

Biotechnology and genetic modification revision notes

Biotechnology uses living organisms, such as bacteria and yeast, or substances from them, such as enzymes, to make useful products. This topic covers how yeast, enzymes and fermenters are used in industry, and how genetic modification changes the genes of an organism so that it makes a new product or gains a new feature. You also meet the advantages and disadvantages of genetically modified crops.

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). **Supplement** is Extended content, only examined on Papers 2 and 4.

1 Biotechnology **Spec 21.1, 21.2**

Why bacteria are useful **Spec 21.1.1, 21.1.2**

Biotechnology is the use of living organisms, or substances made by them, to make useful products or to carry out useful processes. **Bacteria** are used a great deal, both in biotechnology and in genetic modification.

Bacteria are useful because of two features. They have a **rapid reproduction rate**, so a large population is made in a short time. They also have the ability to **make complex molecules**, such as proteins. Once genetically modified, they can make human proteins such as insulin.

Why bacteria are useful in biotechnology and genetic modification

Reason	What it means
Rapid reproduction rate	Bacteria divide very quickly, so a large number of cells, and a large amount of product, is made in a short time
Make complex molecules	Bacteria can make proteins and other complex molecules that are difficult to make in other ways

Supplement

Further reasons

Supplement

- **Few ethical concerns.** There are few ethical concerns over manipulating bacteria and growing them in large numbers, unlike the use of animals.
- **Plasmids.** Bacteria contain **plasmids**, small circular loops of DNA separate from the main bacterial DNA. A gene can be inserted into a plasmid, and the plasmid can then be put into a bacterium.

Exam tip: If asked why bacteria are useful in genetic modification, give the feature and link it to the result: for example, they reproduce rapidly so many copies of the gene and a lot of product are made quickly.

Yeast: biofuels and bread Spec 21.2.1, 21.2.2

Yeast is a single-celled fungus. When there is no oxygen it respire **anaerobically**, breaking down glucose to make ethanol (alcohol) and carbon dioxide. This is called fermentation.

glucose → alcohol (ethanol) + carbon dioxide

Supplement



Biofuels

Sugar from plants such as sugar cane, or sugar made by breaking down starch from maize, is fed to yeast in a closed tank with no oxygen. The yeast respire anaerobically and makes **ethanol**. The ethanol is separated and used as a **biofuel**, for example mixed with petrol to fuel vehicles. The plants can be regrown, so it is a renewable fuel.

Bread-making

1. Yeast is mixed with flour, sugar and water to make dough, and the dough is kept warm.
2. The yeast respire anaerobically and makes carbon dioxide (and ethanol).
3. The carbon dioxide forms bubbles that are trapped in the dough, which makes the dough **rise**.
4. When the bread is baked, the gas bubbles expand, the yeast is killed and the dough sets with air spaces. The ethanol evaporates.

Common mistake: It is the carbon dioxide that makes bread rise, not the ethanol. Write that the yeast respire anaerobically, not just that it 'ferments'.

Pectinase, biological washing powders and lactase Spec 21.2.3, 21.2.4, 21.2.5

Pectinase in fruit juice production

Plant cell walls contain pectin, which helps to hold the cells together. The enzyme **pectinase** breaks down pectin. It is added to crushed fruit pulp before pressing. This breaks down the cell walls, so more juice is released (a higher yield). Pectinase also makes the juice clearer, because less pectin is left in the juice.

Biological washing powders

Biological washing powders contain enzymes that digest stains. **Proteases** break down protein stains (such as blood or egg) into amino acids. **Lipases** break down fat and grease stains into fatty acids and glycerol. Amylases break down starch stains into sugars. The products are small, soluble molecules, so they wash out of the clothes.

Biological powders clean well at low temperatures, such as 30 to 40 °C, so less energy is used to heat the water. If the water is too hot, the enzymes are denatured and the powder removes stains no better than a non-biological powder.

Investigating a biological washing powder

1. Stain identical squares of the same cloth with the same volume of the same stain, such as egg white, and leave them to dry for the same time.
2. Make up the same volume and concentration of biological washing powder solution in several beakers, and put each in a water bath at a different temperature (for example 20, 30, 40, 50 and 60 °C).

3. When each solution has reached its temperature, add one cloth and stir in the same way.
4. Record the time taken for the stain to disappear. (Alternatively, wash every cloth for the same time and compare how much stain is left.)
5. Repeat at each temperature and calculate a mean. Set up controls: the same stain washed in water only, and in biological powder solution that has been boiled and cooled (so its enzymes are denatured).

Practical skill: Independent variable: temperature (or pH, or type of powder). Dependent variable: time for the stain to disappear. Keep the same: cloth, stain, volume and concentration of solution, stirring and pH. Typical result: the stain is removed fastest at about 40 °C, more slowly at lower temperatures, and slowly or not at all at high temperatures, where the enzymes are denatured. Enzyme powders can cause allergies and irritate skin and eyes, so avoid contact and wear eye protection.

Supplement

Lactase and lactose-free milk

Supplement

Milk contains the sugar lactose. Some people are lactose intolerant: they cannot digest lactose properly. The enzyme **lactase** breaks down lactose into the simpler sugars **glucose and galactose**, which are easily absorbed. Adding lactase to milk produces lactose-free milk, which lactose-intolerant people can drink.

Supplement

Exam tip: Name the substrate and both products when explaining lactase: lactose is broken down into glucose and galactose.

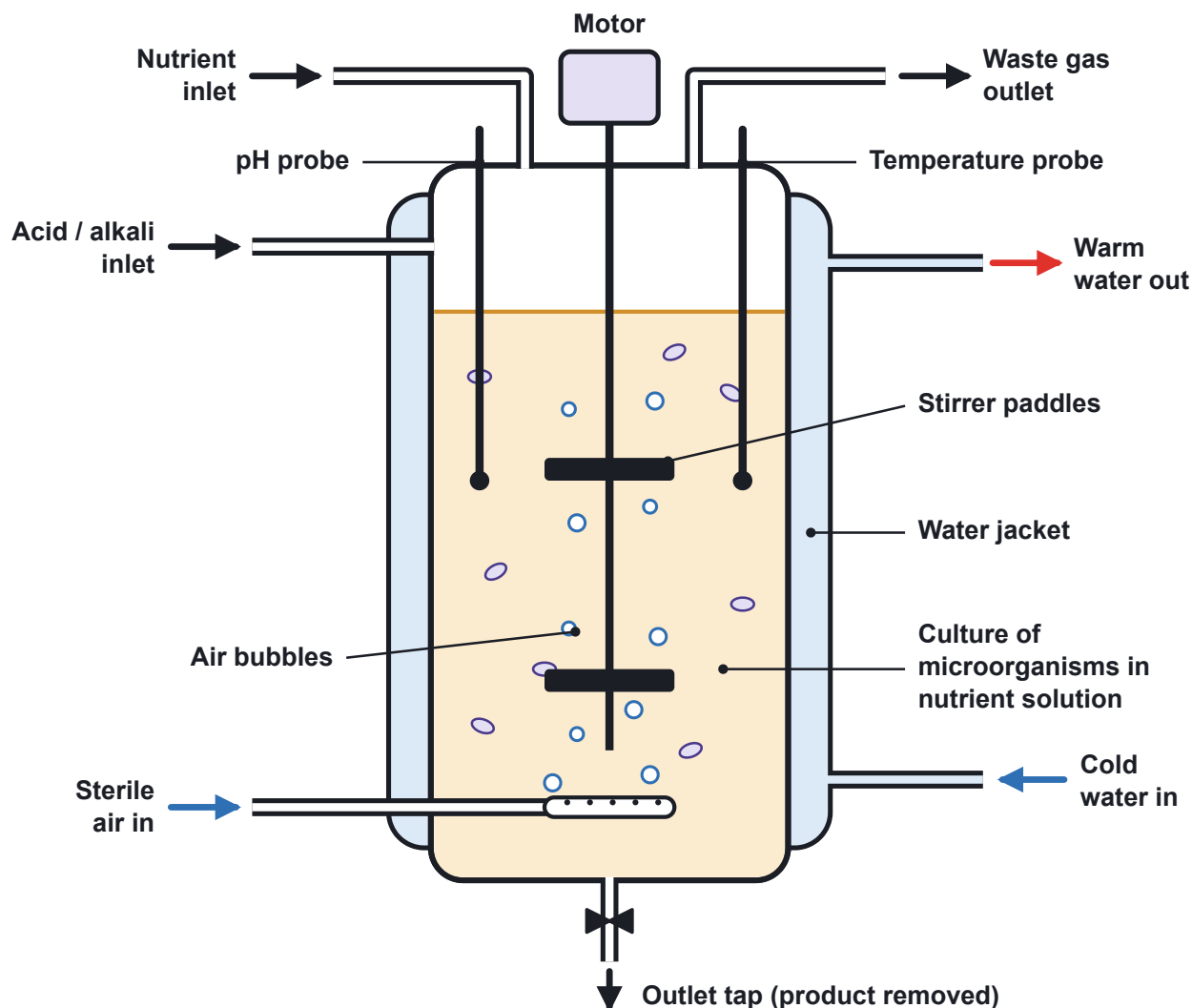
Fermenters Spec 21.2.6, 21.2.7

Supplement

A **fermenter** is a large container in which bacteria or fungi are grown in large numbers to make a useful product. Conditions are controlled so that the microorganisms grow and make the product as fast as possible, giving a high **yield**.

Products made in fermenters

Product	Made by	Use
Insulin	Genetically modified bacteria	Treating diabetes
Penicillin	The fungus <i>Penicillium</i>	An antibiotic that kills bacteria
Mycoprotein	The fungus <i>Fusarium</i>	A protein-rich food for humans



A **fermenter**. Probes, the water jacket, acid / alkali, sterile air and stirring keep conditions at the optimum.

Conditions that are controlled

Conditions in a fermenter and why they are controlled		
Condition	How it is controlled	Why
Temperature	Cooling water in a water jacket, checked by a temperature probe	Keeps the temperature at the optimum for the enzymes of the microorganisms. If too low, reactions are slow; if too high, enzymes are denatured. Respiration releases heat that must be removed
pH	pH probe; acid or alkali is added	Keeps the pH at the optimum for the enzymes. A wrong pH changes the shape of the active site and denatures enzymes
Oxygen	Sterile air is pumped in; the stirrer spreads it through the liquid	Needed for aerobic respiration , which releases energy for growth and making the product
Nutrient supply	Nutrients such as a sugar (glucose) and minerals are added	Provide the energy source and the raw materials for growth and for making the product
Waste products	Waste gases, such as carbon dioxide, leave through an outlet; stirring stops waste building up in one place	A build-up of waste (such as carbon dioxide or other toxic substances) could poison the microorganisms or change the pH

Exam tip: For 'describe and explain' on a fermenter condition, give how it is controlled and why. Link temperature and pH to enzymes, and oxygen to aerobic respiration.

Quick check

1. Give two reasons why bacteria are useful in biotechnology.
2. Which gas makes bread dough rise?
3. What does pectinase do in fruit juice production?
4. **Supplement** What does lactase break lactose into?
5. **Supplement** Why is oxygen supplied to a fermenter?

2 Genetic modification Spec 21.3

What genetic modification is Spec 21.3.1, 21.3.2

Genetic modification is changing the genetic material of an organism by **removing**, **changing** or **inserting** individual genes. An organism that has had its genes altered in this way is called a **genetically modified organism** (GMO). The inserted gene is often taken from another species.

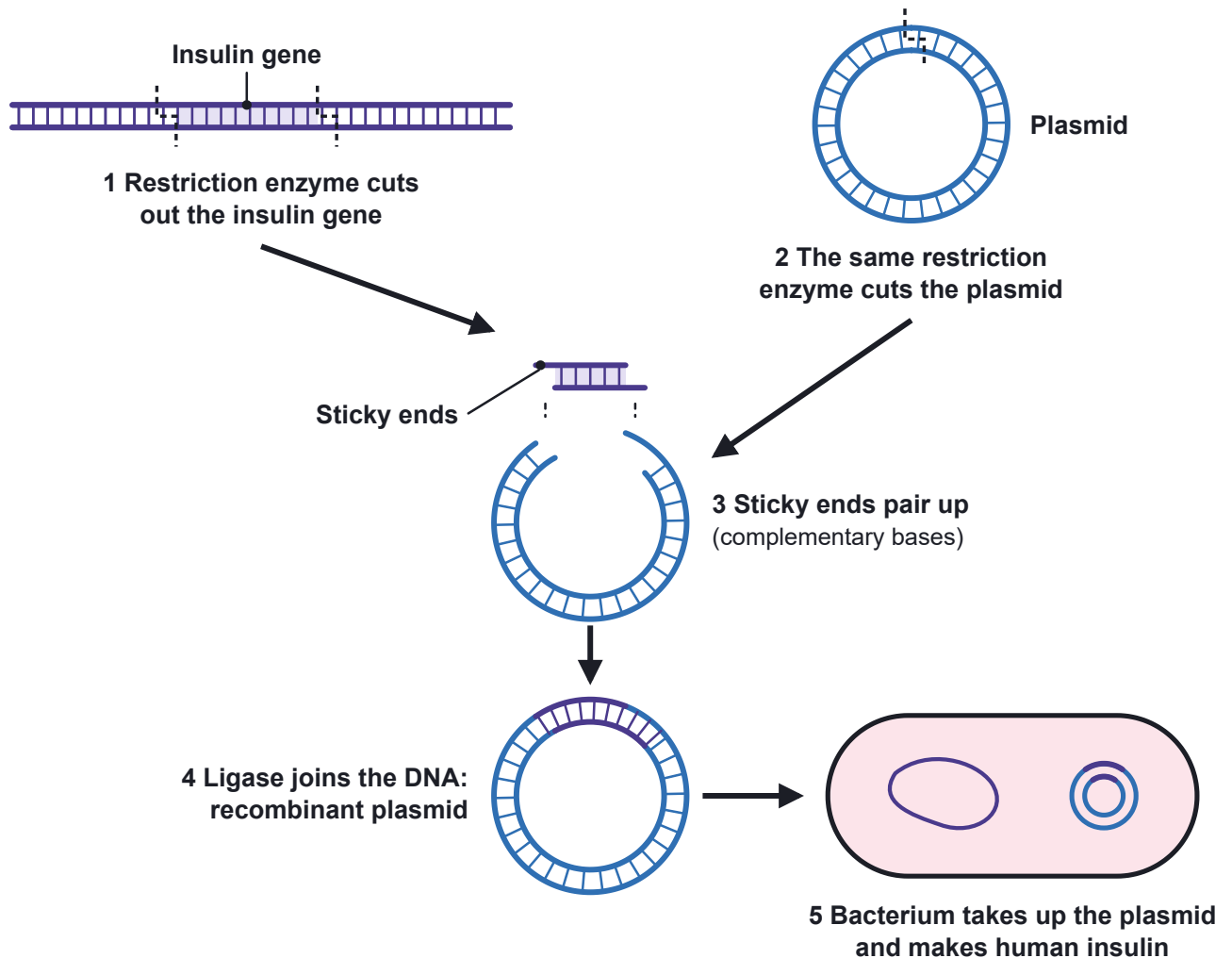
Examples of genetic modification		
Example	What is done	Result
Human protein from bacteria	Human genes are inserted into bacteria	Bacteria make human proteins, such as insulin
Herbicide resistance	Genes are inserted into crop plants	The crop is not killed by a herbicide, so the field can be sprayed to kill weeds without harming the crop
Insect resistance	Genes are inserted into crop plants	Crop is resistant to insect pests, so less insecticide is needed and yield is higher
Improved nutritional quality	Genes are inserted into crop plants	Crop contains more of a nutrient; for example, rice modified to contain a vitamin A precursor (golden rice)

Exam tip: Use the word 'gene' in the definition: genetic modification changes an organism by removing, changing or inserting individual genes, not 'changing the whole organism'.

How bacteria are modified to make a human protein Spec 21.3.3 Supplement

Human insulin can be made by bacteria. The same process can be used for other human proteins.

1. **Isolate the gene.** The DNA making up the human gene is cut out of human DNA using **restriction enzymes**. These cut the DNA leaving **sticky ends** (short single-stranded overhangs).
2. **Cut the plasmid.** A bacterial **plasmid** is cut open using the same restriction enzymes, which forms complementary sticky ends.
3. **Insert the gene.** The human gene is joined into the plasmid using the enzyme **DNA ligase**, which joins the sticky ends. This forms a **recombinant plasmid**.
4. **Put into bacteria.** The recombinant plasmids are inserted into bacteria (specific details of how are not required).
5. **Multiply.** The bacteria containing the recombinant plasmids are grown and multiply, so there are many copies of the gene.
6. **Expression.** The human gene is expressed in the bacteria, which make the human protein.



A human gene is cut out, inserted into a plasmid and put into bacteria, which make the protein.

Common mistake: Restriction enzymes cut DNA, and ligase joins DNA. Do not swap them. The same restriction enzyme is used on the gene and the plasmid so the sticky ends match.

GM crops: advantages and disadvantages Spec 21.3.4 Supplement

Crops such as **soya**, **maize** and **rice** have been genetically modified. Examples are herbicide-resistant soya, insect-resistant maize (which makes a toxin that kills insect pests that eat it), and golden rice, which makes a substance the body converts to vitamin A.

Advantages and disadvantages of genetically modifying crops

Advantages	Disadvantages
Higher yield, as less is lost to weeds and insect pests	Gene may spread to wild plants (for example weeds could become herbicide resistant)
Less insecticide needed, which saves money and reduces harm to other insects	May harm other organisms, such as non-pest insects, and reduce biodiversity
Improved nutrition, such as golden rice, which could help to reduce vitamin A deficiency	Seeds can be expensive, and farmers may need to buy new seed each year
Crops can be grown in conditions that would otherwise be unsuitable, helping to feed a growing population	Some people are concerned about eating GM food, as long-term effects on health are not fully known
Less time and money spent on spraying insecticide	Insect pests may become resistant to the toxin made by the crop

Exam tip: For 'discuss', give at least one advantage and one disadvantage, and name a crop with its modification, for example insect-resistant maize.

Quick check

1. Define genetic modification.
2. Give an example of a human protein made by genetically modified bacteria.
3. **Supplement** Which enzyme cuts DNA to leave sticky ends?
4. **Supplement** Which enzyme joins the gene into the plasmid?
5. **Supplement** Name one disadvantage of GM crops.

Quick check answers

Biotechnology

1. They reproduce rapidly; they can make complex molecules (such as proteins).
2. Carbon dioxide, from anaerobic respiration in yeast.
3. Breaks down pectin in cell walls, so more juice is released and it is clearer.
4. Glucose and galactose.
5. For aerobic respiration, to release energy for growth and making the product.

Genetic modification

1. Changing the genetic material of an organism by removing, changing or inserting individual genes.
2. Insulin.
3. A restriction enzyme.
4. DNA ligase.
5. The gene may spread to wild plants; or it may harm other organisms.