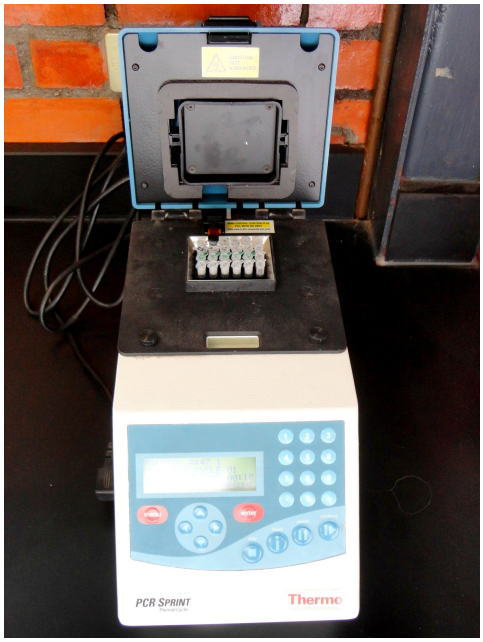
Genetic technology

A-Level Biology

Principles of genetic technology

Recombinant 重组 DNA is DNA that has been made by joining together DNA from two different sources. **Genetic engineering** 基因工程 is the deliberate changing of an organism's genetic material —often by transferring a **gene** 基因 into an organism so that the gene is **expressed** (switched on to make its **protein** 蛋白质).



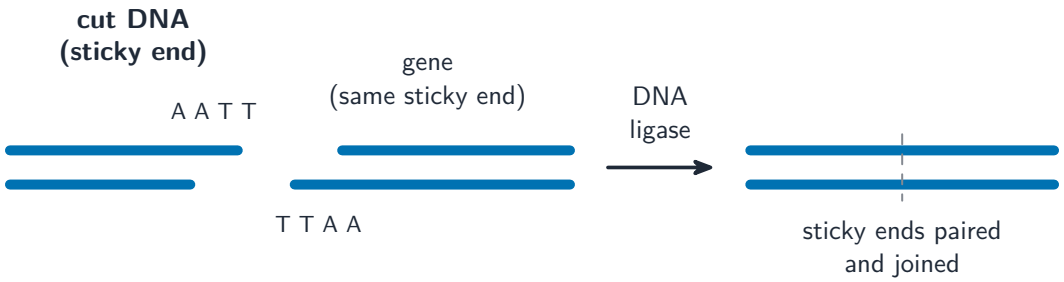
A thermal cycler (PCR machine) makes many copies of a DNA sample

The gene to be transferred can be obtained in three ways:

- cut out of the DNA of a **donor** 供体 organism,
- made from the donor's mRNA, using the enzyme **reverse transcriptase** 逆转录酶,
- built chemically from **nucleotides** 核苷酸.

The tools

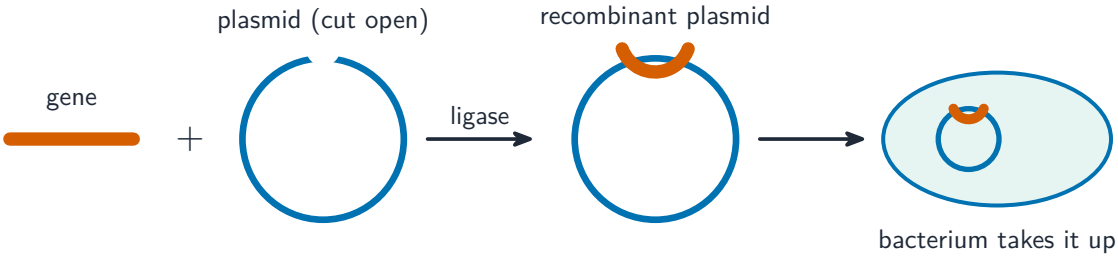
Tool	Role
restriction endonuclease 限制性内切酶	cuts DNA at a specific base sequence, leaving "sticky ends"
DNA **ligase** 连接酶	joins pieces of DNA together
plasmid 质粒	a small ring of bacterial DNA used as a **cloning vector** 载体 to carry the gene into a cell
DNA **polymerase** 聚合酶	copies DNA
reverse transcriptase	makes DNA from an mRNA template



A restriction endonuclease leaves matching sticky ends; DNA ligase joins a gene to the cut DNA

A **promoter** 启动子 often has to be transferred along with the gene. The promoter is the "switch" that lets the gene be transcribed in its new organism, so without it the gene would stay silent.

To check the gene has gone in and is working, scientists add a **marker gene** 标记基因 next to it —for example one that codes for a **fluorescent** 荧光 (glowing) product. If the cells glow, the transfer worked.



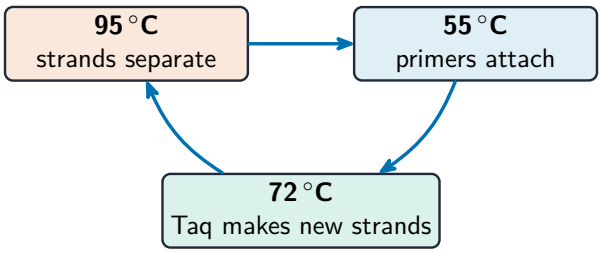
A plasmid acts as a cloning vector: the gene is joined into it, and the recombinant plasmid is taken up by a bacterium

Gene editing

Gene editing 基因编辑 is a precise form of genetic engineering. It inserts, deletes or replaces DNA at an exact site in the **genome** 基因组.

Copying and sorting DNA

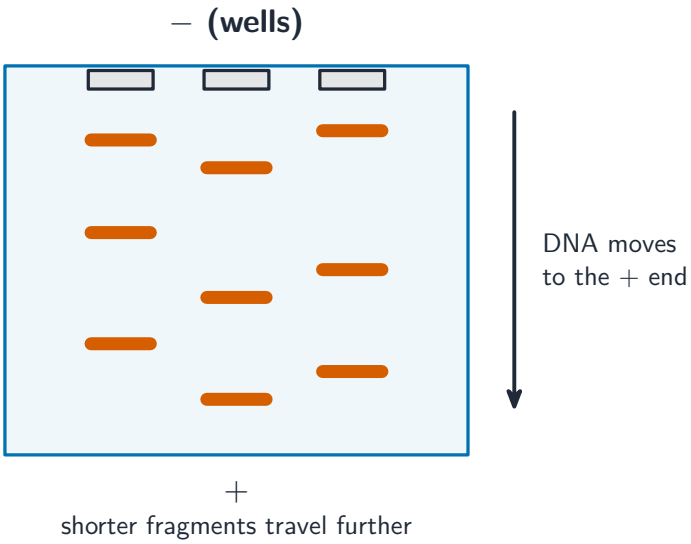
- the **polymerase chain reaction** 聚合酶链式反应 (PCR) is used to **clone** 克隆 and **amplify** 扩增 DNA —to make millions of copies. It repeats cycles of heating and cooling, using a heat-stable enzyme called Taq polymerase.



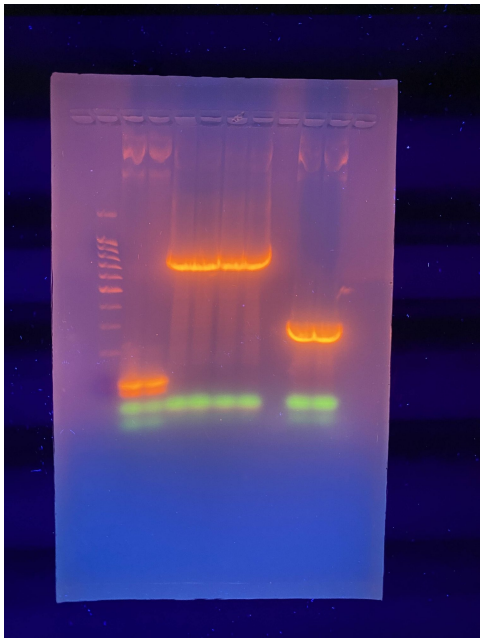
each cycle **doubles** the DNA → millions of copies

PCR repeats heat-and-cool cycles; each cycle doubles the DNA, making millions of copies

- **gel electrophoresis** 凝胶电泳 separates DNA **fragments** 片段 by length. The fragments move through a gel in an electric field, and shorter fragments move further, so the lengths spread out into bands.



Gel electrophoresis: DNA moves towards the + end, and shorter fragments travel further, sorting them by length



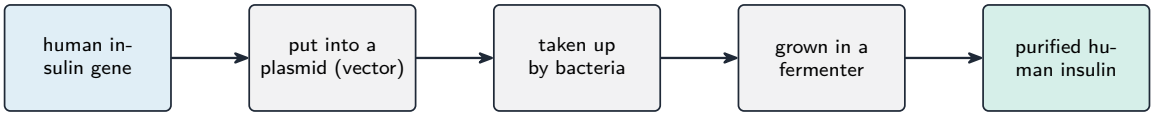
*A real gel under **UV light**: the left lane is a DNA ladder, and the glowing bands show how the fragments have separated by length*

- **microarrays** 微阵列 are used to study whole **genomes** and to detect which genes are switched on, by picking up their mRNA.
- **databases** 数据库 store the nucleotide sequences of genes and the **amino acid** 氨基酸 sequences of proteins, so scientists anywhere can compare them.

Genetic technology in medicine

Recombinant human proteins

A human gene can be put into bacteria or other cells so that they make a **recombinant** human **protein** —an exact copy of the human one. This is safer and never in short supply, and it avoids using proteins taken from animals or donors. Examples are **insulin** 胰岛素 (for **diabetes** 糖尿病), factor VIII (for haemophilia) and adenosine deaminase (for a faulty immune system).



The same tools make a human protein: the insulin gene goes into bacteria, which become living factories —so the insulin is an exact human copy and never in short supply

Genetic screening

Genetic screening 基因筛查 tests a person's DNA for disease alleles before symptoms appear. Examples are the BRCA1 and BRCA2 alleles (which raise the risk of **breast**

cancer 乳腺癌), **Huntington's disease** 亨廷顿病, and **cystic fibrosis** 囊性纤维化. Knowing the result helps people make informed choices about treatment and family.

Gene therapy

Gene therapy 基因治疗 treats a genetic disease by putting a working copy of a gene into the patient's cells. It has been used for SCID (a disease in which the immune system fails) and for some inherited eye diseases.

Social and ethical questions

Genetic screening and gene therapy raise concerns: who should see your genetic results, whether insurers or employers could misuse them, whether changes are safe and permanent, and who decides. These **ethical** 伦理 and social questions must be weighed against the benefits.

Genetically modified organisms in agriculture

Genetic engineering can help feed a growing world by improving farmed animals and crops. Examples of **genetically modified organisms** 转基因生物 (GMOs) are:

- **GM salmon** 鲑鱼 that grow to size faster.
- **soybean** 大豆 made resistant to a **herbicide** 除草剂, so weeds can be sprayed without harming the crop.
- **cotton** 棉花 made resistant to insect **pests** 害虫, because it makes a protein that kills the insects.

Both plants faced the same insects. The insect-resistant GM cotton on the left is barely touched; the ordinary cotton on the right has been stripped —because the GM plant makes a protein that kills the pests as they feed

GMOs also raise ethical and social questions: whether they are safe to eat, what effect they have on the environment and wild species, whether the engineered genes might spread, and whether a few large companies should control the food supply.

Worked example. A tiny DNA sample from a crime scene must be amplified and then compared with a suspect's. Outline the two techniques and what each achieves. **PCR** copies the DNA in repeated cycles: **denaturation** at about 95 °C separates the strands, **annealing** at about 55 °C lets primers bind at each end of the target, and **extension** at about 72 °C has **Taq polymerase** build the new strands. Each cycle **doubles** the amount, so n cycles give 2^n copies - 30 cycles turn one molecule into roughly a billion. **Gel electrophoresis** then separates the fragments: DNA is **negatively charged** because of its phosphate groups, so it moves towards the **anode**, and **shorter fragments travel further** through the gel. Matching band patterns point to the same source. Taq polymerase is used because it is **thermostable** - an ordinary polymerase would denature at 95 °C in the very first cycle.

Exam tips

- Outline the toolkit: **restriction enzymes** (cut at specific sequences, sticky ends), **ligase** (join), **plasmid vectors**, and **PCR** (amplify).
- Explain **gel electrophoresis**: DNA separates by size, smaller fragments travel further —used in genetic fingerprinting.
- Give a balanced **benefit vs concern** for GMOs and gene therapy.