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**WHAT YOU NEED TO KNOW**

**AQA GCSE BIOLOGY. UNIT 6-INHERITANCE, VARIATION AND EVOLUTION.**

In this section we will discover how the number of chromosomes are halved during meiosis and then combined with new genes from the sexual partner to produce unique offspring. Gene mutations occur continuously and on rare occasions can affect the functioning of the animal or plant. These mutations may be damaging and lead to a number of genetic disorders or death. Very rarely a new mutation can be beneficial and consequently, lead to increased fitness in the individual. Variation generated by mutations and sexual reproduction is the basis for natural selection; this is how species evolve. An understanding of these processes has allowed scientists to intervene through selective breeding to produce livestock with favoured characteristics. Once new varieties of plants or animals have been produced it is possible to clone individuals to produce larger numbers of identical individuals all carrying the favourable characteristic. Scientists have now discovered how to take genes from one species and introduce them in to the genome of another by a process called genetic engineering. In spite of the huge potential benefits that this technology can offer, genetic modification still remains highly controversial.

| **Specification code** | **Expected knowledge and understanding** | **** |
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| 4.6.1.1  Sexual and asexual reproduction | 1. Students should understand that meiosis leads to non-identical cells being formed while mitosis leads to identical cells being formed. 2. Sexual reproduction involves the joining (fusion) of male and female gametes:  * sperm and egg cells in animals. * pollen and egg cells in flowering plants.  1. In sexual reproduction there is mixing of genetic information which leads to variety in the offspring. The formation of gametes involves meiosis. 2. Asexual reproduction involves only one parent and no fusion of gametes. There is no mixing of genetic information. This leads to genetically identical offspring (clones). Only mitosis is involved. |  |
| 4.6.1.2 Meiosis | 1. Students should be able to explain how meiosis halves the number of chromosomes in gametes and fertilisation restores the full number of chromosomes. 2. Cells in reproductive organs divide by meiosis to form gametes. When a cell divides to form gametes:  * copies of the genetic information are made * the cell divides twice to form four gametes, each with a single set of chromosomes. * all gametes are genetically different from each other.  1. Gametes join at fertilisation to restore the normal number of chromosomes. The new cell divides by mitosis. The number of cells increases. As the embryo develops cells differentiate. Knowledge of the stages of meiosis is not required. |  |

**4.6.1 Reproduction**

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| 4.6.1.3 Advantages and disadvantages of sexual and asexual reproduction (biology only) | 1. Advantages of sexual reproduction:  * produces variation in the offspring. * if the environment changes variation gives a survival advantage by natural selection. * natural selection can be speeded up by humans in selective breeding to increase food production.  1. Advantages of asexual reproduction:  * Some organisms reproduce by both methods depending on the circumstances. * Malarial parasites reproduce asexually in the human host, but sexually in the mosquito. * Many fungi reproduce asexually by spores but also reproduce sexually to give variation. * Many plants produce seeds sexually, but also reproduce asexually by runners such as strawberry plants, or bulb division such as daffodils.  1. Knowledge of reproduction in organisms is restricted to those mentioned. |  |
| 4.6.1.4  DNA and the genome | 1. Students should be able to describe the structure of DNA and define genome. 2. The genetic material in the nucleus of a cell is composed of a chemical called DNA. DNA is a polymer made up of two strands forming a double helix. The DNA is contained in structures called chromosomes. 3. A gene is a small section of DNA on a chromosome. Each gene codes for a particular sequence of amino acids, to make a specific protein. 4. Students should be able to discuss the importance of understanding the human genome. 5. This is limited to the:  * search for genes linked to different types of disease * understanding and treatment of inherited disorders. * use in tracing human migration patterns from the past. |  |
| 4.6.1.5  DNA structure (biology only) | 1. Students should be able to describe DNA as a polymer made from four different nucleotides. Each nucleotide consists of a common sugar and phosphate group with one of four different bases attached to the sugar. 2. DNA contains four bases, A, C, G and T. 3. A sequence of three bases is the code for a particular amino acid. The order of bases controls the order in which amino acids are assembled to produce a particular protein. |  |

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|  | 1. The long strands of DNA consist of alternating sugar and phosphate sections. Attached to each sugar is one of the four bases. 2. The DNA polymer is made up of repeating nucleotide units. 3. (HT only) Students should be able to:  * recall a simple description of protein synthesis * explain simply how the structure of DNA affects the protein made * describe how genetic variants may influence phenotype: a) in coding DNA by altering the activity of a protein: and b) in non- coding DNA by altering how genes are expressed.  1. (HT only) In the complementary strands a C is always linked to a G   on the opposite strand and a T to an A.   1. (HT only) Students are not expected to know or understand the structure of mRNA, tRNA, or the detailed structure of amino acids or proteins. 2. (HT only) Students should be able to explain how a change in DNA structure may result in a change in the protein synthesised by a gene. 3. (HT only) Proteins are synthesised on ribosomes, according to a template. Carrier molecules bring specific amino acids to add to the growing protein chain in the correct order. 4. (HT only) When the protein chain is complete it folds up to form a unique shape. This unique shape enables the proteins to do their job as enzymes, hormones or forming structures in the body such as collagen. 5. (HT only) Mutations occur continuously. Most do not alter the protein, or only alter it slightly so that its appearance or function is not changed. 6. (HT only) A few mutations code for an altered protein with a different shape. An enzyme may no longer fit the substrate binding site or a structural protein may lose its strength. |  |
| 4.6.1.6  Genetic Inheritance | 1. Students should be able to explain the terms:  * gamete, chromosome, gene, allele, dominant, recessive, homozygous, heterozygous, genotype, phenotype.  1. Some characteristics are controlled by a single gene, such as: fur colour in mice; and red-green colour blindness in humans. Each gene may have different forms called alleles. 2. The alleles present, or genotype, operate at a molecular level to develop characteristics that can be expressed as a phenotype. |  |

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|  | 1. A dominant allele is always expressed, even if only one copy is present. A recessive allele is only expressed if two copies are present (therefore no dominant allele present). 2. If the two alleles present are the same the organism is homozygous for that trait, but if the alleles are different they are heterozygous. 3. Most characteristics are a result of multiple genes interacting, rather than a single gene. 4. Students should be able to understand the concept of probability in predicting the results of a single gene cross, but recall that most phenotype features are the result of multiple genes rather than single gene inheritance. 5. Students should be able to use direct proportion and simple ratios to express the outcome of a genetic cross. 6. Students should be able to complete a Punnett square diagram and extract and interpret information from genetic crosses and family trees. 7. (HT only) Students should be able to construct a genetic cross by Punnett square diagram and use it to make predictions using the theory of probability. |  |
| 4.6.1.7 Inherited disorders | 1. Some disorders are inherited. These disorders are caused by the inheritance of certain alleles.  * Polydactyly (having extra fingers or toes) is caused by a dominant allele. * Cystic fibrosis (a disorder of cell membranes) is caused by a recessive allele.  1. Students should make informed judgements about the economic, social and ethical issues concerning embryo screening, given appropriate information. |  |
| 4.6.1.8  Sex determination | 1. Ordinary human body cells contain 23 pairs of chromosomes. 2. 22 pairs control characteristics only, but one of the pairs carries the genes that determine sex.  * In females the sex chromosomes are the same (XX).   • In males the chromosomes are different (XY).   1. Students should to be able to carry out a genetic cross to show sex inheritance. 2. Students should understand and use direct proportion and simple ratios in genetic crosses. |  |

**4.6.2 Variation and evolution**

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| 4.6.2.1 Variation | 1. Students should be able to describe simply how the genome and its interaction with the environment influence the development of the phenotype of an organism. 2. Differences in the characteristics of individuals in a population is called variation and may be due to differences in:  * the genes they have inherited (genetic causes) * the conditions in which they have developed (environmental causes) * a combination of genes and the environment.  1. Students should be able to:  * state that there is usually extensive genetic variation within a population of a species * recall that all variants arise from mutations and that: most have no effect on the phenotype; some influence phenotype; very few determine phenotype.  1. Mutations occur continuously. Very rarely a mutation will lead to a new phenotype. If the new phenotype is suited to an environmental change it can lead to a relatively rapid change in the species. |  |

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| 4.6.2.2 Evolution | 1. Students should be able to describe evolution as a change in the inherited characteristics of a population over time through a process of natural selection which may result in the formation of a new species. 2. The theory of evolution by natural selection states that all species of living things have evolved from simple life forms that first developed more than three billion years ago. 3. Students should be able to explain how evolution occurs through natural selection of variants that give rise to phenotypes best suited to their environment. 4. If two populations of one species become so different in phenotype that they can no longer interbreed to produce fertile offspring they have formed two new species. |  |
| 4.6.2.3 Selective breeding | 1. Students should be able to explain the impact of selective breeding of food plants and domesticated animals. 2. Selective breeding (artificial selection) is the process by which humans breed plants and animals for particular genetic characteristics. Humans have been doing this for thousands of years since they first bred food crops from wild plants and domesticated animals. 3. Selective breeding involves choosing parents with the desired characteristic from a mixed population. They are bred together. From the offspring those with the desired characteristic are bred together. This continues over many generations until all the offspring show the desired characteristic. 4. The characteristic can be chosen for usefulness or appearance:   • Disease resistance in food crops.  • Animals which produce more meat or milk.  • Domestic dogs with a gentle nature.  • Large or unusual flowers.   1. Selective breeding can lead to ‘inbreeding’ where some breeds are particularly prone to disease or inherited defects. |  |
| 4.6.2.4 Genetic engineering | 1. Students should be able to describe genetic engineering as a process which involves modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic. 2. Plant crops have been genetically engineered to be resistant to diseases or to produce bigger better fruits. 3. Bacterial cells have been genetically engineered to produce useful substances such as human insulin to treat diabetes. |  |

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|  | 1. Students should be able to explain the potential benefits and risks of genetic engineering in agriculture and in medicine and that some people have objections. 2. In genetic engineering, genes from the chromosomes of humans and other organisms can be ‘cut out’ and transferred to cells of other organisms. 3. Crops that have had their genes modified in this way are called genetically modified (GM) crops. GM crops include ones that are resistant to insect attack or to herbicides. GM crops generally show increased yields. 4. Concerns about GM crops include the effect on populations of wild flowers and insects. Some people feel the effects of eating GM crops on human health have not been fully explored. 5. Modern medical research is exploring the possibility of genetic modification to overcome some inherited disorders. 6. HT only) Students should be able to describe the main steps in the process of genetic engineering. 7. (HT only) In genetic engineering:  * enzymes are used to isolate the required gene; this gene is inserted into a vector, usually a bacterial plasmid or a virus * the vector is used to insert the gene into the required cells * genes are transferred to the cells of animals, plants or microorganisms at an early stage in their development so that they develop with desired characteristics. |  |
| 4.6.2.5 Cloning (biology only) | 1. Tissue culture: using small groups of cells from part of a plant to grow identical new plants. This is important for preserving rare plant species or commercially in nurseries. 2. Cuttings: an older, but simple, method used by gardeners to produce many identical new plants from a parent plant. 3. Embryo transplants: splitting apart cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers. 4. Adult cell cloning:  * The nucleus is removed from an unfertilised egg cell. * The nucleus from an adult body cell, such as a skin cell, is inserted into the egg cell. * An electric shock stimulates the egg cell to divide to form an embryo. * These embryo cells contain the same genetic information as the adult skin cell. * When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development. |  |

**4.6.3 The development of understanding of genetics and evolution**

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| 4.6.3.1 Theory of evolution (biology only) | 1. Charles Darwin, as a result of observations on a round the world expedition, backed by years of experimentation and discussion and linked to developing knowledge of geology and fossils, proposed the theory of evolution by natural selection. 2. Individual organisms within a particular species show a wide range of variation for a characteristic.  * Individuals with characteristics most suited to the environment are more likely to survive to breed successfully. * The characteristics that have enabled these individuals to survive are then passed on to the next generation.  1. Darwin published his ideas in *On the Origin of Species* (1859). There was much controversy surrounding these revolutionary new ideas. 2. The theory of evolution by natural selection was only gradually accepted because:  * the theory challenged the idea that God made all the animals and plants that live on Earth. * there was insufficient evidence at the time the theory was published to convince many scientists. * the mechanism of inheritance and variation was not known until * 50 years after the theory was published.  1. Other theories, including that of Jean-Baptiste Lamarck, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur. 2. A study of creationism is not required. |  |
| 4.6.3.2 Speciation (biology only) | 1. Students should be able to:  * describe the work of Darwin and Wallace in the development of the theory of evolution by natural selection * explain the impact of these ideas on biology.  1. Alfred Russel Wallace independently proposed the theory of evolution by natural selection. He published joint writings with Darwin in 1858 which prompted Darwin to publish *On the Origin of Species* (1859) the following year. 2. Wallace worked worldwide gathering evidence for evolutionary theory. He is best known for his work on warning colouration in animals and his theory of speciation. 3. Alfred Wallace did much pioneering work on speciation but more evidence over time has led to our current understanding of the theory of speciation. 4. Students should be able to describe the steps which give rise to new species. |  |

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| 4.6.3.3  The understanding of genetics (biology only) | 1. Students should be able to:  * describe the development of our understanding of genetics including the work of Mendel. * understand why the importance of Mendel’s discovery was not recognised until after his death.  1. In the mid-19th Century Gregor Mendel carried out breeding experiments on plants. One of his observations was that the inheritance of each characteristic is determined by ‘units’ that are passed on to descendants unchanged. 2. In the late 19th Century behaviour of chromosomes during cell division was observed. 3. In the early 20th Century it was observed that chromosomes and Mendel’s ‘units’ behaved in similar ways. This led to the idea that the ‘units’, now called genes, were located on chromosomes. 4. In the mid-20th Century the structure of DNA was determined and the mechanism of gene function worked out. 5. This scientific work by many scientists led to the gene theory being developed. |  |
| 4.6.3.4 Evidence for evolution | 1. Students should be able to describe the evidence for evolution including fossils and antibiotic resistance in bacteria. 2. The theory of evolution by natural selection is now widely accepted. 3. Evidence for Darwin’s theory is now available as it has been shown that characteristics are passed on to offspring in genes. There is further evidence in the fossil record and the knowledge of how resistance to antibiotics evolves in bacteria. |  |
| 4.6.3.5  Fossils | 1. Fossils are the ‘remains’ of organisms from millions of years ago, which are found in rocks. 2. Fossils may be formed:  * from parts of organisms that have not decayed because one or more of the conditions needed for decay are absent. * when parts of the organism are replaced by minerals as they decay. * as preserved traces of organisms, such as footprints, burrows and rootlet traces.  1. Many early forms of life were soft-bodied, which means that they have left few traces behind. What traces there were have been mainly destroyed by geological activity. This is why scientists cannot be certain about how life began on Earth. |  |

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|  | 1. We can learn from fossils how much or how little different organisms have changed as life developed on Earth. 2. Students should be able to extract and interpret information from charts, graphs and tables such as evolutionary trees. |  |
| 4.6.3.6 Extinction | 1. Extinctions occur when there are no remaining individuals of a species still alive. 2. Students should be able to describe factors which may contribute to the extinction of a species. |  |
| 4.6.3.7 Resistant bacteria | 1. Bacteria can evolve rapidly because they reproduce at a fast rate. Mutations of bacterial pathogens produce new strains. Some strains might be resistant to antibiotics, and so are not killed. They survive and reproduce, so the population of the resistant strain rises. The resistant strain will then spread because people are not immune to it and there is no effective treatment. 2. MRSA is resistant to antibiotics. 3. To reduce the rate of development of antibiotic resistant strains:  * doctors should not prescribe antibiotics inappropriately, such as treating non-serious or viral infections. * patients should complete their course of antibiotics so all * bacteria are killed and none survive to mutate and form resistant strains. * the agricultural use of antibiotics should be restricted.  1. The development of new antibiotics is costly and slow. It is unlikely to keep up with the emergence of new resistant strains. |  |

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| 4.6.4 Classification of living organisms | 1. Traditionally living things have been classified into groups depending on their structure and characteristics in a system developed by Carl Linnaeus. 2. Linnaeus classified living things into kingdom, phylum, class, order, family, genus and species. Organisms are named by the binomial system of genus and species. |
|  | 1. Students should be able to use information given to show understanding of the Linnaean system. Students should be able to describe the impact of developments in biology on classification systems. 2. As evidence of internal structures became more developed due to improvements in microscopes, and the understanding of biochemical processes progressed, new models of classification were proposed. 3. Due to evidence available from chemical analysis there is now a ‘three-domain system’ developed by Carl Woese. In this system organisms are divided into:    * Archaea (primitive bacteria usually living in extreme environments)    * Bacteria (true bacteria)    * Eukaryota (which includes protists, fungi, plants and animals). 4. Understand how scientific methods and theories develop over time. 5. Evolutionary trees are a method used by scientists to show how they believe organisms are related. They use current classification data for living organisms and fossil data for extinct organisms. Interpret evolutionary trees. |

4.6.4 Classification of living organisms