A History of Life on Earth

Evolutionary Biology Course (LS221)

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Era/Period/Epoch			Time (Myr ago)
Archaeozoic (Archean) era			5000-1500
Proterozoic era			1500-545
Paleozoic era	Cambrian period		545-505
	Ordovician period		505-438
	Silurian period		438-410
	Devonian period		410-355
	Carboniferous (Mississipian/Pennsylvanian) period		355-290
	Permian period		290-250
Mesozoic era	Triassic period		250-205
	Jurassic period		205-135
	Cretaceous period		135-65
Cenozoic era "Recent Life"	Tertiary period	Paleocene epoch	65-55
		Eocene epoch	55-38
		Oligocene epoch	38-26
		Miocene epoch	26-6
		Pliocene epoch	6-1.8
	Quarternary period	Pleistocene epoch	1.8-0.01
		(Lower Paleolithic)	0.50-0.25
		(Middle Paleolithic)	0.25-0.06
		(Upper Paleolithic)	0.06-0.01
		Holocene epoch	0.01-0

The Geological Timescale

Major events in the history of life on earth

Time (mya)	Event	Period/ era
4600	Formation of the earth	Archean era
4300	Light dissociates atmospheric water into oxygen and hydrogen	
3800	The earth's crust solidifies, and the earliest rocks are formed, atmospheric water condenses into oceans	
3500 - 2800	Prokaryotes develop (earliest fossils ~3000 mya); photosynthesis by blue-green algae	
1500	Eukaryotic cells develop	
1500 - 600	Rise of multicellular organisms	Proterozoic era
545	Cambrian explosion of hard-bodied organisms	Cambrian period
517 - 515	Fossilization of the Burgess shale	
500 - 450	Rise of the fish – first vertebrates	Ordovician period
420	Millipedes – first land animals	Silurian period

Major events in the history of life on earth

Time (mya)	Event	Period/ era
375	The Appalachian mountains are formed by plate tectonic collision between North America, Africa and Europe	Devonian period
350 - 300	Rise of the amphibians	Carboniferous period
350	Primitive insects, primitive ferns – first plants with roots.	
300 - 200	Rise of the reptiles	Carboniferous – early Jurassic period
300	Winged insects	
280	Beetles and weevils	
250	Permian mass extinction	
225	Modern ferns, bees	
200	Pangea starts to break apart, primitive crocodiles	Jurassic period

Major events in the history of life on earth

Time (mya)	Event	Period/ era
145	*Archaeopteryx* walks the earth	Jurassic period
136	Primitive kangaroos	
90	Modern sharks	Cretaceous period
65	K-T boundary, extinction of the dinosaurs and beginning of the reign of mammals	Cretaceous – Tertiary period
60	Rats, mice, squirrels, herons and storks	Paleocene epoch
50	Primitive monkeys	Eocene epoch
20	Parrots and pigeons	Oligocene epoch
20 - 12	The chimpanzee and hominid lines evolve	Miocene epoch
4	Hominid bipedalism	Pliocene epoch
0.5 - 0	*Homo sapiens sapiens* exist	Upper Paleolithic – Holocene epoch

The Cambrian Explosion

545 mya, an explosion of diversity happened over a relatively short span of time (5 – 10 my).

A huge number of complex multicellular organisms developed.

Every extant phylum was born.

First shelled animals and animals with an exoskeleton were born.

The Cambrian Explosion

The development of hard parts and skeletons gave rise to entirely new animals.

Skeletal structures provided leverage for muscles, support for body organs, and protection for soft tissues.

Prey species grew protective spines and shells, while predators grew teeth, thus leading to an evolutionary arms race.

The Cambrian Explosion

What triggered the cambrian explosion?

There are various theories, but no way of testing them.

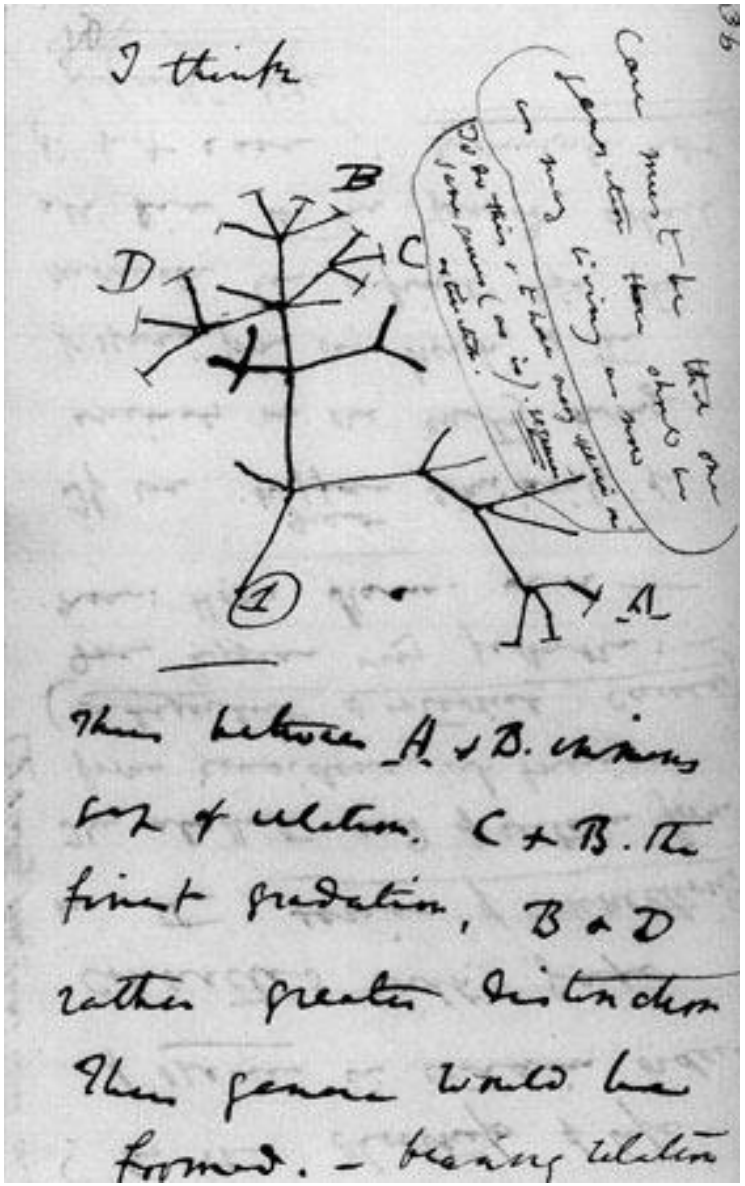
A warming trend leading to mineralization, accumulation of enough atmospheric oxygen through photosynthesis leading to an aerobic environment are considered to be some of the possible factors for this phenomenon.

The Cambrian Explosion

The evolution of sexual reproduction is considered to be a factor that could have led to an increase of diversity.

Cropping has been suggested as another possible reason.

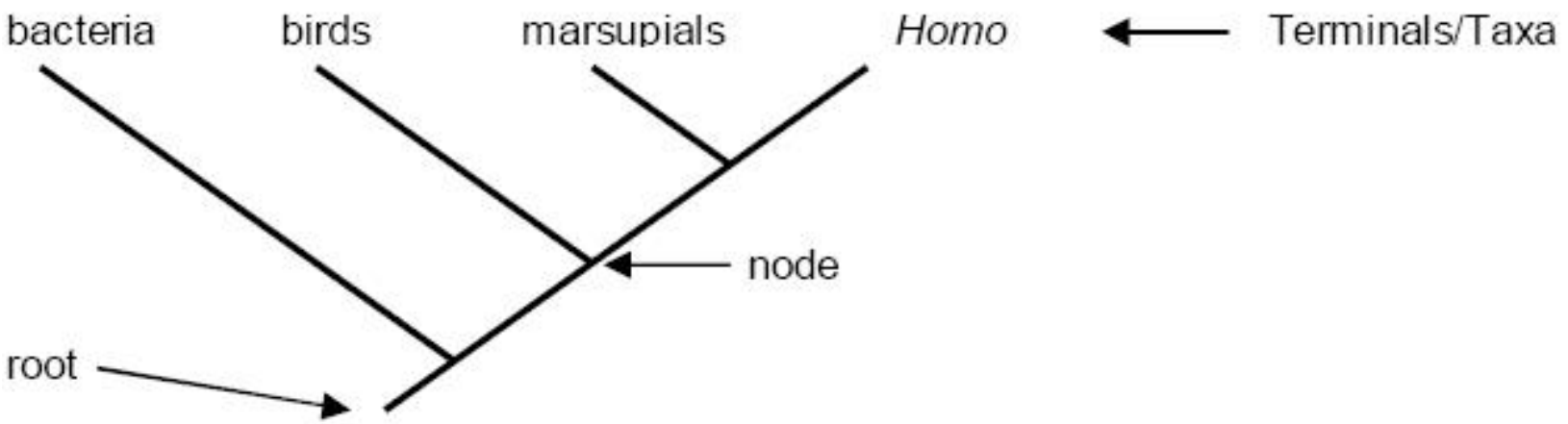
The tree of life



The first **evolutionary** tree drawn by Darwin in his notebook (1837).

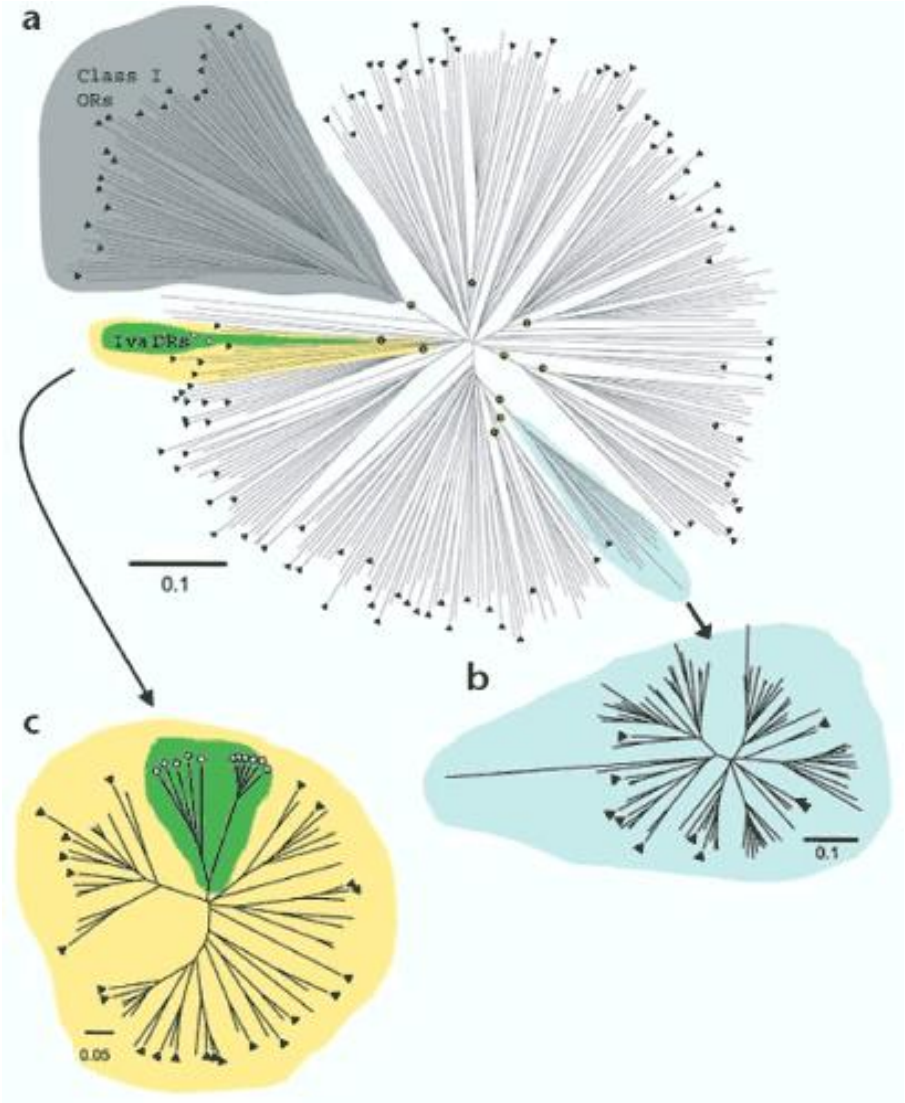
The tree of life

Rooted: A rooted phylogenetic tree is a directed tree with a unique node corresponding to the most recent common ancestor of all the entities at the leaves of the tree. In a rooted tree one branch (which is usually unlabeled) corresponds to the common ancestor of all the species included in the tree.



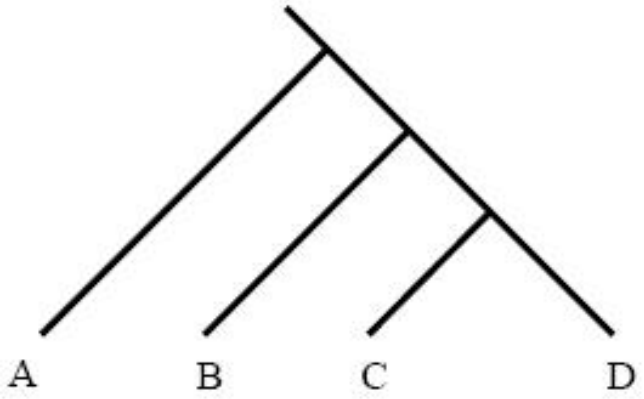
The tree of life

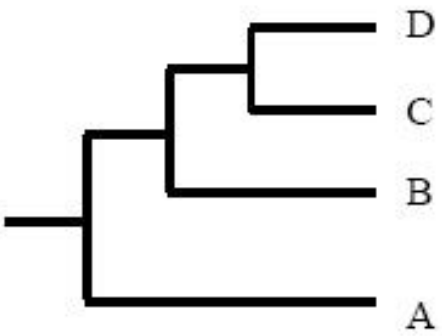
Unrooted: Unrooted trees illustrate the relatedness of the leaf nodes without making assumptions about ancestry at all. While unrooted trees can always be generated from rooted ones by simply omitting the root, a root cannot be inferred from an unrooted tree without some means of identifying ancestry.



Unrooted phylogenetic tree of human and mouse ORs.

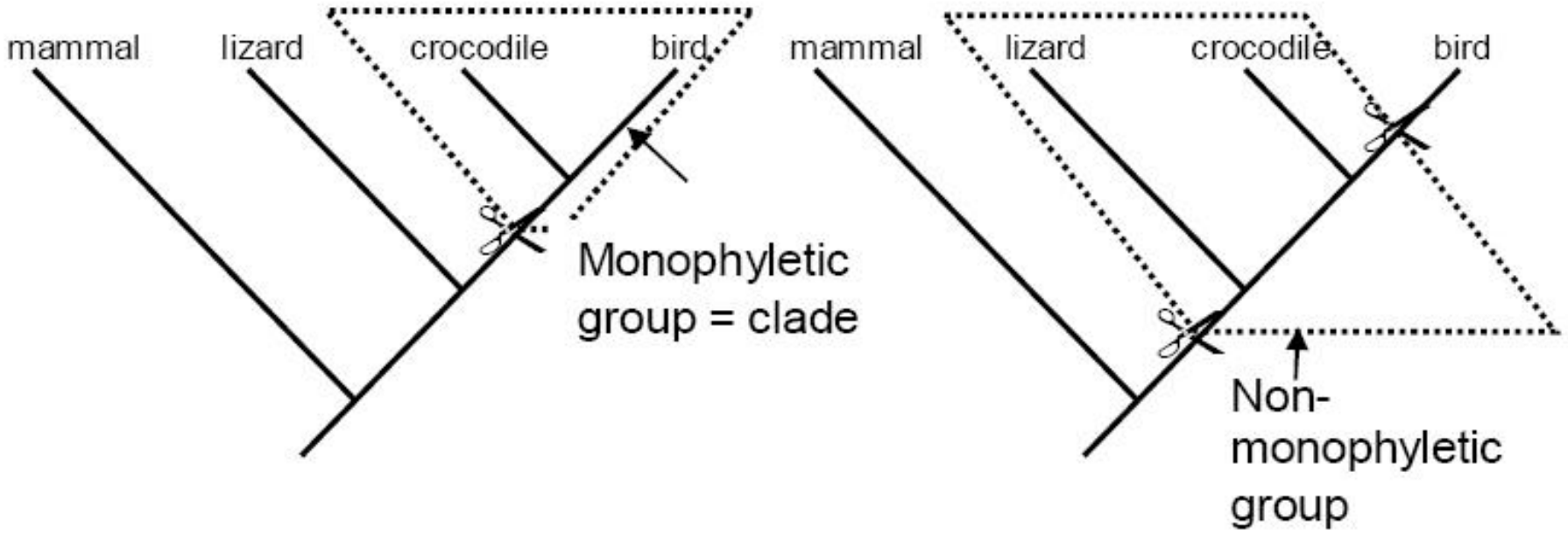
The tree of life





A tree can be drawn in many ways. All these trees carry the same information. The lines of a tree represent evolutionary lineages--and evolutionary lineages do not have any true position or shape.

The tree of life



A **clade** is a piece of a phylogeny that includes an ancestral lineage and all the descendants of that ancestor. This group of organisms has the property of monophyly (from the Greek for "single clan"), so it may also be referred to as a monophyletic group.

The tree of life

http://www.nature.com/scitable/topicpage/reading-a-phylogenetic-tree-the-meaning-of-41956

Citation: Baum, D. (2008) Reading a phylogenetic tree: The meaning of monophyletic groups. *Nature Education* 1(1)

The evolution of Vertebrates

Vertebrates belong to the phylum **chordata**.

A paired series of clefts or gills present in both embryonic and sometimes also in adult stages.

The presence of a notochord along the anterior-posterior axis of the body.

A post-anal tail.

A single hollow nerve cord that runs dorsally above the notochord.

The evolution of Vertebrates

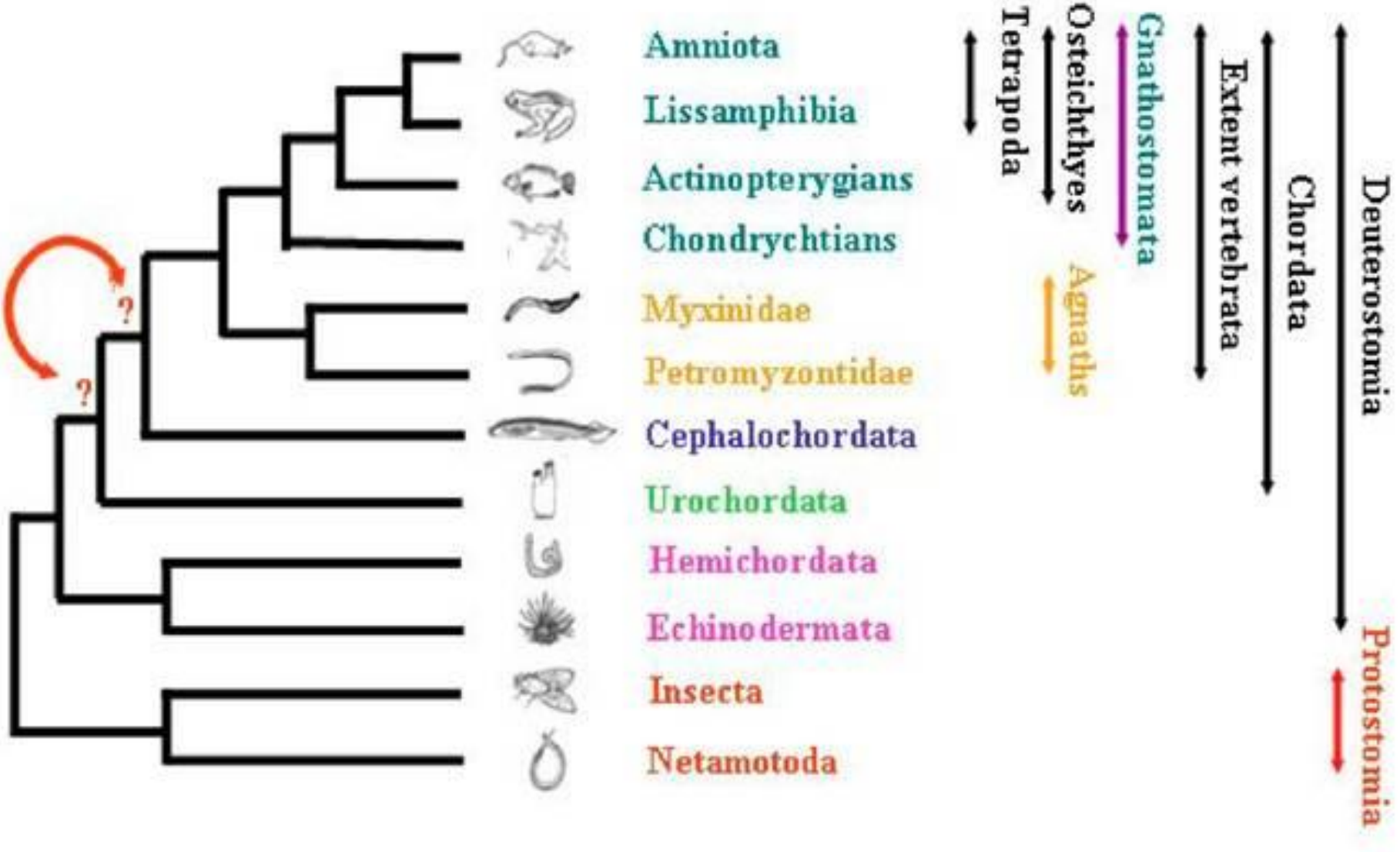
Two homologous pairs of genes that affect dorsal-ventral development are common between vertebrates and arthropods.

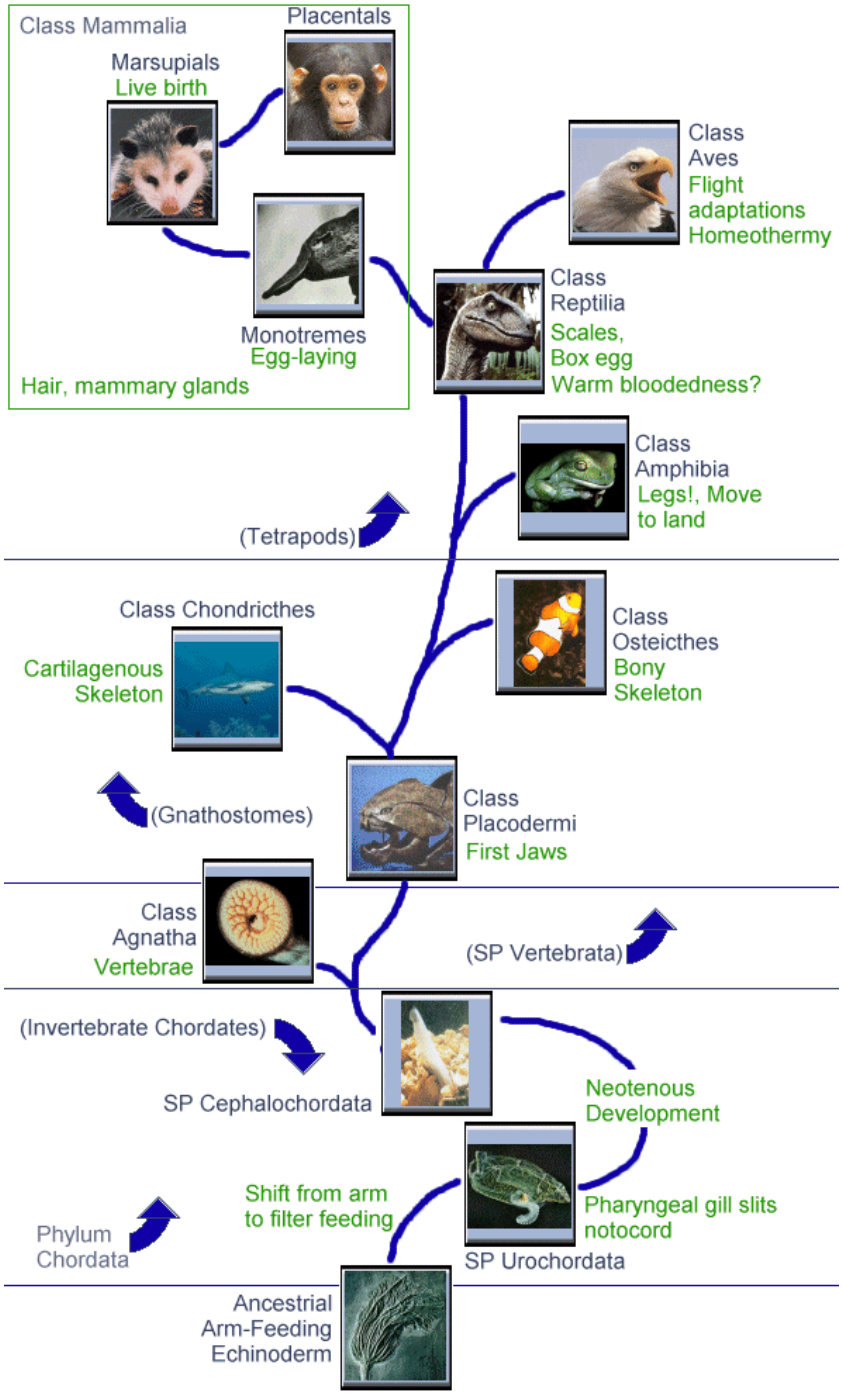
This indicates a common vertebrate-arthropod ancestor gave rise to both body plans, and one is the inversion of the other.

However, no such fossils have been found.

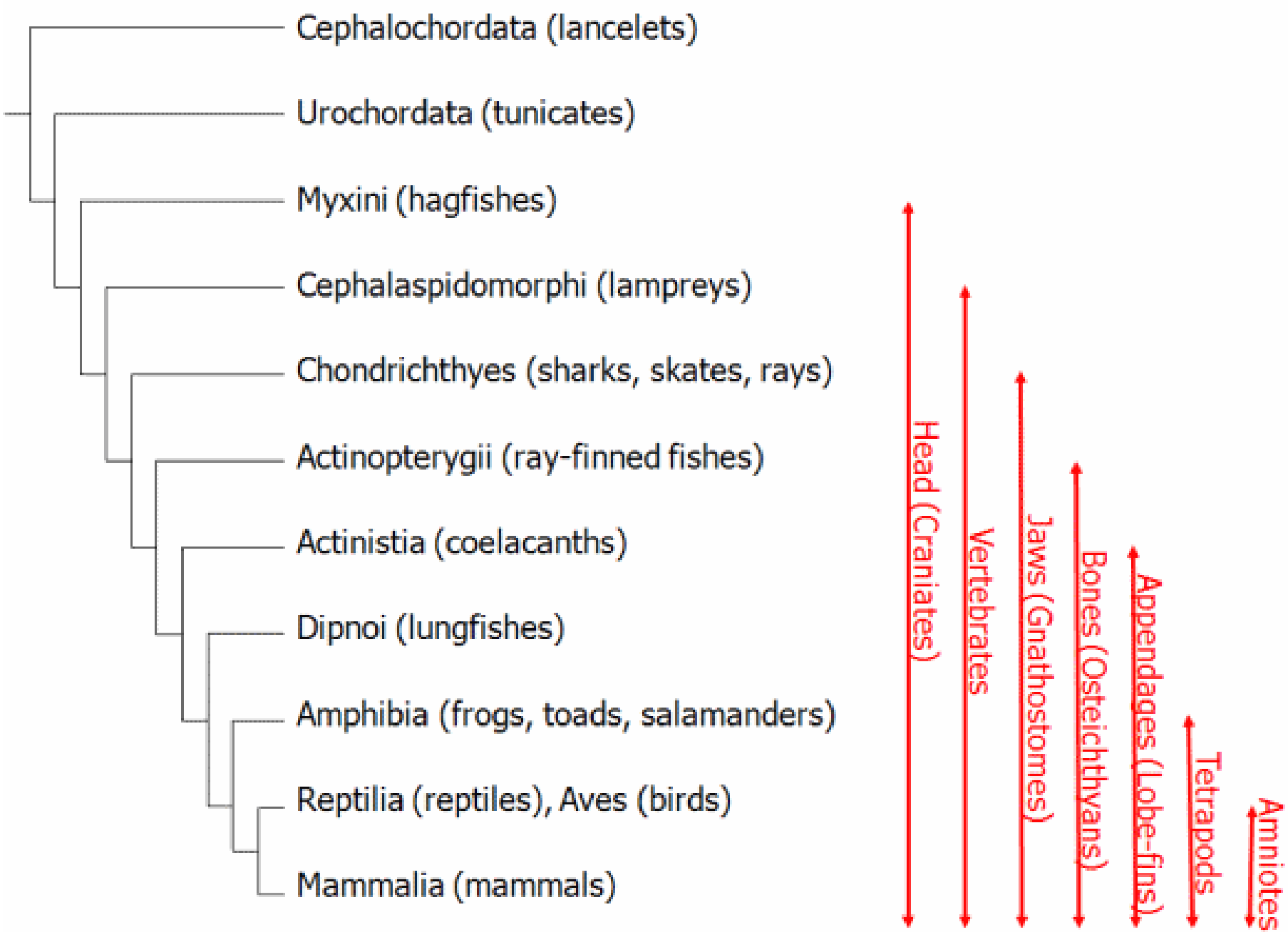
The most accepted hypothesis today is a common ancestry of vertebrates shared with echinoderms.

The evolution of Vertebrates





Major steps in the evolution of chordates


Cephalochordata (lancelets)
Urochordata (tunicates)
Myxini (hagfishes)
Cephalaspidomorphi (lampreys)
Chondrichthyes (sharks, skates, rays)
Actinopterygii (ray-finned fishes)
Actinistia (coelacanths)
Dipnoi (lungfishes)
Amphibia (frogs, toads, salamanders)
Reptilia (reptiles), Aves (birds)
Mammalia (mammals)
Head (Craniates)
Vertebrates
Jaws (Gnathostomes)
Bones (Osteichthyans)
Appendages (Lobe-fins)
Tetrapods
Amniotes

Echinodermata

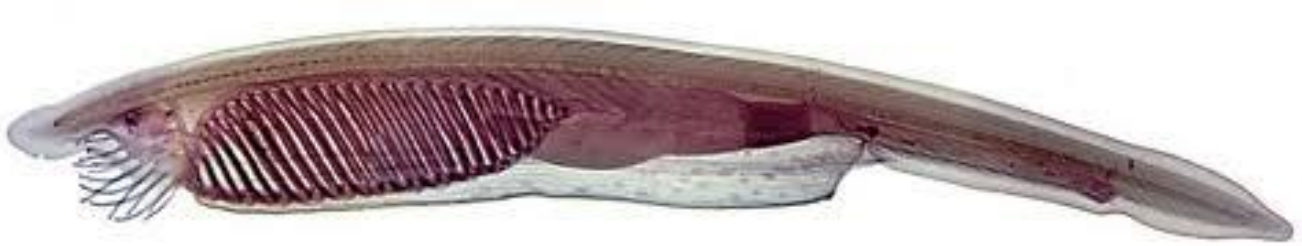
Pentaradial symmetry

Calcitic skeleton composed of ossicles.

Mutable collagenous tissue.

Water vascular system.

Sub-phylum Cephalochordata



Amphioxus or lancelet (both ends pointed).

All typical chordate features are present.

The brain is very small, sense organs and the brain are poorly developed.

No hard parts present, hence it is difficult to find fossils.

Sub-phylum Urochordata

Also known as Tunicata.

The larvae resemble the ancestral chordate. They look like tadpoles.

The adults are sedentary.

The adults have a thick-walled sac with an incurrent and an excurrent siphon.

Gill slits are the only chordate feature in the adults.

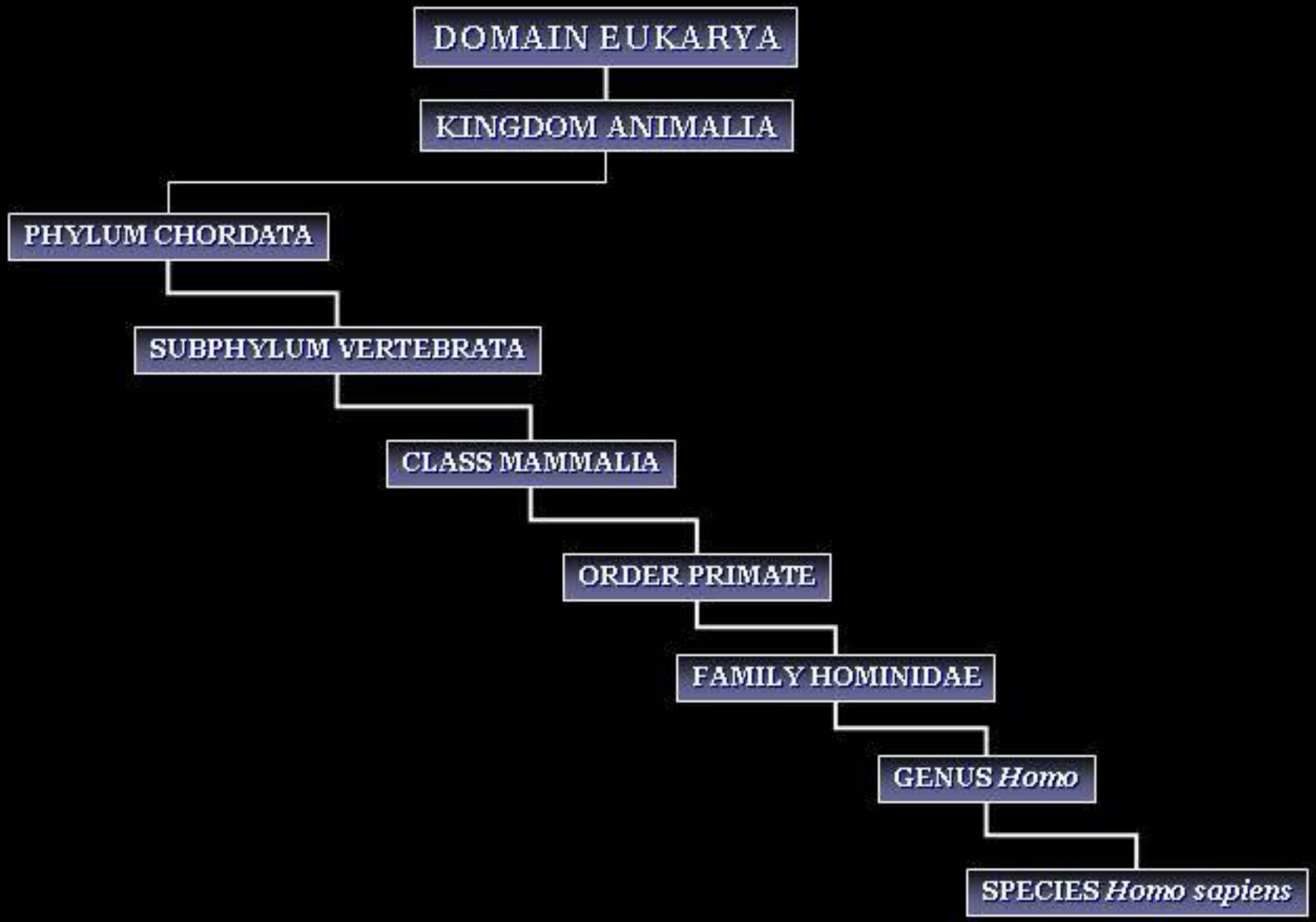
Sub-phylum Vertebrata

Chordates with a backbone and a spinal chord.

Craniates.

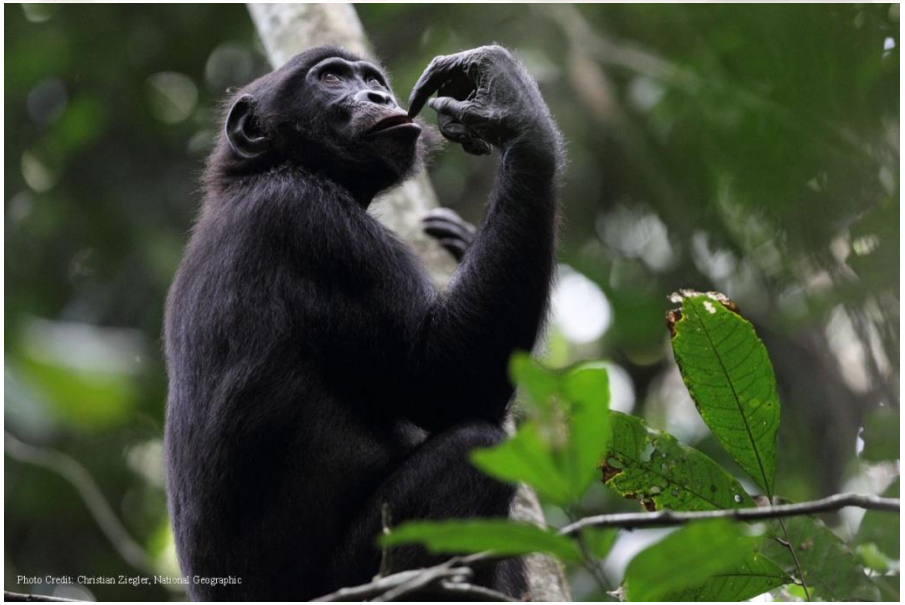
- Class Agnatha (jawless fish)
- Class Chondrichthyes (cartilaginous fishes)
- Class Osteichthyes (bony fishes)
- Class Amphibia (amphibians)
- Class Reptilia (reptiles)
- Class Aves (birds)
- Class Mammalia (mammals)

CLASSIFICATION OF *Homo sapiens*



Designed by Nasif Nahle

Order Primates



Order Primates

The presence of opposable thumbs.

Forwardly directed orbits and stereoscopic vision.

Unfused and highly mobile radius and ulna in the forelimb, and tibia and fibula in the hindlimb.

Relatively large brain case.

http://www.primates.com/primate/index.html

Superfamily Hominoidea

APES & HUMANS

Tubular tympanic bone.

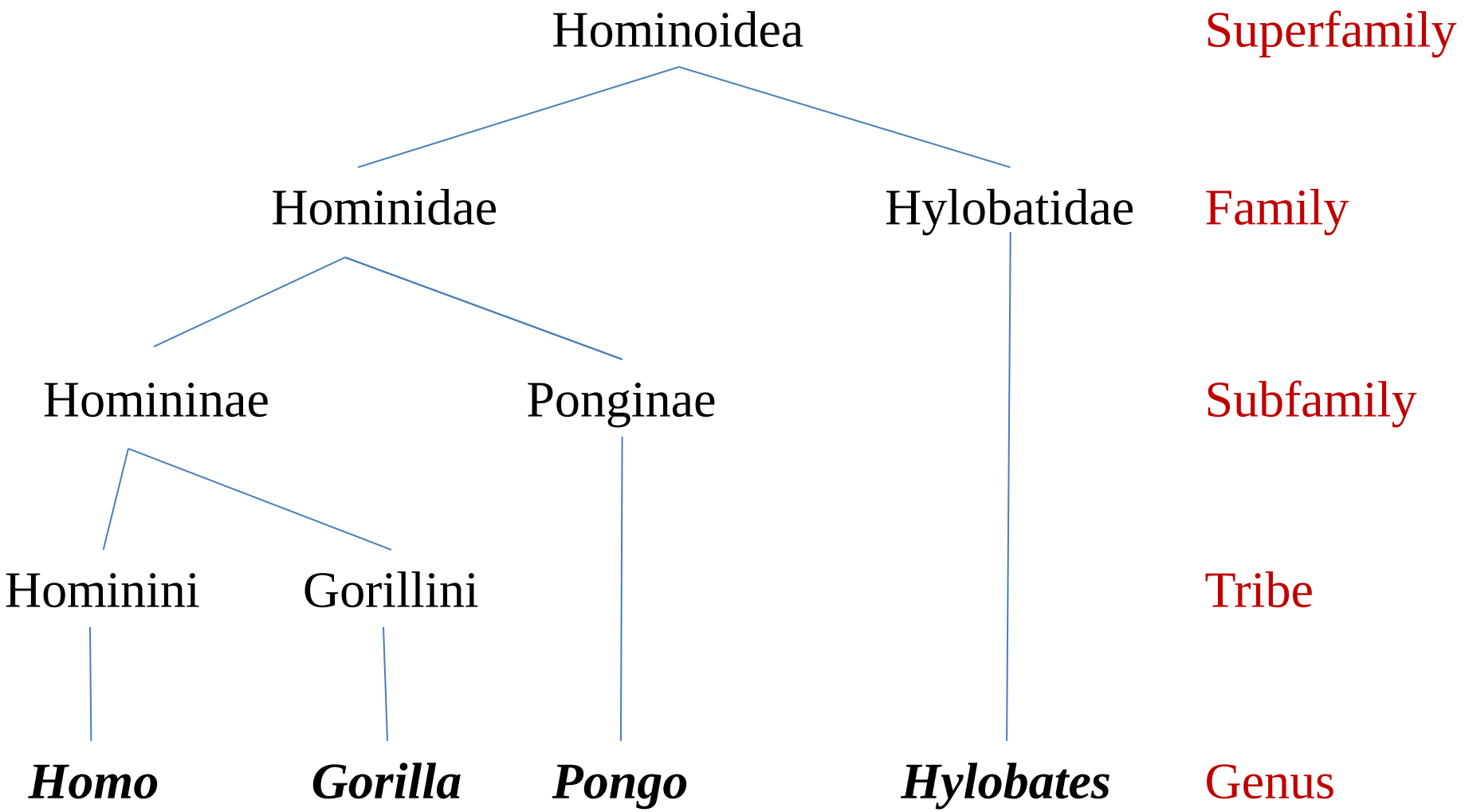
Dental formula 2.1.2.3., with broad incisors and rounded molars.

No tail.

Large brain.

Long upper limbs.

Superfamily Hominoidea



Family Hominidae

Humans and the great apes (chimps, gorillas, orangutans).

Earlier only humans and their extinct relatives were considered under this category.

Genetic studies have changed this. Genera that share more than 97% of their DNA with the modern human genome are considered in this category.

Hominids have well developed brains and high cognitive skills, including the ability to recognize themselves in a mirror.

Tribe Hominini

Genus Ardipithecus (4.4mya)
Genus Australopithecus (3.9 – 2.9 mya)
Genus Paranthropus (2.7 mya)
Genus Kenyanthropus (3.5 mya)
Genus Homo (2.3 – 2.4 mya)

http://www.archaeologyinfo.com/skullpage.htm
http://www.modernhumanorigins.net/platyops.html
http://compuball.com/Inquisition/homo.htm

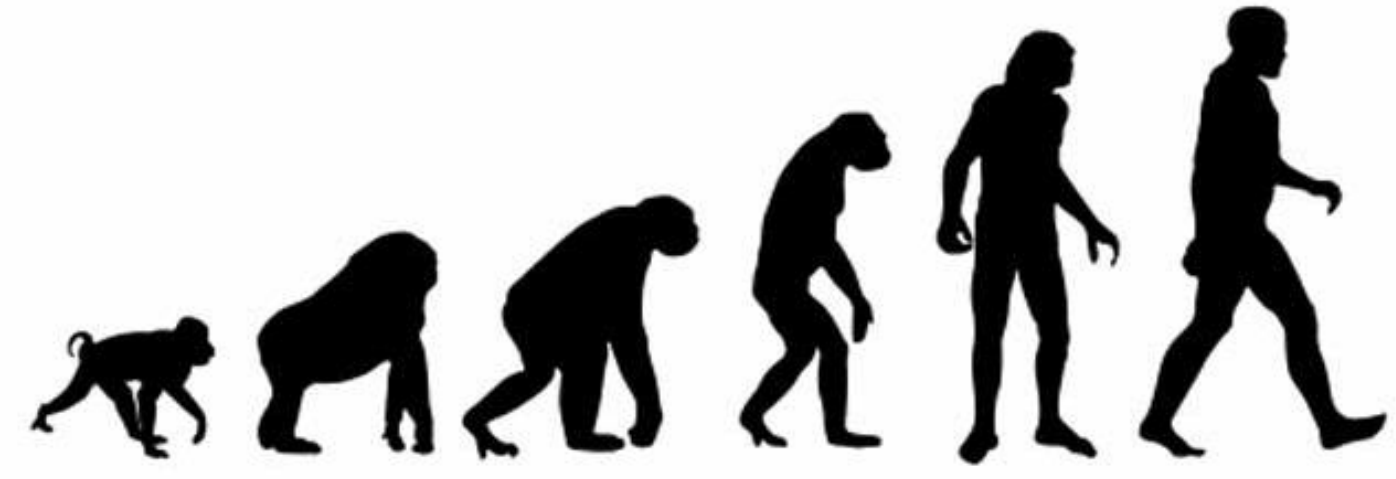
The earliest record of bipedalism, Laetoli, Tanzania (3.5 – 3.6 mya)

Tribe Hominini

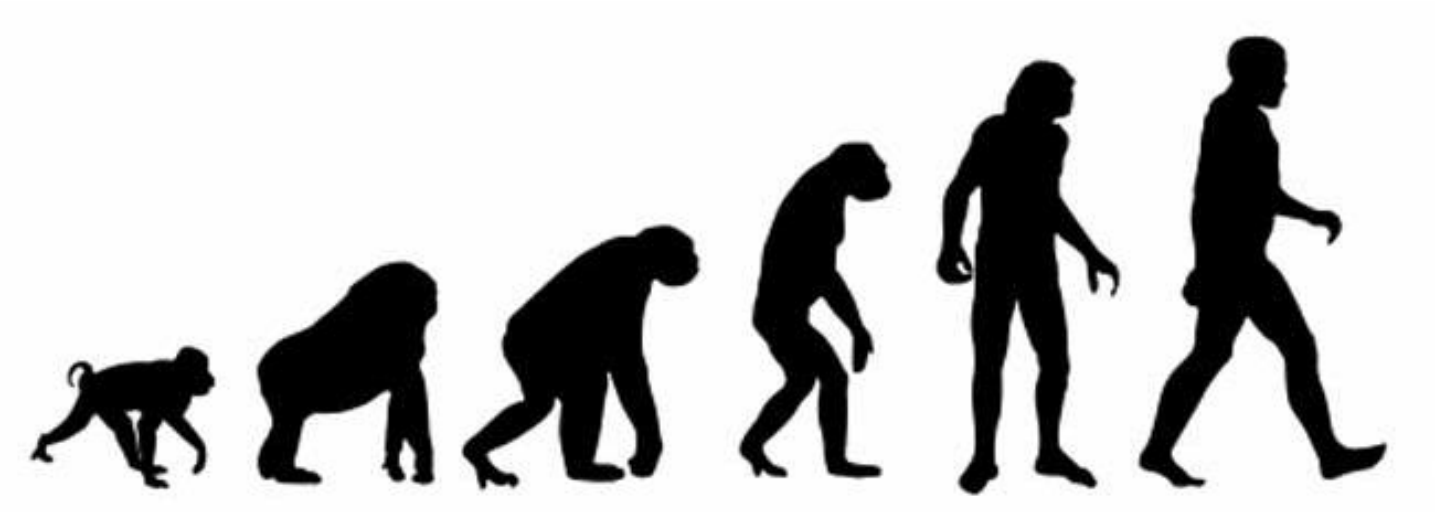
Australopithecus afarensis

Paranthropus boisei

Kenyanthropus platyops



What makes us Human?



Australopithecus

Early (3.9-3.5mya) and late (3.5-2.96mya).

Lucy: Hadar, Ethiopia; found in 1974 by T. Johnson and group.

1.1m tall, 29 kg, small brain, pelvis and leg bones almost identical to modern humans.

Bipedal

Australopithecus

Deep impressions showing pronounced heel strike.

Lateral transmission of force from the heel to the base of the lateral metatarsal.

A well-developed medial longitudinal arch.

Adducted big toe, in front of the ball of the foot and parallel to the other digits.

A deep impression for the big toe commensurate with toe-off.

Homo habilis

One of the earliest members of the genus *Homo*, has a slightly larger braincase and smaller face and teeth than in *Australopithecus*. But it still retains some ape-like features, including long arms and a moderately-prognathic face.

Its name, which means ‘handy man’, was given in 1964 because this species was thought to represent the first maker of stone tools.

Lived 2.4 million to 1.4 million years ago in Eastern and Southern Africa.

Homo erectus

The oldest known early humans to have possessed modern human-like body proportions with relatively elongated legs and shorter arms compared to the size of the torso.

The most complete fossil individual of this species: ‘Turkana Boy’

Adaptations to a life lived on the ground, indicating the loss of earlier tree-climbing adaptations, with the ability to walk and possibly run long distances.

Expanded braincase relative to the size of the face.

Homo erectus

Lived in Northern, Eastern, and Southern Africa; Western Asia (Dmanisi, Republic of Georgia); East Asia (China and Indonesia) between about 1.89 million and 143,000 years ago.

The appearance of *Homo erectus* in the fossil record is often associated with the earliest handaxes, the first major innovation in stone tool technology.

Generally considered to have been the first species to have expanded beyond Africa.

Homo erectus

Some unanswered questions….

Was *Homo erectus* the direct ancestor of *Homo sapiens*?

Data suggest that increasing body size, greater reliance on animal food resources, and increased range size were part of a web of factors that facilitated the initial early dispersal of *H. erectus* from Africa. Was one of these factors more important than the others?

Are the fossils from earlier time periods in East Africa, and from Georgia, all part of a single species (*Homo erectus*), regionally variable in size and shape? Or are there actually several species of early human represented by what we are now calling *Homo erectus*?

How well did Homo erectus master the control of fire and how widespread was fire used?

Homo neanderthalensis

Our closest extinct human relative.

Lived about 200,000 - 40,000 years ago, in Europe and southwestern to central Asia.

Large middle part of the face, angled cheek bones, and a huge nose.

Their bodies were shorter and stockier than ours, their brains were just as large as ours and often larger.

Homo neanderthalensis

Neanderthals deliberately buried their dead and occasionally even marked their graves with offerings, such as flowers.

Neanderthals made and used a diverse set of sophisticated tools, controlled fire, lived in shelters, made and wore clothing, were skilled hunters of large animals and also ate plant foods, and occasionally made symbolic or ornamental objects.

Homo floresiensis (Hobbit)

Discovered in 2004, on the island of Flores, Indonesia.

Lived between 95,000 and 17,000 years ago on the Island of Flores, Indonesia.

Approximately 3 feet 6 inches tall, had tiny brains, large teeth for their small size, shrugged-forward shoulders, no chins, receding foreheads, and relatively large feet due to their short legs.

The diminutive stature and small brain of *H. floresiensis* may have resulted from island dwarfism.

Homo floresiensis (Hobbit)

Made and used stone tools, hunted small elephants and large rodents, coped with predators such as giant Komodo dragons, and may have used fire.

There is also evidence that *H. floresiensis* selectively hunted *Stegodon* (an extinct type of elephant) as hundreds of *Stegodon* bone fragments are found within *H. floresiensis* occupation layers and some of these *Stegodon* bones show butchery marks.

Homo naledi

A hominid ancestor with a small brain but limbs very similar to modern day humans.

Discovered in the Dinaledi Chamber of the Rising Star cave system in Johanesburg in September 2015.

Lived 335,000 - 236,000 years ago.

Height approximately 4’9”, weight 39.7 – 55.8 kg.

Homo naledi

The hand morphology of *Homo naledi* suggests its use in climbing trees, whereas studies of the *Homo naledi* foot indicate adaptation to a terrestrial lifestyle. Why?

Due to the lack of other animal fossils or tools associated with *Homo naledi*, very little is known about the ecology and life of this species.

It is believed that they buried their dead.

Homo luzonensis

Found in a cave in the island of Luzon, Philippines.

13 bones and teeth.

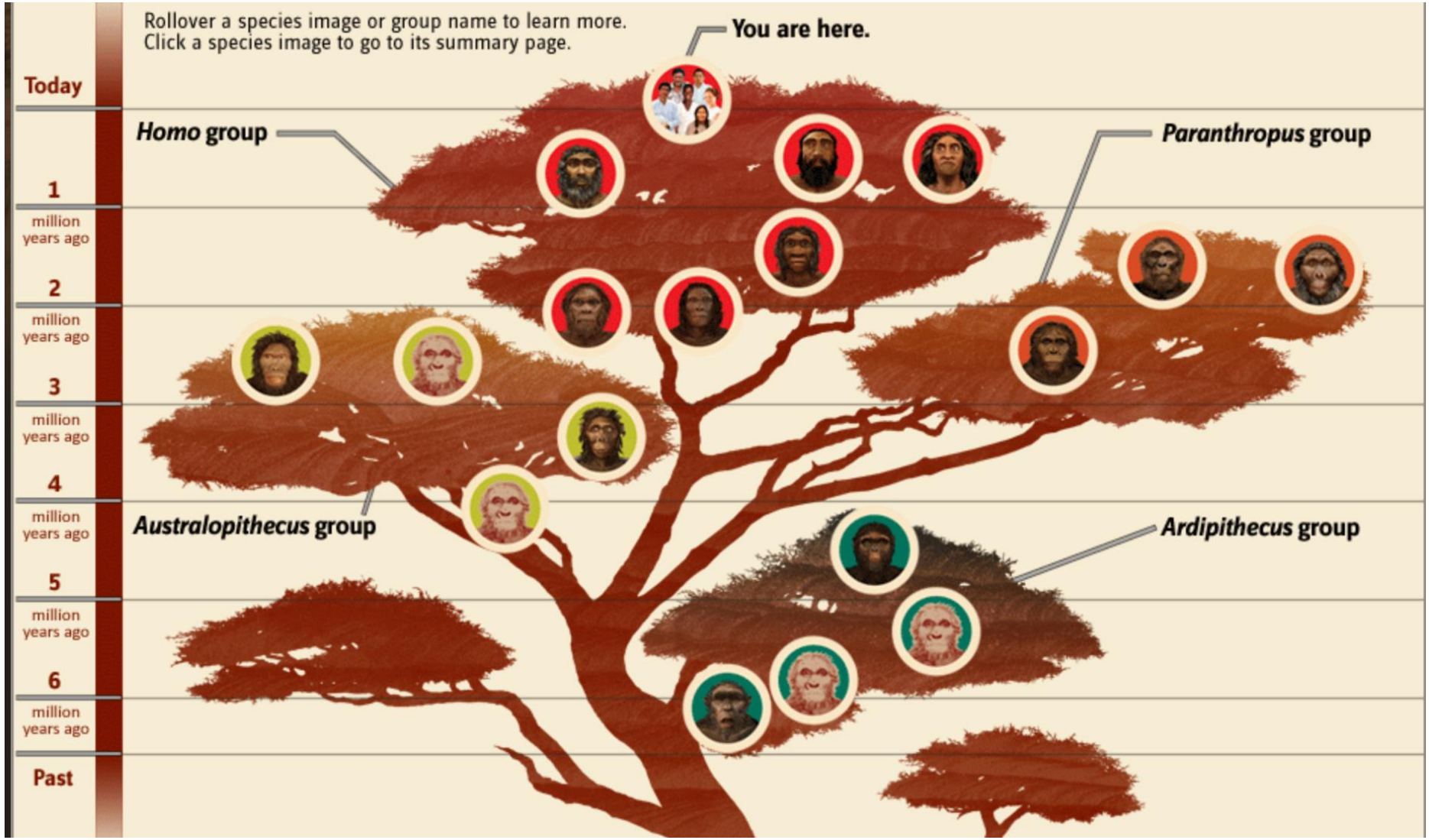
Reported on 10th April 2019.

Lived 50,000 – 67,000 years ago.

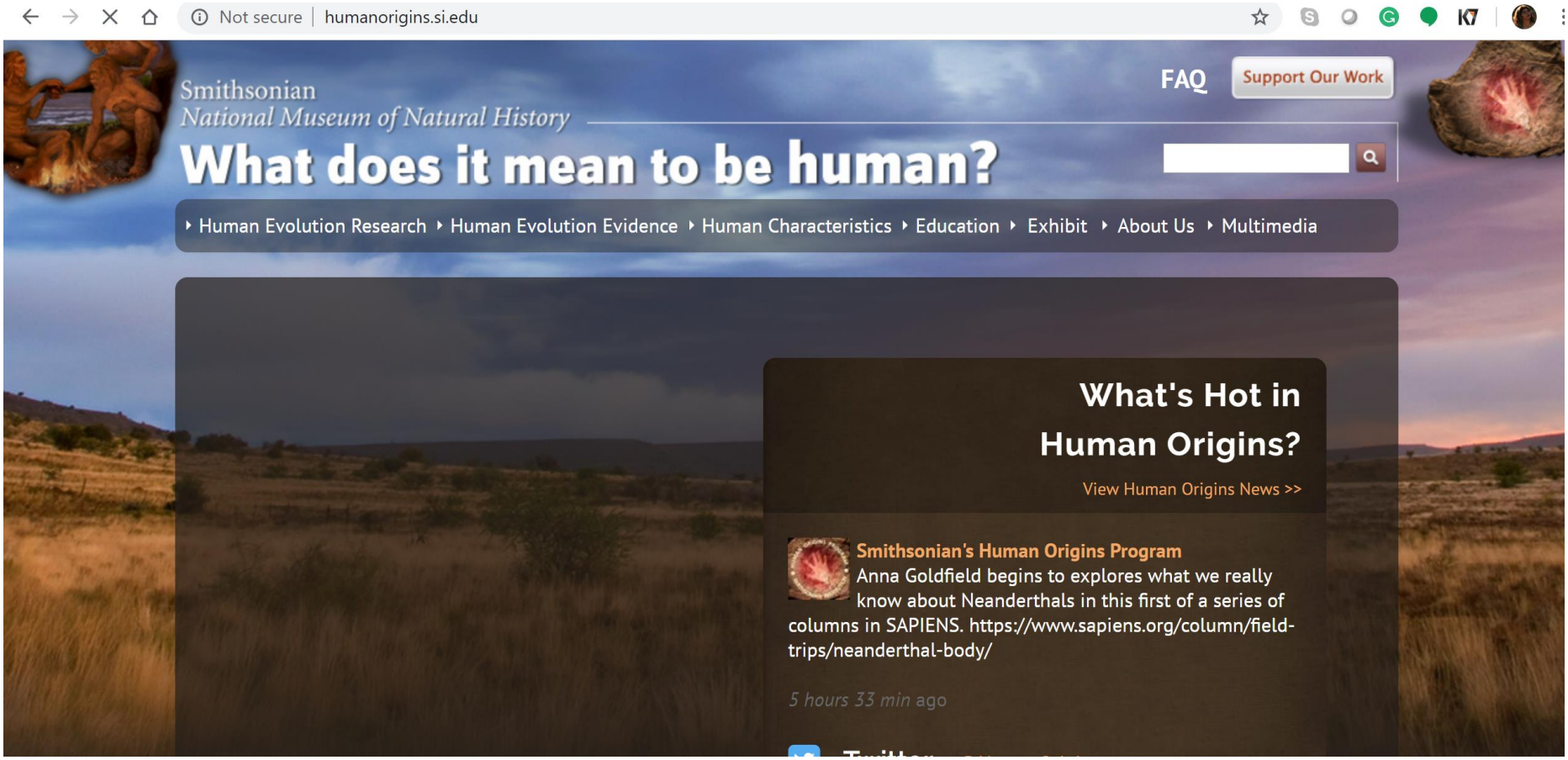
Co-existed with Neandarthals, Denisovans, *Homo floresiensis* and *Homo sapiens*.

Teeth like *Homo erectus*, digits curved like *Australopithecus*.

The Human Origins



The Human Origins



The Human Origins