S6 Biology Practice Paper (Set 2): Mendelian Inheritance and Probability, Gene Linkage and Genetic Mapping, DNA Structure and Semi-conservative Replication, Protein Synthesis and Frameshift Mutation, PCR and Genetic Engineering, Hardy-Weinberg Principle

S6 Biology | 100 marks | 75 minutes

Question 1: Mendelian Inheritance and Probability

In garden peas, the tall allele T is dominant to the dwarf allele t, and the round allele R is dominant to the wrinkled allele r. The two genes are located on different chromosome pairs.

State the genotypic and phenotypic ratios of the offspring from the cross Tt x Tt. *(3 marks)*

Answer: Genotypes 1 TT : 2 Tt : 1 tt; phenotypes tall : dwarf = 3 : 1.

If the cross above produces 400 seeds that are all planted, how many dwarf plants are expected? *(4 marks)*

Answer: 400 x 1/4 = 100 plants.

State the ratio of the four phenotypes in the offspring of the test cross TtRr x ttrr. *(5 marks)*

Answer: TtRr : Ttrr : ttRr : ttrr = 1 : 1 : 1 : 1, that is tall round : tall wrinkled : dwarf round : dwarf wrinkled = 1 : 1 : 1 : 1.

The cross TtRr x TtRr produces 480 plants. How many are expected to be tall round and how many dwarf wrinkled? *(6 marks)*

Answer: Tall round 480 x 9/16 = 270 plants; dwarf wrinkled 480 x 1/16 = 30 plants.

Question 2: Gene Linkage and Genetic Mapping

In fruit flies the body colour gene (A/a) and the wing shape gene (B/b) are on the same chromosome pair. A test cross of an AaBb individual with an aabb individual gives 800 offspring: AB 368, ab 352, Ab 40 and aB 40.

Identify the parental type offspring and their numbers. *(4 marks)*

Answer: AB 368 and ab 352, 720 in total (90%), far more numerous than the other two classes, so they are the parental types.

Calculate the recombination frequency. *(4 marks)*

Answer: Recombinants = 40 + 40 = 80; 80 / 800 x 100% = 10%.

Find the map distance between the two genes. *(4 marks)*

Answer: A recombination frequency of 10% corresponds to 10 cM (10 map units).

If the AaBb individual produces 1,000 gametes, how many AB gametes are expected? *(4 marks)*

Answer: Parental gametes make up 90%, half of them AB, so 45%; 1,000 x 45% = 450 gametes.

Question 3: DNA Structure and Semi-conservative Replication

A double-stranded DNA molecule has 1,000 base pairs, of which 600 are adenine (A).

Find the numbers of T, G and C. *(5 marks)*

Answer: Total bases = 1,000 x 2 = 2,000; T = A = 600; G = C = (2,000 - 1,200) / 2 = 400.

Calculate the ratio (A + G) : (T + C) and state the reason. *(4 marks)*

Answer: (600 + 400) : (600 + 400) = 1 : 1, because A pairs with T and G pairs with C, so purines always equal pyrimidines.

How many free purine nucleotides are needed for one round of replication? *(5 marks)*

Answer: Each template strand needs A + G = 1,000 purine nucleotides, so 2 x 1,000 = 2,000 purines in total per replication.

After three rounds of semi-conservative replication, what is the total number of DNA molecules and how many contain an original strand? *(4 marks)*

Answer: Total molecules = 2^3 = 8; 2 of them each retain one original strand (semi-conservative replication).

Question 4: Protein Synthesis and Frameshift Mutation

A mature mRNA has 900 bases, including one stop codon. Translation starts at the first codon.

How many codons does this mRNA contain? *(3 marks)*

Answer: 900 / 3 = 300 codons.

How many amino acids are produced? *(4 marks)*

Answer: 300 - 1 = 299; the stop codon does not code for an amino acid, it only terminates translation.

How many bases are on the DNA template strand that produced this mRNA? *(4 marks)*

Answer: 900 bases; the template strand is the same length as the mRNA and is transcribed by complementary base pairing.

If one base is deleted after the 200th codon, explain the effect on the protein produced. *(5 marks)*

Answer: This is a frameshift mutation: the reading frame after codon 200 is shifted, so every later codon specifies a different amino acid. The protein is usually non-functional, and a premature stop codon may shorten the polypeptide.

Question 5: PCR and Genetic Engineering

The polymerase chain reaction (PCR) starts from one double-stranded DNA molecule and the target fragment doubles in every cycle.

How many copies are obtained after 20 cycles? *(4 marks)*

Answer: 2^20 = 1,048,576 copies.

And after 30 cycles? *(4 marks)*

Answer: 2^30 = 1,073,741,824 copies (about 1.07 x 10^9).

In gel electrophoresis of fragments of 200 bp, 600 bp and 1,800 bp, which migrates furthest and why? *(4 marks)*

Answer: The 200 bp fragment migrates furthest; it is the shortest, meets the least resistance from the gel network and therefore moves fastest.

A 6,000 bp plasmid is cut by a restriction enzyme into a 4,200 bp fragment and one other fragment. Find the length of the other fragment and explain towards which electrode DNA moves. *(4 marks)*

Answer: 6,000 - 4,200 = 1,800 bp. DNA carries negative charges on its phosphate groups, so it moves from the negative electrode towards the positive electrode.

Question 6: The Hardy-Weinberg Principle

A population of 1,000 people contains 90 individuals showing the recessive trait (genotype aa). Assume the population is in Hardy-Weinberg equilibrium and the gene has only two alleles, A and a.

Find the frequency q of allele a. *(4 marks)*

Answer: q^2 = 90 / 1,000 = 0.09, so q = 0.3.

Find the frequency p of allele A. *(4 marks)*

Answer: p = 1 - q = 1 - 0.3 = 0.7.

Find the number of carriers (Aa). *(4 marks)*

Answer: 2pq = 2 x 0.7 x 0.3 = 0.42; 0.42 x 1,000 = 420 people.

Find the number of individuals showing the dominant trait and write the formula used. *(4 marks)*

Answer: p^2 + 2pq = 0.49 + 0.42 = 0.91; 0.91 x 1,000 = 910 people (or 1,000 - 90 = 910).