DNA, Genes and Protein Synthesis

- AQA Biology (Oxford): pp. 202–228
- AQA Biology (Hodder Education): pp. 56–83, 192–196

THE BASICS

Genes and Diversity

- Differences between individuals of a species, and different species, are due to **genetic variation** and **environmental factors**.
- DNA contains **non-coding** sections and sections with **regulatory** functions. A complete set of genes is a **genome**.
- A **gene** is a specific section of DNA, located at its **locus**, that codes for a particular **protein**. Proteins form and regulate other processes. A complete set of proteins is a **proteome**.
- Genetic variation is due to **gene mutations**, **chromosome mutations** or **randomisation** during **meiosis** and **fertilisation**.

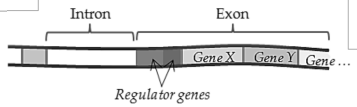
Structure of DNA and Genes

Homologous pair: Each chromosome is part of an identical pair (except male sex chromosomes).

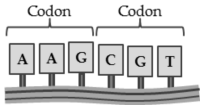
Chromosome: Each has two **chromatids** joined at the **centromere**. Chromatids can **crossover** and **recombine** different parts.

Genes and Alleles: Chromatids contain genes at their **locus**. An **allele** is a different form of the same gene on the sister chromatid. DNA coils and wraps around **histones**.

Introns and Exons: **Introns** are non-coding, consisting of unique **multiple base repeats** and 'start' or 'stop' **signals**. **Exons** code for **genes**.



Triplet code: Three bases code for a specific amino acid to form a protein. The **triplet code** is **universal** among life on earth, **non-overlapping** and **degenerate** – meaning most amino acids have more than one code.

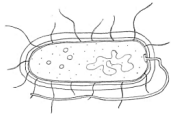


Differences between DNA and RNA:

- DNA consists of two complementary strands that form a double helix. Messenger RNA (**mRNA**) has a **single strand** that forms a **helix**, transfer RNA (**tRNA**) is a single strand that forms a **clover-leaf** shape.
- tRNA also has an **attachment site** where it is connected to an **amino acid**.

Eukaryotic and Prokaryotic DNA

Eukaryote	Prokaryotes
Long DNA	Short DNA
Linear DNA	**Circular** DNA
DNA arranged into **chromosomes**	DNA as single, circular loop
Associated with **histone** proteins	No association with proteins
DNA contained in nucleus	DNA within the cytoplasm



Mitochondria and **chloroplasts** in eukaryotes have prokaryotic DNA.

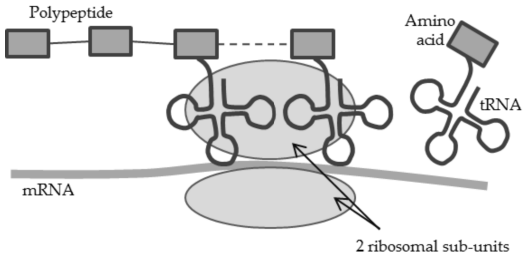
Protein Synthesis

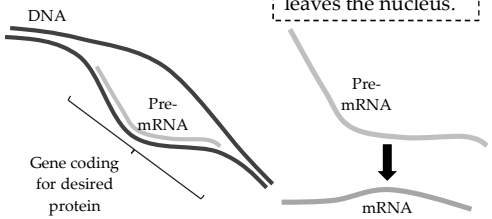
Transcription: A section of the DNA strands is separated **and pre-mRNA** is formed.

Splicing: In eukaryotic cells, **introns** are removed to form **mRNA**, which leaves the nucleus.

Translation: Ribosomes hold mRNA together with tRNA that has a complementary **anticodon**.

ATP provides energy to create **peptide bonds** between amino acids held by tRNA molecules creating a **protein**.





Mutation

There are five types of mutations in **somatic** cells or **germ** cells.

The table shows these mutations in the sequence CCAGTAT:

Type	Level	Description	Example
Substitution	Gene	A bases is **swapped**	CCATTAT
Addition	Gene	A base is **added**	CCAGCTAT
Deletion	Gene	A base is **deleted**	CCGTAT
Inversion	Chromosome	A section is **inverted**	CCATGAT
Duplication	Chromosome	A section is **duplicated**	CCAGCCATAT

Addition and **deletion** mutations are dangerous because they cause a **frame-shift**, where each subsequent **triplet codon is altered**. This means each subsequent amino acid in the protein could be wrong.

Mutations occur **randomly**; however, **mutagenic agents** increase mutation rate. These include **radiation**, such as UV light, X-rays and microwaves, and **chemicals**, such as cigarette smoke and mustard gas.

Meiosis

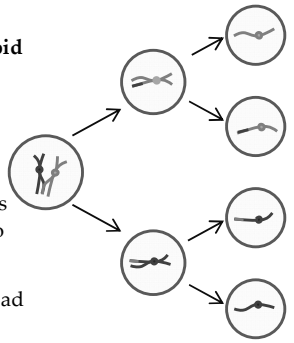
Meiosis involves **two stages of cell division** to produce **four haploid daughter cells**.

Meiosis I: **homologous** chromosomes split.

Meiosis II: **sister chromatids** divide.

Independent segregation and **recombination** of chromatids means each daughter cell is **unique**. **Random fertilisation** of gametes also increases genetic variation.

Errors in segregation, such as chromatids failing to separate, can lead to **genetic disorders** such as Down's syndrome.



Word cloud

Homologous pair, Chromosome, Chromatid, Locus, Allele, Histones, Intron, Exon, Triplet code, Codon, Independent segregation, Recombination, Random fertilisation, Pre-mRNA, mRNA, tRNA, Anticodon, Mutation, Somatic, Germ, Frame-shift, Mutagenic agent, Meiosis

Diversity, Adaptation and Taxonomy

- AQA Biology (Oxford): pp. 229–256
- AQA Biology (Hodder Education): pp.210–236

THE BASICS

Genetic Diversity and Biodiversity

- The closer related individuals are, the fewer **genetic differences** they have.
- Genes may be **advantageous**, so the individual is better **adapted** and more likely to survive and pass on their genes, increasing **reproductive success**.
- Comparing the differences between **physical features**, **genes** and **proteins** of many species allows organisms to be classified in a **hierarchy** based on their **evolutionary relationships**.
- A **species** is a group of individuals that can **interbreed** to produce **fertile** offspring. The **fossil record** shows how species have evolved over time.
- **Speciation** occurs when a species becomes isolated. **Genetic variation** provides a range of alleles within the two populations and **natural selection** results in individuals that are better **adapted** to each environment. The two populations become increasingly genetically different until they can no longer interbreed.

Allele Frequency

Genetic diversity involves the number of different **alleles** in a population. There are four main stages to **genetic change** in a population:

Random **mutation** changes an allele

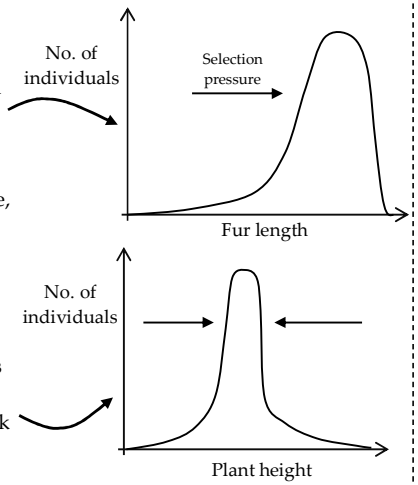
- **Beneficial**: increases reproductive success (e.g. attractiveness, health of offspring) → Beneficial allele is **inherited** → Beneficial allele **increases in frequency** in population
- **Harmful**: decreases reproductive success (e.g. prevents fertilisation, infertile/sickly offspring) → Harmful allele is **not inherited** → Harmful allele **decreases in frequency** in population

Natural Selection

Natural selection drives **evolution**. A species' **environment** determines which alleles are beneficial and form an **adaptation**. A change in the environment causing natural selection is a **selection pressure**.

Natural selection acts in different ways:

1) **Directional selection** – strong **directional response** in a population to **one selection pressure**, e.g. if the habitat of a wolf species becomes colder, those with **longer fur** are more likely to survive and reproduce, so longer fur would become more common in the population).
   Another, e.g. **antibiotic resistance**.
2) **Stabilising selection – reinforces a trait** within a population due to **two selection pressures**, e.g. taller **plants** receive more sunlight for photosynthesis, but are at greater risk of herbivory).
   Another example: **human birth**



Phylogenetic Classification and Taxonomy

Analysing **phylogenetic relationships** allows life to be classified into a **taxonomic hierarchy**. For example, red deer would be classified as:

Eukarya — Animalia — Chordata — Mammalia — Artiodactyla — Cervidae — Cervus — Red Deer

Domain — Kingdom — Phylum — Class — Order — Family — Genus — Species

Cervus elaphus

Exam Tip!
Come up with a mnemonic phrase to help you remember, e.g. **D**ear **K**ing **P**hillip **C**limbs **O**ver **F**ences **G**etting **S**plinters.

Binomial name: typed in italics or underlined if written, the genus is capitalised. The binomial name allows **universal** identification; however, **defining a species** is difficult if two species occasionally produce fertile offspring (e.g. horses and donkeys) or are in the process of **speciation**.

There are **three domains**, the highest taxonomic rank:

Bacteria	Archaea	Eukarya
Single-celled prokaryotes	Single-celled prokaryotes	Single- or multi-celled eukaryotes
Small 70s ribosomes	Small 70s ribosomes	Larger 80s ribosomes
Murein cell walls	Non-murein cell walls	Cellulose / chitin / no cell walls

Breeding with another species is rarely successful! **Species recognition** involves identifying your **own species**, the **healthiest** individuals and **when** they are able to breed. Characteristics for species recognition include:

- **colourful patterns** and visual displays, such as a male peacock's tail
- chemical signals called **pheromones**, these often signal when a female can be fertilised
- complex **courtship behaviours**, such as giving presents (other animals do this too!)

Species can look very similar; for example, an okapi looks like a cross between a horse and a zebra, but is actually the closest relative of giraffes. The **inaccuracy** of **anatomical classification** means need to compare **DNA**, **mRNA** or **protein** sequence and structure.

DNA Hybridisation

- DNA from two species is **cut** into small sections and the DNA from one of them is **radioactively** marked.
- DNA is **heated** to separate strands and cooled so **hybrid** strands form.
- Radioactive markers allow hybrid strands to be separated.
- Hybrid strands are heated again – if they split at a higher temperature it means they had more **hydrogen bonds between complementary bases**, meaning DNA was **similar** and the species were **closely related**.

Immunological comparisons

- **Monoclonal antibodies** bind **antigens** from each species
- More antigens from closely **related** organisms will bind because they will have **similar antigen structures**

Adaptations

Adaptations can be **anatomical** (e.g. longer legs for longer stride), **physiological** (e.g. more efficient respiration to produce ATP) or **behavioural** (e.g. stalking closer before sprinting).

Biodiversity and Conservation

Ecosystem diversity is the range of **habitats** in an ecosystem. **Species diversity** is the number of **different species** in a **community**, which can be measured using **Simpson's Diversity Index**. Communities have to be **randomly sampled** to remove **bias** and sample numbers have to be high to reduce the influence of **chance**.

Data is analysed using the **mean**, median and mode, and the **standard deviation** to measure the variation of data around the mean.

Intensive farming reduces biodiversity, farming practices must be **balanced** to maintain food production and conserve wildlife.
Damaging practices include:

- **Hedgerow** and **tree removal**
- Heavy **machinery** use
- **Monoculture**
- Use of **artificial herbicides**, **pesticides** and **fertilisers**

Simpson's Diversity Index

$$d = \frac{N(N-1)}{\Sigma n(n-1)}$$

d = diversity
N = no. individuals of all species
n = no. in each species

Word cloud

Genetic variation, Physiological, Courtship, DNA hybridisation, Selection pressure, Immunological, Directional selection, Monoclonal antibodies, Stabilising selection, Antigen structure, Behavioural, Ecosystem diversity, Reproductive success, Species diversity, Taxonomic hierarchy, Anatomical, Phylogenetics, Mean and standard deviation, Binomial, Intensive farming, Species recognition, Simpson's Diversity Index