HELICATE · AS AND A-LEVEL BIOLOGY · TOPIC BANK

3.4.4 Genetic diversity and adaptation

Mark scheme

Version 1 · 9 October 2026

TOTAL MARKS	QUESTIONS
70	10

How to use this mark scheme

;	Separates marking points. Each semicolon marks the end of one creditable point, and each point is worth one mark.
;;	Two marks for this answer (used for calculations).
/	Alternative words or phrases that are credited for the same point.
OR	An alternative answer for the same mark.
( )	Words in brackets are not needed to gain the mark.
max	More marking points are listed than marks available. Award up to the number of marks shown.
Accept	An alternative answer that gains credit.
Reject	A wrong answer. It does not gain credit and cancels a correct point it contradicts.
Ignore	Neither credited nor penalised. Mark the rest of the answer.
ECF	Error carried forward: credit correct working that uses an earlier wrong answer.
AO	Assessment objective: AO1 knowledge and understanding; AO2 applying knowledge; AO3 analysing, interpreting and evaluating.

Where an answer is correct but not listed, credit it if it is biologically accurate and answers the question at the depth the marks require. Right + wrong = wrong: a contradiction cancels a correct point.

Genetic diversity and natural selection 3.4.4

Question	Marking guidance	Mark	Comments
01.1	The number of different alleles of genes in the population;	**1** (1 × AO1)	

Question	Marking guidance	Mark	Comments
01.2	1. For: the wild relative has more different alleles of every gene OR 34 alleles compared with 10 in total; 2. For: the same number of plants (80) was sampled from each, so the comparison is fair; 3. Against: only six genes were studied OR other genes may show a different pattern; 4. Against: only one population/sample of each was studied OR the plants may not be representative;	**2 max** (2 × AO3)	**Max 1** if only points for or only points against are given 1. **Accept** a comparison for a named gene, eg gene C, 9 alleles compared with 3 **Ignore** 'no statistical test' unqualified **Ignore** 'sample size too small' unqualified

Question	Marking guidance	Mark	Comments
01.3	Correct answer for 2 marks: 70.6 (%);; Accept for 1 mark, means of 5.67 and 1.67 **OR** (34 − 10) ÷ 34 × 100 **OR** 70.59 or 71 (%) (not to one decimal place)	**2** (2 × AO2)	**Accept** 70.5 (%) for 2 marks (from means rounded to 5.67 and 1.67) **Reject** 240% (percentage increase from the crop variety) for 2 marks

Question	Marking guidance	Mark	Comments
01.4	1. Crop variety has fewer different alleles of every gene OR 10 alleles compared with 34, so lower genetic diversity; 2. So few(er) plants (of the crop variety) have an allele that gives resistance (to the fungus); 3. Genetic diversity is needed for natural selection to occur OR in the wild relative, plants with a resistance allele are more likely to be present to survive and reproduce; 4. So most plants of the crop variety are likely to be killed OR there are too few resistant survivors to reproduce/maintain the population;	**3 max** (2 × AO1) (1 × AO2)	1. A reference to the data in Table 1 is needed, eg only one allele of genes B, D and F in the crop variety 2. **Accept** 'allele' for resistance; penalise 'gene' for allele once **Reject** plants become immune **Reject** the fungus causes mutations that give resistance

Question	Marking guidance	Mark	Comments
02.1	Mutations occur randomly, and only some new alleles benefit an organism in a particular environment;	**1** (1 × AO1)	

Question	Marking guidance	Mark	Comments
02.2	1. Bacteria are resistant, not immune OR bacteria do not have an immune system; 2. Individual bacteria do not change OR the population changes because (the few) resistant bacteria survive and reproduce while non-resistant bacteria are killed; 3. Mutation is random/spontaneous OR the antibiotic does not cause the mutation OR the (resistance) allele was already present before the antibiotic was used;	**3** (3 × AO1)	Points may be given in any order 2. **Accept** the antibiotic is a selection pressure that selects (bacteria with) the resistance allele 2. **Accept** divide/binary fission for reproduce 3. **Reject** the antibiotic causes the bacteria to adapt **Reject** 'bacteria mutate in order to survive/to become resistant' **Ignore** references to antibodies or white blood cells

Question	Marking guidance	Mark	Comments
03.1	Correct answer for 2 marks: 2.38×10^4;; Accept for 1 mark, 23 800 (not in standard form) **OR** $3.5 \times 10^4 \times 0.68$	**2** (2 × AO2)	Plotted value is 68%. Accept readings of 67–69%, giving 2.35×10^4 to 2.42×10^4 for 2 marks **Accept** 2.4×10^4 for 2 marks

Question	Marking guidance	Mark	Comments
03.2	1. (Random) mutation produced (the new) allele E^R; 2. Herbicide H is the selection pressure OR plants with allele E^R survive spraying because their enzyme E is not inhibited (and they can make lipids), but other plants die; 3. Plants with allele E^R reproduce/produce seeds and pass on allele E^R (to their offspring); 4. Frequency of allele E^R increases over (many) generations/years;	**4** (2 × AO1) (2 × AO2)	1. **Accept** allele E^R introduced from another population, eg in seeds/pollen 1. **Reject** the herbicide caused the mutation 2. and 3. Allele E^R must be referred to at least once for full marks; 'advantageous allele' alone is not enough Penalise 'gene' for allele once 4. **Accept** proportion/percentage of plants with allele E^R increases 4. **Ignore** 'number of alleles increases' **Reject** immune for resistant

Question	Marking guidance	Mark	Comments
03.3	Directional (selection);	**1** (1 × AO1)	**Ignore** 'natural selection' alone **Reject** stabilising

Directional and stabilising selection 3.4.4

Question	Marking guidance	Mark	Comments
04.1	Correct answer for 2 marks: 0.01 (%) OR 1×10^{-2} (%);; Accept for 1 mark, 100 (resistant) **and** 1 000 000 OR 1×10^{6} (total)	**2** (2 × AO2)	**Reject** 33% (log values divided) for 2 marks **Accept** 0.0001 for 1 mark (fraction not converted to a percentage)

Question	Marking guidance	Mark	Comments
04.2	1000;	**1** (1 × AO2)	$\log_{10}$ values 2.0 and 5.0; 10^3 = 1000

Question	Marking guidance	Mark	Comments
04.3	1. Antibiotic A is a selection pressure (that favours resistant bacteria) OR only resistant bacteria survive (to reproduce); 2. Resistant bacteria survive and reproduce/divide, passing on the (resistance) allele; 3. So the proportion/frequency of resistant bacteria/the resistance allele increases from 0.01% to almost 100% OR so by 10 hours almost all bacteria are resistant;	**3** (2 × AO1) (1 × AO2)	**Ignore** references to mutation; the question states that resistant bacteria were present at the start 1. **Ignore** restatement that antibiotic A kills non-resistant bacteria 2. **Accept** binary fission/replicate for reproduce Penalise 'gene' for allele once 3. **Accept** total number is (almost) the same as the number of resistant bacteria at 10 hours **Reject** immune for resistant

Question	Marking guidance	Mark	Comments
04.4	The numbers range over several orders of magnitude/from about 100 to 1 000 000 OR so that both small and large numbers can be shown (clearly) on the same graph/scale;	**1** (1 × AO3)	**Ignore** 'easier to plot' unqualified

Question	Marking guidance	Mark	Comments
04.5	Correct answer for 2 marks: 6.3×10^{3};; Accept for 1 mark, 630 (per cm^3 of diluted sample) **OR** 6 300 (not in standard form)	**2** (2 × AO2)	**Reject** 6.3×10^{2} (dilution not taken into account) for 2 marks

Question	Marking guidance	Mark	Comments
05.1	Correct answer for 2 marks: 5×10^{-5};; Accept for 1 mark, probability of 1×10^{-15} **OR** $5 \times 10^{10} \times 1 \times 10^{-8} \times 1 \times 10^{-7}$	**2** (2 × AO2)	**Accept** 0.00005 for 1 mark (not in standard form)

Question	Marking guidance	Mark	Comments
05.2	1. With antibiotic P alone, (about 500) bacteria resistant to P survive (the selection pressure); 2. Surviving resistant bacteria reproduce/divide and pass on the resistance allele, so the frequency of resistance increases OR a resistant population develops; 3. With both antibiotics, a bacterium resistant to only one antibiotic is killed by the other OR a bacterium needs (alleles for) resistance to both to survive; 4. (As mutations are random/independent), it is very unlikely that any bacterium is resistant to both OR the expected number (5×10^{-5}) is much less than 1;	**3 max** (2 × AO1) (1 × AO2)	**Max 2** if neither point 3 nor point 4 is given Penalise 'gene' for allele once **Reject** antibiotics cause the mutations **Reject** immune for resistant

Question	Marking guidance	Mark	Comments
06.1	Correct answer for 2 marks: 39.6 (%);; Accept for 1 mark, total of 5.30 deaths per 1000 babies born OR 530 per 100 000 **OR** 2.1 deaths per 1000 babies born are of babies less than 1.5 kg **OR** 39.60 or 40 (%) (not to three significant figures)	**2** (2 × AO2)	**Reject** 85.4% (death rates added without weighting by the percentage of babies) for 2 marks Working: 1.2 × 175 + 5.8 × 21 + 52.6 × 2.4 + 38 × 1.6 + 2.4 × 4.8 = 530.36 per 100 000 babies born

Question	Marking guidance	Mark	Comments
06.2	1. (Description) babies with an intermediate/average birth mass (2.5 to 4.4 kg) have the lowest death rate (2.4 and 1.6 per 1000) OR babies at both extremes have higher death rates (175 and 4.8 per 1000); 2. (Explanation) so babies of intermediate birth mass are more likely to survive (and reproduce) / are selected for, **and** both extremes (very low and very high birth mass) are selected against;	**2** (2 × AO3)	**Accept** weight for mass 1. Data from the table must be used 1. Describing both the intermediate and the extreme death rates still gains only point 1 2. Both extremes are needed for point 2 2. **Accept** 'so the range/variation of birth mass narrows and the mean stays about the same' as the explanation **Ignore** references to most babies being of intermediate mass unless linked to survival/death rate

Question	Marking guidance	Mark	Comments
06.3	The mean birth mass stays about the same and the standard deviation decreases;	**1** (1 × AO1)	

Adaptation 3.4.4

Question	Marking guidance	Mark	Comments
07.1	5.1;	**1** (1 × AO2)	Plotted values are 92% and 18%. Accept readings within 1% of each, giving answers from 4.8 to 5.5 **Accept** 5.11 or a correct value to more decimal places (5.111…) **Reject** 0.20 (ratio inverted)

Question	Marking guidance	Mark	Comments
07.2	1. Mine 0.31 to 0.55 (g) **and** pasture 0.35 to 0.55 (g); 2. The ranges/mean ± 2 standard deviations overlap, so there is no significant difference OR the difference (in means) is (likely to be) due to chance, so the statement is not supported;	**2** (2 × AO3)	**Accept** SD for standard deviation 2. **Accept** either 'no significant difference' or '(likely) due to chance' 2. **Reject** 'the results are due to chance'; the answer must refer to the difference 2. **Accept** ECF from incorrect ranges in point 1 **Reject** use of 1 standard deviation for point 1

Question	Marking guidance	Mark	Comments
07.3	So that any differences (in tolerance) are genetic/inherited OR are not caused by the different soils/environments the (adult) plants grew in;	**1** (1 × AO3)	**Accept** so the only variable is the site the seeds came from **Ignore** 'to make it a fair test' unqualified

Question	Marking guidance	Mark	Comments
07.4	1. There are no/few zinc ions in pasture soil, so (alleles for) zinc tolerance give no advantage (there); 2. Zinc-tolerant plants produce fewer seeds OR have lower reproductive success (in the pasture) (42% fewer seeds); 3. So (alleles for) zinc tolerance are less likely to be passed on to the next generation; 4. So the frequency of (alleles for) zinc tolerance stays low OR decreases over generations; 5. The few tolerant plants in the pasture may come from seeds/pollen carried from the mine (200 m away);	**3 max** (3 × AO2)	Penalise 'gene' for allele once 2. **Accept** tolerant plants are outcompeted by non-tolerant plants **Ignore** differences in dry mass with no zinc ions added (not significant) 4. **Ignore** 'number of alleles decreases'

Question	Marking guidance	Mark	Comments
08	1. For: the difference between island Q and island P lizards (1.2 m compared with 4.1 m) remains in lizards hatched in the laboratory (1.3 m compared with 4.0 m), so it is not learned/caused by predators present OR it is likely to be genetic/inherited; 2. For: the means ± 2 standard deviations do not overlap, so the difference is (likely to be) significant OR (probably) not due to chance; 3. For: with no predators, running away early has a cost, eg less time feeding/basking, more energy used, so lizards with alleles for a short flight initiation distance have greater reproductive success; 4. Against: there are no data on how flight initiation distance changed over time OR on the ancestral/original population, so it is not shown that selection produced the change; 5. Against: there are no data showing that a short flight initiation distance increases survival/reproductive success on island Q (no fitness data); 6. Against: the eggs developed in the mother/on the island, so conditions before hatching may have affected behaviour OR no genes/alleles were identified, so a genetic basis is not proven; 7. Against: only one population on each island was studied, so the difference could be due to random changes in allele frequency/genetic drift rather than selection;	**4 max** (4 × AO3)	**Max 3** if only points for or only points against are given **Accept** SD for standard deviation 1. A difference between the islands alone, without the laboratory comparison, does not gain this point 2. **Accept** a correct calculation, eg island Q laboratory 0.3–2.3 and island P laboratory 2.4–5.6 2. **Accept** either 'significant difference' or '(probably) not due to chance' 3. **Accept** no predation pressure, so the cost of fleeing is not balanced by a benefit 7. Genetic drift is credited when given, but it is not required 5. and 7. Ignore 'other factors/other differences between the islands' unqualified; selection by any factor is still natural selection **Ignore** 'sample size too small' unqualified

Required practical 6: antimicrobial substances 3.4.4

Question	Marking guidance	Mark	Comments
09.1	1. To show the number of bacteria that survive without mouthwash OR to show the bacteria do not die in water/during the procedure (over 4 minutes); 2. So any decrease in the number of colonies is due to the mouthwash/antiseptic OR to give a value to compare with/to calculate the percentage surviving;	**2** (2 × AO3)	**Accept** 'negative control' only if the purpose is explained **Ignore** 'to make it a fair test' or 'to compare' unqualified

Question	Marking guidance	Mark	Comments
09.2	Correct answer for 2 marks: 40.8 (%);; Accept for 1 mark, means of 98 **and** 240 **OR** 40.83 or 41 (%) (not to three significant figures)	**2** (2 × AO2)	**Reject** 59.2% (percentage killed) for 2 marks; award 1 mark if the means are shown

Question	Marking guidance	Mark	Comments
09.3	So the contact time is exactly the time stated OR so the antiseptic does not continue to kill bacteria (in the solution/on the agar plate) after the sample is taken;	**1** (1 × AO2)	**Accept** so the results show only the effect of the stated contact time **Ignore** 'to make it accurate' unqualified

Question	Marking guidance	Mark	Comments
09.4	1. Wash hands with soap OR disinfect the bench/work surface; 2. Use a sterile pipette/syringe to transfer the 0.1 cm^3; 3. Flame the neck of the bottle/tube; 4. Lift the lid of the plate (only slightly/at an angle); 5. Work close to (the upward air movement from) a Bunsen burner flame; 6. Use a sterile spreader OR sterilise the spreader by flaming (after dipping in alcohol); 7. Put the used pipette/spreader into disinfectant (immediately);	**3 max** (3 × AO1)	2. **Reject** loop for transferring 0.1 cm^3; a set volume needs a pipette/syringe 2. **Accept** unopened pipette/syringe 4. **Ignore** 'lid off for less time' or 'work quickly' 5. **Reject** 'air movements sterilise the air' **Ignore** 'sterilise hands/surfaces' **Ignore** gloves, closing windows, 'sterilise all equipment'

Question	Marking guidance	Mark	Comments
09.5	1. The plate is contaminated with another microorganism/species OR different types of colony show that more than one species is present; 2. So some colonies are not (survivors of) the test bacterium OR the count is higher than the number of surviving bacteria, so it does not show the effect of the mouthwash;	**2** (2 × AO2)	1. **Ignore** contamination with chemicals/dirt 2. **Accept** the count would overestimate survival **Ignore** 'it is an anomaly' unqualified

Question	Marking guidance	Mark	Comments
09.6	1. For: the mouthwash kills (some) bacteria OR there are fewer colonies at every contact time than with sterile water OR more bacteria are killed with longer contact; 2. Against: after 0.5 minutes, 65% survive OR only 35% are killed, not 99%; 3. Against: even after 4 minutes, only 98% are killed OR 2% survive; 4. Against: only one (species/strain of) bacterium was tested OR the bacterium is non-pathogenic, so the results may not apply to (other) bacteria in the mouth/bacteria that cause disease; 5. Against: tested in a tube, not in the mouth OR saliva may dilute the mouthwash OR the contact did not take place at mouth/body temperature (about 37 °C) OR the contact temperature was not stated; 6. Against: the sterile water was sampled only at 4 minutes, so there is no control for 0.5 minutes OR a colony may grow from more than one bacterium/a clump, so counts may not equal the number of survivors;	**5 max** (5 × AO3)	Full marks may be gained from points against only, because the data do not support the claim **Ignore** 'only three plates', 'not enough repeats' or 'counts vary between plates' (the plate counts agree closely and the investigation was repeated) 2. and 3. Accept correct calculations from the means, eg 156 ÷ 240 5. **Ignore** references to the incubation temperature (20 °C); the antiseptic was stopped before the plates were incubated **Ignore** 'no statistical test' unqualified

Extended response: selection and adaptation 3.4.4

Question	Marking guidance	Mark	Comments
10	1. Variation in shell thickness is due to different alleles OR the population has genetic diversity; 2. (Before 1900) stabilising selection; 3. Snails with intermediate/average shell thickness have the greatest survival/reproductive success OR snails with very thin **and** very thick shells are selected against; 4. So the mean (shell thickness) stays the same (over generations) OR the range/standard deviation decreases; 5. (After 1900) directional selection OR the crab is a (new) selection pressure; 6. Snails with thicker shells are less likely to be crushed/eaten, so they survive and reproduce; 7. They pass on alleles for thicker shells (to their offspring); 8. So the frequency of alleles for thicker shells increases over (many) generations, increasing the mean (shell thickness);	**6 max** (4 × AO1) (2 × AO2)	**Max 4** if only one observation is explained Penalise 'gene' for allele once 1. **Accept** mutation produces new alleles, but it is not required 3. **Accept** suggested reasons why the extremes are selected against, but they are not required 8. **Ignore** 'number of alleles increases' **Reject** the crabs cause mutations OR snails develop thicker shells in order to survive

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