

Natural Selection Notes

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Evolution by natural selection: a process of change in a species in which certain organisms are more likely to survive and reproduce as they have useful genetic characteristics.

Organisms that do not have the useful genetic characteristics are less likely to survive and reproduce.

Lamarck's Theory of Evolution

Who was Lamarck? Jean-Baptiste Lamarck was a French naturalist and he is most famous for being one of the very first scientists to publicly put forward a theory of evolution.

What theory did Lamarck put forward? He put forward the theory that a characteristic used frequently by an organism would become stronger and more developed during its lifetime. Unused characteristics would weaken and disappear. He said that these changes acquired during the organism's lifetime are passed on directly to their offspring.

The classic example that most people mention when talking about Lamarck is Giraffes 😊

Early giraffes had short necks. They stretched their necks constantly to reach leaves high in trees. This stretching caused their necks to get longer during their lifetime. This newly acquired long neck was passed on to their offspring.

Why was Lamarck's theory rejected?

1. **Lack of evidence:** there is no evidence to support that changes in an organism's lifetime are inherited for example if you build large muscles at the gym, your baby will not be born with large muscles.
2. **Discovery of genetics:** we now know that inheritance is determined by DNA passed in gametes (sperm and egg). Changes to the physical body (phenotype) during an organism's life do not change their DNA (genotype).

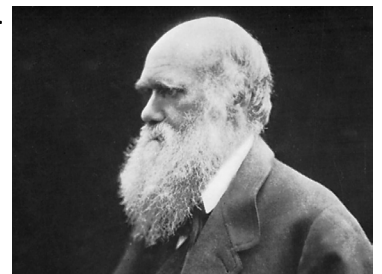
Charles Darwin and Alfred Wallace

Charles Darwin and **Alfred Wallace** were both British naturalists who studied differences in animals and plants as well as their fossils. They **both put forward their work on evolution around the same time**.

The fact that organisms evolve from other organisms, like humans evolving from primates, is without question. In science, a **theory** is a well substantiated explanation for a natural phenomenon, supported by a vast body of evidence, and repeatedly tested and confirmed. Evolution is a fact.

Darwin's theory of natural selection resulted in him having a lot of problems from the Christian church. But most religions weren't fond of it at the time.

Most have now accepted the theory of natural selection.



Darwin rocking a beard in later life

Put simply Darwin's theory of natural selection is survival and reproduction of the organisms that are **best adapted** to their environment.

Process of Natural Selection

Over the years, quite a few questions in paper 2 have asked about the **process** of natural selection. Let's look at a point by point method for answering a question of this type.

1. **Mention variation:** State that individuals in a population show genetic variation.
2. **Discuss competition:** Is there a struggle for survival? Is it competition for food or a toxin or new predator etc?
3. **Survival:** Individuals with characteristics that are best suited to the environment are more likely to survive.
4. **Reproduction:** These survivors pass on their advantageous alleles to their offspring.
5. **Increase in frequency:** Over time the number of individuals with characteristics that are best suited to their environment will increase.

Evidence for Evolution – Resistant organisms

Rats

We have used **Warfarin** – rat poison – to kill rats for years. The rats that were sensitive to the poison died. While the rats that were resistant to the poison survived and reproduced. This resistance is due to a genetic variation in the rats. As a consequence of more resistant rats surviving and more sensitive rats dying many of the rats alive today are resistant to rat poison.

Bacteria

Let's use the format from the process of evolution above to explain this.

1. **Variation:** Due to random mutation, there is genetic variation within the bacterial population. Some bacteria may possess an allele that provides resistance to an antibiotic.
2. **Competition:** The antibiotic acts as a type of competition. It kills the non-resistant (sensitive) bacteria.
3. **Survival and:** The resistant bacteria survive.
4. **Reproduction:** With reduced competition, they are able to reproduce rapidly by binary fission. They pass on the allele for resistance to all their offspring.
5. **Increase in frequency:** Over time, the frequency of the resistant allele increases in the population. Eventually, the entire population of bacteria is resistant, and the antibiotic is no longer effective against it.

Fossil Evidence

What do we need to know about fossils? We need to know what they are, how they form and why fossils records are often incomplete. Let's start with the first one, what are fossils? 😊

Fossils: are the preserved remains of organisms that were once alive. We can use these remains to see how organisms have changed over time.

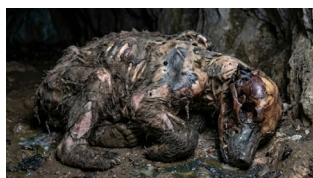
How are fossils formed? Fossils can form in three different ways let's look at each...

1. **Gradual replacement by minerals** – in this process, the hard parts of organisms such as the bones, teeth or shells which do not decompose easily are slowly replaced by minerals. This happens over a very long period of time.

The figure below shows the fossilisation of a cave bear.



Death



Decomposition



Mineralisation over time

2. **Preservation when decomposition isn't possible** – decomposition only occurs when the conditions allow it to take place. For decomposition to happen it needs microorganisms, oxygen, warmth, and moisture. If these are missing, the organism is preserved entirely.

Some examples are **amber** (fossilised tree sap which can trap insects and small animals) or **tar pits** (which have no oxygen), glaciers (too cold for microorganisms to work), **peat bogs** (too acidic for microorganism).



An insect preserved in amber

3. **Preserved traces** – these are not the organisms themselves, but evidence they were there.

These include things like fossilised footprints, burrows, rootlet traces, or fossilised droppings (coprolites) covered by sediment that turns to rock. The figure below shows some fossilised dinosaur footprints.



We have a very large number of fossils but nowhere near the number of the plants and animals that have lived in the past. The fossil record is often incomplete meaning we don't have fossils for all of the animals and plants of the past.

Why is the fossil record incomplete? Well... there are a few reasons for this...

1. **Soft-bodied early life** – early forms of life were soft-bodied meaning they didn't have shells or bones. When they died they decomposed completely and left almost no fossils behind for us to find.
2. **Geological activity**: lots of the fossils that did form were destroyed over millions of years by geological activity for example earthquakes or in volcanic eruptions.
3. **Many are undiscovered**: many fossils are buried deep underground and simply haven't been found yet.

Extinction

Extinction: occurs when there are no remaining individuals of a species still alive anywhere in the world.

What can cause a species to become extinct?

- **Environmental change** – the environment changes too quickly for the species to adapt.
- **New predators** – a new predator arrives and wipes out the prey species before they can evolve a defence.
- **New diseases** – a new, lethal microorganism is introduced that kills the entire population.
- **New competitors** – or a new species introduced to the area. These outcompete the original species for food or space. For example the grey squirrels outcompeting red squirrels in the UK and Ireland.
- **Catastrophic events** – a single massive disaster wipes out the species instantly like the asteroid that hit Earth which killed the dinosaurs.

Exam note: if we do get a question about extinction do try to include an example of a species that has become extinct. A very good example is the Dodo which was a large flightless bird that couldn't easily avoid the hunters that were armed with muskets when they came to the Dodo's island. As a result it was completely wiped out.

Speciation

Speciation: the development of a new species.

A species: a group of similar organisms that can reproduce to give fertile offspring.

Speciation happens when populations of the same species become so different that they can't successfully breed.

How does this happen? Let's break it down into stages 😊

Stage 1: isolation – two populations of a species become separated.

This is usually due to a physical barrier like a mountain range or a large river. This is known as geographical isolation.

Stage 2: variation in populations – because of random mutations, each isolated population will have genetic variation.

Stage 3: different environments – the environment on each side of the barrier will be slightly different. For example the climate could be different or there could be different predator. Factors like these will affect the organisms in that environment.

Stage 4: natural selection – in each isolated population, the individuals that are best adapted to their specific environment are more likely to survive and reproduce, passing on their alleles to their offspring.

Stage 5: speciation occurs – over a long period of time, the phenotypes of the two populations change so much that they can no longer interbreed to produce fertile offspring. We now have two distinct species !

That's speciation 😊 !

Adult Cell Cloning

Adult cell cloning: a type of cloning where a new organism is created using the DNA from an adult body cell.

Adult cell cloning is a technique used to create a genetically identical copy of an organism, this was very famously used in 1996 with the cloning of Dolly the sheep, she was the first mammal cloned from an adult body cell 😊. You can still see Dolly today, her body is on display at the National Museum of Scotland in Edinburgh.

Stages of Adult Cell Cloning

Stage 1 – Enucleate the adult cell: in the first stage of adult cell cloning we collect a cell from the animal that we want to clone. We then remove the nucleus from this cell. The removal of a nucleus from a cell is called enucleation. So, this cell has been enucleated.

Stage 2 – Enucleate an unfertilised ovum cell: in the second stage we remove the nucleus from an unfertilised ovum so now it contains no DNA. We can then get rid of this nucleus as it is not needed in this process.

Stage 3 – Nucleus transfer: we insert the nucleus from an adult body cell into the empty ovum cell.

Stage 4 – Electric shock: we then apply a very mild electric shock to stimulate the egg to start dividing by mitosis.

Stage 5 – Embryo development: we then wait a few days until the ovum cell has divided into an embryo.

Stage 6 – Implantation: The embryo is implanted into the uterus of a surrogate female of the same species.

What is the result? If the whole process works and an animal is born after this process, the animal will be genetically identical to the original animal from stage 1. It will be a clone.

What are the advantages of adult cell cloning? It can be used to save endangered species and it can produce genetically identical animals with desired traits.

What are the disadvantages of adult cell cloning? The process has a low success rate and many embryos die. It is also a very expensive process and when it comes the cloning of humans there are lots of ethical concerns.

Genetic analysis

One of the coolest developments in the study of evolution in modern times has been genetic analysis.

Genetic analysis: allows scientists to examine the DNA sequences of two species and see how closely or distant they are related.

Selective Breeding

Selective breeding: the breeding of certain plants or animals based on certain genetic traits.

For example, if a farmer wanted to increase the milk yield of his cows, he would only allow cows with high milk yields to breed. The farmer will repeat this process over and over until the desired results are achieved.

Selective breeding is often done to increase the food production or disease resistance of the animal or plant.

The stages of selective breeding

Stage 1: decide which characteristics are important enough to select.

Stage 2: choose parents that show these characteristics from a mixed population.

Stage 3: breed these individuals together.

Stage 4: choose the best of the offspring with the desired characteristics to produce the next generation.

Stage 5: Repeat the process continuously over many generations, until all offspring show the desired characteristics.

Examples of desirable characteristics in plants	Examples of desirable characteristics in animals
Large yield of food (if it's a food crop)	Animals that produce lots of meat or milk
Disease resistance	Disease resistance
Large flowers	Good temperament/ easy to handle

Advantages of selective breeding in animals include:

1. Higher economic gains by producing more or better quality food.
2. Increase in disease resistance.
3. Animals can be selected that cannot cause harm, for example cattle can be bred without horns.

Disadvantages of selective breeding in animals include:

1. Inbreeding can lead to a reduction in the size of the gene pool.
2. Animal discomfort, for example many Pugs struggle to breathe, some suffocate. Having short faces is a feature that humans have bred for. It is not an advantage to the Pug to have a flat face.

Advantages of selective breeding in plants include:

1. Higher economic gains by producing more or better quality food.
2. Increase in disease resistance.

Disadvantage of selective breeding in plants include:

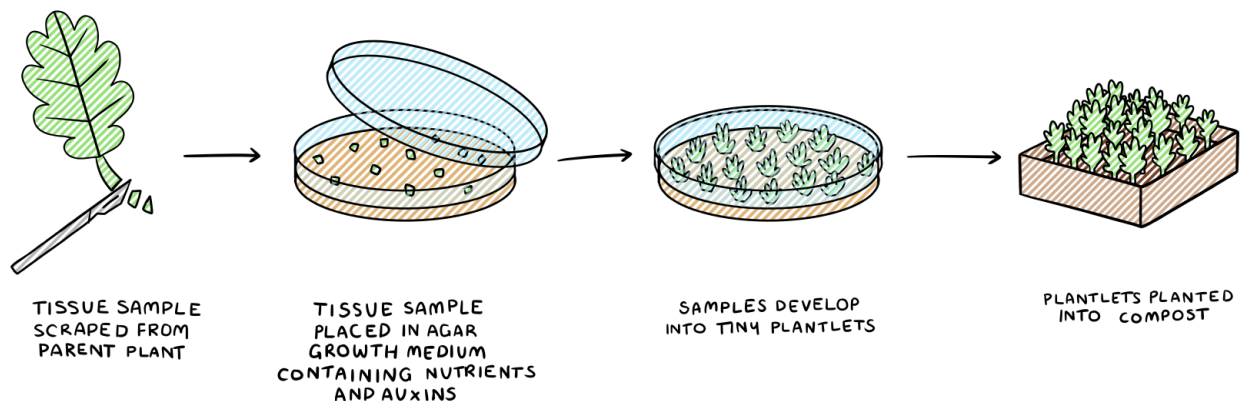
1. Inbreeding can lead to a reduction in the size of the gene pool.

Tissue Culture

Tissue culture: the growth in an artificial medium (usually agar jelly) of cells derived from living tissue.

Before tissue culturing became a thing if people wanted to clone plants they would simply take a cutting from the plant and allow that to grow. The new plant would be genetically identical to the original plant. The only real downside to this process is that only a certain number of cuttings could be taken at once so that limits the number of genetically identical plants we could make. Let's look at tissue culturing then 😊

The figure below shows roughly how tissue culturing works.



Tissue culture works with small pieces of plants, called **explants**. These are grown in vitro using sterile agar jelly that contains plant hormones and nutrients.

Advantages of tissue culturing plants:

1. A large number of plants can be produced from a single parent.
2. It is an important way to preserve rare plant species or grow commercially in larger nurseries.
3. Cloning expensive food crops has been carried out for many years, and causes the public fewer ethical and moral concerns than animal cloning.

Disadvantages of tissue culturing plants:

1. Tissue culturing is more expensive than producing plants from cuttings.
2. Plants produced in this way can be less resilient to diseases than wild plants.