

GCSE / IGCSE Biology – Inheritance and Evolution

GCSE / IGCSE Biology (Edexcel/AQA/Cambridge style) · Total marks: 39 · Answers on the last page

Questions on DNA and genes, genetic crosses and Punnett squares, variation and selection, and genetic engineering. A calculator is not required, but working should be shown for all genetics calculations.

Section A – DNA and Genes

- (a) State what is meant by the terms gene and allele.
 - (b) Describe the basic structure of a DNA molecule. [4]
- Distinguish between a dominant allele and a recessive allele, and explain the difference between the terms genotype and phenotype. [3]
- Explain, in outline, how a mutation in a gene can lead to a change in the phenotype of an organism. [3]
- A human body cell contains 46 chromosomes.
 - (a) State how many chromosomes would be present in a human gamete (sex cell), and explain why this number is important for fertilisation.
 - (b) Name the type of cell division that produces gametes. [3]

Section B – Genetic Crosses (Show all Punnett square working)

- Cystic fibrosis is caused by a recessive allele, f . Two parents, both unaffected carriers with genotype Ff , have a child.
 - (a) Draw a genetic (Punnett square) diagram to show the possible genotypes of their children.
 - (b) Calculate the probability that a child of these two parents has cystic fibrosis. [4]
- In pea plants, round seed shape (R) is dominant to wrinkled (r), and yellow seed colour (Y) is dominant to green (y). Two plants that are heterozygous for both genes ($RrYy$) are crossed.
 - (a) State the expected phenotypic ratio of the offspring.
 - (b) Calculate the probability that an offspring plant has round, yellow seeds. [4]
- Red-green colour blindness is caused by a recessive allele carried on the X chromosome. A woman who is a carrier ($X^N X^n$) has children with a man who has normal colour vision ($X^N Y$).
 - (a) Draw a genetic diagram to show the possible genotypes of their children.
 - (b) Calculate the probability that a son of this couple is colour blind. [4]
- Explain how a test cross can be used to determine whether an organism showing the dominant phenotype is homozygous dominant or heterozygous. [2]

Section C – Variation, Selection and Genetic Engineering

- Distinguish between continuous variation and discontinuous variation, giving one example of each. [2]
- Explain, using the theory of natural selection, how a population of bacteria can become resistant to an antibiotic over time. [4]

11. Describe the main steps involved in using genetic engineering to produce a genetically modified (transgenic) organism, such as bacteria producing human insulin. [4]
12. Explain one benefit and one potential risk or ethical concern associated with genetic engineering of crop plants. [2]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

- (a) A gene is a section of a DNA molecule (on a chromosome) that codes for a particular protein (characteristic). An allele is one of the different versions of a gene.

(b) DNA is a polymer made of two strands, each made of repeating nucleotide units, wound together to form a double helix; the two strands are held together by (complementary) base pairing between the bases on each strand (A with T, and C with G).
- A dominant allele is one whose characteristic appears in the phenotype even if only one copy is present (heterozygous or homozygous); a recessive allele's characteristic only appears in the phenotype when two copies are present (homozygous recessive). Genotype is the genetic make-up of an organism in terms of the alleles present (e.g. Ff); phenotype is the observable physical or biochemical characteristic that results from the genotype (and, in some cases, the environment).
- A mutation is a random change to the base sequence of DNA. This may change the sequence of amino acids in the protein for which the gene codes, which can alter the protein's shape (particularly if it is an enzyme's active site) and therefore its function; if the protein no longer functions correctly, this can produce a different, observable characteristic (phenotype). Most mutations have little or no effect on the protein/phenotype, but occasionally a mutation is beneficial or harmful.
- (a) A human gamete contains 23 chromosomes (half the number in a body cell). This is important because when two gametes (sperm and egg) fuse at fertilisation, the resulting zygote has the full number of 46 chromosomes, restoring the normal chromosome number for the species.

(b) Meiosis.
- (a) Cross $Ff \times Ff$ gives offspring genotypes FF, Ff, Ff, ff (in the ratio 1 : 2 : 1).

(b) Only the genotype ff has cystic fibrosis, so the probability is $\frac{1}{4}$ (25).
- (a) The expected phenotypic ratio is 9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green.

(b) The probability of round, yellow seeds ($R_Y_$) is $\frac{9}{16}$.
- (a) Cross $X^N X^n \times X^N Y$ gives offspring $X^N X^N, X^N X^n, X^N Y, X^n Y$, each with probability $\frac{1}{4}$.

(b) Among sons only ($X^N Y$ or $X^n Y$, each equally likely), the probability that a son is colour blind ($X^n Y$) is $\frac{1}{2}$.
- The organism of unknown genotype is crossed with an organism that is homozygous recessive for the characteristic. If all the offspring show the dominant phenotype, the unknown organism is homozygous dominant; if approximately half the offspring show the recessive phenotype, the unknown organism is heterozygous.
- Continuous variation shows a full range of values between two extremes with no distinct categories (e.g. human height or body mass), often influenced by both genes and environment. Discontinuous variation falls into a small number of distinct, separate categories with no intermediate forms (e.g. human ABO blood group, or flower colour controlled by a single gene), usually controlled entirely by genes.
- Within the bacterial population there is genetic variation, and by chance some bacteria may already carry a mutation that gives resistance to the antibiotic. When the antibiotic is used, non-resistant bacteria are killed, but the resistant bacteria survive and are able to reproduce, passing

the resistance allele on to their offspring. Over many generations, the proportion of resistant bacteria in the population increases, until eventually most or all of the population is resistant to that antibiotic.

11. The desired gene (e.g. for human insulin) is identified and cut out of the human DNA using a restriction enzyme; a plasmid from a bacterium is cut open using the same restriction enzyme, leaving complementary sticky ends; the gene is inserted into the plasmid and joined using an enzyme called ligase, producing recombinant DNA; the recombinant plasmid is inserted into a (host) bacterial cell, which is then cultured (grown) so that it multiplies and expresses the new gene, producing the desired protein (e.g. insulin) on a large scale.
12. Benefit: a gene for resistance to a pest, disease or herbicide (or for improved nutritional content) can be inserted into a crop, potentially increasing crop yield and food security. Risk/ethical concern: any valid point, e.g. the possibility of the introduced gene spreading to wild relative species through cross-pollination, potential unknown long-term effects on human health or the environment, or reduced genetic diversity in crops grown as a monoculture.

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