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DNA replication

This is the means by which chromosomes (DNA) can form identical copies of themselves.

DNA replication begins when:

- The **hydrogen bonds** holding the base pairs together break.
- The strands of the parent DNA then separate.
- The DNA double helix unwinds.
- Each strand of the DNA now acts as a template.
- **Nucleotides**, with specific bases from the cytoplasm, match the free bases on each of the parent strands of DNA.

key point

Two enzymes are involved in DNA replication:

1. **DNA polymerase** creates a new strand of DNA by joining DNA nucleotides together.
2. **DNA ligase** joins separate strands of DNA together.

This process produces two DNA helices identical to the first. One half of each double helix contains the original parent strand (see fig. 2.33).

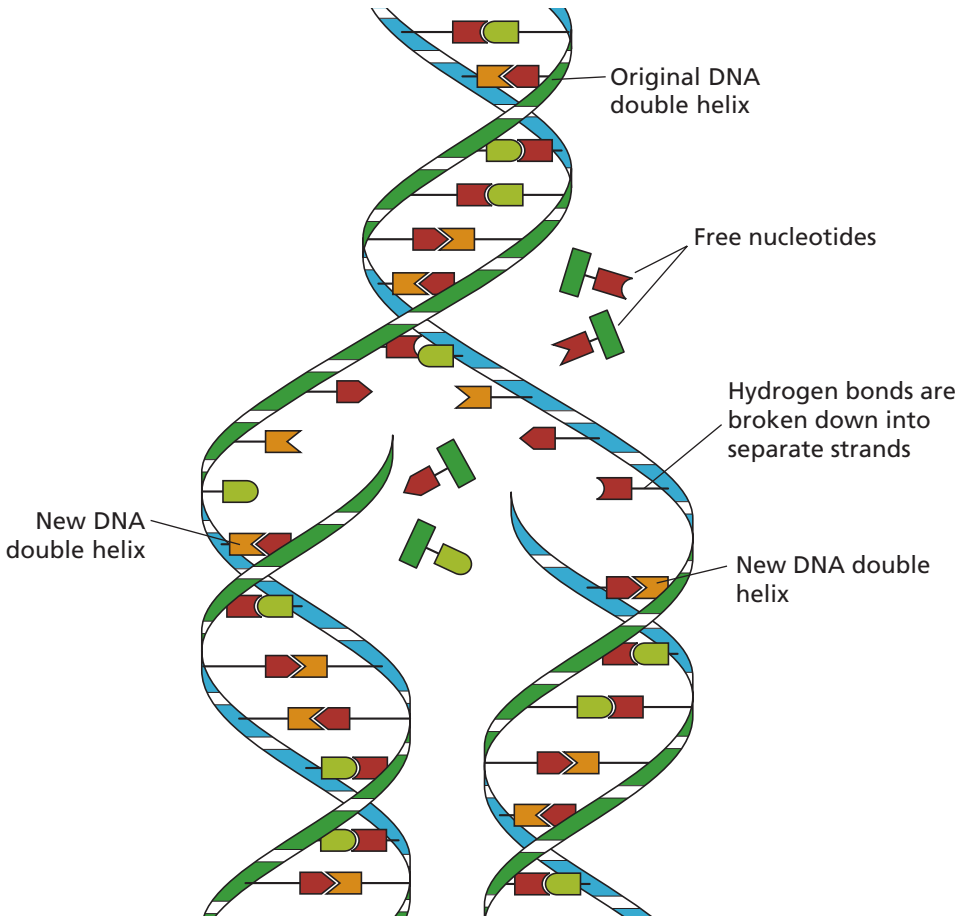

Figure 2.33 DNA replication

DNA and protein synthesis

Specific enzymes control all chemical reactions in the body. Enzymes are proteins made up of a defined sequence of amino acids.

- DNA codes for amino acids, and their correct sequence, through a triplet code.
- The nitrogen-containing bases (A, T, G and C) in DNA are arranged in threes along the double helix.
- Each triplet codes for one specific amino acid.
- DNA sends its code for an enzyme to the ribosome by messenger RNA, or **mRNA**.
- **Ribosomes**, in the cytoplasm, make the proteins.

Protein synthesis

HL

The whole process of protein synthesis occurs in two stages: transcription and translation.

1. Transcription

- When a particular enzyme is needed by a cell, the portion of DNA in the nucleus that codes for it unwinds, exposing its bases.
- A strand of mRNA is produced from RNA nucleotides, mirroring the DNA code.
- When complete, the strand of mRNA separates from the DNA and moves to a ribosome (rRNA) in the cytoplasm.

key point

The nucleotides on mRNA are arranged in a triplet code forming codons. Each **codon** codes for a particular amino acid.

tRNA also has a triplet code of nucleotides that match the codons of mRNA. Each matching triplet is known as an **anticodon**.

2. Translation

- At the ribosome, the mRNA code is matched by nucleotides of transfer RNA (tRNA). Each tRNA molecule carries a specific amino acid.
- The tRNA carries the amino acids in the correct sequence to the ribosome.
- The amino acids are then linked together in strict order, producing the protein (enzyme), which then assumes its unique **folded shape**.

Differences between DNA and RNA

	Structure	Function	Location
DNA	Deoxyribose is the sugar Double helix shape Base pairing Has the base thymine instead of uracil	Codes for genotype	Nucleus
RNA	Ribose is the sugar Single helix No base pairing Has the base uracil instead of thymine	**mRNA** carries code from nucleus to **rRNA** (ribosomes); **tRNA** transports amino acids	Cytoplasm

HL Non-nuclear inheritance of DNA

Many scientists believe that **mitochondria** and **chloroplasts** evolved from forms of bacteria. Through evolution they became assimilated into larger-celled organisms. The two organisms then formed a mutualistic (symbiotic) relationship, giving rise to plant and animal cells. Mitochondria and chloroplasts are unique as organelles in that they:

- contain their own DNA
- can replicate themselves in the cell.

key point

Non-nuclear DNA in chloroplasts and mitochondria does not undergo meiosis or fertilisation during sexual reproduction.

Mandatory activity

To isolate DNA from plant tissue

Note: *The extra information in brackets below is not required when describing the procedure.*

1. Add 3 g of **salt** to 10 cm^3 of washing-up liquid in a beaker and bring up to 100 cm^3 with distilled water. (*Salt reduces the attraction between protein and DNA. Washing-up liquid breaks down phospholipid membranes in the cell.)*
2. **Chop** some onion into very small pieces and add to the beaker. (*Chopping breaks down the cell walls and allows cytoplasm to leak out.*)
3. Put the beaker in a water bath at **60 °C for exactly 15 minutes**. (*High temperature denatures enzymes harmful to DNA. Any longer than 15 minutes, the DNA itself would break down.*)
4. **Cool** the mixture by placing in a large beaker of ice water for five minutes. (*Slows the activity of any remaining enzymes harmful to DNA.*)
5. Place the mixture in a **blender for three seconds**. (*Blending further breaks down cell walls and membranes. Any longer than three seconds shreds the DNA.*)
6. **Filter** the mixture into a second beaker. (*Removes cellular debris.*)
7. Place 10 cm^3 of the filtrate into a test tube.
8. Add 3 drops of **protease solution** and mix gently. (*Breaks down proteins associated with DNA.*)
9. Trickle 10 cm^3 of **ethanol from the freezer** down the side of the test tube.
10. Leave for a few minutes to settle. (*Cold ethanol draws water from DNA, condensing it.*)
11. Gently stir with a glass rod.

Expected result

White mucus-like DNA forms at the interface of the ethanol and the filtrate.

DNA profiling

Humans have 23 pairs of chromosomes in the nucleus of every cell in the body (with the exception of gametes). A single chromosome can have up to 4,000 genes, which code for different traits. It is known that 90 per cent of DNA does not code for any gene or protein in the body.

Coding DNA refers to sections of DNA that make up genes. They code for an enzyme or protein.

Non-coding DNA describes sections of DNA, between genes, that do not code for an enzyme or protein. They are often referred to as 'junk DNA'.

The sections of non-coding DNA often have repeating nucleotide sequences in sections called hypervariable regions. The number and length of these nucleotide sequences vary between individuals, but are similar in related individuals.

Forensic scientists use DNA profiling to compare DNA from hair, saliva, blood or semen found at the scene of a crime.

The procedure for DNA profiling is outlined in fig. 2.34.

DNA profiling or DNA fingerprinting uses the repeating nucleotide sequences of non-coding DNA to produce a pattern of bands for comparison of individuals.

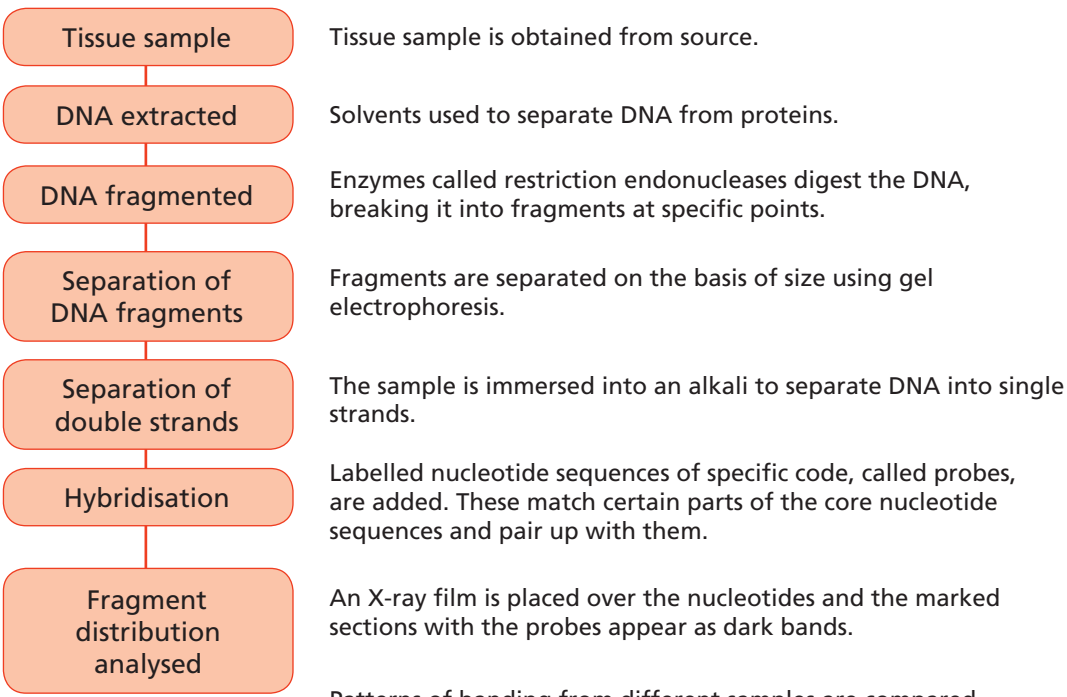

Figure 2.34 DNA profiling

Applications of DNA profiling

DNA profiling can be used to:

- prove the parentage of a child
- detect criminals guilty of violent crimes
- confirm pedigree in animals.

Genetic screening and testing

Genetic screening is the use of laboratory procedures to test a large number of individuals to identify those who may have or may pass on a genetic disorder.

Example: Amniocentesis is the testing of the cells in the amniotic fluid around the foetus for genetic disorders such as **Down's syndrome**.

Genetic testing describes the laboratory procedures used to investigate an individual suspected of having a high risk of a genetic disorder, based on family history or a positive screening test.

Example: The testing for the genetic disorder responsible for **cystic fibrosis**.

Genetic engineering and applications

Genetic engineering is a process where genes from one organism are introduced into the genome (DNA) of an unrelated organism, usually micro-organisms.

The micro-organisms with the new genes are replicated and used to create large quantities of useful chemicals.

Note: The process is often referred to as **recombinant DNA technology**.

Genetic engineering involves the following steps.

- Locating a specific gene in a donor cell.
- Isolation of the gene.
- Insertion of the gene into the DNA that has been removed from a micro-organism.
- Transferring the DNA and new gene back into the micro-organism.
- Replicating the micro-organism and harvesting the chemicals produced due to the new gene.

The process is summarised in fig. 2.35.

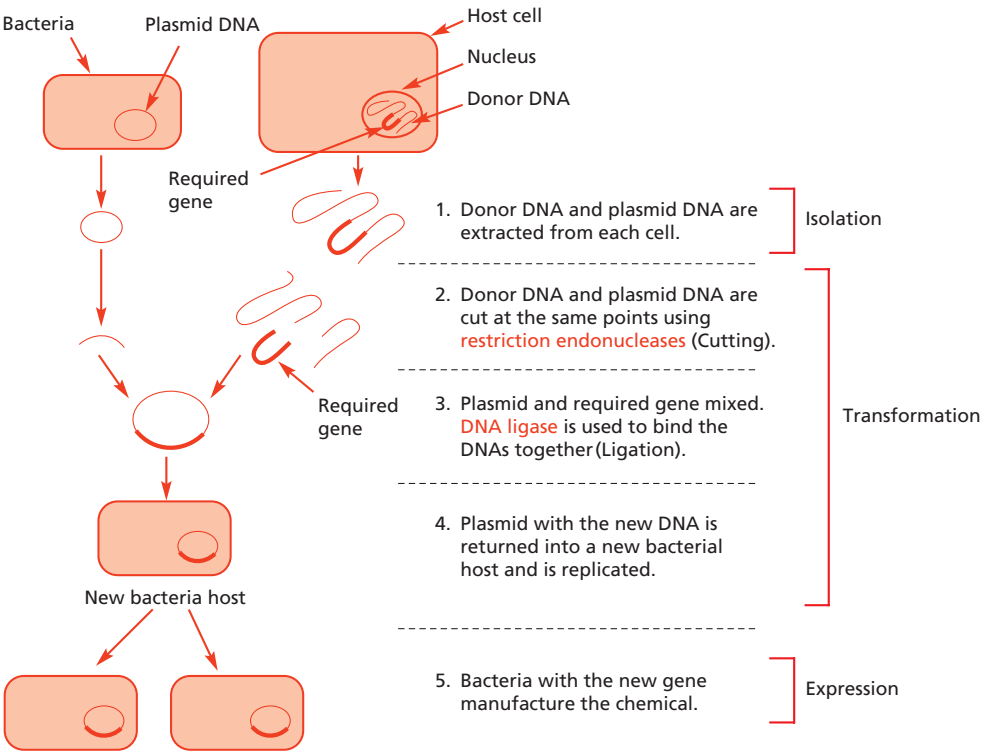

Figure 2.35 Genetic engineering

Applications of genetic engineering

- There is enormous demand for the hormone insulin to treat **insulin-dependent diabetes**. This disease used to be treated by using insulin obtained from the pancreas of cattle and pigs. Subtle differences in the forms of insulin stimulated antibody responses in some humans. Genetic engineering is now used to isolate the human gene for insulin production. The gene is inserted into a host bacterium to produce large quantities of human insulin.
- Genetically modified **plants** have an advantageous gene inserted into their DNA which is passed on to future generations. Characteristics such as disease and insect resistance have been introduced into food crops. The improved plant has greater yields.
- In **animals**, genetic engineering has been used to increase meat and milk yields in cattle.
- In **microorganisms**, bacteriophage can be genetically engineered to kill antibiotic-resistant bacteria.

exam Q

HL

2014 Q7 (a)/(b) HIGHER LEVEL

7. (a) (i) What is the chemical composition of a chromosome?

(ii) What is meant by the term junk DNA?

(b) (i) In relation to the isolation of DNA from a plant tissue, explain why you used each of the following:

1. Washing-up or similar liquid.
2. Sodium chloride.
3. Protease.
4. Freezer-cold ethanol.

LEAVING CERT MARKING SCHEME

7. (a) 5 + 1

(a) (i) DNA and protein

(ii) Non-coding (DNA)

(b) 8 + 8 + 1 + 1

(b) (i) 1. To breakdown the (cell) membrane(s)

2. To cause the DNA to clump
3. To breakdown (or remove or digest) the protein in the chromosomes
4. To bring the DNA out of solution **or** to make the DNA visible **or** to separate the DNA

HL

2015 Q10 (b) HIGHER LEVEL

10. (b) Write notes on each of the following topics in relation to nucleic acids. In each case your notes should contain three points. Do not give diagrams in your answers.

(i) Complementary base pairs.

(ii) Codons.

(iii) Transcription. **(27)**

LEAVING CERT MARKING SCHEME

10. (b) (i) (Two bases joined by) hydrogen bonds / purine with pyrimidine / Cytosine with Guanine / Adenine with Thymine in DNA / Adenine with Uracil in RNA **or** Thymine replaced by Uracil in RNA **(3[3])**

(ii) Sequence(c) of three bases / on DNA / on mRNA **or** on tRNA / (each codon) codes for one amino acid / that codes for a start (or stop) **(3[3])**

(iii) mRNA is formed / using a (single) strand of DNA / (DNA acts) as a template (or described) / in nucleus / (catalysed by) RNA polymerase **(3[3])**