Edexcel GCSE Biology

Your notes

Natural Selection & Evolution

Contents

* The Work of Darwin & Wallace
* Evolution by Natural Selection
* Evidence of Evolution
* The Pentadactyl Limb
* The Three Domains

The Work of Darwin & Wallace

Your notes

The Work of Darwin & Wallace

Charles Robert Darwin

- Charles Darwin spent five years on a voyage **around the world** on a ship called HMS Beagle
- During the voyage, he studied the **plants** and **animals** at all the **different locations** around the world that the ship visited
- He noticed that there was **variation** in members of the **same species**
  - He also noted that those **individuals with characteristics most suited to their environment** were **more likely** to **survive**, **reproduce** and, therefore, **pass on their characteristics** to their offspring
- To explain his observations, Darwin developed his **theory of evolution by natural selection**

Alfred Russel Wallace

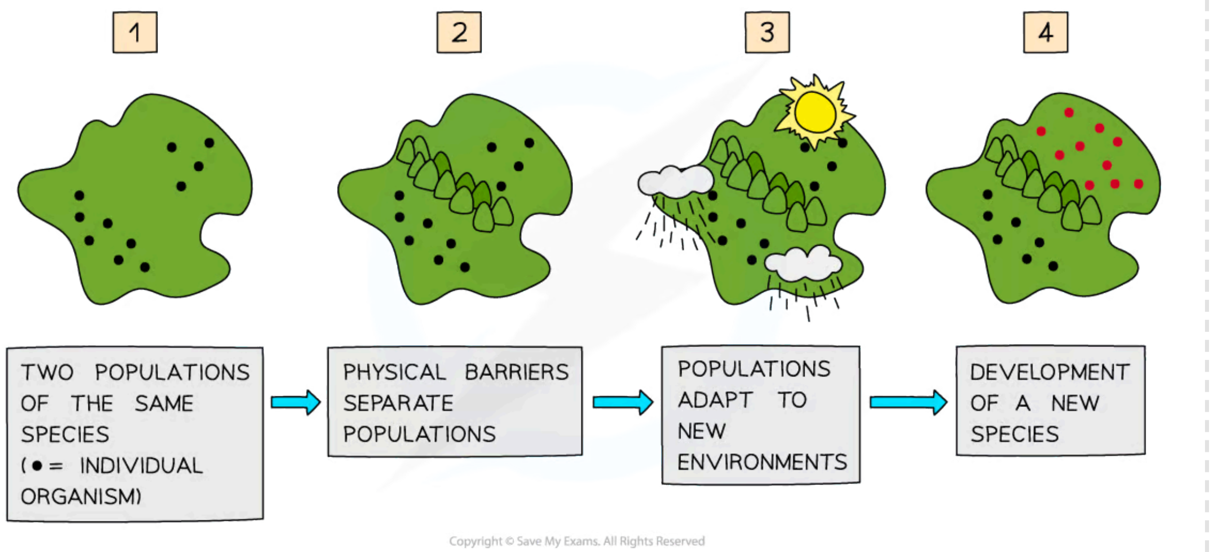
- Alfred Russel Wallace was a scientist who, after conducting his own travels around the world and gathering much evidence, **independently developed his own theory of evolution** based on the process of natural selection
- He published scientific papers on this theory with Darwin in 1858 (Darwin published his book, **On the Origin of Species**, the following year)
- Wallace is best known for:
  - His work studying the warning colouration of species (particularly butterflies) and how this must be an example of a **beneficial characteristic** that had **evolved by natural selection**, as the warning colouration helps to deter predators
  - **Developing** the **theory of speciation**

Speciation

- Wallace did much pioneering work on speciation but more evidence over time has led to our current understanding of the theory of speciation
- Speciation is a process that results in the **formation of a new species**
- When **populations of the same species become so different** that they are **unable to interbreed and produce fertile offspring**, they are considered different species and speciation has occurred
- Speciation can occur as a result of a combination of **isolation** (when populations of the same species become separated) and **natural selection**:

Your notes

- Populations of the same species can become **isolated** from one another due to the formation of a **physical barrier** (eg. a new river or mountain range) – this is known as geographic isolation
- The **environment will be different on either side** of this physical barrier (eg. different climates or different food available)
- The environmental differences on either side will provide different selection pressures and **natural selection will cause a different set of characteristics to become more common in the two isolated populations**
- Over many generations, individuals from the two populations will have become so distinct (genetically, behaviorally, physically) that they will **no longer be able to interbreed and produce fertile offspring**
- The two populations are now **separate species**



The process of speciation

The impact of Darwin and Wallace on modern biology

- The theory of evolution by natural selection is still **very important to this day** and helps modern scientists and biologists to understand **many areas of biology**
- For example:
  - We now know that **all life forms** (i.e. all species) **change** through the process of **evolution**
  - We now know that **all life forms** on the planet today are **descended from a common ancestor**

- This means all life forms are **related** to some extent and this knowledge has affected the way we **classify species** (arrange them into **groups**), as modern biologists now do this based on **how closely related** species are to each other
- In terms of **conservation** (preventing species from going extinct), the theory of evolution by natural selection eventually led to the realisation that conserving the **genetic diversity** (the variety in the genes) of a species is **very important** as it helps species to **adapt to changing environments**. This knowledge has helped guide conservation projects in protecting endangered species

Your notes

Evolution by Natural Selection

Darwin's Theory of Evolution by Natural Selection

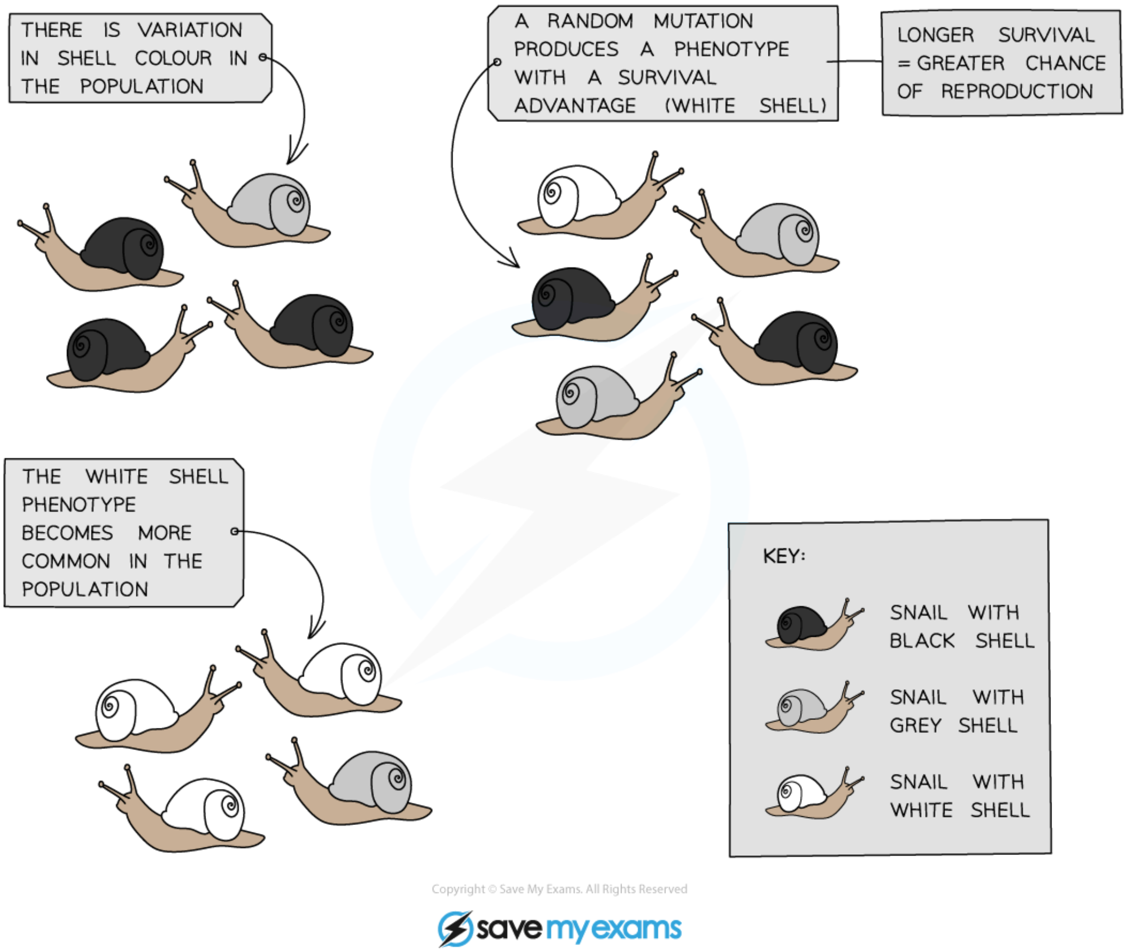
- Charles Darwin proposed the **theory of evolution by natural selection**
  - He came up with this theory as a result of observations from a round-the-world expedition, years of experimentation and his knowledge of geology and fossils
- Evolution can be defined as **the change in the frequency of a phenotype in a population over many generations**
- Darwin's theory, very simply, is:
  - Individuals in a species show a wide **range of variation** caused by differences in genes
  - Individuals with characteristics **most suited to the environment** have a higher chance of survival and **more chances to reproduce**
  - Therefore these characteristics are **passed to their offspring at a higher rate** than those with characteristics less suited to survival
  - Over many generations, these **beneficial characteristics** become **more common in the population** and the species changes (the species evolves)
- This idea of natural selection became known as **'survival of the fittest'**
- Darwin published his ideas in his famous book, *On the Origin of Species* (1859)

The acceptance of evolution

- The theory of evolution by natural selection was only gradually accepted because:
  - There was much controversy surrounding these **revolutionary new ideas**
  - The theory **challenged the idea that God made all the animals and plants** that live on Earth
  - There was **insufficient evidence** at the time the theory was published to convince many scientists
  - The **mechanism of inheritance and variation was not known** until 50 years after the theory was published
  - The theory of evolution by natural selection **developed over time** and from information gathered by many scientists

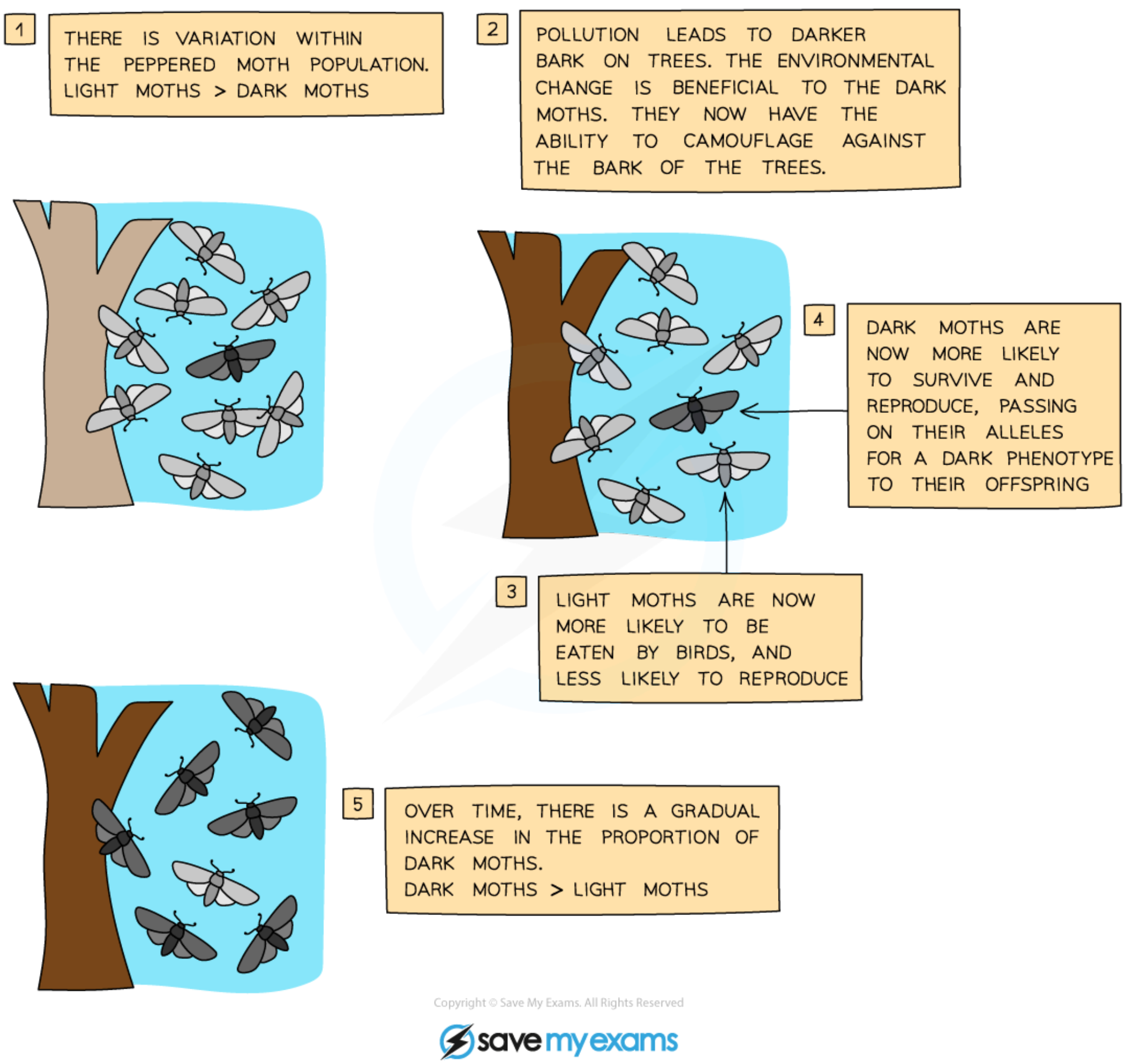
Examples of evolution by natural selection

Your notes



Natural selection illustrated by snail shell colour

Your notes



Another good example of natural selection is the evolution of the peppered moths

Examiner Tips and Tricks

There are many examples of natural selection but they ALL follow the same sequence described above:

- Within a species, there is always variation and chance mutation

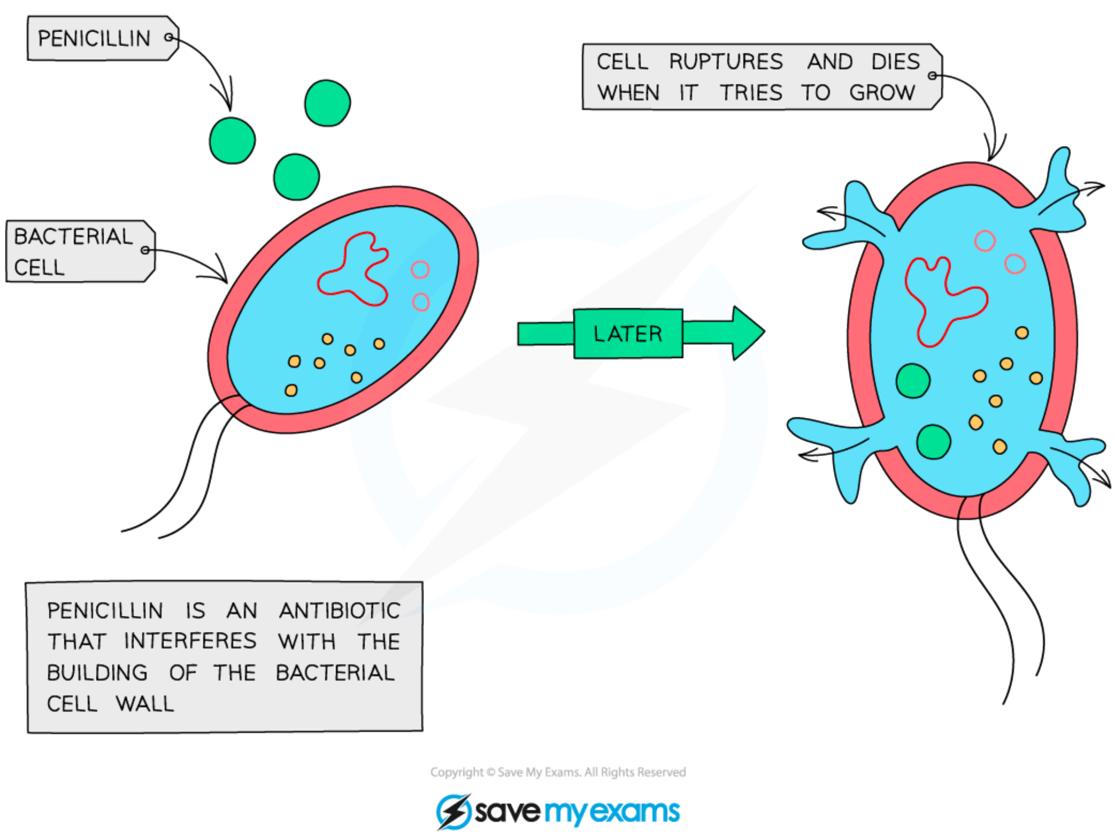
- Some individuals will develop a phenotype (characteristic) that gives them a survival advantage and this allows them to:
    - live longer
    - breed more
    - be more likely to pass their genes on
- Repeated over generations, the 'mutated' phenotype will become the norm

Remember, it is the concept you have to understand, not the specific example.

Your notes

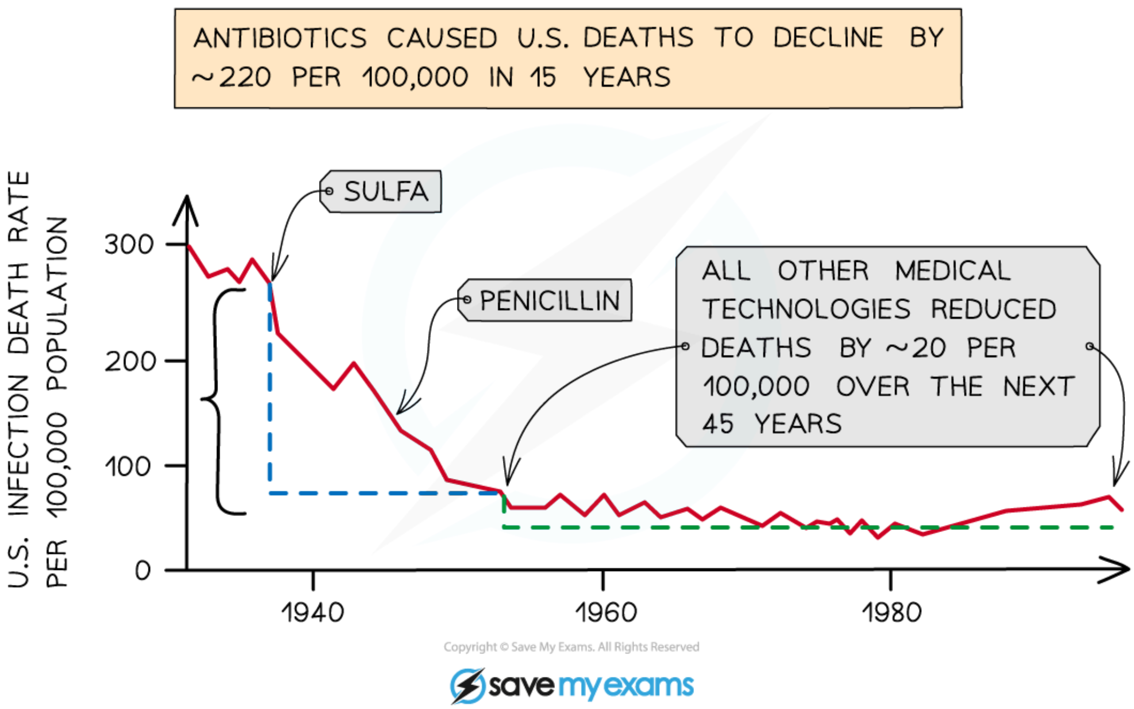
Antibiotic Resistance

- Antibiotics are **chemical substances** made by certain **fungi or bacteria** that affect the working of bacterial cells, either by **disrupting their structure or function** or by **preventing them from reproducing**
- Antibiotics are **effective against bacteria but not against viruses**
- Antibiotics target processes and structures that are specific to bacterial (prokaryotic) cells; as such they do not generally harm animal cells



How antibiotics work

- The use of antibiotics has increased exponentially since they were first introduced in the 1930s
- In that time they have saved millions of lives

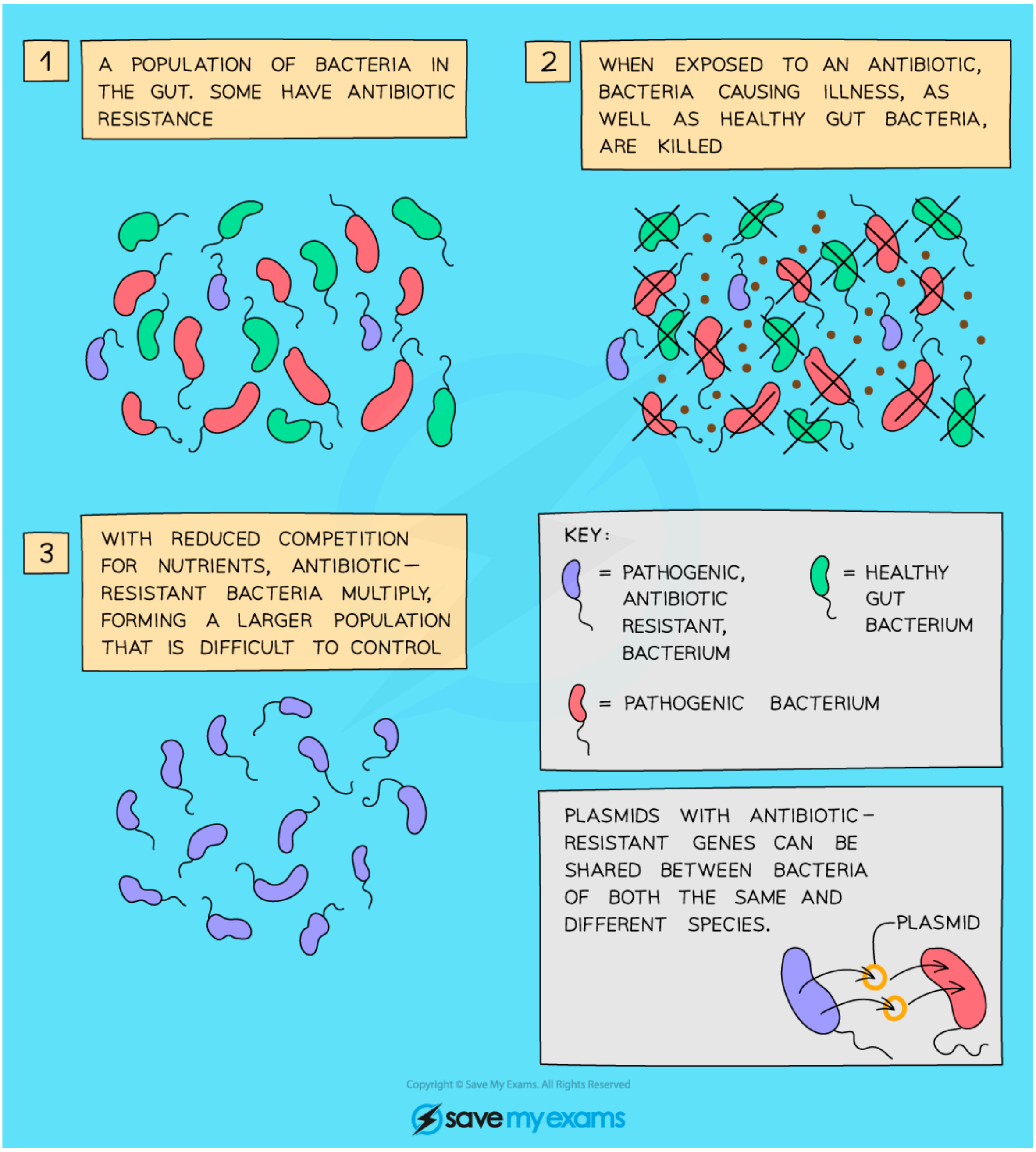


The introduction of antibiotics has had one of the largest impacts on global health, shown by this example in the USA

- However, since their discovery and widespread use, antibiotics have been **overused** and **antibiotic resistance** has developed in many different types of bacterial species
  - Bacteria, like all organisms, have **random mutations** in their DNA
  - One of these mutations may give them resistance to an antibiotic
  - If an organism is infected with bacteria and some of them have resistance, they are likely to survive treatment with antibiotics
  - The population of the resistant bacteria will increase
  - If the resistant strain is causing a serious infection then another antibiotic will be needed

Your notes

- A strain of ***Staphylococcus aureus*** has developed resistance to a powerful antibiotic methicillin, this is known as MRSA (Methicillin resistant *Staphylococcus aureus*)
- MRSA can infect wounds and is difficult to treat without antibiotics



Bacteria evolve rapidly as they reproduce quickly and acquire random mutations – some of which confer resistance

Your notes

Preventing resistant bacteria

- To reduce the number of bacteria that are becoming resistant to antibiotics:
  - Doctors need to avoid the overuse of antibiotics, prescribing them only when needed – they may test the bacteria first to make sure that they prescribe the correct antibiotic
  - Antibiotics shouldn't be used in non-serious infections that the immune system will 'clear up'
  - Antibiotics shouldn't be used for viral infections
  - Patients need to finish the whole course of antibiotics so that all the bacteria are killed and none are left to mutate to resistant strains
  - Antibiotics use should be reduced in industries such as agriculture – controls are now in place to limit their use in farming

Reducing the spread of resistant strains

- Good hygiene practices such as handwashing and the use of hand sanitisers have reduced the rates of resistant strains of bacteria, such as **MRSA**, in hospitals
- The isolation of infected patients to prevent the spread of resistant strains, in particular in surgical wards where MRSA can infect surgical wounds

Antibiotics do not affect viruses

- Viruses cannot be treated with antibiotics
- This is because antibiotics work by **disrupting cell functions such as respiration, or breaking down the structure of the cell in some way**
- However, viruses **do not carry out any cell functions** and **do not have cell walls, cell membranes or any cell organelles** as viruses infect and utilise the machinery of animal cells to reproduce, which are not affected by antibiotics.
- Therefore the action of antibiotics **do not affect them**

Your notes

Evidence of Evolution

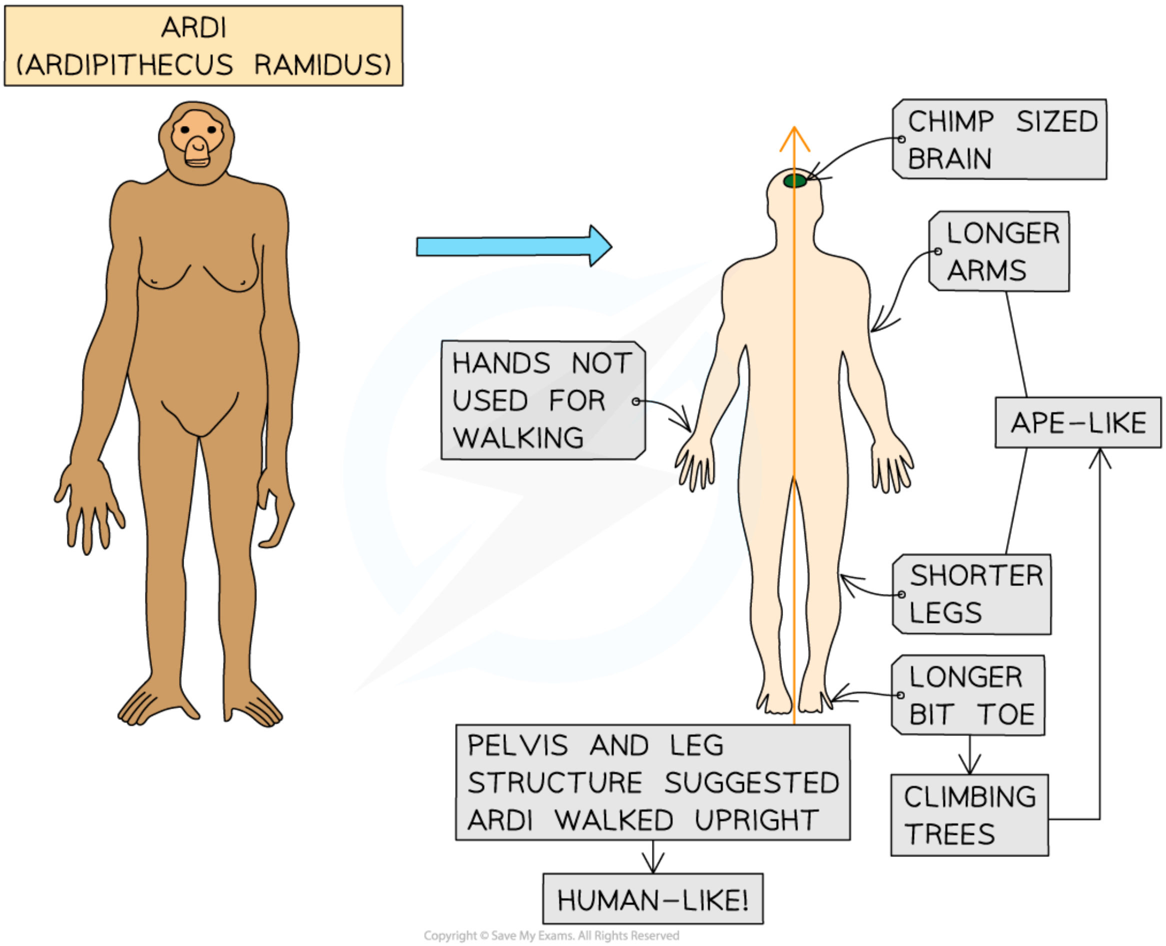
Evidence of Evolution

- There is a large amount of **fossil evidence** suggesting that **modern-day humans** (*Homo sapiens*) evolved from a **common ancestor** with other **apes**
    - For example, fossil evidence shows that humans (*Homo sapiens*) and chimpanzees (*Pan troglodytes*) evolved from a common ancestor that existed approximately 6 million years ago
    - Humans and their ancestors are known as **hominids**
    - Fossils from several different hominid species have been discovered, all with **various characteristics that lie somewhere between apes and humans**
    - By studying these fossils, **evolutionary biologists** have been able to understand more about **how humans have evolved over time**

'Ardi' the fossil hominid

- 'Ardi' is the name given to a fossil (more specifically, 125 fragments of fossilised bone) of a female individual of the species ***Ardipithecus ramidus***
- Ardi was found in **Ethiopia** and is **4.4 million years old**
- Ardi's features are **a mixture of those seen in apes and humans**. For example:
    - Ardi's foot structure suggests that she **climbed trees** (the fossils show she had **an ape-like big toe** to help **grip** onto **branches)**
    - Ardi had **short legs but long arms** (more similar to an ape than to a human)
    - Ardi's **brain** was around the **same size as a chimpanzee's**
    - But Ardi's **leg bone structure** suggests she walked **upright**. This theory is supported by her **hand bone structure**, which suggests she **did not use her hands when walking** (like apes do)

Your notes

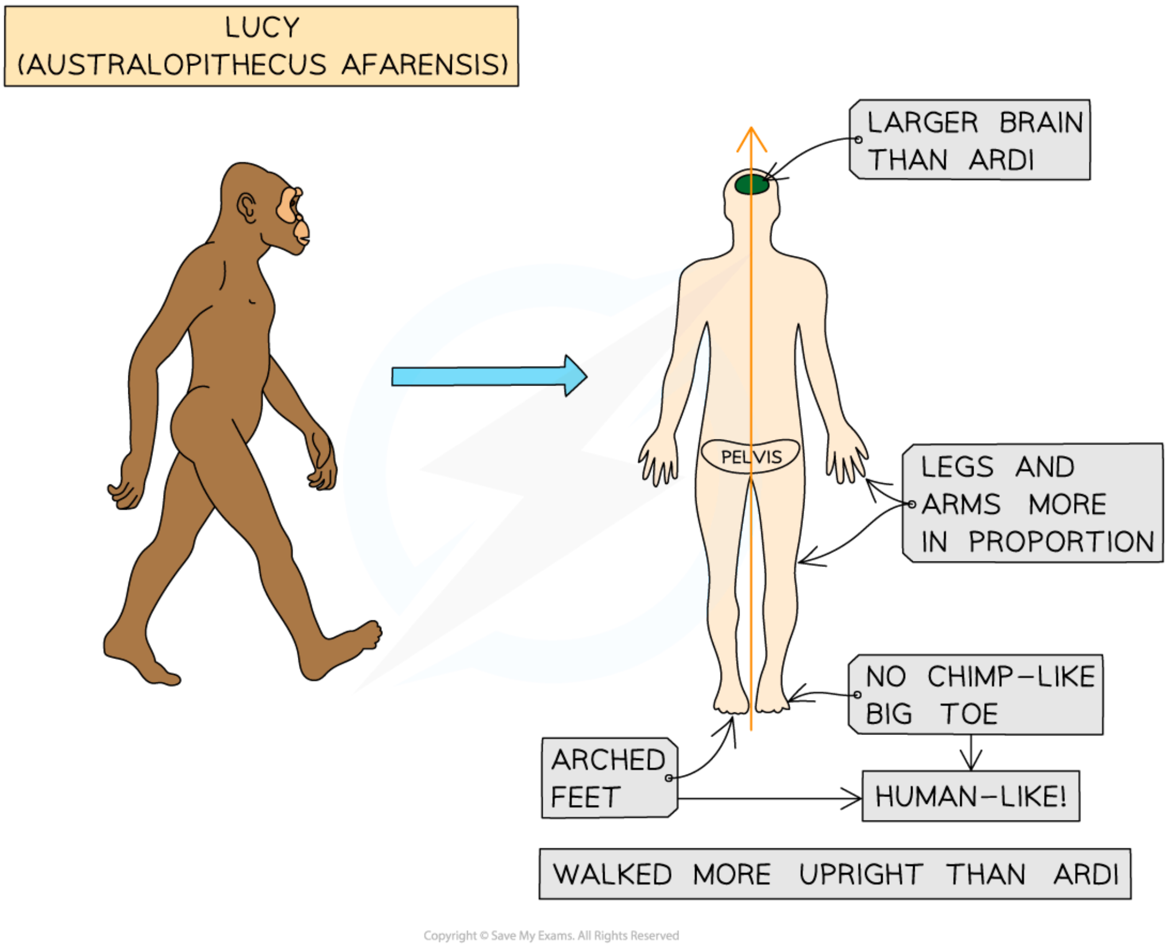


Ardi - a fossil hominid of the species Ardipithecus ramidus

'Lucy' the fossil hominid

- 'Lucy' is the name given to a fossil (again, made up of over a hundred fragments of fossilised bone) of a female individual of the species ***Australopithecus afarensis***
- Lucy was also found in **Ethiopia** but is less old than Ardi (Lucy is **3.2 million years old**)
- Like Ardi, Lucy's features are also **a mixture of those seen in apes and humans**. However, she is **more human-like than Ardi**. For example:
  - Lucy's **foot structure** shows she had **arched feet** (better adapted to **walking** compared to climbing) and **did not have an ape-like big toe**
  - The size of her legs and arms were still somewhere between those of an ape and those of a human but were less ape-like than Ardi's

- Lucy's **brain** was **slightly larger** than Ardi's (although still similar in size to a chimpanzee's brain)
- Like Ardi, Lucy's **leg bone structure** suggests she walked **upright** (but **more efficiently** than Ardi)



Lucy - a fossil hominid of the species Australopithecus afarensis

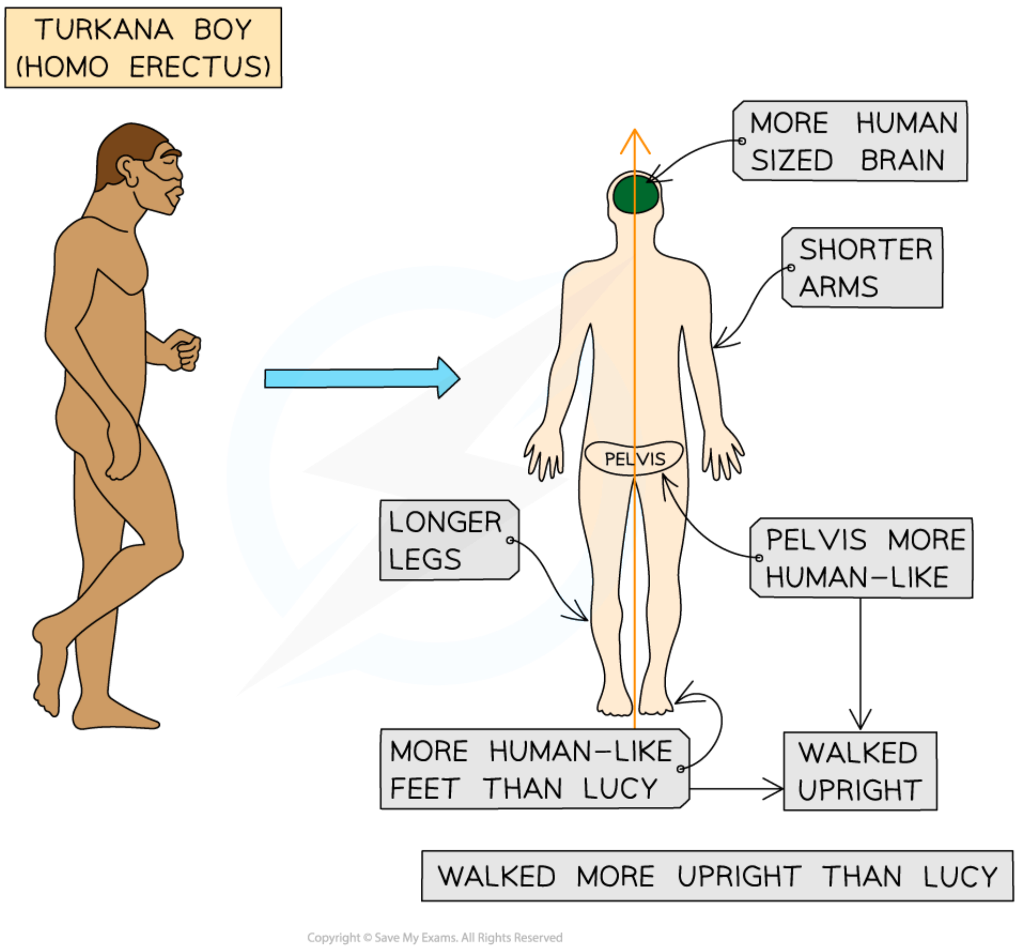
Leakey and his hominid fossil discoveries

- In 1984, a scientist called **Richard Leakey** led an expedition to **Kenya** to search for **hominid fossils**
- The team on the expedition found many fossils of individuals from the genus ***Australopithecus*** and the genus ***Homo***
- '**Turkana Boy**' is the name given to one of these fossil skeletons (of a male individual of the species ***Homo erectus***)
- Turkana Boy is **1.6 million years old** (less old than Lucy)

Your notes

Your notes

- Like Ardi and Lucy, Turkana Boy's features are **a mixture of those seen in apes and humans**. However, he is **even more human-like than Lucy**. For example:
  - The size of his legs and arms were much closer to those of a human than of an ape
  - His **brain** was **much larger** than Lucy's (similar in size to a human brain)
  - The structure of his legs and feet suggests he **walked upright even more efficiently than Lucy**



Turkana Boy - a fossil hominid of the species Homo erectus

The development of stone tools

- In addition to all these hominid fossils, findings of the **stone tools** used by various hominid species over time provide **strong evidence for human evolution**
- As different species within the genus ***Homo*** evolved, they started using stone tools that **gradually became more complex over evolutionary time** (as their **brains** were also evolving to be **larger and**

Your notes

larger)

- These stone tools, as well as the hominid fossils, can be **dated** (i.e. have their age determined) in a few ways:
  - By looking at the **structural features** of the tool or fossil (e.g. **simpler tools** are probably **older** than more complex tools)
  - By using **stratigraphy** (the study of **rock layers**). Older rock layers are usually found below younger rock layers, meaning that tools or fossils found in **deeper layers** are probably **older**)
  - By using **Carbon-14 dating** (fossils contain carbon and stone tools are sometimes found along with carbon-containing materials e.g. a wooden tool handle)

Tool Use by *Homo* Species over Evolutionary Time Table

Homo species	Tool use
Homo habilis (2.5 – 1.5 million years ago)	Simple stone tools made by hitting rock together to produce sharp flakes e.g. that could be used to scrape meat from bones
Homo erectus (2 – 0.3 million years ago)	Rocks sculpted into more complex shapes e.g. simple hand-axes (a rock with a blunt handle at one end and a sharper, scraping edge at the other end) that could be used to hunt, dig, chop and scrape meat from bones
Homo neanderthalensis (300,000 – 25,000 years ago)	Even more complex tools (e.g. flint tools, pointed tools an even wooden spears)
Homo sapiens (200,000 years ago – present)	The most complex tools of all first appeared about 50,000 years ago e.g. flint arrow-heads, fish hooks and even needles

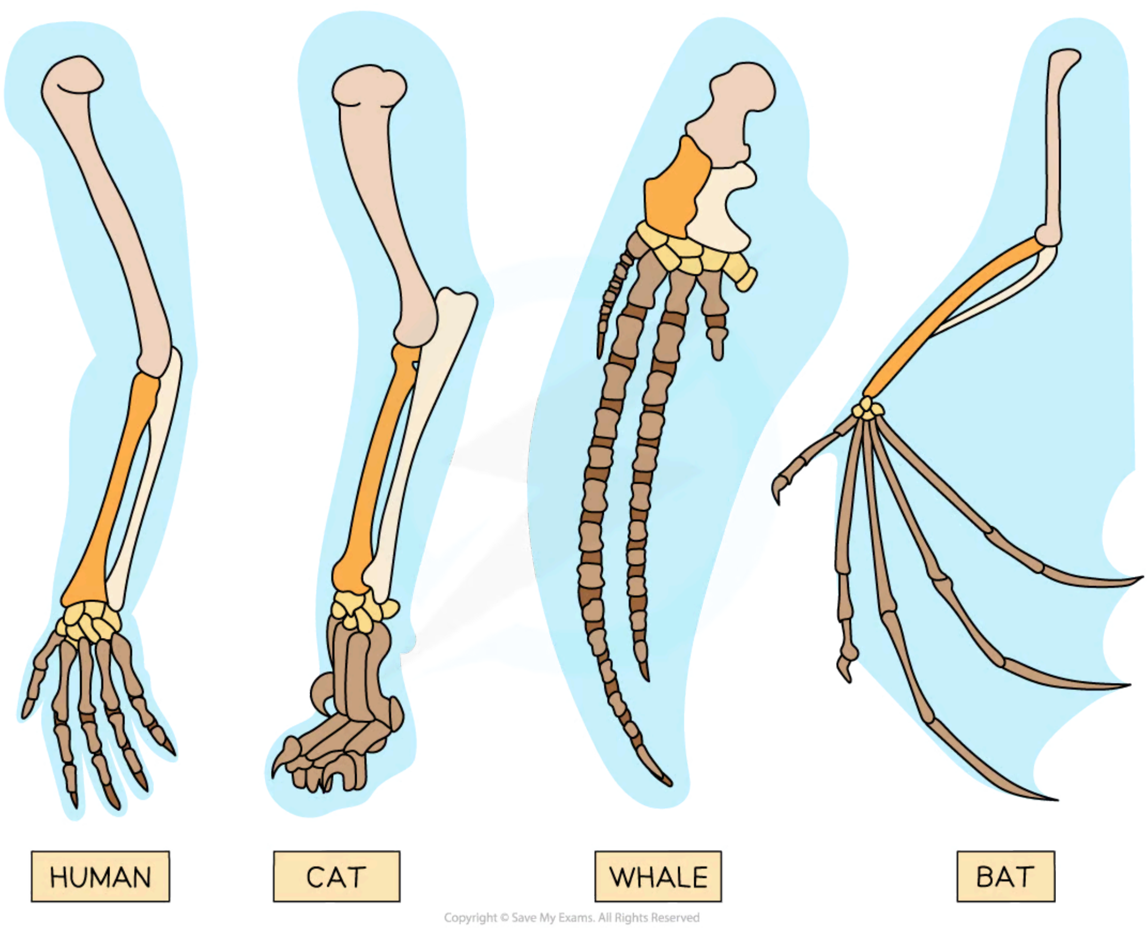
The Pentadactyl Limb

Your notes

The Pentadactyl Limb

- A pentadactyl limb is any limb that has **five digits** (e.g. five fingers or toes)
- Pentadactyl limbs are present in **many species** from **many groups of organisms**, including mammals, reptiles and amphibians
- In these different species, the pentadactyl limb has a fairly **similar bone structure** but sometimes fulfils quite a **different function**
  - For example, the **human hand** is used for **handling tools and other objects** but the pentadactyl limb of a **bat** (i.e. the bones that make up a bat's **wing**) is **highly adapted for flight**
  - Although the **individual bones** of the pentadactyl limb in these two species are **very different shapes and sizes**, their **layout** is almost **exactly the same**
- The high level of similarity in the bone structure of the pentadactyl limbs of mammals, reptiles and amphibians provides **strong evidence** that these groups all **evolved from a common ancestor**
  - Their limbs would most likely have had **very different** bone structures if they had all evolved from **different ancestors**

Your notes



The bone structure of the pentadactyl limb of a human, a cat, a whale and a bat – although they have all evolved for different purposes, they all have the same basic layout

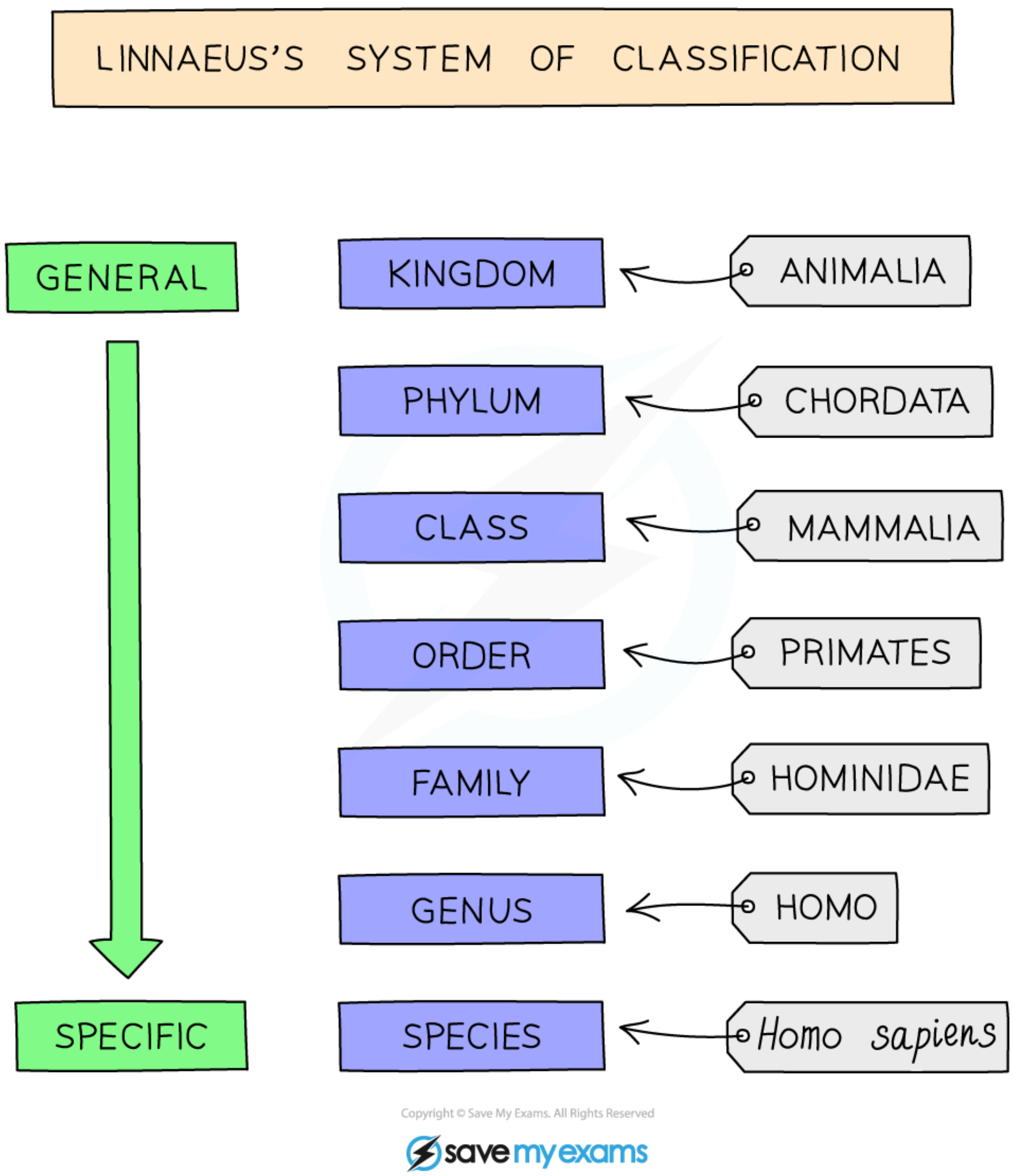
The Three Domains

Your notes

The Three Domains

- Traditionally, all living things have been classified into **groups** depending on their **structure** and **characteristics**
- Organisms were first classified in this way by a Swedish naturalist called **Linnaeus**
- This system allows the subdivision of living organisms into **smaller and more specialised groups**
  - The species in these groups have **more and more features in common** the **smaller** and **more subdivided** the groups get
- The sequence of classification is: **Kingdom**, **Phylum**, **Class**, **Order**, **Family**, **Genus**, **Species**

Your notes



Linnaeus' system of classification

- For a long time, biologists have regarded there to be **five kingdoms** at the **top** of the **classification hierarchy**
- These five kingdoms include:
  - **Prokaryotes** (all single-celled organisms without a nucleus e.g. bacteria)

Your notes

- **Protists** (eukaryotic single-celled organisms e.g. algae)
- **Fungi** (mushrooms, toadstools, yeasts etc.)
- **Plants** (grasses, trees etc.)
- **Animals** (fish, mammals, reptiles, amphibians, birds etc.)

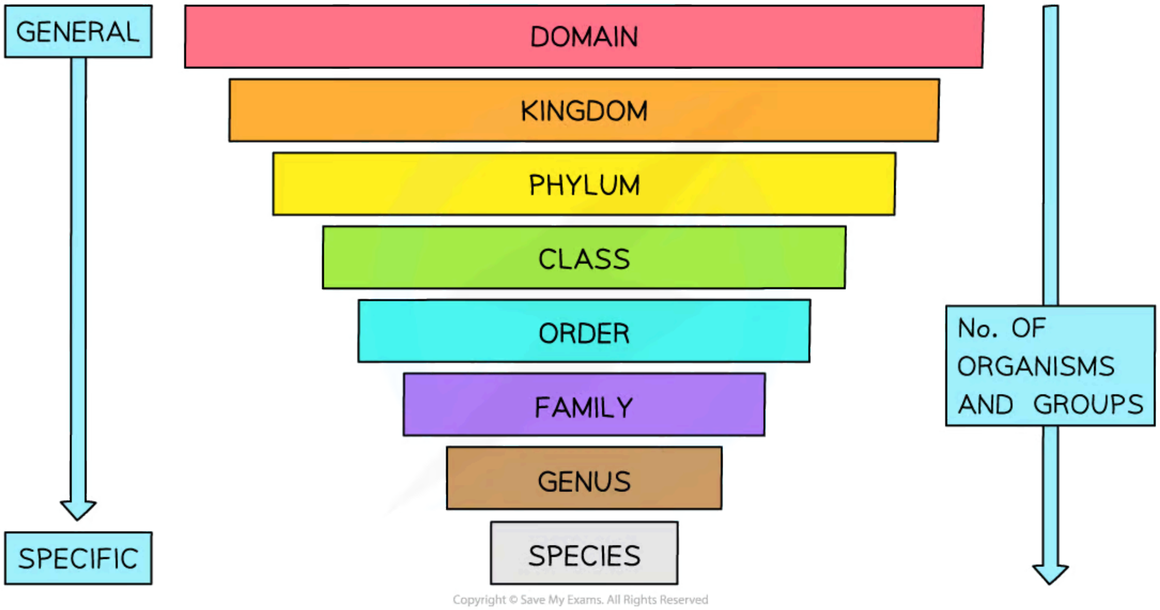
The development of classification

- Originally, organisms were classified using **morphology** (the overall form and shape of the organism e.g. whether it had wings or legs) and **anatomy** (the detailed body structure as determined by dissection)
- As evidence of internal structures became more developed due to **improvements in microscopes**, and the understanding of **biochemical processes** and **genetics** progressed, **new models of classification** were proposed
- As technology advanced, **genetic analyses** (such as **DNA sequencing**) allowed us to classify organisms using a more scientific approach
- Studies of **DNA** or **RNA sequences** of different species show that **the more similar the base sequences** in the DNA or RNA of two species, **the more closely related those two species are** (and the more recent in time their common ancestor is)
    - For example, the base sequences in a mammal's DNA are more closely related to all other mammals than to any other vertebrate group, such as birds or fish

The three-domain system

- Due to evidence available from **genetic analysis**, there is now a **'three-domain system'** of classification
- This was developed by **Carl Woese** in 1990
- In this system, organisms are divided into **three large groups** called **domains**
- These domains are:
    - **Archaea** (primitive bacteria usually living in extreme environments such as hot springs and salt lakes)
    - **Bacteria** (true bacteria such as *E. coli* and *Staphylococcus*)
    - **Eukaryota** (which includes protists, fungi, plants and animals)
- These domains are then subdivided into the smaller groups previously used (i.e. kingdom, phylum, class, order, family, genus, species)

Your notes



Today, biologists regard the 'domain' (rather than 'kingdom') to be the highest level of classification for organisms