S5 Biology Practice Paper 1 | Mendel, blood groups, sex linkage, DNA replication, population genetics

Senior Secondary Biology

S5 Biology practice paper 1 with full solutions: Mendelian ratios, ABO and Rh blood groups, sex-linked inheritance, DNA replication, codons and Hardy-Weinberg frequencies.

1. Mendelian monohybrid crosses (16 marks)

In peas, tall stem (T) is dominant to dwarf stem (t) and height is controlled by one pair of alleles. The first cross is between two heterozygous tall plants (Tt x Tt) and gives 320 offspring; the second cross is between a heterozygous tall plant and a dwarf plant (Tt x tt) and gives 240 offspring. Assume the offspring numbers reflect the theoretical ratios.

#	Question	Answer and marking notes
1	(a) In the first cross (Tt x Tt), what is the theoretical ratio of tall to dwarf offspring, and how many of each?	Answer: tall : dwarf = 3 : 1; tall = 320 x 3/4 = 240 plants and dwarf = 320 x 1/4 = 80 plants.
2	(b) Among the offspring of the first cross, how many are homozygous tall (TT) and how many heterozygous tall (Tt)?	Answer: TT is 1/4, i.e. 320 x 1/4 = 80 plants; Tt is 2/4, i.e. 320 x 1/2 = 160 plants.
3	(c) How many tall and how many dwarf plants result from the second cross (Tt x tt), and in what ratio?	Answer: ratio 1 : 1; tall = 240 x 1/2 = 120 plants and dwarf = 240 x 1/2 = 120 plants.
4	(d) If one plant is picked at random from the 320 offspring of the first cross, what is the probability that it carries the t allele? Give the answer as a percentage.	Answer: plants carrying t are Tt and tt, i.e. 160 + 80 = 240 plants; probability = 240 / 320 = 0.75, i.e. 75 per cent.

2. Dihybrid cross (16 marks)

In peas, round seed (R) is dominant to wrinkled seed (r) and yellow cotyledon (Y) is dominant to green cotyledon (y). The two gene pairs lie on different chromosomes, so they assort independently. Two round yellow plants (RrYy x RrYy) are crossed and give 800 offspring.

#	Question	Answer and marking notes
5	(a) What is the theoretical ratio of the four phenotypes, and how many plants show each?	Answer: ratio 9 : 3 : 3 : 1; round yellow 450, round green 150, wrinkled yellow 150, wrinkled green 50.
6	(b) What percentage of the offspring is round yellow, and what are the number and percentage of wrinkled green offspring?	Answer: round yellow = 450 / 800 x 100 = 56.25 per cent; wrinkled green = 50 plants, i.e. 6.25 per cent.
7	(c) How many offspring have the genotype RrYy?	Answer: RrYy accounts for 4/16, i.e. 800 x 4/16 = 200 plants.
8	(d) How many plants are homozygous round yellow (RRYY) and how many are homozygous wrinkled green (rryy)?	Answer: RRYY is 1/16, i.e. 800 x 1/16 = 50 plants; rryy is also 1/16, i.e. 50 plants.

3. ABO and Rh blood group inheritance (18 marks)

ABO blood group is controlled by three alleles I^A, I^B and i; I^A and I^B are dominant to i, and I^A with I^B gives group AB. The first couple is a father of group A (I^A i) and a mother of group B (I^B i), with 400 children recorded. The Rh factor is controlled by a separate pair of alleles, with Rh positive (D) dominant to Rh negative (d).

#	Question	Answer and marking notes
9	(a) Which blood groups can the children of this couple have, in what ratio, and how many of the 400 children fall in each group?	Answer: groups A, B, AB and O in the ratio 1 : 1 : 1 : 1; 100 children each (400 x 1/4).
10	(b) A second couple has a father of group O (ii) and a mother of group AB (I^A I^B). How are their 320 children distributed by blood group?	Answer: only groups A and B in the ratio 1 : 1; 160 of group A and 160 of group B.
11	(c) Can a father of group AB and a mother of group O have a child of group O? Explain in terms of alleles.	Answer: No, the probability is 0 per cent. The father gives only I^A or I^B and the mother only i, so every child is I^A i or I^B i, that is group A or group B; genotype ii never appears.
12	(d) A Dd x dd couple has 200 children. How many are Rh positive and how many Rh negative?	Answer: Dd x dd gives 1/2 Dd and 1/2 dd; Rh positive = 200 x 1/2 = 100 children and Rh negative = 100 children.

4. Sex-linked inheritance and the frequency of colour blindness (18 marks)

Red-green colour blindness is caused by a recessive allele (c) on the X chromosome; the normal allele (C) is dominant and the Y chromosome carries no corresponding gene. A carrier mother (X^C X^c) and a father with normal vision (X^C Y) have 400 children, 200 sons and 200 daughters. In another population 16 of 200 men are red-green colour blind.

#	Question	Answer and marking notes
13	(a) In that family, how many sons and how many daughters are colour blind?	Answer: a son has a 1/2 chance of receiving X^c from his mother, so 100 sons (200 x 1/2) are colour blind; a daughter always receives X^C from her father, so 0 daughters are colour blind.
14	(b) What phenotypes result from a colour-blind father (X^c Y) and a homozygous normal mother (X^C X^C), and what proportion of the daughters are carriers?	Answer: every son receives Y from the father and X^C from the mother, so all are normal; every daughter receives X^c from the father and X^C from the mother, so all have normal vision but 100 per cent are carriers (X^C X^c).
15	(c) What is the frequency of colour blindness among the men, what is the allele frequency q of c, and what percentage of women would be expected to be colour blind?	Answer: frequency among men = 16 / 200 = 0.08, so q = 0.08; a woman is colour blind only with X^c X^c, frequency q squared = 0.64 per cent.
16	(d) Under Hardy-Weinberg equilibrium p = 1 - q. What is the frequency 2pq of carrier women (X^C X^c)? Give it as a percentage.	Answer: p = 1 - 0.08 = 0.92; 2pq = 2 x 0.92 x 0.08 = 0.1472, that is 14.72 per cent.

5. DNA base pairing, replication and protein synthesis (16 marks)

A double-stranded DNA molecule contains 1200 base pairs, that is 2400 bases, and adenine (A) makes up 30 per cent of all the bases. During replication each original strand acts as a template on which a new strand is built, giving two identical molecules. In translation every three mRNA bases form one codon coding for one amino acid.

#	Question	Answer and marking notes
17	(a) How many A, T, G and C bases are there in this DNA molecule?	Answer: A = 2400 x 30 per cent = 720 bases; A pairs with T so T = 720; the remaining 2400 - 720 - 720 = 960 bases are G and C, so G = C = 960 / 2 = 480 bases.
18	(b) What percentage of all the bases is A plus T, and what percentage is G?	Answer: A + T = 720 + 720 = 1440 bases, that is 60.0 per cent; G = 480 bases, that is 20.0 per cent.
19	(c) After three successive rounds of replication, how many molecules are produced, and how many newly made DNA strands are there in total?	Answer: molecules = 2 cubed = 8; each molecule has 2 strands, giving 16 strands, of which 2 are the original strands, so 14 strands are newly made.
20	(d) An mRNA of 90 bases can form how many codons and code for how many amino acids at most? If a protein has 45 amino acids, what is the minimum number of mRNA bases needed (ignoring the stop codon)?	Answer: codons = 90 / 3 = 30, coding for at most 30 amino acids; 45 amino acids need 45 x 3 = 135 bases.

6. Hardy-Weinberg equilibrium and allele frequencies (16 marks)

An island carries 500 snails whose shell colour is controlled by one pair of alleles, dark (D) being dominant to pale (d). A survey finds 320 dark and 180 pale snails, and the population is in Hardy-Weinberg equilibrium, that is p squared + 2pq + q squared = 1 with p + q = 1. The climate then changes and all pale snails are eaten by predators.

#	Question	Answer and marking notes
21	(a) Find q squared, q and p; how many dark homozygous snails (DD) would be expected?	Answer: q squared = 180 / 500 = 0.36; q = the square root of 0.36 = 0.6; p = 1 - 0.6 = 0.4; DD = p squared x 500 = 80 snails.
22	(b) How many heterozygotes (Dd) would be expected, and does the total with DD equal the number of dark snails?	Answer: 2pq = 2 x 0.4 x 0.6 = 0.48, so 500 x 0.48 = 240 snails; 80 + 240 = 320, which equals the 320 dark snails.
23	(c) After all pale snails are removed, what is the frequency of allele D among the remaining dark snails?	Answer: total alleles = 320 x 2 = 640; allele D = 80 x 2 + 240 = 400, so the frequency = 400 / 640 = 0.625 (frequency of d is 0.375).
24	(d) If the remaining population mates at random, how many pale snails are expected among 500 offspring?	Answer: frequency of pale = q squared = 0.375 squared = 0.140625, about 14.06 per cent; expected 500 x 0.140625 = about 70 snails.