1.11 Biology: Genetics, Populations and Evolution: 1-hour Pack

Total Marks

AQA 7402 · Calculator allowed · about 60 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Priya is investigating the population size of Cepaea nemoralis snails in a section of hedgerow at Fenwick Down using the mark-release-recapture method. She catches, marks and releases a first sample of snails, then returns 48 hours later to take a second sample. Her results are shown below.

Number of snails marked and released in the first sample (n1): 84
Number of snails caught in the second sample (n2): 96
Number of marked snails recaptured in the second sample (m2): 21
The Lincoln index formula is: estimated population size (N) = (n1 x n2) / m2

Sample measure	Number of snails
First marked sample (n1)	84
Second sample (n2)	96
Marked recaptured in second sample (m2)	21

(a) Name this method of estimating population size. **(1)**

(b) Suggest three features that a suitable marking method for these snails must have, for this technique to give a valid estimate of population size. **(3)**

(c) Explain why Priya waited 48 hours between releasing the first sample and taking the second sample. **(2)**

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(d) Using the Lincoln index formula given, calculate Priya's estimate of the total population size of snails in this section of hedgerow. Show your working. **(3)**

(e) State three assumptions that must be true for the Lincoln index to give a valid, reliable estimate of population size. **(3)**

(f) The following year, a new road is built alongside the hedgerow, splitting the snail population into two smaller, isolated sub-populations with no gene flow between them. Using ideas about genetic drift, explain how this fragmentation could affect the genetic diversity of the snail population at Fenwick Down over subsequent generations. **(4)**

(g) Define the term genetic diversity. **(2)**

(Total for Question 1 is 18 marks)

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2 In humans, red-green colour blindness is caused by a recessive allele (n) located on the X chromosome; the dominant allele (N) gives normal colour vision. A woman who is a known carrier of the n allele has normal colour vision. She has children with a man who has normal colour vision and does not carry the allele.

(a) Using the symbols given, state the genotypes of the mother and the father. **(2)**

(b) Complete a genetic diagram for this cross and use it to determine the probability that a son born to this couple will be colour blind. **(3)**

(c) Explain, in terms of the chromosomal location of the allele, why X-linked recessive conditions such as colour blindness are much more common in males than in females. **(3)**

(d) Explain, using ideas about dominance, why natural selection acting against the colour-blindness phenotype is unlikely to remove the n allele completely from the population's gene pool. **(3)**

(Total for Question 2 is 11 marks)

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3 A population of two-spot ladybirds, Adalia bipunctata, living at Fenwick Down nature reserve shows two colour forms. For the purposes of this question, assume colour is controlled by a single gene with two alleles: M (melanic, black form, dominant) and m (red form, recessive). A survey of 1000 ladybirds in this population found that 360 were the red form.

(a) State the Hardy-Weinberg equations that link allele frequencies (p and q) and genotype frequencies in a population. **(1)**

(b) Calculate the frequency of the m allele (q) and the frequency of the M allele (p) in this population. **(3)**

(c) Using your values of p and q, calculate the number of ladybirds in this population of 1000 expected to be homozygous dominant (MM) and the number expected to be heterozygous (Mm). **(3)**

(d) State two conditions that must be met for a population to be in Hardy-Weinberg equilibrium. **(2)**

(e) A follow-up survey twenty years later found that q had risen to 0.75. Over this period, average local temperatures at Fenwick Down have risen due to climate change. Suggest, using ideas about thermal melanism and natural selection, why the allele frequencies in this population might have changed over this time. **(3)**

(Total for Question 3 is 12 marks)

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4 Genetic drift is the random change in allele frequencies from one generation to the next, due to chance events rather than natural selection.

(a) Define the term genetic drift. **(2)**

(b) Explain why genetic drift tends to have a much greater effect on allele frequencies in small populations than in large populations. **(3)**

(c) A small group of 15 grove snails (Cepaea nemoralis) from a mainland population is accidentally transported to a previously snail-free island, where they establish a new, isolated population. By chance, this founding group includes an unusually high proportion of yellow-shelled (bb) individuals compared with the mainland population. Explain, using this example, what is meant by the founder effect. **(3)**

(d) Suggest one event, other than colonising a new habitat, that could cause a population to undergo a genetic bottleneck, and explain the likely effect of this bottleneck on the genetic diversity of the population. **(3)**

(Total for Question 4 is 11 marks)

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Mark scheme · 1.11 Biology: Genetics, Populations and Evolution: 1-hour Pack

Question 1

(a) mark-release-recapture (Lincoln index method) **B1**

(a) Answer: Mark-release-recapture (Lincoln index)

(b) any one of: the mark must not be toxic/must not harm the snail or affect its health **B1**

(b) any other one of: the mark must not be so visible/conspicuous that it increases the snail's risk of predation (e.g. by making it easier for birds to see) **B1**

(b) any other one of: the mark must not wash off, fade or be shed before the second sample is taken (durable enough for the study period), and must not affect the snail's normal behaviour or movement **B1**

(b) Answer: For example: the marking method must not be toxic or harm the snails; must not increase predation risk by being too visible; and must be durable enough not to wash off before the second sample.

(c) to allow enough time for the marked snails to redistribute themselves randomly/remix thoroughly throughout the whole population **B1**

(c) so that the second sample taken is representative of the whole population, with marked and unmarked individuals equally likely to be caught **B1**

(c) Answer: To allow the marked snails time to disperse and mix randomly back into the whole population, so that the second sample is representative of the population as a whole.

(d) substitutes correctly: N = (84 x 96) / 21 **M1**

(d) 84 x 96 = 8064 **M1**

(d) N = 8064 / 21 = 384 (snails) cao **A1**

(d) Answer: 384 snails

(e) any one of: the population is 'closed', i.e. there is no significant immigration, emigration, birth or death in the population between the two samples **B1**

(e) any other one of: marked individuals mix/redistribute completely at random throughout the population before the second sample is taken **B1**

(e) any other one of: every individual (marked or unmarked) has an equal chance of being caught in the second sample; the marks are not lost and do not affect survival or catchability **B1**

(e) Answer: Any three of: the population is closed (no immigration, emigration, births or deaths during the study); marked individuals mix randomly with the rest of the population before recapture; every individual has an equal chance of being caught; the marks are retained and do not affect survival/catchability.

(f) each of the two new sub-populations is smaller than the original population, so allele frequencies in each are more susceptible to large random change by genetic drift between generations **M1**

(f) by chance, some alleles could be lost completely from one or both sub-populations (reducing genetic diversity within each), while others could increase in frequency (become fixed) purely by chance **M1**

(f) because the two sub-populations are now isolated (no gene flow/interbreeding between them), drift is likely to act independently in each one **M1**

(f) so, over time, the allele frequencies of the two sub-populations are likely to diverge from each other (and from the original population), even without any difference in natural selection between the two sides of the road **M1**

(f) Answer: Both resulting sub-populations are smaller than the original, so genetic drift is likely to have a stronger effect, potentially causing loss of alleles or chance fixation of others. Because the sub-populations are isolated from each other, drift will act independently in each, so their allele frequencies are likely to diverge over subsequent generations, even without any difference in selection.

(g) the number/variety of different alleles (of each gene) present within the gene pool of a population or species **B1**

(g) a greater variety of alleles corresponds to greater genetic diversity **B1**

(g) Answer: Genetic diversity is the number/variety of different alleles present within the gene pool of a population or species.

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Question 2

(a) mother: $X^N X^n$ **B1**

(a) father: $X^N Y$ **B1**

(a) Answer: Mother $X^N X^n$; father $X^N Y$.

(b) correct gametes shown: mother X^N, X^n; father X^N, Y **M1**

(b) correct offspring genotypes shown: $X^N X^N$, $X^N X^n$, $X^N Y$, $X^n Y$, each with probability 1/4 **M1**

(b) probability a son is colour blind = 1/2 oe (of the two possible male genotypes, $X^N Y$ and $X^n Y$, each is equally likely) **A1**

(b) Answer: 1/2 (50%)

(c) males are hemizygous for X-linked genes/have only one X chromosome, paired with a Y chromosome that does not carry this gene locus **M1**

(c) so a male carrying a single copy of the recessive allele always shows the recessive phenotype, as there is no second allele to mask it **M1**

(c) females have two X chromosomes, so a female needs two copies of the recessive allele (homozygous) to show the condition; a female with only one copy is an unaffected carrier **M1**

(c) Answer: Males have only one X chromosome, so a single recessive allele is always expressed; females have two X chromosomes, so the recessive allele can be masked in heterozygotes, making the condition much rarer in females.

(d) natural selection can only act on the phenotype produced (in females, the homozygous recessive genotype), not directly on the allele itself **M1**

(d) in heterozygous females the recessive allele is masked by the dominant allele, so carriers are unaffected and are not selected against **M1**

(d) the allele therefore persists, hidden, in the gene pool within unaffected carriers, maintaining it at low frequency rather than being eliminated **M1**

(d) Answer: Selection cannot act directly on a masked recessive allele; because heterozygous carriers are unaffected, the allele is protected from selection and persists at low frequency in the gene pool rather than being eliminated.

Question 3

(a) $p + q = 1$ and $p^2 + 2pq + q^2 = 1$ **B1**

(a) Answer: $p + q = 1$; $p^2 + 2pq + q^2 = 1$

(b) $q^2 = 360/1000 = 0.36$ **M1**

(b) $q = \sqrt{0.36} = 0.6$ **M1**

(b) $p = 1 - q = 0.4$, both values correct **A1**

(b) Answer: $q = 0.6$; $p = 0.4$

(c) $p^2 \times 1000 = 0.4^2 \times 1000 = 0.16 \times 1000 = 160$ (MM) **M1**

(c) $2pq \times 1000 = 2 \times 0.4 \times 0.6 \times 1000 = 0.48 \times 1000 = 480$ (Mm) **M1**

(c) both values correct (160 and 480) cao **A1**

(c) Answer: MM = 160; Mm = 480

(d) any one of: no mutation occurring **B1**

(d) any other one of: no natural selection (all genotypes have equal survival and reproductive success); mating is random; no migration into or out of the population (no gene flow); the population is very large (so no genetic drift) **B1**

(d) Answer: Any two of: no mutation; no selection; random mating; no migration/gene flow; very large population (no genetic drift).

(e) melanic (M_) ladybirds absorb more solar radiation/heat than red (mm) ladybirds, which is an advantage for warming up in cool conditions but a disadvantage (risk of overheating) in warm conditions **M1**

(e) as local temperatures have risen, melanic ladybirds are now more likely to overheat, reducing their survival/reproductive success relative to red ladybirds **M1**

(e) red (mm) individuals are therefore more likely to survive and reproduce in the warmer climate, increasing the frequency of the m allele (and reducing the frequency of M) in the gene pool over successive generations (directional selection) **M1**

(e) Answer: Rising local temperatures mean melanic ladybirds are now more likely to overheat, so red (mm) ladybirds are more likely to survive and reproduce, increasing the frequency of the m allele over time (directional selection favouring the red form).

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Question 4

(a) a random change in allele frequency in a population's gene pool from one generation to the next **B1**

(a) caused by chance (random) sampling of alleles/gametes during reproduction, rather than by natural selection **B1**

(a) Answer: Genetic drift is a random (chance) change in allele frequencies in a population's gene pool between generations, unrelated to natural selection.

(b) the alleles present in each generation are effectively a random sample of gametes/alleles taken from the previous generation's gene pool **M1**

(b) in a small population this sample is small, so chance/sampling error can cause a relatively large change in allele frequency from one generation to the next **M1**

(b) in a large population the sample is large, so random chance fluctuations tend to average out and allele frequencies change relatively little by chance alone **M1**

(b) Answer: Each generation's alleles are effectively a random sample from the previous gene pool; small samples (small populations) are more strongly affected by chance/sampling error, whereas in large populations random fluctuations tend to average out.

(c) the founder effect is when a new population is established by a small number of individuals from a larger original population **M1**

(c) the founding individuals carry only a small, non-representative sample of the alleles present in the original population's gene pool, purely by chance **M1**

(c) so the new (island) population's allele frequencies differ from the original (mainland) population from the outset, here having a higher-than-average frequency of the b allele/yellow shell phenotype **M1**

(c) Answer: The founder effect occurs when a new population is started by a small number of individuals whose alleles are, by chance, not representative of the original population's gene pool; here the island population has a higher-than-average frequency of the b allele purely by chance, not because of selection.

(d) any valid suggestion, e.g. a disease epidemic, natural disaster (flood, fire) or severe winter that kills most of the population, leaving only a small number of survivors **M1**

(d) the surviving individuals carry only a small, by-chance sample of the alleles that were present in the gene pool before the bottleneck, so many alleles are likely to be lost **M1**

(d) this reduces the overall genetic diversity of the population, and allele frequencies in the survivors' descendants may differ substantially from those in the original (pre-bottleneck) population **M1**

(d) Answer: For example, a disease epidemic could kill most of the population; the small number of survivors carry only a chance sample of the original alleles, reducing genetic diversity and shifting allele frequencies away from those before the bottleneck.

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