B6bD Variation, Evolution and Selection: Exam Drill

AQA 8464 · Calculator allowed · about 95 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Variation within a species can arise in more than one way.

(a) State what is meant by a 'mutation'. **(1)**

(b) State what is meant by 'natural selection'. **(1)**

(Total for Question 1 is 2 marks)

2 A farmer sprayed the same pesticide on a field of cabbages every year to control a population of aphids (small insects that damage the crop). An entomologist recorded the percentage of the aphid population that survived being sprayed, over five years.

Year -- Percentage of aphids surviving spraying
1 -- 4%
2 -- 9%
3 -- 21%
4 -- 38%
5 -- 55%

(a) Calculate the increase in the percentage of aphids surviving spraying between year 1 and year 5. **(1)**

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(b) Use the theory of natural selection to explain the trend shown in the data. **(3)**

(c) Suggest one strategy the farmer could use to slow down the rate at which the aphid population becomes resistant to the pesticide. **(1)**

(Total for Question 2 is 5 marks)

3 The diagram below is a simplified phylogenetic tree showing the evolutionary relationships between four species of big cat, labelled J, K, L and M, based on comparisons of their DNA. J and K share the most recent common ancestor. L branches from an earlier point on the tree. M shares a separate, much older common ancestor with J, K and L, branching near the base of the tree.

Figure (to be drawn): A branching phylogenetic tree with four tips labelled J, K, L and M. J and K share the most recent common ancestor (the branching node closest to the tips); L branches from an earlier node; M branches from a separate, older common ancestor near the base of the tree.

(a) State which two of the four species shown are most closely related to each other. **(1)**

(b) Explain how the tree shows that species M is the most distantly related to the other three species. **(1)**

(c) Name the type of evidence most likely to have been used to construct this phylogenetic tree. **(1)**

(Total for Question 3 is 3 marks)

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4 A class of students measured their hand span (in cm) and also recorded their blood group (A, B, AB or O).

(a) State whether hand span shows continuous or discontinuous variation, and give a reason for your answer. **(1)**

(b) State whether blood group shows continuous or discontinuous variation, and give a reason for your answer. **(1)**

(c) Suggest why hand span is affected by both genes and the environment, while blood group is affected by genes alone. **(1)**

(Total for Question 4 is 3 marks)

5 A plant breeder wants to develop a variety of wheat that is more resistant to a fungal disease that currently reduces crop yields.

(a) Describe how the breeder could use selective breeding, over several generations, to develop a wheat variety with improved disease resistance. **(4)**

(b) Selective breeding for disease resistance can reduce the genetic variation within a wheat population. Explain why this could be a disadvantage in the future. **(2)**

(Total for Question 5 is 6 marks)

6 A student investigated the effect of three different antibiotic discs, D, E and F, on the growth of a culture of harmless Staphylococcus epidermidis bacteria, using aseptic technique. Each disc was placed on an agar plate evenly spread with the bacteria, then incubated at 25 degrees C for 48 hours. The student measured the diameter of the clear zone (no bacterial growth) around disc E three separate times: 14 mm, 15 mm, 22 mm, 15 mm. The clear zone around disc D had a diameter of 18 mm. A control disc, with no antibiotic, produced no clear zone.

(a) Identify the anomalous result in the repeated measurements of disc E's clear zone, and suggest one possible cause. **(2)**

(b) Calculate the mean diameter of the clear zone around disc E, excluding the anomalous result. **(2)**

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(c) Calculate the area of the clear zone produced by disc D. Use the equation area of a circle = $\pi \times r^2$, with $\pi = 3.14$. Give your answer to 3 significant figures. **(2)**

.....

(d) The student measured each clear zone to the nearest millimetre, using a ruler. Explain how this level of precision could affect the reliability of a comparison between disc D and disc E. **(1)**

(e) Explain the purpose of including the control disc, with no antibiotic, in this investigation. **(1)**

(Total for Question 6 is 8 marks)

7 Bacteria can be genetically engineered to produce human insulin, which is used to treat people with type 1 diabetes. Describe how a bacterium can be genetically engineered to produce human insulin.

(Total for Question 7 is 5 marks)

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8 The diagram shows a cross-section through undisturbed layers of sedimentary rock exposed in a quarry. Fossils of three different trilobite species, labelled G, H and I, were found in three different rock layers: G in the lowest (deepest) layer, H in the middle layer, and I in the uppermost (shallowest) layer. Geologists estimate that each rock layer took approximately 2 million years to form, and that species G first appeared 15 million years ago.

Figure (to be drawn): A cross-section of a quarry face showing three horizontal, undisturbed sedimentary rock layers stacked on top of one another; fossil G is embedded in the bottom layer, fossil H in the middle layer, and fossil I in the top layer.

(a) State which fossil, G, H or I, is the youngest (most recent), and explain how you know. **(2)**

(b) Estimate the age, in millions of years, of the rock layer containing fossil I, given that species G first appeared 15 million years ago and each layer took approximately 2 million years to form. **(2)**

(c) Explain why scientists cannot be completely certain about ages estimated in this way. **(1)**

(Total for Question 8 is 5 marks)

9 A small population of flightless beetles lived only on a remote island. A new species of beetle-eating bird colonised the island for the first time, and within 30 years the flightless beetle had become extinct on the island.

(a) Suggest why the arrival of the new predator caused the flightless beetle population to become extinct. **(1)**

(b) Give two other factors, other than the arrival of a new predator, that can cause a species to become extinct. **(2)**

(Total for Question 9 is 3 marks)

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10 Higher tier only. Speciation is the process by which a new species forms.

(a) State what is meant by two organisms belonging to the same 'species'. **(1)**

(b) Explain how the geographical isolation of two populations of the same species can eventually lead to speciation. **(3)**

(Total for Question 10 is 4 marks)

11 A population of a mouse species lived on both sides of a river valley. A landslide dammed the river, forming a new lake that permanently separated the population into two groups, unable to cross the water to interbreed. One side of the valley became much drier over the following centuries, while the other side remained damp and forested. Explain, using ideas about mutation, natural selection and isolation, how this separation could eventually lead to the formation of two different species of mouse.

(Total for Question 11 is 6 marks)

Mark scheme · B6bD Variation, Evolution and Selection: Exam Drill

Question 1

- (a) **B1** a random change to the base sequence of an organism's DNA (genetic material), oe
- **(a) Answer: A random change to the base sequence of an organism's DNA.**
- (b) **B1** the process by which organisms with characteristics best suited to their environment are more likely to survive and reproduce, passing on the alleles for those characteristics to their offspring, oe
- **(b) Answer: The process by which organisms with characteristics best suited to their environment are more likely to survive and reproduce, passing on the alleles for those characteristics.**

Question 2

- (a) **B1** 51 percentage points (55 - 4), cao
- **(a) Answer: 51 percentage points**
- (b) **B1** before the pesticide was first used, there was already genetic variation in the aphid population, and a small number of aphids happened to carry a mutation/allele giving resistance to the pesticide, oe
- (b) **B1** each time the pesticide was sprayed, non-resistant aphids were killed, while resistant aphids survived and faced less competition for food and space, oe
- (b) **B1** surviving resistant aphids reproduced, passing the resistance allele on to their offspring, so the proportion of resistant aphids in the population increased with each generation, oe
- **(b) Answer: Genetic variation already existed in the aphid population before spraying began, and a small number of aphids already carried a resistance mutation. Each time the pesticide was sprayed, non-resistant aphids were killed while resistant aphids survived, faced less competition, and reproduced, passing on the resistance allele. This increased the proportion of resistant aphids with each generation.**
- (c) **B1** e.g. rotate/alternate between different pesticides with different modes of action, only spray when necessary rather than routinely, or use a non-chemical method of pest control (e.g. introducing a natural predator) alongside the pesticide, oe
- **(c) Answer: For example, rotate between different pesticides with different modes of action, or only spray when necessary rather than routinely, so that resistance to any one pesticide develops more slowly.**

Question 3

- (a) **B1** J and K
- **(a) Answer: J and K.**
- (b) **B1** species M branches from the node closest to the base (the earliest branching point) of the tree, meaning it shares the oldest common ancestor with the other species, oe
- **(b) Answer: Species M branches from the node closest to the base of the tree, meaning it shares the oldest common ancestor with the other three species.**
- (c) **B1** comparison of DNA (base sequences/genomes) between the species, oe
- **(c) Answer: Comparison of DNA base sequences (genomes) between the species.**

Question 4

- (a) **B1** continuous variation, because hand span can take any value within a range, with no distinct/separate categories, oe
- **(a) Answer: Continuous variation, because hand span can take any value within a range, with no distinct categories.**
- (b) **B1** discontinuous variation, because blood group falls into a small number of distinct categories, with no intermediate values, oe
- **(b) Answer: Discontinuous variation, because blood group falls into a small number of distinct categories, with no intermediate values.**
- (c) **B1** hand span (like other body measurements) is affected by many genes acting together as well as by environmental factors such as diet and nutrition during growth, while blood group is determined entirely by a single gene, unaffected by lifestyle or environment, oe
- **(c) Answer: Hand span is affected by many genes acting together, as well as by environmental factors such as diet and nutrition during growth, whereas blood group is determined entirely by a single gene and is not affected by lifestyle or environment.**

Question 5

- (a) **B1** select the individual wheat plants from the current population that show the greatest natural resistance to the disease, oe
- (a) **B1** breed these selected, more resistant plants together, oe
- (a) **B1** select the most disease-resistant offspring from this generation, oe
- (a) **B1** repeat this process of selecting and breeding the most resistant individuals over many generations, until most/all plants in the population show strong disease resistance, oe
- **(a) Answer: Select the wheat plants showing the greatest natural disease resistance, breed them together, select the most resistant offspring, then repeat this selection and breeding process over many generations until most plants show strong resistance.**
- (b) **B1** reduced genetic variation means there are fewer different alleles present in the population, oe
- (b) **B1** this makes the population less able to adapt if a new disease, pest or environmental change (e.g. a new strain of the fungus) appears, because fewer individuals are likely to already carry a useful resistance allele, risking the whole crop, oe
- **(b) Answer: Reduced genetic variation means fewer different alleles are present in the population, making it less able to adapt if a new disease, pest, or environmental change appears, since fewer individuals are likely to already carry a useful resistance allele, putting the whole crop at risk.**

Question 6

- (a) **B1** 22 mm is the anomalous result
- (a) **B1** a possible cause, e.g. a measuring error, the disc may have moved slightly on the agar, or two nearby clear zones may have merged/been misread, oe
- **(a) Answer: 22 mm is the anomalous result, possibly caused by a measuring error, the disc moving slightly on the agar, or nearby clear zones merging and being misread.**
- (b) **M1** (14 + 15 + 15) / 3
- (b) **A1** 14.7 mm cao
- **(b) Answer: 14.7 mm**
- (c) **M1** radius = 18 / 2 = 9 (mm); correct substitution shown: 3.14×9^2
- (c) **A1** 254 mm^2 cao (3 s.f.)
- **(c) Answer: 254 mm^2**
- (d) **B1** measuring only to the nearest mm means small real differences between the discs' zones could be hidden by rounding, so a small difference in mean diameter may not represent a genuine difference in antibiotic effectiveness, oe
- **(d) Answer: Measuring only to the nearest millimetre means small real differences between the zones could be hidden by rounding, so a small difference in mean diameter may not represent a genuine difference in effectiveness between the antibiotics.**
- (e) **B1** to show that any clear zones seen around the other discs were caused by the antibiotics, and not by some other factor, such as the paper disc itself or the general growth conditions on the plate, oe
- **(e) Answer: To show that any clear zones around the other discs were caused by the antibiotics themselves, and not by some other factor such as the paper disc or the general growth conditions.**

Question 7

- **B1** the gene for human insulin is identified and cut out of human DNA, usually using a restriction enzyme, oe
- **B1** a plasmid (a small circular piece of bacterial DNA) is removed from a bacterium and cut open using the same restriction enzyme, leaving matching/complementary ends, oe
- **B1** the insulin gene is inserted into the cut plasmid and joined together using an enzyme called ligase, forming recombinant DNA, oe
- **B1** the recombinant plasmid (acting as a vector) is inserted into a new bacterial cell, oe
- **B1** the genetically modified bacteria are cultured/grown in large numbers (e.g. in fermenters), where they express the inserted gene and produce human insulin, which is then extracted and purified, oe
- **Answer: The insulin gene is cut from human DNA and a bacterial plasmid is cut open, both using the same restriction enzyme; the gene is inserted into the plasmid using ligase to form recombinant DNA; the recombinant plasmid (vector) is inserted into a bacterium, which is cultured in large numbers to express and produce human insulin.**

Question 8

- (a) **B1** I is the youngest
- (a) **B1** because, in undisturbed sedimentary rock, the uppermost (shallowest) layers were deposited most recently, so fossils found there must be the youngest, oe
- **(a) Answer: I is the youngest, because in undisturbed rock the uppermost layers were deposited most recently, so contain the youngest fossils.**
- (b) **M1** 15 - (2 x 2)
- (b) **A1** 11 million years cao
- **(b) Answer: 11 million years**
- (c) **B1** e.g. the rate at which rock layers form is not always constant/the same everywhere, and layers may have been disturbed, compressed or partly eroded since they formed, so the estimate is based on assumptions, oe
- **(c) Answer: The rate at which rock layers form is not always constant, and layers may have been disturbed, compressed, or partly eroded since they formed, so any estimate based on assuming a constant rate involves some uncertainty.**

Question 9

- (a) **B1** the flightless beetles could not fly away to escape the new predator, so were eaten faster than they could reproduce, causing the population to decline until no individuals remained, oe
- **(a) Answer: The flightless beetles could not fly away to escape the new predator, so they were eaten faster than they could reproduce, causing the population to decline until no individuals were left.**
- (b) **B1** any one valid factor, e.g. a new disease, a new competitor species, or a change in the environment (e.g. climate change) that happens too quickly for the species to adapt to
- (b) **B1** any second valid factor, e.g. a single catastrophic event, such as a volcanic eruption or a collision with an asteroid
- **(b) Answer: Any two of: a new disease; a new, more successful competitor species; a change in the environment (such as climate change) that happens too quickly for the species to adapt; a single catastrophic event, such as a volcanic eruption or an asteroid collision.**

Question 10

- (a) **B1** organisms that can breed (interbreed) with each other to produce fertile offspring, oe
- **(a) Answer: Organisms that can breed with each other to produce fertile offspring.**
- (b) **B1** a physical barrier separates the population into two groups, which can no longer interbreed with each other, oe
- (b) **B1** the two isolated environments may differ, so different mutations arise and different characteristics are favoured by natural selection in each population, oe
- (b) **B1** over many generations, the allele frequencies of the two populations change and become increasingly different, until individuals from the two populations can no longer interbreed to produce fertile offspring, meaning a new species has formed, oe
- **(b) Answer: A physical barrier separates the population into two groups that can no longer interbreed. The two isolated environments may differ, so different mutations arise and different characteristics are favoured by natural selection in each group. Over many generations, the allele frequencies of the two populations become increasingly different, until they can no longer interbreed to produce fertile offspring, meaning a new species has formed.**

Question 11

- **Level 3** (5-6): A clear, logically sequenced explanation that links geographical isolation, differing selection pressures in the two environments, changing allele frequencies over many generations, and the eventual inability to interbreed, to the formation of two new species.
- **Level 2** (3-4): A mostly correct explanation covering some of: isolation, differing selection pressures, and changing allele frequencies, but the reasoning may be incomplete or not fully sequenced, or the final step (reproductive isolation defining a new species) may be missing.
- **Level 1** (1-2): A simple, partial answer, for example stating that the mice are separated and become different, with little or no explanation of the mechanism (mutation, selection, allele frequency change).
- **Indicative content:**
  - The landslide and new lake formed a physical barrier that geographically isolated the two mouse populations, so they could no longer interbreed with each other.
  - Mutations occur randomly in both populations, producing new alleles and increasing genetic variation within each group.
  - The two environments differ (one drier, one damp and forested), so different characteristics will be advantageous for survival in each; natural selection will therefore favour different alleles in the two populations.
  - Individuals with characteristics better suited to their own environment are more likely to survive and reproduce, passing on the favourable alleles to their offspring.
  - Over many generations, the allele frequencies of the two populations diverge (become increasingly different), because different alleles are being selected for in each environment.
  - Eventually, the genetic differences between the two populations become so great that individuals from one population can no longer interbreed with individuals from the other population to produce fertile offspring.
  - At this point, the two populations are classified as two separate species, formed by the process of speciation.