Microorganisms and biotechnology

The use of microorganisms and biotechnology

- Biotechnology is the use of microorganisms such as bacteria and fungi to make useful products or carry out services for us.
- The use of both bacteria and fungi are in various processes is widespread
    - Bacteria reproduce very quickly with a generation time of less than 30 minutes
    - Unlike animals and plants, microbes can convert raw materials into the finished product very quickly
    - The use of bacteria means that food production can ne independent of climate
    - Bacteria can produce complex proteins that pass out into the surrounding medium and can be harvested. Enzymes made by microorganisms are used in the food industry
- Examples of enzymes that are produced by bacteria for use in the food industry are:
    - Amylase for breaking down starch in the production of glucose syrup
    - Pectinase for extracting juice from fruit
    - Sucrose for breaking down sucrose in making confectionery
    - Protease for making meat more tender
- With the aid of genetic engineering, scientists can quickly alter microbes and so modify products
- Breeding new varieties of plants and animals can take a long time
- Plasmids in bacteria are easy to work with, since they replicate very quickly
- Plasmids can be cut open by enzymes and a gene from another organisms can be spliced into them
- In nutrient media, bacteria multiply rapidly, making many copies of the plasmid and the inserted gene
- The use of bacteria and fungi in the manufacture of complex chemicals raises some ethical concerns over their manipulation and growth

Biofuels and bread making

- Many microbes can respire successfully without oxygen
- Yeasts can respire with or without oxygen
- When yeast respires without oxygen (anaerobically) it is called fermentation
- $Glucose \rightarrow alcohol + carbon\ dioxide + energy\ released$

Biofuels

- Biofuels are fuels made from biological materials
- The raw materials often used is sugar cane juice which contains a lot of carbohydrates
- Glucose from maize starch is another raw material
- This is obtained by treating the starch with carbohydrase enzymes
- Ethanol is a good substitute for petrol because it has a high energy content when burnt and does not produce toxic gases
- Using ethanol as fuel means there is no overall increase in carbon dioxide in the atmosphere
- As a result this fuel is carbon neutral
- Car engines need to be modified to be able to use pure ethanol
- Oil seed rape is a crop that provides oil that is converted into fuel called biodiesel

Bread making

- Baking is another example of using yeast to produce a food
- Bread is made from dough
- This mixture is kept at a warm temperature
- The yeast starts to ferment the sugar, producing carbon dioxide gas and alcohol
- Bubbles of carbon dioxide are trapped inside the dough and make it rise
- When the bread is baked in a hot oven the bubbles of the gas make the bread light in texture
- The heat causes the alcohol to evaporate leaving behind the traditional taste of bread]

Enzymes and biotechnology

Biological washing powders

Biological washing powders may contain one or more of the following enzymes:

- Proteases to break down protein stains
- Lipases to break down fats in grease stains
- Amylases to break down starch
- Celluloses to break down cellulose fibers on the outside of cotton fabric to remove the dirt attached to them
- The enzymes have been modified so that they withstand the high temperatures and alkaline conditions
- During a wash cycle, the enzymes break down the stains and the products of the reaction dissolve or are suspended in water and are removed when the washing machine is emptied

Extracting fruit juices

- Pectinases are enzymes that break down pectin
- Pectins are molecules that act like glue in plant cell walls
- Pectinases are used for extracting fruit juices and for softening vegetables

The use of lactase in making lactose-free milk

- Some people do not produce enough lactase and therefore have problems digesting lactose
- They may get diarrhea, wind or stomach cramps if they consume lactose products
- Lactose is a complex sugar, similar to sucrose that can be broken down into simple sugars by lactase

Fermenters

Industrial production of penicillin

- One important use of large-scale industrial fermentation is the production of antibodies such as penicillin
- The fermenter is inoculated with a culture of suitable fungus
- Then fermentation is carried out under certain conditions that have to be maintained inside the fermenter
- These conditions should include:
    - Adding nutrients, such as sugar or starch as a source of carbon for respiration
    - Ammonia or urea is added as a source of nitrogen to make proteins

- Vitamin B complex is added for respiration
- Maintaining a constant temperature of about 30°C
- Maintaining a constant pH of about 6.5

Batch Culture

- It takes about 30 hours for penicillin production to start
- Penicillin is secreted into the surrounding liquid by fungus
- This is because penicillin is a secondary metabolite, a substance which is not necessary for the growth of fungus
- Penicillin production starts after the exponential growth phase in response to one or more limiting factors
- After about 6 days, the mixture in the fermenter is filtered, the penicillin is extracted using a solvent and then purified into a crystalline salt
- This type of production is known as batch culture
- After the 6 day period, the fermenter is emptied, cleaned and sterilized ready for the next batch

Industrial fermentation

- Industrial fermenters are large tanks that can hold as much as 500 000 dm^3 of fermenting mixture
- Conditions inside these huge tanks are carefully controlled
- How fermenters work:
    - The fermentation vessel is made of stainless steel and is filled with a medium containing the required nutrients. These include sugars and ammonium salts. Some of the fungus is added
    - The fungus grows well in the conditions in the fermenter. Sugars provide energy for respiration and ammonium salts are used by the fungus to make proteins and nucleic acid. After a few days, the fungus starts to produce penicillin, which accumulates in the fermenter
    - A stirrer keeps the microorganisms suspended so they always have access to nutrients and oxygen. Stirring also helps to maintain an even temperature throughout the fermenter
    - An air supply provides oxygen for the aerobic respiration of the fungus
    - A water-cooled jacket removed the heat produced by fermentation to give a constant temperature of 24°c
    - Probes monitor the temperature and make sure the pH is constant at 6.5 by adding alkalis if necessary

Genetic engineering

- Genetic engineering involves changing the genetic material of an organism by removing, changing or inserting individual genes
- A gene is a section of DNA that codes for the production of a specific protein
- Genetic engineering is the transfer of a gene from the DNA of one species to the DNA of another species
- This is a process that can never be achieved by artificial selection because only in rare species would one species breed with another
- Genetic engineering allows the transfer of genes between totally unrelated species

Examples of genetic engineering

Human medicines

- Insulin, human growth hormones and blood clotting agents are produced by bacteria that have been genetically modified with the appropriate human genes
- These proteins are mass produced and used as medicines

Herbicide resistance in crop plants

- Genetically modified variety of rape seed has been developed in which a gene is transferred into it from a soil bacterium
- This gene makes oilseed rape resistant to the herbicide glufosinate
- When applied to fields of oilseed rape this herbicide would not only kill the weeds but the crop itself
- But the GM oilseed rape is not affected by the herbicide and so continues to grow while only the weed is destroyed

Insect resistance in crop plants

- Maize and cotton can be attacked by insects which reduce their yields
- The major pests of maize are root worm larvae and stem-boring caterpillars
- The genetically modified plants produce their own toxin which kills insect larvae that feed on it
- This has less environmental impact than sprayed pesticides, because only the insects feeding on the crop plants are killed

Additional vitamins in crop plants

- GM varieties of rice have been developed by transferring genes from maize and a soil bacterium, that enables people to make vitamin A
- The resultant rice is a pale yellow in color giving its name, Golden Rice
- If, or when, this rice becomes available to grow on a large scale it will improve the diets if the people who eat it
- They will be able to make vitamin A
- This will reduce the high mortality rates as a result of poor immune systems

Industrial production on insulin

- Genetic engineering makes it possible to make insulin quickly and cheaply on a large scale
- The human gene that codes for the production of insulin is identified
- Restriction enzymes act as chemical scissors to cut the human insulin-making gene from the rest of DNA
- A circular piece of DNA called a plasmid is removed from a bacterium
- The same restriction enzymes are then used to cut open the plasmid
- The two ends of the DNA of the insulin-making gene are an exact match with the two DNA ends and the plasmid
- These are called sticky ends
- Another enzyme called ligase is used to attach the sticky ends of the insulin-making gene to the sticky ends and plasmid
- The plasmid is now known as a recombinant plasmid as is inserted back into the bacteria

- The bacteria now has the gene code for insulin
- The bacteria multiply very rapidly inside an industrial fermenter and produce insulin

Advantages and disadvantages of genetically modified crops

Benefits:

- Solving global hunger- GM could feed more people as the crops that are produced are able to tolerate extreme climate conditions and soils. Food production could be increased in marginal areas
- Environmentally friendly- GM crops can be resistant to insects, weeds and diseases so there will be less use of pesticides. Also genes that improve nitrogen uptake would mean less need for chemical fertilizers and lessen the environmental threat they pose
- Consumer benefits- GM crops have already been produced with improved flavor and better keeping qualities. They are easier to produce and require less additives

Concerns:

- Environmental safety- There are concerns that new GM plants will become successful weeds. Pollen from GM crops are resistant to weed killers and may be transferred to other plants by insects or the wind
- Food safety- new gene combinations may have effects that are so far unknown, they result in harmful substances being produced
- Biodiversity- increasing use of herbicides and plant breeding will reduce the number of plant varieties and wild varieties