Edexcel Biology GCSE

Topic 4: Natural Selection and Genetic Modification

Notes

(Content in **bold** is for higher tier only)

CONTENTS

4.1B - **Biology Only** Darwin and Wallace's Theory
4.2 - Evolution by Natural Selection
4.3 - Emerging Resistance
4.4 - Fossil Evidence for Human Evolution
4.5 - Dating Stone Tools
4.6B - **Biology Only** Anatomical Evidence for Evolution
4.7 - Five Kingdoms vs. Three Domains
4.8 - Selective Breeding
4.9B - **Biology Only** Tissue Culture
4.10 - Genetic Engineering
4.11 - **Higher Only Stages of Genetic Engineering**
4.12B - **Biology Only** Advantages and Disadvantages of GM Organisms
4.13B - **Biology Only** Agricultural Solutions
4.14 - Implications of Genetic Engineering and Selective Breeding

4.1B **Biology Only** - Darwin and Wallace's Theories and 4.2 - Evolution by Natural Selection

Alfred Russel Wallace developed the theory of speciation, and therefore evolution by natural selection.

- On his travels, he had the idea that the individuals who did not have characteristics to help them survive a change in the environment would die out.
- He published joint studies with Darwin.
- The publication of **'On the Origin of Species'** meant Darwin received the credit for the theory.
- He continued to work across the world to collect evidence – one of his most important works was on warning colouration in animals
- Much more evidence over time has resulted in our current understanding.

The process of speciation:

1. **Variation** exists within a population as a result of **genetic mutations.**
2. Alleles which provide a survival advantage are selected for through natural selection.
3. Populations of a species can become **isolated**, for example through physical barriers such as a rock fall preventing them from breeding together.
4. Different alleles may be advantageous in the new environment, leading to them being selected for.
5. Over time the **selection of different alleles** will **increase the genetic variation** between the two populations.
6. When they are **no longer able to breed together to produce fertile offspring,** a new species has formed.

Charles Darwin

- Scientist and naturalist
- Put forward the theory of evolution
- This was supported by experimentation and his knowledge of geology and fossils that he discovered on a round the world expedition
- Published 'On the Origin of Species' in 1859

Theory of Evolution:

- Variation exists within species as a result of mutations in DNA
- Organisms with characteristics most suited to the environment are more likely to survive to reproductive age and breed successfully – called **survival of the fittest**.
- The beneficial characteristics are then passed on to the next generation
- Over many generations the frequency of alleles for this advantageous characteristic increase within the population

There was lots of controversy surrounding his ideas for many reasons:

1. It contradicted the idea that God was the creator of all species on Earth.
2. There was not enough evidence at the time as few studies had been done on how organisms change over time.
3. The mechanism of inheritance and variation were not known at the time.

4.3 - Emerging Resistance

Bacteria are labelled resistant when they are not killed by antibiotics which previously were used as cures against them.

- Bacteria reproduce at a fast rate.
- Mutations during reproduction can result in new genes, such as the gene for antibiotic resistance. This the creation of a new strain.
- Exposure to antibiotics creates a selection pressure, as those with antibiotic resistant genes survive and those without die.
- As a result those with antibiotic resistance can reproduce and **pass on the advantageous gene** to their offspring. Therefore, the **presence of these new, resistant bacteria** supports Darwin's theory of natural selection (as the new bacteria have been selected by the environment to have a feature **(resistance)** advantageous to survival.)
- This population of antibiotic resistant bacteria increases.
- Bacterial diseases spreads rapidly because people are not immune to these new resistant bacteria and there is no treatment for it.

An example is MRSA.

- Called a 'superbug' as it is resistant to many different types of antibiotics
- Common in hospitals: spreads when doctors and nurses move to different patients

4.4 - Fossil Evidence for Human Evolution

Fossil evidence shows how developments in organisms arose slowly. This is because we can use **carbon dating** and related techniques to estimate when a fossil was formed, giving us a more complete picture of how an organism or species developed over time. Examples of these include:

a) **Ardi -** Ardipithecus ramidus, or Ardi, is the oldest known human ancestor - estimated to have lived 4.4 million years ago.
Her fossilised skeleton contains many 'humanoid' features but also resembles an ape - thus, it is **phenotypically** somewhere between the two. The presence of this 'intermediate' organism is good evidence that **natural selection**, and eventually **evolution**, occurred gradually.

The bone structure in Ardi's feet also gives us a clue - it is different from that of chimpanzees, suggesting that the two evolved separately rather than together.

b) **Lucy -** This fossilised skeleton dates from 3.2 million years ago. Her bone structure suggests that she walked in an **upright, human-like position**. However, Lucy had a **small, chimp-like skull and brain** and therefore represents another intermediate between apes and early humans.
c) Fossils discovered by the archaeologists **Louis and Mary Leakey** in the 1950s helped support the theory of natural selection, especially an early fossil which contained **remnants of stone tools** (thought to be an early toolmaker), and **Homo habilis**, which is now considered to be one of the most important early human species.

4.5 - Dating Stone Tools and 4.6B **Biology Only** - Anatomical Evidence for Evolution

We can use stone tools found as part of archaeological digs as evidence for human evolution. It is clear how stone tools have become more complex as our brains evolved in complexity:

Early Stone Age tools - Homo habilis (1.5 million years ago)
- Used basic pebble tools ('Oldowan tools') created by smashing rocks together.
- These tools had simple uses, such as cracking nuts.

Late Stone Age tools - Homo neanderthalensis (40,000 years ago) and modern **Homo sapiens**
- These more advanced species used pointed arrowheads, spears and hooks
- This enabled more advanced tasks to be carried out, such as catching fish.

We can date these tools using two main methods:

1. **Radiometric carbon dating** - by looking at the natural radioactive decay of an **isotope** of Carbon (Carbon-14) we can estimate how long ago an organism lived. If any once-living material is found with a tool, such as a **piece of wood or fur**, we can date this to find the age of the rock.
2. **Stratifying rock layers** - looking at the layer of sediment in which a rock was found is a useful tool for archaeologists. Each layer of sediment, and everything within it, must have been formed at the same time. Therefore, we can date once-living **fossils** in this layer and use this to **estimate when the tools were formed**.

Looking at how anatomical features developed over time using fossils also provides important evidence for evolution.

A pentadactyl limb is a limb with five digits. This can be seen in a number of organisms, implying that they all come from a **common ancestor** - and that each 'branched off' at some stage of evolution. This could have been **due to different selection pressures** within different environments.

The human hand has **five digits** (four fingers and a thumb), but bats, cats, horses and birds also have this pattern within their limbs. However, that does not mean that we evolved **directly** from these animals but humans are distantly related to them via a **common ancestor.**

4.7 - Five Kingdoms vs. Three Domains

It is important to classify organisms so that we know about the genetic relationships between species and organisms. We can do this by the old **Five Kingdoms system**, or the newer **Three Domains system**.

Five Kingdoms system

The Five Kingdoms Classification splits all organisms into one of 5 groups:

- **Animals**
- **Plants**
- **Fungi**
- **Prokaryotes** (e.g bacteria)
- **Protists** (e.g algae, amoebas and other single-celled eukaryotic organisms)

Each kingdom is then subdivided into a **phylum, class, genus, order** and **species**. These are different for each organism. For example, a human (Homo sapiens) would be of the **Animal** kingdom, its phylum is **Chordata**, class is **Mammalia** and Order is **Primate**.

The **binomial naming system** is based on the **genus** and **species**; for example, Homo sapiens is of the genus **Homo**, which also contains Homo habilis and Homo erectus, to name a few.

Three-domain system

- Developments in science such as the improvement of the microscope and increased knowledge of biochemistry (for example, RNA sequence analysis) found that some species were more distantly related than first thought
- Carl Woese added three large groups called domains above kingdoms
    - **Archaea**: primitive bacteria which live in extreme environments such as hot springs
    - **Bacteria**: true bacteria (despite having similar features to archaea)
    - **Eukaryota**: organisms who have a nucleus enclosed in membranes, includes the kingdoms protists, fungi, plants and animals

4.8 - Selective Breeding

Selective breeding is when humans choose which organisms to breed in order to produce offspring with a certain desirable characteristic (e.g animals with more meat, plants with disease resistance or big flowers).

This has been happening for many years since animals were domesticated and plants were grown for food.

- Parents with desired characteristics are chosen.
- They are bred together.
- From the offspring those with desired characteristics are bred together.
- The process is repeated many times until all the offspring have the desired characteristic.

The problem is that it can lead to **inbreeding**.

- Breeding those with similar desirable characteristics means it is likely you are breeding closely related individuals.
- This results in the reduction of the **gene pool**, as the number of different alleles reduce (as they mostly have the same alleles).
- This means **if the environment changes or there is a new disease**, the species could become extinct as they all have the same genetic make-up (so the chance of a few organisms having a survival advantage and not dying is reduced). This is particularly relevant in **selective breeding of plants**, as one disease could spread rapidly and destroy the entire population of crops. This could cause **severe economic problems**, especially for the farmers **who rely on income** from their crops.
- Another problem is that the **small gene pool** leads to a greater chance of genetic defects being present in offspring, as **recessive characteristics are more likely to present**. This is particularly relevant in **domesticated animals**, which have a much higher frequency of genetic conditions than normal.

4.9B **Biology Only** - Tissue Culture

Tissue culture is a method of **culturing** living tissue, i.e making it grow outside the organism, within a **growth medium**. This is especially useful for plants - we can produce an entire field of identical cloned crops using **just a small cutting**. Tissue culture can also be used to culture **animal and human tissues** outside of the body.

In plants, this is performed as follows:

1. Take the plant that you would like to clone - for example, a plant with **desirable characteristics.**
2. Using tweezers, remove a piece of tissue from a fast-growing region of the plant, e.g the **root or shoot tip**.
3. Using **aseptic technique** (maintaining sterile conditions), place the tissue on a special growth medium (containing hormones and nutrients).
4. Once the tissue has developed enough (e.g produced shoots and roots), it can be **transferred to compost for further growth**.

Benefits of tissue culture	Risks of tissue culture
Produces lots of offspring with a specific desirable feature.	The gene pool is reduced through producing clones, meaning it is less likely that the population will survive if a disease arises with low diversity in the population.
Increasing the number of crops resistant to bad weather, for example, can increase crop yields	Clones have a low survival rate, and tend to have some genetic problems.
Can help extremely endangered species, or even bring back species that have become extinct.	It may lead to human cloning.

4.10 - Genetic Engineering

Genetic engineering: Modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic.

- Plant cells have been engineered for disease resistance or to have larger fruits
- Bacterial cells have been engineered to produce substances useful to humans, such as human insulin to treat diabetes.

4.11 **Higher Only** - Stages of Genetic Engineering

1. **Genes from chromosomes are 'cut out' using restriction enzymes.**
2. **The same restriction enzymes are used to cut the vector (such as a virus or bacterial plasmid) into which the genes will be placed.**
3. **Ligase enzyme is used to attach the sticky ends of the gene and the vector together, to produce a recombinant gene product.The vector is placed in another organism at an early stage in development so the desired gene moves into its cells and cause the organism to grow with the desired characteristics. In plants the vector is put into meristematic cells (unspecialised cells) which can then produce identical copies of the modified plant.**

4.12B **Biology Only** - Advantages and Disadvantages of GM Organisms

Genetically modified crops

- They are engineered to be resistant to insects and to herbicides.
- This will result in increased yields as less crops will die.

Genetic modification in medicine

- It may be possible to use genetic engineering to cure inherited disorders.
- It is called gene therapy and involves transferring normal genes (not faulty) into patients so the correct proteins are produced.

Perceived benefits of genetic engineering	Perceived risks of genetic engineering
It can be very useful in medicine to mass produce certain hormones in microorganisms (bacteria and fungi).	GM crops might have an effect on wild flowers and therefore insects. • GM crops are infertile and these genes could spread into wild plants, leading to infertility in other species, which affects the entire environment. • Growing with herbicides and pesticides can kill insects and other plants, which would reduce biodiversity.

In agriculture it can be used to improve yields by: • Improving growth rates • Introducing modifications that allow the crops to grow in different conditions, e.g. hotter or drier climates • Introducing modifications that allow plants to make their own pesticide or herbicide	People are worried that we do not completely understand the effects of GM crops on human health.
Crops with extra vitamins can be produced in areas where they are difficult to obtain.	Genetic engineering in agriculture could lead to genetic engineering in humans. This may result in people using the technology to have designer babies.
Greater yields can help solve world hunger, which is becoming an increasingly bigger issue due to population growth.	They pose a selection pressure, which could lead to increased resistance in other species, creating super weeds and pests.

Bt crops

Bacillus thuringiensis is the name of a bacteria that produces toxins that kill insect larvae.

This is a useful function for crops, so we use genes from the bacteria in crops to increase their **insect resistance**.

Genes are cut out from the bacteria using **restriction enzymes**, and re-inserted into the crop using ligase, as described above. The crop will then **produce the toxin** - **any insects that eat the crop will die**.

As a result, less of the crop gets eaten by insects, increasing the crop yield and profits.

However, there are concerns over this method - **we don't know if the toxin has any effect on human health**, for example. Killing insects also results in a loss of biodiversity, which can affect the **entire ecosystem**.

4.13B **Biology Only** - Agricultural Solutions

We can use various agricultural solutions to cope with the demands of a growing human population. Two of the most useful methods are:

1) **Fertilisers** - fertilisers provide useful nutrients **(nitrates and phosphates)** to plants, making them more resistant to environmental conditions and able to grow faster and larger - resulting in increased crop yields. However, excess fertiliser can often run off into rivers, killing fish and other wildlife and affecting biodiversity.

2) **Biological control** - biological control is the use of certain species to control population of other species. For example, Aphelinus abdominalis, the aphid killer wasp, has been used successfully to control aphid populations - which feed on fruit crops. However, this reduces biodiversity, and again, has a knock-on effect across the whole ecosystem.

4.14 - Implications of Genetic Engineering and Selective Breeding

Perceived benefits of genetic engineering	Perceived risks of genetic engineering
It can be very useful in medicine to mass produce certain hormones in microorganisms (bacteria and fungi).	GM crops might have an effect on wild flowers and therefore insects. • GM crops are infertile and these genes could spread into wild plants, leading to infertility in other species, which affects the entire environment. • Growing with herbicides and pesticides can kill insects and other plants, which would reduce biodiversity.
In agriculture it can be used to improve yields by: • Improving growth rates • Introducing modifications that allow the crops to grow in different conditions, e.g. hotter or drier climates • Introducing modifications that allow plants to make their own pesticide or herbicide	People are worried that we do not completely understand the effects of GM crops on human health.
Crops with extra vitamins can be produced in areas where they are difficult to obtain.	Genetic engineering in agriculture could lead to genetic engineering in humans. This may result in people using the technology to have designer babies.
Greater yields can help solve world hunger, which is becoming an increasingly bigger issue due to population growth.	They pose a selection pressure, which could lead to increased resistance in other species, creating super weeds and pests.

Benefits of selective breeding	Disadvantages of selective breeding
It is possible to greatly increase the yield of a particular crop by selectively breeding only individuals that produce higher quality or a larger mass of food.	Selecting for advantageous characteristics can sometimes cause severe health problems in the offspring - e.g chickens that have been bred to have more meat (muscle) are sometimes too large to be able to walk.
Individual plants or animals can be bred to be resistant to a particular disease, which could increase crop yield	Lack of genetic variation - Despite the bred population being able to have resistance to a particular disease (or multiple diseases), if one of them has susceptibility to a different disease then they all do - and the entire population could be wiped out as a result.
	There are ethical issues associated with selective breeding -many people consider it unethical to selectively breed for characteristics wanted by humans if it means that the offspring will suffer, or have a reduced quality of life as a result.