HELICATE · AS AND A-LEVEL BIOLOGY · TOPIC BANK

3.4.3 Genetic diversity can arise as a result of mutation or during meiosis

Mark scheme

Version 1 · 9 October 2026

TOTAL MARKS	QUESTIONS
66	13

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.

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Gene mutations 3.4.3

Question	Marking guidance	Mark	Comments
01	Gene mutations can arise spontaneously when DNA is replicated;	**1** (1 × AO1)	

Question	Marking guidance	Mark	Comments
02.1	A change in the base/nucleotide sequence (of DNA/a gene/a chromosome);	**1** (1 × AO1)	**Accept** a named mutation, eg substitution/deletion of a base, for 'change' **Reject** a change in the genetic code / 'the code' unqualified **Reject** a change in the number of chromosomes

Question	Marking guidance	Mark	Comments
02.2	1. (Base) substitution; 2. Thymine is replaced by cytosine (in the second triplet) OR T to C OR CTT to CTC;	**2** (2 × AO2)	1. **Accept** single-base substitution 1. **Reject** deletion 2. **Reject** thiamine for thymine 2. **Reject** mRNA bases, eg A to G or GAA to GAG

Question	Marking guidance	Mark	Comments
02.3	1. (The mRNA) codon changes from GAA to GAG; 2. Both (codons) code for glutamic acid OR the same amino acid is coded for; 3. (Because) the genetic code is degenerate OR (some) amino acids are coded for by more than one codon/triplet; 4. (So) no change in primary structure OR no change in tertiary structure OR no change in (the shape of) the active site;	**3 max** (3 × AO2)	**Max 2** if no data from Table 2 are used (GAA, GAG or glutamic acid) 2. **Reject** 'the same amino acid is produced/formed/made' for 'coded for' 2. and 3. One statement that GAA and GAG are different codons that both code for glutamic acid gains points 2 and 3 3. **Reject** 'DNA is degenerate' OR 'degenerate code of amino acids'

Question	Marking guidance	Mark	Comments
03.1	(A factor/substance that) increases the rate of (gene) mutation;	**1** (1 × AO1)	**Accept** increases the number/frequency/chance of mutations **Ignore** 'causes mutations' without reference to an increase

Question	Marking guidance	Mark	Comments
03.2	1. (Some) gene mutations arise spontaneously (during DNA replication) OR mutations happen without a mutagenic agent; 2. To show the number of colonies/mutations without UV light, so that any increase can be attributed to UV light OR for comparison (as a control);	**2** (2 × AO3)	2. **Accept** 'as a control' only if its purpose is explained 2. **Ignore** 'to make it a fair test'

Question	Marking guidance	Mark	Comments
03.3	Correct answer of 11 for 2 marks;; Accept for 1 mark: $66 \div (6.0 \times 10^{6})$ **OR** 1.1×10^{-5} (per cell)	**2** (2 × AO2)	**Accept** 11.0 for 2 marks

Question	Marking guidance	Mark	Comments
03.4	1. (Supports) more colonies after 30 s (104) than after 40 s (66); 2. (Against) mutation frequency is higher after 40 s (11) than after 30 s (6.5 per million cells that survived); 3. Fewer cells survived 40 s than 30 s (6.0×10^{6} compared with 1.6×10^{7}), so fewer cells could form colonies OR longer exposure killed more cells OR mutations in cells killed by UV light are not counted; 4. Mutation frequency increases across at least three exposure times (from 0.12 at 0 s to 11 at 40 s), so longer exposure causes more mutations per surviving cell OR per million cells that survived; 5. Only mutations that restore the enzyme are detected, so other gene mutations are not counted; 6. No repeats/no measure of variation/no statistical test, so not known whether differences are significant;	**4 max** (4 × AO3)	**Max 2** unless point 2 or point 4 is given 2. and 4. The 30 s and 40 s comparison alone gains point 2 only; point 4 needs the trend across at least three exposure times 2. **ECF** from 03.3 2. **Accept** frequencies calculated correctly for other exposure times, eg 3 at 20 s

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Question	Marking guidance	Mark	Comments
03.5	1. Distance of the yeast cells from the UV lamp; 2. Intensity/wavelength of the UV light OR the same UV lamp; 3. Volume/depth of the cell suspension exposed OR number/concentration of cells exposed; 4. Temperature (during exposure or incubation); 5. Incubation time (3 days) OR volume/composition of the medium;	**2 max** (2 × AO3)	**Ignore** 'amount of UV light' unqualified **Ignore** time of exposure (the independent variable)

Non-disjunction and chromosome mutations 3.4.3

Question	Marking guidance	Mark	Comments
04.1	5, 5, 3 and 3;	**1** (1 × AO2)	Both homologous chromosomes of one pair go to one cell in the first division; the second division then separates chromatids normally.

Question	Marking guidance	Mark	Comments
04.2	5, 3, 4, 4 (in any order);	**1** (1 × AO2)	All four numbers are needed for the mark

Question	Marking guidance	Mark	Comments
04.3	1. Homologous chromosomes are separated in the first meiotic division and (sister) chromatids are separated in the second meiotic division; 2. Non-disjunction in the first division gives both cells from that division an abnormal number (one has an extra chromosome and the other lacks one), so the error passes to all four cells; 3. Non-disjunction in the second division affects only one of the two cells; the other cell divides normally, giving two cells with the normal number;	**3** (2 × AO1) (1 × AO2)	1. **Accept** chromosomes for chromatids in the second division. Reject homologous chromosomes separate in the second division 1. **Accept** stage names that show the two divisions, eg anaphase I and anaphase II **Do not accept** abbreviations, eg NDJ for non-disjunction

Question	Marking guidance	Mark	Comments
05.1	Non-disjunction is rare/few cells have an abnormal number of chromosomes, so a large sample is needed to find enough of them OR so that the sample is representative/the percentage is reliable;	**1** (1 × AO3)	**Accept** to reduce the effect of chance/anomalous results **Ignore** 'to make it accurate/fair' unqualified

Question	Marking guidance	Mark	Comments
05.2	Correct answer of 15.2 (%) for 2 marks;; Accept for 1 mark: 179 (abnormal cells) **OR** 179 ÷ 1180 **OR** a correct answer not given to 1 decimal place, eg 15.17 or 15	**2** (2 × AO2)	**Reject** 7.5 or 7.7 (one group only) for 2 marks

Question	Marking guidance	Mark	Comments
05.3	1. In non-disjunction, both chromosomes of a homologous pair OR both chromatids (of a chromosome) go into the same cell; 2. So the other cell (from that division) lacks that chromosome OR each non-disjunction produces cells with 13 and cells with 11 chromosomes (in equal numbers); 3. Small differences are due to chance/sampling OR some abnormal cells may die/not be counted;	**2 max** (1 × AO2) (1 × AO3)	**Max 1** if point 2 is not given

Question	Marking guidance	Mark	Comments
05.4	1. (Supports) the percentage of cells with an abnormal number of chromosomes increases above 25 °C, eg 1.8% at 25 °C, 4.8% at 30 °C and 15.2% at 35 °C; 2. (Supports) little difference between 20 °C and 25 °C (1.1% and 1.8%), so the increase is mainly above 25 °C OR (Against) the conclusion implies an effect only above 25 °C, but the percentage also rises from 20 °C to 25 °C (1.1% to 1.8%), so a threshold at 25 °C is not supported; 3. No statistical test/no measure of variation, so not known whether the differences are significant; 4. No temperatures between 25 °C and 30 °C (or above 35 °C), so the temperature at which the increase starts is not known; 5. Number of plants (at each temperature) not given OR cells may come from only a few plants; 6. Only meiosis in the anthers (pollen formation) was studied, so the effect on meiosis in the ovules (female meiosis) is not known; 7. Other growing conditions, eg light intensity/humidity/water supply, are not stated to have been kept the same, so another variable may have caused the difference;	**3 max** (3 × AO3)	**Max 2** if only points that support or only points that question the conclusion are given 1. **Accept** comparisons of the numbers of abnormal cells, eg 21 at 25 °C and 179 at 35 °C

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Meiosis: chromosome content of cells and life cycles 3.4.3

Question	Marking guidance	Mark	Comments
06.1	**Q**;	**1** (1 × AO2)	Q has three chromosomes, one from each homologous pair, each still made of two chromatids

Question	Marking guidance	Mark	Comments
06.2	1. Cell S contains both chromosomes of one homologous pair/both chromosomes labelled 1 OR has no chromosome from one homologous pair/no chromosome labelled 2; 2. In (the first division of) meiosis homologous chromosomes are separated, so each cell receives one chromosome from each pair;	**2** (2 × AO2)	1. **Accept** 'one from each parent' for the two chromosomes labelled 1 1. Describing both features (two chromosomes from pair 1 and none from pair 2) still gains only point 1 2. **Reject** chromatids are separated in the first division

Question	Marking guidance	Mark	Comments
07.1	1. 3.5 (arbitrary units); 2. DNA is replicated before meiosis (to 14.0) and halves at each of the two divisions OR sperm cells are haploid and each chromosome is made of one chromatid OR it is half the mass in a diploid cell before replication (7.0);	**2** (2 × AO2)	2. **Accept** a quarter of the mass in a cell that has replicated its DNA 2. Only award point 2 if 3.5 is given

Question	Marking guidance	Mark	Comments
07.2	1. Some could be diploid cells that have not (yet) replicated their DNA OR diploid cells produced by mitosis OR diploid cells that are not dividing; 2. Some could be (haploid) cells at the end of the first meiotic division; 3. These haploid cells have half the number of chromosomes, but each chromosome is (still) made of two chromatids; 4. So the statement is not supported OR the mass of DNA alone cannot show whether a cell is haploid or diploid;	**3 max** (3 × AO3)	**Max 2** unless point 2 is given 2. **Accept** cells between the first and second meiotic divisions 2. **Reject** cells at the end of the second meiotic division

Question	Marking guidance	Mark	Comments
07.3	Cells about to divide by mitosis have also replicated their DNA/also contain 14.0 arbitrary units of DNA, so they cannot be distinguished from cells about to divide by meiosis;	**1** (1 × AO3)	**Accept** the converse

Question	Marking guidance	Mark	Comments
08	1. Meiosis involves two (nuclear) divisions, so four cells are produced OR mitosis produces two cells and meiosis produces four cells; 2. Homologous chromosomes are separated in the first meiotic division, so cells from meiosis are haploid OR cells from mitosis are diploid/have the same number of chromosomes as the parent cell and cells from meiosis are haploid/have half the number; 3. In mitosis, (sister) chromatids (identical copies made by DNA replication) are separated, so the cells are genetically identical (to each other and to the parent cell); 4. Cells from meiosis are genetically different from each other because of independent segregation of homologous chromosomes; 5. Independent segregation produces new combinations of maternal and paternal chromosomes; 6. Crossing over/exchange of parts of chromatids/alleles between homologous chromosomes (produces new combinations of alleles);	**5 max** (5 × AO1)	**Max 3** if no difference in genetic make-up is explained (points 3–6) 1. **Accept** stage names only where they show two divisions, eg anaphase I and anaphase II 2. **Reject** the first meiotic division produces diploid cells 3. **Accept** chromosomes for chromatids. Reject homologous chromosomes separate in mitosis 4. **Accept** independent assortment. Ignore 'chromatids' alone for homologous chromosomes 6. **Accept** 'within a bivalent'. Accept chiasma(ta) for the term 'crossing over', but it does not supply 'between homologous chromosomes'/'between non-sister chromatids', which must still be stated **Do not accept** abbreviations, eg IS for independent segregation

Question	Marking guidance	Mark	Comments
09.1	1. When the zygote divides to produce spores; 2. The zygote is diploid/contains 34 chromosomes and the spores are haploid/contain 17 OR this is the only stage at which the chromosome number halves;	**2** (2 × AO2)	2. Only award point 2 if point 1 is given **Reject** meiosis when gametes are produced

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Question	Marking guidance	Mark	Comments
09.2	1. Gametes are produced by mitosis (from haploid cells); 2. Spores are produced by meiosis, with independent segregation of homologous chromosomes OR crossing over (between homologous chromosomes);	**2** (1 × AO1) (1 × AO2)	2. Meiosis alone is not enough; one source of variation must be named 2. **Accept** random/independent assortment 2. **Accept** chiasma(ta) for crossing over **Ignore** random fertilisation

Meiosis, random fertilisation and genetic variation 3.4.3

Question	Marking guidance	Mark	Comments
10	Crossing over between homologous chromosomes;	**1** (1 × AO1)	

Question	Marking guidance	Mark	Comments
11.1	1. (Parts of) chromatids/alleles are exchanged between homologous chromosomes; 2. Produces new combinations of alleles (on chromosomes/in gametes);	**2** (2 × AO1)	1. **Accept** 'between non-sister chromatids' / 'within a bivalent' 1. **Reject** exchange between sister chromatids 1. 'Chiasma(ta) form' alone does not gain point 1: chiasma(ta) may replace the term 'crossing over', but the exchange of parts of chromatids/alleles between homologous chromosomes must still be stated 2. **Ignore** 'genes' for alleles

Question	Marking guidance	Mark	Comments
11.2	1. DE and de; 2. De and dE;	**2** (2 × AO2)	Answers in any order **Accept** the alleles in either order, eg ED for DE **Max 1** if any combination is given more than once or a combination other than these four is given

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Question	Marking guidance	Mark	Comments
11.3	1. Independent segregation of homologous chromosomes (in the first meiotic division); 2. Produces different combinations of maternal and paternal chromosomes/alleles in the sperm cells; 3. Gene mutations (during DNA replication) can produce new alleles;	**2 max** (2 × AO2)	1. **Accept** independent assortment. Ignore 'chromatids' alone for homologous chromosomes **Ignore** random fertilisation (the sperm cells are already formed) **Ignore** crossing over

Question	Marking guidance	Mark	Comments
12.1	Correct answer of 2.62×10^5 for 2 marks;; Accept for 1 mark: 2^9 OR 512 (combinations in the gametes of each plant) **OR** $(2^9)^2$ OR 2^{18} OR 4^9 OR 512×512 **OR** 262 144 (not in standard form)	**2** (2 × AO2)	**Accept** 2.6×10^5 OR 2.621×10^5 for 2 marks **Accept** every equivalent form of $(2^n)^2$, eg 2^{2n}, 4^n, $2^n \times 2^n$ **Reject** 512 (gametes only) for 2 marks

Question	Marking guidance	Mark	Comments
12.2	Correct answer of 24 for 2 marks;; Accept for 1 mark: n = 12 **OR** $2^{12} = 4096$	**2** (2 × AO2)	12 (the haploid number) gains 1 mark

Question	Marking guidance	Mark	Comments
13	1. Gene mutation is a change in the base sequence of DNA, eg (base) substitution or deletion; 2. Mutations arise spontaneously during DNA replication OR mutagenic agents increase the rate of mutation; 3. Mutation produces new alleles; 4. Independent segregation of homologous chromosomes (in the first meiotic division); 5. Produces new combinations of maternal and paternal chromosomes in gametes; 6. (Crossing over) parts of chromatids/alleles are exchanged between homologous chromosomes; 7. (Crossing over) produces new combinations of alleles (on chromosomes/in gametes); 8. Random fertilisation/random fusion of (male and female) gametes; 9. Produces new combinations of alleles OR of maternal and paternal chromosomes in the zygote/offspring;	**6 max** (6 × AO1)	**Max 4** if any one of mutation (points 1–3), meiosis (points 4–7) or random fertilisation (points 8–9) is not addressed 1. **Ignore** non-disjunction/chromosome mutation for point 1 (it is not a gene mutation) 4. **Accept** independent assortment. Ignore 'chromatids' alone for homologous chromosomes 6. **Accept** 'between non-sister chromatids' / 'within a bivalent'. Accept chiasma(ta) for the term 'crossing over', but it does not supply 'between homologous chromosomes'/'between non-sister chromatids', which must still be stated 8. 'Fertilisation is random' without reference to gametes does not gain point 8. Ignore random mating 3., 7. and 9. Ignore 'genes' for alleles **Do not accept** abbreviations, eg IS for independent segregation **Ignore** natural selection, migration and epigenetics

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