1.4 Genetic Information, Variation and Relationships: Test Pack

Total Marks

AQA 7402 · Calculator allowed · about 60 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question tests core definitions from molecular genetics.

(a) Give the definition of a gene. **(1)**

(b) Give the definition of an allele. **(1)**

(c) Give the definition of a codon. **(1)**

(Total for Question 1 is 3 marks)

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2 Hardy-Weinberg and mutation. In a large population of wildflower plants the recessive allele a causes white petals, while the dominant allele A gives purple petals. A sample survey estimates that 9% of the population displays white petals.

(a) Assuming Hardy-Weinberg equilibrium, calculate the frequency of the recessive allele a in the population. Show your working and give your answer to 3 significant figures. **(3)**

(b) Using your answer in (a), calculate the expected percentage of heterozygous plants in the population. Give your answer to 3 significant figures. **(3)**

(c) A mutagen exposure increases the mutation rate from A to a so that each generation an additional 0.5% of A alleles mutate to a. Assuming other Hardy-Weinberg conditions hold and the population is large, explain qualitatively how this will affect allele frequencies over many generations. **(2)**

(Total for Question 2 is 8 marks)

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3 Chi-squared test on inheritance. A geneticist examines inheritance of a single gene with complete dominance in pea plants. She crosses two heterozygotes and obtains 160 offspring: 118 show the dominant phenotype and 42 the recessive phenotype. Use chi-squared test at 5% significance level with expected ratio 3:1. Critical value for df = 1 is 3.84.

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

(b) Calculate the expected numbers for dominant and recessive phenotypes under the null hypothesis. **(2)**

(c) Compute the chi-squared statistic using chi-squared = sum((observed - expected)^2 / expected) and show your working. Give the value to 2 decimal places. **(4)**

(d) State whether the null hypothesis should be rejected at the 5% level and explain your conclusion using the critical value provided. **(3)**

(Total for Question 3 is 10 marks)

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4 This question links genetic diversity, natural selection and speciation.

(a) Compare allopatric and sympatric speciation, giving the type of isolating mechanism associated with each. **(4)**

(b) Explain, using ideas about natural selection, how two geographically isolated populations of the same original species could eventually become two separate species. **(5)**

(c) A population of 2,000 insects is founded by just 5 individuals that colonise a remote island (a founder event). Explain, using this figure, why the new island population is likely to show reduced genetic diversity compared with the original mainland population. **(2)**

(Total for Question 4 is 11 marks)

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5 Synoptic question. Modern agriculture sometimes uses selective breeding to increase crop yield but can reduce genetic diversity. Discuss the potential genetic, ecological and evolutionary consequences of intensive selective breeding in a crop species. In your answer consider genetic variation, inbreeding depression, disease susceptibility, potential for future adaptation, and management strategies to mitigate risks. Support your discussion with appropriate examples and link concepts across genetics, population biology and ecology.

(Total for Question 5 is 8 marks)

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Mark scheme · 1.4 Genetic Information, Variation and Relationships: Test Pack

Question 1

(a) a sequence of DNA nucleotides that codes for a polypeptide or functional RNA oe **B1**

(a) Answer: A sequence of DNA nucleotides that codes for a polypeptide or a functional RNA.

(b) one of two or more alternative forms of a gene at the same locus differing in DNA sequence oe **B1**

(b) Answer: One of two or more alternative forms of a gene at the same locus that differ in DNA sequence.

(c) a sequence of three nucleotide bases in mRNA that codes for one amino acid or a stop signal oe **B1**

(c) Answer: A sequence of three nucleotide bases in mRNA that codes for one amino acid or a stop signal.

Question 2

(a) recognise q^2 = frequency of homozygous recessive = 0.09 **M1**

(a) compute $q = \sqrt{0.09} = 0.3$ **M1**

(a) q = 0.300 cao **A1**

(a) Answer: 0.300

(b) use 2pq with p = 1 - q = 0.700, q = 0.300 **M1**

(b) compute 2 x 0.700 x 0.300 = 0.42 **M1**

(b) 42.0% cao **A1**

(b) Answer: 42.0%

(c) mutation from A to a will increase the frequency of a each generation, introducing new a alleles to the gene pool **B1**

(c) over many generations this will shift allele frequencies towards higher q unless balanced by selection or back mutation, leading to more white plants, oe **B1**

(c) Answer: The directed mutation A -> a will increase the frequency of a generation by generation; over many generations q will rise and the population will have more white plants unless countered by selection or reverse mutation.

Question 3

(a) null hypothesis: observed offspring fit a 3:1 dominant:recessive ratio (differences due to chance) **B1**

(a) Answer: Null hypothesis: the offspring follow a 3:1 dominant:recessive ratio; any deviation is due to chance.

(b) compute expected dominant = 3/4 x 160 = 120 and recessive = 1/4 x 160 = 40 **M1**

(b) expected dominant 120, expected recessive 40 cao **A1**

(b) Answer: Expected dominant = 120, expected recessive = 40

(c) substitute values: $(118 - 120)^2/120 + (42 - 40)^2/40$ **M1**

(c) compute each term: (4)/120 = 0.033333... and (4)/40 = 0.1 **M1**

(c) sum terms to give 0.133333... **M1**

(c) chi-squared = 0.13 cao to 2 d.p. **A1**

(c) Answer: 0.13

(d) compare chi-squared 0.13 with critical value 3.84 **M1**

(d) 0.13 < 3.84 so do not reject the null hypothesis **M1**

(d) conclusion: data are consistent with a 3:1 ratio; differences attributed to chance oe **A1**

(d) Answer: Do not reject the null hypothesis because 0.13 < 3.84; the data are consistent with a 3:1 ratio.

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Question 4

(a) allopatric speciation occurs when populations are separated by a physical/geographical barrier (e.g. a river, mountain range or ocean) **B1**

(a) geographical isolation prevents gene flow between the two populations **B1**

(a) sympatric speciation occurs without geographical separation; populations become reproductively isolated while occupying the same area (e.g. behavioural, mechanical, seasonal or ecological isolation) **B1**

(a) reproductive isolation prevents interbreeding/gene flow between the two populations even though they occupy the same area **B1**

(a) Answer: Allopatric = geographical isolation; sympatric = reproductive isolation without geographical separation.

(b) mutation introduces new alleles into each population independently (different mutations may arise in each population) **B1**

(b) within each population, the environment/selection pressures may differ (e.g. different climate, food availability or predators) **B1**

(b) individuals with alleles advantageous in their local environment are more likely to survive and reproduce (differential reproductive success) **B1**

(b) these advantageous alleles are passed on to offspring, so allele frequencies in each population gradually change, over many generations, in different directions **B1**

(b) eventually the genetic differences between the two populations become so great that, even if reunited, individuals could no longer interbreed successfully to produce fertile offspring, so they are now two separate species **B1**

(b) Answer: Independent mutation and differing selection pressures cause divergent allele frequency changes until reproductive isolation results in two species.

(c) only a small number of individuals (5) founded the new population, so only a small, possibly unrepresentative, sample of the alleles present in the original mainland gene pool would have been carried to the island **B1**

(c) as the population grows it does so from this limited allele pool, so the genetic diversity of the island population will be lower than that of the mainland population (some mainland alleles may be completely absent from the island population) **B1**

(c) Answer: A founder population of 5 carries only a small, unrepresentative sample of mainland alleles, reducing diversity in the descendant population.

Question 5

discussion of how selective breeding reduces genetic variation by favouring particular alleles and increasing homozygosity **M1**

explain inbreeding depression: expression of deleterious recessive alleles leading to reduced fitness, seed set or vigour **M1**

describe increased disease susceptibility due to uniform host genotypes and examples where monoculture led to epidemics **M1**

discuss reduced adaptive potential: lower standing variation limits response to novel pests, climate change or new selection pressures **M1**

suggest management strategies: maintain genetic reservoirs, use crop rotation, deploy cultivar mixtures, introgression from wild relatives, and genomic selection to manage diversity **M1**

evaluate trade-offs: higher yield versus resilience, economic considerations and ethical/social implications **M1**

link across scales: population genetics processes to ecosystem-level impacts such as effect on pollinators or soil microbiome **M1**

conclude with balanced judgement and examples (e.g. Irish potato blight, modern wheat breeding strategies) demonstrating synoptic understanding **M1**

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