

Biotechnology and genetic modification

IGCSE Biology 0610 · Topic 21 revision notes

Everything from the 4 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

1. Why bacteria are used

3. Fermenters

2. Yeast and enzymes in industry

4. Genetic modification

1 Why bacteria are used

Syllabus 21.1

Bacteria are useful in biotechnology and genetic modification because of their **rapid reproduction rate** and their **ability to make complex molecules**, such as proteins.

Extended: there are **few ethical concerns** over their manipulation and growth, and they contain **plasmids**, small circular pieces of DNA that can be cut open and used to carry new genes into them.

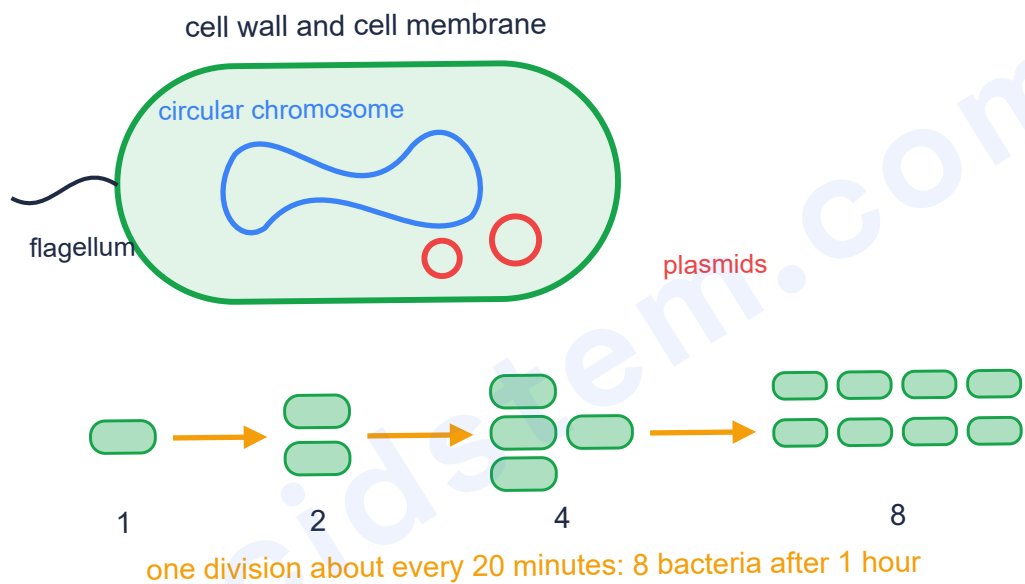


Fig. 1: a bacterial cell with its circular chromosome and plasmids; dividing about every 20 minutes, one cell becomes 8 in an hour

Fast, clever, uncontroversial.

- ✓ **Core reasons:** rapid reproduction rate; ability to make complex molecules (e.g. proteins).
- ✓ **Extended reasons:** few ethical concerns over their manipulation and growth; they contain plasmids.
- ✓ **Doubling:** number = 2^n , where $n = \text{time} \div \text{time for one division}$.
- ✓ **Plasmid:** small circular DNA, separate from the chromosome, copied every time the cell divides.

Watch out!

Doubling is not adding. After 1 hour there are 8 bacteria, not 3 or 4: each 20 minutes the number is multiplied by 2 (1, 2, 4, 8, ...).

A plasmid is not the bacterial chromosome and it is not a nucleus. Bacteria have no nucleus: the chromosome lies free in the cytoplasm, and plasmids are extra small rings of DNA.

2 Yeast and enzymes in industry

Syllabus 21.2

Yeast respire **anaerobically**: $\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide}$. In **biofuel** production the **ethanol** is the useful product; in **bread-making** the **carbon dioxide** makes the dough rise. **Pectinase** breaks down pectin in fruit cell walls, so more juice is released and it is clearer. **Biological washing powders** contain enzymes that digest stains into small soluble molecules at low temperatures. Extended: **lactase** breaks lactose into glucose and galactose to make lactose-free milk.

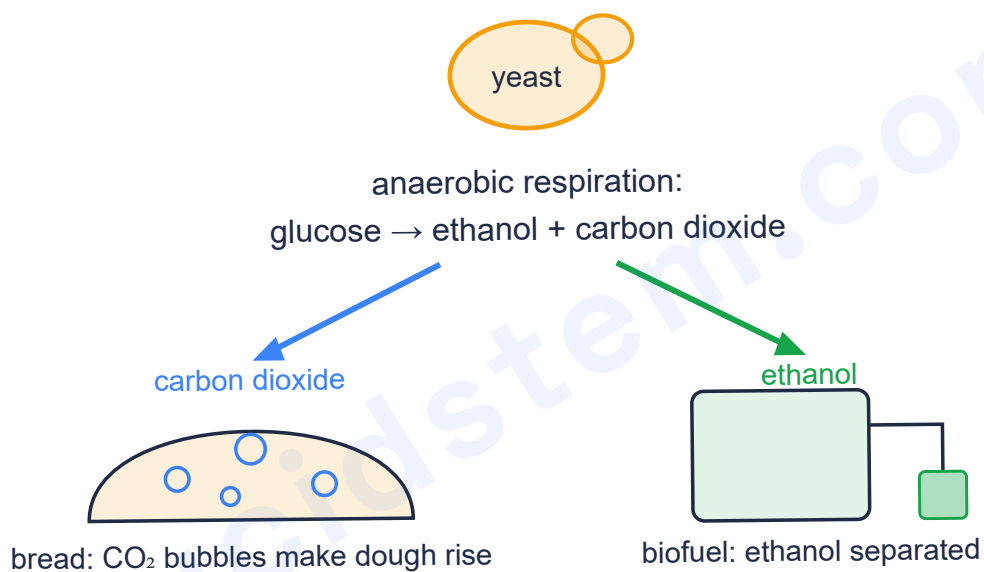


Fig. 1: the same anaerobic respiration in yeast is used two ways: bakers keep the carbon dioxide, biofuel producers keep the ethanol

Which product, which enzyme.

- ✓ **Yeast:** glucose → ethanol + carbon dioxide; bread uses the CO_2 , biofuel uses the ethanol.
- ✓ **Pectinase:** breaks down pectin in cell walls; more juice, clearer juice.
- ✓ **Washing powders:** protease, lipase, amylase digest stains to small soluble molecules; work at low temperatures.
- ✓ **Lactase (Extended):** lactose → glucose + galactose; lactose-free milk for lactose-intolerant people.

Watch out!

In bread-making the dough rises because of carbon dioxide, not ethanol and not oxygen. For biofuel, the useful product is ethanol.

Very hot water does not help a biological powder: above about 60 °C its enzymes are denatured, so it cleans no better than a non-biological powder.

Lactase does not remove the sugar from milk. It breaks lactose into two smaller sugars, glucose and galactose, which the body can absorb.

3 Fermenters

Syllabus 21.2

Extended. **Fermenters** are large, sterile vessels used to grow bacteria and fungi on a large scale so they make useful products such as **insulin** (genetically modified bacteria), **penicillin** (the fungus *Penicillium*) and **mycoprotein** (the fungus *Fusarium*). The conditions are controlled: **temperature**, **pH**, **oxygen**, **nutrient supply** and removal of **waste products**, so the microorganisms grow fast and give a high yield.

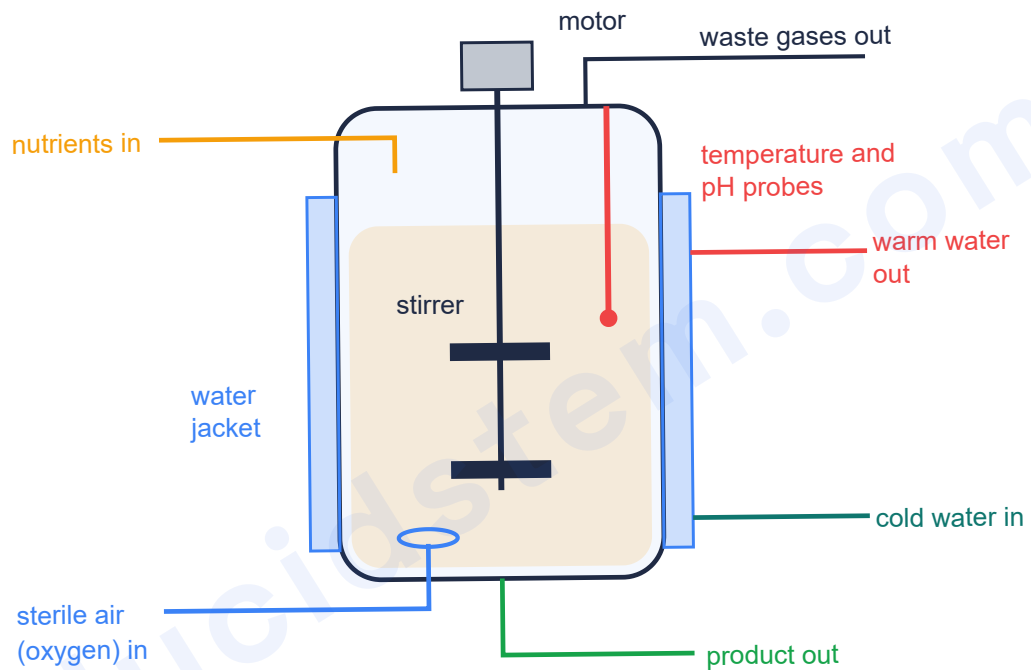


Fig. 1: an industrial fermenter; each inlet, outlet and probe exists to control one of the conditions

Part, condition, reason.

- ✓ **Products:** insulin (GM bacteria), penicillin (*Penicillium*), mycoprotein (*Fusarium*).
- ✓ **Five conditions:** temperature, pH, oxygen, nutrient supply, waste products.
- ✓ **Always link** each condition to enzymes, respiration or growth in your answer.
- ✓ **Sterile** conditions stop contamination by other microorganisms.

Watch out!

The water jacket cools the fermenter. The microorganisms release heat by respiration, so without cooling the temperature would rise and denature their enzymes.

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4 Genetic modification

Syllabus 21.3

Genetic modification is changing the genetic material of an organism by **removing, changing or inserting individual genes**. Examples: human genes inserted into bacteria to produce human proteins such as insulin; genes inserted into crop plants to give resistance to herbicides or insect pests, or to improve nutritional qualities. Extended: a human gene is cut out with **restriction enzymes**, leaving **sticky ends**; a plasmid is cut with the same enzyme; **DNA ligase** joins them into a **recombinant plasmid**, which is put into bacteria that multiply and express the gene.

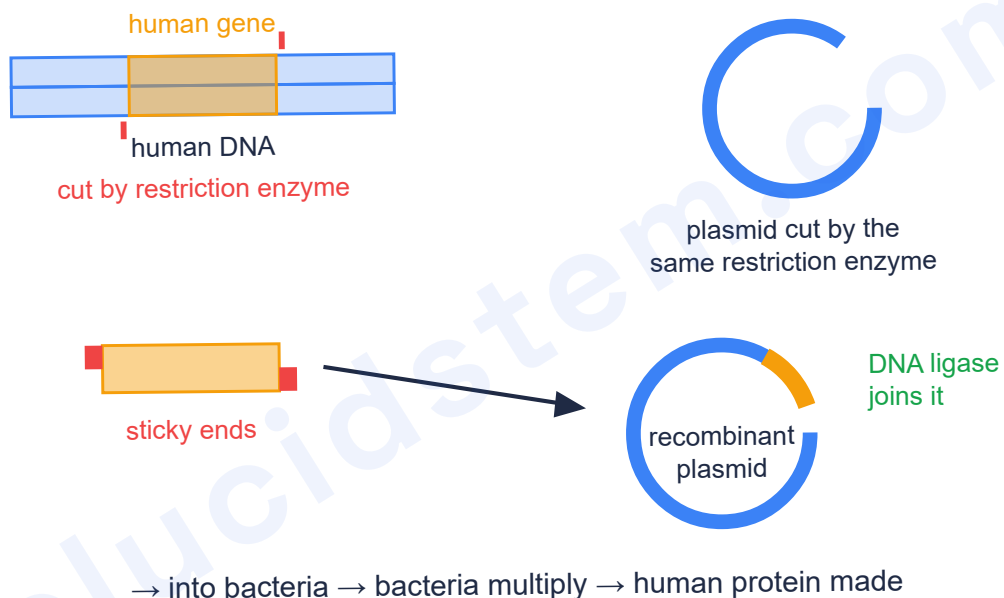


Fig. 1: the same restriction enzyme cuts the human gene and the plasmid, leaving complementary sticky ends that DNA ligase joins into a recombinant plasmid

Which enzyme, which step.

- ✓ **Definition:** removing, changing or inserting individual genes.
- ✓ **Restriction enzymes** cut, leaving sticky ends; use the same enzyme on gene and plasmid.
- ✓ **DNA ligase** joins, forming a recombinant plasmid; bacteria then multiply and express the gene.
- ✓ **Crop examples:** herbicide resistance, insect resistance, improved nutrition (golden rice).

Watch out!

Genetic modification is not the same as selective breeding.

Selective breeding mixes whole sets of genes over many generations; genetic modification moves or changes individual genes, often between different species.

Restriction enzymes cut DNA; DNA ligase joins it. The same restriction enzyme must cut both the gene and the plasmid, or the sticky ends will not be complementary.

In a 'discuss' question give both sides: at least one advantage and one disadvantage, each linked to a named crop where you can (soya, maize, rice).