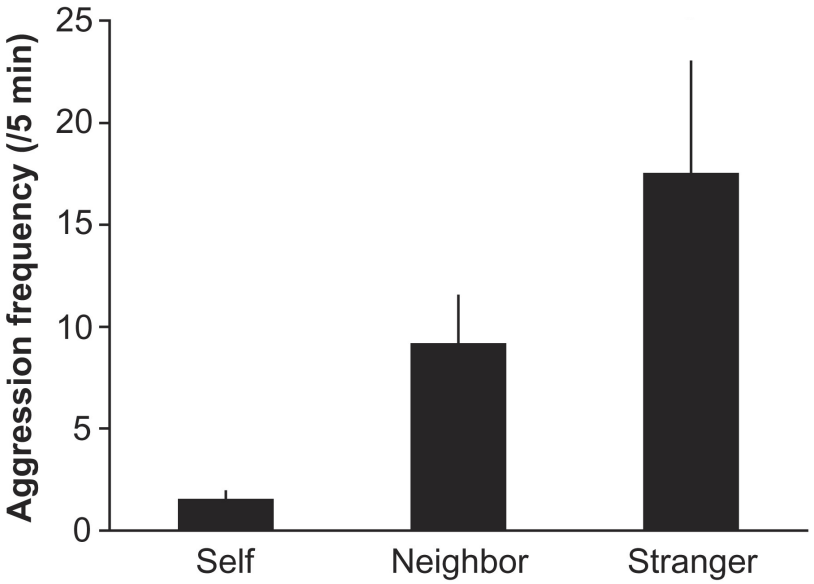
TRUE FALSE

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

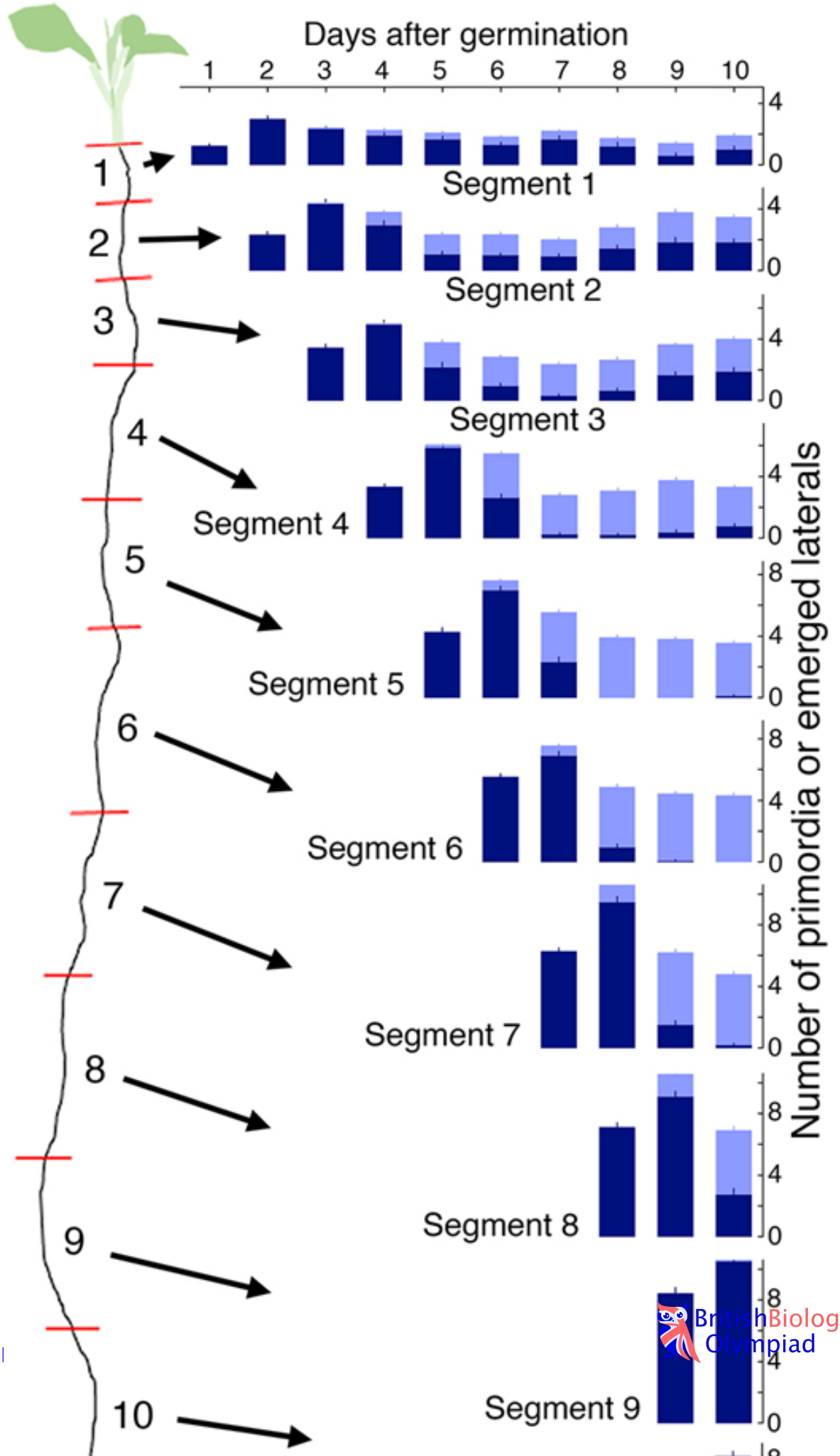
a) Self-recognition

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.


Days after germination
1 2 3 4 5 6 7 8 9 10
Segment 1
Segment 2
Segment 3
Segment 4
Segment 5
Segment 6
Segment 7
Segment 8
Segment 9
Number of primordia or emerged laterals
1
2
3
4
5
6
7
8
9
10
0 4
0 4 8

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

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

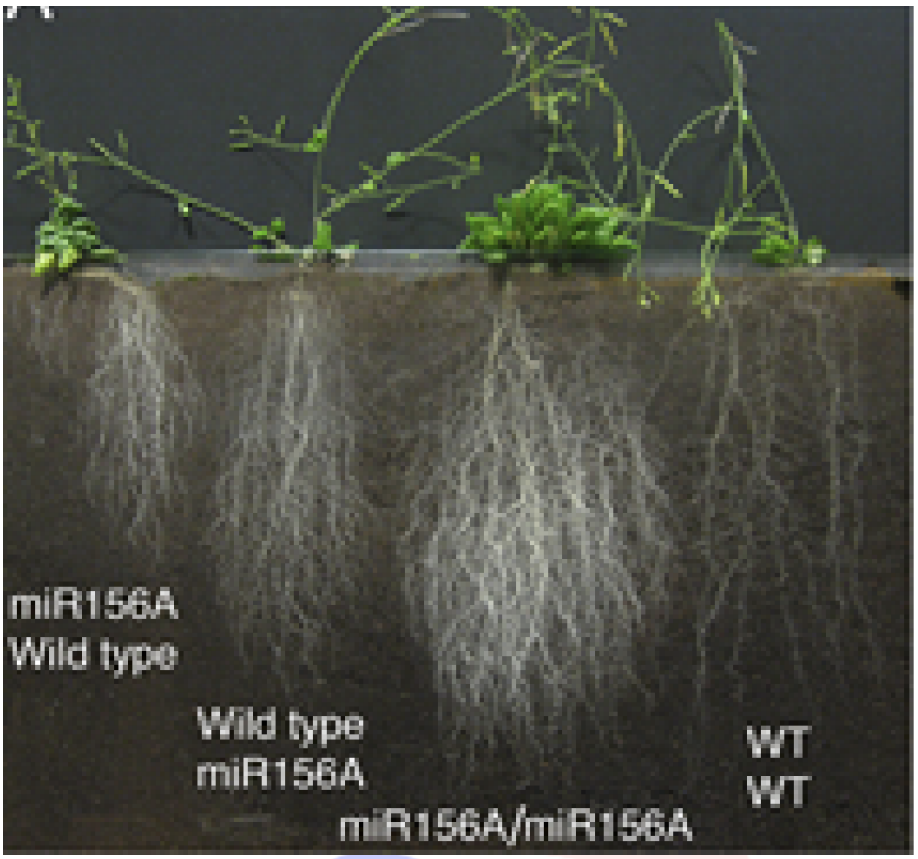
TRUE FALSE
c) Root primordia are guaranteed to eventually become lateral roots

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

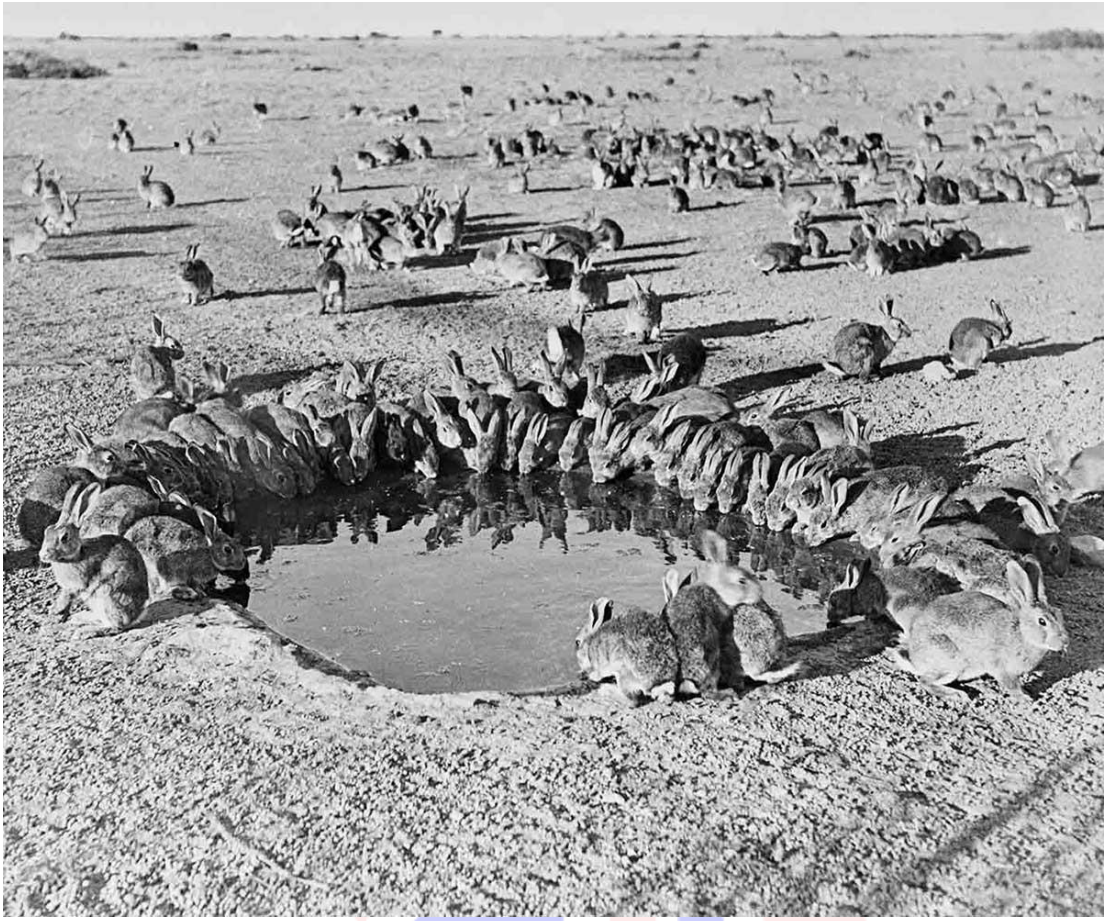
e) Plants with no miR156A could have more lateral root primordia

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.



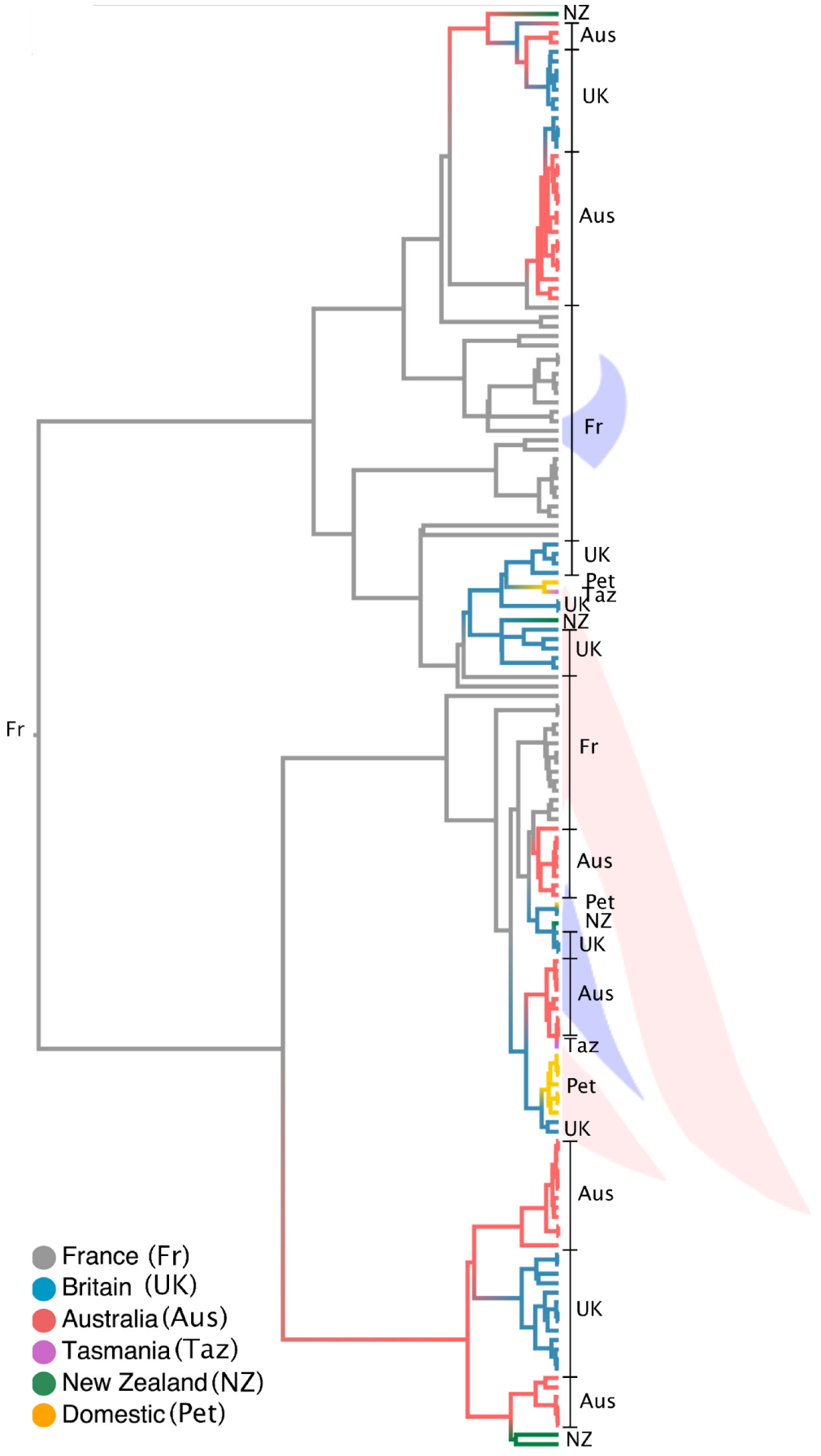
Rabbits around a waterhole during myxomatosis trials, Wardang Island, South Australia, 1938

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.


NZ
Aus
UK
Aus
Fr
UK
Pet
Taz
UK
NZ
UK
Fr
Fr
Aus
Pet
NZ
UK
Aus
Taz
Pet
UK
Aus
UK
Aus
NZ
France (Fr)
Britain (UK)
Australia (Aus)
Tasmania (Taz)
New Zealand (NZ)
Domestic (Pet)

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

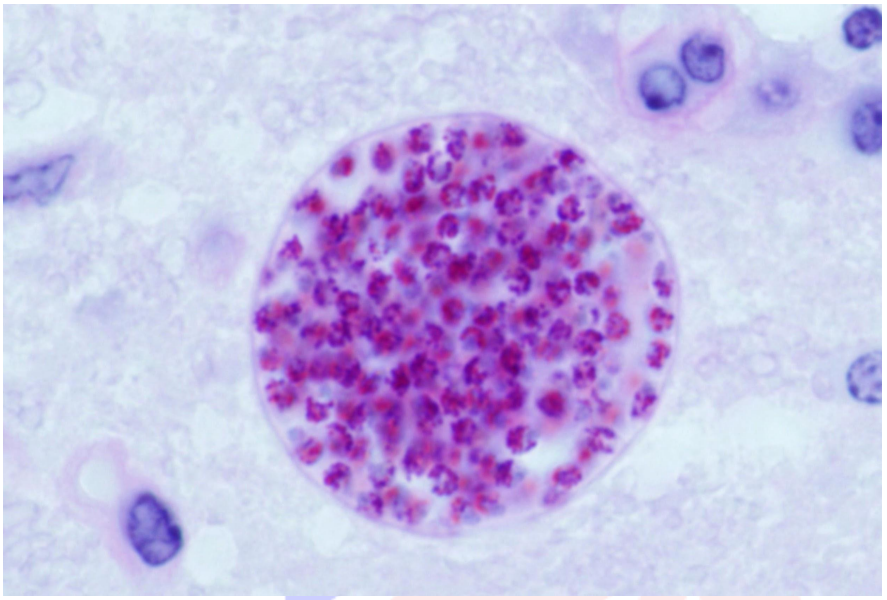
f) Viruses do badly in the Australian climate

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

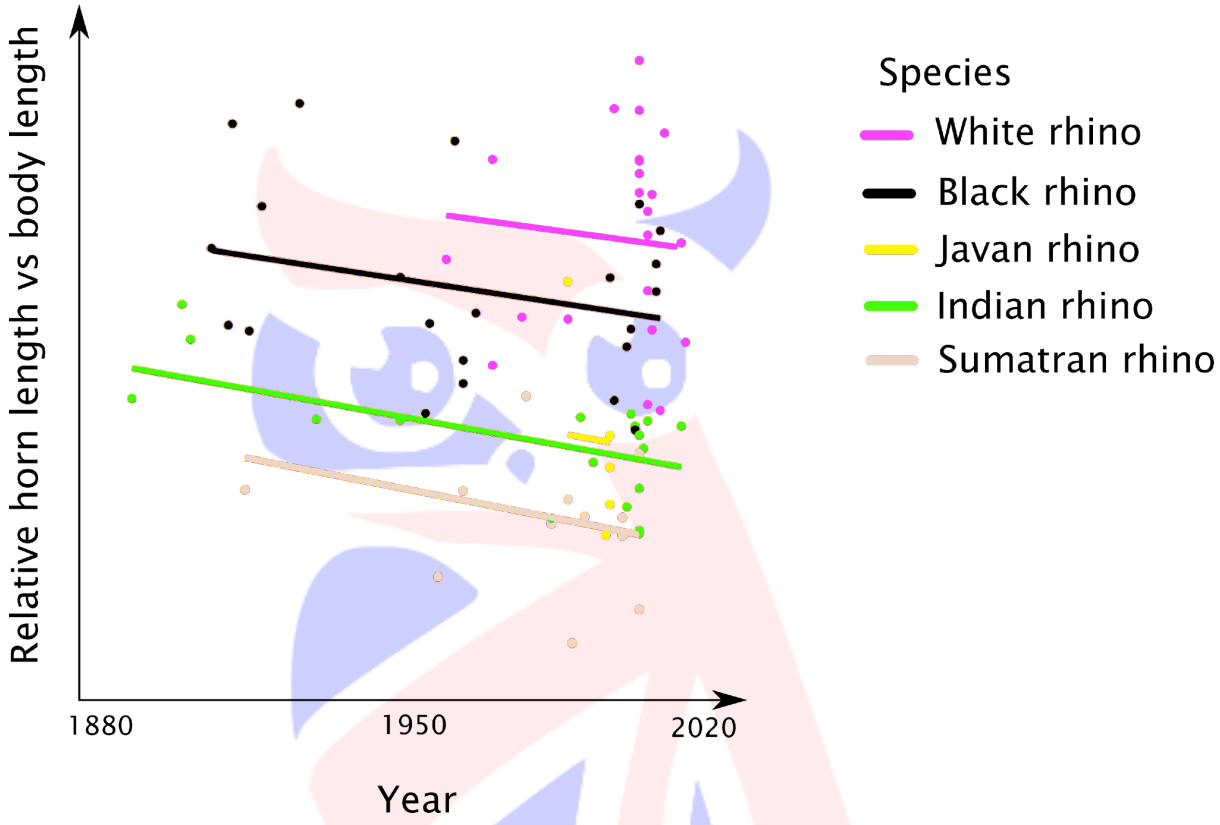
e) Ungulates primarily graze inaccessible slopes rather than open planes and valleys

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

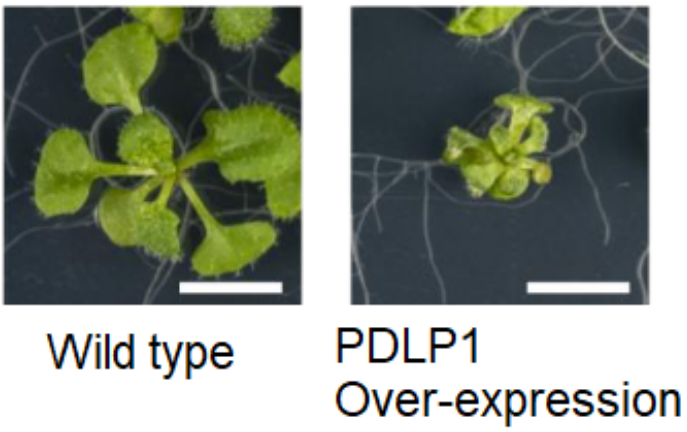
j) If a mix of captive and wild rhinos were measured, this increases our confidence that the trend is real

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.



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

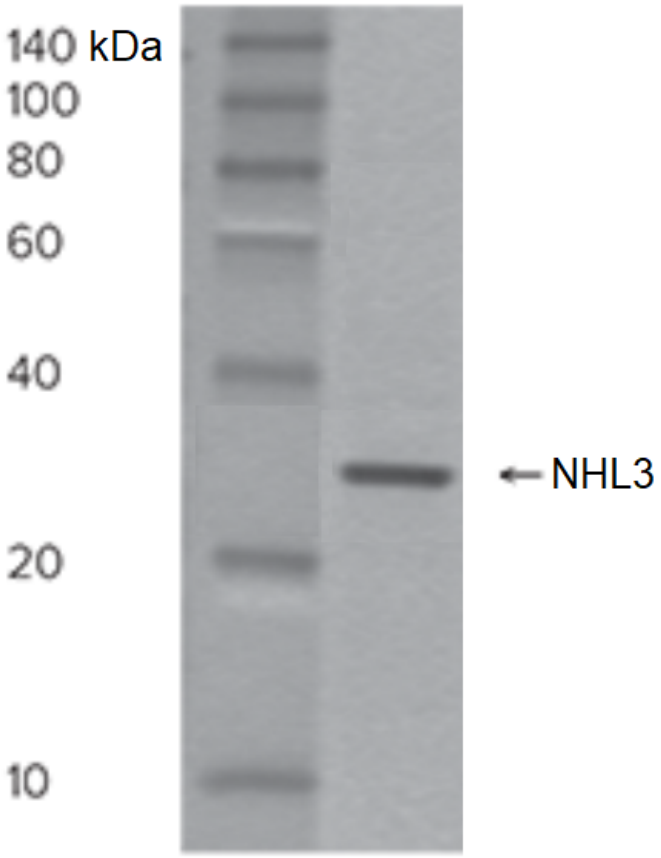
d) PDLP1 is required for normal plant development

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*



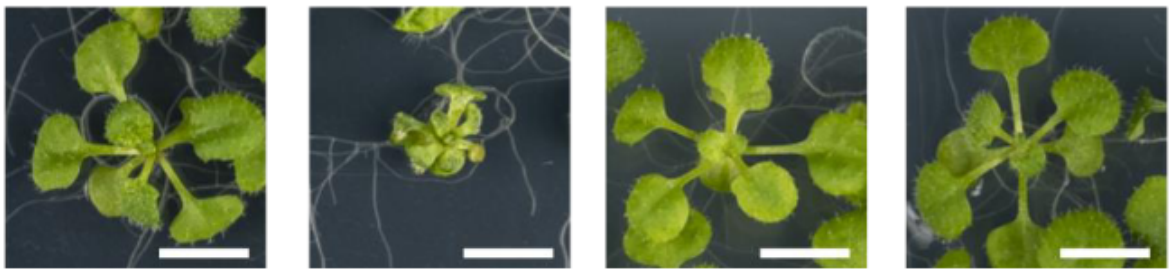
NHL3 run on a Western blot against a ladder

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 PDLP1, 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

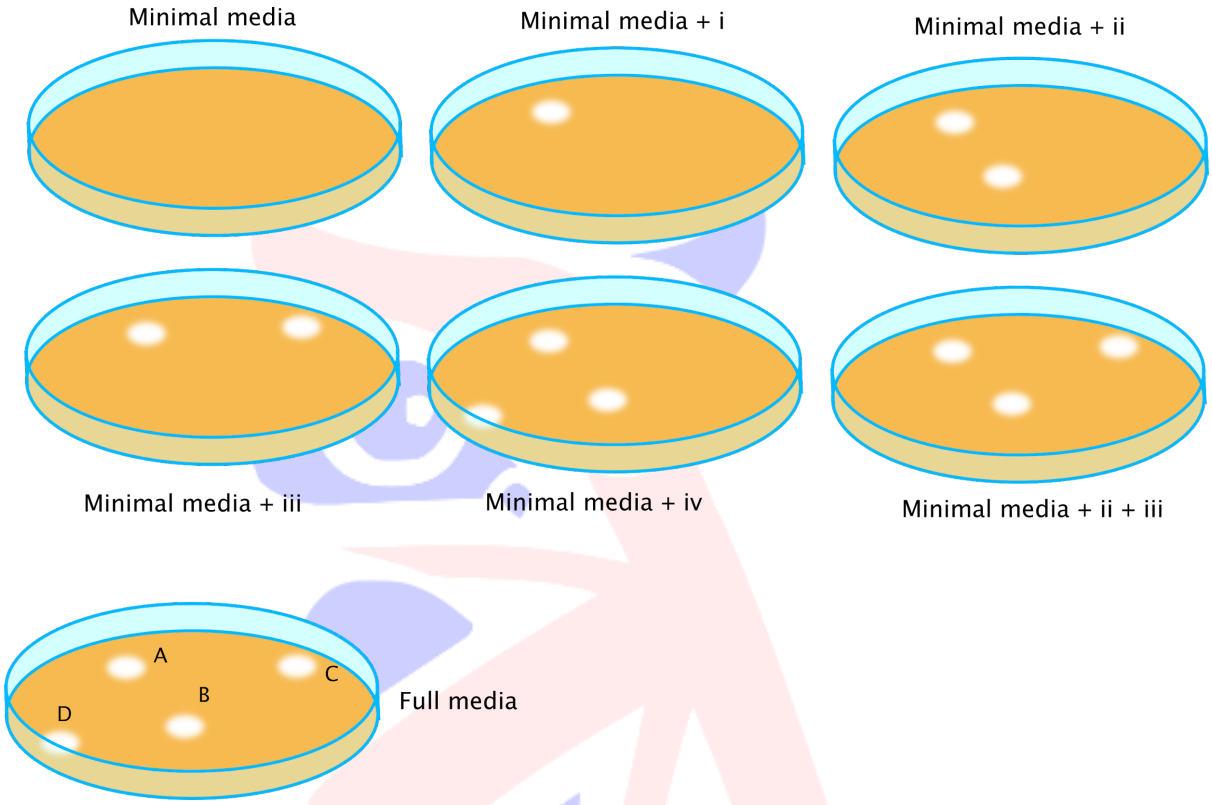
d) Recruitment of immune cells and chondrocytes (collagen producing cells)

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*.

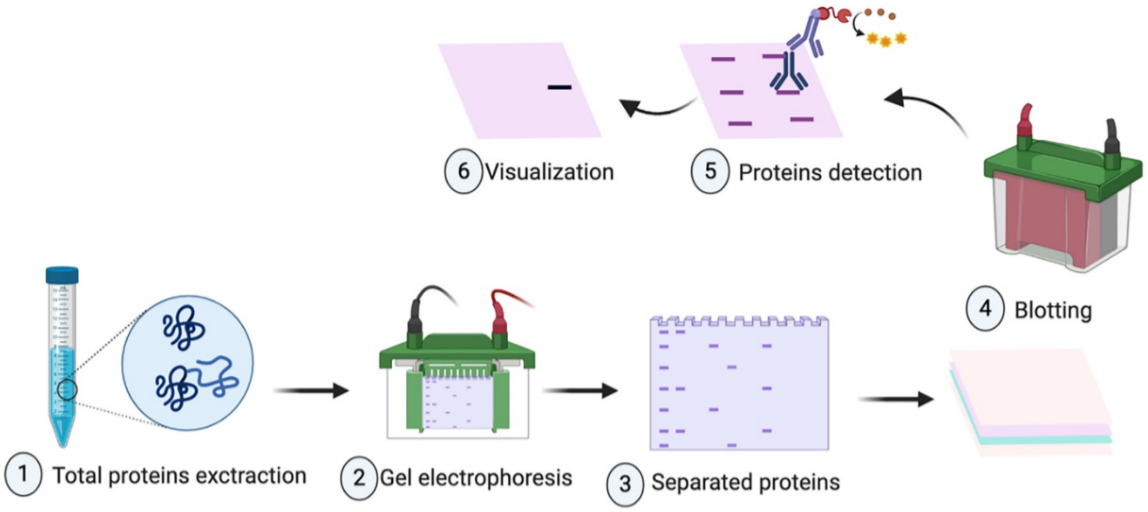
TRUE FALSE

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