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 2021

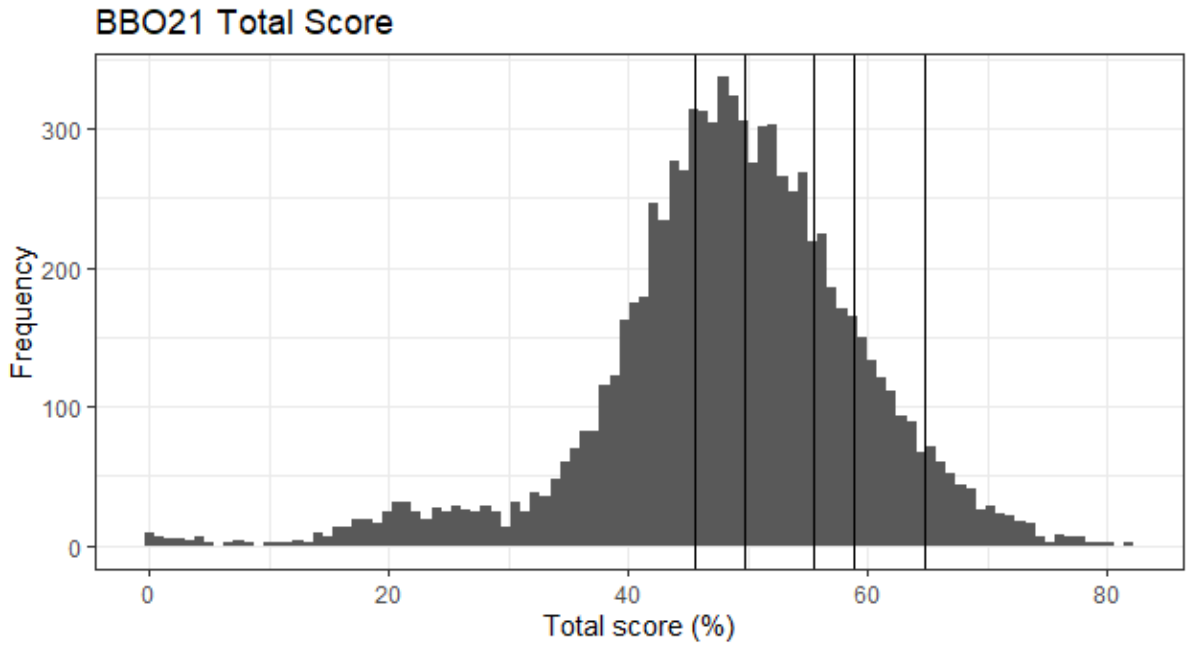
Duration: 45 + 45 minutes
Total marks available: 163

Participation: 8873 students took part from 449 schools.

Grade boundaries:

Medal	Percentage of Students (%)	Mark (%)
Gold	5	64
Silver	10	58
Bronze	15	55
Highly Commended	15	49
Commended	15	20

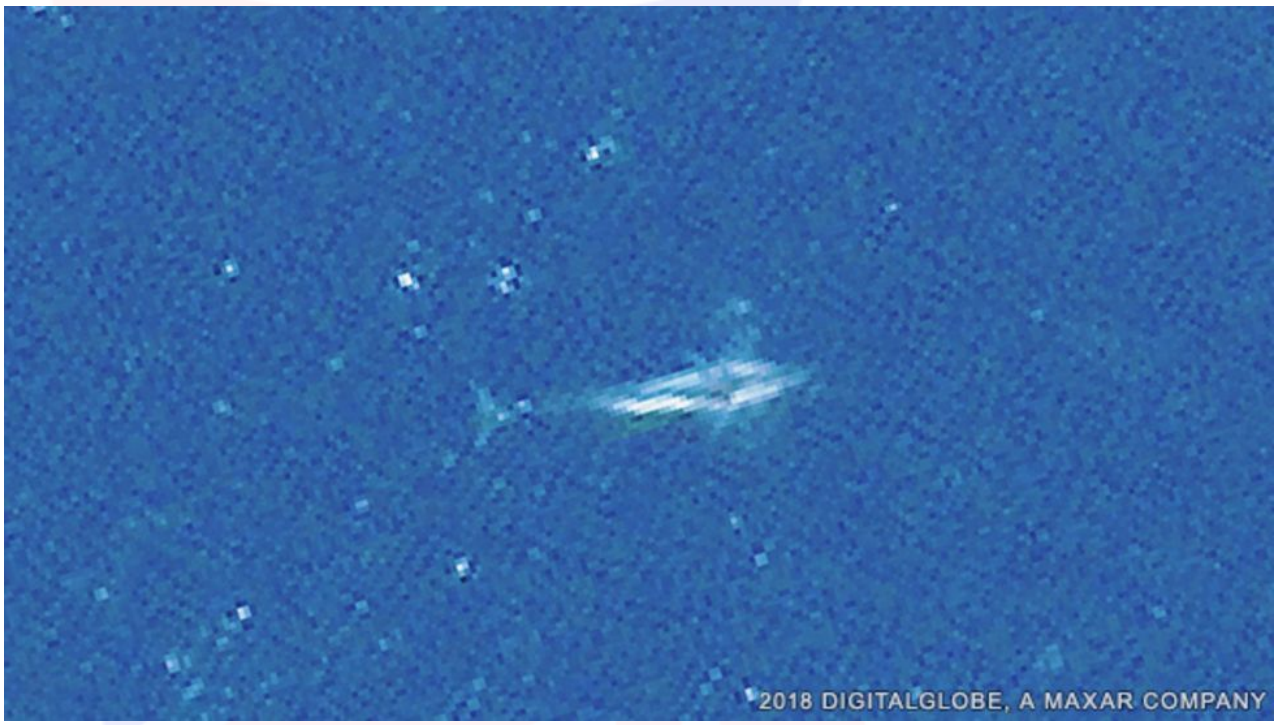
Mark Distribution:



Question 1

Part 1 of 13

Blue whales are the largest organisms ever to have lived. The British Antarctic Survey is developing technology to monitor them from space.



Part 2 of 13

You want to estimate the blue whale population. Most satellites do not take photographs of sufficient quality, so you focus on ten patches of ocean which measure 1000 square miles each. The area of the entire oceans where blue whales live is approximately 20 million square miles. In each square of ocean you count the following numbers of whales:

Year 2010	Image	1	2	3	4	5	6	7	8	9	10
	Number of whales	3	0	0	0	3	2	1	1	0	0

Year 2020	Image	1	2	3	4	5	6	7	8	9	10
	Number of whales	0	1	3	0	4	5	1	4	0	1

Part 3 of 13

Estimate the % change in whale population from 2010 to 2020. *Type a number **without** the % sign.*

1 mark

Write something below

Part 4 of 13

Give an estimate of the total whale population in 2010.

2 marks

Write something below

Part 5 of 13

Are satellite images better at estimating the change in population or the total population?

1 mark

Choose ONE

a) Change in population.

b) Total population.

Part 6 of 13

Based on fossils, whales seem to have gotten larger overtime. Satellite images suggest that the largest individual animals ever to live are currently alive.

Part 7 of 13

Are satellites better at estimating the size of whales or the total population?

1 mark

Choose ONE

a) The size of whales.

b) The total population.

Part 8 of 13

Another project uses a mark-recapture method to count whales, but it takes several years to find enough whales. *Note whales can be visited by a boat without causing distress* In the capture period, 300 whales were identified. In the recapture period, 450 whales were found but only 5 were individuals identified in the capture period.

Part 9 of 13

Give another estimate of the whale population.

2 marks

Write something below

Part 10 of 13

Which method is better for estimating the total whale population?

1 mark

Choose ONE

a) Mark-recapture.

b) Counting from images.

Part 11 of 13

Which method is better for estimating the change in whale population?

1 mark

Choose ONE

a) Mark-recapture

b) Counting from images.

Part 12 of 13

Which method is better for estimating the change in average whale size?

1 mark

Choose ONE

a) Measuring 'captured' animals.

b) Measuring animals from images.

Part 13 of 13

Which factors are important for getting reliable data from these population surveys?

4 marks

Choose as many as appropriate

a) Measure the same number of whales each year.

b) Carry out measurements in a range of areas representing different parts of the ocean.

c) Maximise the number of samples taken in each survey.

d) Sample at the same places each year.

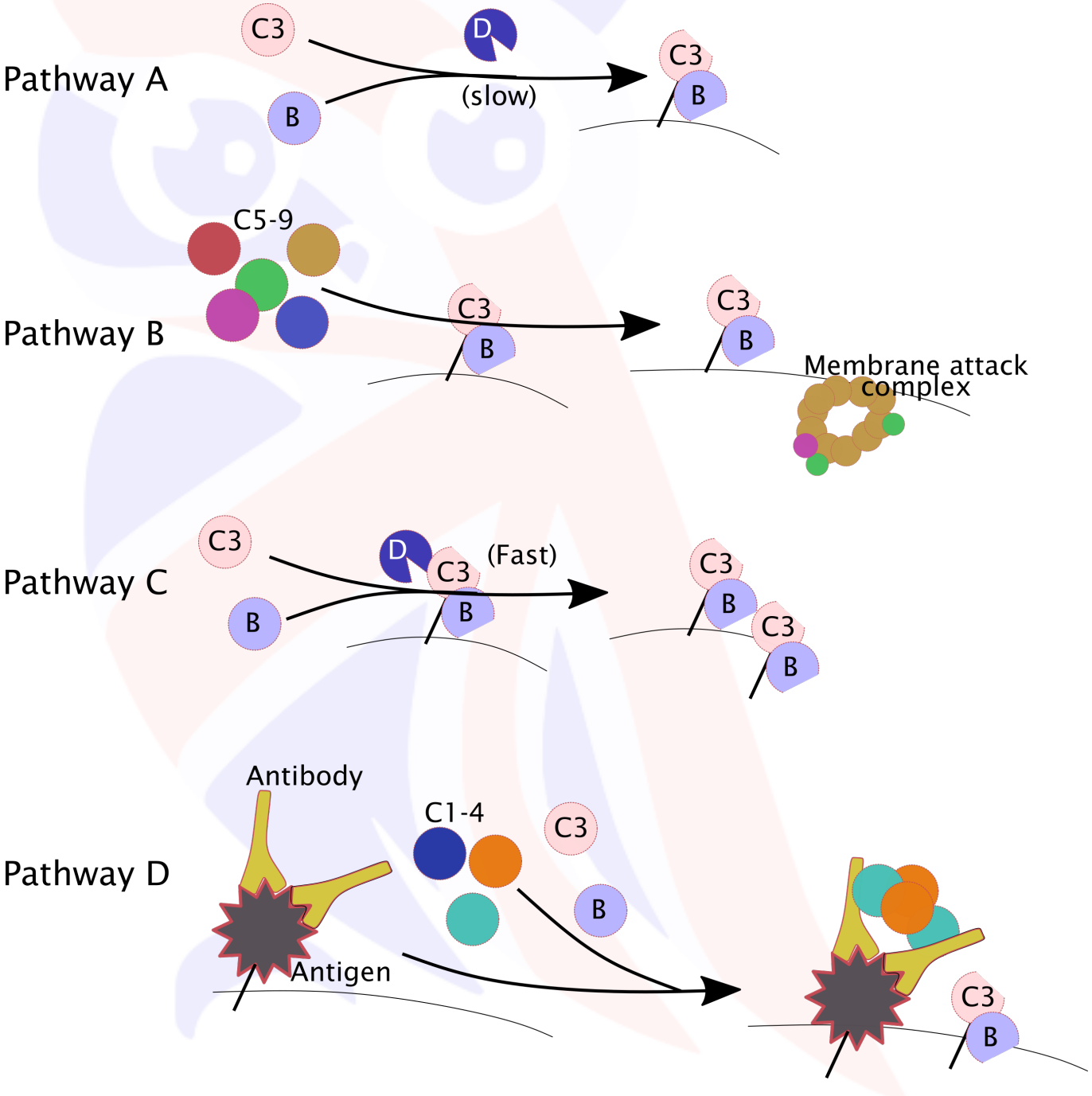
e) Sample in the same season each year.

f) Measure the same whales each year.

Question 2

Part 1 of 8

The complement system is so called because it complements the immune system by tagging and destroying foreign materials. Individual reactions in this system were discovered separately. The reactions are shown.



Part 2 of 8

Complement factors circulate freely in extracellular fluid, but C3B has a highly reactive group which binds any surfaces it touches. The membrane attack complex

punches large holes in membranes, whilst C3B attracts immune cells and stimulates them to attack. The complement system can cause a variety of diseases so scientists need to guess which pathways to target with drugs. **Come up with a hypothesis about what each pathway does.**

Part 3 of 8

Which pathway amplifies the activity of the complement system to increase its speed and destructive power?

1 mark

Choose ONE

a) Pathway A

b) Pathway B

c) Pathway C

d) Pathway D

Part 4 of 8

Which pathway links the complement system to the adaptive immune system?

1 mark

Choose ONE

a) Pathway A

b) Pathway B

c) Pathway C

d) Pathway D

Part 5 of 8

Which pathway causes the complement system to target everything, even an entirely new pathogen?

1 mark

Choose ONE

a) Pathway A

b) Pathway B

c) Pathway C

d) Pathway D

Part 6 of 8

Human cells have precise human-complement inhibitors on their surface so they are not harmed. Which two pathways must they inhibit?

1 mark

Choose as many as appropriate

a) Pathway A

b) Pathway B

c) Pathway C

d) Pathway D

Part 7 of 8

Which pathway causes animal red blood cells to burst if they are transfused into humans?

1 mark

Choose ONE

a) Pathway A

b) Pathway B

c) Pathway C

d) Pathway D

Part 8 of 8

Which factor is the rate limiting factor, so tweaking its levels alters the activity of the complement system?

1 mark

Choose ONE

a) C3

b) B

c) D

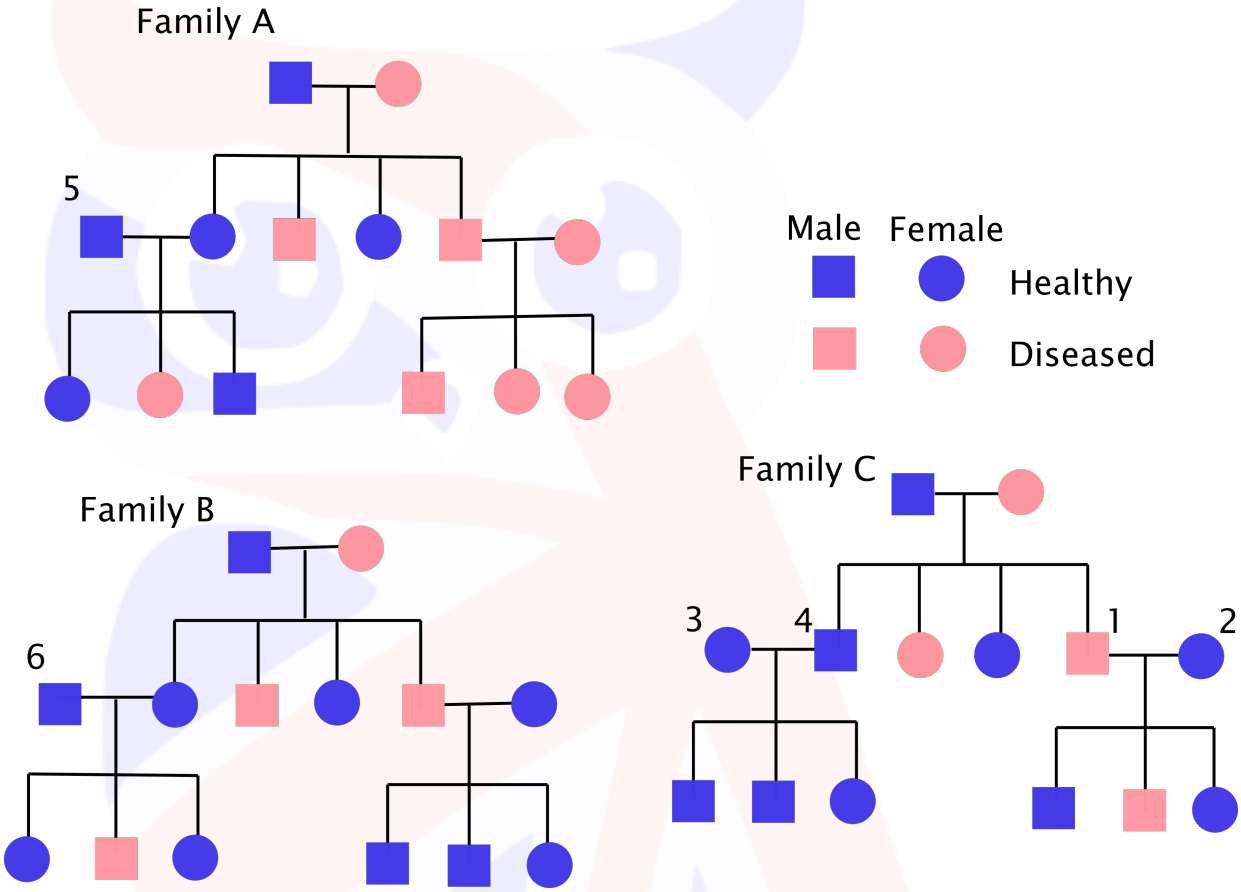
d) C5-9

e) C1-4

Question 3

Part 1 of 4

For the three different diseases, pedigree analysis was performed on family trees.



Part 2 of 4

If family C's disease is caused by a recessive allele, calculate the probability a new child of 1 and 2 gets the disease. *Give your answer as a decimal*

2 marks

Write something below

Part 3 of 4

Secondly, if the frequency of the recessive allele in the population is 0.1, calculate the probability that a new child of 3 and 4 gets the disease. *Give your answer as a decimal.*

4 marks

Write something below

Part 4 of 4

Are these true or false?

4 marks

Mark the following as TRUE or FALSE

a) Family A's disease *could* be due to a dominant allele.

TRUE FALSE

b) Family C's disease *could* be due to a dominant allele.

TRUE FALSE

c) Family B's disease *could* be due to a mutation on the X-chromosome.

TRUE FALSE

d) Individual 5 *cannot* be carrying the disease allele.

TRUE FALSE

e) Individual 6 *must* be carrying the disease allele.

TRUE FALSE

Question 4

Part 1 of 10

Peaches and nectarines are produced by the same species of tree. Peaches have a fuzzy coating but nectarines do not.

Part 2 of 10

In which of the following scenarios are some plants known to evolve fuzzy/furry coatings?

3 marks

Choose as many as appropriate

a) Reduce water loss in dry environments.

b) Reduce UV damage in mountains.

c) Increase CO_2 uptake.

d) Reduce predation by mammals.

e) Reduce predation by insects.

f) Increase surface area for photosynthesis.

Part 3 of 10

To investigate why trees produce peaches or nectarines, the following experiments were carried out.

	Scenario	Result
A	Seeds of peach trees grown in hot or cool conditions	Peaches appear in hot conditions, nectarines in cool conditions
B	Peach tree is crossed with nectarine tree	All offspring produce peaches
C	Peach tree is crossed with nectarine tree	All offspring produce nectarines
D	Peach tree is crossed with nectarine tree	Some offspring produce peaches and some offspring produce nectarines
E	Nectarine trees are left alone for many years	At a certain age, trees produce peaches instead

Part 4 of 10

Which results are expected if fuzz is produced by a single dominant allele?

1 mark

Choose as many as appropriate

a) A

b) B

c) C

d) D

e) E

Part 5 of 10

Which results are expected if fuzz is produced by a single recessive allele?

1 mark

Choose as many as appropriate

a) A

b) B

c) C

d) D

e) E

Part 6 of 10

Which results are expected if fuzz is produced by many alleles in combination?

1 mark

Choose as many as appropriate

a) A

b) B

c) C

d) D

e) E

Part 7 of 10

Which results are expected if fuzz is environmentally controlled?

1 mark

Choose as many as appropriate

a) A

b) B

c) C

d) D

e) E

Part 8 of 10

In actuality, nectarines are the result of a recessive mutation in a single gene. A farmer grows only peaches. She crosses her peaches and gives the seeds to a neighbour to set-up his own farm. However, 9% of the plants on his new farm turn into nectarines.

Part 9 of 10

What is the frequency of the mutation on the neighbour's new farm? *Type a decimal*

1 mark

Write something below

Part 10 of 10

What is the frequency of the mutation on the original farm? *Type a decimal*

1 mark

Write something below

Question 5

Part 1 of 4

The adult cells of baobab trees have 168 chromosomes, compared to 46 in humans. These contain four copies of the genome, compared to two copies in humans.

Part 2 of 4

How many chromosomes need to be sequenced to get one complete copy of the baobab genome?

1 mark

Write something below

Part 3 of 4

How many chromosomes does a baobab gamete contain?

2 marks

Write something below

Part 4 of 4

During meiosis, how many different combinations of chromosomes could be produced in **human** gametes. (Write the number in full)

4 marks

Write something below

_____

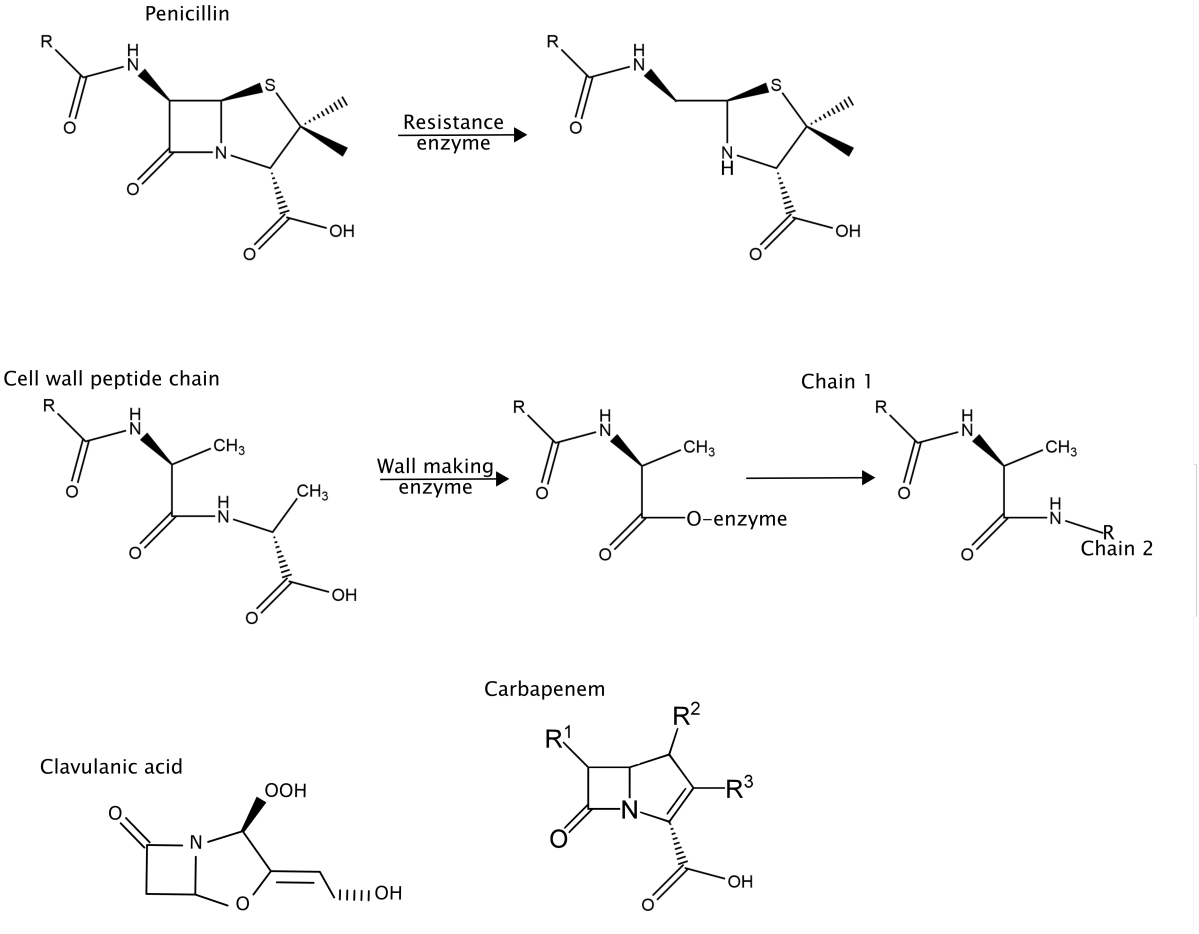
Question 6

Part 1 of 8

In 2021, the Chief Medical Officer warned increasing antibiotic resistance signals "the end of modern medicine." The most important antibiotics are based on penicillin. Penicillin-like antibiotics inhibit enzymes which synthesise bacterial cell walls. These enzymes link different peptide chains. Bacteria use resistance enzymes to inactivate penicillin-like antibiotics. To counter this, clavulanic acid can be mixed with penicillin. Clavulanic acid alone does not work as an antibiotic. Alternatively, carbapenem-like antibiotics can be used instead of penicillin.

Part 2 of 8

Look carefully at these molecular structures and reactions. **Form hypotheses for how the antibiotics work.**



Part 3 of 8

How does penicillin work?

1 mark

Choose ONE

a) Binds enzyme away from the active site, changing its conformation.

b) Binds enzyme at active site, preventing substrate binding.

c) Makes cell walls more linked and too rigid.

d) Lowers the pH of bacterial cells, killing them.

e) Reacts with peptide chains in the cell wall, disrupting them.

Part 4 of 8

What is the best description of the kinetics of penicillin inhibition?

1 mark

Choose ONE

a) Reversible competitive inhibitor.

b) Reversible allosteric/non-competitive inhibitor.

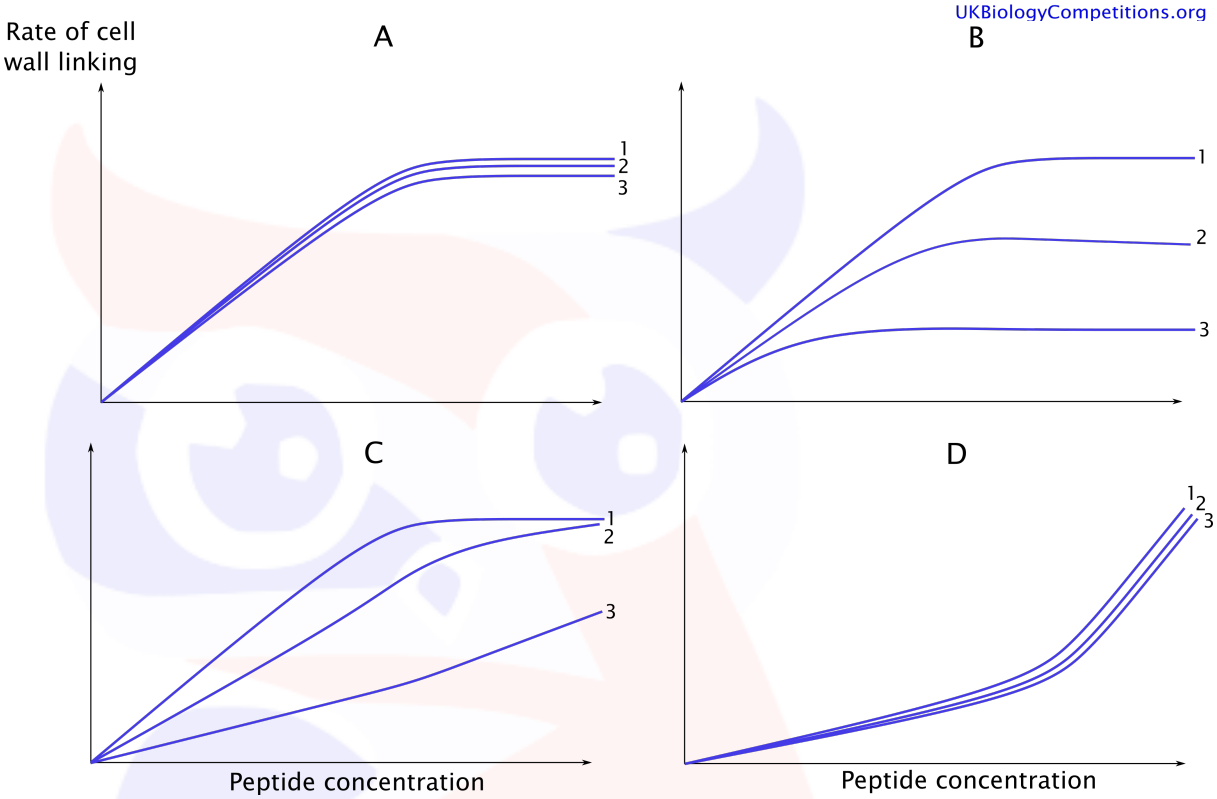
c) Reversible uncompetitive inhibitor (binds intermediate enzyme/substrate complex).

d) Irreversible/suicide inhibitor (forms covalent bond with enzyme if enzyme tries to use it).

e) Quencher (binds other things needed for enzyme to work).

Part 5 of 8

The rate of cell-wall synthesising enzyme activity was plotted against the concentration of peptide substrate. **Penicillin resistant** bacteria were used. *Assume carbapenem kinetics look as if it were a non-competitive inhibitor.*



Part 6 of 8

Which graph shows what happens when 1, 2, 3 are increasing concentrations of penicillin?

1 mark

Choose ONE

a) A

b) B

c) C

d) D

Part 7 of 8

Which graph shows what happens when 1, 2, 3 are increasing concentrations of carbapenem?

1 mark

Choose ONE

a) A

b) B

c) C

d) D

Part 8 of 8

Which graph shows what happens when 1, 2, 3 are increasing concentrations of clavulanic acid mixed with a fixed concentration of penicillin?

1 mark

Choose ONE

a) A

b) B

c) C

d) D

Question 7

Part 1 of 7

Viruses which can deliver genes into human cells are essential for research, gene-therapy and vaccines. Somehow, scientists must make virus particles which are infectious, but only carry the useful gene and will not produce new virus within the person. To do this, scientists infect factory cells in large vats with different genes. The factory cells then release viral particles which can be harvested and used. A schematic of a generic virus genome is shown below.

Part 2 of 7

* 1 is the binding site for the virus transcription factor and replicating-polymerase. * 2 is the gene encoding the transcription factor. * 3 is the gene encoding the replicating-polymerase. * 4 is the gene encoding the envelope proteins which make up the outside of the virus particle. They bind site 1 to package the genome inside the viral particle.

Part 3 of 7

In the course of infection by a generic virus, put these steps in order starting with entry into the cell at the top.

2 marks

Put into the correct order

a) Viral genes are transcribed and replicated

b) Envelope proteins, transcription factor and polymerase is made

c) Envelope proteins form viral particles with genome and proteins inside

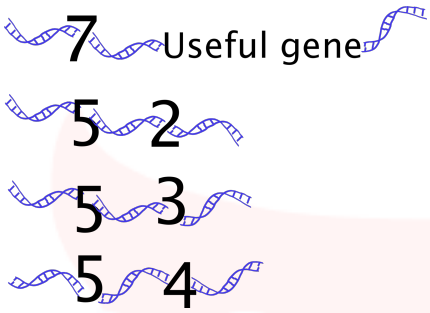
d) Polymerase and transcription factor bind the viral genome

Part 4 of 7

Second generation methods infect cells with three ‘genomes’ which look like this: * 5 is an artificial promoter.

Part 5 of 7

Third generation methods infect cells with four ‘genomes’ which look like this: * 7 is the same as 1, but the replicating-polymerase binding site inactivates itself.



Part 6 of 7

Why are second generation methods quite safe?

1 mark

Choose ONE

a) Polymerase and transcription factor proteins are not contained in the viral particles.

b) The genes packaged in the viral particles are not replicated or transcribed.

c) The viral particles do not contain genes for making more viral proteins.

d) Envelope proteins are not contained in the viral particles.

Part 7 of 7

Sort the following into whether they are true of second or third generation methods.

5 marks

Groups

Second generation

Third generation

Put into the groups above

a) Fewer components needed to be infected into factory cells

b) Safest

c) Higher yield of virus particles from factory cells

d) More likely natural viruses already in patients spread the introduced gene

e) More likely all genes needed for virus growth go into viral particles accidently

Question 8

Part 1 of 5

The RECOVERY trial run by the NHS is the most successful trial to identify proven treatments for COVID-19, and has disproven several popular candidates.

Part 2 of 5

What features should a randomised control trial like RECOVERY have?

3 marks

Choose as many as appropriate

a) Doctors do not know what drug they are administering until after the trial.

b) Patients do not know which drug they received until after the trial.

c) Hypothesis can be changed during the trial.

d) Number of patients used in trial maximised.

e) Include patients without COVID-19

Part 3 of 5

What things can a randomised control trial like RECOVERY conclude?

4 marks

Choose as many as appropriate

a) What causes a disease.

b) Whether a drug causes the improvement or is just correlated with it.

c) Whether a drug is better than placebos.

d) Whether a drug has side-effects or they are just symptoms of diseases.

Part 4 of 5

More data from the Oxford/AstraZeneca COVID-19 vaccine trial was released last month looking at people given two full doses of vaccine 12-weeks apart. * They found 15 out of 2038 people given the COVID-19 vaccine caught COVID-19. * They found 76 out of 2093 people given a meningitis vaccine caught COVID-19. Vaccine efficiency is calculated as the percentage decrease in cases caused by vaccination.

Part 5 of 5

Calculate the vaccine efficiency. *Type your answer to the nearest 1%*

3 marks

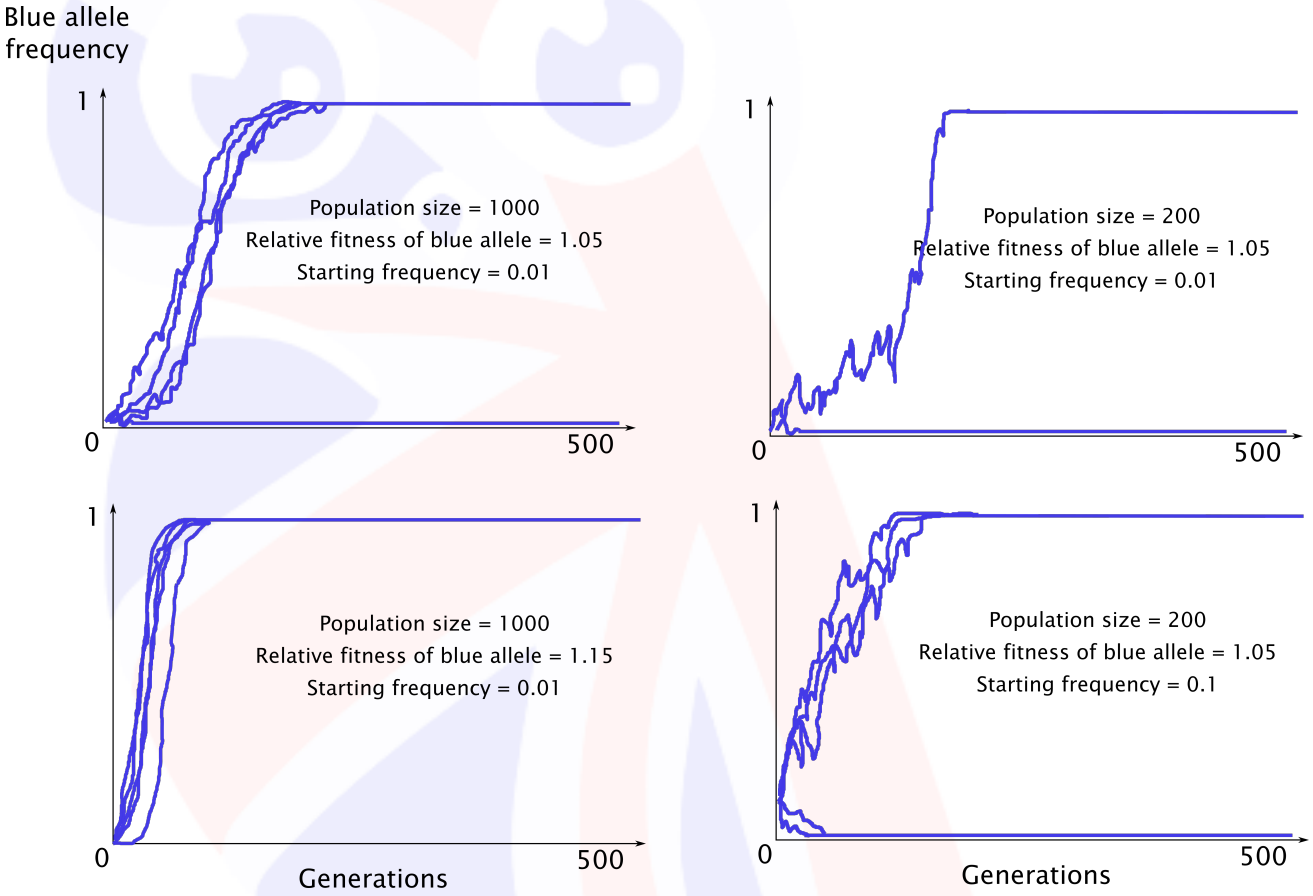
Write something below

_____

Question 9

Part 1 of 5

The 'UK variant' of Covid-19 was discovered to be more transmissible using genetic analyses of relative fitness. This involved deciding whether it was taking-over from other variants by chance, or by natural selection. In these simulations, a 'blue' allele appears in a population. The relative fitness of the blue allele, its starting frequency in the population, and the size of the population was modified. The simulations were repeated 5 times for each condition (shown as separate lines).



Part 2 of 5

Sort these scenarios into the correct column based on which factor dominates predictions for what happens to an allele in the future.

3 marks

Groups

Genetic drift dominates

Natural selection dominates

Put into the groups above

a) High current allele frequency

b) Large population

c) Large difference in relative fitness

d) Population split into isolated groups

Part 3 of 5

Sort these observations into whether they are caused by natural selection, genetic drift, or both.

6 marks

Groups

Caused by natural selection

Caused by both

Caused by genetic drift

Put into the groups above

a) The frequency at which an allele is initially introduced alters the probability it will takeover a population

b) More fit alleles sometimes go extinct before less fit alleles

c) The probability an allele will takeover a population

d) The speed an allele's frequency changes in any one population at any one time

e) The average speed with which allele frequency changes

f) Some alleles takeover very large populations even when they have impacts too small to measure in laboratories

Part 4 of 5

Which observations suggest that the UK-variant is genuinely more transmissible?

4 marks

Choose as many as appropriate

a) Very rapid rise in frequency of UK-variant in the UK.

b) Rise in frequency of UK-variant in multiple different countries.

c) Countries near the UK show a higher frequency of UK-variant than distant countries.

d) Covid cases in the UK were very low around the time the UK-variant is thought to have appeared.

Part 5 of 5

Evolution is often thought to occur slowly, although we have seen this is not always true. When will 'slow and steady' evolution over thousands of generations dominate?

1 mark

Choose ONE

a) Evolving adaptations with slight benefit in very large populations.

b) Evolving adaptations to resist pathogens.

c) Evolving adaptations when populations are regularly separated for long periods of time.

d) Evolving adaptations when there is only one selective pressure on a trait.

e) Evolving non-adaptive traits due to genetic drift.

Question 10

Part 1 of 15

Dynamic programming was invented to align DNA sequences, but now underpins countless processes, such as language-translation. It breaks a problem into small steps to find the optimal solution. In this question, you will use dynamic programming to align two DNA sequences. First you need a system to score an alignment. In this algorithm: * Matching bases will be scored +1 * Miss-matched bases will be scored -1 * Gaps in the alignment will be scored -1 * The highest score 'wins' Next, the two sequences are arranged in a grid.

		G	C	A	T
	0				
G					
A					
T					
T					

Part 2 of 15

You then generate a score for each cell. Moving horizontally or vertically indicates you are skipping bases, creating gaps in the alignment, so you add -1 to the previous score.

		G	C	A	T
	0 →	-1 →	-2 →	-3 →	-4
G	-1				
A	-2				
T	-3				
T	-4				

Part 3 of 15

Moving diagonally indicates you are aligning matching or miss-matching bases. You add +1 to the previous score if they match, or -1 if they miss-match.

		G	C	A	T
	0 →	-1 →	-2 →	-3 →	-4
G	-1	1			
A	-2		0		
T	-3				
T	-4				

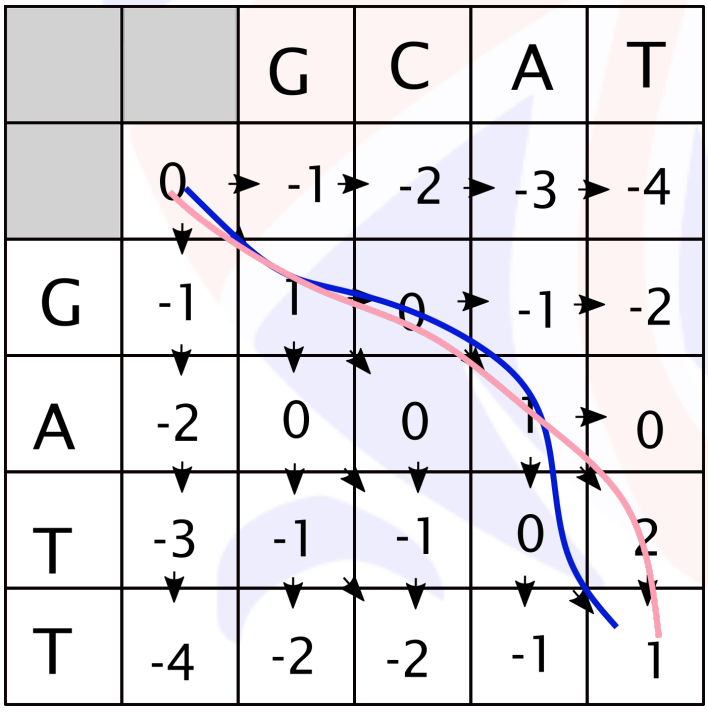
Part 4 of 15

Cells in the middle could be scored based on horizontal, vertical or diagonal movements. The cell should be given the highest score possible. You then mark with an arrow which movement this score came from.

		G	C	A	T
	0	-1	-2	-3	-4
G	-1	1	0	-1	-2
A	-2	0	0	1	0
T	-3	-1	-1	0	2
T	-4	-2	-2	-1	1

Part 5 of 15

Note that some cells can gain an equal score from more than one movement, so both arrows are included. You then trace backwards along arrows from the bottom right to generate your highest scoring alignments.



Part 6 of 15

In this example, the two possible alignments are: · G-ATT 1 GCA-T · G-ATT 2 GCAT-

Part 7 of 15

Now extend the above example to align these two sequences from species i and ii. i) GCAT**GCT** ii) GATT**ACA** A part filled table is provided for you. You will probably need to do this on a sheet of rough paper.

		G	C	A	T	G	C	T
	0	-1	-2	-3	-4	-5	-6	-7
G	-1	1	0	-1	-2	-3	-4	-5
A	-2	0	0	1	0	-1	-2	-3
T	-3	-1	-1	0	2	1	0	-1
T	-4	-2	-2	-1	1			
A	-5	-3	-3	-1				
C	-6	-4	-2	-2				
A	-7	-5	-3	-1				

Part 8 of 15

What is the highest score of your alignments?

1 mark

Write something below

Part 9 of 15

How many different alignments have the highest score? *Type a number.*

1 mark

Write something below

Part 10 of 15

The start of two different alignments was given in the example. How should line 1 be extended? *Type the missing characters: GCA-TXXXXXXXXXXX*

1 mark

Write something below

Part 11 of 15
Species iii is found to have the sequence GCATGC**A**.

Part 12 of 15
Are these true or false?

4 marks

Mark the following as TRUE or FALSE

a) Species ii and iii are more closely related than species ii and i.

TRUE FALSE

b) The best alignment between species ii and iii has a higher score than the best alignment between species ii and i.

TRUE FALSE

c) There are more high scoring alignments between species ii and iii than between species ii and i.

TRUE FALSE

d) There are more gaps in the alignment between species ii and iii than between species ii and i.

TRUE FALSE

Part 13 of 15
It is more common for a pyrimidine nucleotide (C or T) to mutate into another pyrimidine, than into a purine (G or A). The sequence studied above also turned out to be in a protein coding sequence.

Part 14 of 15
How should the scoring system be adapted to account for these findings?

3 marks

Groups

Reduced

Increased

Put into the groups above

a) Penalty for C to A mutations

b) Penalty for gaps in alignment

c) Penalty for C to T mutations

Part 15 of 15

Protein sequences can also be compared. What are the differences between protein and DNA alignments?

4 marks

Groups

DNA

Protein

Put into the groups above

a) Has more complicated scoring system

b) Sequence changes at a faster rate overtime

c) Easier to sequence

d) Better for comparing more distantly related species

Question 1

Part 1 of 7

Which type(s) of molecule are ribosomes made from?

1 mark

Choose as many as appropriate

a) RNA

b) DNA

c) mRNA

d) tRNA

e) Proteins

f) Carbohydrates

Part 2 of 7

Human proteins can be made artificially in bacteria. Which of the following are advantages of using bacteria to make proteins?

2 marks

Choose as many as appropriate

a) Bacteria are easy to transform

b) Bacteria always add the same post-translational modifications as human cells

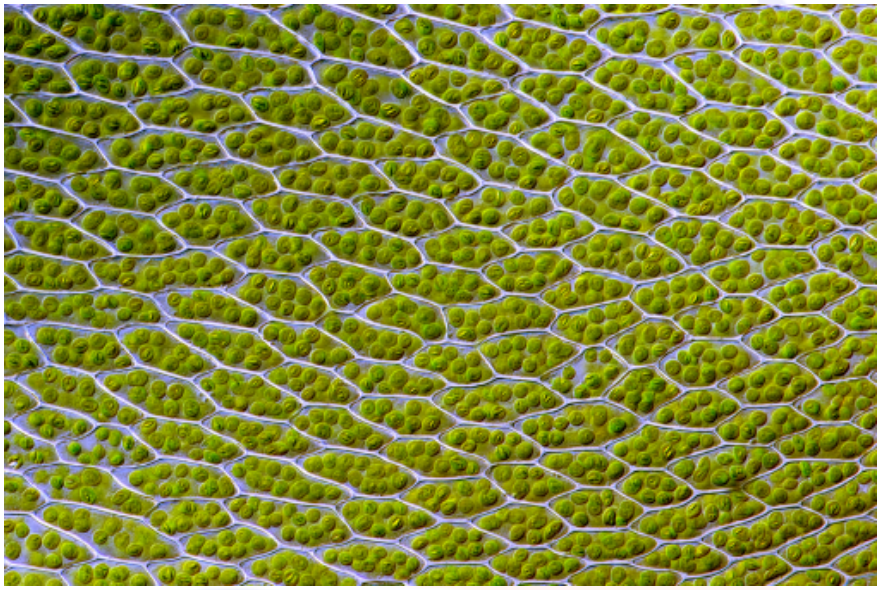
c) Bacteria are easier to grow than human cells

d) Bacteria use the same triplet code as human cells

e) Human genes can usually be transformed into bacteria without modification

Part 3 of 7

Sort the following molecules into the inputs and outputs of **photosynthesis**.



By Des_Callaghan - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=35894254

2 marks

Groups

Input

Output

Put into the groups above

a) Oxygen

b) Water

c) Light energy

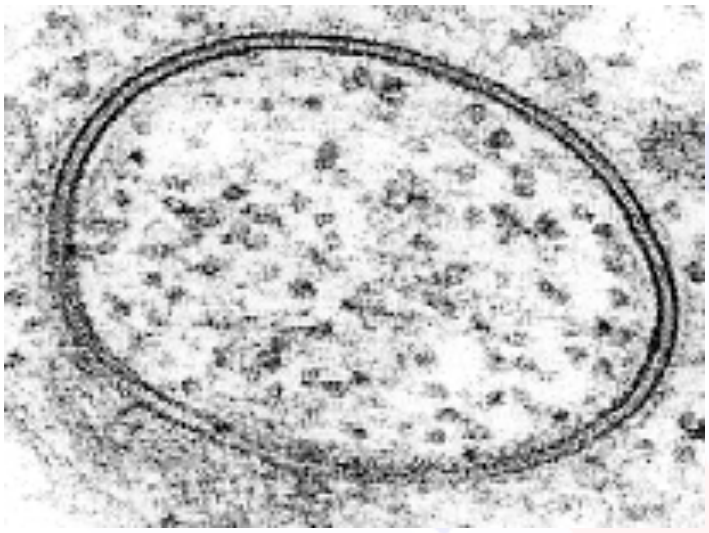
d) Sugar

e) Chemical Energy

f) Carbon dioxide

Part 4 of 7

Which molecules are able to cross a cell-membrane lipid bilayer?



By Sandraamurray - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=5514703

1 mark

Choose ONE

a) Antibodies

b) Glucose

c) Starch

d) Potassium ions

e) Steroid hormones

Part 5 of 7

A random mutation changed an alanine codon to a STOP codon within a protein sequence. Which is the most likely outcome?

1 mark

Choose ONE

a) Antibiotic resistance

b) A new more useful protein

c) A truncated useless protein

d) The protein would probably not be affected

Part 6 of 7

Order the vessels blood flows through as it completes a loop from the leg muscles, around the body and back to the muscles. Place these in the correct order with leaving the leg muscle at the top, and reentering again at the bottom.

2 marks

Put into the correct order

a) Vena cava

b) Left atrium

c) Aorta

d) Right atrium

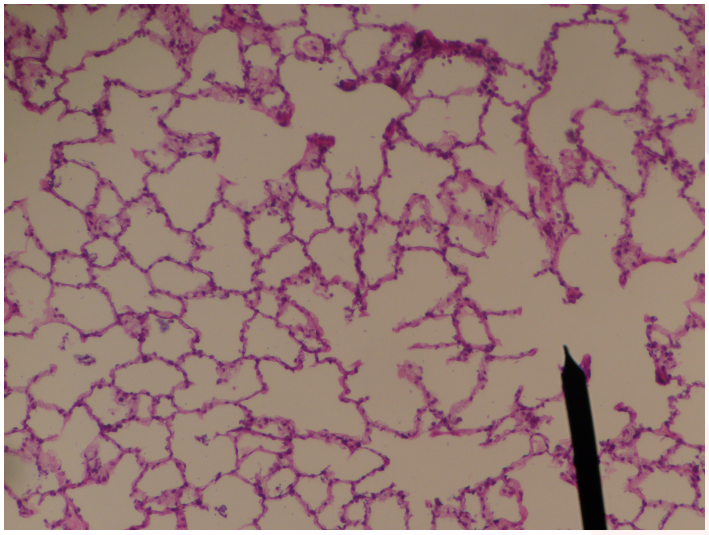
e) Lungs

f) Left ventricle

g) Right ventricle

Part 7 of 7

Which features increase gas exchange within **human** lungs?



By Jpogi - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=46568489

1 mark

Choose as many as appropriate

a) Large surface area of alveoli

b) Large surface area of microvilli

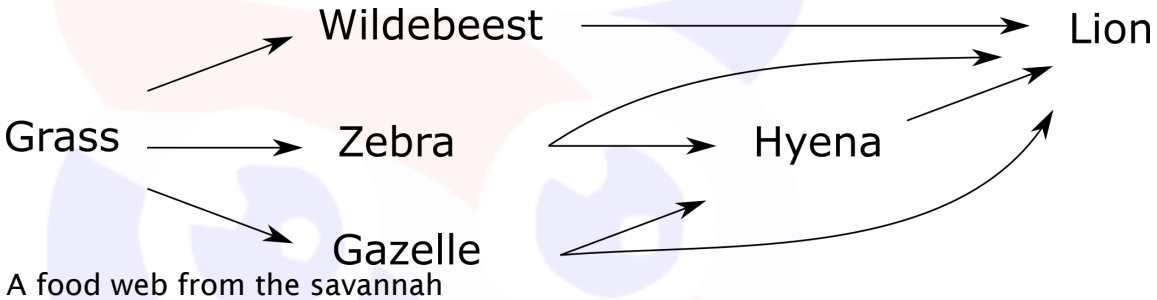
c) Single cell layer of epithelial cells

d) Counter-current exchange of gasses

Question 2

Part 1 of 4

Food webs illustrate energy flow within an ecosystem. Below is part of a food web for the African savannah.



A food web from the savannah

Part 2 of 4

Which organism is the primary producer?

1 mark

Choose ONE

a) Grass

b) Wildebeest

c) Zebra

d) Gazelle

e) Hyena

f) Lion

Part 3 of 4

Mark all organisms which will probably be *negatively* affected by an increased in zebras.

2 marks

Choose as many as appropriate

a) Grass

b) Wildebeest

c) Gazelle

d) Hyena

e) Lion

Part 4 of 4

Which trophic level holds the most energy?

1 mark

Choose ONE

a) Grass

b) Wildebeest/Zebra/Gazelle

c) Hyena

d) Lion

Question 3

Part 1 of 3

Cabbage leaves can be placed in coloured water. Uptake of water can be measured by the speed at which the dye is taken up.

Laura Hamilton, Flickr, https://www.flickr.com/photos/mslaura/4023084459, CC BY-NC-ND 2.0

Part 2 of 3

Which vessel carries water up the plant stem?

1 mark

Choose ONE

a) Artery

b) Xylem

c) Phloem

Part 3 of 3

What would increase the rate of uptake of water?

2 marks

Choose as many as appropriate

a) Moving the plant into a dark room

b) Increasing the humidity

c) Increasing the airflow of the room

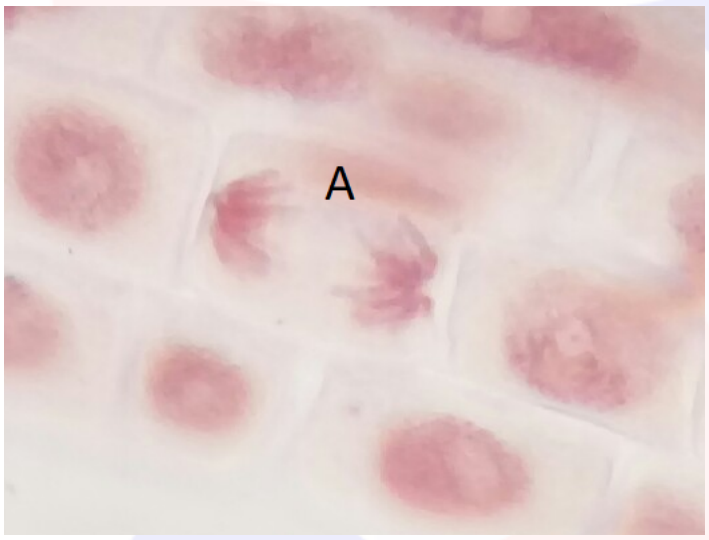
d) Increasing the air temperature

e) Cutting all the leaves in half

Question 4

Part 1 of 3

The image below shows an epidermal onion peel stained for DNA. An onion cell has 8 pairs of chromosomes.



DNA Stained Onion Peel (Credit: Laurararas, Wikimedia, CC4.0)

Part 2 of 3

Which phase of the cell cycle is the cell labelled 'A' in?

1 mark

Choose ONE

a) G1

b) S

c) G2

d) Mitosis

e) Meiosis

Part 3 of 3

How many chromosomes does the cell marked 'A' have?

2 marks

Write something below

Question 5

Part 1 of 9

Tulips can be pink or white. A plant breeding company wanted to find out if the pink allele was dominant or recessive. A pure breeding pink tulip was crossed with a pure breeding white tulip. The progeny of the cross were all pink.

A pink tulip

Part 2 of 9

Is the pink allele dominant or recessive?

1 mark

Choose ONE

a) Dominant

b) Recessive

Part 3 of 9

A population of 1750 tulips is in Hardy-Weinberg equilibrium, and 1253 of them are pink. *The Hardy-Weinberg equilibrium states the allele frequencies of the dominant (*p*) and recessive (*q*) alleles can be calculated as p + q = 1. The frequency of dominant homozygotes, heterozygotes and recessive homozygotes can be calculated as $p^2 + 2pq + q^2 = 1$, respectively.*

Part 4 of 9

What is the frequency of the recessive allele in the population? Give your answer to **two decimal places**.

1 mark

Write something below

_____

Part 5 of 9

What is the frequency of heterozygote tulips in the same population? Give your answer to **two decimal places**.

2 marks

Write something below

Part 6 of 9

The scientists notice some tulips have ruffled edges. The scientists want to know whether the ruffled allele is dominant or recessive. They sowed the seeds of a ruffled plant which had selfed (fertilised its own seed). 75% of the progeny had ruffled petals and 25% had normal petals.

A tulip with ruffled edges

Part 7 of 9

Is the ruffled allele dominant or recessive?

1 mark

Choose ONE

a) Dominant

b) Recessive

Part 8 of 9

Was the parent plant (F0) homozygous or heterozygous for the ruffled allele?

1 mark

Choose ONE

a) Homozygous

b) Heterozygous

Part 9 of 9

The scientists collected the seed from only the progeny **without** ruffles which had selfed. What percentage of these seeds (the F2) had ruffles? Give your answer to the nearest whole number

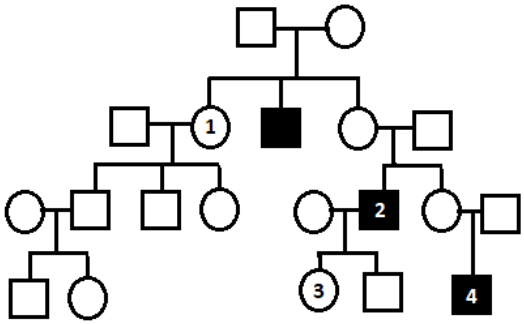
2 marks

Write something below

Question 6

Part 1 of 4

The pedigree below shows the inheritance of colourblindness, a sex-linked condition. * Squares indicate males, and circles females. * An empty shape indicates a normal individual, whereas a filled shape indicates an affected individual.



A disease pedigree

Part 2 of 4

Is individual 1 a carrier of the disease?

1 mark

Choose ONE

a) Yes

b) No

c) Unable to tell

Part 3 of 4

Is individual 3 a carrier of the disease?

1 mark

Choose ONE

a) Yes

b) No

c) Unable to tell

Part 4 of 4

If individual 3 and 4 have a child, what is the chance it is colourblind? (in percent, %)

2 marks

Write something below

_____

Question 7

Part 1 of 4

Evolution is change in the heritable characteristics of populations over successive generations.

Part 2 of 4

Which of the following evolutionary forces **increase** genetic diversity?

2 marks

Choose as many as appropriate

a) Natural Selection

b) Artificial Selection

c) Immigration

d) Spontaneous mutation

e) Horizontal Gene Transfer

Part 3 of 4

An artificial selection pressure was applied to a population of bacteria by the sudden addition of a strong antibiotic. The majority of bacteria die but some survived. What is the most plausible reason for this?

1 mark

Choose ONE

a) The antibiotic caused a mutation

b) An antibiotic resistance gene was already in the population

c) The antibiotic only kills bacteria about 50% of the time

d) The antibiotic quickly degraded in the environment

Part 4 of 4

A scientist compared the haemoglobin found in a lowland goat species and a mountain-dwelling goat species. How has haemoglobin most likely to have evolved within the mountain goat species?

By Darklich14 - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=9825969

1 mark

Choose ONE

a) A greater number of haeme groups

b) Higher affinity for oxygen

c) Different functional groups than haeme

d) **Decreased** expression

e) No functional changes

Question 8

Part 1 of 3

The Svalbard Global Seed Vault contains seeds from hundreds of thousands of plant species buried deep under a mountain on an arctic island. Scientists researching ancient crops with drought resistance lost their collections in the Syrian civil war. They withdrew samples from the Svalbard Vault to revive these species.

By Miksu - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=61440471

Part 2 of 3

What is the likely consequences of reviving species in this way compared to saving existing populations?

1 mark

Choose ONE

a) Increased genetic diversity

b) Increased rate of harmful mutations

c) Increased fitness

d) Increased tolerance to environmental pressures

e) Increased rate of adaptation/evolution

Part 3 of 3

How should seeds be preserved to maintain the genetic health of species (ignore practicalities and the survival of seeds over-time)?

2 marks

Choose as many as appropriate

a) Take seeds from individuals in a wide variety of areas

b) Take seeds from a large number of individuals

c) Revive seeds periodically, grow them, then store only the new seeds

d) Take seeds from individuals of any shape and size (not just the most typical looking individuals)

e) Take seeds only from family lines which have been nurtured by people for a very long time

Question 9

Part 1 of 3

The Regent Honeyeater is an Australian bird. Recently, it has become critically endangered with about 300 individuals in an area 10× greater than the UK. Scientists have noticed that as it became rare, male Regent Honeyeaters have started signing the songs of other birds, rather than their own. Female Regent Honeyeaters do not like males which sing the songs of other birds.

Part 2 of 3

What is a likely reason male Regent Honeyeaters are singing different songs?

1 mark

Choose ONE

a) Natural selection (birds singing these songs are fitter)

b) Sexual selection (birds singing these songs mate more)

c) Their instinct has changed

d) The songs they hear and learn when they are young have changed

e) Hybridisation (other species are mating with Regent Honeyeaters)

Part 3 of 3

What method would **not** help Regent Honeyeaters sing their own songs?

1 mark

Choose ONE

a) Play recordings of Regent Honeyeater songs on loudspeakers

b) Keep young Regent Honeyeaters in captivity with singing adults

c) Keep young Regent Honeyeaters away from other species

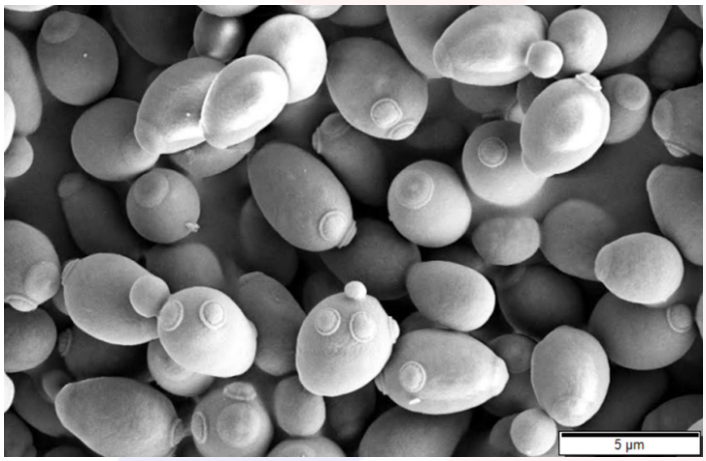
d) Relocate young Regent Honeyeaters to distant areas

e) When raised in captivity, only release Regent Honeyeaters singing the correct songs

Question 10

Part 1 of 6

Yeast is a model organism used in medical research, as well as an industrial organism used in brewing. Scientists wanted to measure whether a mutant yeast strain was better at fermenting sugar. Mutant and non-mutant cells were put in flasks with solutions containing 200 g/l glucose. They then measured the concentration of glucose in the flasks over time.



By Mogana Das Murtey and Patchamuthu Ramasamy - [1], CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=52254246

Part 2 of 6

To ensure they are measuring fermentation, the scientists should:

1 mark

Choose ONE

a) Tightly seal the flasks

b) Bubble oxygen into the flasks

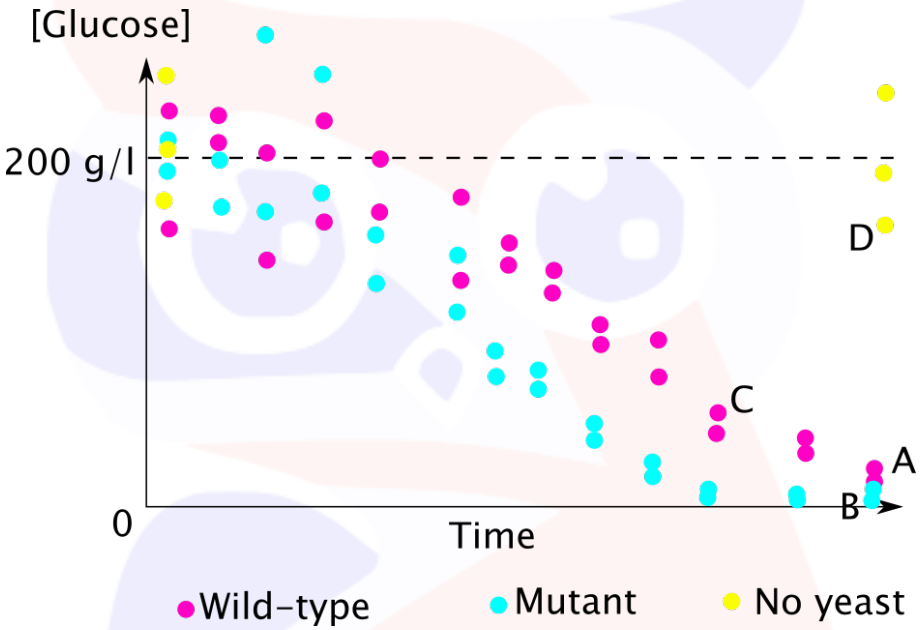
c) Bubble CO_2 into the flasks

d) Use solutions containing plenty of fats (lipids)

e) Use solutions containing plenty of amino-acids (proteins)

Part 3 of 6

The scientists used Benedict's reagent to measure the concentration of glucose in each flask over time. Each dot is a repeated measurement of the same sample.



Growth curves for mutant and wild type yeast

Part 4 of 6

What is revealed by this data?

3 marks

Choose as many as appropriate

a) The mutant strain is better at fermentation

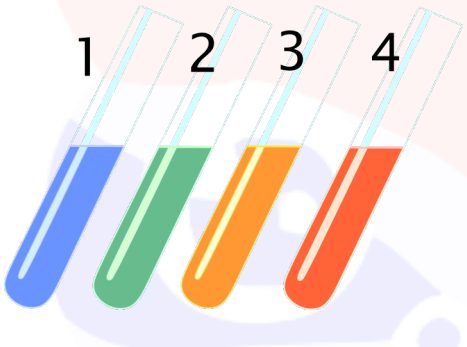
b) Glucose is degraded over time by a non-biological process in this experiment

c) Samples from early time-points should be diluted because the measurements are saturated

d) It is unclear if the difference between strains is caused by a mutation effecting metabolism or cell-division

Part 5 of 6

Which tube of Benedict's reagent and sample matches which letter on the graph?



2 marks

Groups

Tube 1

Tube 2

Tube 3

Tube 4

Put into the groups above

a) Sample C

b) Sample A

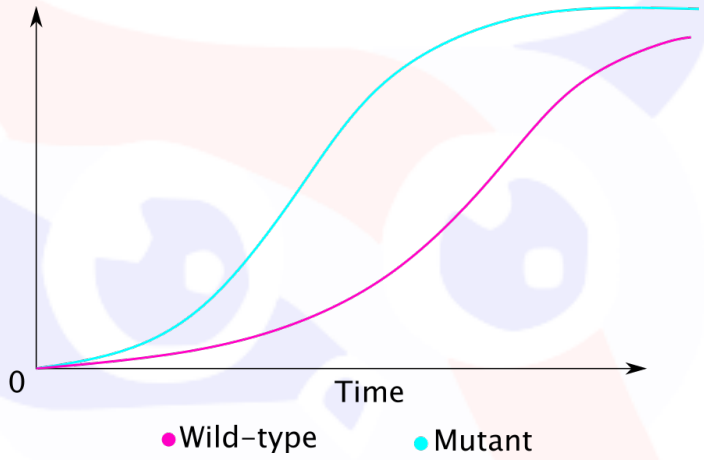
c) Sample D

d) Sample B

Part 6 of 6

The scientists measured the rate of fermentation in the same samples with a second method. What label(s) could the Y axis have)?

Unknown label



Unlabelled graph

2 marks

Choose as many as appropriate

a) Oxygen concentration

b) pH

c) CO_2 concentration

d) Ethanol concentration

e) Number of cells

Question 11

Part 1 of 5

The *Central Dogma* describes how the genetic code is interpreted to make useful products via a one-directional flow of information through different polymers.

Part 2 of 5

Place the molecules of the dogma in the correct order. Put the beginning material at the top and end with the functional material at the bottom.

1 mark

Put into the correct order

a) DNA

b) mRNA

c) Polypeptide

d) pre-mRNA

e) Catalytic and structural biological machines

Part 3 of 5

Sort the following properties into pre-mRNA, mRNA, both or neither:

3 marks

Groups

pre-mRNA

mRNA

Both

Neither

Put into the groups above

a) Contains adenosine

b) Contains introns

c) Contains uracil

d) Double-stranded molecule

e) Contains non-coding information

f) Contains exons

Part 4 of 5

A pre-mRNA molecule has 20% A, 40% U, 10% C, and 30% G. What is the composition of the double-stranded DNA that it was transcribed from?

2 marks

Choose ONE

a) 20% A, 40% U, 10% C, and 30% G

b) 20% A, 40% T, 10% C, and 30% G

c) 40% A, 20% T, 30% C, and 10% G

d) 40% A, 20% U, 30% C, and 10% G

e) 25% A, 25% U, 25% C, and 25% G

f) 30% A, 30% T, 20% C, and 20% G

Part 5 of 5

There are exceptions to the dogma, including viruses which encode information from RNA into DNA. Which protein is responsible for this conversion?

1 mark

Choose ONE

a) Protease

b) Helicase

c) Topoisomerase

d) RNA reverse transcriptase

e) RNAse

f) Transcriptase

g) RNA polymerase

Question 12

Part 1 of 3

Sort the human defence processes into the correct category.

2 marks

Groups

Innate

Adaptive

Put into the groups above

a) Phagocytosis

b) Antibody production by B cells

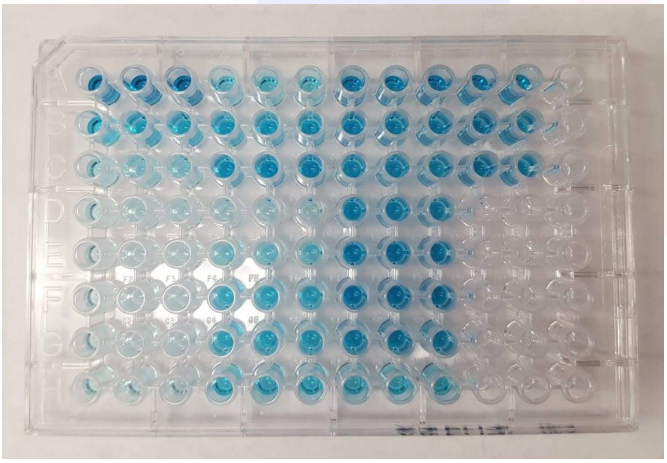
c) Antigen presentation

d) Physical barriers preventing entry

Part 2 of 3

This question will assess how easily you understand unfamiliar methods. Note: ***different ELISAs work in different ways***

People given COVID-19 vaccines usually make antibodies against the viral spike protein. The levels of anti-spike antibodies can be measured with an ELISA (Enzyme-Linked Immunosorbent Assay): 1. The wells of a plate are coated with spike protein. 2. A blood sample is incubated within the well. 3. The well is washed with soapy water. 4. An artificial anti-spike antibody is incubated in the well. This antibody is linked to an enzyme. 5. The well is washed with soapy water. 6. The enzyme's substrate is added to the well. 7. After some time, the colour of the well is recorded. If present, the enzyme catalyses the conversion of the colourless substrate into a bright blue colour.



An ELISA plate with 96 wells

Part 3 of 3

Mark the following true or false

5 marks

Mark the following as TRUE or FALSE

a) If the patient has more anti-spike antibodies, the well will look more blue

TRUE FALSE

b) The scientist should include a control well with water instead of blood to compare the colour levels

TRUE FALSE

c) If the scientist forgets the second wash, the well will look blue

TRUE FALSE

d) If it is a cold day, the well will look more blue

TRUE FALSE

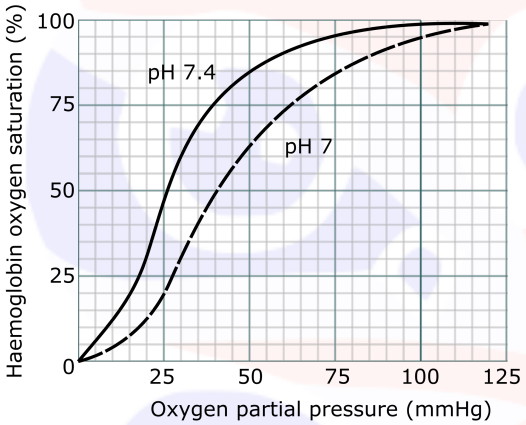
e) This experiment would work better at 100˚C

TRUE FALSE

Question 13

Part 1 of 6

Haemoglobin binds or releases oxygen depending on the partial pressure of oxygen in the tissue. *Partial pressure is a measure of the amount of oxygen in fluids around the haemoglobin, and is usually given in the non-SI unit of pressure, mmHg* The Bohr effect of pH on oxygen saturation is shown.



Bohr effect graph

Part 2 of 6

What happens to the saturation of haemoglobin as it moves into a tissue which has the same pH but lower partial pressure of oxygen?

1 mark

Choose ONE

a) Higher saturation

b) Lower saturation

Part 3 of 6

What happens to the saturation of haemoglobin as it moves into a tissue which has a lower pH but the same partial pressure of oxygen?

1 mark

Choose ONE

a) Higher saturation

b) Lower saturation

Part 4 of 6

Anaerobic respiration produces lactic acid. Does a muscle respiring anaerobically receive more or less oxygen from haemoglobin in the blood than a muscle respiring aerobically?
1 mark

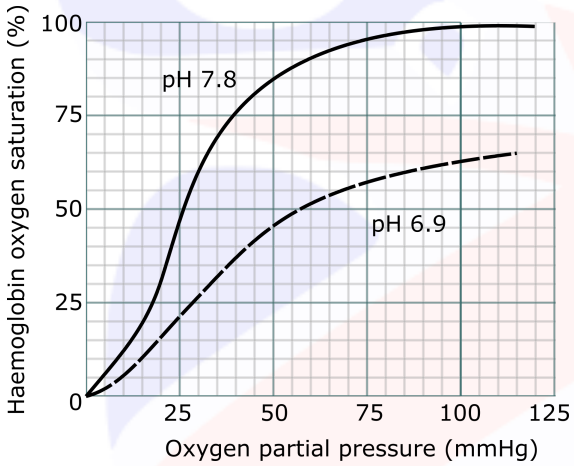
Choose ONE

a) More oxygen

b) Less oxygen

Part 5 of 6

The **Root effect** is analogous to the Bohr effect, but fine tunes haemoglobin within fish. Fish use the Root effect to fill their swim bladders with oxygen gas to control their buoyancy. The Root effect is shown below.



Root effect graph for a rainbow trout

Part 6 of 6

Mark the following as true or false
4 marks

Mark the following as TRUE or FALSE

a) Fish haemoglobin responds to pH in an identical way to mammal haemoglobin.

TRUE FALSE

b) Fish acidify capillaries at the swim bladder to offload oxygen

TRUE FALSE

c) The Root effect can unload oxygen against a concentration gradient

TRUE FALSE

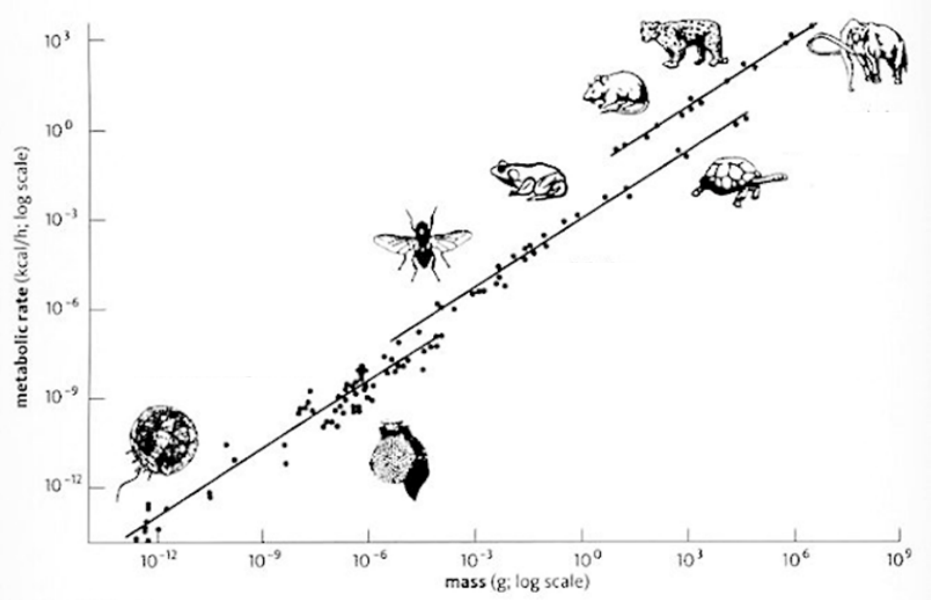
d) The Root effect reduces the efficiency of gills at taking up oxygen

TRUE FALSE

Question 14

Part 1 of 8

This question assesses your numerical skills with unfamiliar biology Keiber's law states that the resting metabolic rate of an organism scales to the ¾ power of the animal's mass (*mass$^{0.75}$*). Thus, a dog having a mass 100 times that of a mouse will consume only about 32 times more energy than the mouse at rest.



Metabolic rate scales to the 3/4 power of mass (Hemmingsen, 1960)

Part 2 of 8

How many times more energy will a cat use at rest compared to a mouse? A cat has a mass 50 times greater than a mouse. Give the nearest **whole number**

2 marks

Write something below

Part 3 of 8

The specific metabolic rate of an animal is their resting metabolic rate divided by their mass.

Part 4 of 8

Which will have a the greatest specific metabolic rate:

1 mark

Choose ONE

a) Mouse

b) Cat

c) Dog

d) They are all roughly equal

Part 5 of 8

Unlike metabolic rate, heart volume scales 1:1 with the mass of an animal. If a mouse has a heart volume of 0.5 mL, what is the heart volume of a cat? A cat has a mass 50 times greater than a mouse. Give the nearest **whole number**

2 marks

Write something below

_____

Part 6 of 8

The heart pumps to provide oxygen to tissues, so resting heart rate is proportional to the resting metabolic rate of an animal. Which animal will have the fastest resting heart beat?

1 mark

Choose ONE

a) Mouse

b) Cat

c) Dog

d) They are all roughly equal

Part 7 of 8

During exercise, metabolic rate increases. Heart rate has a similar maximum speed in all animals. Which animal has the greatest ability to exercise?

1 mark

Choose ONE

a) Mouse

b) Cat

c) Dog

d) They are all roughly equal

Part 8 of 8

Approximately what power of mass do animals' **maximum** metabolic rates scale with? (*mass^{x}*) Give a number with **two decimal** places.

1 mark

Write something below

_____