Gene technology

Genetically modified organisms and drug production, recombinant DNA with restriction enzymes and ligase, inserting genes into cells, microarrays, bioinformatics, and the risks and benefits of GMOs.

Producing drugs with genetically modified organisms

Genetically modified organisms (GMOs) have had **genes from another species** inserted into their genome (**transgenic**). Drugs and other products can be made by GM **microorganisms, plants or animals**.

Host	Example	Advantages and issues
Bacteria	Human **insulin** made by *E. coli*	Fast, cheap, grow in large fermenters; a pure product; no animal sources. But bacteria cannot modify some proteins
Plants	Vaccines or antibodies in plants; **Golden Rice** (beta-carotene)	Cheap to grow, and edible vaccines; slow growth; possible escape of genes
Animals	Human proteins (e.g. clotting factor) in the **milk** of goats or sheep	Can make complex proteins correctly folded and modified; expensive; welfare and ethical issues

Making recombinant DNA

Recombinant DNA is DNA that combines sequences from two different organisms.

1. **Obtain the gene**:
   - cut from the genome using **restriction endonucleases**, or
   - make a copy of the **mRNA** and use **reverse transcriptase** to make **complementary DNA (cDNA)**, or
   - synthesise it from the known sequence.
2. **Cut the gene and the vector** (a **plasmid**) with the **same restriction endonuclease**. Restriction enzymes cut DNA at a specific **recognition sequence** (often palindromic) and many leave **sticky ends**: short single-stranded overhangs.
3. **Join** the gene and plasmid: the **complementary sticky ends** anneal by **hydrogen bonds** between the bases, and **DNA ligase** forms the **phosphodiester bonds** to seal the backbone.

> **The same restriction enzyme must cut both the gene and the plasmid, so that the sticky ends**

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are **complementary**.

Inserting the DNA into cells

- **Bacteria**: **heat shock** or **electroporation** in the presence of calcium ions makes the cell membrane permeable to plasmids; then the **transformed** bacteria are identified.
- **Plant cells**: *Agrobacterium tumefaciens* naturally transfers DNA (a **Ti plasmid**) into plant cells, or a **gene gun** fires DNA-coated metal particles.
- **Animal cells**: **microinjection** into a fertilised egg, or **viral vectors** (a modified virus carrying the gene).

Identifying transformed cells

Only a few cells take up the plasmid. A **marker gene** on the plasmid (for **antibiotic resistance** or **fluorescence**, such as GFP) shows which cells have taken it up. Cells are grown on a medium containing the antibiotic; only those with the plasmid survive.

Microarrays

A **DNA microarray** shows which genes are **active** (expressed) in a cell.

1. A slide has thousands of **spots**, each with a **single-stranded DNA probe** for a known gene.
2. **mRNA** from the cells is extracted, and used to make **cDNA** labelled with a **fluorescent dye**.
3. The labelled cDNA is applied to the array, and **hybridises** (binds by complementary base pairing) to matching probes.
4. After washing, the **fluorescence** is measured. The **brightest spots** show the genes with the greatest expression.

Uses: comparing **healthy and diseased tissue** (e.g. cancer), identifying genes involved in a condition, and testing the effect of a drug.

Bioinformatics

Bioinformatics is the use of **computer software and databases** to store, search and analyse **biological data**, such as DNA sequences. It helps to:

- **compare sequences** between species to find genes and study **evolutionary relationships**,
- **identify genes** and predict the proteins they encode,
- find **mutations** that cause disease,
- design drugs and **model** protein structures.

It relies on large international databases (such as the human genome project data).

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Risks and benefits of GMOs

Benefits	Risks and concerns
Higher yields, resistance to pests and disease, so less pesticide is needed	**Gene transfer** to wild or non-GM plants (by pollen), which could create "superweeds"
Added nutrients (Golden Rice to tackle vitamin A deficiency)	Effects on **non-target** organisms (e.g. insects) and **biodiversity**
Crops that tolerate **drought**, salt or herbicides	**Allergies** and unknown long-term effects on **human health**
Cheap production of medicines	Seed companies may **control** the supply (patents), making farmers dependent
Longer shelf life	**Ethical** objections (moving genes between species), and animal welfare

NOTE

When discussing GMOs, give **both** the benefits and the risks, mention who is affected (farmers, consumers, the environment), and say how the risks are managed (regulation, testing, labelling, separation distances for crops).

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