Evolution Scope

TOPIC	SUBTOPIC	KEY INFORMATION
EVOLUTION	Evidence for evolution	• Role of the following as evidence for evolution: ✓ Fossil record ✓ Biogeography ✓ Modification by descent (homologous structures) ✓ Genetics
	Sources of variation	• Meiosis: ✓ Crossing over ✓ Random arrangement of chromosomes • Mutations • Random fertilisation • Random mating
	Lamarck and Darwin's theories	• State the general theories according to the Exam Guidelines but apply it to a given example
	Natural and artificial selection	• Describe the processes • Tabulate the differences
	Punctuated equilibrium	• Define, describe & be able to identify examples
	Speciation	• Apply the example given in a paper according to the format in the Examination Guidelines • Be able to identify the geographic barrier and speciation of one species becoming different species
	Mechanisms for reproductive isolation	• Refer to Examination Guidelines for different mechanisms
	Evolution in present times	• Any ONE example according to Examination Guidelines
	Human evolution: similarities of humans and African apes	• With the aid of diagrams, as it applies to the characteristics in the Examination Guidelines
	Human evolution: anatomical differences between humans and African apes	See Examination Guidelines: e.g. • Long and narrow vs. short and wide • Large canines vs. small canines • The significance of the evolutionary changes e.g. Foramen magnum more in front and under the scull
	Trends in human evolution	• Interpretation of phylogenetic trees proposed by different scientists showing possible evolutionary relationships as it applies to hominid evolution
	Out of Africa hypothesis	• According to the examination guidelines • Focus on species found in Africa or found ONLY in Africa

Adapted from DBE revision guidelines

Evolution

Key concepts

- origin of ideas about origins
- theories of evolution
- Darwin's theory of evolution by natural selection
- formation of a new species
- artificial selection
- mechanisms of reproductive isolation
- evolution in present times

Origin of Ideas

Evolution - change over time

Theory vs Hypothesis

A **theory** is an explanation of something that has been observed in nature which can be supported by facts, generalisations, tested hypotheses, models and laws.

A **hypothesis** is a possible solution to a problem.

Evidence for evolution

- Fossils - Remains of dead matter preserved in rocks
- Biogeography - the study of the distribution of fossils
- Genetics - the study of heredity
- Other - embryology, vestigial organs, comparative anatomy (not part of syllabus)

Biological evolution refers to any genetic change in a population that is inherited and becomes a characteristic of that population over several generations.

Genetic evidence & Variation

genetics deals with the similarities in and differences of related organisms. Genetic evidence that organisms are closely related and are likely to have a common ancestor includes:

- identical DNA structure
- similar sequence of genes
- similar portions of DNA with no functions
- similar mutations (mitochondrial DNA)

What causes variation?

- Meiosis (crossing over & Random arrangement of chromosomes)
- Random fertilisation
- Random mating
- Mutations

Evolution

By natural selection

Theories of evolution

We look at ideas of Jean Baptiste de Lamarck and Charles Darwin

Lamarckism

Law of use and disuse : if a structure was used more often, that structure then became bigger in the following generations. Similarly, if a structure was not being used, then this structure would become smaller and might eventually disappear.

Inheritance of acquired characteristics : organisms could inherit these changed structures from their parents. Characteristics developed during the life of an individual (acquired characteristics) could be passed on to its offspring.

Lamarckism - Why cacti have long roots?

All cacti had short roots originally.
Cacti frequently stretched their roots.
They did this to reach deeper for water in the soil.
As a result, the roots became longer.
The characteristic of long roots acquired in this way was then passed on to the next generation.
Eventually all the plants had longer roots.

Why Lamarckism was rejected?

Lack of supporting evidence as to how organism change.
Organisms so don't change because they want to.

Lamarckism - Why giraffes have long necks?

All giraffes had short necks originally.
These giraffes frequently stretched their necks.
They did this to reach the leaves that were available only higher up on the trees.3
As a result, their necks became longer.
The characteristic of long necks acquired in this way was then
passed on to the next generation.
Eventually all the giraffes had longer necks.

You should be able to apply Lamarckism in any example

Evolution
By natural selection
Theories of evolution

Darwinism

Charles Darwin's theory of evolution by natural selection is based on the four main observations made by him while on his around-the-world trip on the ship, the HMS Beagle.

- Populations can produce far more offspring than needed.
- Sizes of most natural populations and resources remain relatively constant.
- There is a natural variation of characteristics among members of the same species.
- Some characteristics are inherited and are passed on to the next generation

His conclusions:

All organisms are involved in a struggle for survival and only those best suited to the environment would survive there.

Organisms that survive are more likely to reproduce, and therefore pass on their useful characteristics to their offspring.

Over many generations, reproduction between individuals with different genetic makeup changes the overall genetic composition of the population.

Theory of natural selection

Organisms best suited to a particular environment produce the most offspring.

Some species are better equipped to face changing conditions in their environment.

Such changes include:

- type and availability of food
- shelter,
- competition
- or predation.

Having favourable traits that are suitable to the changing environmental conditions may lead to the formation of new species (speciation). *Natural selection always acts on variation already present in a population and the environment is the selective pressure for change.*

Darwinism - Why cacti have long roots?

As a result of **genetic variation** in the cacti population, *some cacti plants had longer roots than others.*

As a result of drought, competition for water occurred.

Plants with shorter roots died and those with longer roots survived.

This is called **natural selection.**

The **allele** for longer roots was passed on to subsequent generations.

Eventually all the plants had longer roots.

	Lamarckism	Darwinism
make-up of a population	members of population are all the same	members have similar characteristics with a measure of variation
transformation of a species/population	individuals are able to transform during a life time	populations, not individuals, transform over time and only through genetic means
mechanism of change	individual chooses which traits to pass on to offspring changes are directed to meet survival	natural selection – the environment exercises selective pressure causing change variation exists regardless of organisms needs.

You should be able to apply Darwinism in any example

Evolution

By natural selection

Theories of evolution

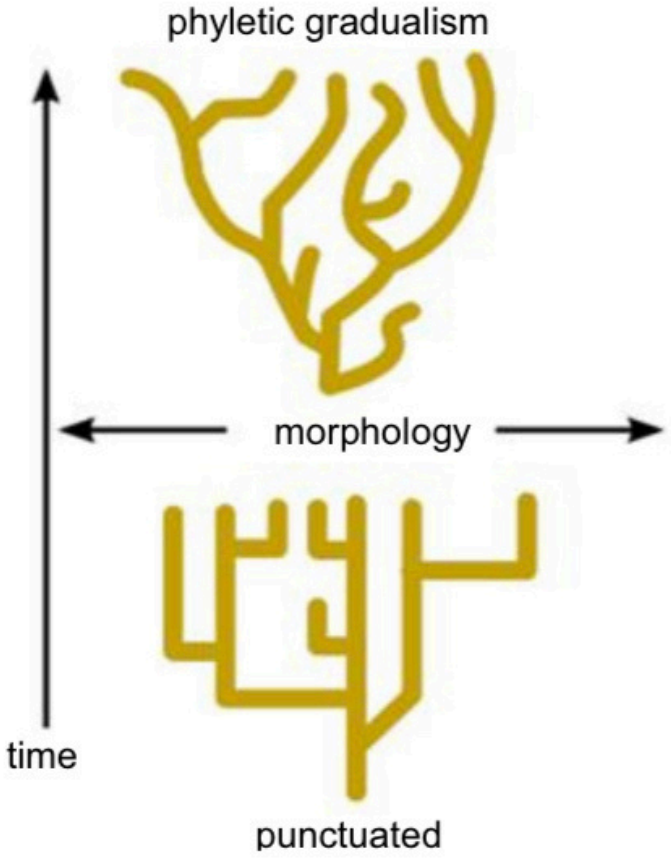
Punctuated equilibrium

developed by Niles Eldredge and Stephen J. Gould in 1972

Punctuated equilibrium refers to a form of evolution characterised by long periods of little or no change followed by short periods of rapid change.

Darwin had proposed that species evolve gradually with small changes over a period of time (**gradualism**) - the physical (phenotypic) characteristics of a population change gradually

Eldredge and Gould noticed that in the fossil record, there were long periods of time where species did not change or changed very little. This was interspersed with periods of rapid change. Therefore, new species were formed over a short period of time. The main evidence for this type of evolution was the absence of transitional fossils (the "missing-links").



Evolution
By natural selection

Speciation

Formation of new species

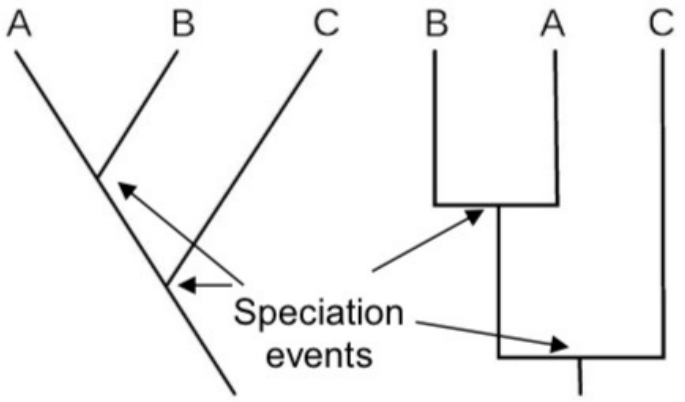
Biological species- a group of organisms with similar characteristics that interbreed with one another to produce fertile offspring.

Geographic/Alopatric speciation

Geographic speciation occurs when part of a population becomes isolated from the parent population due to physical barriers. Such barriers could be continental drift, oceans, rivers, mountains, or other natural disturbances such as volcanos or earthquakes.

General description

A population is separated by a geographical barrier and splits into two populations.
The two populations cannot mate and so gene flow between the two populations stops.
The two populations are exposed to different environmental conditions and selective forces.
Natural selection works independently on both populations simultaneously
The two populations become different from the original population both genotypically and phenotypically.
Even if the populations were to come together again, they would not interbreed with one another and therefore would have become different species.



A cladogram showing speciation. The point where organisms split is where speciation occurs. If a line does not reach the top of the tree, the organism has become extinct.

Evolution

By natural selection

Artificial selection

Artificial selection - human-driven selective force, e.g. breeding of plants and animals to produce desirable traits

Natural selection	Artificial selection
The **environment or nature** is the selective force.	**Humans** represent the selective force.
Selection is in response to **suitability to the environment.**	Selection is in response to **satisfying human needs.**
Occurs within **a species.**	May involve **one or more species** (as in cross breeding).

Mechanisms of reproductive isolation

Reproductive isolation is the mechanism that prevents two species from mating with one another and making fertile hybrids, even when not separated by a geographic barrier.

Strategy	Description
breeding at different times of the year	Different species will have different breeding seasons or, in the case of plants, will flower at different times of the year, in order to prevent cross-pollination.
species-specific courtship behaviour	Some animals have very specific courtship behaviours that do not attract individuals of other species, even if they are closely related species. Courtship behaviour is a physical or chemical signal that an organism is ready to mate. This can include anything from being brightly coloured, to singing elaborate mating songs or mating dances, to the secretion of pheromones in order to attract a mate.
adaptation to different pollinators (plants)	Many plants and their flowers are specifically adapted for specific pollinators. Some closely related species of plants have different characteristics such as flower shape, size, colour, reward type (nectar or pollen), scent and timing of flowering all play a role in attracted certain pollinators to them. Also, cross-pollination between the different species is prevented.
infertile offspring in cross-species hybrids	Even if two species are able to physically mate and produce offspring, they will still be reproductively isolated due to the fact the most hybrid offspring are infertile.

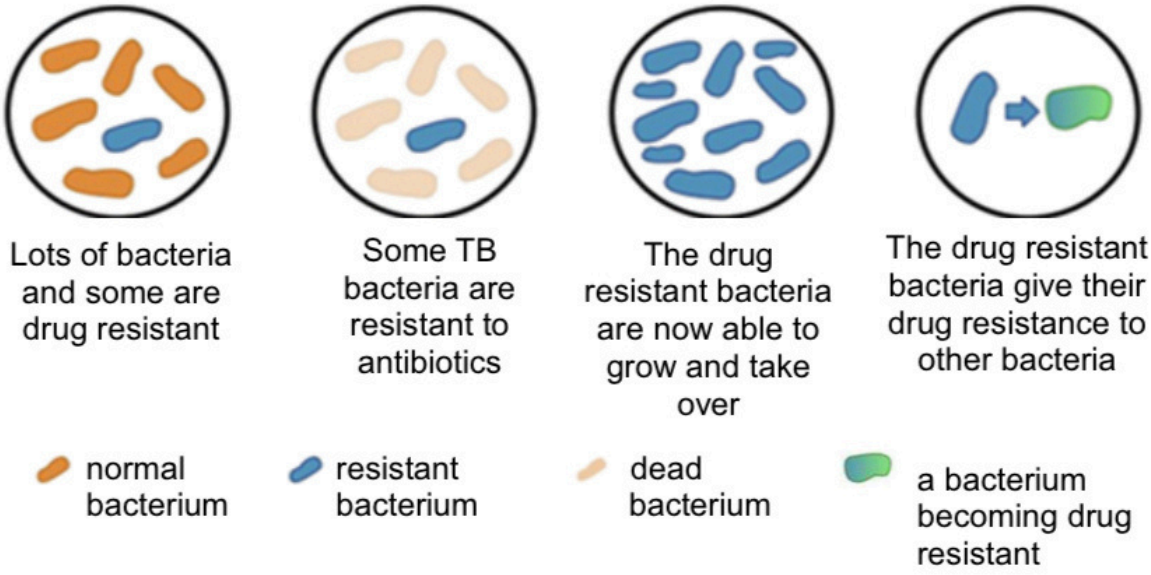
Evolution

By natural selection

Evolution in present times

Pathogens (viruses and bacteria) evolve quickly because there is lots of natural variation amongst them and the fact that mutations occur most often in rapidly reproducing organisms.

Resistance to Antibiotics- TB



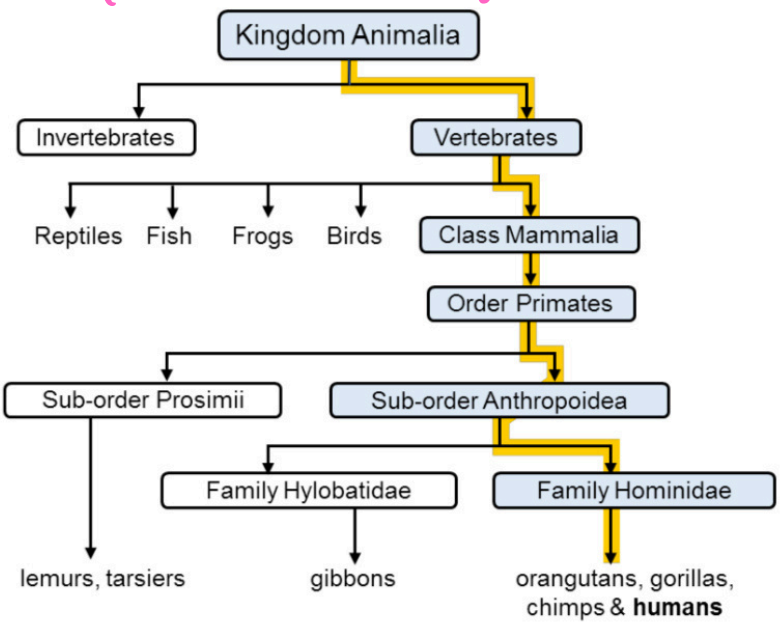
Patients need to complete full course of their treatment, otherwise the bacterium may develop resistance and they may end up sick again.

Evolution

Human evolution

Key concepts

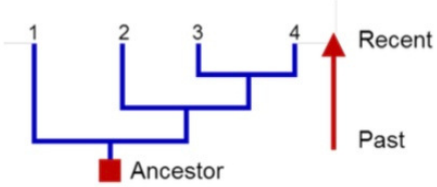
- Interpretation of a phylogenetic tree characteristics that humans share with African apes
- differences of humans from the apes / other primates.
- Fossil, genetic and cultural evidence that support the idea of common ancestors for living hominids
- The 'Out of Africa' hypothesis
- Importance of the Cradle of Humankind (and that of other fossil sites in South Africa and Africa)
- Alternatives to evolution.

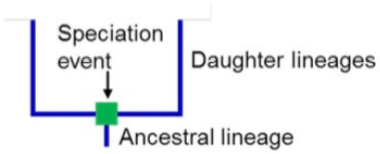


A **Phylogenetic tree** evolutionary relationships of ancestral species and their descendants

Phylogenetic tree interpretation

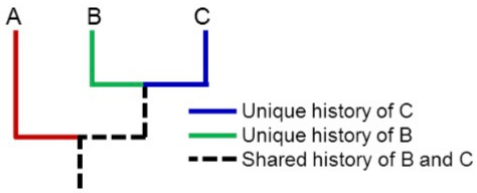
The root of the phylogenetic diagram represents the ancestor, and the tips of the branches, the descendants of that ancestor (see below, left). To move upwards is to move forward in time.





Speciation is represented as a branching of the tree, as a single ancestral lineage gives rise to two or more daughter lines.

Each lineage has a part of its history that is unique and parts that are shared with other lineages



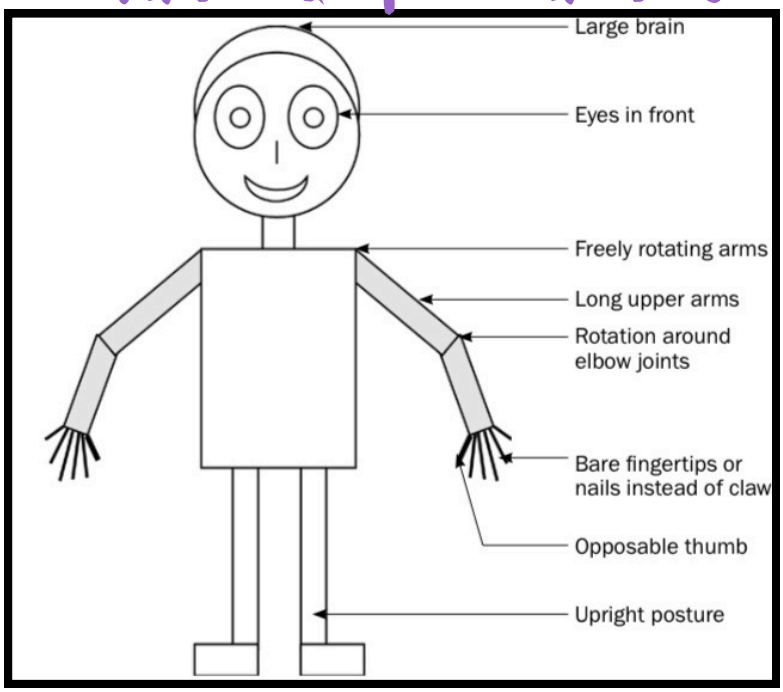
And each lineage has ancestors that are unique to that lineage and common ancestors that are shared with other lineages

Belonging to the same Family Hominidae suggests that humans, chimpanzees, gorillas and orangutans share a common ancestor.

Evolution

Human evolution

Humans & Apes similarities



- **Large brains**: to process and store information.
- **Two eyes in the front** of the head: for good binocular vision.
- The **eyes have cones** : for colour vision & greater clarity.
- **Freely rotating arms**: arms can be lifted above the head to swing from branch to branch, or to pick fruit hanging relatively high above the ground.
- **Long upper arms**: apes are normally quadrupeds. Longer front limbs also make it easier to grasp and swing from branches.
- **Rotation around elbow joints**: this allows the limb to extend or flex to grasp and reach for objects. It also enables the flexing and rotation of the wrists.

- **Bare fingertips** or **nails instead of claws**: Protect sensitive these pads.
- **Opposable thumb**: Enables the hand to grip an object.
- **Upright posture**: Enables them to stand erect (upright) and use their hands for grasping; it also gives a better view of surroundings; give exposure of genitals to attract the opposite sex
- **Sexual dimorphism**: differences between males and females of the same species. Humans and apes are sexually dimorphic. This is linked to competition.

Humans & Apes Differences

Feature	Humans (*Homo sapiens*)	African apes
cranium	large cranium / brain	small cranium / brain
brow ridges	not well developed	well developed, prominent
spine	more curved (S-shaped)	less curved (C-shaped)
pelvic girdle	short and wide	long and narrow
canines	small	large
arrangement of teeth	small gaps between teeth	big gaps between teeth
palate shape	small, semi-circular	long, rectangular
jaws	small, less prognathous	large, more prognathous
cranial ridges	none	across top of cranium
foramen magnum	in a forward position	in a backward position

Hominin- Hunan
Hominid - African ape

Evolution

Major phases

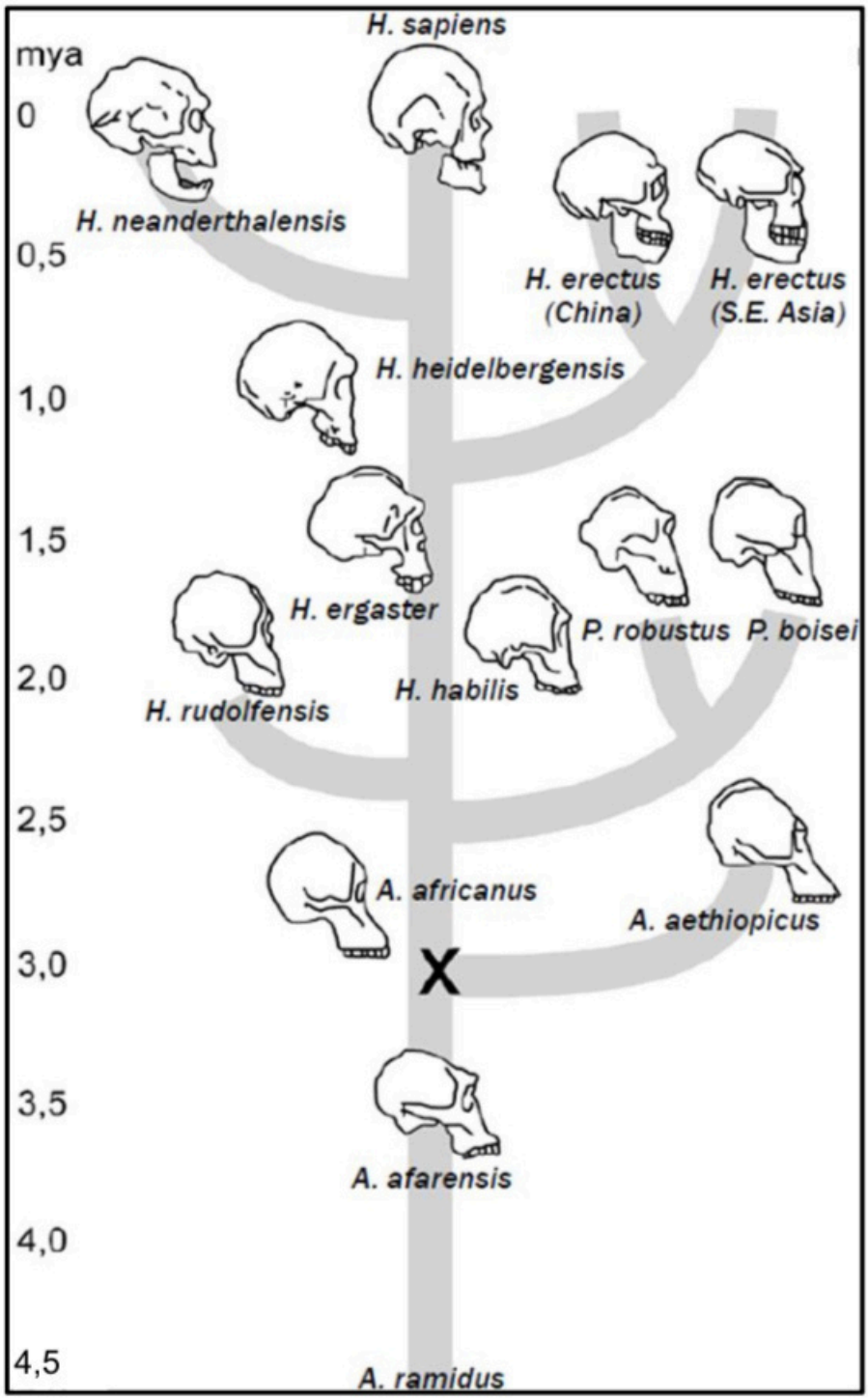
Human evolution

Organism	When organism existed	Fossil site	Discovered by	Characteristics
Ardipithecus ramidus	5 – 4 mya	North-East Ethiopia	Tim White	Brain size: 300–350 ml Forward position of foramen magnum Very prognathous (more protruding jaws) Heavy brow ridges Pelvis structure: bipedal and tree climbing
Australopithecus afarensis	4 – 2,7 mya	Ethiopia, Kenya, Tanzania	Donald Johanson	Brain size: 375–550 ml Forward position of foramen magnum Very prognathous Heavy brow ridges Canines large and pointed Long arms No cranial ridge
Australopithecus africanus	3 – 2 mya	Taung; Sterkfontein	Raymond Dart	Brain size: 428–625 ml Forward position of foramen magnum Prognathous Brow ridges Teeth large, canines not long Long arms No cranial ridge
Australopithecus sediba	1,9 – 1,8 mya	Malapa Cave – in the cradle of humankind	Lee Burger	Brain size: 420 ml Less prognathous Brow ridges Large teeth, canines not long Long arms No cranial ridge
Homo habilis	2,2 – 1,6 mya	Tanzania	Louis and Mary Leakey	Brain size: 650 ml Less prognathous Less pronounced brow ridges Human-like teeth – smaller canines Long arms
Homo erectus	2 – 0,4 mya	Java in Indonesia and then Swartkrans	Eugene Dubois	Brain size: 900 ml Prognathous Cranial ridges Short canines Longer legs and shorter arms
Homo sapiens	200 000 years ago – present	Makapansgat in Limpopo; Border Cave in KZN; Blombos Cave in the Western Cape	Tim White	Brain size: 1200–1800 ml No brow ridges Small teeth Short arms

Evolution

Human evolution

Phylogenetic tree – evolution of humans

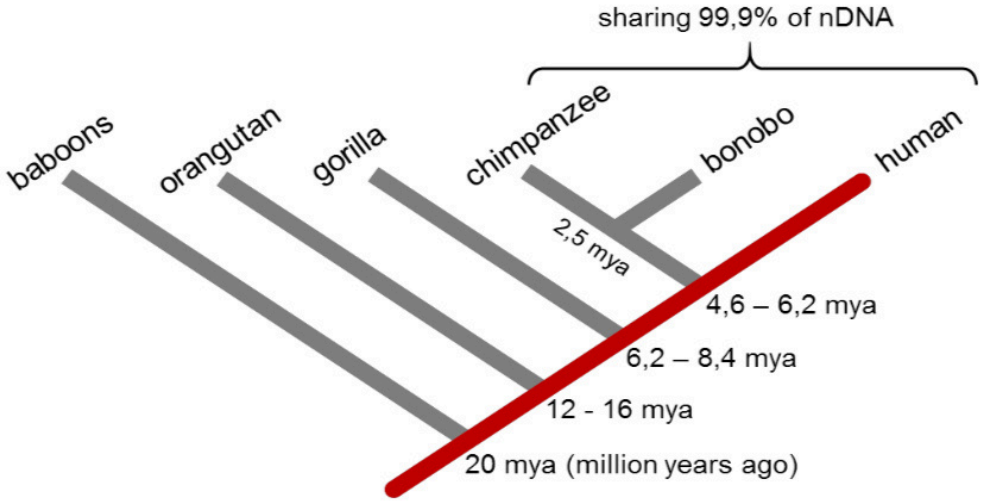


Human Evolution

Evidence of common ancestry

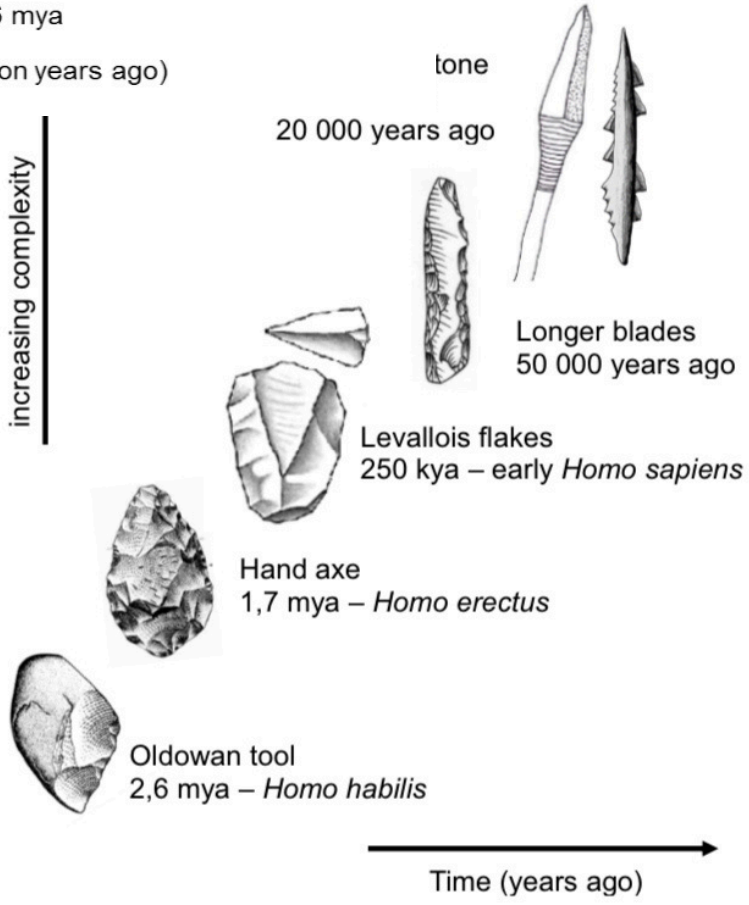
Genetic evidence

Studies show that, of the African apes, the chimpanzee is the closest relative of humans. Chimps and humans share 98,8% of the same genes – there is a 1,2% difference (10 – 12 times larger than the difference between humans).
The analysis of mitochondrial DNA (mtDNA) and the differences that exist between the mtDNA of two different species enables scientist to determine how long ago the species separated.



Cultural evidence

- Oldowan tool culture
- Hand axes
- Flakes
- cooking with fire
- cave painting



Human Evolution
Out of Africa Hypothesis

The '**Out of Africa**' hypothesis states that all modern humans originated in Africa, and then migrated out of Africa to the rest of the world.

Supported by:
- Genetic evidence
- Fossil evidence

Genetic evidence

Using MtDNA- scientists conclude that:
- African populations of Homo sapiens have the greatest number of mtDNA markers and are thus the oldest.
- The most recent common ancestor whose genetic marker is found in all living humans, must have lived in eastern Africa approximately 150 000 years ago.

Fossil evidence

- Fossils from the earliest hominin species, Ardipithecines and Australopi- thecines, have been found only in Africa and not anywhere else.
- Fossils for the earliest species of the genus Homo, Homo habilis, have also only been found in Africa.
- Fossil evidence for Homo erectus indicates this species lived in eastern and southern Africa between 1,9 – 1,4 million years ago. The earliest finds in Africa are the oldest fossils of Homo erectus discovered anywhere in the world.
- Finally, Homo sapiens emerged in Africa. The oldest Homo sapiens fossils were discovered in 2005 near Ethiopia's Omo River and are dated to between 195 000 and 160 000 years ago.

Fossil sites in SA

Sterkfontein
- Robert Broom discovered Mrs Ples
- Ron Clarke, working with Stephen Motsumi and Nkwane Molefe, discovered Little Foot

Malapa
- Karabo (*Homo sediba*), dated 2 mya – a transitional species linking A. afarensis and the earliest form of the genus Homo.

Importance of cradle of humankind

- The first adult skull was found at Sterkfontein.
- Little foot was found at Sterkfontein
- The first fossils of *Homo erectus* were found by Robert Broom at Swartkrans.

Other fossil sites

- Taung (North-West Province): Taung child discovered here. It was the first ever specimen of *Australopithecus africanus*
- Louis and Mary Leakey discovered fossils of *Homo habilis* in Tanzania
- Donald Johansen discovered the first specimen of the species *Australopithecus afarensis* at Hadar, Ethiopia

Evolution Terminology

Biological term	Description
Anthropology	The study of humans, including the different belief systems, customs and social habits.
Australopithecus	The genus of the fossil 'Little Foot'
Biogeography	The distribution of species in different parts of the world
Biological evolution	Any genetic change in a population that is inherited over several generations. These changes may be small or large, noticeable or not so noticeable.
Bipedalism	The ability of an organism to walk on two limbs
Extinction	The permanent disappearance of a species from earth
Foramen magnum	The opening at the base of the skull through which the spinal cord enters
Fossils	The mineralised remains of organisms that have lived in the past
Hominidae/Hominids	The family to which humans belong
Homo habilis	The first *Homo* species to use tools
Homologous structures	Similar structures on different organisms that suggest they have a common ancestor
Hypothesis	A tentative explanation of a phenomenon that can be tested and may be accepted or rejected
Natural selection	The process by which organisms best suited to survival in the environment achieve greater reproductive success, thereby passing advantageous characteristics onto future generations
Out of Africa hypothesis	The hypothesis that states that modern humans/*Homo sapiens* originated in Africa and migrated to other parts of the world
Palaeontology	Study of fossils
Phylogenetic tree/cladogram	A diagrammatic representation showing possible evolutionary relationships among different species
Population	A group of organisms of the same species living in the same habitat at the same time
Punctuated equilibrium	Type of evolution involving long periods of time when species do not change and short periods of rapid change
Quadrupedal	The ability of an organism to walk on four limbs
Speciation	Process whereby new species are formed from the original population
Species	A group of organisms which can interbreed to produce fertile offspring
Theory	Explanation of an observation that is supported by facts, models and laws