S6 Biology Practice Paper: Genetics and Dihybrid Crosses, DNA and Protein Synthesis, Biotechnology and Genetic Engineering, Evolution and Population Genetics, Ecosystem Energy Flow, Human Physiology and Homeostasis (100 marks)

S6 | Biology | Time: 75 minutes | Total: 100 marks | 24 questions

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Part 1: Genetics and Dihybrid Crosses (17 marks)

Show a genetic diagram or full working; use standard symbols for genotypes.

1. In peas, round seed (R) is dominant to wrinkled (r) and yellow cotyledon (Y) is dominant to green (y); the two genes are on different chromosomes. Two RrYy plants are crossed. Out of 320 offspring, how many are expected to be round and yellow? [4]

Answer: The genes assort independently, giving a 9:3:3:1 ratio over 16 combinations. Round yellow is 9/16, so 9/16 x 320 = 180 plants.

2. A test cross is made between an RrYy plant and an rryy plant. If 240 offspring are produced, how many of each phenotype are expected? [4]

Answer: A test cross gives four phenotypes in a 1:1:1:1 ratio, so each phenotype = 240 / 4 = 60 plants.

3. Human ABO blood group is controlled by alleles IA, IB and i, with IA and IB codominant. If the mother is type A (IAi) and the father is type B (IBi), find the probability that a child is type O and list all possible blood groups. [4]

Answer: The cross IAi x IBi gives IAIB, IAi, IBi and ii in equal proportions. Type O (ii) has probability 1/4, i.e. 25 percent; possible groups are AB, A, B and O.

4. Red-green colour blindness is X-linked recessive. A carrier mother with normal vision (XcX) marries a father with normal vision (XY). If they have 200 sons, how many are expected to be colour-blind, and what proportion of daughters are carriers? [5]

Answer: Each son receives Xc or X from the mother with equal chance, so 200 x 1/2 = 100 colour-blind sons. All daughters receive X from the father and are unaffected, but half receive Xc from the mother, i.e. 50 percent are carriers.

Part 2: DNA and Protein Synthesis (17 marks)

Show the base-pairing rule or formula; state the units in your answers.

5. In a double-stranded DNA sample, adenine (A) makes up 30 percent of all bases. Find the percentages of thymine (T), guanine (G) and cytosine (C). [4]

Answer: A pairs with T, so T = A = 30 percent; the remaining 100 - 30 - 30 = 40 percent is shared equally by G and C, so G = C = 20 percent.

6. A protein consists of 150 amino acids. Ignoring the start codon, find the minimum number of codons needed on the mRNA, and the number of bases including the stop codon. [4]

Answer: Each amino acid is coded by one codon of 3 bases, so 150 codons and 150 x 3 = 450 bases are needed; adding one stop codon gives 151 codons and 453 bases.

7. After 3 rounds of semi-conservative replication, how many DNA molecules are produced from one DNA molecule, and what percentage of them contain an original parental strand? [4]

Answer: Three rounds give 2 to the power 3 = 8 molecules; each molecule has one new and one old strand, and the two parental strands end up in 2 molecules, i.e. 2 / 8 = 25 percent.

8. A gene has 300 bases and one base pair is deleted at position 10. How many codons before the affected codon remain unchanged, and approximately how many codons from the affected codon onwards are changed? [5]

Answer: The 9 bases before the deletion form 3 complete codons that are unaffected. The remaining 299 - 9 = 290 bases are read in a shifted frame, changing about 290 / 3 = 96 codons and possibly creating a premature stop codon.

Part 3: Biotechnology and Genetic Engineering (17 marks)

Show the formula in calculations; use correct biological terms in explanations.

9. A circular plasmid is 4000 bp long and a restriction enzyme has 3 recognition sites on it. How many DNA fragments result from complete digestion, and how many if the same enzyme acts on a linear DNA of the same length? [4]

Answer: Cutting circular DNA 3 times gives 3 fragments; a linear molecule cut 3 times gives 4 fragments.

10. In the polymerase chain reaction (PCR), each cycle doubles the amount of target DNA. Starting from one target molecule, how many molecules are present after 10 cycles and after 20 cycles? [4]

Answer: Number of molecules = 2 to the power n. After 10 cycles = 2 to the power 10 = 1024; after 20 cycles = 2 to the power 20 = 1048576.

11. After digestion and gel electrophoresis a plasmid gives three bands of 1800, 1200, 1000 bp. The plasmid is 4000 bp long. Find the sum of the three band sizes and explain how to decide whether they come from the same circular plasmid. [4]

Answer: The bands sum to 1800 + 1200 + 1000 = 4000 bp, which matches the plasmid size, so the three bands can come from one circular plasmid: a total equal to the full length means complete digestion and the fragments join end to end.

12. In an experiment 0.5 microgram of recombinant plasmid is used to transform bacteria. A 0.1 mL sample of the 1.0 mL culture is plated and gives 200 colonies. Find the transformation efficiency in colonies per microgram of DNA. [5]

Answer: Total colonies = 200 / 0.1 = 2000; efficiency = 2000 / 0.5 = 4000 colonies per microgram.

Part 4: Evolution and Population Genetics (17 marks)

For Hardy-Weinberg calculations, state the values of p, q and 2pq.

13. A recessive disease affects 1 in 10000 people in a population at Hardy-Weinberg equilibrium. Find the recessive allele frequency q, the dominant allele frequency p, and the percentage of carriers. [4]

Answer: q squared = 1/10000, so q = 0.01 and p = 1 - 0.01 = 0.99; carriers 2pq = 2 x 0.99 x 0.01 = 0.0198, i.e. 1.98 percent.

14. A population of 500 people contains 20 individuals showing a recessive trait and the rest normal, in Hardy-Weinberg equilibrium. Find q, p and the number of carriers. [4]

Answer: q squared = 20 / 500 = 0.04, so q = 0.2 and p = 0.8; 2pq = 2 x 0.8 x 0.2 = 0.32, giving 0.32 x 500 = 160 carriers.

15. In a beetle population, dark colour is controlled by a dominant allele. Before selection there are 400 dark and 100 pale beetles; after selection 360 dark and 40 pale remain. Find the percentage of dark beetles before and after selection and explain how the population evolves. [4]

Answer: Before selection: 400 / (400 + 100) = 80.0 percent; after selection: 360 / (360 + 40) = 90.0 percent. The rise in the dark proportion means the dominant allele frequency has increased, which is directional evolution by natural selection.

16. A bacterial population contains 10 to the power 8 cells and the mutation rate for drug resistance is 1 in 10 to the power 7 cells. Find the number of resistant cells before any antibiotic is used, and explain why resistant bacteria quickly dominate after antibiotic treatment. [5]

Answer: Resistant cells = 10 to the power 8 x 1/10 to the power 7 = 10. The antibiotic kills sensitive cells, so resistant cells multiply without competition and the resistance allele frequency rises rapidly, making them dominant within a short time.

Part 5: Ecosystems and Energy Flow (16 marks)

Show the formula and units in energy calculations.

17. Producers in an ecosystem fix 50000 kJ of energy and the transfer efficiency between trophic levels is 10 percent. Find the theoretical energy available to primary, secondary and tertiary consumers. [4]

Answer: Primary consumers = 50000 x 10 percent = 5000 kJ; secondary = 5000 x 10 percent = 500 kJ; tertiary = 500 x 10 percent = 50 kJ.

18. Gross primary production (GPP) in a forest is 8000 kJ per square metre per year and producers respire 3000 kJ per square metre per year. Find net primary production (NPP) and state its significance. [4]

Answer: NPP = GPP - respiration = 8000 - 3000 = 5000 kJ per square metre per year. NPP is the energy available to consumers and decomposers and limits the biomass the ecosystem can support.

19. In the same forest, primary consumers assimilate 1200 kJ per square metre per year. Find the energy transfer efficiency from producers to primary consumers and explain where the rest of the energy goes. [4]

Answer: Efficiency = 1200 / 8000 x 100 percent = 15.0 percent. The rest is lost as heat from respiration, egested in faeces and uneaten parts, or stored in biomass not yet transferred.

20. A woodland produces 1000 kg of dry leaf litter per year containing 45 percent carbon. If all of it is decomposed, find the mass of carbon released and the equivalent mass of carbon dioxide (C = 12, CO2 = 44). [4]

Answer: Carbon mass = 1000 x 0.45 = 450.0 kg; CO2 mass = 450.0 x 44 / 12 = 1650 kg. Decomposers oxidise organic carbon to CO2 and return it to the atmosphere, completing the carbon cycle.

Part 6: Human Physiology and Homeostasis (16 marks)

Show the formula; in explanations describe the control mechanism.

21. A person has a glomerular filtration rate of 125 mL per minute, and 99 percent of the filtrate is reabsorbed in the tubules. Find the urine production per minute and per day (1440 minutes). [4]

Answer: Urine = 125 x (1 - 0.99) = 1.250000000000001 mL per minute; per day = 1.250000000000001 x 1440 = 1800 mL, about 1.8 L.

22. A person has a stroke volume of 70 mL and a resting heart rate of 72 beats per minute. Find the cardiac output in mL per minute and in litres per minute. [4]

Answer: Cardiac output = stroke volume x heart rate = 70 x 72 = 5040 mL per minute = 5.04 litres per minute.

23. A person has a tidal volume of 500 mL, a breathing rate of 15 per minute and an anatomical dead space of 150 mL. Find the total ventilation and the alveolar ventilation per minute. [4]

Answer: Total ventilation = 500 x 15 = 7500 mL per minute; alveolar ventilation = (500 - 150) x 15 = 5250 mL per minute.

24. After a meal a person blood glucose rises to 8.0 mmol per litre and falls to 6.0 mmol per litre two hours later; the fasting level is 5.5 mmol per litre. Find the percentage change from the peak to the two-hour value and describe the hormones involved. [4]

Answer: Percentage change = (6.0 - 8.0) / 8.0 x 100 percent = -25.0 percent. Insulin released by pancreatic beta cells increases glucose uptake and glycogen synthesis, lowering blood glucose; glucagon acts in the opposite direction when glucose is low.
