

7.3 Genetics, populations, evolution, ecosystems (A-Level Only) - Populations including Hardy-Weinberg – Mark schemes

Q1.

1. Use 1 in 400 to find frequency of homozygous recessive / q^2

OR

1 in 400 gives frequency of 0.0025;

Note - convention has recessive allele as q and dominant allele as p but allow reversal (since outcome is the same) as long as this is consistent throughout

2. Find square root of q^2 / find square root of 0.0025;
3. Use of $p + q = 1.0$ / determine frequency of both alleles / both p and q / find $p = 0.95$ and $q = 0.05$;
4. Use of $2pq$ to find carriers / heterozygotes;

The question requires a description but credit working where correct as alternative since this shows the stages

[3]

Q2.

- (a) Both alleles are expressed / shown (in the phenotype).
Accept: both alleles contribute (to the phenotype)
Neutral: both alleles are dominant
- (b) Only possess one allele / Y chromosome does not carry allele / gene / can't be heterozygous.

1

Accept: only possess one gene (for condition)

Neutral: only 1 X chromosome (unqualified)

1

- (c) 1. $X^G X^B$, $X^B X^B$, $X^G Y$, $X^B Y$;

Accept: equivalent genotypes where the Y chromosome is shown as a dash e.g. X^G- , or is omitted e.g. X^G

Reject: GB, BB, GY, BY as this contravenes the rubric

2. Tortoiseshell female, black female, ginger male, black male;

3. (Ratio) 1:1:1:1

2 and 3. Award one mark for following phenotypes tortoiseshell, black, (black) ginger in any order with ratio of 1:2:1 in any order.

Allow one mark for answers in which mark points 1, 2 and 3 are not awarded but show parents with correct genotypes i.e. $X^G X^B$ and $X^B Y$ or gametes as X^G , X^B and X^B , Y

3. Neutral: percentages and fractions

3. Accept: equivalent ratios e.g. for 1:1:1:1 allow 0.25 : 0.25 : 0.25 : 0.25

3

(d) (i) Correct answer of 0.9 = 2 marks;

Incorrect answer but shows $q^2 = 0.81 =$ one mark.

Note: 0.9% = one mark

2

(ii) Homozygous dominant increases and homozygous recessive decreases.

1

[8]

Q3.

(a) 1. (Expression/appearance/characteristic due to) genetic constitution/genotype/allele(s);

Accept: named characteristic.

Accept: homozygous/ heterozygous/genes/DNA.

Ignore: chromosomes.

2. (Expression/appearance/characteristic due to) environment;

2

(b) (i) 1. (Individual) 2 has colour vision but 4 is colour blind / 10 has colour vision but 12 is colour blind
OR
4/12 is colour blind but parents have colour vision;

2. So 2/10 must be heterozygous/carriers;

Accept: (1), 2 and 4 or 10, (11) and 12.

Accept: any suitable description and explanation equivalent to points 1 and 2.

Reject: (both) parents heterozygous/carriers.

Accept: correct genotypes for 2 and 10.

Accept: for 2 marks, if it was dominant the daughters (8 and 10) of individual 4 would be colour blind.

2

(ii) $X^B X^b$ or $X^b X^B$;

Reject: Bb / bB

Accept: $X^B X^b$ or $X^b X^B$;

Accept: use of other letter than B

e.g. $X^R X^r$, $X^H X^h$.

1

(c) (i) 2 marks for the correct answer of 0.0625 / 6.25% / $\frac{1}{16}$;;
1 mark for incorrect answer but shows 0.03125 / 3.125% / $\frac{1}{32}$;

Accept: 0.063 / 0.06 / 6.3% / 6% for 2 marks.

Accept: incorrect answer but shows / 0.0313 / 0.031 / 0.03 / 3.13% / 3.1% / 3% / $\frac{1}{4} \times \frac{1}{4}$ / 0.25×0.25 for 1 mark.

Note: if probability is calculated as a percentage but no % shown in the answer then deduct one mark. For example 6.25 = one mark, 3.125 = zero.

2

(ii) 2 marks for the correct answer of 48(%);;
1 mark for an incorrect answer but shows understanding that $2pq =$ heterozygous or attempts to calculate $2pq$;

Q4.

(a) 0.32.

Correct answer = 2 marks

Accept 32% for 1 mark max

Incorrect answer but identifying 2pq as heterozygous = 1 mark

2

- (b) 1. Mutation produced *KDR minus* / resistance allele;
2. DDT use provides selection pressure;
3. Mosquitoes with *KDR minus* allele more likely (to survive) to reproduce;
4. Leading to increase in *KDR minus* allele in population.

4

- (c) 1. Neurones remain depolarised;
2. So no action potentials / no impulse transmission.

2

- (d) 1. (Mutation) changes shape of sodium ion channel (protein) / of receptor (protein);
2. DDT no longer complementary / no longer able to bind.

2

[10]

Q5.

(a) All the alleles in a population;

Accept: The number of alleles in a population.

Note: All or number of alleles in a species on its own is not enough on its own.

1

- (b) 1. Occurs in the same habitat / environment / population;
2. Mutation/s cause different flowering times;
3. Reproductive separation / isolation
OR
No gene flow
OR
Gene pools remain separate;
4. Different allele/s passed on / selected
OR
Change in frequency of allele/s
5. Disruptive (natural) selection;
6. Eventually different species cannot (inter)breed to produce fertile offspring;

1. *Accept: are **not** geographically isolated / separated.*

1. *Accept: same place*

3. *Accept: no interbreeding but must be a separate idea from mark point 6 which relates to definition of a species.*

Note: Answers relating only to allopatric speciation = 3 max, mark points 3, 4 and 6.

5 max

Q6.

- (a) 1. (Expression / appearance / characteristic due to) genetic constitution / genotype / allele(s);
 2. (Expression / appearance / characteristic due to) environment;
 1. *Accept: named characteristic.*
 1. *Accept: homozygous / heterozygous / genes / DNA.*
 1. *Ignore: chromosomes.* 2
- (b) Epistasis
OR
 Epistatic (interaction / control);
 Accept: phonetic spellings.
 Ignore: preceding word e.g. (recessive / dominant) epistasis. 1
- (c) **AAbb** – white
aaBB – yellow;
 Both correct for one mark. 1
- (d) 1. AaBb, Aabb, aaBb, aabb;
 2. White, (white), yellow, green;
 3. 2 : 1 : 1;
 Note: If genotypes are incorrect = zero marks.
 1. *Accept: equivalent genotypes e.g. ABab for AaBb.*
 Accept: sequence of phenotypes does not need to mirror genotypes but must be correct.
 3. *Accept: ratios of 2:1:1 or 1:2:1 or 1:1:2 even if sequence of phenotypes do not match if mark points 1 and 2 have been awarded.*
 3. *Accept: alternative ratios in correct proportions e.g. 4:2:2*
 3. *Ignore: percentages / fractions.* 3
- (e) 1. Correct answer of 32% = **2 marks**;
 2. Incorrect answer but shows understanding that $2pq$ = heterozygous / carriers = 1 mark;
 Accept: understanding of $2pq$ by using a calculation involving $2 \times$ two different numbers. 2

Q7.

- (a) 1. Bb / suitable equivalent;
 Reject sex linkage or superscripts
2. Both parents have bar eyes, but have some offspring with round eyes, so parents must be carriers of recessive allele for round eyes; 2
- (b) 3:1;

- (c) Fertilisation is random
OR
 Fusion of gametes is random;

2. Small / not large population / sample;
 3. Selection advantage / disadvantage / lethal alleles;

2 max

- (d) χ^2 / chi squared;

1

- (e) Both alleles expressed in the phenotype (if both are present);

1

- (f) 0.25;

1

- (g) 304;

Award 1 mark for answers which show understanding that 2pq represents heterozygous

2

[10]

Q8.

- (a) (Recessive) allele is always expressed in females / females have one (recessive) allele / males need two recessive alleles / males need to be homozygous recessive / males could have dominant and recessive alleles / be heterozygous / carriers;

*Accept: Y chromosome does not carry a dominant allele.
 Other answers must be in context of allele not chromosome or gene.*

1

- (b) (i) 1. 1, (2) and 5;

Accept: for 1 mark that 1 and 2 have slow (feather production) but produce one offspring with rapid (feather production).

Neutral: any reference to 3 being offspring of 1.

2. 1 must possess / pass on the recessive allele / 1 must be a carrier / heterozygous / if slow (feather production) is recessive all offspring of (1 and 2) would be slow (feather production) / if rapid (feather production) was dominant 1 would have rapid (feather production);

Reject: both parents must be carriers / possess the recessive allele.

Reject: one of the parents (i.e. not specified) must be a carrier / heterozygous.

2

- (ii) 5 = X^fY / X^fY^- / f / f^- / fY ;

7 = X^FX^f **and** X^FX^F (either way round) /

or X^fX^F **and** X^fX^F (either way round) /

or $X^F X^f$, $X^f X^F$ and $X^F X^F$ (in any order);

Note: allow 5 = $X^f Y$, $X^f Y$.

Accept: for both 5 and 7 a different letter than F. However, lower case and capital letter must correspond to that shown in the answer. For example accept 7 = $X^R X^r$ and $X^R X^R$.

2

(iii) $X^F X^f$ and $X^f Y$ or $X^f X^F$ and $X^f Y$

or $X^F X^f$ and $X^f Y$ or $X^f X^F$ and $X^f Y$ /

or Ff and fY /

or Ff and fY /

or Ff and f- /

or Ff and f;

Accept: a different letter than F. However, lower case and capital letter must correspond to that shown in the answer.

Accept: each alternative either way round.

1

(c) Correct answer of 32 (%) = 3 marks;;;

Accept: 0.32 = 2 marks

If incorrect answer, allow following points

1. $p^2 / q^2 = 4\% / 0.04$ / or $p / q = 0.2$;

2. Shows understanding that $2pq$ = heterozygotes / carriers;

Accept: answer provided attempts to calculate $2pq$. This can be shown mathematically i.e. 2 x two different numbers.

3

[9]

Q9.

(a) 1. Allows (valid) comparison;

2. Number / sample size may vary;

2

(b) 1. Increased chance of (severe malaria) with blood group A / decreased chance of (severe malaria) with sickle cell;

Accept: converse for mild malaria i.e. increased chance of mild malaria with sickle cell / decreased chance of mild malaria with blood group A.

Accept: if answer is comparative e.g. greatest risk of severe malaria with blood group A.

2. One mark for one of the following:

almost equal chance with blood group O / slightly greater chance of mild malaria with O / slightly lower chance of severe malaria with O / 2.5 x / 2.48 x / more than twice the chance of severe with blood group A / (almost) 50% / half the chance of severe malaria with sickle cell / twice the chance of mild malaria with sickle cell;

Neutral: answers which only refer to or use ratios.

2

- (c) 1. Individuals with the **Hb^C** (allele) reproduce;
2. Pass on **Hb^C** (allele) which increases in frequency;
3. **Hb^A Hb^A** individuals less likely to survive / reproduce / frequency of **Hb^A** (allele) decreases;

3

[7]

Q10.

- (a) (i) Two marks for correct answer of 4;;

One mark for calculation involving 0.2×0.2 or 0.04;

2

- (ii) 0.2 / the frequency remains the same;

Reject if wrong frequency is quoted

1

- (b) (i) 1. There is a probability of 5% / 0.05;

2. That difference in frequencies / difference in results are due to chance;

Accept 95% probability changes in frequencies not different as a result of chance

2

- (ii) 1. Directional;

2. The recessive allele confers disadvantage / the dominant allele confers advantage / more likely to survive / reproduce;

Assume "it" to refer to the recessive allele

2. References to selection do not gain credit as the term is in the question. Allow reference to phenotype / enzyme functionality (instead of allele) when describing advantage / disadvantage.

2

[7]

Q11.

- (a) Is always expressed / shown (in the phenotype);

Reject 'is always present' without further qualification

1

- (b) $C^B C^B$, $C^B C^P$ and $C^B C^Y$;

All three are required for the mark

Or

$C^B C^B$, $C^P C^B$ and $C^Y C^B$;

Accept $C^B C^B$, $C^B C^P$, $C^B C^Y$,

$C^Y C^B$ and $C^P C^B$

Accept BB, BP and BY or

- (c) 1. Two genotypes (as parents) shown as $C^P C^Y$
*Award **one mark maximum** for candidates who have misread the question and complete a correct genetic cross between a pink snail, $C^P C^Y$ and a yellow snail, $C^Y C^Y$ to give pink and yellow offspring*

Or

Two sets of gametes shown as C^P and C^Y ;

2. Genotypes of offspring shown as $C^P C^Y$, $C^P C^P$ and $C^Y C^Y$;
3. Above genotypes of offspring correctly linked to phenotypes i.e. pink and yellow;
Accept ratio (or equivalent) of 3 pink: 1 yellow for mark point 3

3

- (d) 1. Correct answer of 42% = 3 marks
Answer of 0.42 = 2 marks
*Award **one mark maximum** for answer of 49.9 / 49.98 / 50% or 0.49 / 0.5*
2. $q^2 = 0.49 / 49%$ **OR** $q = 0.7 / 70%$
*Award **one mark maximum** for answer of 40.8 / 41% or 0.41*
3. Shows understanding that $2pq$ = heterozygotes / carriers / shows answer is derived from $2pq$;
Accept: $b^2 = 0.49 / 49%$ or $b = 0.7 / 70%$ for mark point 2

3

[8]

Q12.

- (a) The frequency / proportion of alleles (of a particular gene);

Will stay constant from one generation to the next / over generations / no genetic change over time;

Providing no mutation / no selection / population large / population genetically isolated / mating at random / no migration;

The three principles for marking are:

What feature

What happens to it

Providing . . .

Accept: genotype / explanation of genotype

Accept: alternative wording, e.g. there is no gene flow / genetic drift for genetically isolated.

3

- (b) White / deaf cats unlikely to survive / selected against;

Will not pass on allele (for deafness / white fur) (to next generation) / will reduce frequency of allele;

Accept: alternative wording, e.g. have a disadvantageous

phenotype
Neutral: will not breed

2

- (c) In Paris / London frequencies (of these alleles) add up to more than 1;
Can be shown by correct figures to be more than 1
e.g. $0.71 + 0.78 = 1.49$
Accept: more than 100%

1

- (d) Two marks for correct answer of 44(.22);;

One mark for incorrect answer in which p / frequency of H determined as 0.67 and q / frequency of h as 0.33

OR

Answer given as 0.44(22);

2

[8]

Q13.

- (a) (i) Only expressed / shown (in the phenotype) when homozygous / two (alleles) are present / when no dominant allele / is not expressed when heterozygous;

1

- (ii) Both alleles are expressed / shown (in the phenotype);
Allow both alleles contribute (to the phenotype).

1

- (b) (i) Evidence (not a mark)

3 and 4 / two Rhesus positives produce Rhesus negative child / children / 7 / 9;

Explanation (not a mark)

Both Rhesus positives / 3 and 4 carry recessive (allele) / are heterozygous / if Rhesus positive was recessive, all children (of 3 and 4) would be Rhesus positive / recessive;

Do not negate mark if candidate refers to gene rather than allele.

Answers including correct and incorrect evidence = zero marks evidence and explanation.

2

- (ii) Evidence (not a mark)

3 would not be / is Rhesus positive / would be Rhesus negative;

Explanation (not a mark)

3 would receive Rhesus negative (allele) on X (chromosome) from mother / 3 could not receive Rhesus positive (allele) from mother / 3 would not receive Rhesus positive (allele) / X (chromosome) from father / 1 / 3 will receive Y (chromosome) from father / 1;

OR

Evidence (not a mark)

9 would be Rhesus positive / would not be / is Rhesus negative / 8 and 9 / all daughters of 3 and 4 would be Rhesus positive;

Explanation (not a mark)

As 9 would receive X chromosome / dominant allele from father / 3;

Do not negate mark if candidate refers to gene rather than allele.

One mark for evidence and one mark for explanation linked to this evidence.

Any reference to allele being on Y chromosome negates mark for explanation.

2

- (c) Correct answer of 48(%) = 3 marks;;;

$$q^2 / p^2 = 16\% / 0.16 / p / q = 0.4;$$

Shows that $2pq$ = heterozygotes / carriers;

Final answer of 0.48 = 2 marks

Allow mark for identifying heterozygotes if candidate multiplies incorrect p and q values by 2.

3

[9]

Q14.

(a) Parents genotypes Aabb aaBb ;

Gametes formed Ab ab aB ab ;

if parental genotypes wrong allow correctly derived gametes only

Offspring genotypes AaBb Aabb aaBb aabb

and

Offspring phenotypes 1 Walnut ; 1 Pea : 1 Rose : 1 single ;

*Just **one** mark for offspring genotypes **and** phenotypes
If parents not diploid, no marks gained*

3

- (b) Correct answer 0.6, however derived, scores 2 marks

Wrong answer, but evidence of correct working

(e.g. $p^2 / q^2 = 0.36$) scores 1 mark

2

[5]

Q15.

- (a) 1. frequent use of antibiotic creates selection pressure / antibiotic kills bacteria;
2. bacteria with mutation / resistance have (selective) advantage over others / described;
3. (survive to) reproduce more than other types pass on advantageous allele / mutated allele in greater numbers;
4. frequency of (advantageous) allele increases in subsequent generations;

(penalise use of "gene" instead of allele once only)

5. frequency of resistant types increases in subsequent generations;

5

- (b) correct answer = 0.18;
And three marks for three of:
 $p + q = 1$ and $p^2 + 2pq + q^2 = 1$;
 $0.01 = q^2$;
 $q = 0.1$;
 $p = 0.9$
frequency of heterozygotes = $2pq = 2 \times 0.1 \times 0.9 / 2 \times$ candidates
 $p \times$ candidates q ;

4 max

[9]

Q16.

- (a) Mutation / (spontaneous) change in a gene / change in DNA;

1

- (b) (i) Correct answer: 0 / 6;; 2 marks
OR

Use of $56 \text{ and } \frac{176}{2}$ or $88 / \underline{56 \times 2}$ or $112 \text{ and } 176$; 1 mark

max 2

- (ii) 64;

1

- (c) (i) Correct answer = 42%;;; (only if $q^2 = 0.49$) 3 marks
OR 0.42;;; 2 marks
OR
 $p + q = 1 / p^2 + 2pq + q^2 = 1 / p = 1 - 0.7 / q^2 = 0.49 / q = 0.7$;

Answer = $2pq$ / use of appropriate numbers; 2 marks

max 3

- (ii) 1. Parental genotypes correct: both **W^RW^S**
(ACCEPT 'RS')

AND

W^S (ACCEPT 'S') / gamete from each parent;

2. **W^SW^S** (ACCEPT 'SS') / offspring formed and identified as susceptible;

If different symbols:

– defined : max 2 marks

– not defined max 1 mark (= pt.2)

2

- (iii) 1. Description: decrease + rate of decrease slows with time;

Explanation: Any **three** from:

2. Resistant rats / rats with **W^R** allele survive
OR susceptible / **W^SW^S** rats killed

3. (more likely) to pass on **W^R** allele to offspring / less likely to pass on **W^S** / higher proportion of next generation has **W^R** allele / lower proportion has **W^S**;

4. Chance of mating with W^sW^s is reduced / W^sW^s becomes rare;

5. Rate of selection against W^s slows because W^s allele is in heterozygotes;

max 4

- (iv) No selective advantage / All genotypes equally fertile;
Large population;
Random mating; (IGNORE 'random fertilisation')
No mutation;
No emigration / immigration;

max 2

[15]

Q17.

- (a) Gg / suitable equivalent;
Grey : black about 3: 1;

[Note: Can be in table / diagram]

2

- (b) To determine the probability;
[Accept: Likelihood]
Of the results being due to chance;
[Accept: Coincidence]

2

- (c) (i) both alleles will be expressed (in the phenotype);

1

- (ii) 0.25 / 25%; = 2 marks
 $C^N = 250 / 1000$; = 1 mark

2

- (iii) $P^2 = (0.25)^2 / 0.0625$ / square of calculated figure for C^N ; = 2 marks
 $p^2 + 2pq + q^2 = 1.0$; = 1 mark
= 31.25 / 31;

[Accept: Derived from either p^2 or q^2]

3

[10]