Edexcel GCSE Biology

Your notes

Genetic Modification

Contents

Selective Breeding

Your notes

Selective Breeding in Animals

- Selective breeding or artificial selection means to **select individuals with desirable characteristics and breed them together**
- The process doesn't stop there though because it's likely that not all of the offspring will show the characteristics you want so **offspring that do show the desired characteristics are selected and bred together**
- This process has to be **repeated for many successive generations** before you can definitely say you have a **'new breed'** that will **reliably** show those selected characteristics in all offspring

Natural Selection vs Artificial Selection Table

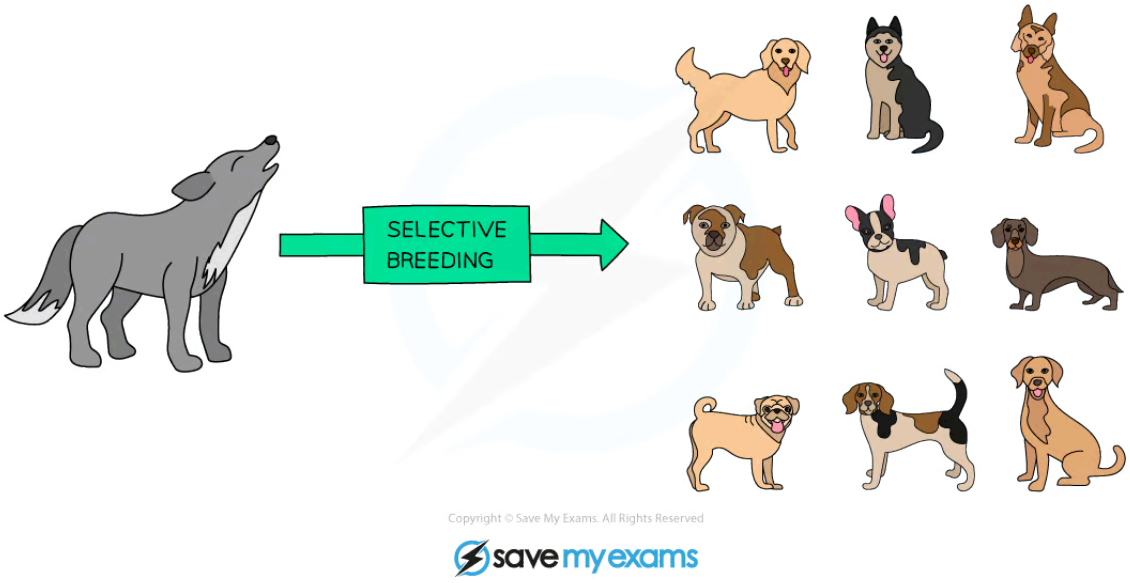
NATURAL SELECTION	ARTIFICIAL SELECTION
OCCURS NATURALLY	ONLY OCCURS WHEN HUMANS INTERVENE
RESULTS IN DEVELOPMENT OF POPULATIONS WITH FEATURES THAT ARE BETTER ADAPTED TO THEIR ENVIRONMENT AND SURVIVAL	RESULTS IN DEVELOPMENT OF POPULATIONS WITH FEATURES THAT ARE USEFUL TO HUMANS AND NOT NECESSARILY TO SURVIVAL OF THE INDIVIDUAL
USUALLY TAKES A LONG TIME TO OCCUR	TAKES LESS TIME AS ONLY INDIVIDUALS WITH THE DESIRED FEATURES ARE ALLOWED TO REPRODUCE

Selective breeding of animals

- Individuals with the characteristics you want are **bred together** (often several different parents all with the desired characteristics are chosen so siblings do not have to be bred together in the next generation)
- **Offspring** that show the **desired characteristics are selected and bred together**
- This process is **repeated for many successive generations**
- Animals are commonly selectively bred for various characteristics, including:
  - Cows, goats and sheep that produce lots of **milk** or **meat**

- Chickens that lay large **eggs**
- Domestic dogs that have a gentle nature
- Sheep with good quality wool
- Horses with fine features and a very fast pace

- An example of an animal that has been selectively bred by humans in many ways to produce breeds with many different characteristics is the domestic dog, all breeds of which are descended from wolves:



Selective breeding has produced many different breeds of domestic dog

Examiner Tips and Tricks

Make sure that you include the need to repeat the selective breeding process for **many generations** in any exam answer you give – selecting two parents with desired characteristics, breeding them and stopping there is not selective breeding and will not give rise to a new breed.

Selective Breeding in Plants

- Selective breeding of plants takes place in the same way as selective breeding of animals
- Plants are selectively bred by humans for development of many characteristics, including:

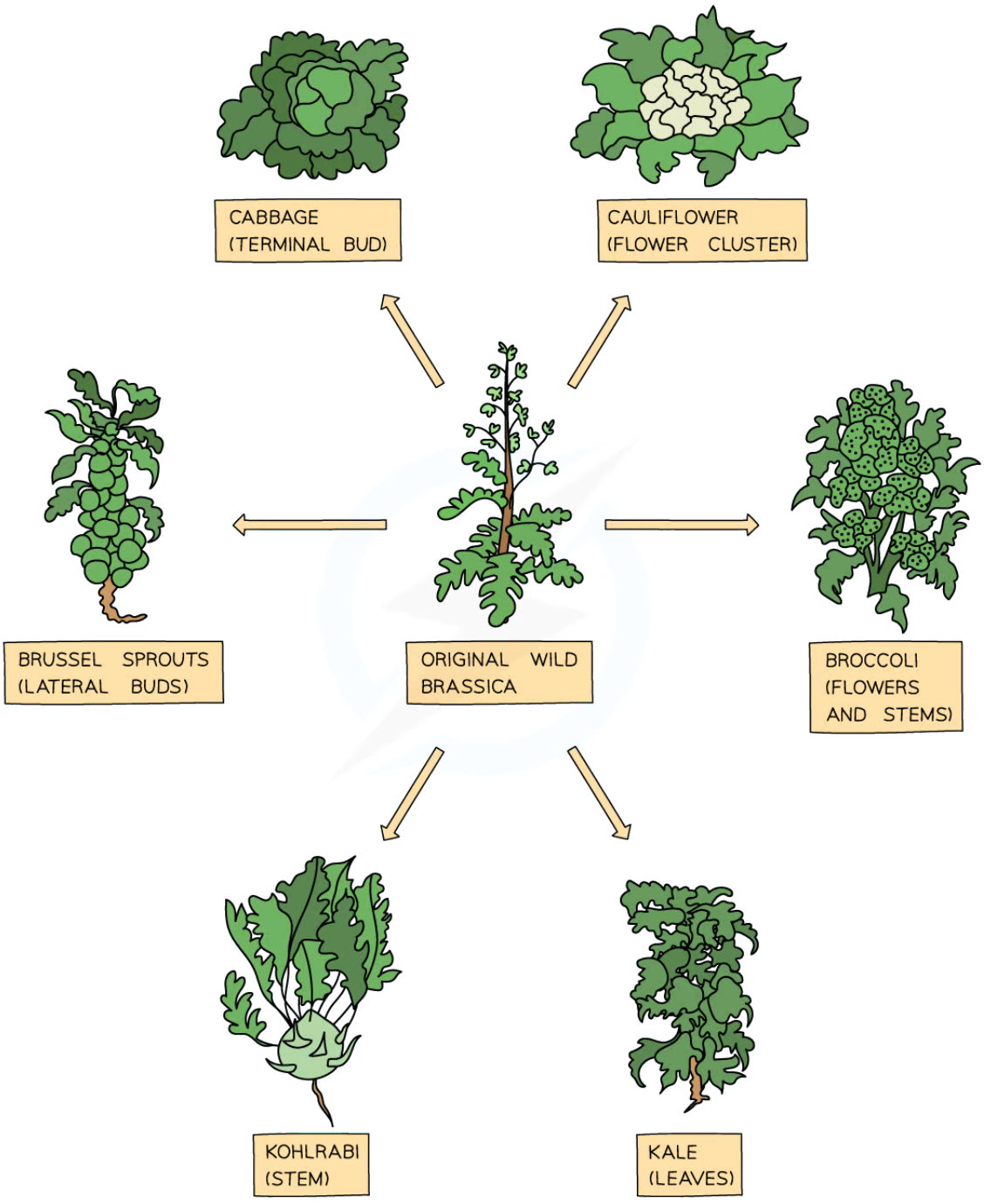
Your notes

- **Disease resistance** in food crops
- **Increased crop yield**
- **Hardiness to weather conditions** (eg. drought tolerance)
- Better tasting fruits
- Large or unusual flowers

- An example of a plant that has been selectively bred in multiple ways is wild brassica, which has given rise to cauliflower, cabbage, broccoli, brussel sprouts, kale and kohlrabi:


Your notes

Your notes



An example of selective breeding in plants

Problems with selective breeding

- Selective breeding can lead to **'inbreeding'**
- This occurs when only the 'best' animals or plants (which are **closely related to each other**) are bred together
- This results in a **reduction in the gene pool** – this is a reduction in the number of **alleles** (different versions of genes) in a **population**
- As inbreeding limits the size of the gene pool, there is an increased chance of:
  - Organisms inheriting **harmful genetic defects**
  - Organisms being vulnerable to **new diseases** (there is less chance of resistant alleles being present in the reduced gene pool)


Your notes

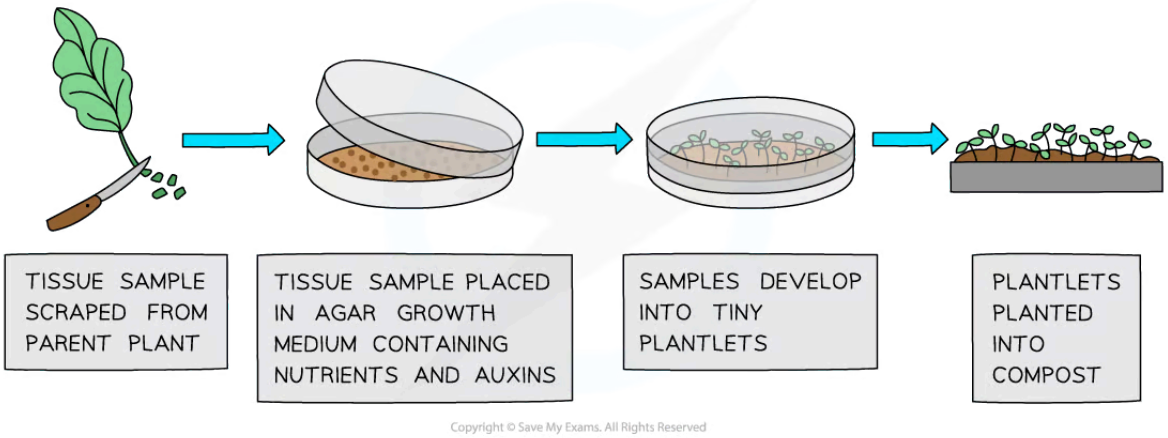
Your notes

Tissue Cultures

- Tissue culture is a process in which very small pieces of organisms (**'tissues'**) are grown (**'cultured'**) using nutrient media (i.e. in some kind of **artificial growth medium**)
- This allows scientists to produce a **large amount of tissue** from just a **single individual organism**
- This tissue can then be used for a variety of different purposes

Plant tissue culture

- Using tissue culture, whole plants can be grown from a very small amount of plant tissue
- New plants are produced via tissue culture in the following way:
  - A **parent plant** is chosen (this should have the **desired characteristics** e.g. beautiful flowers, interesting shaped leaves or a large fruit crop)
  - A **very small amount of tissue** (usually a small group of cells) is scraped from the parent plant (these small pieces of tissue are known as **explants**)
  - Under **aseptic (sterile) conditions**, the tissue pieces are transferred to a sterile petri dish containing **nutrient agar**. This step must be done under aseptic conditions to **prevent the growth of microbes** that might **harm** the plant
  - **Hormones** (e.g. auxins) are added to **encourage the cells of the explants to grow**
  - The explants continue to grow and eventually form **plantlets** that can be transferred to **individual potting trays** with **compost**, where they can develop into plants



Tissue culture: using small groups of cells from a part of a plant to grow identical new plants


Your notes

- The plants produced via tissue culture are all **clones** (**genetically identical** individuals)
- The cloning of plants has many important **commercial uses** (mainly in **plant breeding programmes**)
- It allows a variety of a plant with desirable characteristics (e.g. pesticide resistance, good tasting fruit etc.) to be produced:
  - **Cheaply**
  - With a **greater yield** (a large number of plants can be produced)
  - In a **small space**
  - **Quickly**
  - At **any time of the year**
- It can also ensure diseases prevalent in other areas of the world are not imported and spread by ensuring native varieties of plants are produced in large enough quantities to supply demand in one country without importing plants from abroad
- Plant tissue culture can also play an important role in **preserving rare plant species**

Animal tissue culture

- **Genetically identical animal cells** and **tissues** can be produced in large quantities via a slightly different tissue culture process:
  - A sample of the tissue to be studied (e.g. tissue from the pancreas) is extracted from the animal
  - **Enzymes** are used to **separate the cells** that make up the tissue sample
  - The cells are placed in a **culture vessel** (i.e. some kind of container) along with a **growth medium**
  - This contains all the nutrients needed for the cells to **grow** and **multiply** into **tissues**
  - Once the tissue culture has been grown, it can be **stored** for future use
- Animal tissues grown via tissue culture can be used in **medical research**:
  - For example, the effect of glucose on pancreatic cells can be tested on samples of pancreatic tissue grown via tissue culture
  - This means that experiments can be conducted on tissues **in isolation**, **without negatively affecting a living organism**
  - For example, scientists can study the effects of a particular **chemical** or **environmental change** on the cells of a single tissue **without complications** and **external factors** caused by other processes that would normally occur in the whole organism

Your notes

Genetic Engineering

- **Genetic engineering** is a process that involves **modifying the genome of an organism** to introduce **desirable characteristics**
- Specifically, genetic engineering 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 being a **transgenic organism**
- The DNA of the organism that now contains DNA from another organism as well is known as **recombinant DNA**
- There are many examples of genetically modified organisms, including:
  - The gene for **human insulin** has been inserted into **bacteria**, which then produce human insulin that 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**, e.g. **'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 **vitamin A deficiency** in certain areas of the world

Genetic engineering in medicine

- Modern medical research is exploring the possibility of **genetic modification to overcome some inherited disorders**
- As these inherited genetic diseases are caused by **faulty genes**, it may be possible to treat these by inserting **working versions of these genes** into people with the genetic disease
- This is called **gene therapy**

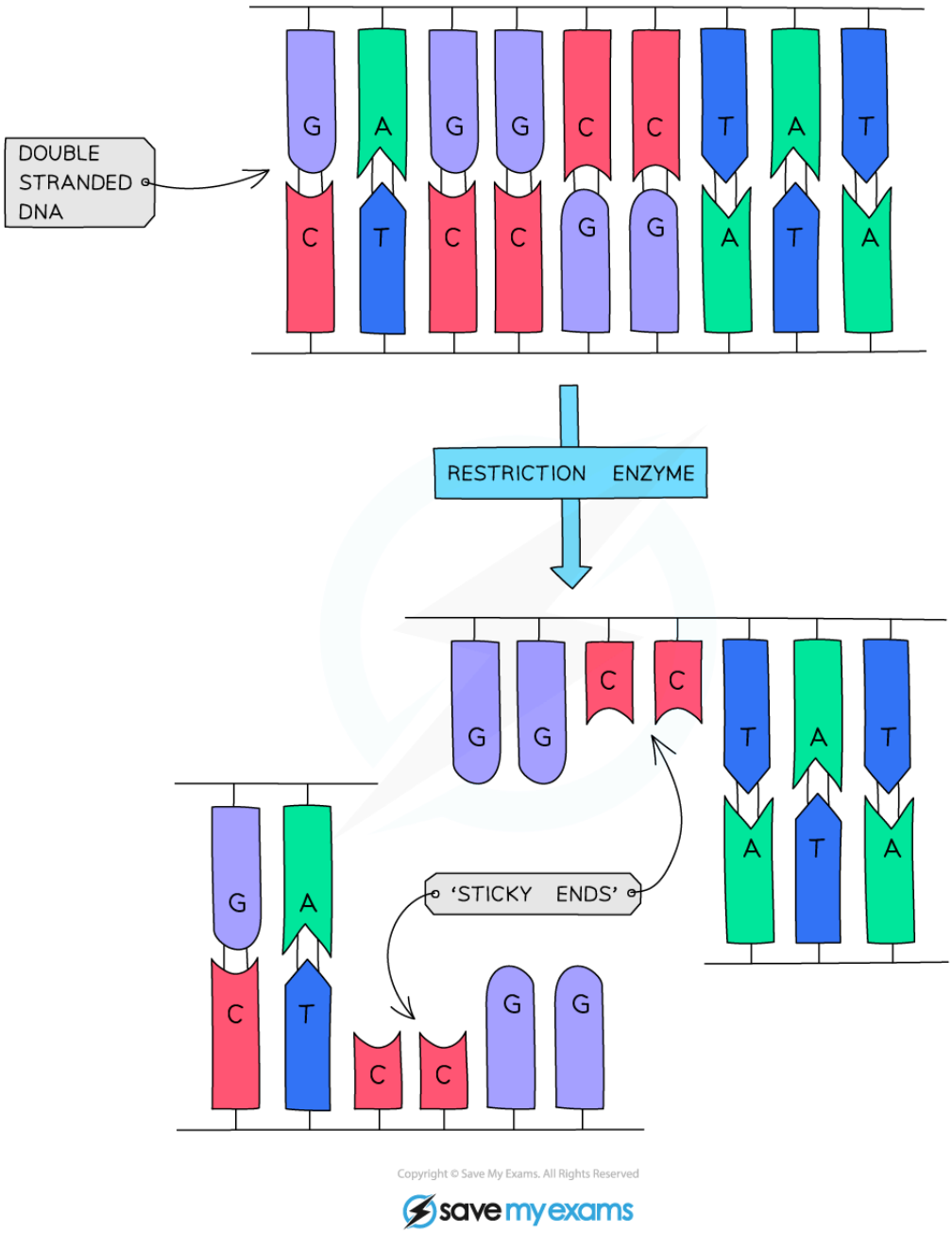
Your notes

The Process of Genetic Engineering

Higher tier only

- The gene that is to be inserted is located in the original organism
- **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)

Your notes

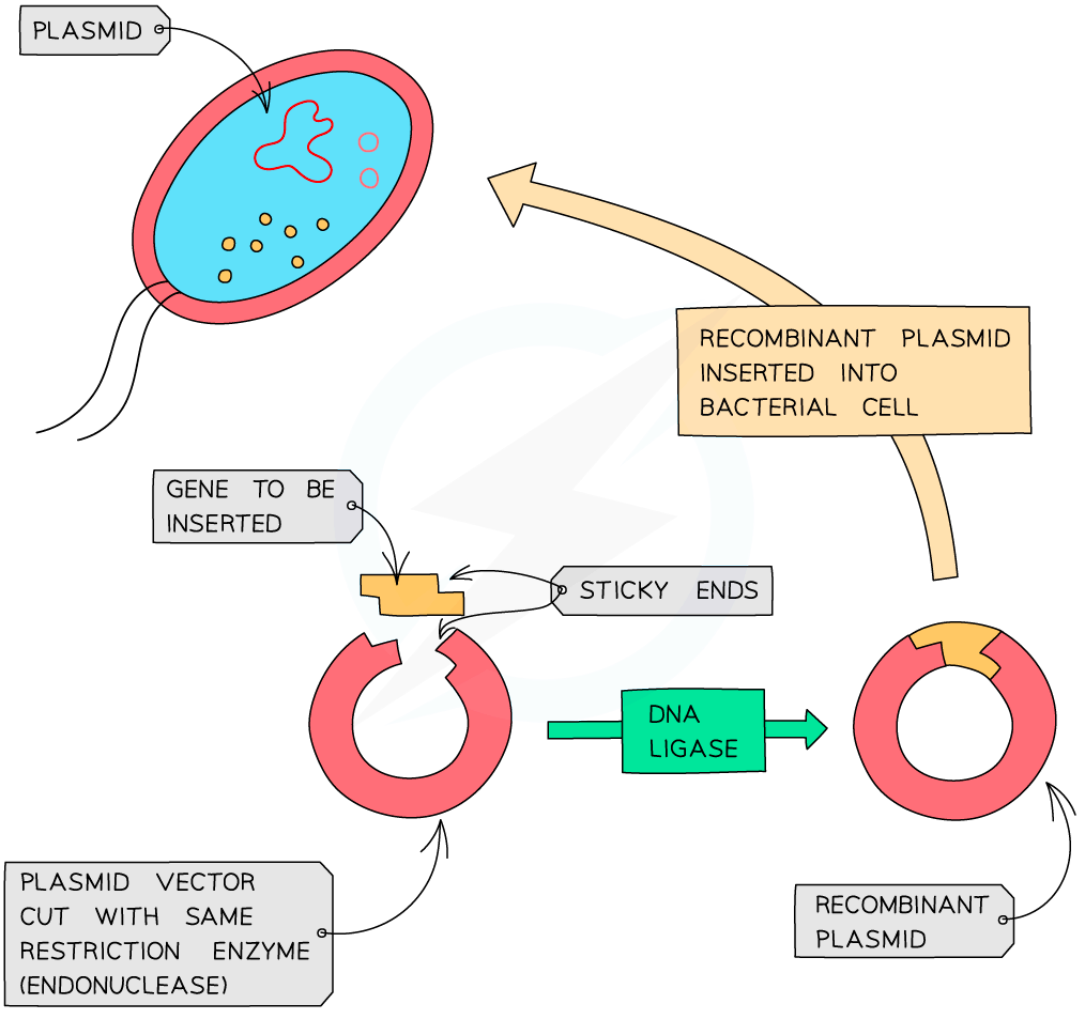


Restriction enzymes cut DNA strands at specific sequences to form 'sticky ends'

- The plasmid and the isolated gene are joined together by **DNA ligase enzyme**

Your notes

- 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



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


Your notes

Meeting Global Food Demands

Your notes

GM Crops

Higher Tier Only

- Modern technology has increased food supply substantially in a number of ways, including:
  - **Agricultural machinery** has replaced humans and **improved efficiency** due to the ability to farm **much larger areas** of land
  - **Chemical fertilisers improve yields** - fertilisers increase the amount of nutrients in the soil for plants, meaning that they can grow larger and produce more fruit
  - **Insecticides and herbicides** - these chemicals kill off unwanted insects and weed species, meaning that there is **less damage done** to plants and fruit lost to insects (insecticides), as well as **reducing competition** from other plant species (herbicides)
  - **Selective breeding** - animals and crop plants that produce a large yield are selectively bred to produce breeds that **reliably produce high yields**
- More recently, **genetic engineering** has been used to produced **genetically modified crop plants** that have **increased yields** compared to normal crop plants
  - These genetically modified crops are known as **GM crops**

Genetic engineering of crops

- Crop plants have been genetically modified to be:
  - **Resistant to pests** – increases productivity / yield
  - **Resistant to herbicides** – increases productivity / yield
  - **Enriched in vitamins** – increases the nutritional value
- Crop plants have been genetically modified to **produce poisons that kill insects**, making them **resistant to insect pests**. This can **improve crop yields** and **reduce** the need for **chemical pesticides**
  - For example, maize (corn) and cotton plants have been genetically modified with a gene for a toxin (a poison) that kills many insect larvae that are harmful to these crops
  - The toxin is called **Bt toxin** as it was taken from the bacterium *Bacillus thuringiensis*
  - The crops with the **Bt gene** produce the toxin in their stems and leaves
  - The significance of genetically engineering crops to be **insect resistant** is that there is an **increase in yield** and **fewer pesticides are used** which could have ecological benefits (e.g. non-targeted

invertebrates are not harmed)

- Crop plants have also been genetically modified to make them **resistant to certain herbicides** (chemicals that kill plants)
  - This means 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** and **improved nutritional value**
  - For example, '**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
- Some crops have been genetically modified to be drought-resistant (to grow better in very dry conditions). This can also **improve crop yields** in arid countries that are prone to droughts

Advantages & Disadvantages of GM Crops Table


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


Your notes

Fertilisers & Biological Control

Higher Tier Only


Your notes

Using fertilisers to increase crop yields

- Plants require a **range** of **mineral ions** in order to **grow well**
- As crop plants take up these mineral ions from the soil, the mineral ions need to be **replaced** if crops are grown repeatedly in the same field (i.e. year after year)
- **Fertilisers** are used to replace these mineral ions
- They can make crops grow **faster** and **bigger** so that **yields are increased**
- Fertilisers can be in the form of **organic fertiliser** or **chemical fertiliser**
  - Organic fertilisers commonly used by farmers include farmyard **manure** and **compost**
  - Chemical fertilisers are often applied to the soil as **dry granules** or can be **sprayed on in liquid form**
- They mainly provide crop plants with **nitrogen**, **phosphorus** and **potassium**
- However, a major **disadvantage** is that **excess fertilisers** not taken up by crops can get **washed into lakes and rivers** and cause problems, such as **eutrophication**

Using biological control to increase crop yields

- Pests such as **insects and other animals** can damage crops by eating them
- Pests such as weeds can **outcompete** crop plants for **space, water and soil nutrients**
- Many of these pests can be controlled by **introducing other species** to the farmland (a technique known as biological control)
- Biological control can happen **naturally** - for example, ladybirds eat aphids (which can damage certain crops)
- Usually, a **new species** is **introduced** specifically to **prey upon** or **parasitise** the **pest species** - for example, cane toads were introduced into Australia to eat crop-damaging beetles and parasitic wasps can control whitefly in glasshouse tomato crops
- An **advantage** of biological control is that it can have **longer-lasting effects than chemical pesticides** and be **less harmful to the environment** (e.g. to non-target species)
- However, as biological control is based on a **predator-prey cycle** or a **parasite-host relationship**, it **does not completely remove a pest** but keeps it at **lower levels**
- Also, in some cases, the introduction of new organisms to an ecosystem can cause problems - for example, cane toads are now themselves considered a pest species in Australia as they poison the

native species that eat them

Your notes

Your notes

Evaluating the Use of Genetic Engineering

- **Genetic engineering** and **selective breeding** are used in modern-day **agriculture**
- Genetic engineering is also used in modern-day **medicine**
- Both these techniques have **many benefits** but their use also comes with certain **risks**, as well as other **practical and ethical implications**

Advantages & Disadvantages of Genetic Engineering Table

Advantages	Disadvantages
Can be used in medicine to mass-produce certain hormones (e.g. insulin) using microorganisms (e.g. bacteria)	It is difficult to predict the effects of modifying the genome of an organism – many genetically modified embryos don't survive and if they do, the organism may suffer from health problems later on
May be used in future medicine to produce animals that have organs suitable for organ transplantation into humans	Genetic engineering in agriculture and medicine may lead to genetic engineering in humans (e.g. 'designer babies'), which would have many ethical implications

Can be used in agriculture to genetically modify crops to be resistant to droughts (increasing yields in hotter, drier climates) or resistant to herbicides (increasing yields by allowing farmers to kill weeds without harming the crop)	Genes from GM crops could get into the environment (e.g. a herbicide resistance gene could spread into wild plants, creating a 'superweed' that could reduce crop yields)
Can be used to genetically modify crops to produce their own pesticides (e.g. Bt corn)	GM crops (e.g. those that produce their own pesticides) create a selection pressure, which could lead to pesticide resistance evolving in pest species

Advantages & Disadvantages of Selective Breeding Table


Your notes

Advantages	Disadvantages
The yield of crops or livestock can be greatly increased by selectively breeding individuals that produce higher quality or a larger mass of food	Selective breeding can result in health problems in organisms, which may be seen as unethical e.g. some chickens have been bred to grow so much muscle (more meat) that they are unable to walk properly
Crops or livestock can also be selectively bred to be resistant to certain diseases, which also increases the yield	Selective breeding can also result in a lack of genetic variation in crops or livestock, by reducing the gene pool (i.e. the number of different alleles) in these populations. This is due to inbreeding (breeding closely related organisms)
	Inbreeding increases the chance of organisms inheriting harmful genetic defectsvand organisms being vulnerable to new diseases (there is less chance of resistant alleles being present in the reduced gene pool)


Your notes

Your notes

The Human Genome Project

- The **entire set** of **genetic material** of an organism is known as its **genome**
- Biologists now know the entire **human genome** (they have worked out all the genes that are found in humans)
- The **Human Genome Project** (completed in 2003) was the name of the international, collaborative research effort to determine the DNA sequence of the entire human genome and record every gene in human beings
- This was a very important breakthrough for several reasons, including:
  - The **prediction** and **prevention** of **diseases**
  - The **testing** and **treatment** for **inherited disorders**
  - The **development** of **new** and **improved medicines**

Prediction and prevention of diseases

- Diseases such as **cancers** and **heart disease** are partially caused by **genes** (as well as **lifestyle factors**)
- A greater understanding of which genes **predispose** people to these diseases would enable doctors to provide people with much **more specific advice** on the **best lifestyle and diet** to help them **avoid** or **delay** the onset of these diseases
- Doctors would also be much better at **predicting** what diseases someone might develop and **ensuring early treatment** if someone develops a disease

Testing and treatment for inherited disorders

- Inherited disorders such as cystic fibrosis arise due to one or more **faulty alleles** in a person's genome
- The Human Genome Project has allowed doctors to **identify** these faulty alleles **much more quickly** than in the past
- Once these faulty alleles are identified, people can be **tested for them** and it is possible to **develop treatments** for the inherited disorder

Development of new and improved medicines

- A greater understanding of how genetic variations can make people more susceptible to certain diseases has allowed doctors to **design new medicinal drugs** specifically tailored to those with genetic variations that affect **how they react to specific diseases and treatments**

- It has also allowed these drugs or other treatments to be made **more effective** and have **fewer side-effects**
- Doctors are also now able to **much better predict** how **well** an existing drug or other treatment will work for a specific person


Your notes

Disadvantages of the Human Genome Project

- There are also **several potential drawbacks** to the Human Genome Project, including:
  - Someone who is told they have a high chance of developing a certain genetic disease may suffer from **increased anxiety and stress** (and this could be completely unnecessary as they may never even develop the disease)
  - People with known genetic diseases and disorders (or who carry a faulty allele but do not have the disease themselves) could potentially be **pressured into not having children**
  - These same people may be **unfairly discriminated against** by **employers** (who may not want to hire them and invest resources in them in case they become ill) or **insurers** (who could make life insurance much more expensive for people they know are more likely to develop a fatal disease)