Cambridge (CIE) IGCSE Biology

Your notes

Biotechnology & Genetic Modification

Contents

Use of Bacteria

- Microorganisms can be used by humans to produce foods and other useful substances
- The most common type of microorganisms used in biotechnology are **bacteria**
- They are useful because they are **capable of producing complex molecules** (eg. certain bacteria added to milk produce enzymes that turn the milk into yoghurt)
- They are also useful because they **reproduce rapidly**, meaning the amount of chemicals they can produce can also rapidly increase

Usefulness of Bacteria: Extended

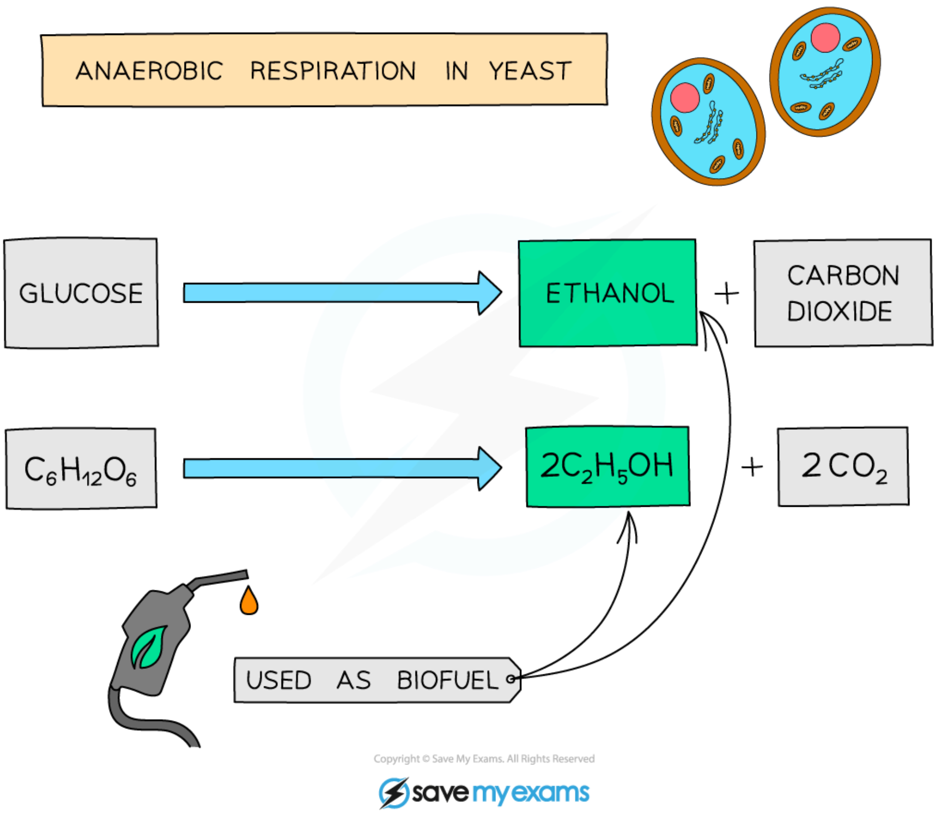
- In addition to the benefits of rapid reproduction and the ability to make complex molecules, bacteria have other benefits in biotechnology
  - There are few ethical considerations to growing them in large numbers in the laboratory
  - They possess plasmids
    - Plasmids are small, circular loops of DNA which can be an ideal way of transferring DNA from one cell to another during genetic manipulation

Your notes

Everyday Products Made with Biotechnology

Biofuels

- **Yeast** is a single celled fungus that uses sugar as its food source
- Anaerobic respiration in yeast produces **ethanol** and **carbon dioxide**, as well as releasing energy for the yeast cell



The alcohol produced by fermentation of glucose can be used as biofuel

- The **ethanol** produced by anaerobic respiration in yeast can be used in the production of biofuels
    - In countries such as Brazil, biofuel is partly replacing petrol as the fuel for vehicles
- Biofuel production using yeast can be carried out as follows:
    1. **plant material** is broken up into small pieces and mixed with **yeast**
    2. yeast cells use the plant material as a substrate in anaerobic respiration and produce **ethanol** as a product

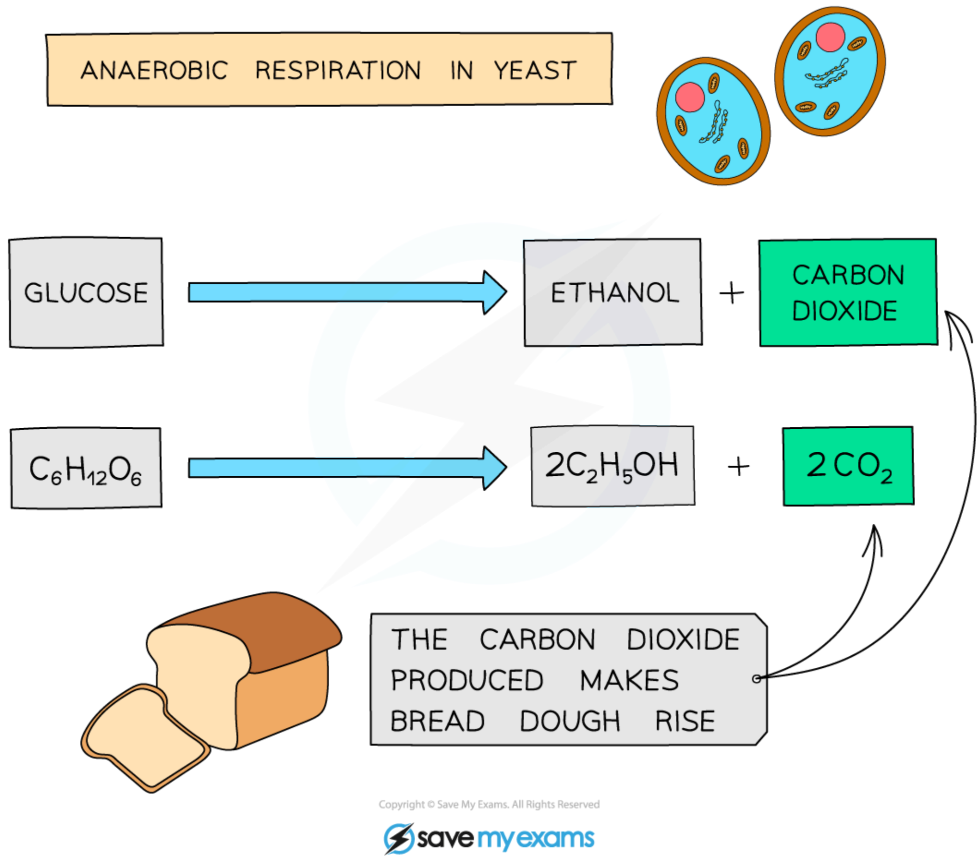
3. the liquid is separated from the remaining solids and any water is removed, leaving a **concentrated solution of ethanol**

4. the ethanol may then be blended with petrol, or used on its own as a fuel

- It is possible to use the **waste parts** of crop plants, such as the stalks or outer leaves, in biofuel production, but **crops may also be grown specifically** to be harvested for making ethanol
  - This is causing concern that there is **less land available** for local people to grow food crops needed for survival

Bread

- Yeast will **respire anaerobically** if it has access to plenty of **sugar**, even if oxygen is available
- This is taken advantage of in **bread making**, where the yeast is mixed with flour and water and respires anaerobically, producing **carbon dioxide**:



The carbon dioxide produced by fermentation (anaerobic respiration) of glucose is what makes bread dough rise

- The **carbon dioxide** produced by the yeast during respiration is caught in the dough, causing the bread to **rise**

Fruit Juice Production

Your notes

- Fruit juice is produced by squeezing the fruits to remove the juice
- Chopping the fruit up before squeezing helps to release a lot more juice, but this does not break open all the cells so **a lot of juice is lost**
- By adding an enzyme called **pectinase** to the chopped up fruit, more juice is released
- Pectinase works by breaking down a chemical called **pectin** that is found inside plant cell walls
- Once pectin is broken down, the **cell walls break more easily** and more juice can be squeezed out of the fruit
- Adding pectinase to fruits also helps to **produce a clearer juice** as larger polysaccharides like pectin can make the juice seem cloudy - once they are broken down into smaller molecules, the juice becomes clearer

Biological Washing Powders

- Many stains on clothes are **organic molecules** – oil from skin, protein from blood, fat and protein from food
- Detergents that only contain soap can remove some of these stains when mixed with hot water, but it can take **a lot of time and effort and very high temperatures** to remove the stains entirely
- Biological washing powders contain **enzymes** similar to the digestive enzymes produced in the alimentary canal that help to break down large food molecules
- Using biological washing powders has several advantages, including:
  - **Quickly** breaking down **large, insoluble molecules** such as fats and proteins into **smaller, soluble ones** that **will dissolve** in washing water
  - They are **effective at lower temperatures**, meaning **less energy (and money)** has to be used in order to wash clothes to get them clean as washing water does not need to be heated to higher temperatures
  - They can be used to clean **delicate fabrics** that would not be suitable for washing at high temperatures

Other Uses of Biotechnology: Extended

- Lactose is the **sugar found in milk**
- Human babies are born with the ability to produce **lactase**, the **enzyme** that breaks down lactose
- In certain areas of the world, many people **lose the ability to produce lactase as they get older**
- This means that they can become **lactose intolerant** and react badly to the lactose in milk and products made from milk (cheese, yoghurt etc)

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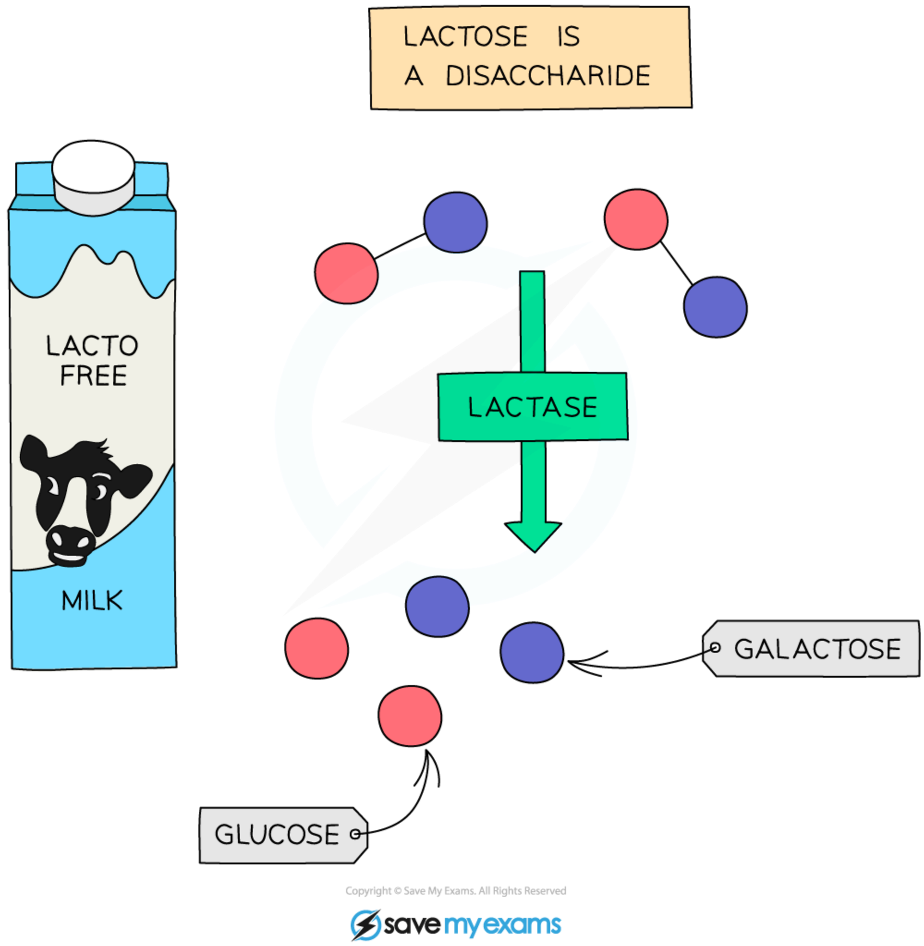
- Symptoms of lactose intolerance include **nausea, flatulence and diarrhoea** as their digestive system is upset by the lactose
- Milk can be made **lactose free** by **adding the enzyme lactase to it** and leaving it to stand for a while to allow the enzyme to break down the lactose



Lactose-free milk is a product made from adding the enzyme lactase to dairy milk to break down the sugars in it

Penicillin Production

- Penicillin was the **first antibiotic**, discovered in 1928 by **Alexander Fleming**
- He noticed that some bacteria he had left in a Petri dish had been killed by the naturally occurring ***Penicillium* mould**
- The penicillium mould produces a **chemical** to prevent it being infected by certain types of bacteria

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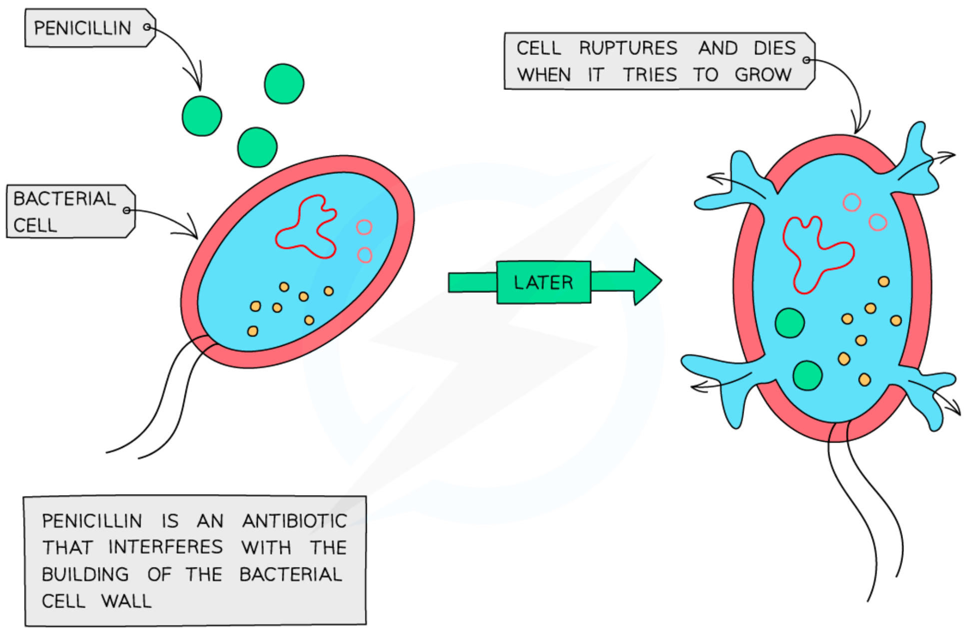
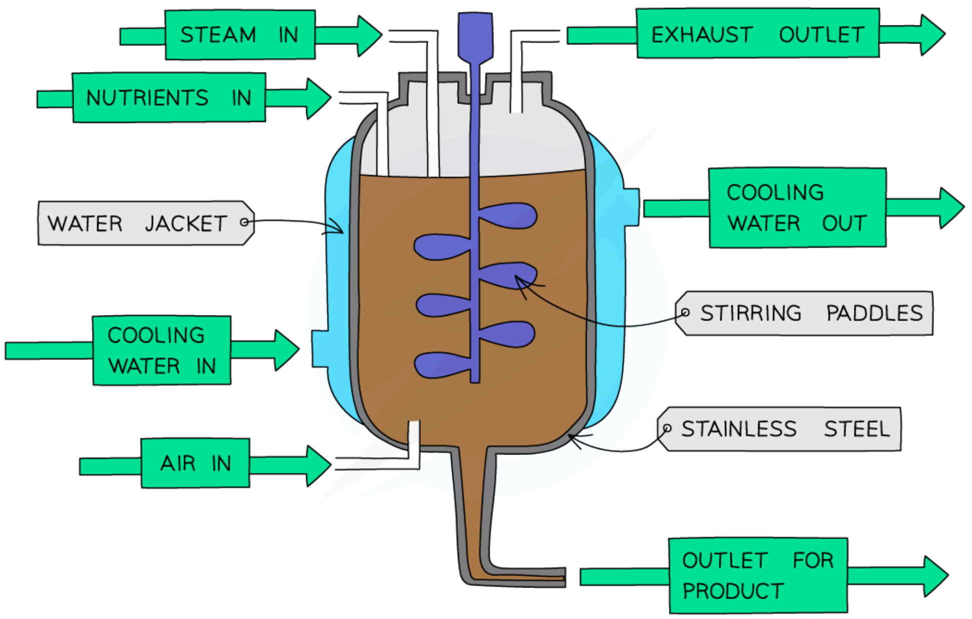


Penicillin produced by the fungus Penicillium inhibits bacterial growth

- The chemical was isolated and named **penicillin**
- Since the discovery of penicillin, methods have been developed to **produce it on a large scale**, using an **industrial fermenter**



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A diagram of an industrial fermenter used to produce large quantities of microorganisms

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- **Fermenters** are containers used to grow ('**culture**') microorganisms like bacteria and fungi in **large amounts**
- These can then be used for many biotechnological processes like producing **genetically modified bacteria** and the **penicillium mould that produces penicillin**
- The advantage of using a fermenter is that **conditions can be carefully controlled** to produce large quantities of exactly the right type of microorganism

Condition	Why and how it is controlled
Aseptic precautions	Fermenter is cleaned by steam to kill microorganisms and prevent chemical contamination, which ensures only the desired microorganisms can grow
Nutrients	Nutrients are needed for use in respiration to release energy for growth and reproduction of the microorganisms
Optimum temperature	Temperature is monitored using probes and maintained using a water jacket. This ensures an optimum environment for enzymes to increase enzyme activity and prevent denaturation
Optimum pH	pH is monitored using a probe to check it is at the optimum value for the microorganism being grown. The pH can be adjusted using acids and alkalis
Oxygenation	Oxygen is required for aerobic respiration to take place
Agitation	Stirring paddles are used to ensure temperature, pH, nutrients, and oxygen are all distributed evenly throughout the fermenter
Waste	The contents are filtered to remove waste created by the microorganisms

Mycoprotein – the process of creating food from a fungus

- The fungus Fusarium is cultured (grown) on an industrial scale in fermenters
- These fermenters are large vats that can be kept at the optimum pH and temperature for Fusarium to grow
- The fungus is grown in aerobic conditions (it is provided with oxygen) and provided with glucose syrup as a food source (to allow the fungus to respire)
- The fungus grows and multiplies within the fermenter
- The fungal biomass is then harvested and purified to produce mycoprotein

- Mycoprotein is a protein-rich food suitable for vegetarians eg. it is used in Quorn^{TM} products

Your notes

Production of Insulin

- Genetic modification is changing the genetic material of an organism by removing or altering genes within that organism, or by inserting genes from another organism
- The organism receiving the genetic material is said to be '**genetically modified**', or is described as a 'transgenic organism'
- The DNA of the organism that now contains DNA from another organism as well is known as 'recombinant DNA'
- The gene for human insulin has been inserted into bacteria which then produce **human insulin** which can be collected and purified for medical use to treat people with **diabetes**

Genetic Modification: Definition

Genetic modification

- Genetic modification is **changing the genetic material of an organism by removing, changing or inserting individual genes from another organism**
- The organism receiving the genetic material is said to be **'genetically modified'**, or is described as a **'transgenic organism'**
- The DNA of the organism that now contains DNA from another organism as well is known as **'recombinant DNA'**

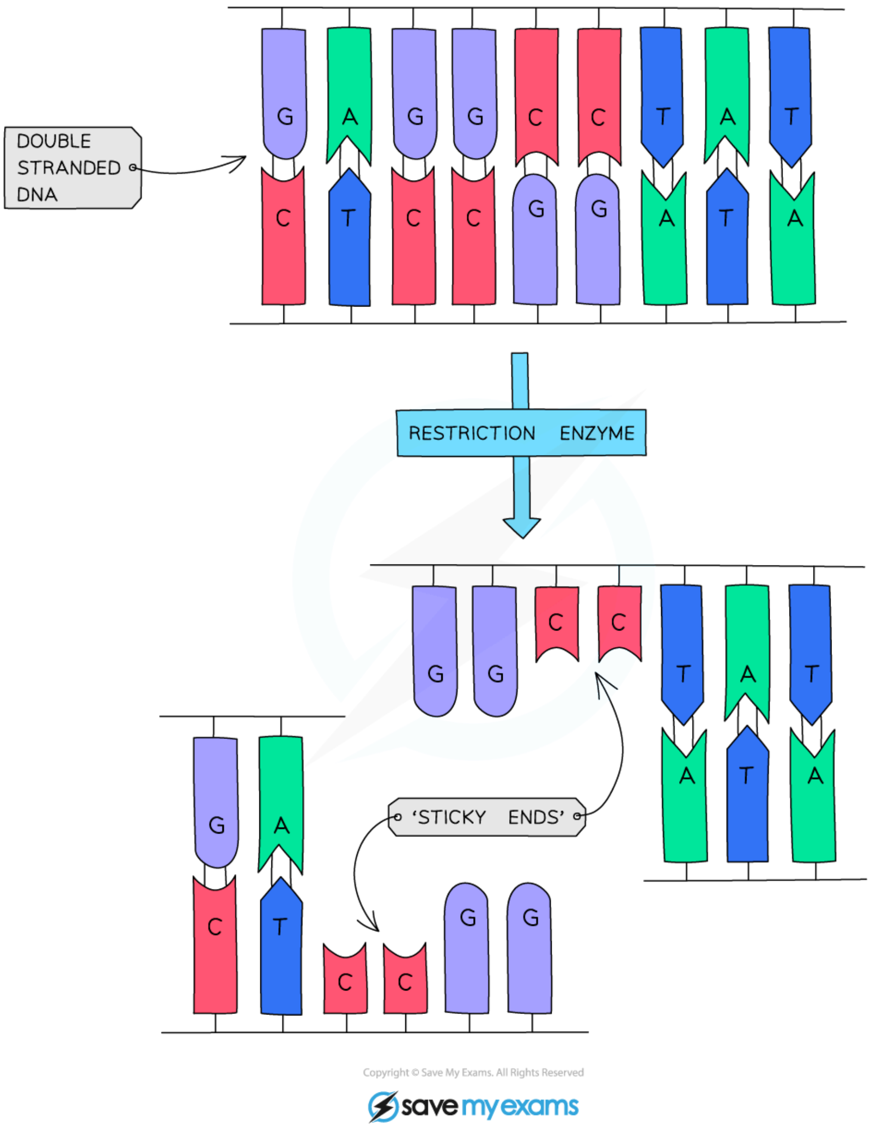
Genetic Modification: Examples

- There are many examples of genetically modified organisms, including:
- The gene for **human insulin** has been inserted into **bacteria** which then produce human insulin which can be collected and purified for medical use for diabetics
- **Crop plants**, such as wheat and maize, have been genetically modified to contain a gene from a bacterium that **produces a poison that kills insects**, making them **resistant to insect pests** such as caterpillars
- **Crop plants** have also been genetically modified to make them **resistant to certain herbicides** (chemicals that kill plants), meaning that when the herbicide is sprayed on the crop it only kills weeds and does not affect the crop plant
- Some crops have been genetically modified to **produce additional vitamins**, eg **'golden rice'** contains genes from another plant and a bacterium which make the rice grains produce a chemical that is turned into **vitamin A** in the human body, which could help prevent deficiency diseases in certain areas of the world

Genetic Modification: Examples : Extended

Genetic modification using bacterial production of a human protein

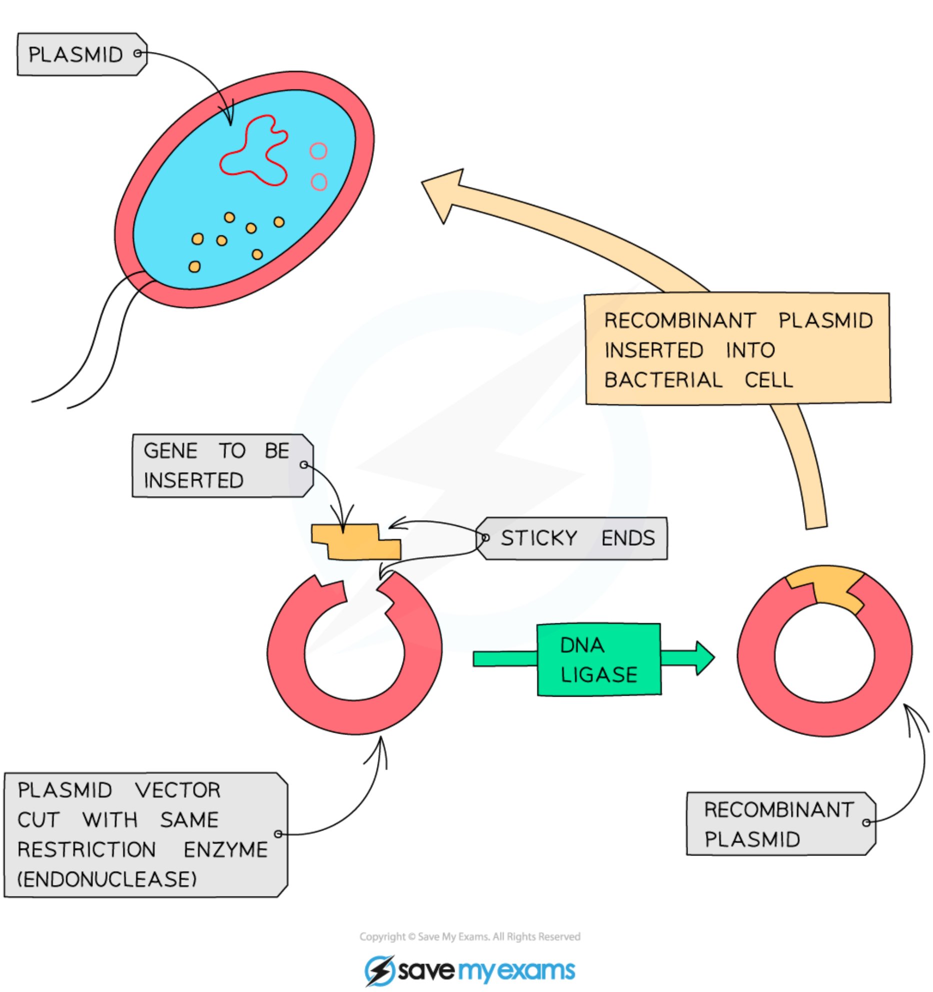
- The gene that is to be inserted is located in the original organism (for example, this could be the gene for human insulin)
- **Restriction enzymes** are used to isolate the required gene, leaving it with **'sticky ends'** (a short section of unpaired bases)
- A bacterial plasmid is **cut by the same restriction enzyme leaving it with corresponding sticky ends** (plasmids are **circles of DNA** found inside bacterial cells)



Restriction enzymes cut DNA strands at specific sequences to form 'sticky ends'

- The plasmid and the isolated gene are joined together by **DNA ligase enzyme**
- If two pieces of DNA have **matching sticky ends** (because they have been **cut by the same restriction enzyme**), DNA ligase will link them to form a single, unbroken molecule of DNA

Your notes



DNA ligase is used to join two separate pieces of DNA together

- The genetically engineered plasmid is **inserted into a bacterial cell**
- When the bacteria reproduce the **plasmids are copied as well** and so a recombinant plasmid can **quickly be spread** as the bacteria multiply and they will then all **express the gene** and make the human protein
- The genetically engineered bacteria can be placed in a **fermenter** to reproduce quickly in controlled conditions and make **large quantities** of the human protein
- Bacteria are extremely useful for genetic engineering purposes because:
  - They contain the **same genetic code** as the organisms we are taking the genes from, meaning they can easily 'read' it and **produce the same proteins**
  - There are **no ethical concerns over their manipulation and growth** (unlike if animals were used, as they can feel pain and distress)
  - The **presence of plasmids** in bacteria, separate from the main bacterial chromosome, makes them **easy to remove and manipulate** to insert genes into them and then place back inside the bacterial cells

Your notes

GM Crops: Extended

Your notes

ADVANTAGES	DISADVANTAGES
REDUCED USE OF CHEMICALS SUCH AS HERBICIDES AND PESTICIDES – BETTER FOR THE ENVIRONMENT CHEAPER / LESS TIME–CONSUMING FOR FARMERS	INCREASED COSTS OF SEEDS – COMPANIES THAT MAKE GM SEEDS CHARGE MORE FOR THEM TO COVER THE COST OF DEVELOPING THEM THIS CAN MEAN SMALLER, POORER FARMERS CANNOT COMPETE WITH LARGER FARMS
INCREASED YIELDS FROM THE CROPS AS THEY ARE NOT COMPETING WITH WEEDS FOR RESOURCES OR SUFFERING FROM PEST DAMAGE	INCREASED DEPENDENCY ON CERTAIN CHEMICALS, SUCH AS THE HERBICIDES THAT CROPS ARE RESISTANT TO – OFTEN MADE BY THE SAME COMPANIES THAT PRODUCE THE SEED AND MORE EXPENSIVE TO BUY
	RISK OF INSERTED GENES BEING TRANSFERRED TO WILD PLANTS BY POLLINATION WHICH COULD REDUCE THE USEFULNESS OF THE GM CROP (EG IF WEEDS ALSO GAIN THE GENE THAT MAKES THEM RESISTANT TO HERBICIDE)
	REDUCED BIODIVERSITY AS THERE ARE FEWER PLANT SPECIES WHEN HERBICIDES HAVE BEEN USED – THIS CAN IMPACT INSECTS AND INSECT–EATING BIRDS
	SOME RESEARCH HAS SHOWN THAT PLANTS THAT HAVE HAD GENES INSERTED INTO THEM DO NOT GROW AS WELL AS NON–GM PLANTS