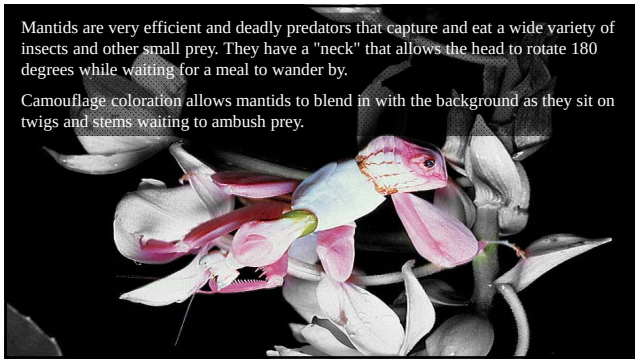
Evolution



Mantids are very efficient and deadly predators that capture and eat a wide variety of insects and other small prey. They have a "neck" that allows the head to rotate 180 degrees while waiting for a meal to wander by.

Camouflage coloration allows mantids to blend in with the background as they sit on twigs and stems waiting to ambush prey.

How did the mantid come to so closely match its environment?

Did it change its body on purpose?

Did it choose to be pink?

If I sat on the same flower for five years would I turn pink too?

The answer to all of these questions is evolution.

What is evolution?

Evolution is the change in a species over time.

Descent with Modification

Things Change

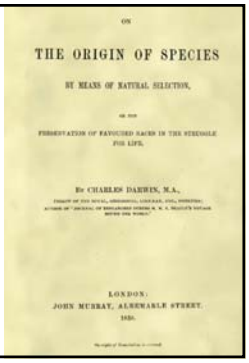
Organisms Evolve

What's The Big Deal?

A Historical Background for Evolutionary Theory

1. **Western culture resisted evolutionary views of life**
2. **Theories of geologic gradualism helped clear the path for biologists**
3. **Lamarck placed fossils in an evolutionary context**

- On November 24, 1859, Charles Darwin published *On the Origin of Species by Means of Natural Selection*.
- Darwin's book drew a cohesive picture of life by connecting what had once seemed like a bewildering array of unrelated facts.

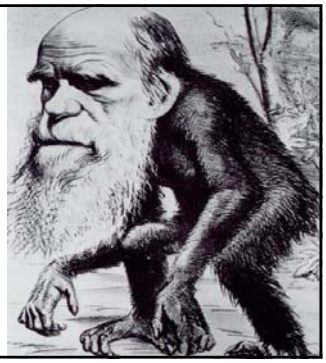

ON
THE ORIGIN OF SPECIES
BY MEANS OF NATURAL SELECTION,
OR THE
PRESERVATION OF FAVOURED RACES IN THE STRUGGLE
FOR LIFE.
By CHARLES DARWIN, M.A.,
LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

Darwin made two points in *The Origin of Species*:

1. Today's organisms descended from ancestral species.

2. That **natural selection** provided a mechanism for evolutionary change in populations.

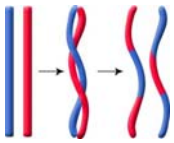
Darwin did not say that humans are monkeys or that there is no such thing as God.



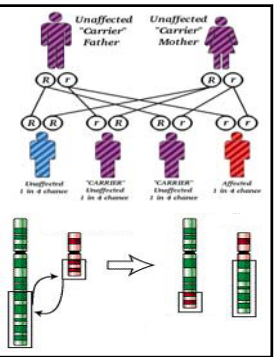
What Darwin Did Say

Natural Selection is the process within every population of organisms where random variations have different **survival value**.

Those variations which aid survival (or enhance reproductive capacity) are "selected for" by being genetically transmitted to succeeding generations.

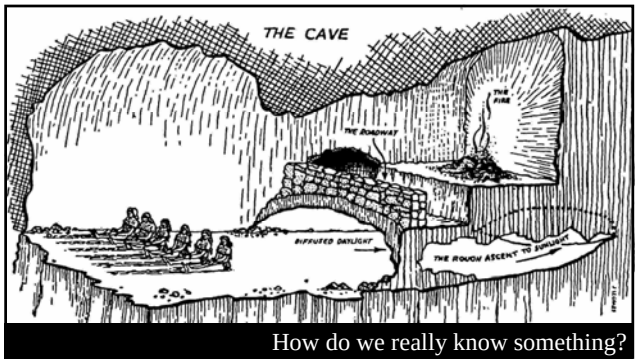


Meiosis, Mutations and Sexual Reproduction all work to create variation within a species.



Western culture resisted evolutionary views of life

- The *Origin of Species* challenged a worldview that had been accepted for centuries.
- The Greek philosophers who influenced Western culture, Plato and Aristotle, opposed any concept of evolution.
  - Plato believed in two worlds: one real world that is ideal and perfect and an illusory world of imperfection that we perceive through our senses.



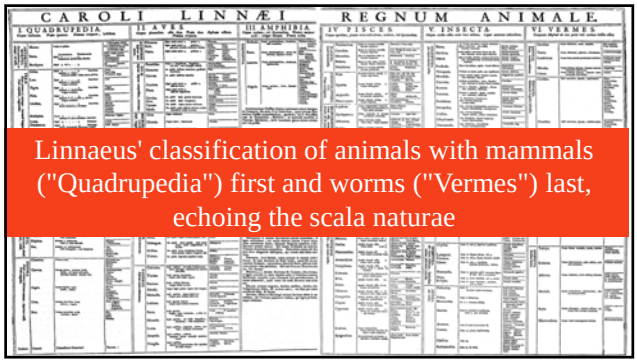
How do we really know something?

The great chain of being (Latin: "ladder/stair-way of nature")

Aristotle believed that all living forms could be arranged on a ladder (*scala naturae*) of increasing complexity with every rung taken with perfect, permanent species.

The absolutely set nature of species, and thus the permanence of each creature's place in the Great Chain, would come to cause many problems

- The Judeo-Christian account of creation in the Old Testament fortified the idea that species were individually designed and did not evolve.
- In the 1700s, the dominant philosophy, **natural theology**, was dedicated to studying the adaptations of organisms as evidence that a **creator had designed** each species for a purpose.
- At the time, Carolus Linnaeus, a Swedish botanist, developed **taxonomy**, a system for naming species and grouping species into a hierarchy of increasingly complex categories.



Linnaeus' classification of animals with mammals ("Quadrupedia") first and worms ("Vermes") last, echoing the scala naturae

In the 1840's this started happening…

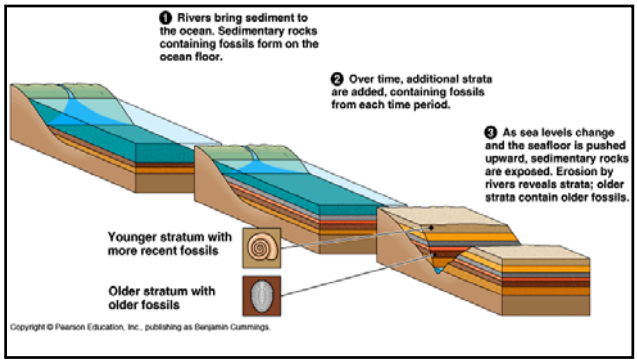
Darwin's views were influenced by fossils.
Fossils are the traces or impressions of organisms from the past, mineralized **in sedimentary rocks**.

Fossils (Latin: fossus, "having been dug up") are the preserved remains or traces of animals, plants and other organisms that are at least 10,000 years old.

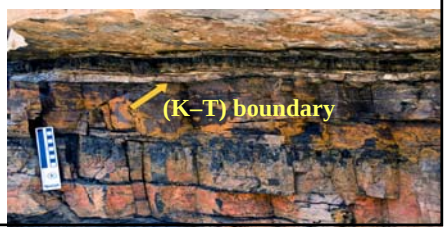
Sedimentary rocks form when mud and sand settle to the bottom of seas, lakes, and marshes.

New layers of sediment cover older ones, creating layers of rock called strata.

Fossils within layers show that a succession of organisms have populated Earth throughout time.



The Cretaceous–Tertiary (K–T) extinction, was a mass extinction of 75% of plant and animal species on Earth—including all non-avian dinosaurs—that occurred over a geologically short period of time, 66 million years ago.



The boundary clay shows high levels of the metal iridium, which is rare in the Earth's crust but abundant in asteroids.

In the geologic record, the K–T event is marked by a thin layer of sediment called the K–T boundary, which can be found throughout the world in marine and terrestrial rocks.

Fossilization is an exceptionally rare event, because most organisms tend to decompose quickly after death.

This is why we see many more shells and sea creatures than soft land based life forms.

In order for an organism to be fossilized the remains need to be covered by sediment as soon as possible.

There are exceptions to this: organism can be frozen, desiccated, or die in an anoxic (oxygen-free) environment.

The first frozen high mountain Inca human sacrifice was found atop a peak in Chile in 1954. More recently, additional discoveries, including the remarkably preserved "Juanita" and the huddled body of a small boy, have shed light on this controversial Inca ritual. Children sacrificed to the mountain gods are now revealing details of an ancient Inca practice. The bodies are not fossils as they are only 500 years old.

Theories of geologic gradualism helped clear the path for evolutionary biologists

- James Hutton, a Scottish geologist, proposed that the diversity of landforms (mountains and canyons) could be explained by mechanisms *currently* operating.
  - Hutton proposed a theory of **gradualism**, in that profound change to the Earth results from very slow, continuous processes.

- Hutton's observations and theories had a strong influence on Darwin.
  - First, if geologic changes result from slow, continuous processes, rather than sudden events, then the Earth must be far older than the 6,000 years assigned by theologians from biblical inference.
  - Second, **slow and subtle processes** persisting for long periods of time **can add up** to substantial change.

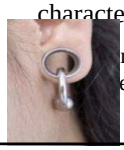
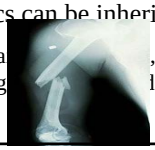
If the environment changes wouldn't the organisms living in it change too?

Lamarck placed fossils in an evolutionary sequence

- In 1809, Jean Baptiste Lamarck published a theory of evolution based on his observations of fossil invertebrates in the Natural History Museum of Paris.
  - Lamarck thought that he saw what appeared to be several lines of descent in the collected fossils and current species.
  - Each was a chronological series of older to younger fossils leading to a modern species.

- Central to Lamarck's mechanism of evolution were the concepts of use and disuse of parts and of inheritance of acquired characteristics.
  - **He proposed that body parts used extensively to cope with the environment became larger and stronger, while those not used deteriorated.**
  - **He also thought that modifications acquired during the life of an organism could be passed to offspring.**
  - The classic example of these is the long neck of the giraffe in which individuals could acquire longer necks

- Lamarck's theory was a visionary attempt to explain both the fossil record and the current diversity of life through its recognition of the great age of Earth and adaptation of organisms to the environment.
- However, there is no evidence that acquired characteristics can be inherited.

Descent with Modification: The Darwinian View of Life

Field research helped Darwin frame his view of life

The Origin of Species **developed two main points:**

the occurrence of evolution

and

natural selection as its mechanism

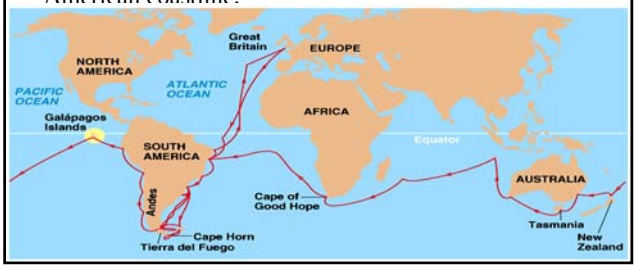
About Darwin the Man

Charles Darwin (1809-1882) was born in western England.

While Darwin had a consuming interest in nature as a boy, his father sent him to the University of Edinburgh to study medicine. After graduation Darwin was recommended to be the conversation companion to Captain Robert FitzRoy, who was preparing the survey ship *Beagle* for a voyage around the world.
FitzRoy chose Darwin because of his education, and because he was of the same social class, and was close in age to the captain.

Darwin's Statue at Shrewsbury school in Shropshire England

- The main mission of the five-year voyage of the *Beagle* was to chart poorly known stretches of the South American coastline.



- Darwin noted that the plants and animals of South America were very distinct from those of Europe.

- The origin of the fauna of the Galapagos, 900 km west of the South American coast, especially puzzled Darwin.
  - On further study after his voyage, Darwin noted that while most of the animal species on the Galapagos lived nowhere else, they resembled species living on the South American mainland.

It seemed that the islands had been colonized by plants and animals from the mainland that had subsequently diversified on the different islands.

- Darwin read about the geologic idea of gradualism, and the idea that the Earth was very old and constantly changing.
- He began to think that the origin of new species and adaptation of species to the environment were closely related processes.

- By the early 1840s Darwin had developed the major features of his theory of natural selection as the mechanism for evolution.
- In 1844, he wrote a long essay on the origin of species and natural selection, but he was reluctant to publish his theory and continued to compile evidence to support his theory.
- In June 1858, **Alfred Wallace**, a young naturalist working in the East Indies, sent Darwin a manuscript containing a theory of natural selection essentially identical to Darwin's.

- Later that year, both Wallace's paper and extracts of Darwin's essay were presented to the Linnaean Society of London.
- Darwin quickly finished *The Origin of Species* and published it the next year.
- While both Darwin and Wallace developed similar ideas independently, the essence of evolution by natural selection is attributed to Darwin because he developed and supported the theory of natural selection earlier and much more extensively.

The Origin of Species developed two main points: the occurrence of evolution and natural selection as its mechanism

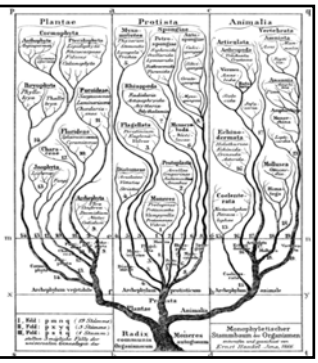
- **It refers to evolution as the explanation for life's unity and diversity.**
- It also refers to the Darwinian concept of natural selection as the cause of adaptive evolution.

Central to Darwin's view on the evolution of life is descent with modification.

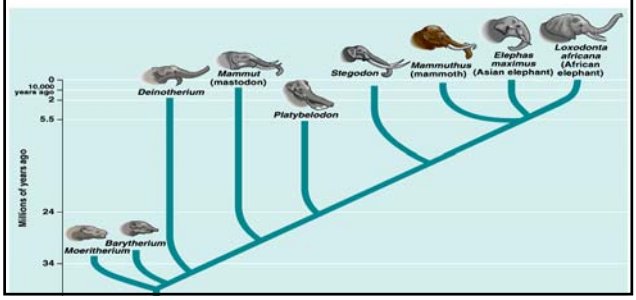
- In descent with modification, all present day organisms are related through descent from unknown ancestors in the past.
- Descendants of these ancestors accumulated diverse modifications or adaptations that fit them to specific ways of life and habitats.

Viewed from the perspective of descent with modification, the history of life is like a tree with multiple branches from a common trunk.

Closely related species, the twigs of the tree, shared the same line of descent until their recent divergence from a common ancestor.



This evolutionary tree of the elephant family is based on evidence from fossils.

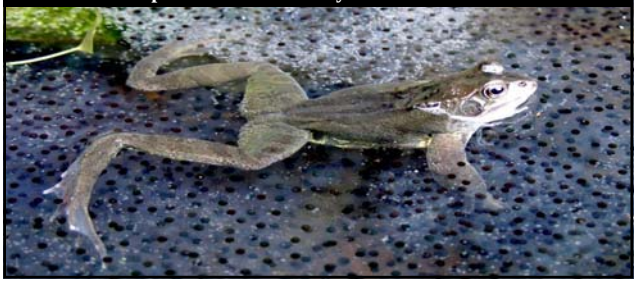


The other major point that Darwin pioneered is the mechanism of evolution - **natural selection**.

Darwin based his theory on a series of observations

1. Organisms demonstrate tremendous fecundity
   (they make lots of babies)
2. There are limited environmental resources
   (there isn't enough food/water/tickets to concert)
3. There is competition for resources
   (if you both want something you have to fight for it)
4. There are variations among individuals
   (everybody is special because your DNA is unique)
5. Variations must be passed to offspring
   (acquired characteristics need not apply)

Observation #1: All species have such great potential fertility that their population size would increase exponentially if all individuals that are born reproduced successfully.



- Observation #2: Populations tend to remain stable in size, Except for seasonal fluctuations.

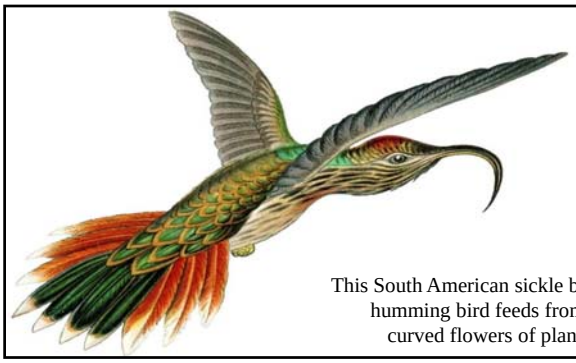
- Observation #3: Environmental resources are limited.
- Inference #1: Production of more individuals than the environment can support leads to a struggle for existence among the individuals of a population, with only a fraction of the offspring surviving each generation.

- Observation #4: Individuals of a population vary extensively in their characteristics; no two individuals are exactly alike.

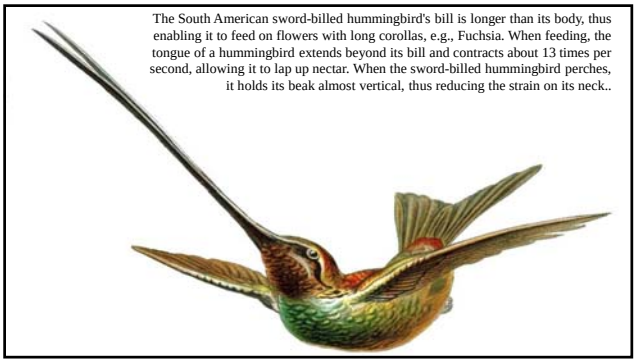
- Observation #5: Much of this variation is heritable.

- Inference #2: Survival in the struggle for existence is not random, but depends in part on the hereditary constitution of the individuals.
  - Those individuals whose inherited characteristics best fit them to their environment are likely to leave more offspring than less fit individuals.
- Inference #3: This unequal ability of individuals to survive and reproduce will lead to a gradual change in a population, with favorable characteristics accumulating over the generations.

- Darwin's main ideas can be summarized in three points.
  1. Natural selection is differential success in reproduction (in English this means the unequal ability of individuals to survive and reproduce).
  2. Natural selection occurs through an interaction between the environment and the variability inherent among the individual organisms making up a population.
  3. The product of natural selection is the adaptation of populations of organisms to their environment.



This South American sickle billed humming bird feeds from the curved flowers of plantains



The South American sword-billed hummingbird's bill is longer than its body, thus enabling it to feed on flowers with long corollas, e.g., Fuchsia. When feeding, the tongue of a hummingbird extends beyond its bill and contracts about 13 times per second, allowing it to lap up nectar. When the sword-billed hummingbird perches, it holds its beak almost vertical, thus reducing the strain on its neck..

- Darwin's views on "overreproduction" were heavily influenced by an essay on human population by Thomas Malthus in 1798.
  - Malthus contended that much human suffering -- disease, famine, homelessness, war -- was the inescapable consequence of the potential for human populations to increase faster than food supplies and other resources.
- The capacity to overproduce seems to be a characteristic of all species, with only a small fraction of eggs developing to leave offspring of their own.

- In each generation, environmental factors filter heritable variations, favoring some over others.
  - Differential reproduction -- whereby organisms with traits favored by the environment produce more offspring than do organisms without those traits -- results in the favored traits being disproportionately represented in the next generation.

This increasing frequency of the favored traits in a population is **evolution**.

The Darwinian view of life has two main features.

(1) The diverse forms of life have arisen by descent with modification from ancestral species.

(2) The mechanism of modification has been natural selection working over enormous tracts of time.

- Darwin's views on the role of environmental factors in the screening of heritable variation were heavily influenced by **artificial selection**.

Humans have modified a variety of domesticated plants and animals over many generations by selecting individuals with the desired traits as breeding stock.

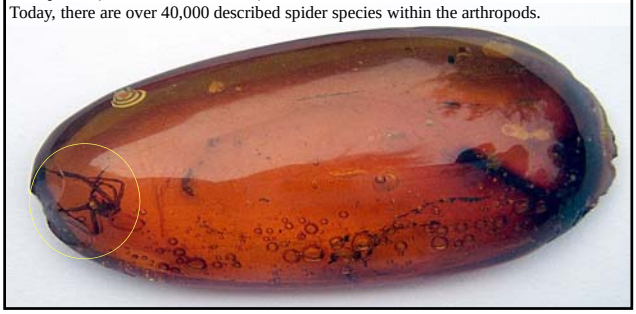
Cabbage, Brussels Sprouts, Broccoli, Cauliflower are all the same plant… **with different traits selected.**

- If artificial selection can achieve such major changes in a relatively short time, then natural selection should be capable of major modifications of species over hundreds or thousands of generations.
- Darwin envisioned the diversity of life as evolving by a gradual accumulation of minute changes through the actions of natural selection operating over vast spans of time.

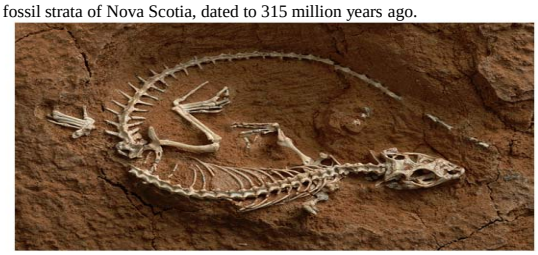
- While natural selection involves interactions between individual organisms and their environment, it is not individuals, but populations that evolve.
- Populations are defined as a group of interbreeding individuals of a single species that share a common geographic area.
- Evolution is measured as the **change in relative proportions** of heritable variation in a population over a succession of generations.

- Natural selection can only **amplify** or **diminish** heritable variations, not variations that an individual acquires during its life, even if these variations are adaptive.
- Also, natural selection is situational.
  - Environmental factors vary in space and time.
  - Therefore, adaptations for one set of environmental conditions may be useless or even detrimental under other circumstances.

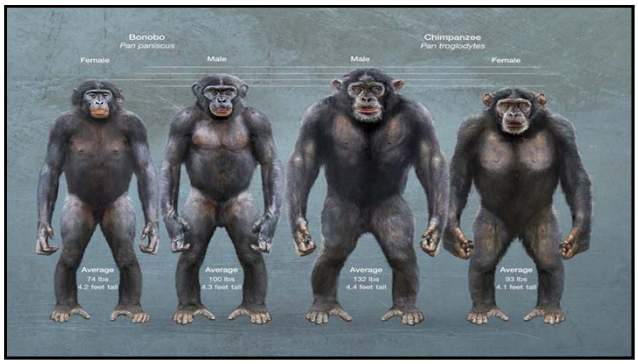
The evolution of spiders has been going on for at least **400 million years**, since the first true spiders (thin-waisted arachnids) evolved from crab-like chelicerate ancestors. Today, there are over 40,000 described spider species within the arthropods.



The origin of the reptiles lies about **320–310 million years ago**, in the steaming swamps of the late Carboniferous, when the first reptiles evolved from advanced reptiliomorph labyrinthodonts. The oldest trace of reptiles is a series of footprints from the fossil strata of Nova Scotia, dated to 315 million years ago.



fossil lizard



DNA: Comparing Humans and Chimps

The chimpanzee and another ape, the bonobo, are humans' closest living relatives.

These three species look alike in many ways, both in body and behavior.

When scientists compare the DNA of these species it was found that Humans and chimps share **98.8 percent** of their DNA.

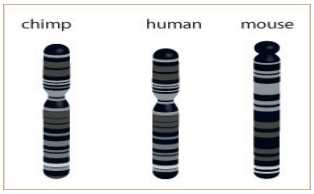
DNA: Comparing Humans and Chimps

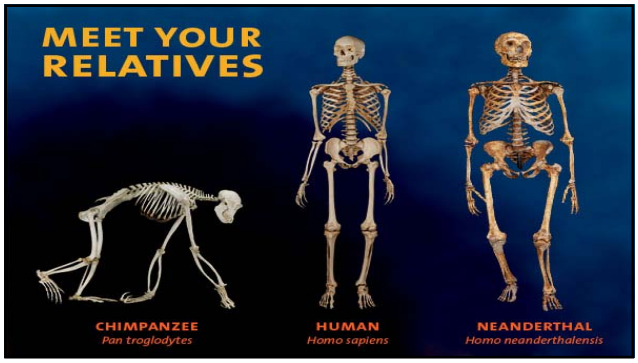
So Much Alike...

Human and chimp DNA is so similar because the two species are so closely related. Humans, chimps and bonobos descended from a single ancestor species that lived six or seven million years ago. As humans and chimps gradually evolved from a common ancestor, their DNA, passed from generation to generation, changed too. In fact, many of these DNA changes led to differences between human and chimp appearance and behavior.

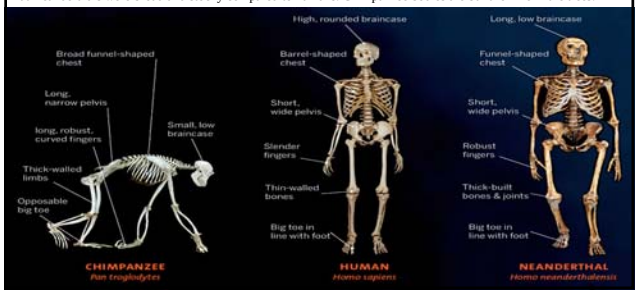
DNA: Comparing Humans and Chimps

Banding Patterns
The light and dark bands on these chromosomes, created by a laboratory dye, reveal similarities and differences among human, chimp and mouse DNA.



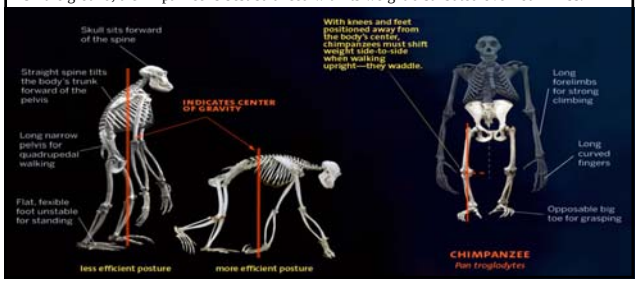


Skeletal Features: To understand how Neanderthals, humans and chimpanzees are related, scientists compare their skeletons. The chimpanzee's small brain case, and arms and legs adapted to climbing, set it apart from the other two. Neanderthals, humans and chimpanzees all evolved from a common ancestor, so their skeletons are similar. But Neanderthals were broad and stocky compared to humans. Chimpanzee bodies are built for life in the trees.



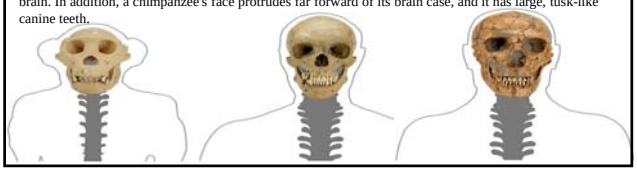
Bipedal Features: An important difference between humans and chimpanzees is our mobility. Humans stand and walk on two feet—we are bipedal. An S-shaped backbone and other features of the skeleton help the human head, spine, pelvis and knees line up directly over the feet. Your skeleton balances your weight so you don't fall over.

Quadrupedal Features: An important difference between humans and chimpanzees is our mobility. Chimpanzees are quadrupedal—they usually move around on four limbs. With long, muscular arms and grasping feet, they climb easily and spend much of their time in the trees. On the ground, a chimpanzee is best balanced with its weight distributed over four limbs.



CHIMPANZEE HUMAN NEANDERTHAL

Some Neanderthal skulls—and brains—were actually larger than those of modern humans. Compared with humans, Neanderthals also had protruding faces, prominent brows, large noses, and receding chins. A chimpanzee's skull is much smaller than a human's, and its brain is about one-third the size of a human brain. In addition, a chimpanzee's face protrudes far forward of its brain case, and it has large, tusk-like canine teeth.

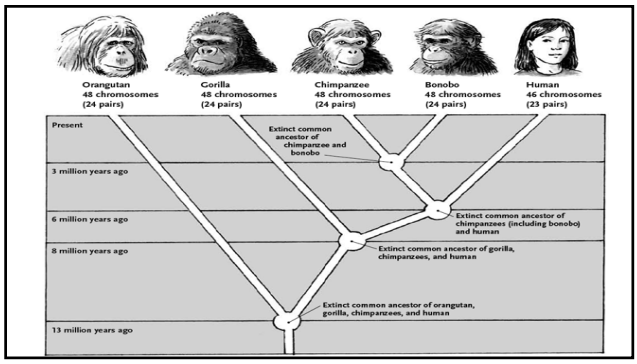


CHIMPANZEE HUMAN NEANDERTHAL

Neanderthal and human pelvises are both shaped like a cup, to support the spine and upper body. Pelvis shape tells scientists that both Neanderthals and humans walk upright on two feet. The chimpanzee pelvis is much longer and narrower than the human pelvis—look at the bones called the iliac blades. The chimp pelvis tilts forward when the animal walks on all fours.

CHIMPANZEE HUMAN NEANDERTHAL

Human and Neanderthal feet are both arched, with strong big toes in line with the rest of the foot. These features help make it easy to walk on two feet. The chimpanzee's opposable big toe—it looks almost like a thumb—is used for grasping and climbing. Humans have a big toe in line with the rest of the foot.



Palaeontologists working in Tanzania have discovered the oldest known fossils from two major primate groups — Old World monkeys, which include baboons and macaques, and the apes, which include humans and chimpanzees. The study, published in Nature, reveals new information about primate evolution.

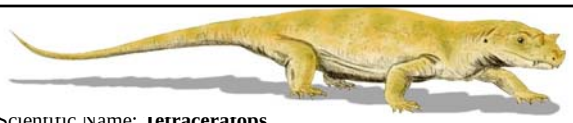
A team led by Nancy Stevens, a palaeontologist at Ohio University in Athens, recovered a lone tooth and a jaw fragment with three teeth from a site in the Rukwa Rift Basin in southwestern Tanzania. Precise geological dating of nearby rocks indicates that the fossils are **25.2 million years old**, several million years older than any other example from either primate group.

Previous geological evidence gathered by the team suggests that tectonic activity in the East African rift system during the late Oligocene may have helped to trigger the evolutionary divergence between Old World monkeys and apes.

Tale of the tooth

To place the latest finds in the evolutionary family tree, Stevens' team took high-resolution computed-tomography scans of the fossil teeth to look for subtle variations in the size and shape of several features.

A Monkey's Uncle?
That's Nothing…



Scientific Name: **Tetraceratops**
Location: **Texas**

Tetraceratops, the oldest known therapsid. This strange synapsid, found in Texas in the last century, has recently been reinterpreted as the only known Lower Permian therapsid.

Mammals are the only living therapsids.