1.7 Genetics, Populations, Evolution and Ecosystems: Test Pack

Total Marks

AQA 7402 · Calculator allowed · about 55 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question tests basic genetic definitions and understanding of DNA structure and gene expression.

(a) State the meaning of the term locus in genetics. **(1)**

(b) Give one difference between DNA and mRNA in terms of sugar and one-nucleotide base. **(2)**

(c) Describe briefly how a point mutation in a coding region could lead to a nonfunctional protein. **(3)**

(d) Name the two main stages of gene expression and give the location in a eukaryotic cell where each occurs. **(2)**

(Total for Question 1 is 8 marks)

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2 This question is based on the required practical investigating the distribution and abundance of organisms using quadrats. A group of students investigated the population size of daisy plants in a school playing field with an area of 800 m^2. They used a random number generator to obtain two random numbers, which were used as coordinates to position a 0.5 m x 0.5 m quadrat at ten random locations across the field. The number of daisy plants rooted within each quadrat was counted.

Results (number of daisy plants per quadrat): 4, 6, 5, 7, 3, 5, 6, 4, 5, 5.

(a) Explain why the students used random numbers to position the quadrats, rather than placing them wherever was convenient. **(2)**

(b) Calculate the mean number of daisy plants per quadrat, and use this to estimate the total daisy population in the field. **(3)**

(c) Suggest one way the reliability of this population estimate could be improved, and explain why this would help. **(2)**

(Total for Question 2 is 7 marks)

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3 Ecological succession is the process by which the species composition of a community changes over time.

(a) Explain what is meant by the term climax community in the context of ecological succession. **(2)**

(b) Describe how primary succession occurs on an area of bare sand at a newly formed coastal sand dune system, from the first colonisation by pioneer species through to the formation of a climax community. In your answer, refer to changes in the abiotic environment and to the biotic community at each stage. **(6)**

(Total for Question 3 is 8 marks)

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4 A plant breeder crossed two pea plants that were both heterozygous for seed shape (Rr) and seed colour (Yy). Round shape (R) is dominant to wrinkled (r) and yellow colour (Y) is dominant to green (y). The two genes assort independently. A chi-squared test was used to test whether the 320 offspring produced from this dihybrid cross (RrYy x RrYy) fitted the expected 9:3:3:1 ratio.

Observed numbers: round yellow = 160, round green = 74, wrinkled yellow = 70, wrinkled green = 16.

(a) State the null hypothesis for this chi-squared test. **(1)**

(b) Calculate the expected number of offspring in each of the four phenotype classes. **(2)**

(c) Calculate the chi-squared value for this data. Show your working. **(3)**

(d) The critical value of chi-squared at p=0.05 for 3 degrees of freedom is 7.82. Using this value and your answer to part (c), state and explain the conclusion that should be drawn about the offspring ratio. **(2)**

(Total for Question 4 is 8 marks)

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5 New species can arise through allopatric speciation (where populations are separated by a geographical barrier) or sympatric speciation (where populations diverge within the same geographical area).

(a) Define the biological species concept, in terms of reproductive isolation. **(2)**

(b) Compare how allopatric speciation and sympatric speciation can lead to the formation of a new species, referring to isolating mechanisms, genetic divergence and reproductive isolation in your answer. **(6)**

(Total for Question 5 is 8 marks)

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Mark scheme · 1.7 Genetics, Populations, Evolution and Ecosystems: Test Pack

Question 1

(a) position of a gene on a chromosome or specific location on DNA **B1**

(a) Answer: Position of a gene on a chromosome.

(b) DNA contains deoxyribose, mRNA contains ribose **B1**

(b) DNA has thymine, mRNA has uracil **B1**

(b) Answer: DNA has deoxyribose and thymine; mRNA has ribose and uracil.

(c) mutation changes a codon in mRNA, altering one amino acid or creating a premature stop codon **M1**

(c) change alters the primary sequence leading to incorrect folding or a truncated polypeptide **M1**

(c) nonfunctional protein results due to lost active site, instability or truncation, cao **A1**

(c) Answer: A point mutation alters a codon so one amino acid is changed or a premature stop codon is produced; this can change the primary sequence and so disrupt folding or produce a truncated polypeptide, preventing normal function.

(d) transcription - nucleus **B1**

(d) translation - cytoplasm (on ribosomes) **B1**

(d) Answer: Transcription in the nucleus; translation in the cytoplasm on ribosomes.

Question 2

(a) random placement avoids sampling bias, e.g. students unconsciously choosing areas with more or fewer daisies oe **B1**

(a) a randomly obtained sample is representative of the whole field, so the results can validly be used to estimate the population of the whole field oe **B1**

(a) Answer: Random placement avoids bias in quadrat positioning, so the sample obtained is representative of the whole field and results can be validly extrapolated.

(b) mean = (4+6+5+7+3+5+6+4+5+5)/10 = 50/10 = 5.0 (per 0.25 m^2 quadrat) **M1**

(b) number of quadrats needed to cover the field = 800/0.25 = 3200 **M1**

(b) estimated population = 5.0 x 3200 = 16000 daisy plants cao **A1**

(b) Answer: 16000 daisy plants

(c) e.g. increase the number of quadrats sampled oe (accept other valid suggestions, e.g. use a larger quadrat if the species is patchily distributed) **B1**

(c) with linked explanation: this reduces the effect of anomalous/unrepresentative results and gives a more reliable estimate of the true mean/reduces the effect of chance variation between samples oe **B1**

(c) Answer: Increase the number of quadrats sampled, as this reduces the effect of chance variation between samples and gives a more reliable estimate of the true mean.

Question 3

(a) the final, relatively stable community reached at the end of succession oe **B1**

(a) which remains in equilibrium with the prevailing environmental (abiotic) conditions as long as they do not change oe **B1**

(a) Answer: A climax community is the final, stable community formed at the end of succession, which remains in equilibrium with the prevailing environmental conditions.

(b) **L3** A detailed, well-sequenced description of primary succession that correctly identifies pioneer species and their tolerance of harsh abiotic conditions, explains how the abiotic environment (e.g. soil/humus formation, water retention) changes as a result of colonisation, and links this to a logical sequence of seral stages of increasing species richness and biomass up to a climax community. Scientific terminology is used accurately throughout. **5-6**

(b) **L2** The answer describes pioneer colonisation and at least one further seral stage, with some reference to changing abiotic conditions and/or increasing species diversity, but the sequence, detail or accuracy may be incomplete. **3-4**

(b) **L1** Basic or isolated statements about succession or pioneer species, with little explanation of how abiotic or biotic conditions change over time. **1-2**

(b) **L0** No relevant content. **0**

(b) Indicative content:

- Bare sand is initially a harsh abiotic environment: little water retention, few nutrients/no soil, high salinity and exposure to wind.
- Pioneer plants (e.g. sea rocket, sand couch and marram grass) can colonise the harsh sand-dune environment, with adaptations to salt, drought and exposure; their roots help stabilise the sand. Lichens occur later on stabilised grey dunes.
- As pioneer plants grow, photosynthesise and eventually die, decomposition by microorganisms adds organic matter (humus) to the sand.
- This changes the abiotic conditions: the developing soil retains more water and has more available nutrients, and there is more shelter from wind, making conditions less hostile.
- These improved conditions allow new, less tolerant species (e.g. grasses, then shrubs) to colonise and out-compete the original pioneers in some areas.
- At each successive seral stage, species diversity/richness and total biomass generally increase, and the community becomes structurally more complex, creating new niches (e.g. shade, shelter) for further species.
- Interspecific competition increases as more species colonise, and less well-adapted earlier species may be replaced.
- Eventually a stable climax community (e.g. woodland) is reached, determined largely by the climate of the area, which persists in equilibrium with the abiotic environment unless a major disturbance occurs.

(b) Answer: Levels-of-response essay; see indicative content.

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Question 4

(a) there is no significant difference between the observed numbers of offspring in each phenotype class and the numbers expected from a 9:3:3:1 ratio (any difference is due to chance) oe **B1**

(a) Answer: There is no significant difference between the observed and expected (9:3:3:1) numbers of offspring; any difference is due to chance.

(b) correct method shown, e.g. 9/16 x 320 **M1**

(b) all four expected values correct: 180, 60, 60, 20 cao **A1**

(b) Answer: 180, 60, 60, 20

(c) correct use of chi^2 = sum[$(O-E)^2/E$] with at least two correct $(O-E)^2/E$ terms **M1**

(c) all four $(O-E)^2/E$ terms correct: 2.22, 3.27, 1.67, 0.80 (awrt 2 dp) **M1**

(c) chi^2 = 7.96 (awrt) cao **A1**

(c) Answer: chi^2 = 7.96 (awrt)

(d) calculated chi^2 (7.96) is greater than the critical value (7.82) ft from (c) **B1**

(d) reject the null hypothesis; the observed offspring counts differ significantly from the expected 9:3:3:1 ratio at the 5% significance level; any suggested reason must be consistent with independent assortment, e.g. chance sampling or differential survival of offspring oe **B1**

(d) Answer: Since chi^2 = 7.96 > 7.82 (3 degrees of freedom, 5% significance level), reject the null hypothesis: the observed counts differ significantly from the expected 9:3:3:1 ratio. Independent assortment is stipulated; a possible reason is differential survival of offspring, or an unusual chance sample.

Question 5

(a) a species is a group of organisms that can interbreed to produce fertile offspring oe **B1**

(a) the group is reproductively isolated from other such groups/species oe **B1**

(a) Answer: A species is a group of organisms that can interbreed to produce fertile offspring and is reproductively isolated from other such groups.

(b) **L3** A detailed and coherent comparison that clearly explains both allopatric and sympatric speciation, correctly identifies the isolating mechanism in each case, and links this to genetic divergence and the eventual evolution of reproductive isolation between the two populations. Scientific terminology is used accurately throughout. **5-6**

(b) **L2** The answer describes both allopatric and sympatric speciation and identifies at least one relevant isolating mechanism, with some link to divergence or reproductive isolation, but detail, accuracy or the comparison between the two routes may be incomplete. **3-4**

(b) **L1** Basic or isolated statements about geographical separation or speciation, with little explanation of mechanism or reproductive isolation. Little or no valid comparison is made. **1-2**

(b) **L0** No relevant content. **0**

(b) Indicative content:

- Allopatric speciation begins when a geographical barrier (e.g. a river, mountain range or stretch of sea) physically separates a population into two groups.
- This prevents gene flow (interbreeding) between the two separated populations.
- Each isolated population is exposed to different environmental/selection pressures, and mutation and genetic drift occur independently in each population.
- Over many generations, the allele frequencies of the two populations diverge.
- Eventually the accumulated genetic differences mean that, even if the barrier is removed, the two populations can no longer interbreed to produce fertile offspring: they have become reproductively isolated, forming two separate species.
- Sympatric speciation occurs without a geographical barrier; populations remain in the same physical area but become reproductively isolated by other mechanisms.
- Examples of isolating mechanisms in sympatric speciation include: temporal isolation (breeding at different times), behavioural isolation (different courtship behaviours/mate preferences), ecological isolation (using different micro-habitats or food sources within the same area), or polyploidy in plants (an instant change in chromosome number preventing successful interbreeding with the parent population).
- As with allopatric speciation, reduced gene flow between the diverging groups allows allele frequencies to change independently (through selection and/or drift) until interbreeding is no longer possible.
- In both cases, the key requirement for speciation is a reduction or cessation of gene flow between the diverging populations, allowing genetic divergence to accumulate until reproductive isolation is complete; the routes differ mainly in whether a geographical barrier or another isolating mechanism causes this reduction in gene flow.

(b) Answer: Levels-of-response essay; see indicative content.

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