CAIE Biology IGCSE

21: Biotechnology and Genetic Modification

Notes

(Content in **bold** is for Extended students only)

Biotechnology and genetic modification

Genetic engineering is the process of **artificially altering genes** in a cell to change the way it works. This could be to make the cell perform a **desired function**, such as making a specific protein, or to make the cell **resistant** to different factors. For example, some strawberries have been genetically modified to become resistant to frost by inserting a gene taken from cold water fish which makes antifreeze proteins.

Genetic engineering and bacteria:
Bacteria are useful to genetic engineering as they **reproduce very rapidly** but still have the **ability to produce complex molecules**. **Bacteria contain plasmids, which are circular rings of DNA, into which new genes can be inserted, removed or changed. There are also no ethical concerns about manipulating the DNA of bacteria.**

Biotechnology

Biotechnology involves using **microorganisms and biological substances** to carry out functions in manufacturing processes:

- **Yeast** is a microorganism which can **respire anaerobically** (without oxygen) to **release carbon dioxide**. This can be used in bread-making to make dough rise as bubbles of carbon dioxide form. **Ethanol** is also released during this reaction, which can be used to make **biofuels** that are used as an **alternative to fossil fuels**.

- **Pectinase** is an **enzyme** used in **fruit juice production**. Pectinase **breaks down pectin**, which is found in **plant cell walls** and is used to hold the cell wall together. Adding pectinase therefore breaks down these walls to release the contents of the cell, which **increases the yield of fruit juice**.

- **Biological washing powders** contain **enzymes** to break down different molecules. Amylases break down starch, lipases break down fats and oils, and proteases break down proteins. Enzymes break these into **smaller products** that are **water soluble**, thus can be washed out easily. As enzymes are **denatured** at high temperatures and extreme pH, a lower washing temperature is needed, and the enzymes may not work in acidic or alkaline water.

- The enzyme lactase can be used to make lactose-free milk. When lactase is added to milk, it breaks down the lactose into glucose and galactose, which can be safely consumed by lactose-intolerant people.

Fermentation can be used for the large-scale production of useful products. The desired microorganism is first placed in a fermenter to keep it at the optimum temperature and pH, so the yield of the product is high. There is also an air inlet so that aerobic respiration can take place. All other undesired microorganisms are killed to limit contamination and competition.

The table below shows how different microorganisms can be used to produce useful products.

Microorganism	Type	Process	Useful products
Penicillium	Fungus	The penicillium fungus is cultured in a liquid medium, leading to penicillin being secreted. This is then isolated and purified.	Penicillin
E.Coli	Bacteria	The bacteria is genetically engineered to produce insulin. The insulin is then extracted.	Insulin
Fusarium	Fungus	It is placed in fermenters with glucose. This leads to the production of mycoprotein.	Mycoprotein

Conditions in fermenters:

- Temperature: The temperature is usually between 25°C to 30°C. Most of the microorganisms used in fermenters show optimum growth within this temperature range. If the temperature is too high or low, then this will kill the microorganisms.
- pH: The pH needs to be maintained to ensure optimum growth. Different microorganisms have a different optimum pH. If the pH is too acidic or alkaline, this will kill the microorganisms.
- Oxygen: Oxygen is needed for the aerobic respiration of microorganisms. Fermenters distribute this oxygen evenly by stirring the liquid medium.
- Nutrient supply: Nutrients are required for the growth of microorganisms. It also allows them to reproduce.
- Waste products : The amount of waste products should be controlled as growth will be restricted by the accumulating waste.

Genetic Modification

Genetic modification is a process of changing genetic material of an organism by removing, changing or inserting individual genes.

Bacteria can be manipulated to produce human proteins, such as insulin:

1. **The gene which codes for the desired protein is located and isolated using restriction enzymes. The isolated gene has "sticky ends".**
2. **The plasmid from the bacterial cell is cut with the same restriction enzymes. This leaves complementary sticky ends to the isolated gene.**
3. **The gene is inserted into the plasmid. The complementary sticky ends are joined using the enzyme DNA ligase. This forms a recombinant plasmid.**
4. **This plasmid is inserted into the bacteria, which will then produce this protein as the inserted gene is expressed.**
5. **The bacterial cell reproduces, making more cells which produce the protein.**

Examples of genetic engineering:

- **Insulin production** - people with diabetes must take insulin to regulate their blood-glucose concentration. Insulin was originally harvested from animals, such as pigs, although this had slight differences to human insulin, which made some people allergic to it. Genetic engineering has allowed human insulin to be made in bacteria cells. This produces cheap, human insulin in high quantities.
- **Herbicide and insect resistant plants** - genes can be inserted into plants to make them resistant to herbicides and insects. This means that less crops die, so farmers have a larger crop yield.
- **Vitamin-rich plants** - some plants can be genetically modified to increase the number of vitamins in them. This is beneficial to places where certain vitamins are hard to find to reduce vitamin deficiency. For example, "golden rice" is a type of rice that has been genetically modified to produce beta carotene, which humans use to produce vitamin A. This reduces vitamin A deficiency in some areas.

Advantages of genetic engineering:

- **Can reduce nutritional deficiencies in certain populations**
- **Improve crop yields and crop quality. This will help alleviate hunger in certain regions of the world.**
- **GM crops are resistant to pests and diseases. This reduces the need for fungicides and herbicides, lowering the costs of farming.**
- **GM crops contain genes which are resistant to harsh environmental conditions, for example flooding or drought.**

Disadvantages of genetic engineering:

- **Loss of biodiversity.**
- **Potential development of weeds that are resistant to herbicides.**
- **GM crops are more expensive.**
- **GM crops may contaminate wild species by crossbreeding.**
- **Long-term health impacts not known.**