AQA A-LEVEL · 7402

# BIOLOGY



## MARK SCHEME

### 3.7.2 POPULATIONS AND HARDY-WEINBERG

| SCORE | PERCENTAGE |
| --- | --- |
| /172 | % |

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## Q1.

(a) 1. No (functional) cones
**OR**
Only rods;

2. Cones are connected to a single neurone
**OR**
Several rods connected to a single neurone;

*Accept correct reference to retinal convergence*

*Accept 'bipolar/nerve cell' for neurone*

*Accept 'many' 2 or more for 'several'*

3. (Cones) Separate (sets of) impulses to brain
**OR**
(Rods) Single (set of) impulse/s to brain;

*Accept 'optic nerve' for brain*

*Reject 'signals', 'messages' for 'impulses'*

*Accept 'action potential'*

**3**

(b) 1. Correct answer in range 42 – 44% = 2 marks;;

2. Incorrect answer but shows that understanding that 2pq = heterozygous/carriers = 1 mark;

*Accept 1 – ($p^2$ + $q^2$)*

*Accept understanding of 2pq by using calculation involving 2 × two different numbers*

**2**

(c) 1. (Gene/allele) is on the X chromosome;

2. Females require two alleles/females can be heterozygous/carriers **and** males require one allele;

*Reference to allele is essential but only required once*

*Reference to females **and** males required*

*Reject dominant allele*

**2**

(d) 1. Green sensitive pigment/cones non-functional
**OR**
Cones that detect green light non-functional;

2. Three different types of pigment/cone;

3. Other/different colours ('seen') due to stimulation of more than one cone/pigment;

*1, 2 and 3. Reject reference to 'green cones'/ 'blue cones / 'red cones' but once only*

*1, 2 and 3. Reject reference to 'green pigment'/ 'blue pigment/ 'red pigment but once only and only if 'green cones' etc, (see above) has not been rejected.*

**3**

(e) 1. (iPS cells) divide;

2. (iPS cells) develop/differentiate into (green sensitive) cones;

*Accept 'produce'/'specialise' 'turn in to' / 'genes switched on' / 'turned on' for 'develop' but ignore 'grow'*

*Reject develop into 'green cones'/blue' cones'/'red cones'*

*Ignore develop/differentiate into (blue/red sensitive) cones;*

*Reject reference to develop in to 'green pigment'/ 'blue pigment/ 'red pigment*

**2**

(f) 1. (Use of iPS cells) long-term;

*Accept 'gene therapy short-term' or 'only two years'*

*Accept 'permanent'*

2. (Use of iPS cells) less chance of rejection/immune response;

3. (Use of iPS cells) single treatment;

*Accept 'gene therapy 'regular/frequent treatment"*

4. Harm/side effects from using viruses (in gene therapy);

**3 max**

**[15]**

## Q2.

(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 × two different numbers.*

**2**

**[9]**

## Q3.

(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**

**[6]**

## Q4.

(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;

**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) $\chi^2$ / 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]**

## Q5.

(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]**

## Q6.

(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) $X^BX^b$ **or** $X^bX^B$;

*Reject: Bb / bB*

*Accept: XBXb or XbXB;*

*Accept: use of other letter than B*

*e.g.* $X^RX^r$, $X^HX^h$.

**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% / ¼ × ¼ / 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;

*1 mark maximum for the answer of 0.48.*

**2**

**[9]**

## Q7.

(a) Both alleles are expressed / shown (in the phenotype).

*Accept: both alleles contribute (to the phenotype)*

*Neutral: both alleles are dominant*

**1**

(b) Only possess one allele / Y chromosome does not carry allele / gene / can't be heterozygous.

*Accept: only possess one gene (for condition)*

*Neutral: only 1 X chromosome (unqualified)*

**1**

(c) 1. $X^GX^B$, $X^BX^B$, $X^GY$, $X^BY$;

*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 <u>with</u> 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. $X^GX^B$ and $X^BY$ **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]**

## 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 <u>allele</u> / 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** $X^FX^f$, $X^fX^F$ **and** $X^FX^F$(in any order);

*Note: allow 5 = $X^fY$, $X^fY$.*

*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 = $X^RX^r$ and $X^RX^R$.*

**2**

(iii) $X^FX^f$ **and** $X^fY$ **or** $X^fX^F$ **and** $X^fY$

**or** $X^FX^f$ **and** $X^fY^-$ or $X^fX^F$ **and** $X^fY^-$ /

**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.

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]**

## Q11.

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

*Reject 'is always present' without further qualification*

**1**

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

*All three are required for the mark*

Or

$C^BC^B$, $C^PC^B$ and $C^YC^B$;

*Accept $C^BC^B$, $C^BC^P$, $C^BC^Y$, $C^YC^B$ and $C^PC^B$*

*Accept BB, BP and BY or BB, BP, BY, YB and PB*

**1**

(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, $C^PC^Y$ and a yellow snail, $C^YC^Y$ 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) (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]**

## 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) 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]**

## Q15.

(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]**

## Q16.

(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 × candidates
p × candidates q;

**4 max**

**[9]**

## Q17.

(a) Population – organisms of one species in an ecosystem / habitat / area;
Community – organisms of all species / all populations in an ecosystem / habitat / area;

**2**

(b) (i) No immigration / migration (Ignore references to emigration);
No reproduction *(Ignore references to death)*;
Idea of mixing;
Marking does not influence behaviour / increase vulnerability to predation;
Sample / population large enough;

**max 2**

(ii) $\frac{96 \times 77}{11}$ ; 672;
*Correct answer (however derived) scores 2 marks*
*Incorrect answer with evidence of correct method scores 1 mark.*

**2**

(c) Principle of randomly placed quadrats and method of producing random quadrats; *(Reject 'throwing')*
Valid method of obtaining no. dandelions in given area (mean per quadrat / total no. in many quadrats);
Multiply to give estimate for total field area;

**3**

(d) (i) Niche of A – 1;
Niche of B – 3;
Too small for B / too hot for A – 4;
Too large for A / too cold for B – 2;
*All four correct = 2 marks; any 2 correct = 1 mark*

**2**

(ii) Original population living in one area / 2 species evolved in the area;
Idea of genetic variability;
Concept of reproductive isolation;
Possible mechanism;
Gene pools become increasingly different;
Until interbreeding does not produce fertile offspring;

**max 4**

**[15]**

## Q18.

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

**1**

(b) (i) Correct answer: 0 / 6;; 2 marks
OR
Use of 56 <u>and</u> $\frac{176}{2}$ or 88 / <u>56 × 2</u> or 112 <u>and</u> 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 $\mathbf{W^RW^S}$

*(ACCEPT 'RS')*

AND

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

2. $\mathbf{W^SW^S}$ (*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 $\mathbf{W^R}$ allele survive
OR susceptible / $\mathbf{W^SW^S}$ rats killed

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

4. Chance of mating with $\mathbf{W^SW^S}$ is reduced / $\mathbf{W^SW^S}$ becomes rare;

5. Rate of selection against $\mathbf{W^S}$ slows because $\mathbf{W^S}$ 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]**

## Q19.

(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]**

## Q1.

(a) Despite only 8% of students obtaining maximum marks, this question proved to be an effective discriminator. 90% of students obtained at least one mark, often for stating that only rods or no (functional) cones are present. Slightly more than half of these students gained a second mark, usually for correctly describing the connections of rods and/or cones to a single neurone. However, poor terminology prevented some of these students from obtaining maximum marks. Some students used terms such as 'messages' and 'signals' rather than impulses. Even when students did refer to impulses, they often omitted reference to the optic nerve or brain, resulting in incomplete explanations.

(b) The majority of students (70%) gained at least one mark for recognising that 2pq represented the heterozygous genotype. 39% of students successfully completed the calculation to obtain both marks. Many students scoring zero simply provided the Hardy-Weinberg equation with no annotation. Students obtaining one mark often thought that 0.1 was q rather than $q^2$, resulting in $2pq = 2 \times 0.9 \times 0.1$. This mark was not awarded when students (commonly) suggested that pq represented the heterozygous genotype.

(c) Almost 70% of students obtained at least one mark for this question, with both of the marking points being awarded in similar numbers. Students who scored zero often correctly stated that red-green colour blindness is sex-linked but did not mention the X chromosome in their explanation. These students often realised that males only required one recessive allele to express the condition, but did not explain that females require two alleles. Some students did refer to males and females, but omitted the term allele. Sex-linked alleles were sometimes said to be on an unspecified sex chromosome, on both X and Y, or just on the Y chromosome preventing females being affected. Females were sometimes thought to be XY and males XX.

(d) The answers to this question were extremely disappointing. Less than 1% of students gained maximum marks and only about a third of students obtained any of the three marks available. The trichromatic theory is a new topic on the specification and many students displayed a poor understanding of how different colours are distinguished. Many students incorrectly referred to green/red/blue cones/pigments rather than green-/red-/blue-'sensitive' cones/pigments. Consequently, fewer than 5% gained a second mark. Although better students did appreciate that 'other colours' were mixtures of different wavelengths of light, they failed to explain that 'other colours' resulted in the stimulation of more than one type of cone at the same time. Students who did gain a mark invariably referred to non-functional green-sensitive pigments or cones. However, this point was often negated as many students suggested that red-sensitive cones were also non-functional or absent, or that all cones were non-functional or absent. It was not uncommon to read answers that provided details on the breakdown of pigments which were not only beyond the requirements of the specification, but were also often inaccurate.

(e) Only 3% of students gained both marks in this question as it was a rarity to see responses that mentioned that iPS cells would divide. Although most students did understand that iPS cells would differentiate, many suggested they formed the 'green-sensitive pigment' rather than cone cells. A significant proportion of students referred to the iPS cells developing into green/red/blue cones, again failing to gain the mark for omitting the term 'sensitive'. There were also answers which referred to iPS 'growing' into cone cells with no indication of development or differentiation.

Some students suggested that rod cells were produced or confused this method with gene therapy and referred to genes being injected into stem cells. Consequently, 48% of students scored zero on this question.

(f) Most students (70%) obtained at least one mark for this question. Usually, this mark was awarded for stating that iPS is a long-term treatment or that gene therapy would only last two years. An additional mark was available if students realised that iPS would be a single treatment or that gene therapy would require regular treatments. However, this idea was rarely conveyed in students' answers. Far more students appreciated that one advantage of iPS was that rejection or an immune response was less likely. Although many students mentioned that gene therapy could cause 'harm' or 'side effects', this was often in the context of the 'injection' rather than due to using viruses. Consequently, only 8% of students obtained maximum marks and only 33% gained two or more marks. Many students also mentioned ethical issues, cost and/or the idea that results on monkeys were not necessarily transferable to humans. However, these constraints could also have applied to the use of iPS cells as a treatment.

## Q2.

(a) The definition of phenotype was generally well known with over 90% of students obtaining at least one mark. Students scoring zero usually provided a GCSE standard answer in terms of the phenotype representing an observable feature. Responses awarded a single mark usually described the genetic influence on the phenotype. Better answers also included the effect of the environment, to gain both marks.

(b) Almost 60% of students correctly named the type of gene interaction shown in the diagram as epistasis. Common incorrect responses included dihybrid and codominance.

(c) Almost 85% of students correctly identified the genotypes provided as phenotypically white and yellow respectively.

(d) Over 55% of students obtained all three marks in this question which proved to be a very effective discriminator. However, it was surprising to note that over 25% of students scored zero marks on what was considered to be a relatively straightforward genetic cross. It was difficult to give any credit to students who started their answer by providing incorrect genotypes of the offspring. A number of students were unable to determine the correct phenotypes despite having provided the correct genotypes. A few gave the correct genotypes and phenotypes, writing white, white, yellow, green but then gave a 1:1:1:1 ratio. The ratio was also sometimes given as 9:3:3:1 even though the genotypes and phenotypes were correct.

(e) Approximately one in six students obtained both marks for this question. This low success rate was not due to a lack of mathematical ability, but due to misinterpreting the information provided. Most students mistakenly thought that 36% represented the homozygous recessive genotype and obtained the incorrect answer of 48%. These students often obtained one mark as they showed that 2pq represented the frequency of the heterozygous genotype. Students who realised that that 64% represented the homozygous recessive genotype generally obtained both marks, although occasionally an answer of 0.32 was given which was awarded one mark.

## Q3.

(a) Less than 50% of students gained this mark. The most common errors included:

referring to genes instead of alleles, describing frequency of an allele, or mentioning species without any reference to a population or area.

(b) Interestingly, this question asked about a new topic on the specification, sympatric speciation, and proved to be the most effective discriminator on the exam paper. Less than 2% of students obtained all five marks, and almost 25% scored zero. The main problem was that many students provided a description of allopatric speciation rather than sympatric speciation, despite the clear direction provided in the question stem. These answers were limited to a maximum of three marks, but often only gained a single mark. When students did describe sympatric speciation, relatively few mentioned that it occurs in the same area / place / population, and fewer still referred to disruptive selection, although maximum marks could still be achieved without including this latter idea. The most frequently credited mark points related to reproductive isolation, described in a variety of ways, and for providing a definition of a species, i.e. the inability to breed to produce fertile offspring. Better students did appreciate that a mutation would have led to a difference in flowering times, and that different alleles would be passed on in the reproductively isolated sub-populations. Unfortunately, many students referred to genes rather than alleles and thus failed to obtain this latter mark point. For some unknown reason, a significant minority of students thought that palms, having been separated by flowering time, go on to reproduce asexually. A few students misinterpreted the question entirely and provided a description of succession.

## Q6.

(a) This was well answered with almost 60% of students obtaining both marks and less than 5% scoring zero. Students who only obtained one mark often referred to the influence of the genotype/genes/alleles on the phenotype but omitted any reference to the effect of the environment.

(b) (i) Four out of every five students obtained at least one mark on this question usually for correctly identifying individuals 2 and 4 or 10 and 12. However, many of these students incorrectly stated that both parents ie 1 and 2 or 10 and 11 would be heterozygous, having failed to note that the condition is sex-linked. However, almost 40% of students did realise this and gained both marks by indicating that only the female parent would be heterozygous.

(ii) Almost 80% of students correctly gave the genotype of individual B as $X^BX^b$.

(c) (i) 40% of students correctly calculated the probability of producing a colour blind, non-tongue-rolling son as 0.0625 (6.25% was accepted). Approximately 5% of students gained one mark for the answer of 0.03125 (or 3.1%), achieved by multiplying the correct answer by 0.5. A common incorrect answer was 0.25 (or 25%) due to students only working out the probability of one outcome.

(ii) This caused few problems with almost 70% of students obtaining both marks and 90% at least one mark. Students gaining a single mark often provided an incorrect answer but provided evidence of attempting to calculate 2pq. A small minority of students were awarded a single mark for providing their answer as a frequency, ie 0.48.

## Q7.

(a) Over ninety percent of students provided a suitable definition of codominance although the quality of expression varied considerably.

(b) Again this was a well answered question, with over eighty percent of students

obtaining the mark. Correct responses usually referred to males possessing only one allele (of the gene) for fur colour or that males could not be heterozygous for this condition. Explanations that focused on the Y chromosome often failed to gain the mark. A few answers only explained that males were XY and females XX without any reference to the alleles (of the gene) for fur colour.

(c) Almost ninety percent of students gained at least two out of the three marks for this question by correctly carrying out the genetic cross and providing the correct genotypes and phenotypes of the offspring. However, just over a third of these students included the sex of the cats when determining the ratio of the phenotypes to obtain maximum marks. Some students did not provide ratios but gave percentages or fractions. A minority of students did not seem to understand the terms genotype and phenotype. Very few students scored zero.

(d) (i) Surprisingly, fewer than thirty percent of students correctly calculated the frequency of the recessive allele as 0.9. A number of students provided an answer of 90%, without always showing the working, to gain at least one mark. A common error was to use 19% as the frequency of the dominant allele, p and then subtract this from 100 to give 0.81 as the frequency of the recessive allele, q. Another incorrect calculation used 0.19 as $q^2$ and then q as 0.44, subtracting this value from 1 to give an answer of 0.56.

(ii) This was not well answered with less than one in four students obtaining the mark. Many students referred to the homozygous dominant genotype increasing in frequency without any mention of the homozygous recessive genotype. Other incorrect responses suggested that both homozygous genotypes would increase, discussed only allele frequencies, or confused allele and genotype. Some answers compared frequency of homozygous with heterozygous genotypes or referred to the allele for polydactyly becoming ‘more dominant’ or ‘recessive’.

## Q8.

(a) Almost two thirds of students gained this mark, most often for stating that females only needed to have one copy of the recessive allele for it to be expressed. Other students referred to males requiring two recessive alleles for the recessive phenotype to be expressed. Unfortunately, some students did not use the correct terminology, with gene or chromosome being used instead of allele. Sometimes, the information that in birds the female is XY and the male XX was forgotten, so the answer was the wrong way round.

(b) (i) The majority of students did use the correct evidence from the figure, ie 1, (2) and 5, and gained one mark. However, only the better answers explained that parent 1 was heterozygous or a carrier; many referred incorrectly to both parents 1 and 2 or to one of the parents being heterozygous without specifying which. Individual 3 was also frequently included as a child of 1 and 2.

(ii) Two thirds of students gained both marks for this question. Students who scored one mark usually did so for correctly identifying the possible genotypes of chicken 7. Common errors were to provide autosomal genotypes or to show an allele on the Y chromosome of chicken 5.

(iii) Just over 50% of students gave the correct genotypes of the parents. As with b(ii), a number of students provided autosomal genotypes.

(c) Two thirds of students obtained all three marks. Few students were awarded two marks but a significant percentage scored one, often for identifying the

heterozygous genotype as 2pq. One common error was that p / q, rather than $p^2$ / $q^2$, was often identified as 0.04.

## Q9.

(a) The vast majority of students gained one mark for explaining that using ratios enabled a (valid) comparison to be made. However, only half of these students then explained that ratios would not be affected by different sample sizes. Incorrect responses referred to ratios being easier to work with, or that they would allow statistical tests to be performed.

(b) Most students had no difficulty linking red blood phenotypes to the chance of developing severe malaria rather than mild malaria for one mark. However, only half of these students then gave a correct numerical comparison to gain a second mark.

(c) The majority of students understood why the frequency of the $Hb^C$ allele was higher in malarial areas but only the better responses explained it in a way that enabled them to gain all three marks. Most answers only referred to the $Hb^C$ allele. Most students appreciated that individuals with the $Hb^C$ allele were more likely to survive malaria and to reproduce. However, students did not always fully explain that the $Hb^C$ allele would be passed on to future generations, thus increasing the frequency of this allele. Very few students appreciated that selection would operate against $Hb^AHb^A$ individuals.

## Q10.

Students frequently struggle with calculations using the Hardy-Weinberg equation. This question allowed those less confident with calculations to describe how the calculation would be carried out. Many students were able to do this, usually achieving full credit.

## Q11.

(a) The vast majority of students gained the mark for explaining what is meant by a dominant allele. Unfortunately some students suggested that it is ‘expressed in a gene’.

(b) Most students were able to provide all the correct genotypes which would result in a brown-shelled snail.

(c) This also proved to be a high-scoring question with many students gaining all three marks. Students gaining two marks often failed to link correctly the genotypes of the offspring to their phenotypes. A small minority of students misread the question and completed a genetic cross between a yellow snail and a pink snail. If this was done correctly, one mark was awarded. Very few students scored zero.

(d) This proved far more demanding. The most common error was to have $q^2 = 0.51$ rather 0.49 as students assumed that 51% represented the homozygous recessive snails, rather than the combination of the homozygous dominant and heterozygous snails. Another incorrect method involved taking 0.51 as the frequency of the dominant allele (i.e. p) and 0.49 as the frequency of the recessive allele (q). These errors often resulted in only a single mark being awarded.

## Q12.

(a) About 50% of candidates gained both of the marks available for part (i), but of the rest there was considerable evidence of confusion. Nearly all wrote out the equation $p^2 + 2pq + q^2 = 1$, when finding $0.2^2$ was all that was needed in this case. Many also

did not know whether the allele frequency of 0.2 was the value for $q$ or for $q^2$. Most candidates responded correctly to part (ii), but a number continued to provide irrelevant detail about the conditions required for the Hardy-Weinberg principle to be valid.

(b) Few candidates gained both the marks available for part (i), as they did not show the necessary understanding of the difference between chance and probability. The answer given by many to part (ii), stabilising selection, suggested that they had not read the stem of this part of the question carefully enough. Those candidates who missed marks in their explanations usually did so because they wrote generally about selection rather than explaining the effect of this allele on survival and reproductive success and the consequent decrease in its frequency.

## Q13.

(a) (i) The majority of candidates gained the mark for explaining what is meant by a recessive allele. Unfortunately, some candidates simply stated that it is 'not expressed in the phenotype'.

(ii) Again, this was well answered with most candidates expressing themselves clearly with appropriate scientific terminology. Incorrect responses suggested that codominance indicates different genes.

(b) (i) Surprisingly, only one in five candidates gained any marks for this question. Most candidates suggested that parents 1 and 2 having produced a rhesus positive child was evidence that the allele for Rhesus positive is dominant. It should also be noted that many candidates suggested that 4 was the child of 1 and 2, indicating a lack of understanding of family trees.

(ii) Again, candidates struggled to gain any marks. A significant number simply stated that as males and females have the condition it can't be on the X chromosome. A similar number of candidates suggested that the gene was carried on the Y chromosome. Candidates who did gain credit often referred to 3 being Rhesus positive as evidence that the gene is not on the X chromosome. Fewer candidates cited 9 being Rhesus negative as evidence. Very few candidates were able to provide a suitable explanation to gain both marks.

(c) Almost half the candidates gained all three marks. The most common error was to assume that q=0.16/16% rather than q2. However, most of these candidates still gained a mark for indicating that 2pq represented heterozygotes. A significant number of candidates gained two marks for the answer 0.48.

## Q14.

(a) Although most candidates knew that the Hardy-Weinberg principle relates to the frequency of alleles, few explained that the frequency should remain constant from one generation to the next.

(b) As in question 2, candidates who performed better could apply their knowledge and demonstrate genuine understanding. Thus, they were able to explain that as white cats were deaf they would be at a selective disadvantage. As such, they would be unlikely to survive and pass on their alleles to the next generation.

(c) Although many candidates were aware that p + q = 1, they could not explain that a combined frequency of greater than 1 would indicate that the alleles were not of the same gene.

(d) Many candidates failed to complete the calculation successfully, either because they assumed the information in the table referred to genotype rather than allele frequency or neglected to produce the answer as a percentage, as required.

## Q15.

(a) A majority of candidates were able to score all three marks available for this section. Nearly all candidates derived correct parental genotypes, although a few made a fundamental error in giving what was, effectively, a haploid genotype (AB, rather than AaBb). Some then lost their way because they wrote down four gametes for each parent - two of each genotype. They then produced a 4 x 4 Punnett square. Because previous experience of this had always produced a 9:3:3:1 ratio, they assumed it would here also.

(b) Again, a majority produced the correct answer of a frequency of 0.6 for the **a** allele. Some candidates, however, correctly identified the combined frequencies of the rose and single-combed chickens as $q^2$, with a frequency of 0.36. They then obtained q by taking the square root of this to obtain 0.6. Perhaps because they have often been required to find the frequency of the heterozygote, they did this next and offered 0.48 as their answer. This is another instance where not reading the question carefully may have cost marks.

## Q16.

(a) Although most candidates recognised this as a question about natural selection, many did not gain marks by failing to identify the nature of the selection pressure (use of the antibiotic) or to explain how resistance would become widespread. Some candidates answered in a completely different way and, effectively, answered part (ii) by describing the nature of mutations and how they could affect the ability of an antibiotic to bind with receptors in the bacterial membrane. This said, however, there were quite a number of very good responses scoring full marks or nearly full marks.

(b) Many candidates, of all abilities, were familiar with the Hardy-Weinberg equations and were able to apply them to the data given to calculate the frequency of the heterozygotes (0.18/18%). The most common error was to assume that the frequency of those homozygous recessive (0.01) in the population is represented by q, rather than by q2. Some then used this wrong value to find p and, from that, 2pq and so were able to gain some credit for showing elements of a correct method, even though they arrived at an incorrect answer.

## Q17.

(a) Most candidates were able to explain the meanings of the two terms correctly, but again, a lack of precision cost marks for some candidates. It is insufficient to describe a population as ‘a group of organisms of the same species’ or ‘all the organisms of a species’. It is, similarly, insufficient to describe a community as ‘ a group of populations’.

(b) (i) Most candidates were able to quote suitable conditions necessary to ensure the validity of the mark-release-recapture technique. They were also usually able to calculate the size of the woodlice population.

(ii) Most candidates were able to quote suitable conditions necessary to ensure the validity of the mark-release-recapture technique. They were also usually able to calculate the size of the woodlice population.

(c) Most candidates knew that the quadrats must be placed randomly and many were

able to describe a method of achieving this. They usually realised that the number of dandelion plants per quadrat must be counted (although some suggested estimating percentage cover, which is *not* suitable in this instance) and the count repeated. However, rather fewer went on to say that one could then calculate the mean number per quadrat and, from this, estimate the number in the field by multiplying by the ratio of area of field to area of quadrat.

(d) (i) A majority of candidates was able to interpret the unfamiliar diagram to establish both the niches of the two species and the areas from which they were excluded. Some established the 'exclusion areas' correctly but not the basic niches.

(ii) Some candidates confused sympatric and allopatric speciation, but the majority answered along the right lines. Most were able to establish the principle of reproductive isolation and could usually suggest a suitable mechanism that would bring this about. However, candidates frequently confused species and populations in their answers, which led to confusion about when the processes they were describing had occurred. For instance, many wrote about 'gene pools of the two *species* becoming more and more different until they could no longer interbreed' when what they should have been describing was gene pools of the *populations*. However, a good number established the principle that the two would be distinct species when they could no longer interbreed to produce fertile (rather than viable) offspring.

## Q18.

(a) Most candidates knew that a mutation could give rise to warfarin-resistant rats but some ignored the information that this was an *isolated* population and suggested that other resistant rats might enter it.

(b) The instructions in part (i) of this section and in part (c)(i) were different: here candidates had to calculate the *actual* frequency of an allele whereas, in (c)(i), the instruction was to use the Hardy-Weinberg equation to *estimate* a percentage. Many candidates attempted, inappropriately, to apply the Hardy-Weinberg equation to the captive population of rats which was in fact far removed from Hardy-Weinberg equilibrium. Candidates who understood the situation made use of the figures 176 and 56 in proportion to the given size of the population. In part (ii), many candidates did make use of the point given in the stem of question that rats with the genotype $W^RW^R$ were susceptible to warfarin in the absence of a large amount of vitamin K in their diets, but often forgot to include the homozygous susceptible rats in their calculation.

(c) In (i), while most candidates knew the Hardy-Weinberg equation, and a good proportion of these realised that the answer they sought related to 2pq, only a minority could follow through the necessary numerical calculations to arrive at the correct value. A common major error was, given that 51% of the population of wild rats were resistant to warfarin, then $p^2$ was thought to be 0.51. Starting with $q^2$ = 0.49 led to the correct estimate of 42% of this population being heterozygous. A significant minority of candidates ignored the given value of 51% and used figures from the captive population of rats which were the subject of part (b).

The genetic diagram in part (ii) should have been a simple cross between two heterozygous rats which would have produced some susceptible offspring. A surprising number of candidates left this section blank. Many others were rather casual in their presentation of the genetic diagram and omitted essential details such as parental genotypes, if using the Punnett square method, or gametes, if using the line diagram method. Many also failed to point out which of the offspring

genotypes they had derived represented susceptible rats.

In (iii), many candidates did not give a full description of the pattern shown in the graph – not only was the frequency of the $W^S$ allele decreasing but the rate of decrease slowed with time. Many wrote about selection operating against rats 'with the $W^S$ allele', but this would only happen if the rats were homozygous. Most had the idea that those with the $W^R$ allele would survive so that the $W^R$ allele was more likely to be passed on to succeeding generations. Better candidates realised that selection would not operate against the $W^S$ allele if it were present in heterozygous rats, but only very few pointed out that the chances of mating with a $W^SW^S$ rat would be reduced. Finally, in part (iv), most candidates were able to give two assumptions necessary for the use of the Hardy-Weinberg equation, but some included an unreasonable assumption such as 'there should be no births or deaths' – perhaps these candidates were confusing the issue with the mark-release-recapture population estimate.

## Q19.

Whilst it was pleasing to see a few excellent candidates achieving full marks with this question, it was more common to see low-scoring answers. Most candidates still struggle with numerical and statistical treatment of data and its application to biological situations.

(a) Most candidates gave an appropriate genotype and recognised the approximate 3:1 ratio in the offspring as the evidence for such. A number incorrectly used different letters for the dominant and recessive alleles or assumed the characteristic to be sex-linked.

(b) Statistical tests are used to test the *probability* of results being due to *chance*. Whilst the concept of chance was well demonstrated, the probability of this being the case was seldom identified.

(c) Well-prepared candidates were familiar with a definition of *codominant*. Answers were then clear and concise − both alleles would be expressed in the phenotype of a heterozygote. Where this was not the case, weak explanations, such as 'neither is dominant', often failed to make the point.

The clue to the calculations was in the wording of the questions. Part (iii) required use of the Hardy-Weinberg equation. This was not requested in part (ii) and attempting to do so was an inappropriate strategy. All that was required was an addition of all alleles present (1000) against which the *actual* frequency of the particular allele could then be established (0.25 or 25%). Many candidates failed to recognise the significance of calculating the *actual* frequency (250 in 1000).

For most candidates, their remaining credit was restricted to identification of the Hardy- Weinberg equation. Those that were able recognised that their actual frequency would be $q$, (but would work equally as $p$) from which $q^2$ could be determined and applied to determine the expected number with the genotype in the population (500). It was interesting to note that candidates who performed well with the mathematical nature of this question were not always successful with questions testing biological understanding.