

Biotechnology and genetic modification

IGCSE Biology

Why bacteria are useful

Biotechnology 生物技术 uses living things (or their **enzymes** 酶) to make useful products. **Bacteria** 细菌 are especially useful because:

- they reproduce very fast (a high **rate** 速率 of reproduction).
- they can make complex **molecules** 分子.
- **(Supplement)** there are few **ethical** 伦理 concerns about growing them, and they contain **plasmids** 质粒 (small DNA rings that are easy to work with).

Biotechnology in action



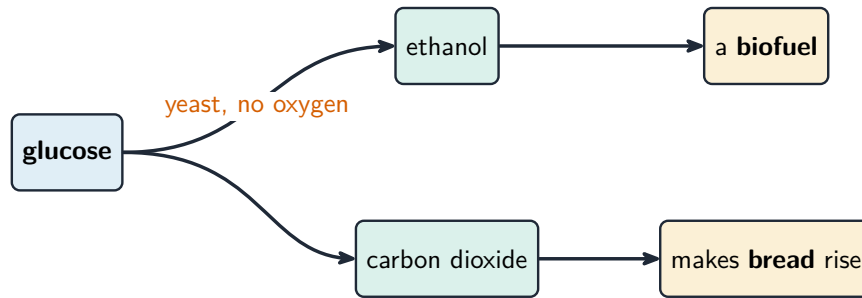
Fermentation tanks: microbes are grown at scale in biotechnology.

Image: Stephen Craven, CC BY-SA 2.0 (commons.wikimedia.org)

Yeast: biofuels and bread

Yeast 酵母 carries out **anaerobic respiration** 无氧呼吸 (without oxygen), making **ethanol** 乙醇 and carbon dioxide.

- the ethanol can be used as a **biofuel** 生物燃料.
- in bread-making, the carbon dioxide makes the dough rise.



Yeast makes ethanol (a biofuel) and carbon dioxide (which makes bread rise)

Enzymes in industry

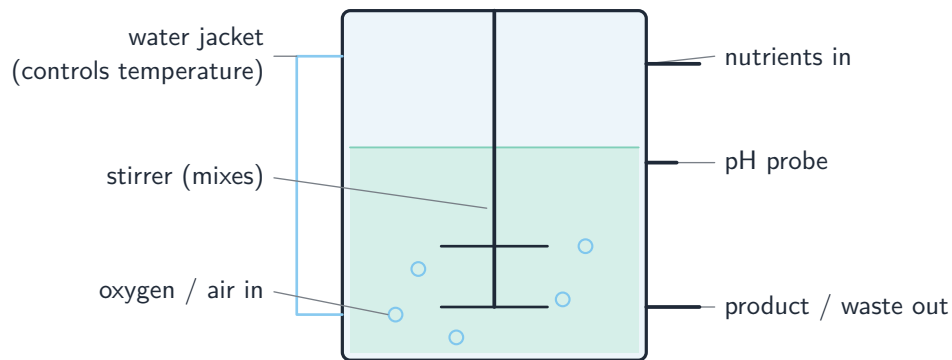
- **pectinase** 果胶酶 breaks down cell walls to release more juice from fruit, giving more and clearer juice.
- biological **washing powders** 洗衣粉 contain enzymes (such as proteases and lipases) that digest stains, even at lower temperatures.
- **(Supplement) lactase** 乳糖酶 breaks down **lactose** 乳糖 to make lactose-free milk, for people who cannot digest lactose.



Enzymes used in industry

Fermenters (Supplement)

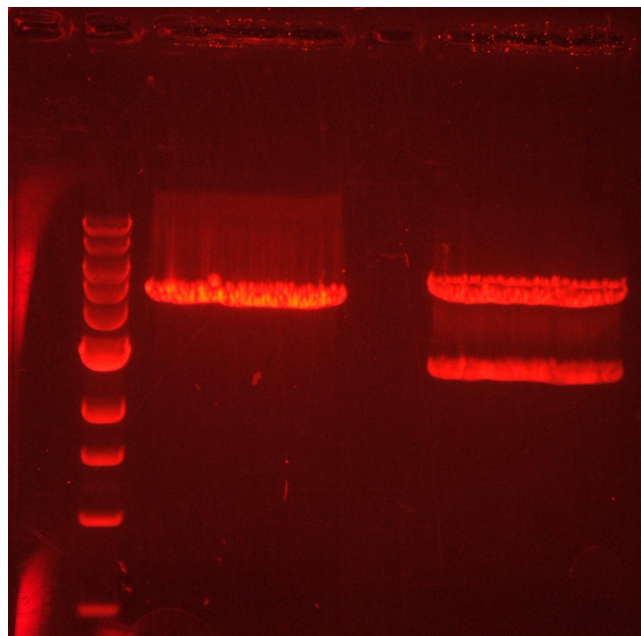
A **fermenter** 发酵罐 is a large tank used to grow bacteria or fungi to make useful products, such as **insulin** 胰岛素, **penicillin** 青霉素 and **mycoprotein** 真菌蛋白. The conditions inside must be carefully controlled: **temperature** 温度, pH, **oxygen** 氧气, the supply of nutrients, and the removal of waste products.



A fermenter grows microbes with the temperature, pH, oxygen and nutrients all controlled

Genetic modification

Genetic modification 基因改造 means changing an organism's **genetic material** 遗传物质 by removing, changing or inserting individual **genes** 基因.



DNA fragments separated by gel electrophoresis appear as glowing bands

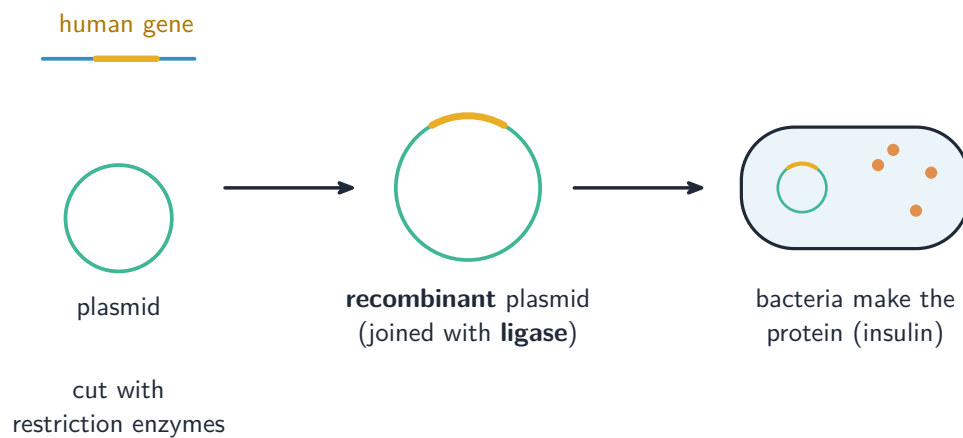
Image: Sgroey, CC BY-SA 4.0 (commons.wikimedia.org)

Making a human protein in bacteria (Supplement)

For example, to make a human **protein** 蛋白质 (such as insulin) in bacteria:

1. cut the human gene out of human DNA using **restriction enzymes** 限制酶, which leave **sticky ends** 黏性末端.
2. cut open a bacterial plasmid with the **same** restriction enzymes, giving matching sticky ends.

3. join the human gene into the plasmid using DNA **ligase** 连接酶, making a **recombinant plasmid** 重组质粒.
4. put the recombinant plasmid into a bacterium.
5. the bacteria multiply and **express** 表达 the human gene, making the human protein.



A human gene is joined into a plasmid, then bacteria make the human protein

Worked example. Put the steps of making human insulin in bacteria in order. **Restriction enzymes** cut the human insulin gene out of human DNA, leaving sticky ends. The **same** restriction enzyme cuts open a bacterial plasmid, so its sticky ends match the gene's. **Ligase** joins the gene into the plasmid, making a recombinant plasmid. The plasmid is put into a bacterium, and the bacteria multiply in a fermenter, each one expressing the gene and making human insulin. Two marks hang on precision: the **same** enzyme must cut both the gene and the plasmid, which is what makes the sticky ends fit; and ligase **joins** - it does not cut.

Examples of genetic modification

Genetic modification is used to:

- put human genes into bacteria to make human proteins (such as insulin).
- put genes into **crop plants** 农作物 to give **resistance** 抗性 to **herbicides** 除草剂.
- put genes into crops to give resistance to insect pests.
- put genes into crops to improve their food value.

(Supplement) GM crops such as soya, maize and rice can give higher yields and better nutrition, but some people worry about effects on health, on wild species, and about the cost of GM seeds.

Exam tips

- Bacteria are used because they reproduce fast, make complex molecules, and contain plasmids.

- Yeast (anaerobic respiration) → ethanol (biofuel) and carbon dioxide (bread). Enzymes: pectinase (fruit juice), proteases and lipases (washing powders), lactase (lactose-free milk).
- Fermenters make insulin, penicillin and mycoprotein; control temperature, pH, oxygen, nutrients and waste.
- Genetic modification: cut a gene with restriction enzymes (sticky ends) → join it into a plasmid with ligase (a recombinant plasmid) → put into bacteria → express the gene to make the protein.
- GM crops can resist herbicides or insect pests, or have better nutrition.