BRITISH BIOLOGY OLYMPIAD 2021

Instructions

Do not open this booklet until you are told to do.

Write your answers on the Multiple Choice Answer Sheet provided.

Use a 2B pencil.

While students are expected to attempt all questions for a complete examination in 90 minutes.

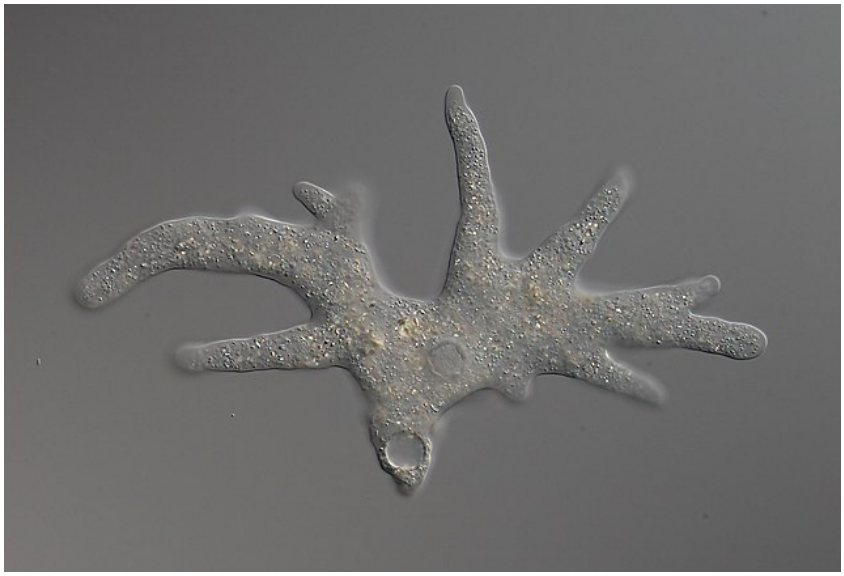
Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

British Biology Olympiad 2021 Paper 1

Total marks: 43

Section 1

Amoebas are found in many different environments. An amoeba found living in a lake formed by a melting glacier was placed in a bucket of water taken from a river estuary. An amoeba taken from the ocean was also placed in the bucket.



1. What happened to the amoeba taken from the glacier?

1 mark.
Choose ONE.

A) It expanded.

B) It shrank.

C) It stayed the same.

2. What happened to the amoeba taken from the ocean?

1 mark.
Choose ONE.

A) It expanded.

B) It shrank.

C) It stayed the same.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 2

3. What is the underlying reason trees have evolved to grow so tall?



1 mark.
Choose ONE.

A) There is brighter light for photosynthesis further from the ground.

B) They are able to trap more water from rainfall.

C) They are in competition with other individuals for light.

D) To disperse seeds further.

E) To escape herbivores.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 3

A species of green flower is a popular ingredient in Chinese medicine, and so it is picked in the wild by professional harvesters. In recent years, many individuals have appeared with textured grey leaves and flowers.



4. Which are correct descriptions of what is occurring in this species?

1 mark.
Choose ONE.

A) Evolution by sexual selection

B) Evolution by natural selection

C) Evolution by artificial selection

D) Evolution by genetic drift

E) Disease

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 4

Norwegian lemmings are more brightly coloured than normal lemmings. They are also very violent, and often attack predators.



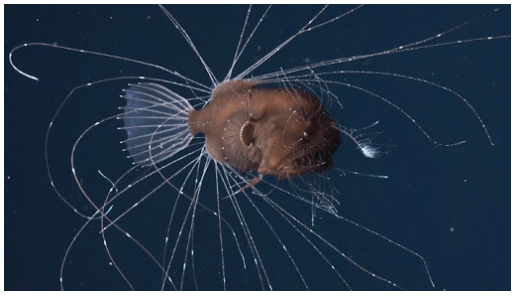
5. Which animal has colouration performing a similar function?

1 mark.
Choose ONE.

A) Tiger



B) Anglerfish



Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

C) Wasp



D) Peacock (peafowl)



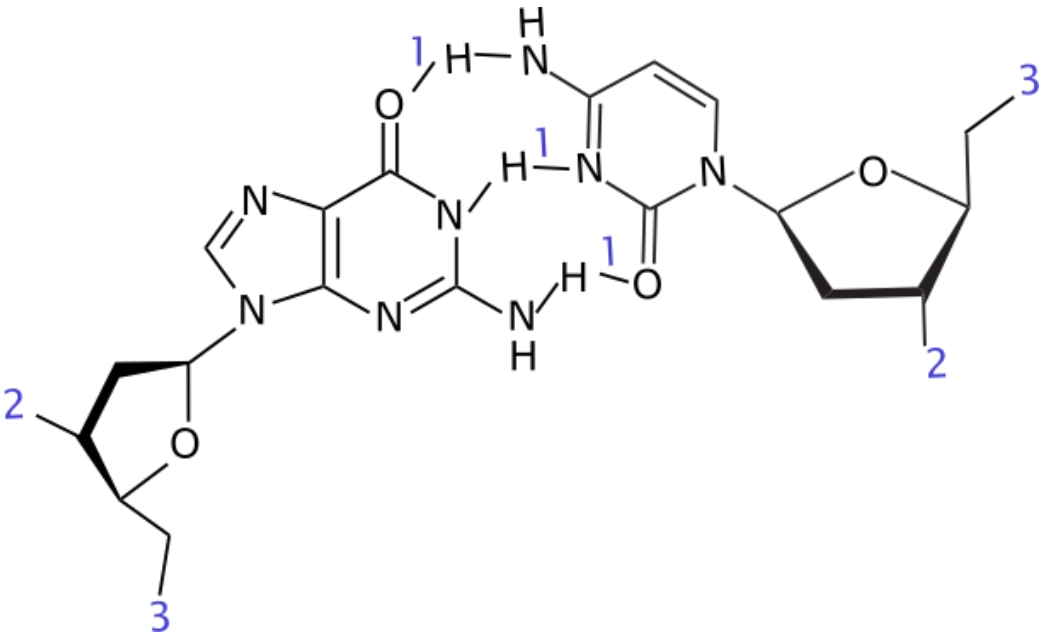
E) Cuttlefish



Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 5

A section of DNA is shown.



6. Bond 1 is…

1 mark.
Choose ONE.

A) ionic.

B) covalent.

C) hydrogen.

D) peptide.

E) phosphate.

7. A cysteine base is included in the image, what else is in the image?

1 mark.
Choose ONE.

A) Thymine

B) Glycine

C) Guanosine

D) Glucose

E) Ribonucleotide

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

8. The bond labelled 3 links the carbon atom to…

1 mark.
Choose ONE.

A) another sugar molecule.

B) an amino acid.

C) a phosphate group.

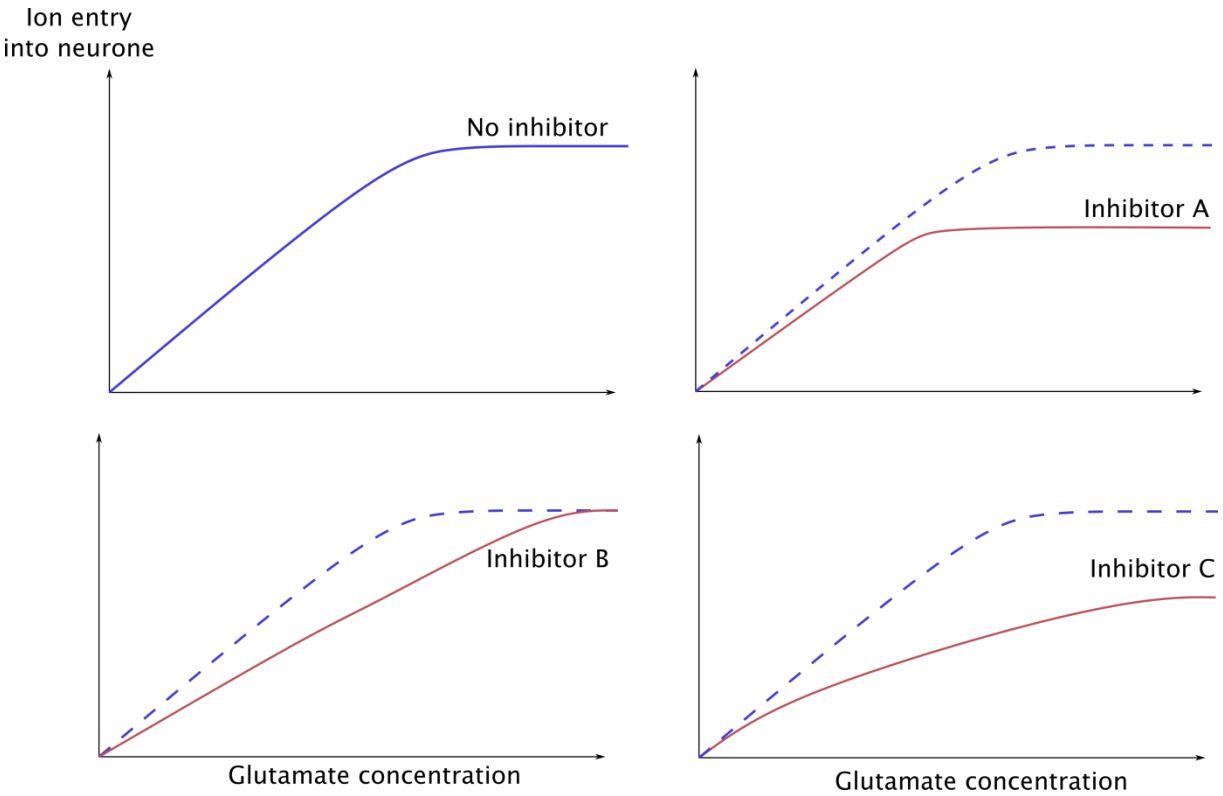
D) a lipid/fat.

E) a hydroxyl/alcohol group

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 6

The NDMAR protein is a membrane channel found on neurones. It binds glutamate then opens to allow ions into the cell. Several drugs (NO, ethanol, ketamine) inhibit NDMAR and can cause powerful psychological dissociation. The effect of several inhibitors is shown.



9. Which inhibitor binds the same site as glutamate?

1 mark.
Choose ONE.

A) A

B) B

C) C

D) All of them

E) None of them

10. Which inhibitor binds elsewhere but still prevents glutamate binding?

1 mark.
Choose ONE

A) A

B) B

C) C

D) All of them

E) None of them

11. Which binds inside the channel of open NDMAR and prevents ions flowing?

1 mark.
Choose ONE.

A) A

B) B

C) C

D) All of them

E) None of them

12. Which inhibitor has the most powerful psychological effects? *Assume all were tested at relevant concentrations.*

1 mark.
Choose ONE.

A) A

B) B

C) C

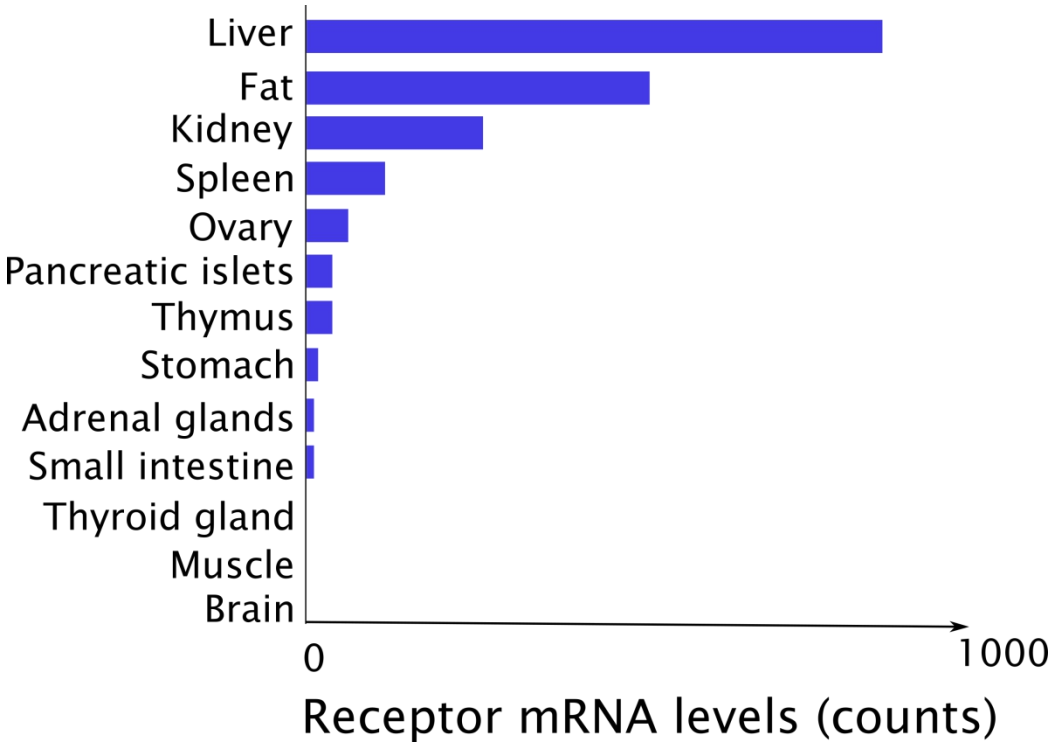
D) All of them

E) None of them

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 7

Glucagon is secreted from pancreatic cells and signals via receptors on the cells of target tissues. The figure shows the amount of receptor mRNA in the same number of cells from different rat tissues.



13. Which of these is true?

1 mark.
Choose ONE.

A) Glucagon expression is often low when an animal first wakes up from sleeping.

B) Glucagon stimulates the liver to produce glycogen.

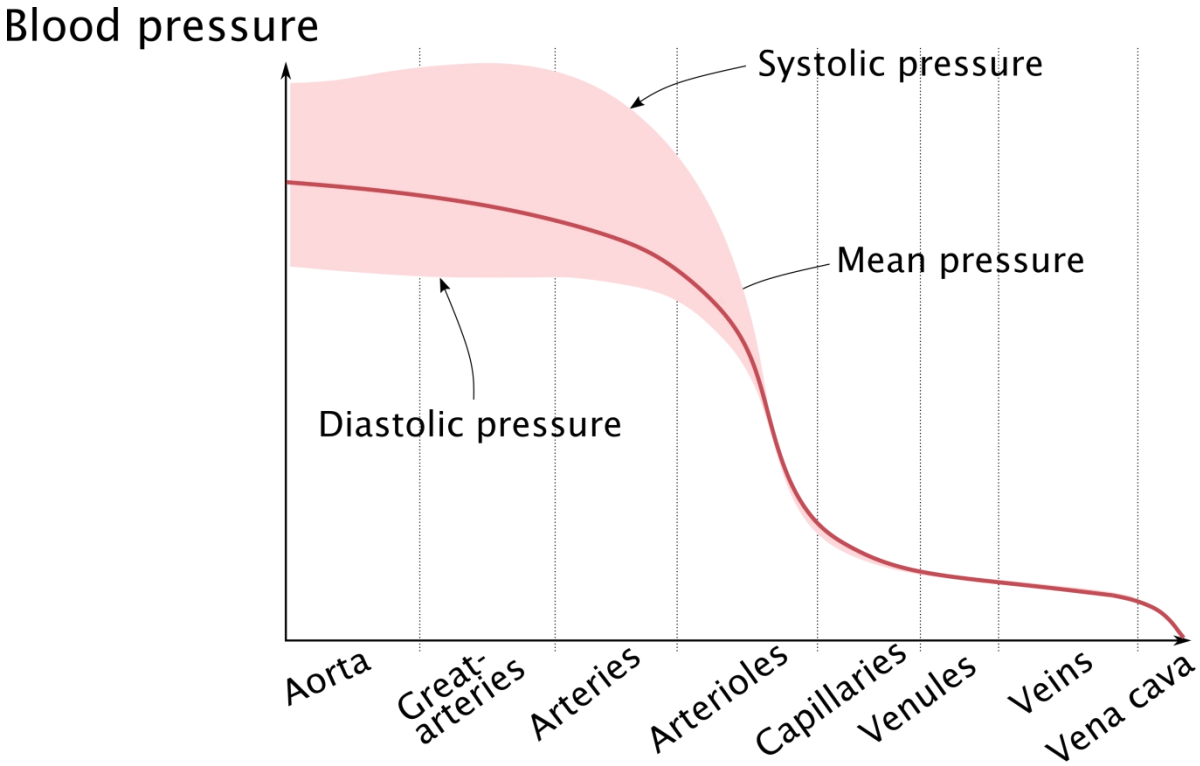
C) Glucagon reduces glucose uptake into muscles.

D) The liver responds to lower levels of glucagon than other organs.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 8

The graph shows pressure of pulses of blood flowing through different vessels.



14. Why does the pulsatility of the blood reduce and become smooth flow as blood flows away from the heart?

1 mark.
Choose ONE.

A) The heart pumps blood continuously, with no moments when blood is not pumped.

B) Muscles in the blood vessels contract and relax in time with pulses.

C) Elastic fibres in arteries stretch and recoil in time with pulses.

D) Fluid is forced out of vessels during pulses so they are reduced over time.

E) The total resistance of vessels increases away from the heart so pulses cannot flow.

15. Why is the average pressure of blood reduced as it flows away from the heart?

1 mark.
Choose ONE.

A) Fluid leaks out of vessels so there is less volume further from the heart.

B) The combined cross-sectional area of vessels is greater further from the heart so blood flows with less resistance.

C) Muscles of arteries are constricted, pressing on the blood.

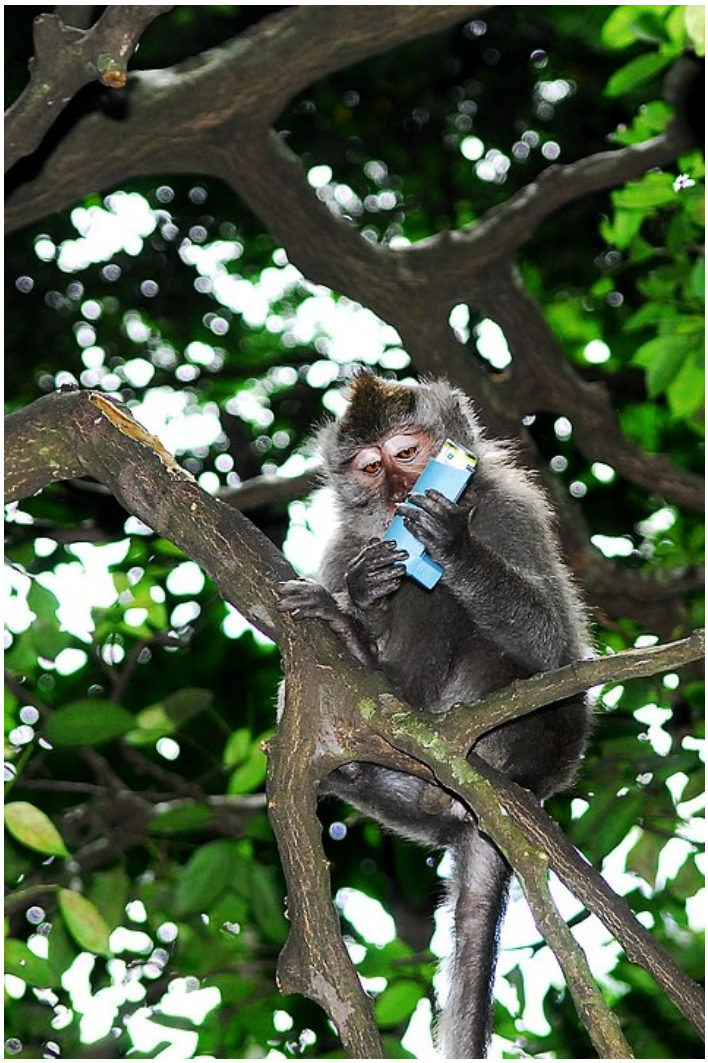
D) The heart sucks on the blood in veins, reducing the pressure in them.

E) Blood flow is very slow through capillaries in organs.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 9

At a temple in Bali, macaques steal things from tourists and barter them for food. The macaques steal high-end items like smartphones more often than easily-accessible items like hats. The macaques then wait until the tourist offers them fruit. The macaques only return the most valuable items when a large amount of fruit has been offered, whereas cheaper items are returned for less fruit.



16. How do the macaques know which items are valuable?

1 mark.
Choose ONE.

A) Reasoning

B) Instinct

C) Association/conditioning

D) Habituation

E) Imprinting

17. How do the macaques know when to accept an offer of fruit instead of holding out in the hope of more?

1 mark.
Choose ONE.

A) Reasoning

B) Instinct

C) Association/conditioning

D) Habituation

E) Imprinting

18. Why do the macaques want fruit?

1 mark.
Choose ONE.

A) Reasoning

B) Instinct

C) Association/conditioning

D) Habituation

E) Imprinting

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 10

The animals below are found in the same food web, but fit into different food chains. One chain takes place close to the ocean surface, and one begins with dead animals resting on the seabed.

19. Which animals go into the ocean surface food chain? *The order does not matter.*

1 mark.
Choose ONE.

A) Phytoplankton / algae, zooplankton, shrimp, whale, small fish
B) Phytoplankton / algae, zooplankton, scavenging crab, octopus, small fish
C) Phytoplankton / algae, zooplankton, scavenging crab, small fish, hammerhead shark
D) Whale, hammerhead shark, scavenging crab, shrimp
E) Phytoplankton / algae, zooplankton, shrimp, hammerhead shark

20. Which animals go into the seabed food chain? *The order does not matter.*

1 mark.
Choose ONE.

A) Scavenging crab, octopus, hammerhead shark
B) Phytoplankton / algae, zooplankton, shrimp, whale, small fish
C) Phytoplankton / algae, zooplankton, scavenging crab, octopus, small fish
D) Octopus, shrimp, scavenging shark
E) Shrimp, small fish, octopus

21. Which food chain has the most energy flowing through it?

1 mark.
Choose ONE.

A) Ocean surface

B) Seabed

C) They are equal

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 11

The way groups of organisms live depends on fundamental aspects of their biology. For each of these characteristics, state whether they belong to plants, animals, fungi and/or bacteria.

22. Have cell walls.

1 mark.
Choose ONE.

A) Plants, animals, fungi

B) Plants, bacteria, fungi

C) Animals, fungi, bacteria

D) Plants, animals, bacteria

E) Plants, animals, bacteria, fungi

23. Have mitochondria.

1 mark.
Choose ONE.

A) Plants, animals, fungi

B) Plants, bacteria, fungi

C) Animals, fungi, bacteria

D) Plants, animals, bacteria

E) Plants, animals, bacteria, fungi

24. Includes many autotrophs (producers).

1 mark.
Choose ONE.

A) Plants, fungi

B) Plants, bacteria

C) Fungi, bacteria

D) Plants, animals

E) Animals, fungi

25. Most can reproduce sexually.

1 mark.
Choose ONE.

A) Plants, animals, fungi

B) Plants, bacteria, fungi

C) Animals, fungi, bacteria

D) Plants, animals, bacteria

E) Plants, animals, bacteria, fungi

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 12

Last year, scientists were stunned when captive sturgeon fish and paddlefish mated and produced offspring. These fish species diverged about 200 million years ago at the beginning of the dinosaur era.



26. Which factors usually do NOT stop different species breeding?

1 mark.
Choose ONE.

A) Live in different places.

B) Not sexually attracted to each other.

C) Different numbers of chromosomes.

D) Different genetic triplet codes.

E) Embryo does not develop.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 13

Pneumonia means the lungs are full of fluid due to infection. Infection triggers blood vessels to leak to increase the delivery of immune system components such as antibodies.

27. Why do patients with severe pneumonia have low blood oxygen levels?

1 mark.
Choose ONE.

A) Air leaks into the blood.

B) Less blood travels through the lungs.

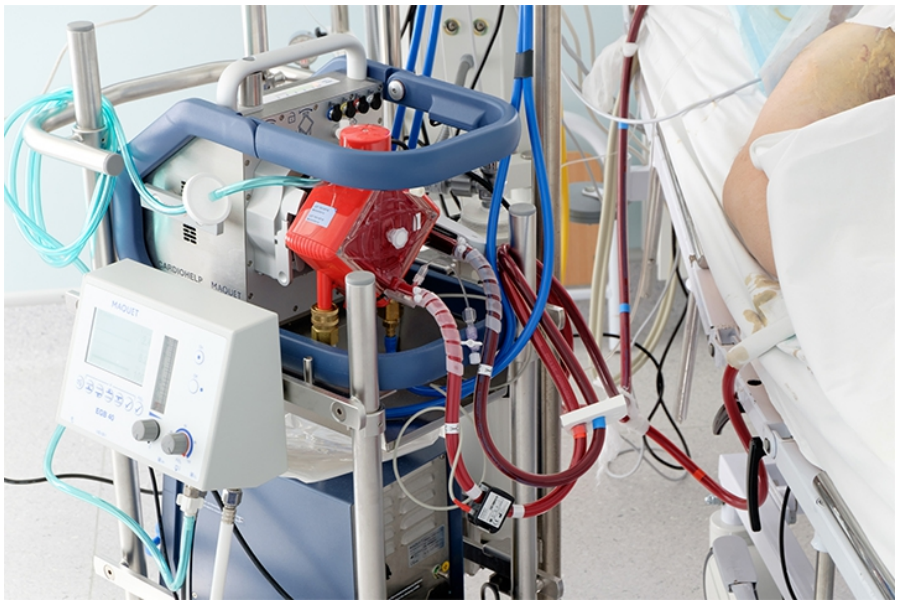
C) More oxygen is consumed by immune cells.

D) They have fewer red blood cells.

E) Oxygen has to diffuse further to get from air to red blood cells.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

ECMO machines are an extreme form of life-support which entirely replaces both the lungs and the heart during the wait for a double transplant or infection to clear. Blood is circulated through a pump, then over a membrane in an air canister.



28. Which of the following would increase delivery of oxygen to the brain?

1 mark.
Choose ONE.

A) Turn the pump up to extremely high speed.

B) Turn the pump down to extremely low speed.

C) Fill the canister with nitrogen.

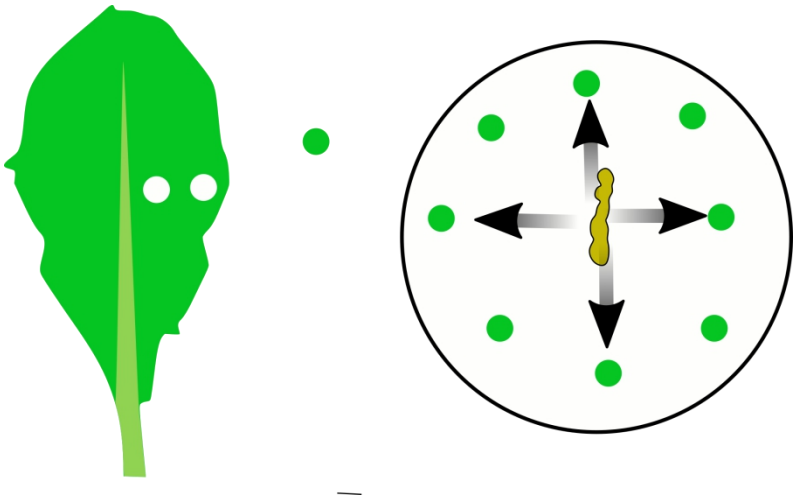
D) Fill the canister with oxygen.

E) Make the membrane shorter.

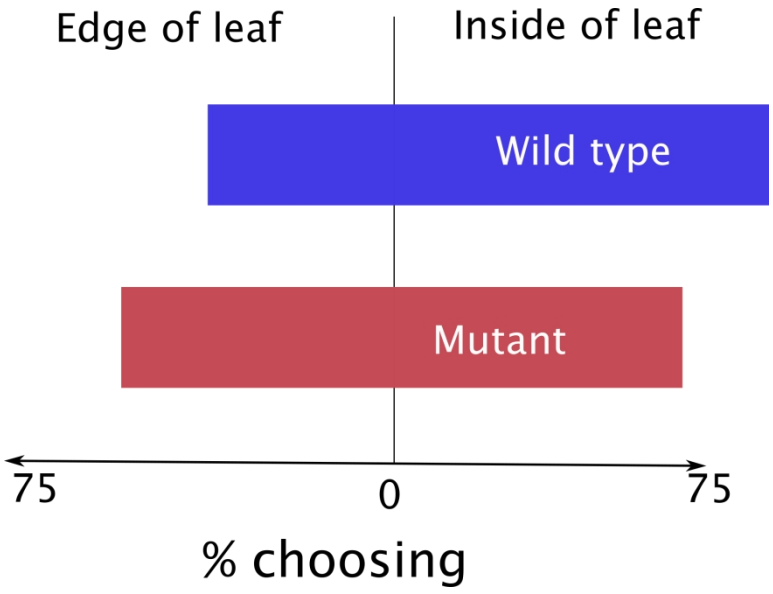
Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 14

Secondary metabolism of plants is not essential for survival, but can be important. Many secondary metabolites, such as nicotine and caffeine, help them resist damage from herbivorous insects. Glucosinolate is accumulated in the leaves of *Arabidopsis* and repels insects. Segments from the centre or edges of leaves were arranged around caterpillars.



The leaves caterpillars chose were recorded. This was repeated for wild type (Wild) plants and mutants incapable of synthesizing glucosinolate.



Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

29. Which is true?

1 mark.
Choose ONE.

A) Glucosinolate accumulates more in the edge of leaves.

B) Glucosianate accumulates equally across leaves.

C) The inside of leaves is more nutritious for caterpillars.

D) The caterpillars are expected to choose wild-type leaves in preference to mutant leaves.

E) The caterpillars never eat leaves containing glucosinolate

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 15

In bacteria, one transcription factor often controls multiple genes. The expression of genes consumes energy so groups of genes controlled by the same factor are finely adapted to help the survival strategy of the bacterium. Floating individuals move vigorously in search of nutrients, but bacteria in biofilms rarely move.

30. Sort whether these genes are more likely to be expressed with the transcription factors controlling biofilm formation or free-floating individual formation.

Which genes turn on for biofilm formation?

1 mark.
Choose ONE.

A) Genes for secreted defensive compounds, Genes for plasmid sharing

B) Genes for secreted defensive compounds, Flagella forming genes, Nutrient sensors

C) Flagella forming genes, Genes for surviving starvation, Nutrient sensors

D) Flagella forming genes, Genes for surviving starvation, Genes for plasmid sharing

E) Genes for secreted defensive compounds, Genes for plasmid sharing, Flagella forming genes

31. Which genes turn on in lone individuals?

1 mark.
Choose ONE.

A) Genes for secreted defensive compounds, Genes for plasmid sharing

B) Genes for secreted defensive compounds, Flagella forming genes, Nutrient sensors

C) Flagella forming genes, Genes for surviving starvation, Nutrient sensors

D) Flagella forming genes, Genes for surviving starvation, Genes for plasmid sharing

E) Genes for secreted defensive compounds, Genes for plasmid sharing, Flagella forming genes

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 16

The Linnaean classification system allows scientists to understand the ancestry and characteristics of organisms at a glance.



32. Sort these taxonomic ranks into order, starting with the oldest/biggest at the top.

2 marks.
Choose ONE.

A) Animalia (animals), Eukarya (eukaryotes), Chordata (inc.vertebrates/backbones), Mammalia (mammals), Carnivora (true carnivores), Canines (canids), *Canis* (dog-like), *Canis lupus* (Grey wolf), *Canis lupus familiaris* (tame dogs)

B) Mammalia (mammals), Chordata (inc.vertebrates/backbones), Eukarya (eukaryotes), Animalia (animals), Carnivora (true carnivores), Canines (canids), *Canis* (dog-like), *Canis lupus* (Grey wolf), *Canis lupus familiaris* (tame dogs)

C) Animalia (animals), Chordata (inc.vertebrates/backbones), Eukarya (eukaryotes), Carnivora (true carnivores), Canines (canids), Mammalia (mammals), *Canis* (dog-like), *Canis lupus* (Grey wolf), *Canis lupus familiaris* (tame dogs)

D) Eukarya (eukaryotes), Animalia (animals), Chordata (inc.vertebrates/backbones), Carnivora (true carnivores), Canines (canids), Mammalia (mammals), *Canis* (dog-like), *Canis lupus* (Grey wolf), *Canis lupus familiaris* (tame dogs)

E) Eukarya (eukaryotes), Animalia (animals), Chordata (inc.vertebrates/backbones), Mammalia (mammals), Carnivora (true carnivores), Canines (canids), *Canis* (dog-like), *Canis lupus* (Grey wolf), *Canis lupus familiaris* (tame dogs)

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 17

A plant is grown in a tank of water under a lamp.

33. The rate at which bubbles are given off will be increased four-fold if:

1 mark.
Choose ONE.

A) The lamp is placed at half the distance.

B) The lamp is placed at a quarter of the distance.

C) The temperature is increased by 40°C.

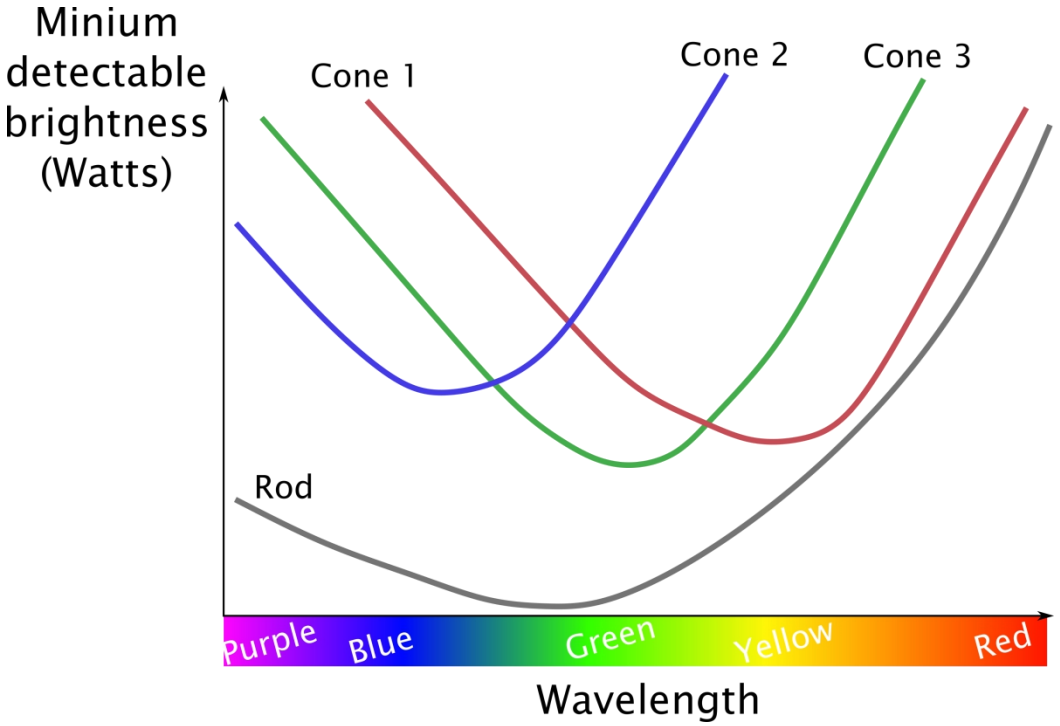
D) The carbon dioxide supply is increased two-fold.

E) The oxygen supply is increased four-fold.

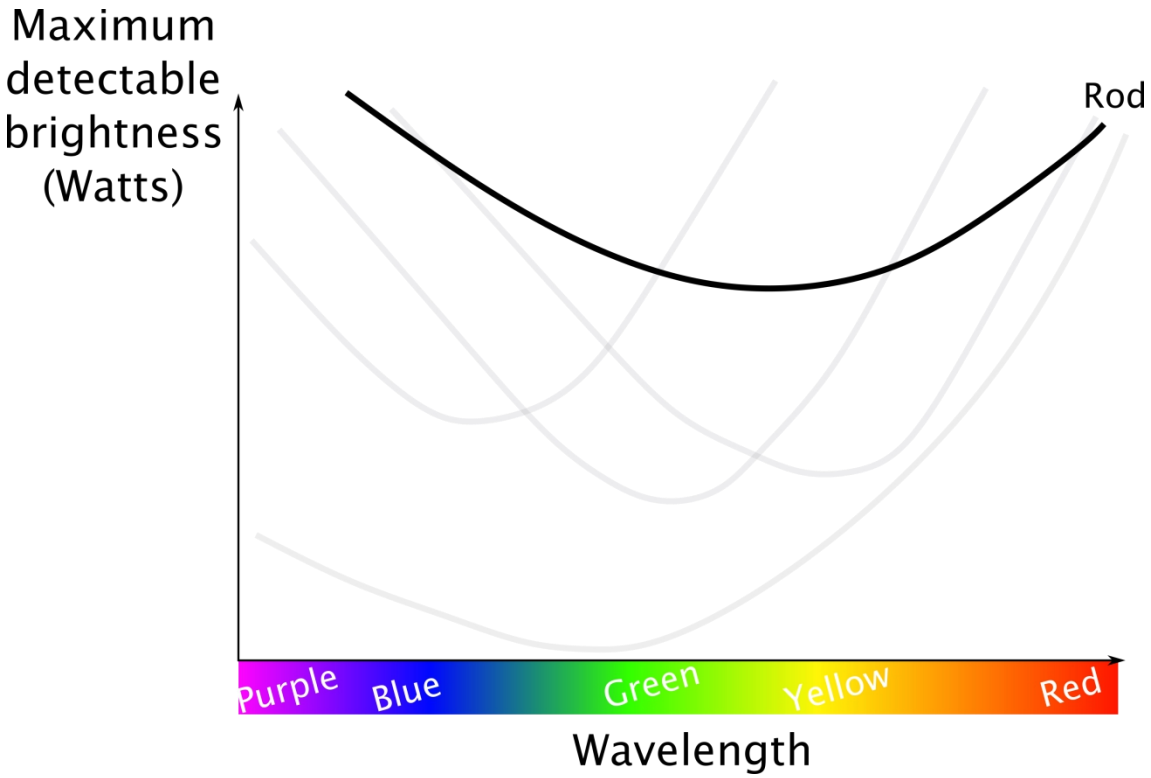
Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 18

Humans eyes have cone and rod cells with different sensitivities to different wavelengths of light. The minimum brightness cells can detect has been plotted against wavelength.



Bright light hitting the cells causes them to reduce signalling to the brain, to maintain contrast in different conditions. The saturation point of rods is plotted below.



Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

34. Which is true?

1 mark.
Choose ONE.

A) Green light displays are the best colour for preserving night vision.

B) Rods are able to detect detail under red light well.

C) Colour vision requires dimmer lights than monochrome vision.

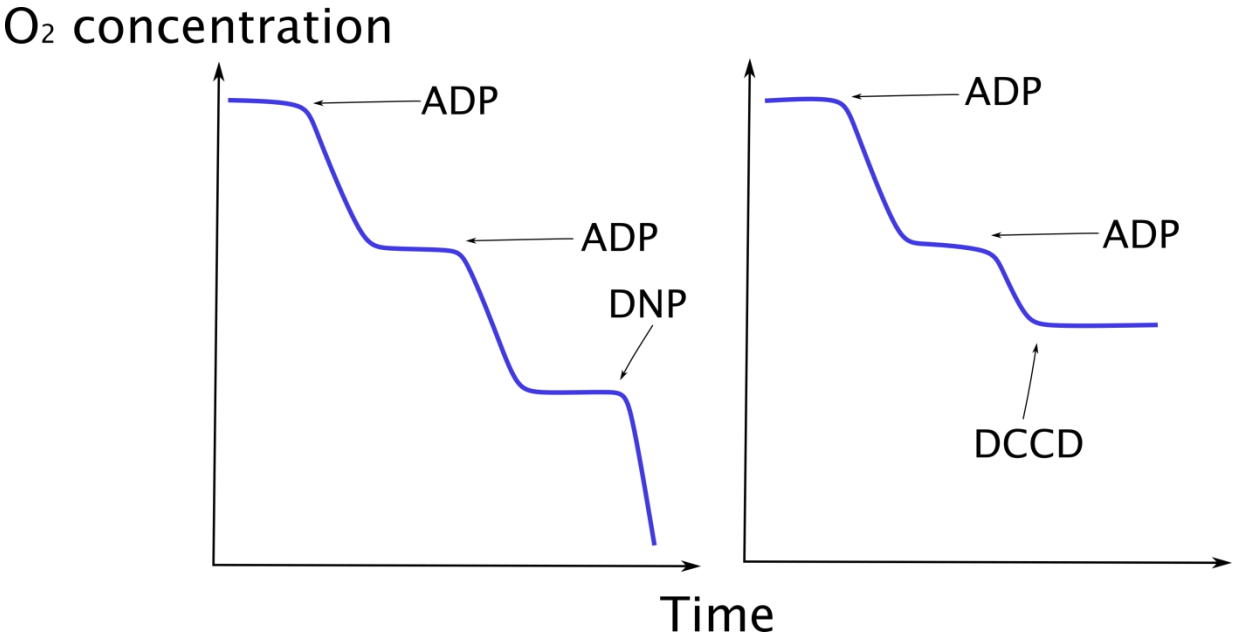
D) The colour blue can be identified correctly in dimmer light than the colour yellow.

E) Bright green light stimulates all cones equally.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 19

The figure shows oxygen consumption (respiration) in mitochondria when ADP, or drugs (DNP or DCCD) are added. The solution already contains respiratory substrates, oxygen and phosphate.



35. Which is false?

1 mark.
Choose ONE.

A) The mitochondria are able to use the added ADP.

B) In normal conditions, the mitochondria respire only when ATP can be produced.

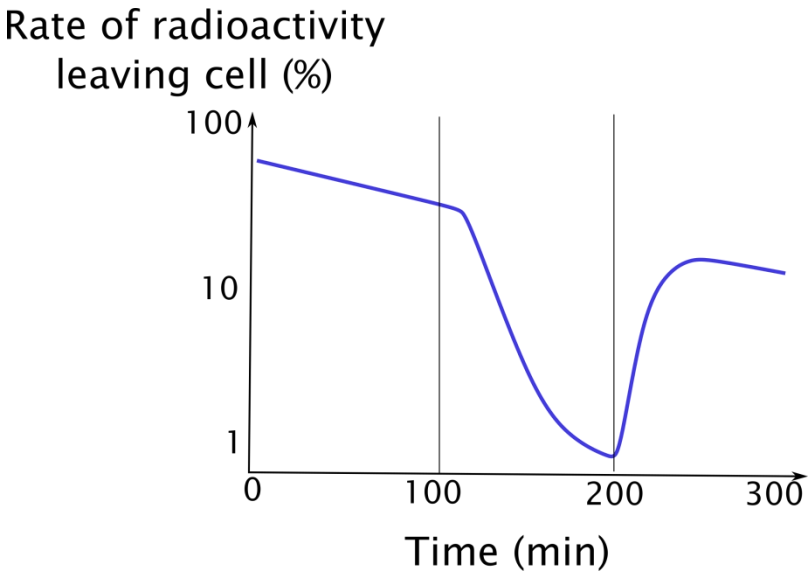
C) DNP stimulates ATP synthesis.

D) DCCD inhibits ATP synthesis.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 20

ATP is important for maintaining a normal membrane potential in nerve cells. A squid giant axon was injected with radioactive $^{24}Na^+$. The rate of $^{24}Na^+$ leaving the cell was measured overtime. The external seawater was replaced with seawater containing a mitochondrial poison between 100 and 200 minutes.



36. Which is false?

1 mark.
Choose ONE.

A) This experiment should have been carried out in the presence of oxygen.

B) Most of the Na^+ leaks out of cells by specific transportation.

C) The effect of the poison is slightly delayed because there is some ATP stored in axons.

D) The poison is a reversible inhibitor.

E) The total amount of Na^+ (radioactive and non-radioactive) in the axon decreases overtime.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 21

Quillwort is an amphibious plant that can live in both aerial and submerged conditions. When submerged, quillwort uses CAM metabolism; CO_2 is fixed into malate at night and released again in the day to be used in photosynthesis. CAM metabolism is not seen unless the plant is submerged. There is strong competition from other photosynthetic organisms during the day.



37. Which is true?

1 mark.
Choose ONE.

A) Malate concentration in the leaves is highest just before sunset.

B) CAM metabolism is used by quillwort because it reduces water loss.

C) CO_2 levels are much higher in air than water during the day.

D) CO_2 levels are much higher in air than water during the night.

E) Quillwort produces oxygen at night when submerged.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 22

Francis Crick stated the central dogma of biology: * There is a one-directional flow of information from the DNA, through RNA, to proteins. Proteins then build and control bodies.

38. Do these observations follow from the central dogma (showing it is true) or are they exceptions to it (showing it is false)?

Which of these observations follow from the central dogma (showing it is often true)?

1 mark.
Choose ONE.

A) Evolution by inheritance of acquired characteristics (proposed by Lamarck).

B) Retroviruses like HIV have reverse transcriptase enzymes.

C) When a mutant allele is correlated with a disease, we are fairly certain the allele causes disease.

D) Prions are misfolded proteins which cause more proteins to misfold, and can spread between animals.

E) Women who suffered starvation as children are more likely to have obese children.

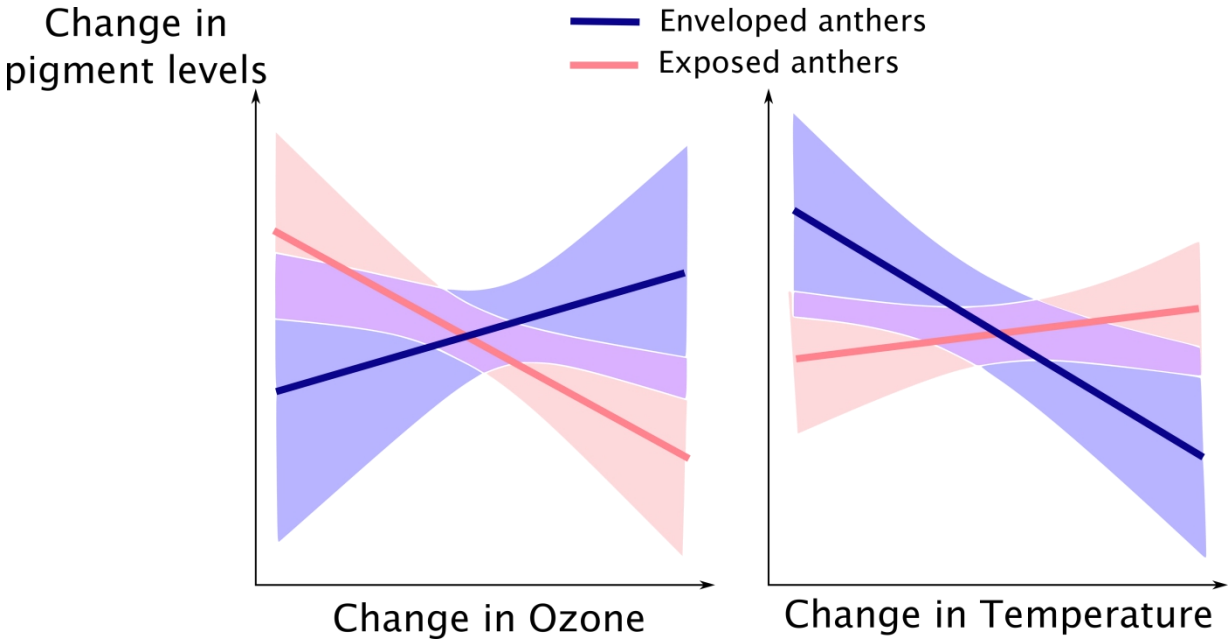
Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 23

The main purpose of flower pigments is to create contrasting patterns which guide pollinators to pollen. However, scientists wanted to investigate whether pigments also protect pollen. Some flowers have anthers exposed in a dish of petals, whereas some flowers have anthers enveloped under petals.



The change in pigmentation of these types of flowers was measured across the world over time. The change in temperature due to global warming, and the change in UV exposure due to depletion and recovery of the ozone layer varies between regions. The correlation between these variables is plotted below.



39. Humans have stopped depleting the ozone layer, but the emission of CO_2 is accelerating. What effect will this have on flower pigmentation in future?

1 mark.
Choose ONE.

A) Pigmentation will increase in flowers with enveloped anthers.

B) Pigmentation will increase in flowers with exposed anthers.

C) Pigmentation will increase in both kinds of flower.

D) Pigmentation will decrease in both kinds of flower.

E) Pigmentation changes will improve the attractiveness of flowers to pollinators.

40. Which of the following conclusions are NOT supported by these data?

3 marks.
Choose ONE.

A) Flower pigments absorb UV light.

B) Flower pigments absorb heat.

C) Pollen in flowers with exposed anthers is at risk of overheating.

D) Pollen in flowers with enveloped anthers is at risk of overheating.

E) Pollen in flowers with exposed anthers is at risk of damage by UV radiation.

END OF PAPER 1.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

British Biology Olympiad 2021 Paper 2

Total marks: 55

Section 1

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



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

41. Estimate the % change in whale population from 2010 to 2020.

1 mark.
Choose ONE.

A) 0.9

B) 9

C) 90

D) 900

E) 4.5

42. Give an estimate of the total whale population in 2010.

1 mark.
Choose ONE.

A) 200

B) 2000

C) 20000

D) 200000

E) 2000000

43. 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.

C) Both

D) Neither

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

44. 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.

C) Both

D) Neither

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.

45. Give another estimate of the whale population.

1 mark.
Choose ONE.

A) 2000

B) 3000

C) 20000

D) 30000

E) 40000

46. Which method is better for estimating the total whale population?

1 mark.
Choose ONE.

A) Mark-recapture.

B) Counting from images.

C) They are equal.

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

1 mark.
Choose ONE.

A) Mark-recapture.

B) Counting from images.

C) They are equal.

48. 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.

C) They are equal.

49. Which factors are NOT important for getting reliable data from these population surveys?

1 mark.
Choose ONE.

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.

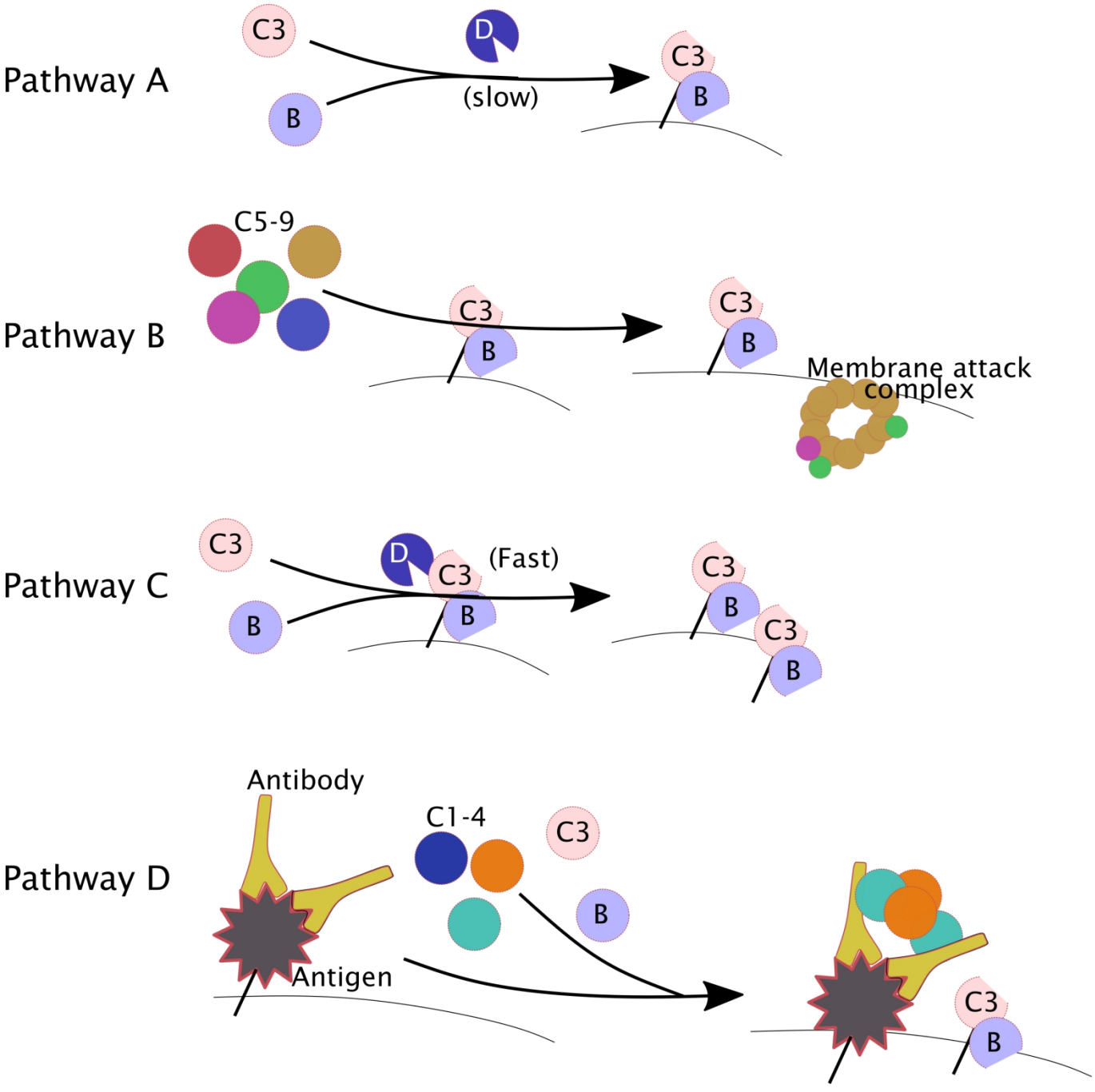
D) Sample at the same places each year.

E) Sample in the same season each year.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 2

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.



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.**

50. 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

51. 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

52. 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

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

1 mark.
Choose ONE.

A) Pathway A and B

B) Pathway B and C

C) Pathway C and A

D) Pathway C and D

54. 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

55. 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

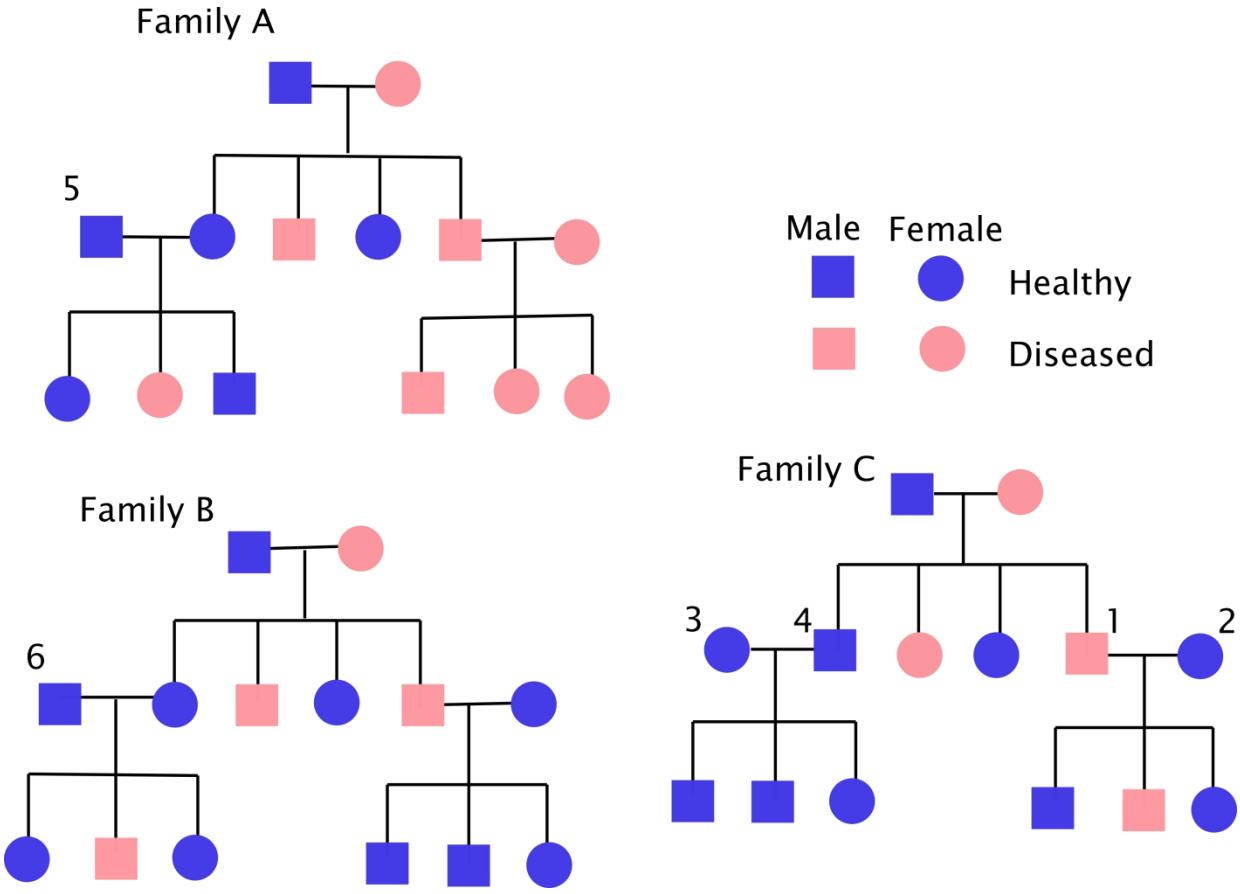
D) C5-9

E) C1-4

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 3

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



56. If family C's disease is caused by a recessive allele, calculate the probability a new child of 1 and 2 gets the disease.

1 mark.
Choose ONE.

A) 0.05

B) 0.1

C) 0.25

D) 0.5

E) 1

57. 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.

2 marks.
Choose ONE.

A) 0.05

B) 0.1

C) 0.25

D) 0.5

E) 1

58. Which is true?

1 mark.
Choose ONE.

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

B) Family C's disease *cannot* be due to a dominant allele.

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

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

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

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 4

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



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

1 mark.
Choose ONE.

A) Reduce water loss in dry environments.

B) Reduce UV damage in mountains.

C) Increase CO_2 uptake.

D) Increase surface area for photosynthesis.

E) a and b

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

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

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

1 mark.
Choose ONE.

A) A

B) B

C) C

D) B and D

E) E

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

1 mark.
Choose ONE.

A) A

B) B

C) C

D) C and D

E) E

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

1 mark.
Choose ONE.

A) A

B) B

C) C

D) D

E) E

63. Which results are expected if fuzz is environmentally controlled?

1 mark.
Choose ONE.

A) A

B) B

C) C

D) D and A

E) E

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.

64. What is the frequency of the mutation on the neighbour's new farm?

1 mark.
Choose ONE.

A) 0.03

B) 0.09

C) 0.3

D) 0.9

E) 0.45

65. What is the frequency of the mutation on the original farm?

1 mark.
Choose ONE.

A) 0.03

B) 0.09

C) 0.3

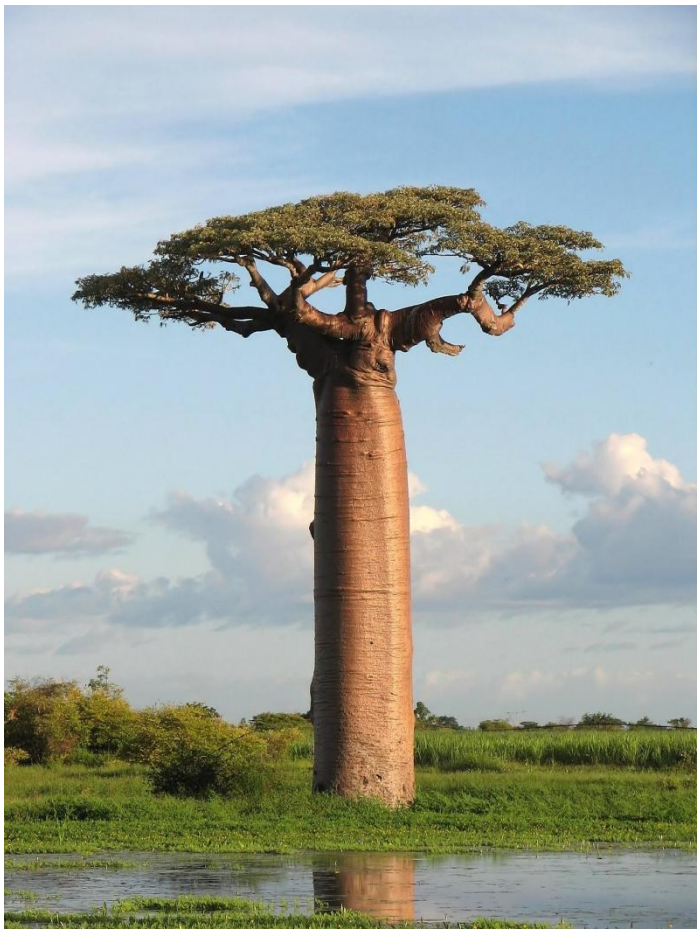
D) 0.9

E) 0.45

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 5

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.



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

1 mark.
Choose ONE.

A) 168

B) 84

C) 63

D) 42

E) 21

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

67. How many chromosomes does a baobab gamete contain?

1 mark.
Choose ONE.

A) 168

B) 84

C) 63

D) 42

E) 21

68. During meiosis, approximately how many different combinations of chromosomes could be produced in human gametes.

2 marks.
Choose the nearest number.

A) 900
B) 9000
C) 90000
D) 900000
E) 9000000

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 6

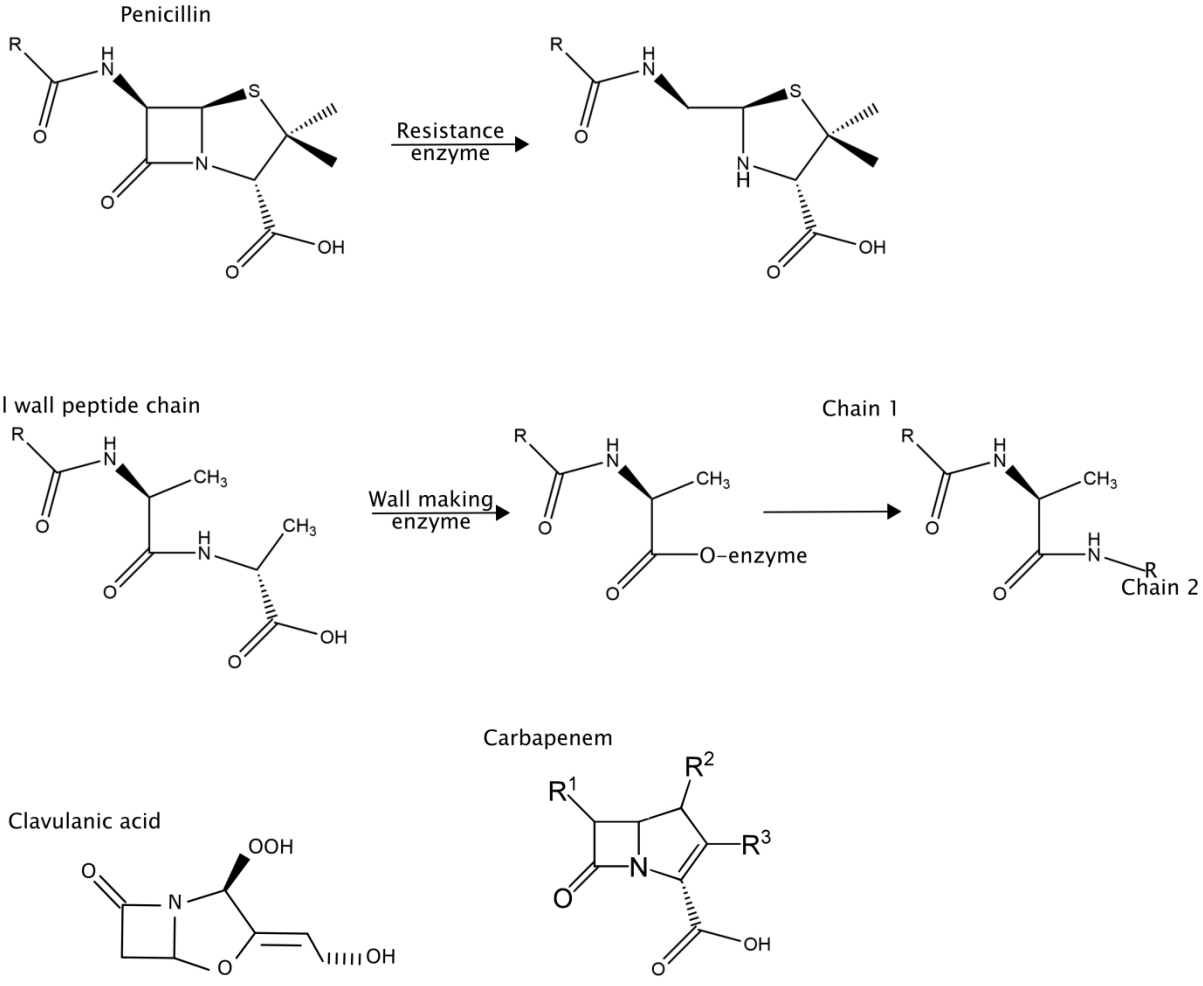
Part 1 of 8

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.

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



Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

69. 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.

70. 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.

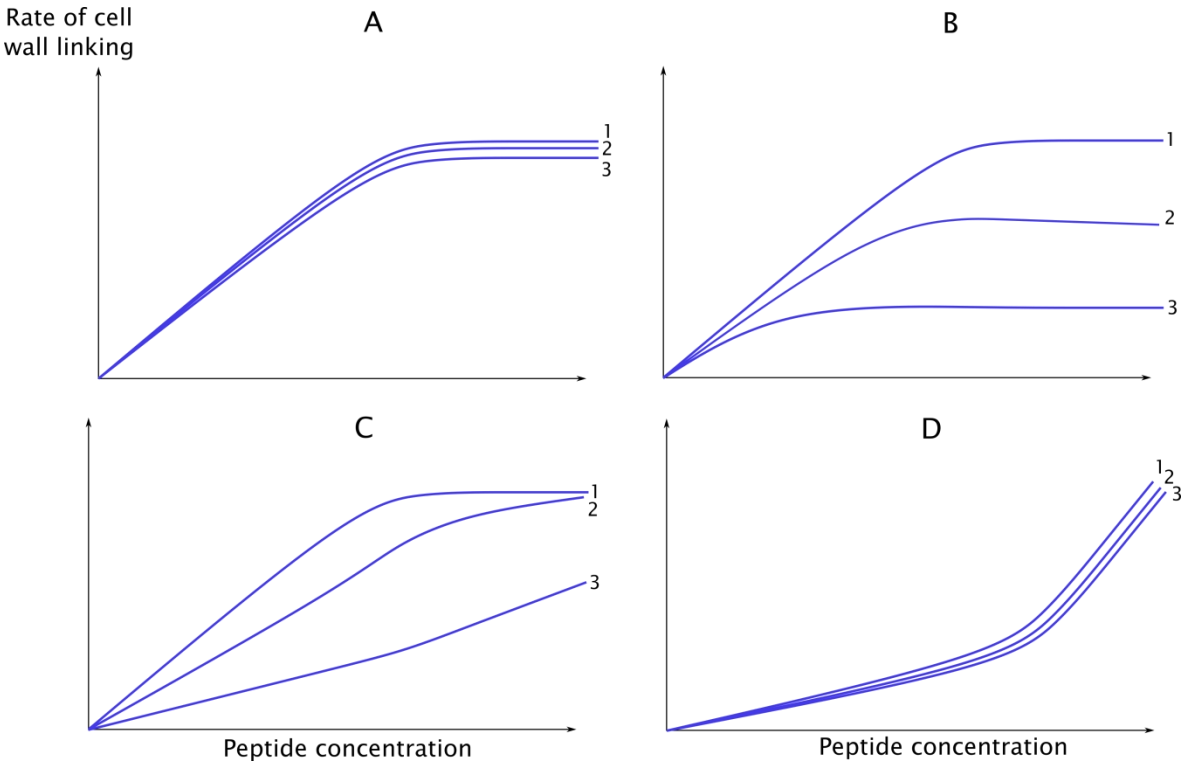
C) Reversible uncompetitive inhibitor (binds intermediate enzyme/substrate complex).

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).

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

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.*



71. 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

72. 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

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

73. 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

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 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.



- 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.

74. 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.
Choose ONE.

A) Envelope proteins, transcription factor and polymerase is made, Polymerase and transcription factor bind the viral genome, Viral genes are transcribed and replicated, Envelope proteins form viral particles with genome and proteins inside

B) Envelope proteins, transcription factor and polymerase is made, Viral genes are transcribed and replicated, Polymerase and transcription factor bind the viral genome, Envelope proteins form viral particles with genome and proteins inside

C) Viral genes are transcribed and replicated, Envelope proteins, transcription factor and polymerase is made, Polymerase and transcription factor bind the viral genome, Envelope proteins form viral particles with genome and proteins inside

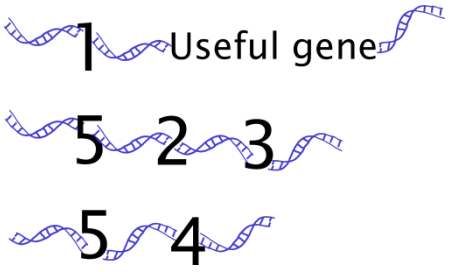
D) Polymerase and transcription factor bind the viral genome, Viral genes are transcribed and replicated, Envelope proteins, transcription factor and polymerase is made, Envelope proteins form viral particles with genome and proteins inside.

E) Envelope proteins form viral particles with genome and proteins inside, Polymerase and transcription factor bind the viral genome, Viral genes are transcribed and replicated, Envelope proteins, transcription factor and polymerase is made.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

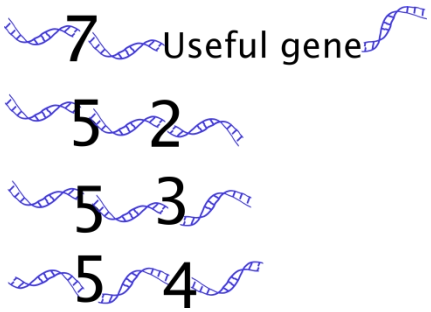
Second generation methods infect cells with three ‘genomes’ which look like this:

- 5 is an artificial promoter.



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.



75. 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.

76. Which is NOT true of second generation methods (versus third generation methods)?

1 mark.
Choose ONE.

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

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

C) Fewer components needed to be infected into factory cells

D) Higher yield of virus particles from factory cells

E) Safest

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 8

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.

77. What features should a randomised control trial like RECOVERY ***NOT*** have?

1 mark.
Choose ONE.

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 fixed at start of the trial.

D) Number of patients used in trial maximised.

E) Include patients without COVID-19

78. What things can a randomised control trial like RECOVERY ***NOT*** conclude?

1 mark.
Choose ONE.

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.

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.

79. Calculate the vaccine efficiency. Pick the nearest number below.

1 mark.
Choose ONE.

A) 60%

B) 70%

C) 80%

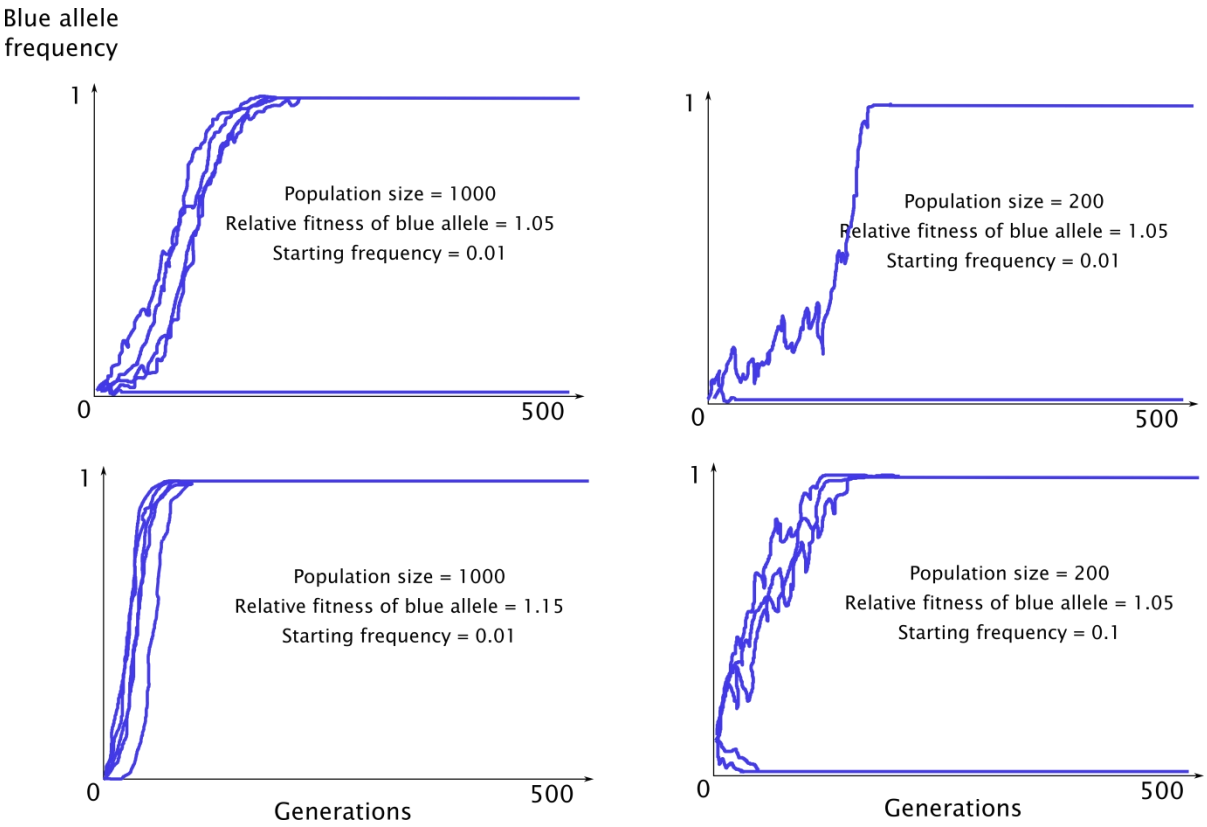
D) 90%

E) 100%

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 9

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).



80. For which of these will genetic drift dominate over natural selection?

1 mark.
Choose ONE.

A) Population split into isolated groups

B) Large population

C) High current allele frequency

D) Large difference in relative fitness

Here are some observations:

1. The average speed with which allele frequency changes
2. Some alleles takeover very large populations even when they have impacts too small to measure in laboratories
3. The probability an allele will takeover a population
4. The speed an allele's frequency changes in any one population at any one time
5. The frequency at which an allele is initially introduced alters the probability it will takeover a population
6. More fit alleles sometimes go extinct before less fit alleles

81. Which are caused by natural selection alone

1 mark.
Choose ONE.

A) 1 and 2

B) 3 and 4

C) 5 and 6

D) 1 only

E) 2, 3 and 4

82. Which are caused by both natural selection and genetic drift

1 mark.
Choose ONE.

A) 1 and 2

B) 3 and 4

C) 5 and 6

D) 1 only

E) 2, 3 and 4

83. Which are caused by drift alone

1 mark.
Choose ONE.

A) 1 and 2

B) 3 and 4

C) 5 and 6

D) 1 only

E) 2, 3 and 4

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

1 mark.
Choose ONE.

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.

E) a and b only.

85. 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.

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

Section 10

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					

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

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				

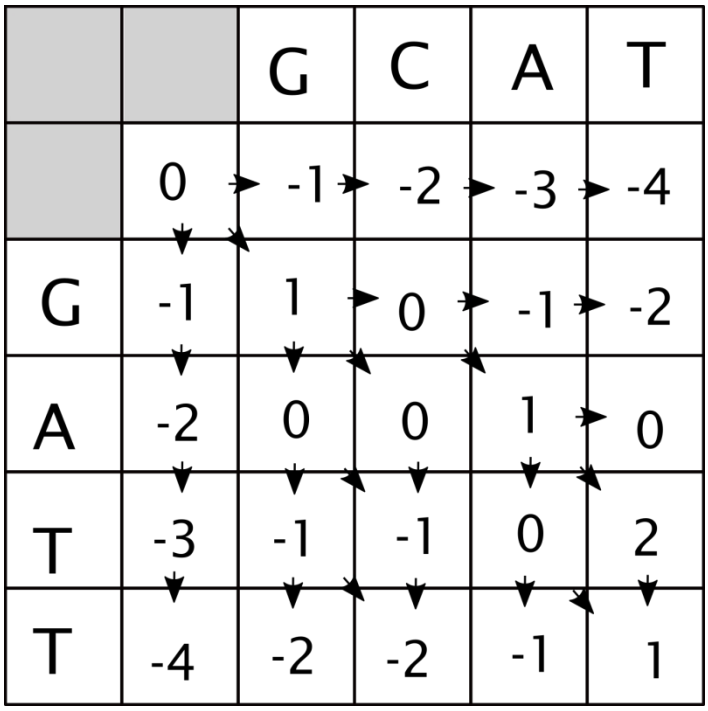
Moving diagonally indicates you are aligning matching or miss-matching bases. You add +1 to the previous score if they match, or -1 if they miss-match.

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

Cells in the middle could be scored based on horizontal, vertical or diagonal movements. The cell should be given the highest score possible.

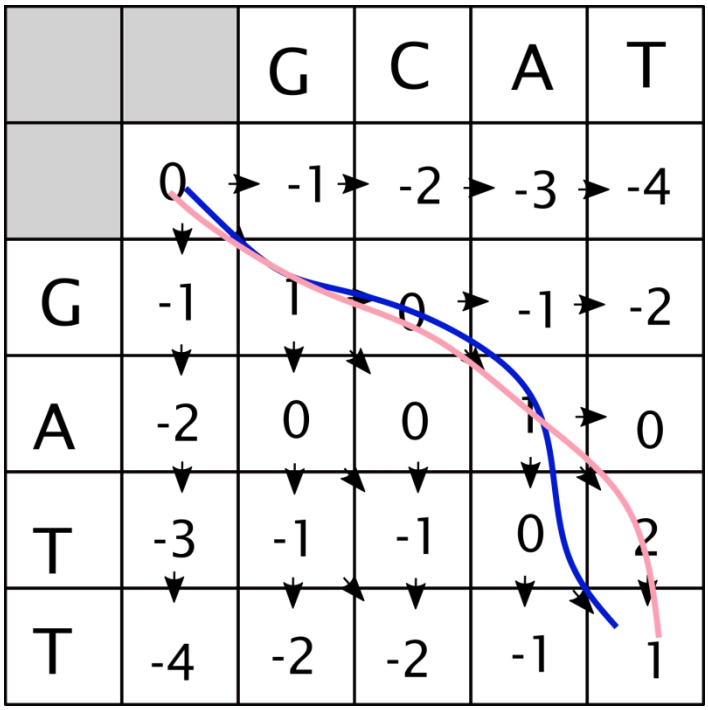
Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

You then mark with an arrow which movement this score came from.



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.



Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

In this example, the two possible alignments are:

• G-ATT

1 GCA-T

• G-ATT

2 GCAT

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				

Copyright 2021 UNITED KINGDOM BIOLOGY COMPETITIONS

86. What is the highest score of your alignments?

1 mark.
Choose ONE.

A) -1

B) 0

C) 1

D) 2

E) 3

87. How many different alignments have the highest score?

2 marks.
Choose ONE.

A) 1

B) 2

C) 3

D) 4

E) 5

88. The start of two different alignments was given in the example.

How should line 1 be extended? *i.e. the missing characters: GCA-TXXXXXXXXXX*

1 mark.
Choose ONE.

A) GCT

B) CGT

C) CCT

D) G-T

E) TCG

Species iii is found to have the sequence GCATGC**A**.

89. Which is true?

1 mark.
Choose ONE.

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

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

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

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

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.

90. How should the scoring system be adapted to account for these findings?

1 mark.
Choose ONE.

A) Penalty for C to T mutations increased

B) Penalty for gaps in alignment increased

C) Penalty for C to A mutations increased

D) Penalty for C to A mutations reduced

E) B and C only

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

1 mark.
Choose ONE.

A) DNA sequence changes at a faster rate overtime

B) DNA is easier to sequence

C) DNA is better for comparing more distantly related species

D) DNA has a more complicated scoring system

E) A and B only

END OF EXAM.