HUMINANITY

Series of PowerPoint Presentations by J. W. Gardner

- **Misbeliefs – Acquisition & Probable Examples**
- **Big Picture Science – Observable Universe**
- **Big Picture Science – Planet Earth**
- **Big Picture Science – Life on Earth**
- **Basic Science Sampler – Quantum Physics, Relativistic Physics and Thermodynamics**

One of Three Presentations on Big Picture Science

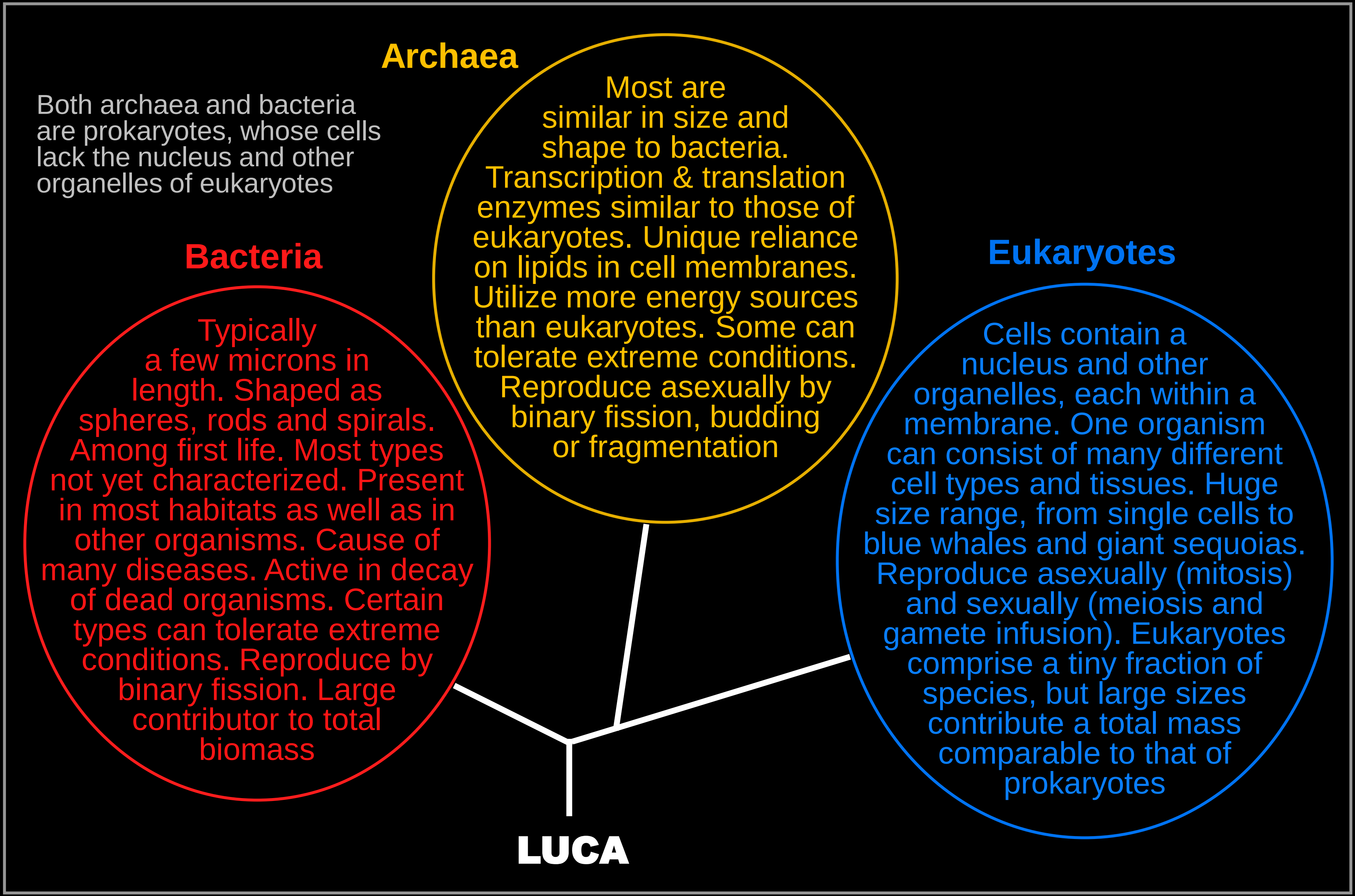
Subject	Key Theory
Observable Universe	Big Bang
Planet Earth	Plate Tectonics
Life on Earth	Evolution

Recommend viewing Planet Earth presentation before this one

Primarily for introduction to geologic time

Preamble: Three domains of life

3 Domains of Life: Archaea, Bacteria & Eukaryotes



Domains proposed by Woese, Kandler & Wheelis (1990) based on small subunit ribosomal RNA. Domain characteristics from Wikipedia. LUCA = Last Universal Common Ancestor

Here life excludes viruses, which are not cell-based and cannot reproduce on their own

History of Life

Evolution

Evidence of Evolution

Morphological

Common structural unit: cell

Transitional forms via fossils

Homologous structures

Morphological remnants

Morphological trees of life

Molecular

Common genetic material (DNA) and near-universal genetic code

Homochirality (key biomolecules)

Molecular remnants

Molecular trees of life

Compare

Other

Biogeographical

Real Time

Anthropogenic Damage to Biosphere

Shortcuts to topics underlined

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

Fossils

Principal Evidence of Extinct Life

- Fossils take variety of forms, including imprints on once soft surfaces (later hardened) & fossilized bones
- Fossil creation is a rare event. Discovery even rarer
- Nonetheless, billions of fossils have been discovered. Large natural history museum will house several million. The number of fossilized species, on the other hand, is much smaller – a few hundred thousand*
- Still, more than 2000 species of dinosaurs alone have been discovered at nearly 8000 sites**

*Graeme Lloyd, Natural History Museum, London, askabiologist.org.uk **Dailymail.co.uk (2017)

Histories of Life

- History of life in a nutshell
- Expanded version in words
- History of life in pictures
- History of life via time-wheel

The last three, more detailed, accounts do not agree exactly with one another, particularly before phanerozoic

History of Life in Nutshell

- Life has evolved over 3.5+ billion years from a single small and simple thing to many kinds of small and simple things as well as many kinds of large and complex things
- The principal change agent has been natural selection of beneficial random mutations
- Many lifeforms have disappeared along the way

Number of prokaryote species much greater than number of eukaryote species. Cumulative mass of bacteria might be as great as that of plants and animals. Also, all life continues to evolve

History of Life in Nutshell

- Life has evolved over 3.5+ billion years from a single small and simple thing to many kinds of small and simple things as well as many kinds of large and complex things
- The principal change agent has been natural selection of beneficial random mutations
- Many lifeforms have disappeared along the way

Although other phenomena also come into play

History of Life in Nutshell

- Life has evolved over 3.5+ billion years from a single small and simple thing to many kinds of small and simple things as well as many kinds of large and complex things
- The principal change agent has been natural selection of beneficial random mutations
- Many lifeforms have disappeared along the way

Estimated that 99+% of 5+ billion species that have existed are extinct (Wikipedia "Evolutionary History of Life" article)

Histories of Life

- History of life in a nutshell
- Expanded version in words
- History of life in pictures
- History of life via time-wheel

History of Life – Word Summary

	Unit	Mya	Events
Epoch	Holocene	0.01	
	Pleistocene	1.8	Ice ages. Homo sapiens appears
	Pliocene	5.3	Genus Homo appears
	Miocene	23	Mammal and flowering plant radiation continues. Apelike human ancestors appear
	Oligocene	33.9	Many primate groups, including apes, originate
	Eocene	55.8	Flowering plant dominance increases. Continued radiation of most modern mammal orders
	Paleocene	65.5	Mammals, birds and pollinating insects radiate
Period	Cretaceous	146	Flowering plants appear. Many groups of organisms, including dinosaurs, go extinct at period end (Cretaceous extinction)
	Jurassic	200	Cone-bearing plants continue as dominant plants. Dinosaurs abundant and diverse
	Triassic	251	Cone-bearing plants dominate landscape. Dinosaurs radiate. Mammal-like reptiles appear
	Permian	299	Reptiles radiate. Most modern insect orders originate. Many marine and terrestrial organisms go extinct at period end ("Great dying")
	Carboniferous	359	Forests of vascular plants. First seed plants. First reptiles. Amphibians dominate
	Devonian	416	Diversification of bony fishes. First tetrapods and insects
	Silurian	444	Diversification of early vascular plants
	Ordovician	488	Abundant marine algae. Plants and arthropods colonize land
	Cambrian	542	Cambrian explosion – Sudden increase in animal diversity, including trilobites
Eon	Proterozoic	2500	Diverse algae and soft-bodied invertebrates (Ediacaran biota) First eukaryotes (2.2 Gya)
	Archaean	↑	Atmospheric oxygen increases (2.7 Gya) First prokaryotes (3.5+ Gya)

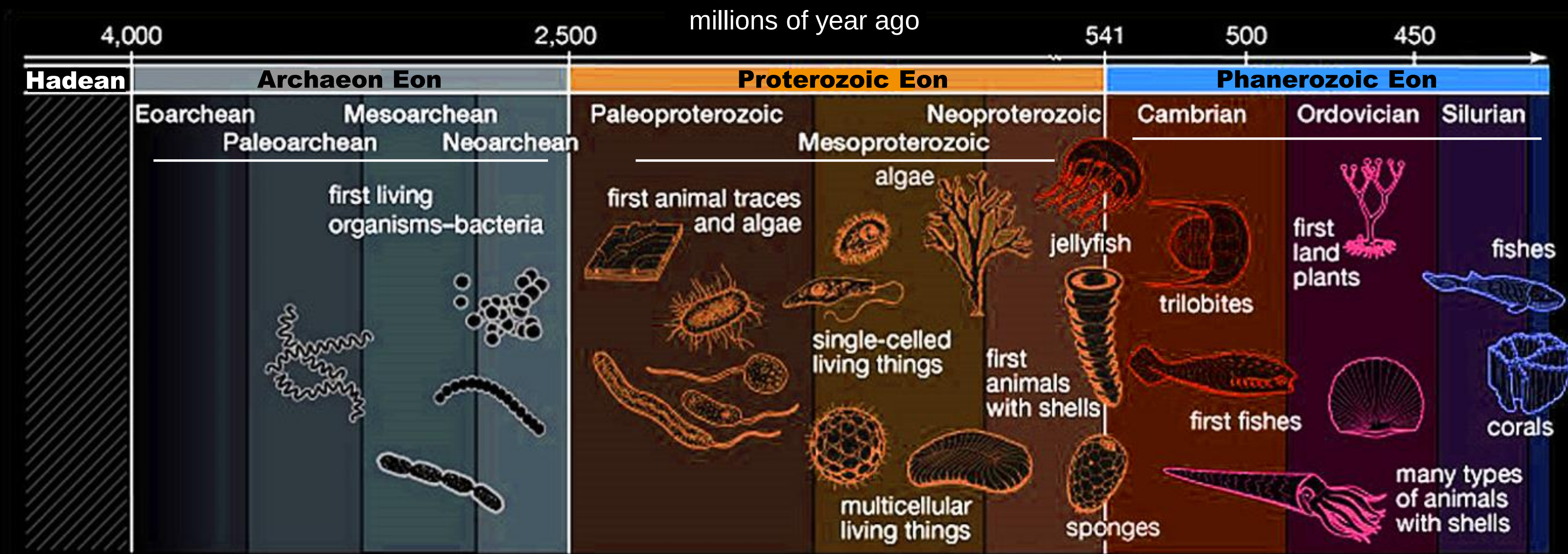
Mya

Events from *Campbell Biology in Focus* (2014)

Histories of Life

- History of life in a nutshell
- Expanded version in words
- History of life in pictures
- History of life via time-wheel

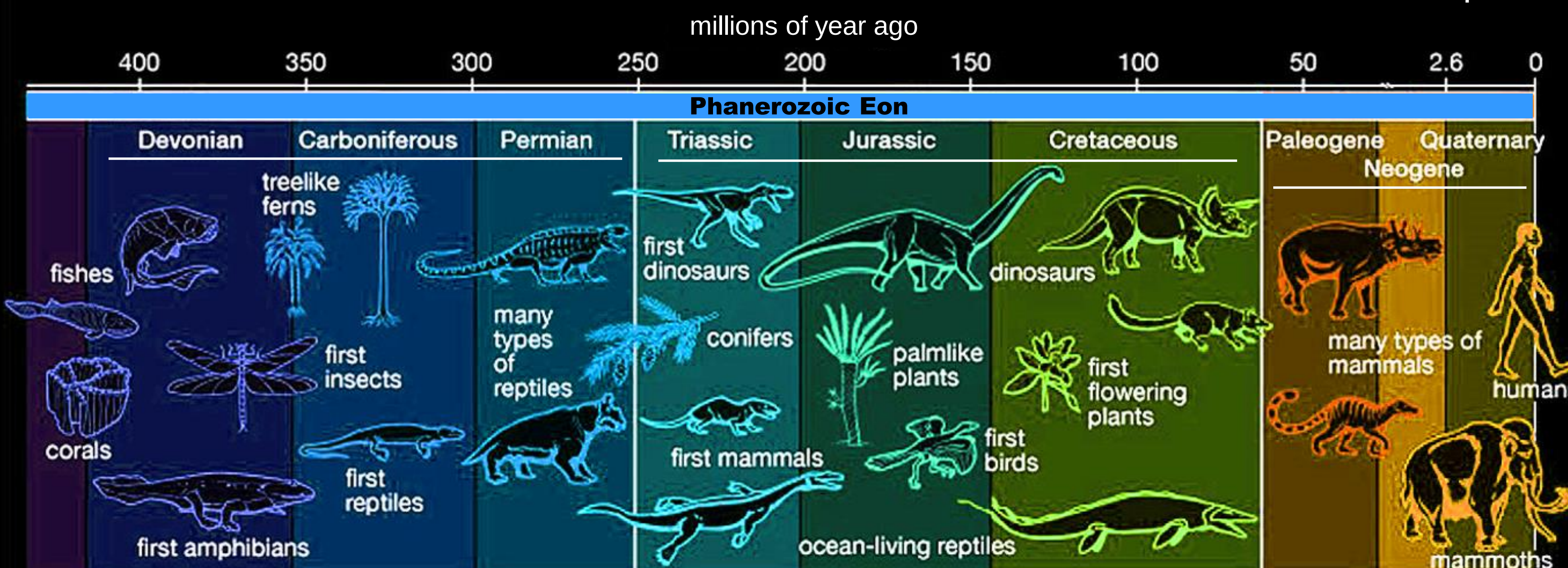
History of Life – Picture Summary



Hadean also eon

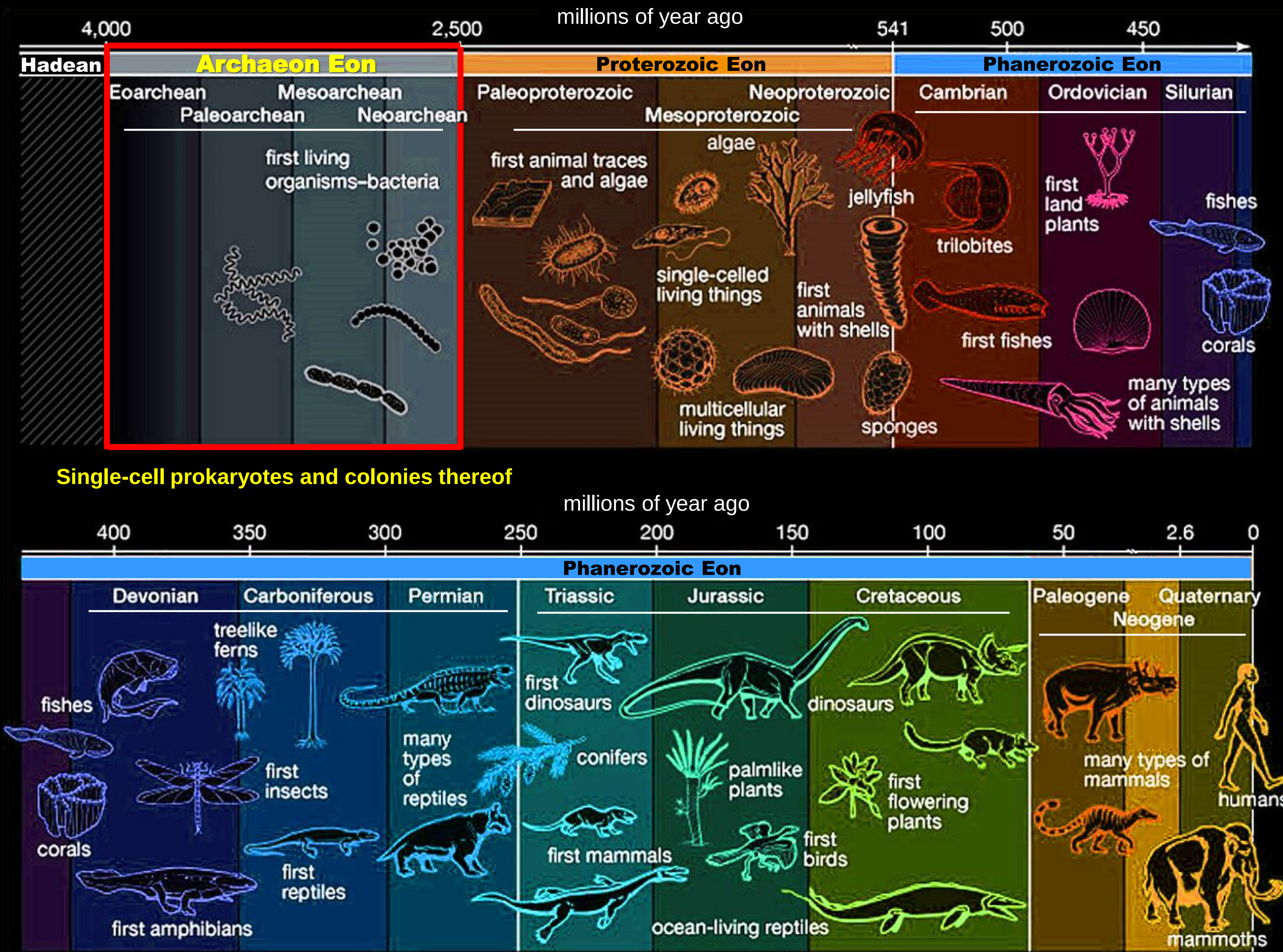
Subdivisions of Archaeon and Proterozoic are eras

Subdivisions of Phanerozoic are periods

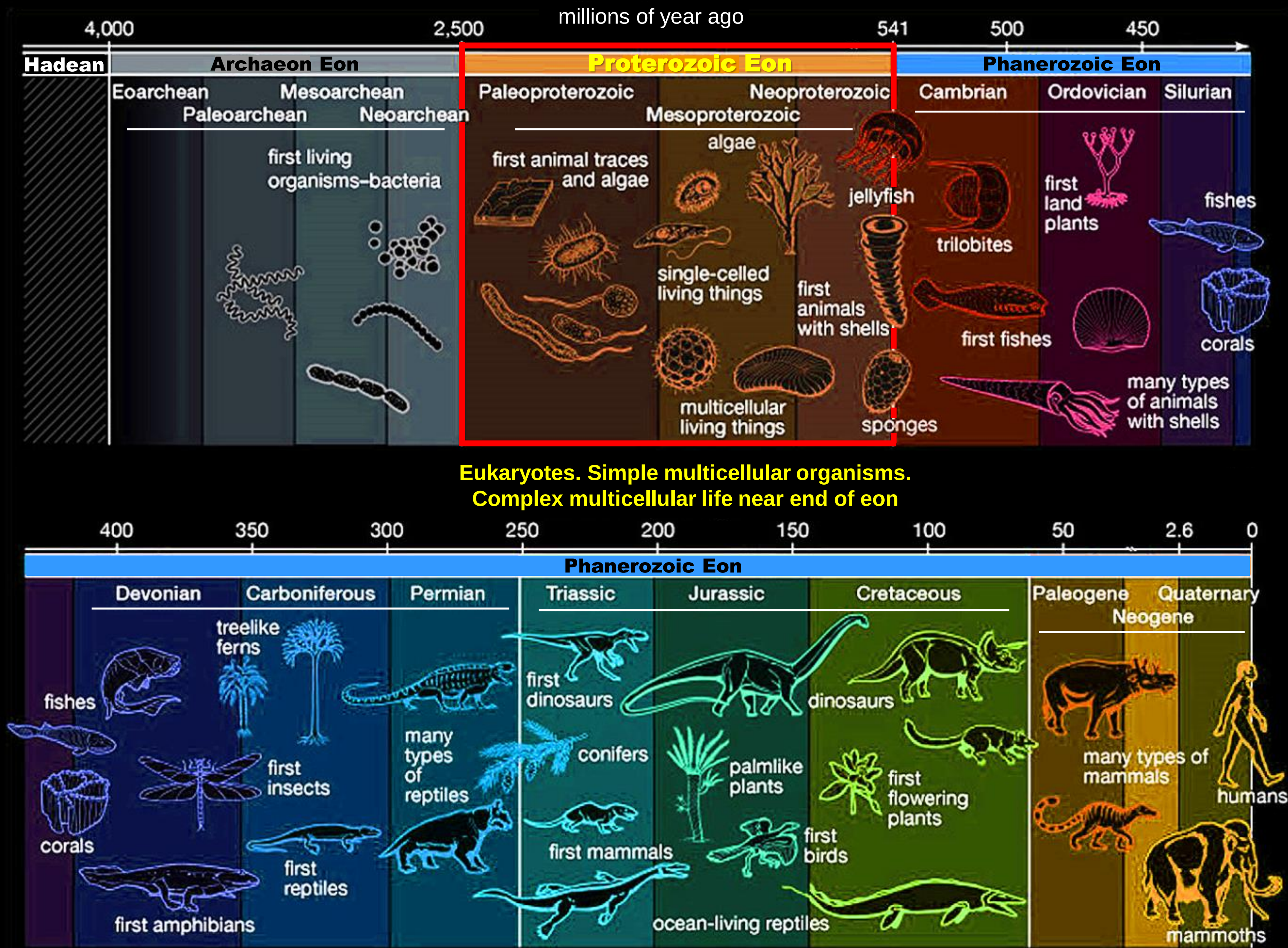


Logarithmic time line. Phanerozoic and Hadean eons of similar duration

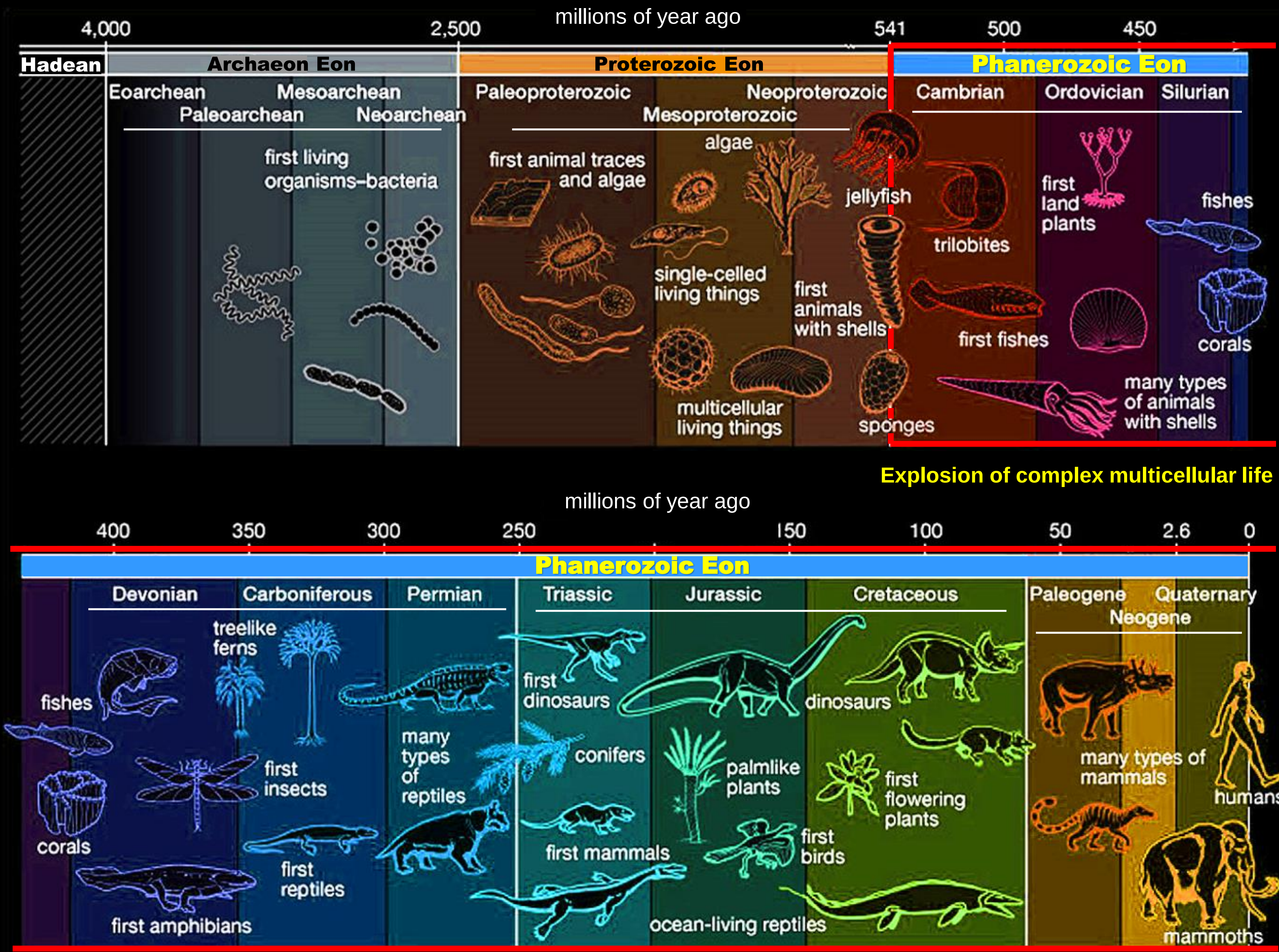
History of Life – Picture Summary



History of Life – Picture Summary

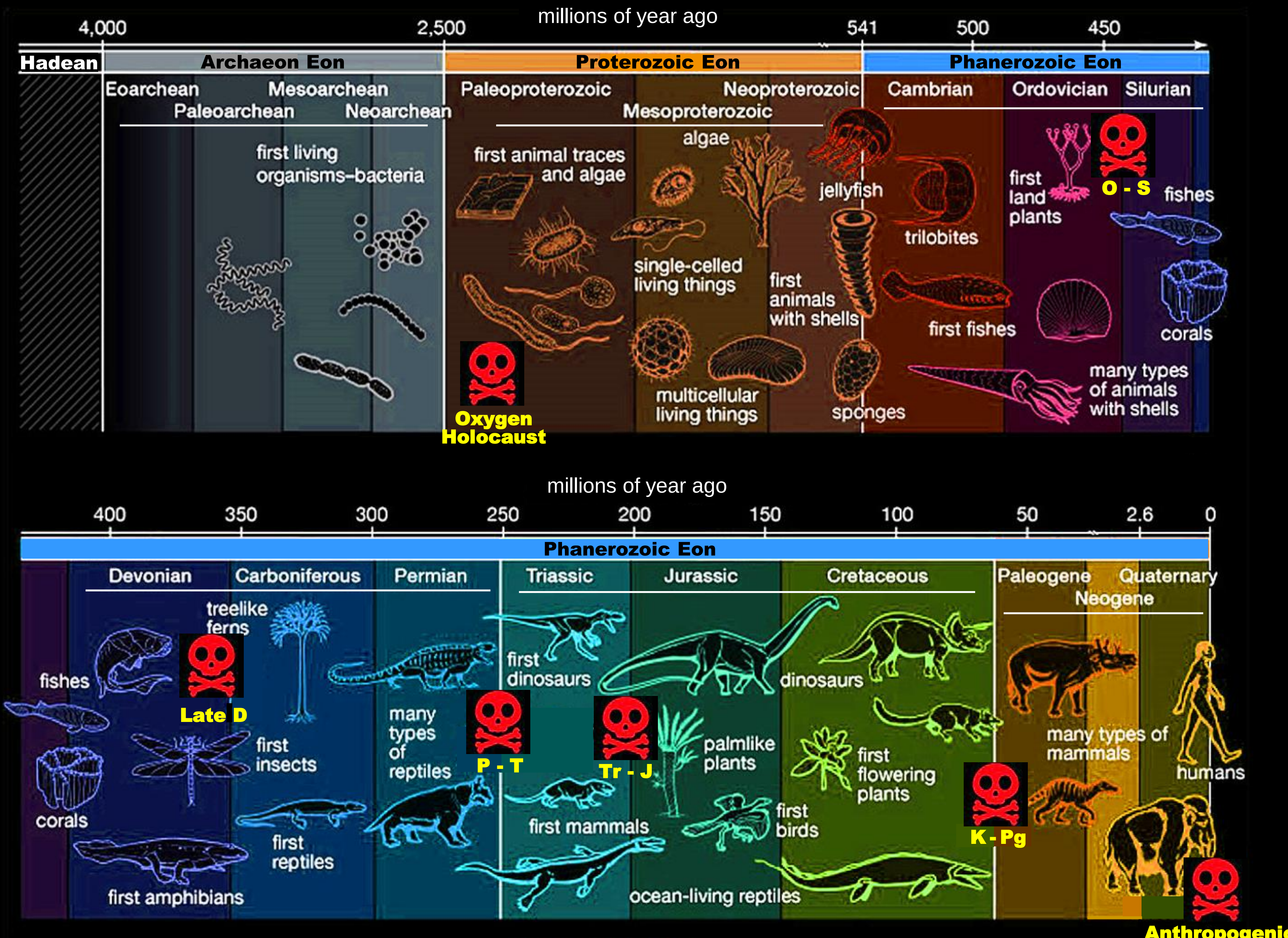


History of Life – Picture Summary



There have been several dramatic reductions in lifeforms. One is probably underway now

History of Life – Mass Extinctions



Oxygen Holocaust discussed in History of Life – Time Wheel

Big-Five Extinctions

Event	Mya	Description
Cretaceous–Paleogene or K-Pg (formerly K-T)	66	75% of species extinguished, including most non-avian dinosaurs
Triassic–Jurassic	201	75% of species extinguished, including most non-dinosaurian archosaurs, therapsids and large amphibians
Permian–Triassic or "Great Dying"	252	90-96% of species extinguished, including trilobites and many mammal-like reptiles
Late Devonian	375 – 360	70+% of species extinguished
Ordovician–Silurian	450 – 440	Actually two events. 70% of species extinguished

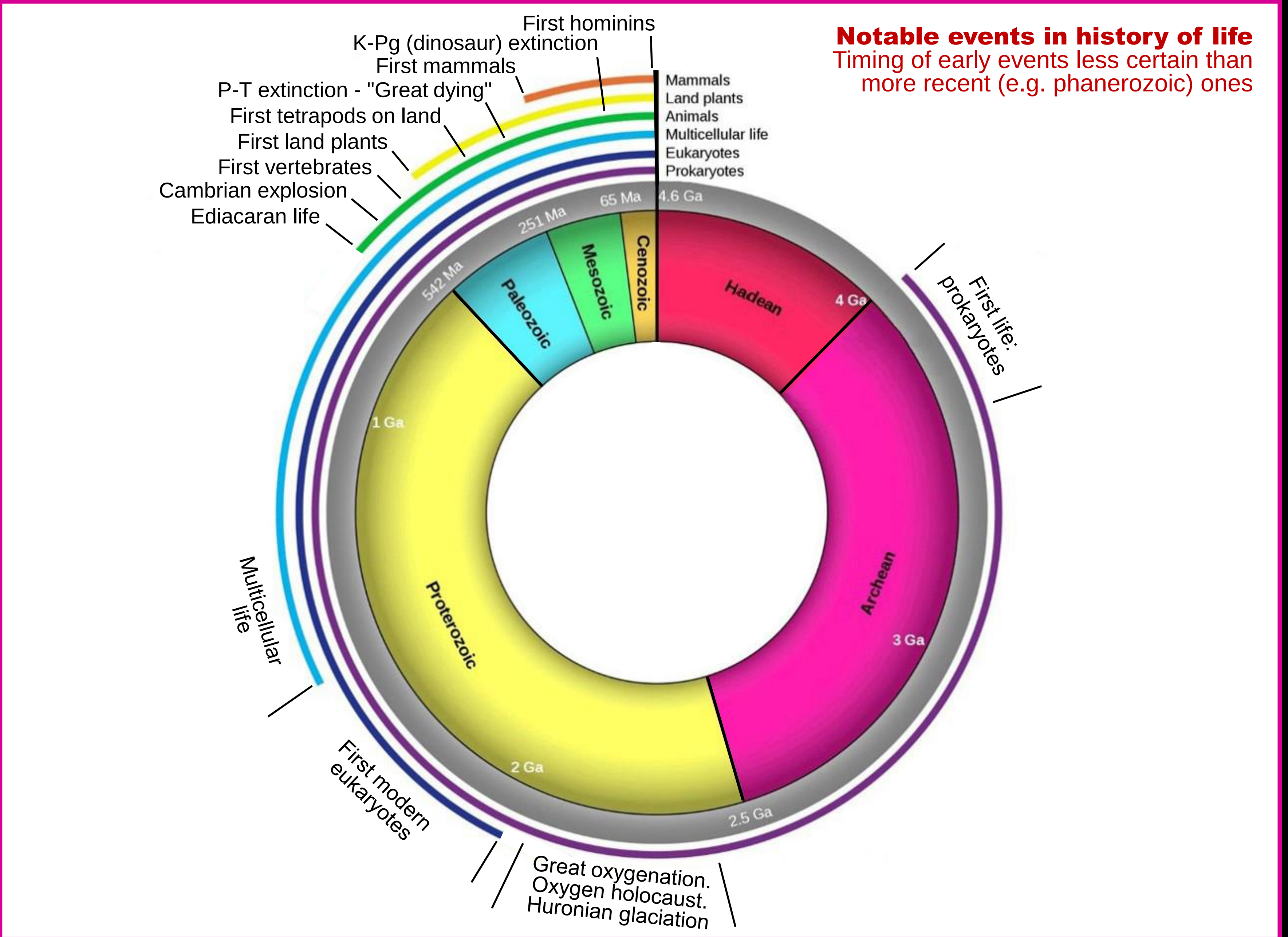
Each major extinction resulted in 70% or more of species disappearing. From Wikipedia "Extinction Event" article

Probable current mass extinction event discussed under Anthropogenic Damage to Biosphere

Histories of Life

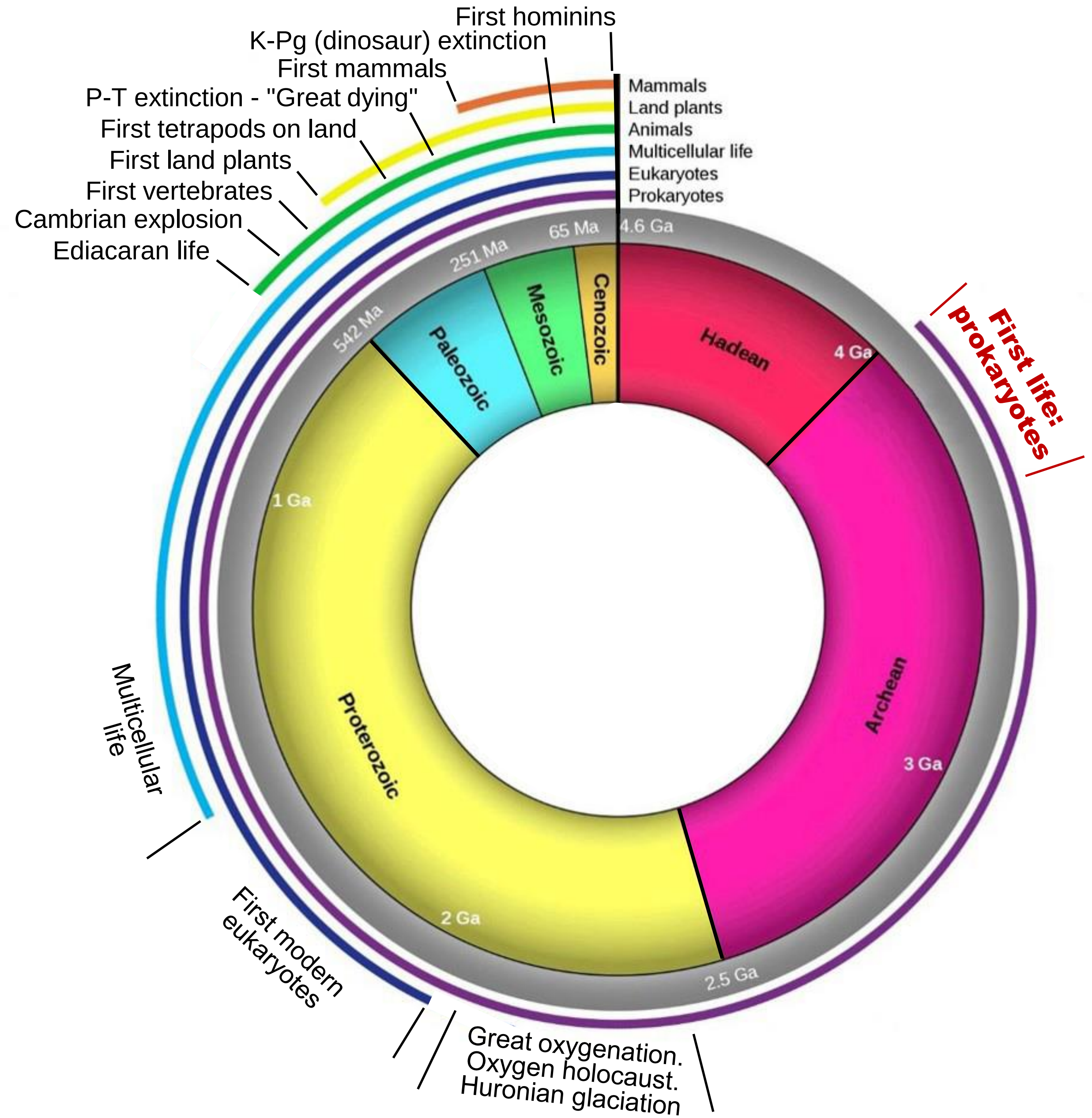
- History of life in a nutshell
- Expanded version in words
- History of life in pictures
- History of life via time-wheel

History of Life – Time Wheel

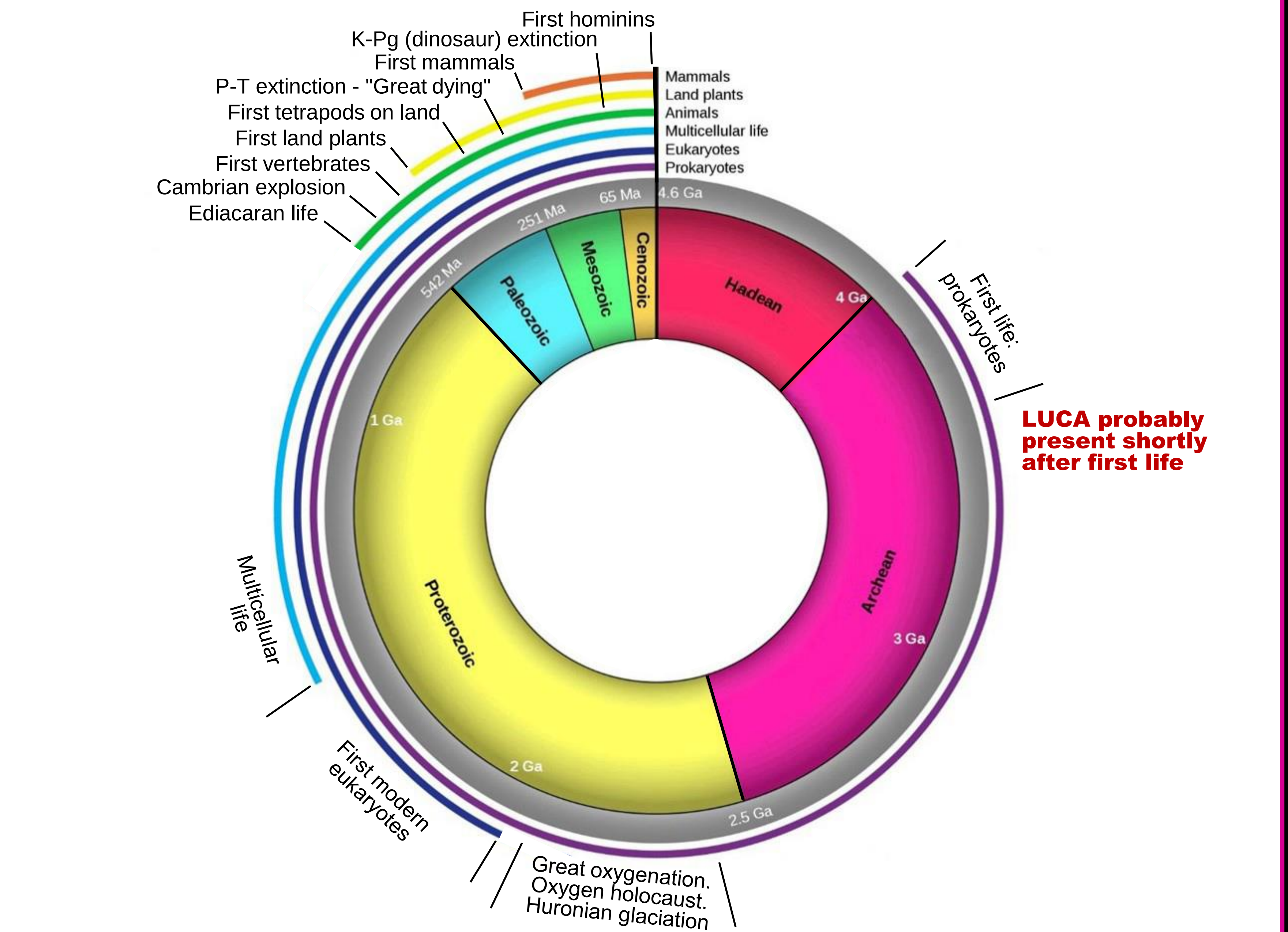


Main sources: "Geological History of the Earth" and "Evolutionary History of Life." Both Wikipedia

History of Life – Time Wheel

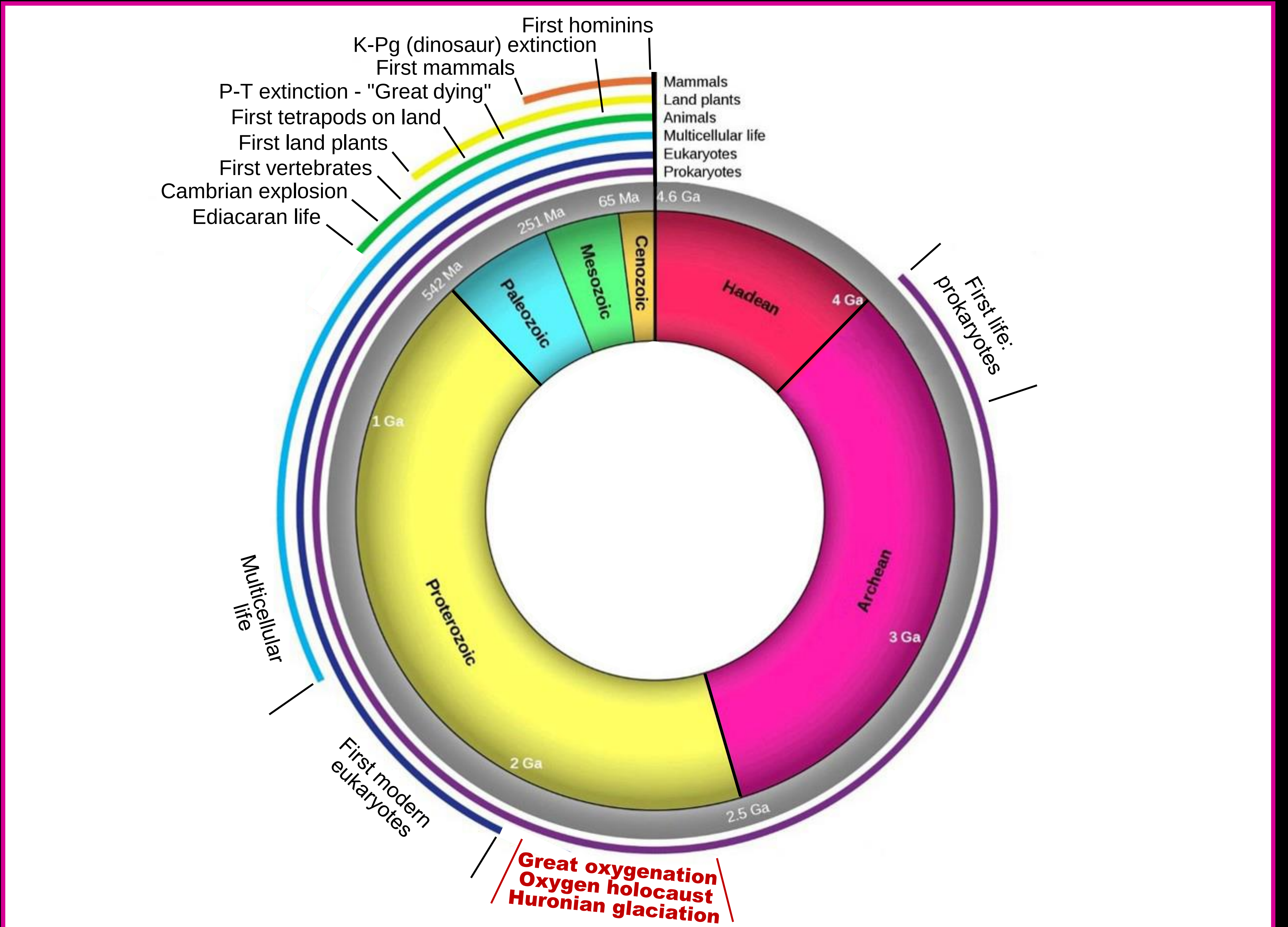


History of Life – Time Wheel



LUCA = Last Universal Common Ancestor

History of Life – Time Wheel



Three related events

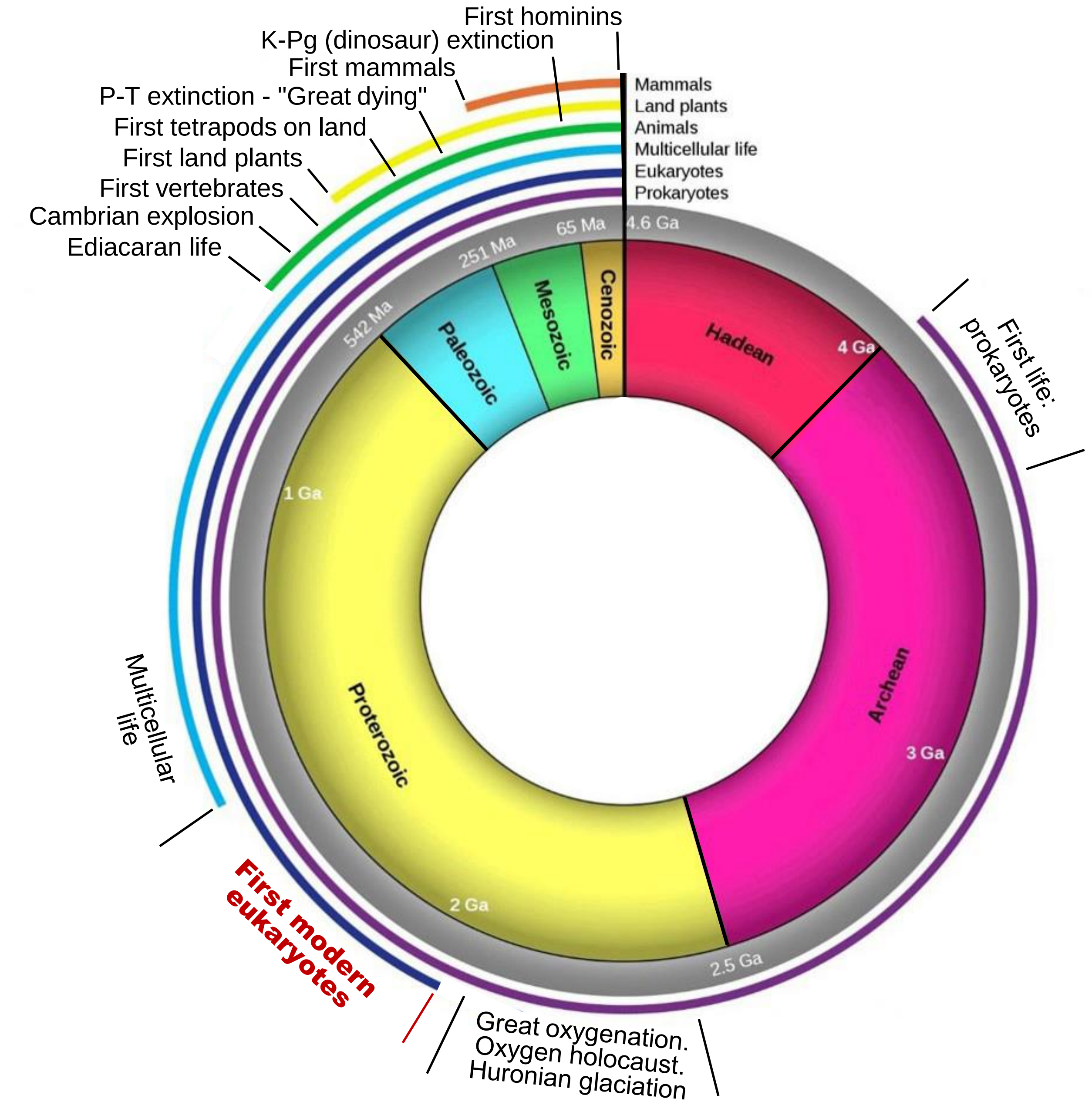
Great Oxygenation, Oxygen Holocaust & Huronian Glaciation

Roughly 2.4 to 2.1 Gya

- **Great Oxygenation** Recently-evolved, photosynthesizing, ocean-dwelling cyanobacteria multiplied rapidly and generated enormous amounts of oxygen (their waste product)
- **Oxygen Holocaust** The other dominant lifeform was anaerobic bacteria, probably present since near the beginning of life and to which oxygen was a poison. The great oxygenation caused a mass extinction of most such life
- **Huronian Glaciation** The oxygen also got into the methane-rich atmosphere and reacted to form CO_2, a weaker greenhouse gas than methane. Resulting cooling led to the Huronian glaciation, the first and longest global ice age

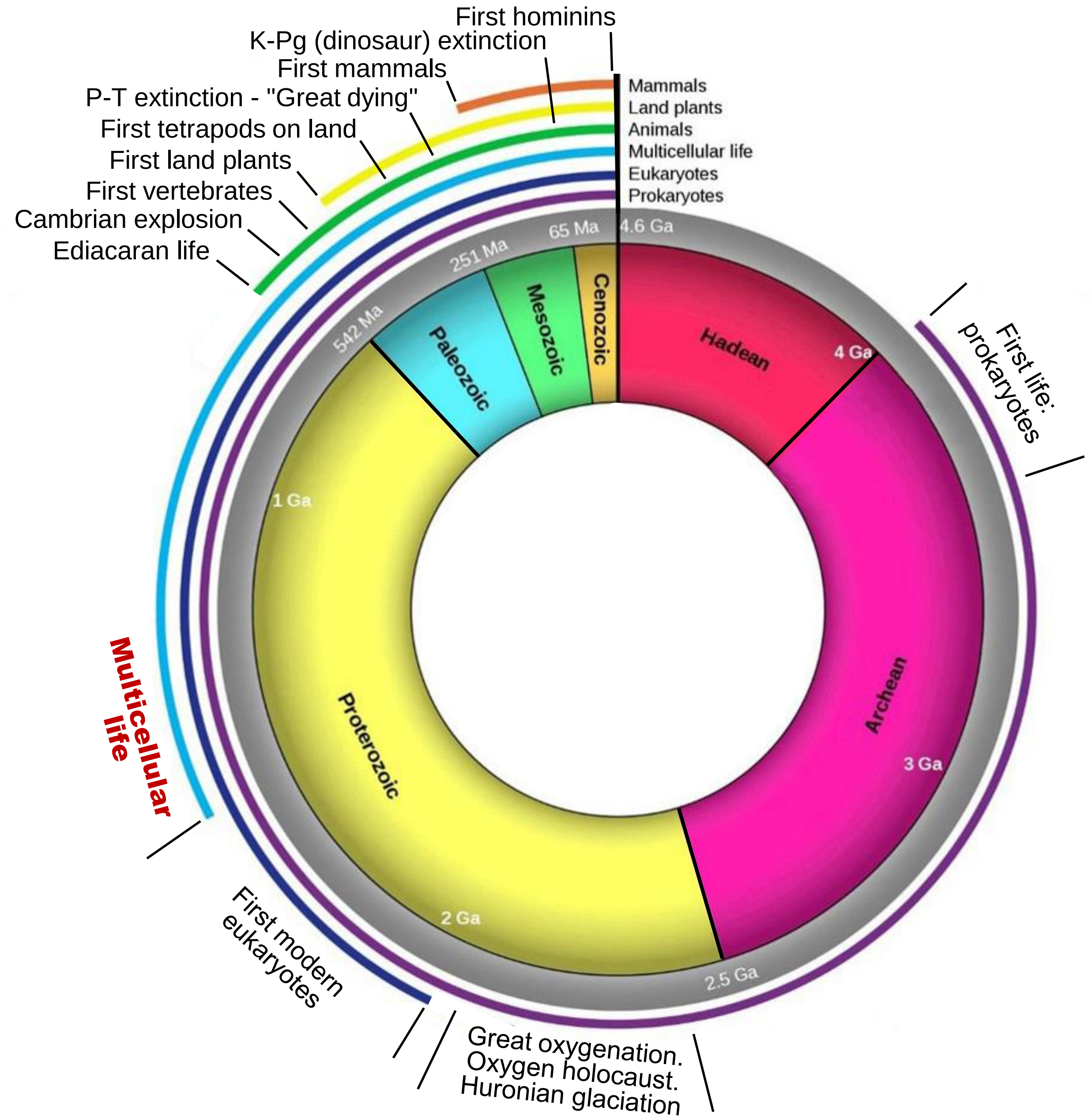
Based on (i) Schirrmeister, et al. Proceedings of the National Academy of Sciences, 2013; DOI:10.1073/pnas.1209927110 and (ii) Plait "Poisoned Planet," *Slate* (July 28, 2014)

History of Life – Time Wheel

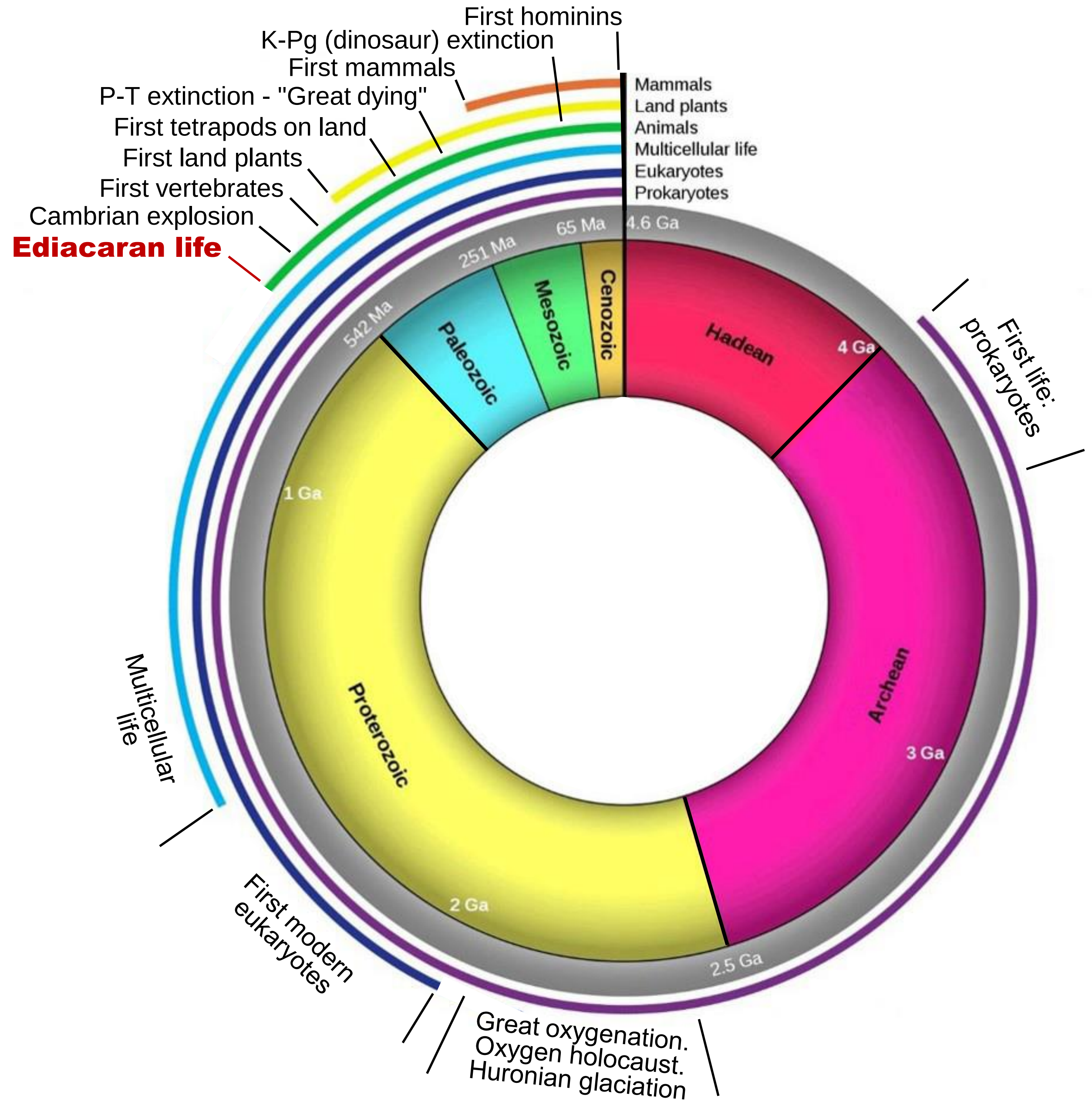


Modern eukaryotes require oxygen. Anaerobic eukaryotes might have been present in the Archaean

History of Life – Time Wheel



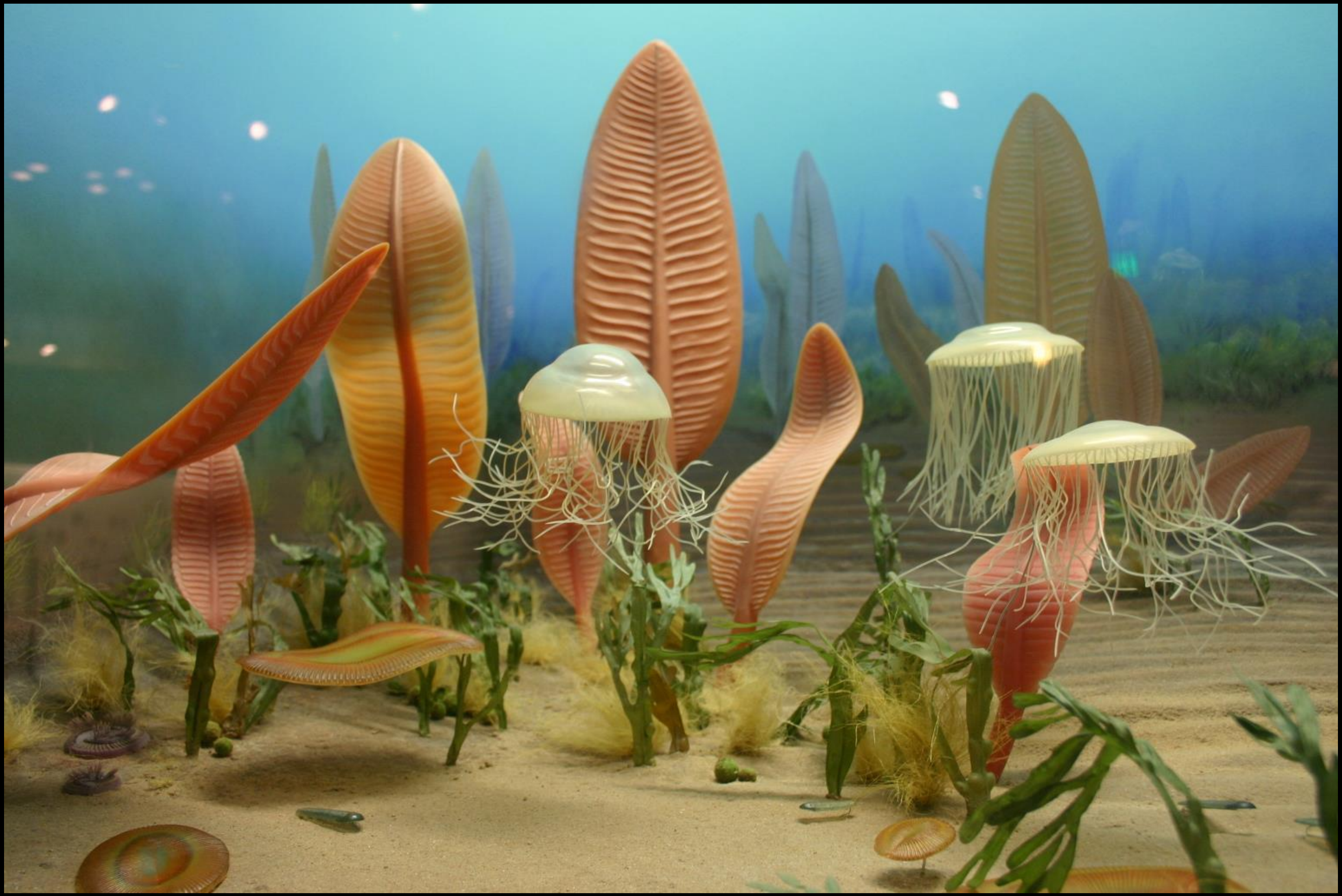
History of Life – Time Wheel



First complex multicellular life

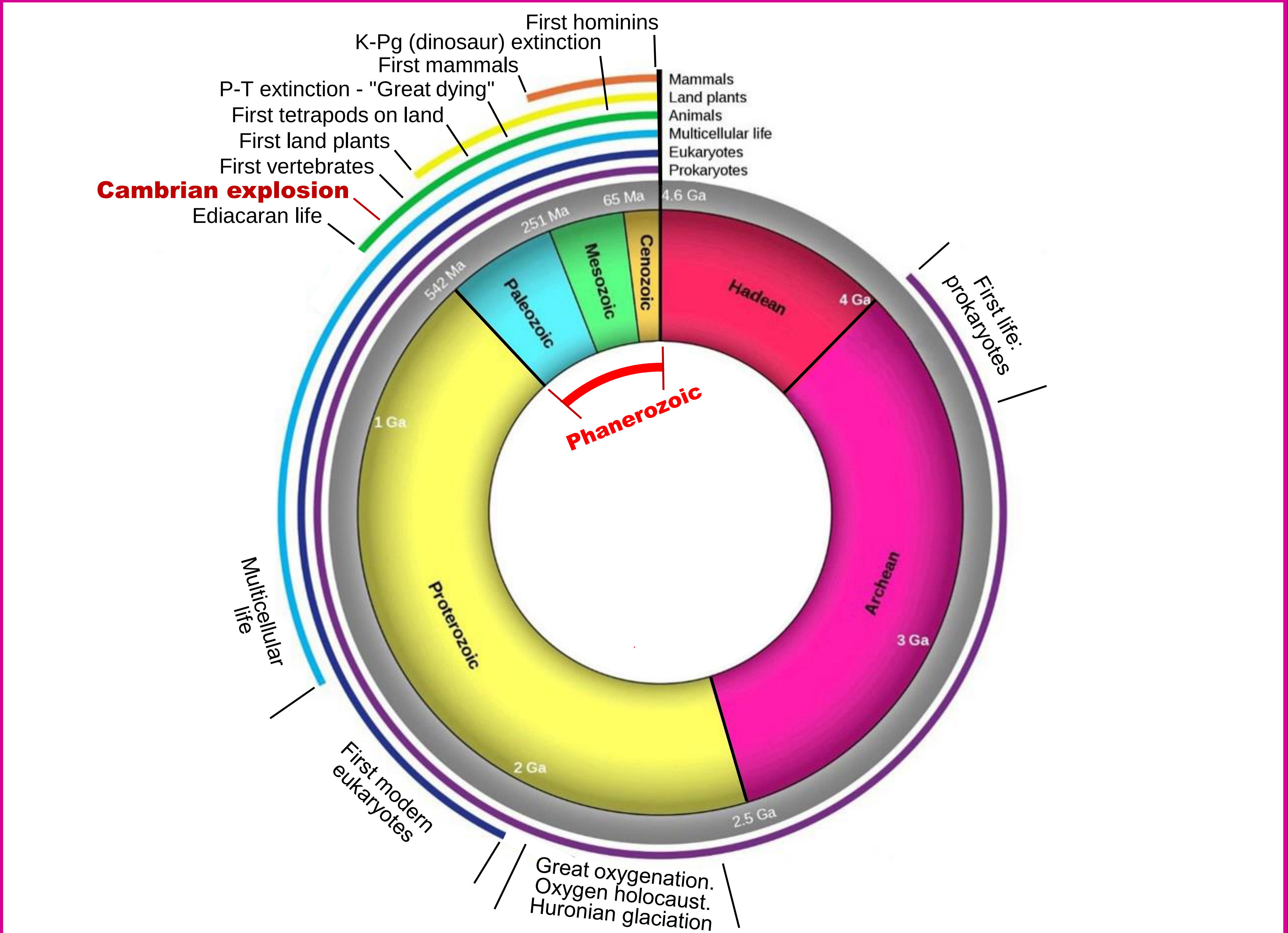
Ediacaran Lifeforms

635–542 Mya



First complex multicellular life. Soft-bodied Ediacaran biota might have been an evolutionary dead-end, quickly replaced by creatures of the Cambrian explosion. Image by Ryan Somma

History of Life – Time Wheel

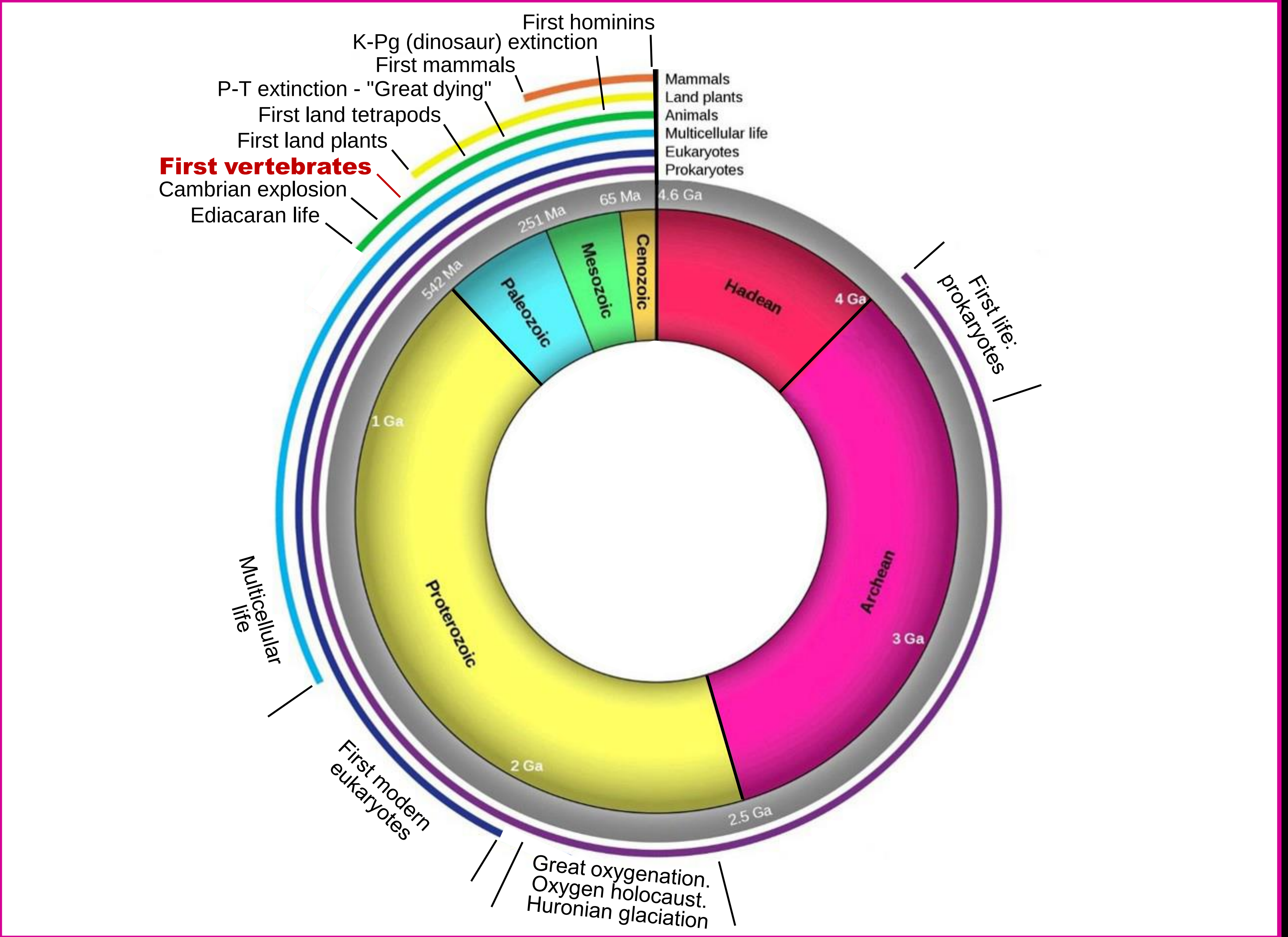


Cambrian Lifeforms

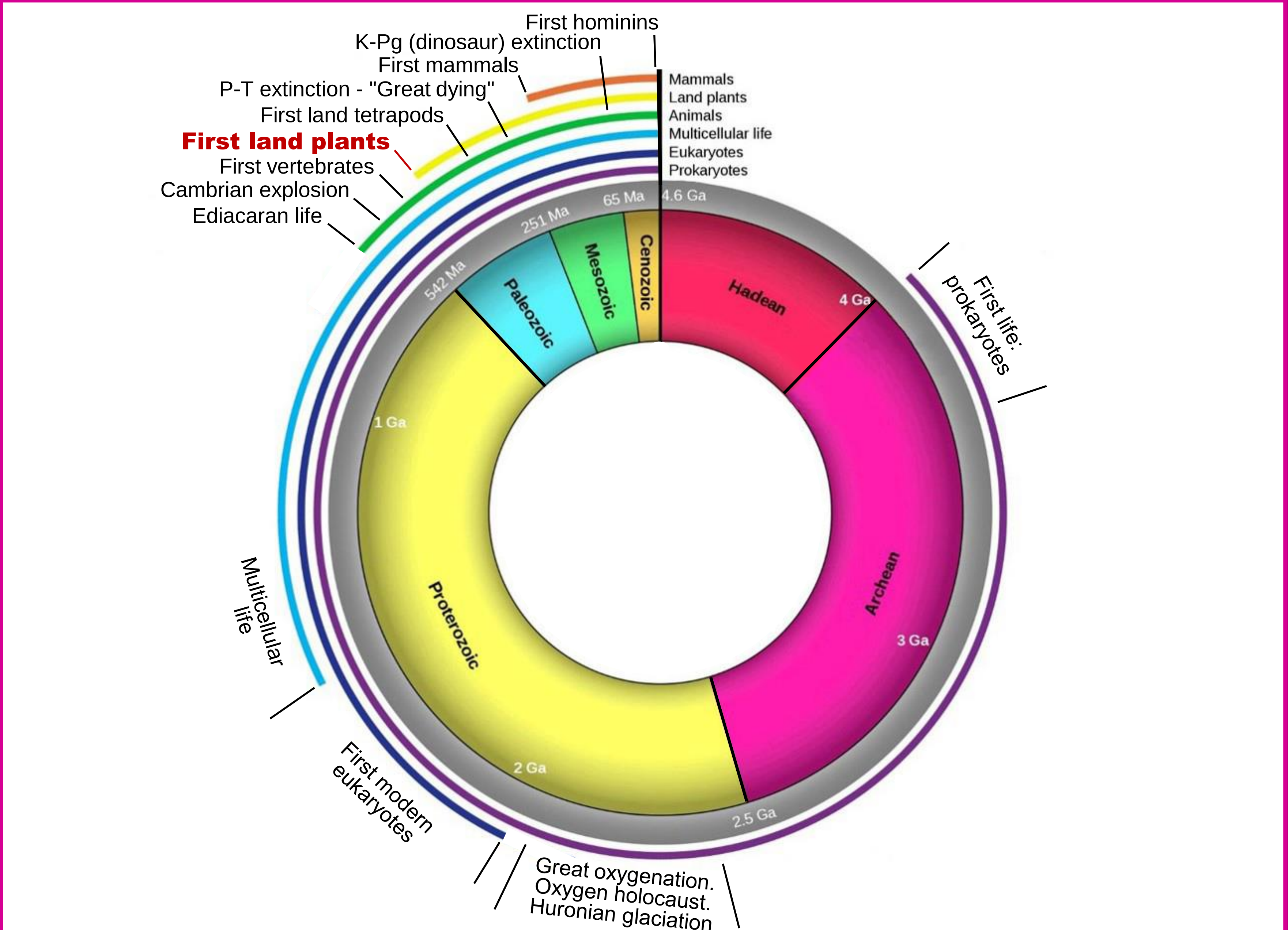
Beginning 542 Mya

Almost every metazoan (animal) phylum with hard parts, and many that lack hard parts, made their first appearance in the Cambrian. Among lifeforms shown above are trilobites and one of first super predators, Anomalocaris. Also present, but too small to see, is tiny Pikaia, one of first chordates. Image by Ken Doud

History of Life – Time Wheel

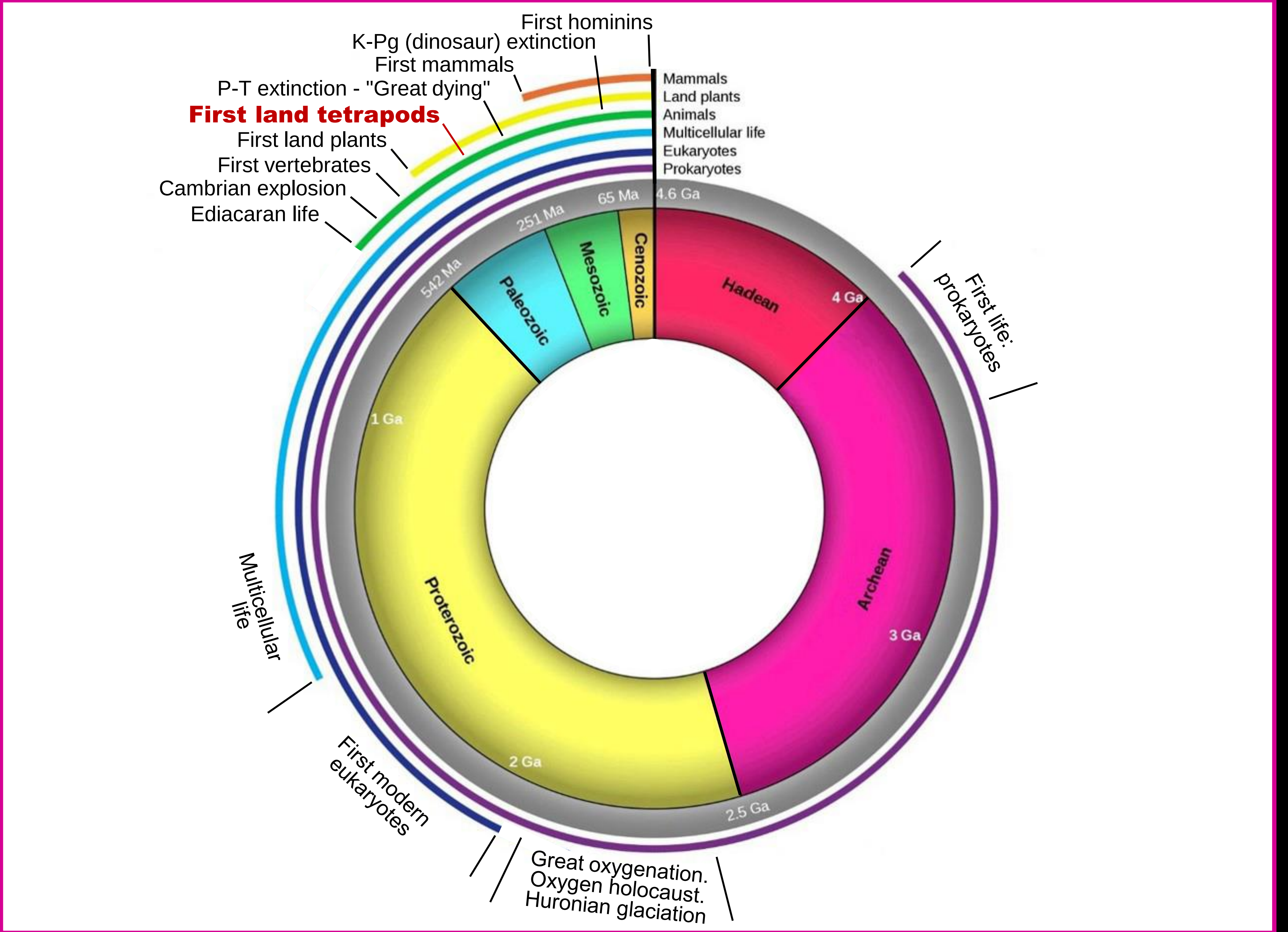


History of Life – Time Wheel



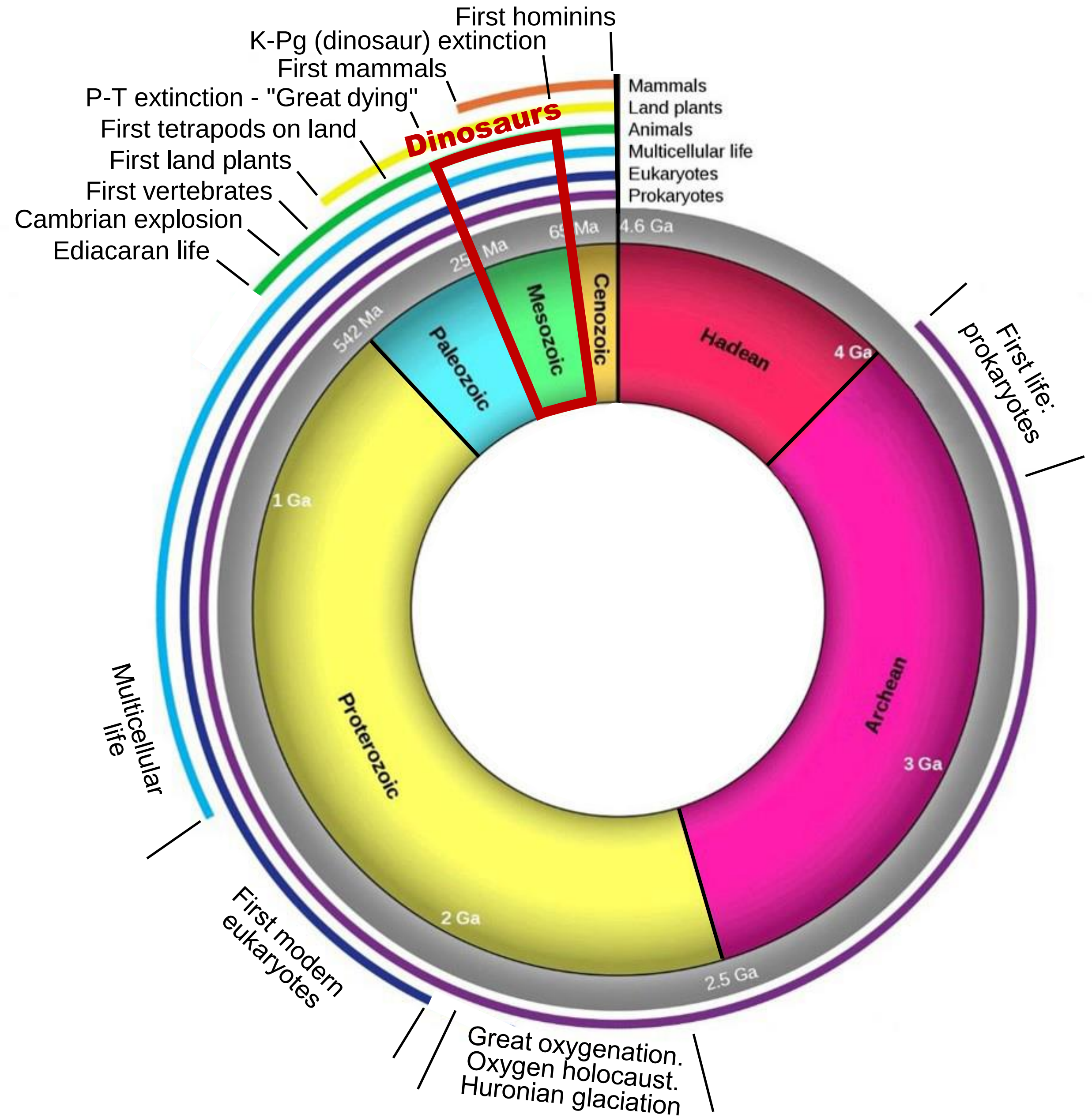
Land plants believed by most biologists to be first land-dwelling life

History of Life – Time Wheel

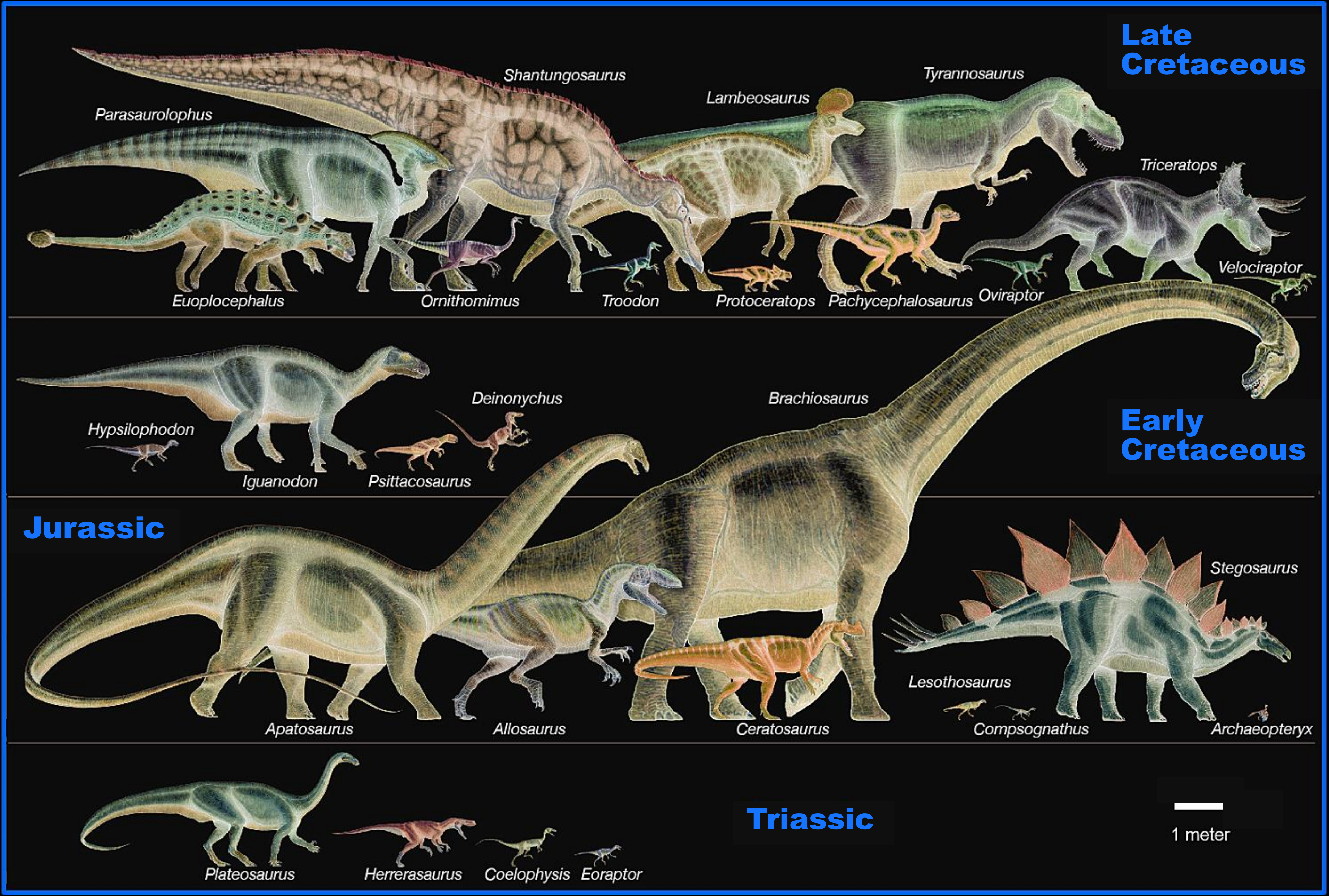


More on this later

History of Life – Time Wheel



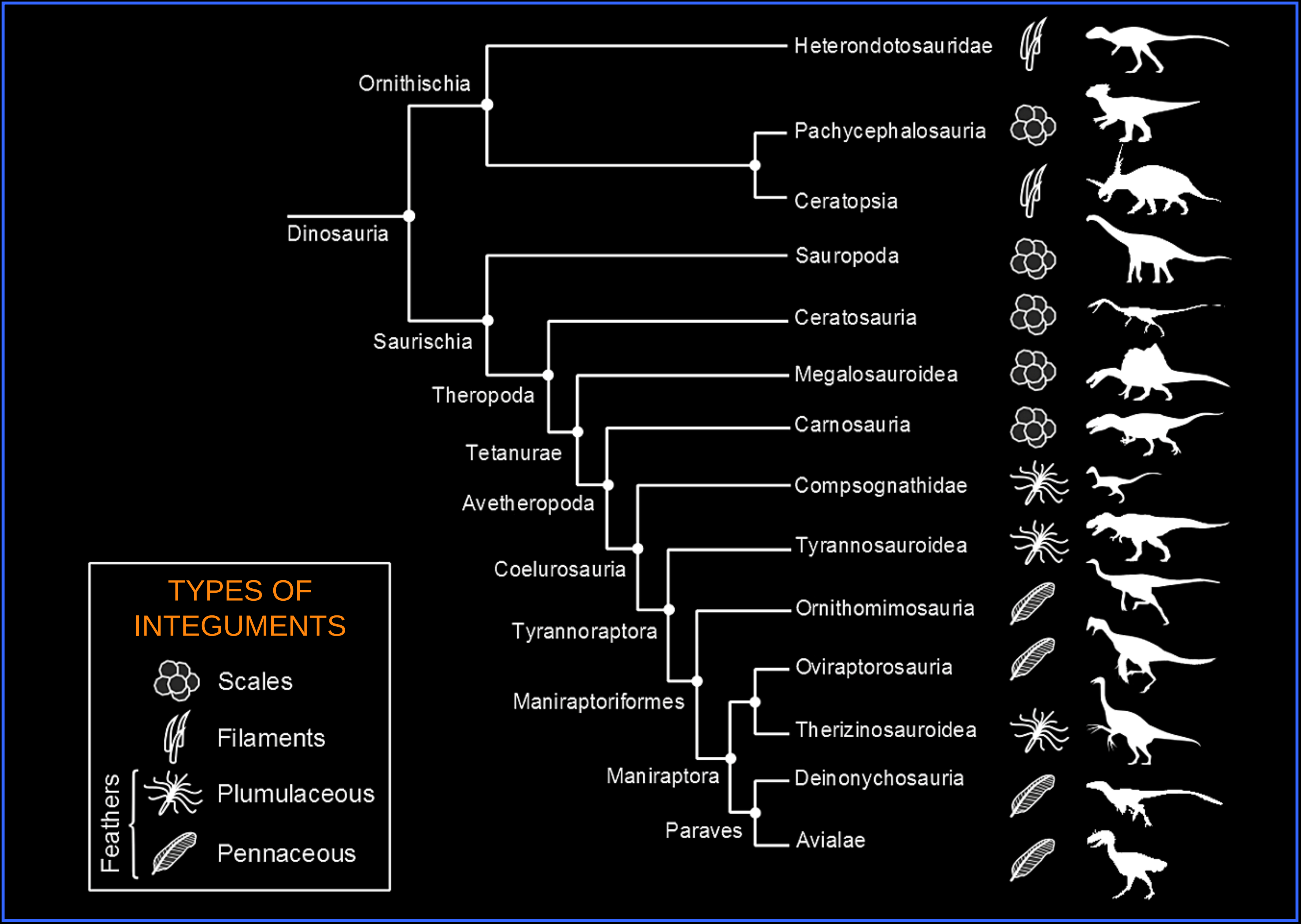
Dinosaurs - Terrestrial Life at Largest



Dinosaurs dominated the Mesozoic Era (252-66 Mya). Encyclopedia Britannica, Inc (2014). Color modified

Not all dinosaurs were scaly creatures

Dinosaur Outer Layers

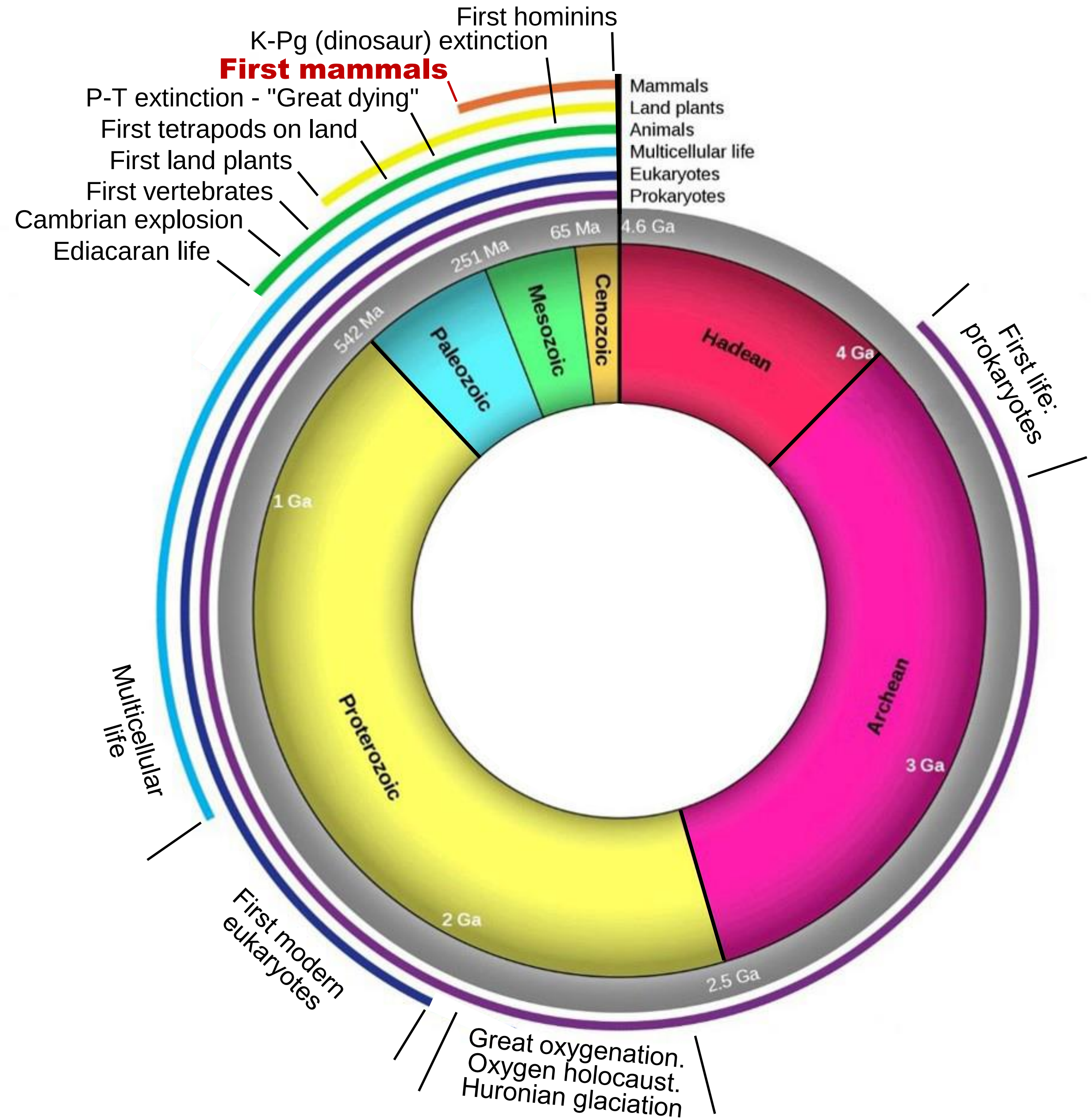


Source: Wikipedia "Distribution of Feathers in Dinosauria" article

Feathered Dinosaur

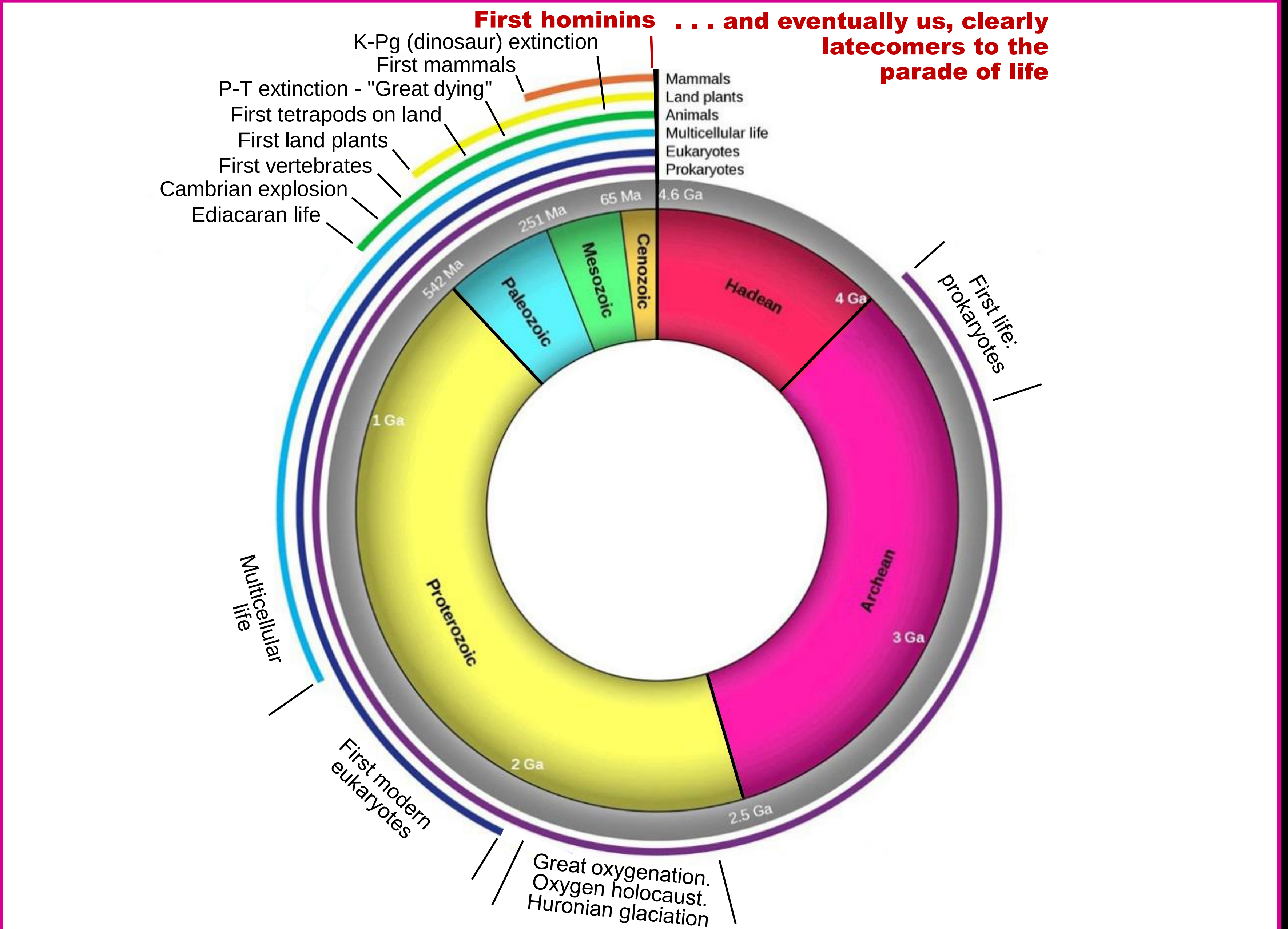
Zhenyuanlong suni, a feathered therapod dinosaur and bird ancestor. Such dinosaurs were the only types to escape the K-Pg extinction. Artist: Zhou Chuang

History of Life – Time Wheel



Mammals first appeared in Mesozoic, but remained small while dinosaurs ruled

History of Life – Time Wheel



History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

Evolution of Life – Descent with Modification

All Life on Earth Descended from Single Common Ancestor

Here life excludes viruses. Image: Artist rendering of DNA double helix (source unknown)

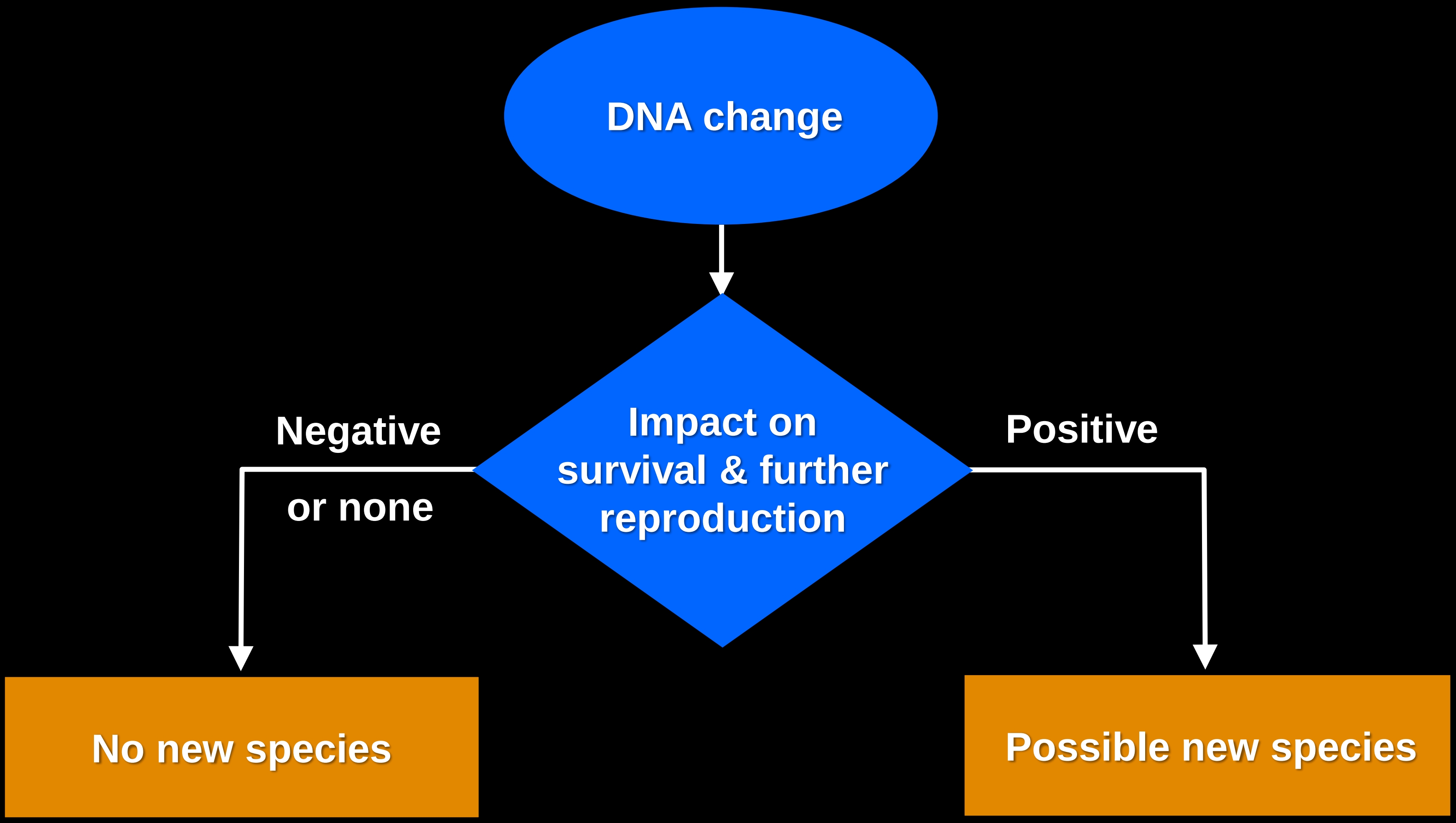
Nothing in biology makes sense except in the light of evolution

– Theodosius Dobzhansky

Evolution – Definition

- Evolution is change to different adaptive state
- Evolution is not synonymous with "progress"
- Many current lifeforms are more complex than early lifeforms, but vast majority (many recently evolved) are simple

Evolution – Basic Mechanism



DNA change usually consists of a mutation caused by copying errors and/or exposure to certain chemicals or radiation. But it also can result from horizontal gene transfer. Whatever the cause, the change must occur in reproductive cells to effect evolution. The favoring of positive modifications is termed "natural selection"

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

History of Life

Evolution

Evidence of Evolution

Morphological

Common structural unit: cell

Transitional forms via fossils

Homologous structures

Morphological remnants

Morphological trees of life

Molecular

Common genetic material (DNA) and near-universal genetic code

Homochirality (key biomolecules)

Molecular remnants

Molecular trees of life

Other

Biogeographical

Real Time

Anthropogenic Damage to Biosphere

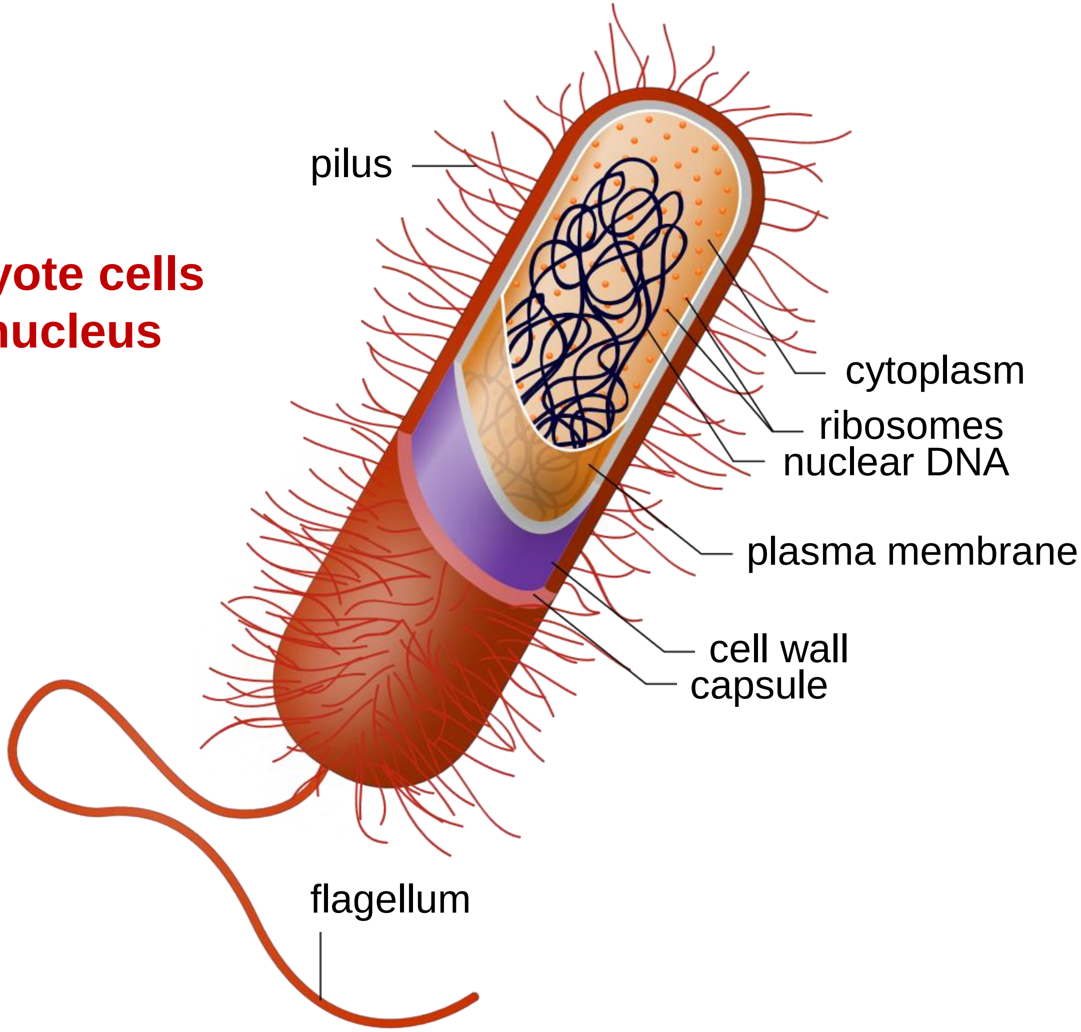
The Cell

- Common structural unit of all life*
- Cells of prokaryotes simpler than those of eukaryotes

*Excludes viruses, which are not cell-based and cannot reproduce on their own (exist in twilight of life)

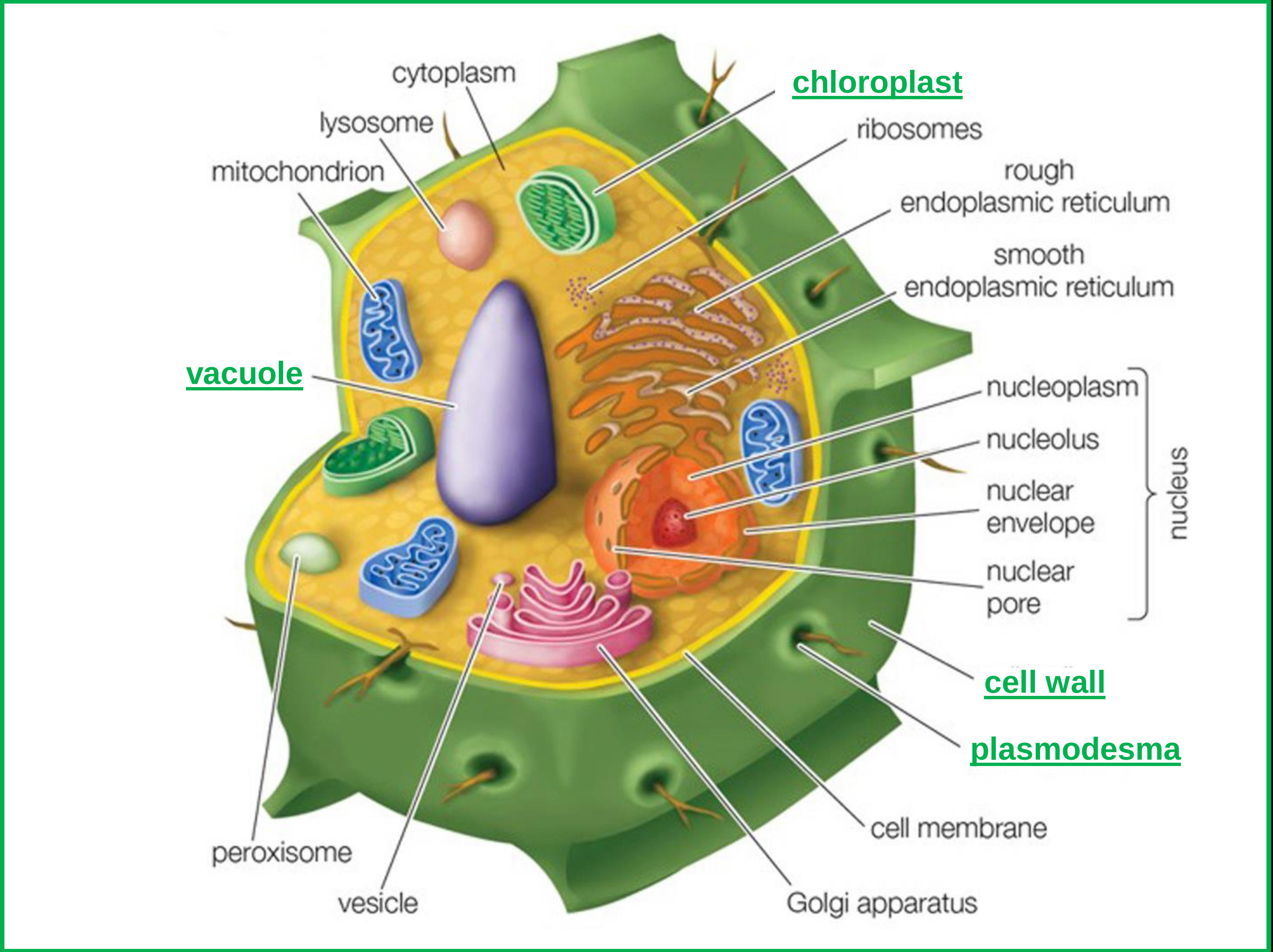
Prokaryote Cell

Prokaryote cells lack a nucleus



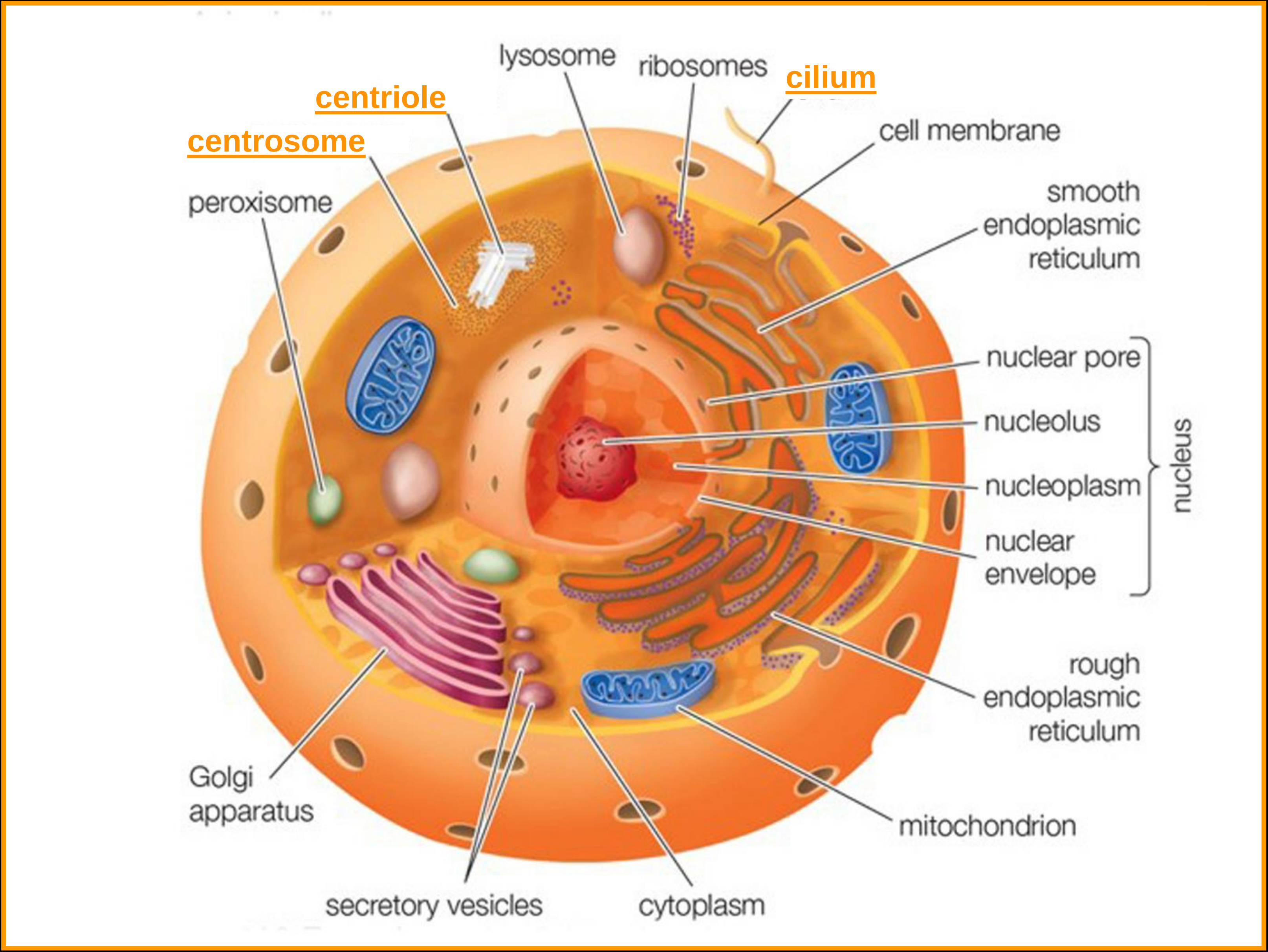
Generic prokaryote cell. Wikipedia "Prokaryote" article

Eukaryote Cell – Plant



Generic plant cell. Underlined green parts not found in animals. ©2010 Encyclopedia Britannica, Inc

Eukaryote Cell – Animal



Generic animal cell. Underlined orange parts not found in plants. ©2010 Encyclopedia Britannica, Inc

History of Life

Evolution

Evidence of Evolution

Morphological

Common structural unit: cell

Transitional forms via fossils

Homologous structures

Morphological remnants

Morphological trees of life

Molecular

Common genetic material (DNA) and near-universal genetic code

Homochirality (key biomolecules)

Molecular remnants

Molecular trees of life

Other

Biogeographical

Real Time

Anthropogenic Damage to Biosphere

DNA – Blueprint of Life

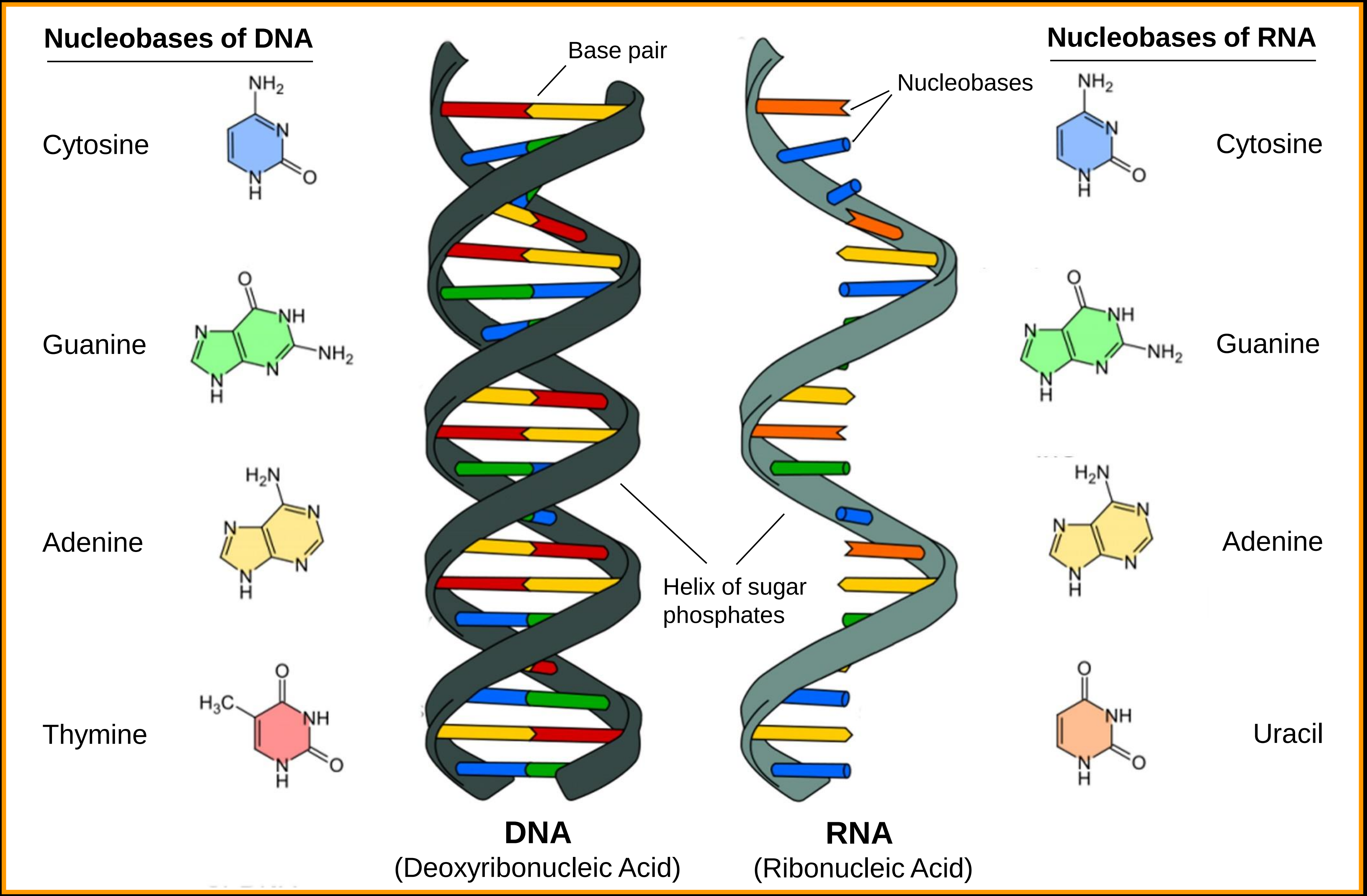
Every cell of every current organism contains, in its DNA-based genome, all of the information needed to grow, maintain itself, and reproduce

Very early life, on the other hand, might have been RNA-based, like most viruses today

RNA & Near-Universal Genetic Code

- Near-universal three-letter codes (codons) used by messenger RNA in ribosomes (tiny protein factories) to specify the next amino acid to be manufactured and added to the growing protein chain – and also when to stop the process
- The few exceptions do not contradict the concept of common descent

DNA and RNA



DNA is a double helix. RNA is a single helix. Thymine in DNA replaces Uracil in RNA. Image: Wikipedia

RNA Codon Table (Near-Universal Genetic Code)

"Rosetta Stone" for Protein Synthesis

SECOND BASE

FIRST BASE	U	C	A	G	THIRD BASE
U	UUU, UUC – Phenylalanine UUA, UUG – Leucine	UCU, UCC, UCA, UCG – Serine	UAU, UAC – Tyrosine UAA – Stop codon UAG – Stop codon	UGU, UGC – Cysteine UGA – Stop codon UGG – Tryptophan	U C A G
C	CUU, CUC, CUA, CUG – Leucine	CCU, CCC, CCA, CCG – Proline	CAU, CAC – Histidine CAA, CAG – Glutamine	CGU, CGC, CGA, CGG – Arginine	U C A G
A	AUU, AUC, AUA – Isoleucine AUG – Methionine	ACU, ACC, ACA, ACG – Threonine	AAU, AAC – Asparagine AAA, AAG – Lysine	AGU, AGC – Serine AGA, AGG – Arginine	U C A G
G	GUU, GUC, GUA, GUG – Valine	GCU, GCC, GCA, GCG – Alanine	GAU, GAC – Aspartic acid GAA, GAG – Glutamic acid	GGU, GGC, GGA, GGG – Glycine	U C A G

Three-letter codes (codons) used by messenger RNA (mRNA) in a ribosome to specify the next amino acid to be linked in forming a protein. Also when to stop. Image: ProProfs (modified)

RNA & Near-Universal Genetic Code

- Near-universal three-letter codes (codons) used by messenger RNA in ribosomes (tiny protein factories) to specify the next amino acid to be manufactured and added to the growing protein chain – and also when to stop the process
- The few exceptions* do not contradict the concept of common descent

*Attributed to horizontal gene transfer (HGT), discussed below

History of Life

Evolution

Evidence of Evolution

Morphological

Common structural unit: cell

Transitional forms via fossils

Homologous structures

Morphological remnants

Morphological trees of life

Molecular

Common genetic material (DNA) and near-universal genetic code

Homochirality (key biomolecules)

Molecular remnants

Molecular trees of life

Other

Biogeographical

Real Time

Anthropogenic Damage to Biosphere

Transitional Forms

- When Charles Darwin's *Origin of the Species* was first published (1859) no transitional forms were known
- The very next year the first transitional fossil – that of the birdlike dinosaur Archaeopteryx – was discovered
- Many more transitional species have since been found

Transitional Forms – Examples

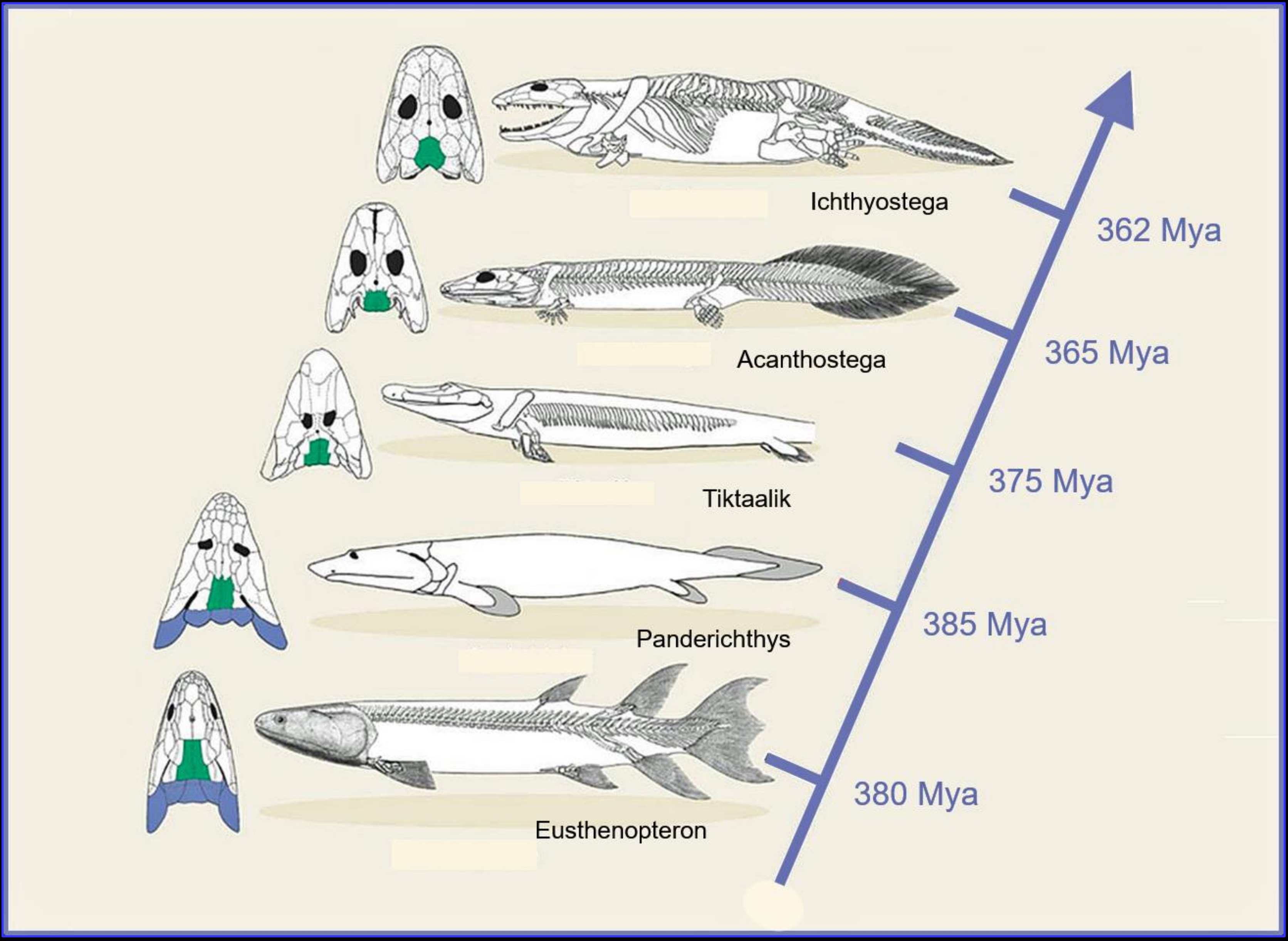
- **Invertebrates to Fish (523 Mya – 419 Mya)**
  Pikaia → Conodont → Haikouichthys → Arandaspis → Birkenia → Guiya
- **Fish to Tetrapods (416 Mya – 210 Mya)**
  Osteolepis → Eusthenopteron → Panderichthys → Tiktaalik → Elginerpeton → Ventastega → Acanthostega → Ichthyostega → Hynerpeton → Tulerpeton → Pederpes → Eryops
- **Synapsids ("mammal-like reptiles") to Mammals (300 Mya – 125 Mya)**
  Protoclepsydrops → Archaeothyris → Haptodus → Dimetrodon → Biarmosuchus → Cynognathus → Thrinaxodon → Morganicodon → Yanoconodon
- **Dinosaurs to Birds (152 Mya – 75 Mya)**
  Juravenator → Pedopenna → Anchiornis → Archeopteryx → Confuciusoris → Eoalulavis → Icthyornis
- **Early Artiodactyla to Whales (56 Mya – 26 Mya)**
  Pakicetus → Ambulocetus → Kutchicetus → Artiocetus → Dorudon → Aetiocetus → Basilosaurus → Eurhinodelphis → Mammalodon
- **"Monkeys" to Humans (36 Mya – 300 kya)**
  Apidium → Aegyptopithecus → Proconsul → Pierolapithecus → Ardipithecus → Australopithecus → Homo habilis → Homo erectus → Homo heidelbergensis

From Wikipedia "List of Transitional Fossils" article. More sequences in article

Transitional Forms – Examples

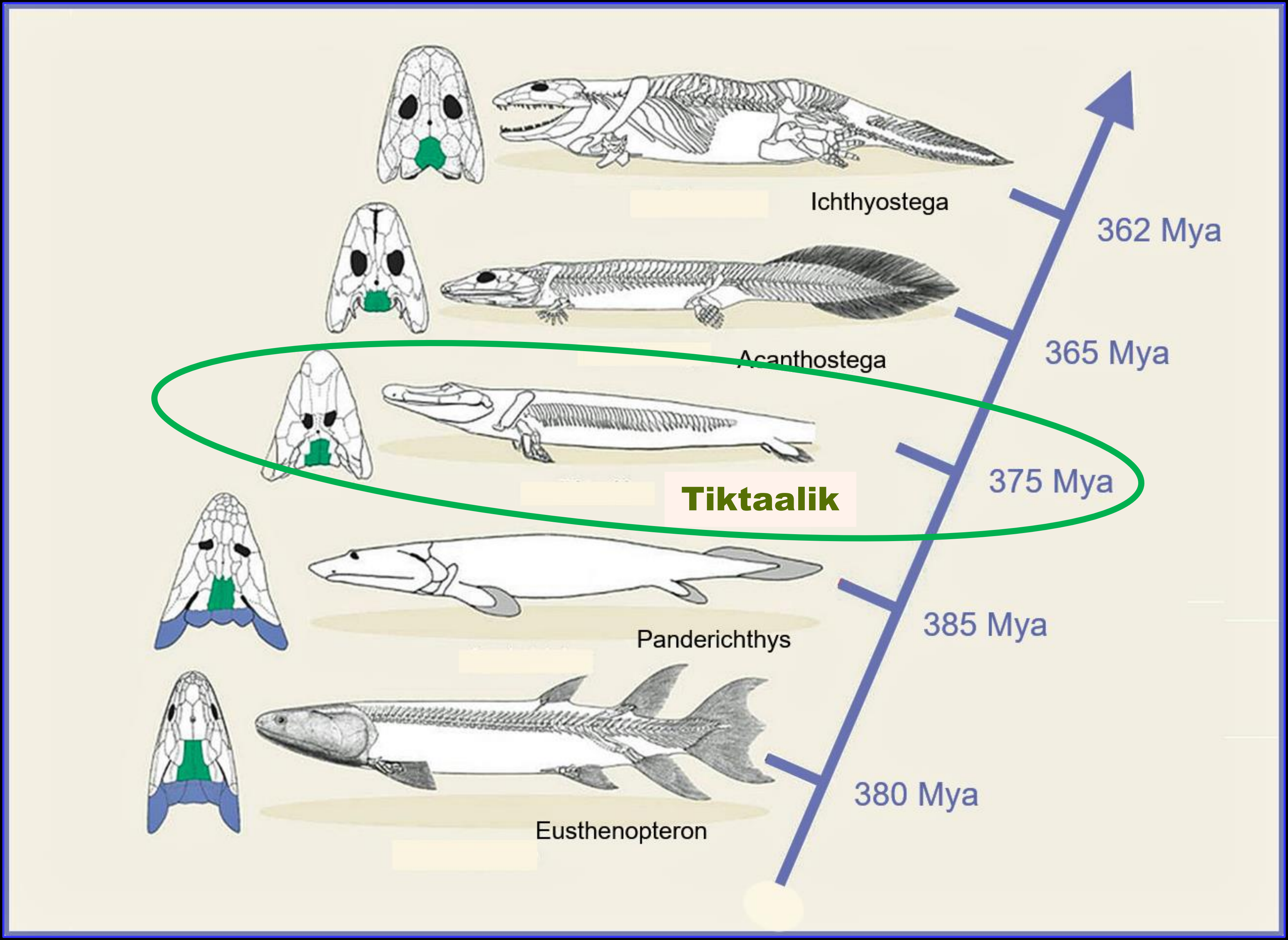
- **Invertebrates to Fish (523 Mya – 419 Mya)**
  Pikaia → Conodont → Haikouichthys → Arandaspis → Birkenia → Guiya
- **Fish to Tetrapods (416 Mya – 210 Mya)**
  Osteolepis → Eusthenopteron → Panderichthys → Tiktaalik → Elginerpeton → Ventastega → Acanthostega → Ichthyostega → Hynerpeton → Tulerpeton → Pederpes → Eryops
- **Synapsids ("mammal-like reptiles") to Mammals (300 Mya – 125 Mya)**
  Protoclepsydrops → Archaeothyris → Haptodus → Dimetrodon → Biarmosuchus → Cynognathus → Thrinaxodon → Morganicodon → Yanoconodon
- **Dinosaurs to Birds (152 Mya – 75 Mya)**
  Juravenator → Pedopenna → Anchiornis → Archeopteryx → Confuciusoris → Eoalulavis → Icthyornis
- **Early Artiodactyla to Whales (56 Mya – 26 Mya)**
  Pakicetus → Ambulocetus → Kutchicetus → Artiocetus → Dorudon → Aetiocetus → Basilosaurus → Eurhinodelphis → Mammalodon
- **"Monkeys" to Humans (36 Mya – 300 kya)**
  Apidium → Aegyptopithecus → Proconsul → Pierolapithecus → Ardipithecus → Australopithecus → Homo habilis → Homo erectus → Homo heidelbergensis

Transitional Forms – Fish to Tetrapods



Basic figure from Ahlberg and Clack 2006, *Nature* 440, 747-749. Dates from various sources

Transitional Forms – Fish to Tetrapods

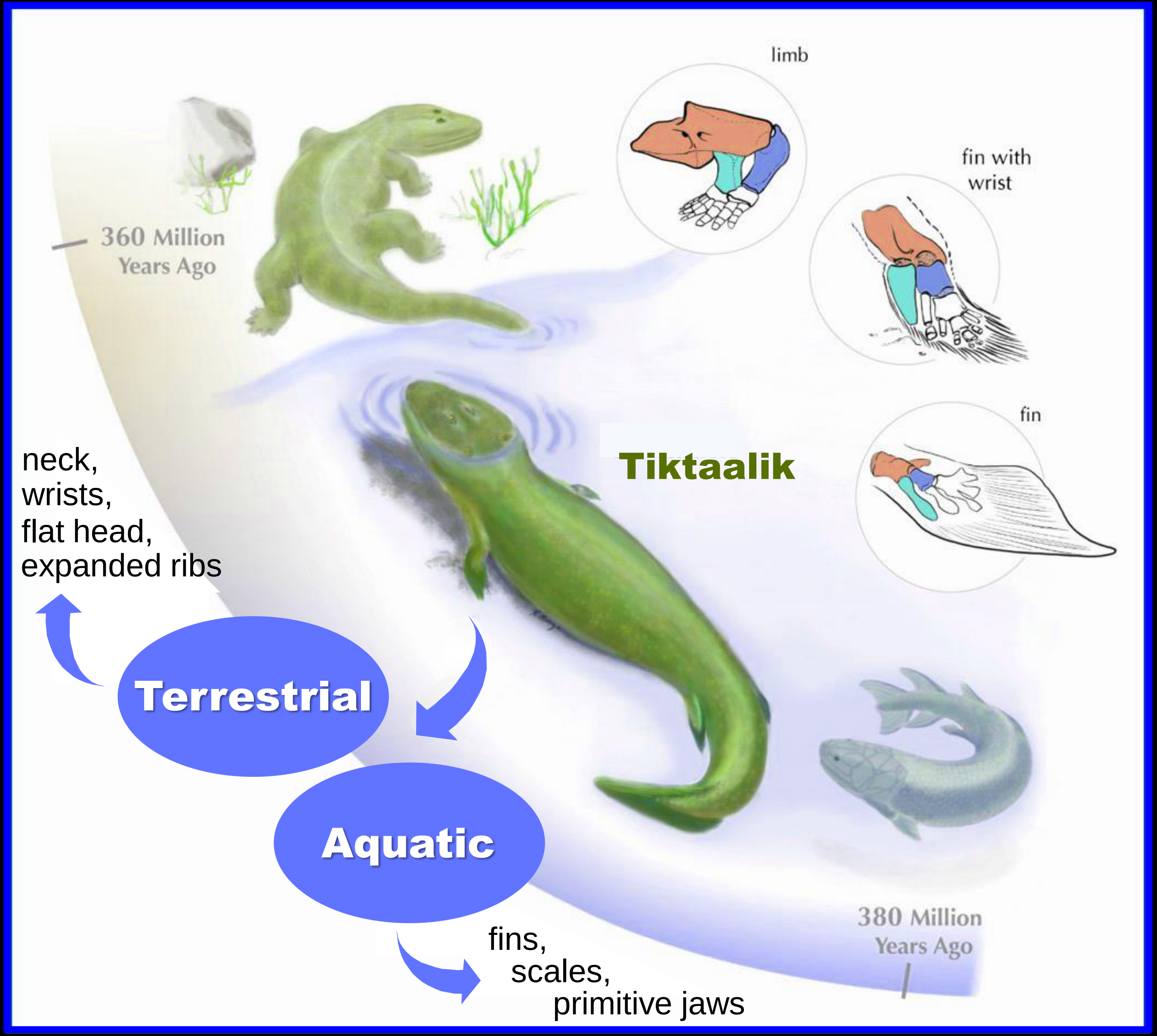


Key transitional species, Tiktaalik, discovered in 2004 by Edward B. Daeschler, N. H. Shubin and Farish A. Jenkins, Jr. Tail missing from single fossil

Tiktaalik

Reconstruction and fossil. U. Chicago

Tiktaalik – Pivotal Link



Tiktaalik shares features of fish and tetrapods. Basic image: U. Chicago

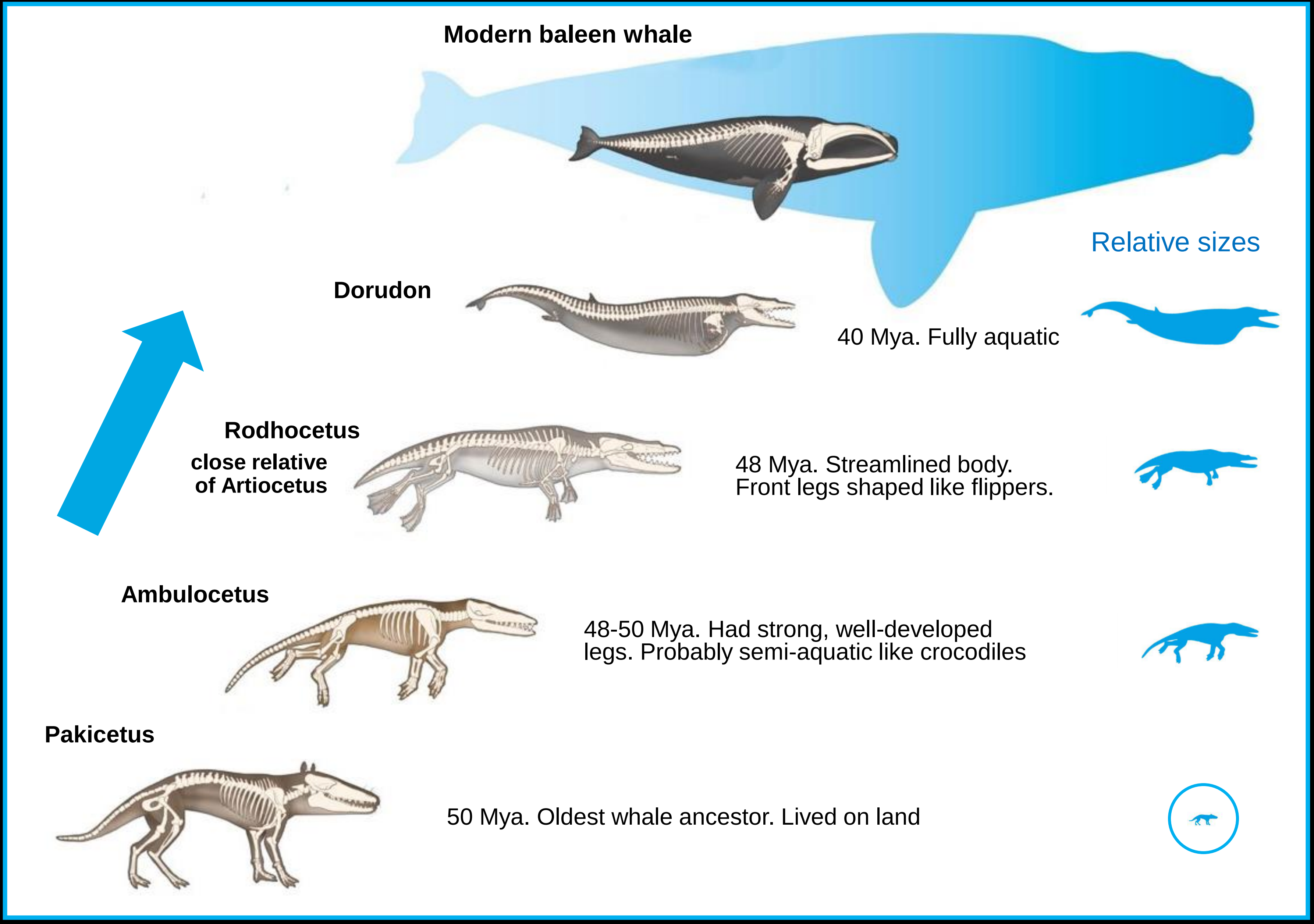
After going to all the trouble to get on land,
some malcontents just had to go back to sea

Transitional Forms – Examples

- **Invertebrates to Fish (523 Mya – 419 Mya)**
  Pikaia → Conodont → Haikouichthys → Arandaspis → Birkenia → Guiya
- **Fish to Tetrapods (416 Mya – 210 Mya)**
  Osteolepis → Eusthenopteron → Panderichthys → Tiktaalik → Elginerpeton → Ventastega → Acanthostega → Ichthyostega → Hynerpeton → Tulerpeton → Pederpes → Eryops
- **Synapsids ("mammal-like reptiles") to Mammals (300 Mya – 125 Mya)**
  Protoclepsydrops → Archaeothyris → Haptodus → Dimetrodon → Biarmosuchus → Cynognathus → Thrinaxodon → Morganicodon → Yanoconodon
- **Dinosaurs to Birds (152 Mya – 75 Mya)**
  Juravenator → Pedopenna → Anchiornis → Archeopteryx → Confuciusoris → Eoalulavis → Icthyornis
- **Early Artiodactyla to Whales (56 Mya – 26 Mya)**
  Pakicetus → Ambulocetus → Kutchicetus → Artiocetus → Dorudon → Aetiocetus → Basilosaurus → Eurhinodelphis → Mammalodon
- **"Monkeys" to Humans (36 Mya – 300 kya)**
  Apidium → Aegyptopithecus → Proconsul → Pierolapithecus → Ardipithecus → Australopithecus → Homo habilis → Homo erectus → Homo heidelbergensis

Artiodactyls are cloven-hoofed mammals

Whale Evolution – Back to the Ocean



After Lisa Carloye (Washington State University) biology lectures notes. Her sequence shortened here

What about human evolution?

Hominins – Bare Bones

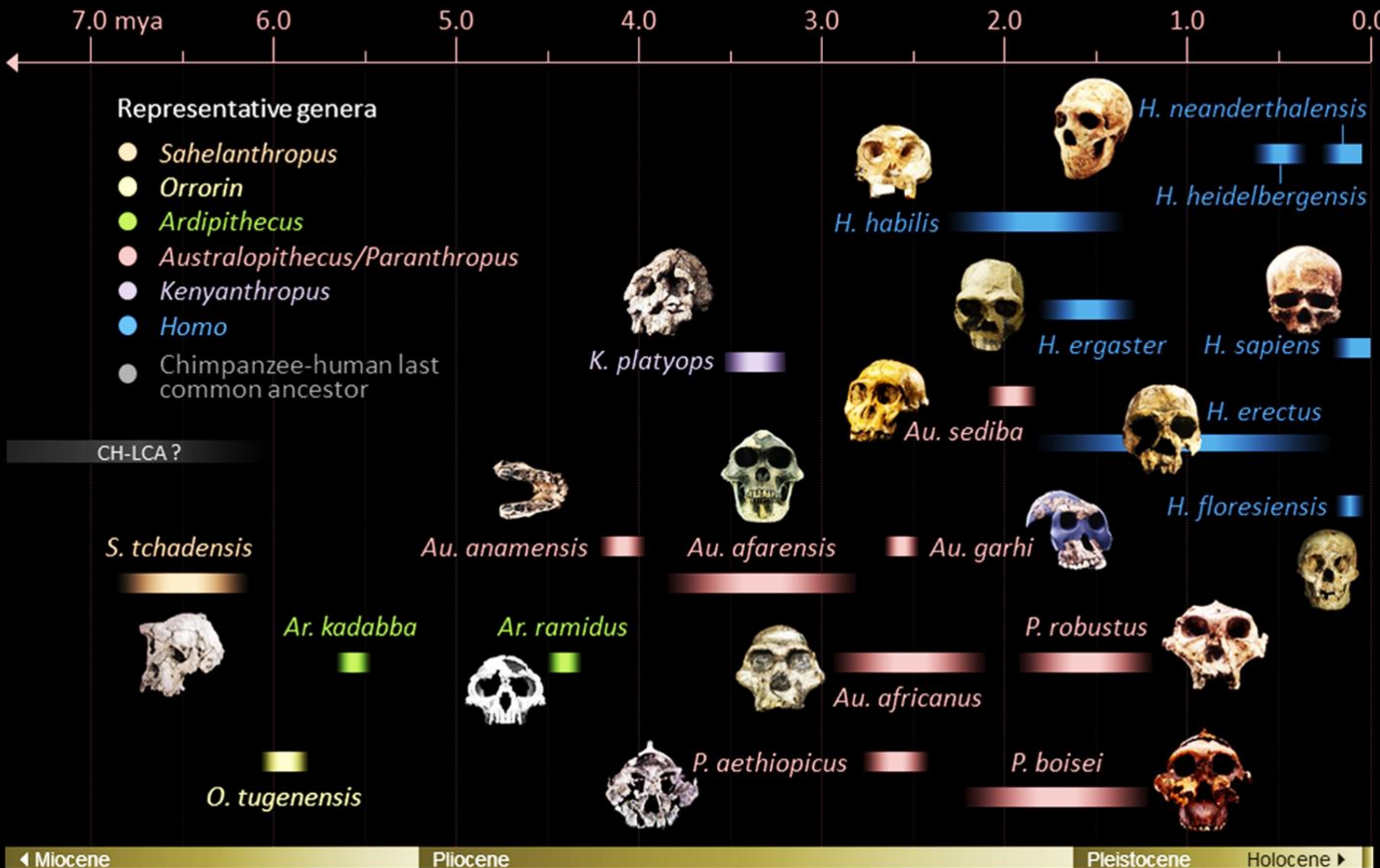


Image source: Prateek Lala. Original Title: "Hominid Evolution"

Hominins – Fleshing Things Out

Sculptures by Smithsonian paleo-artist John Gurche

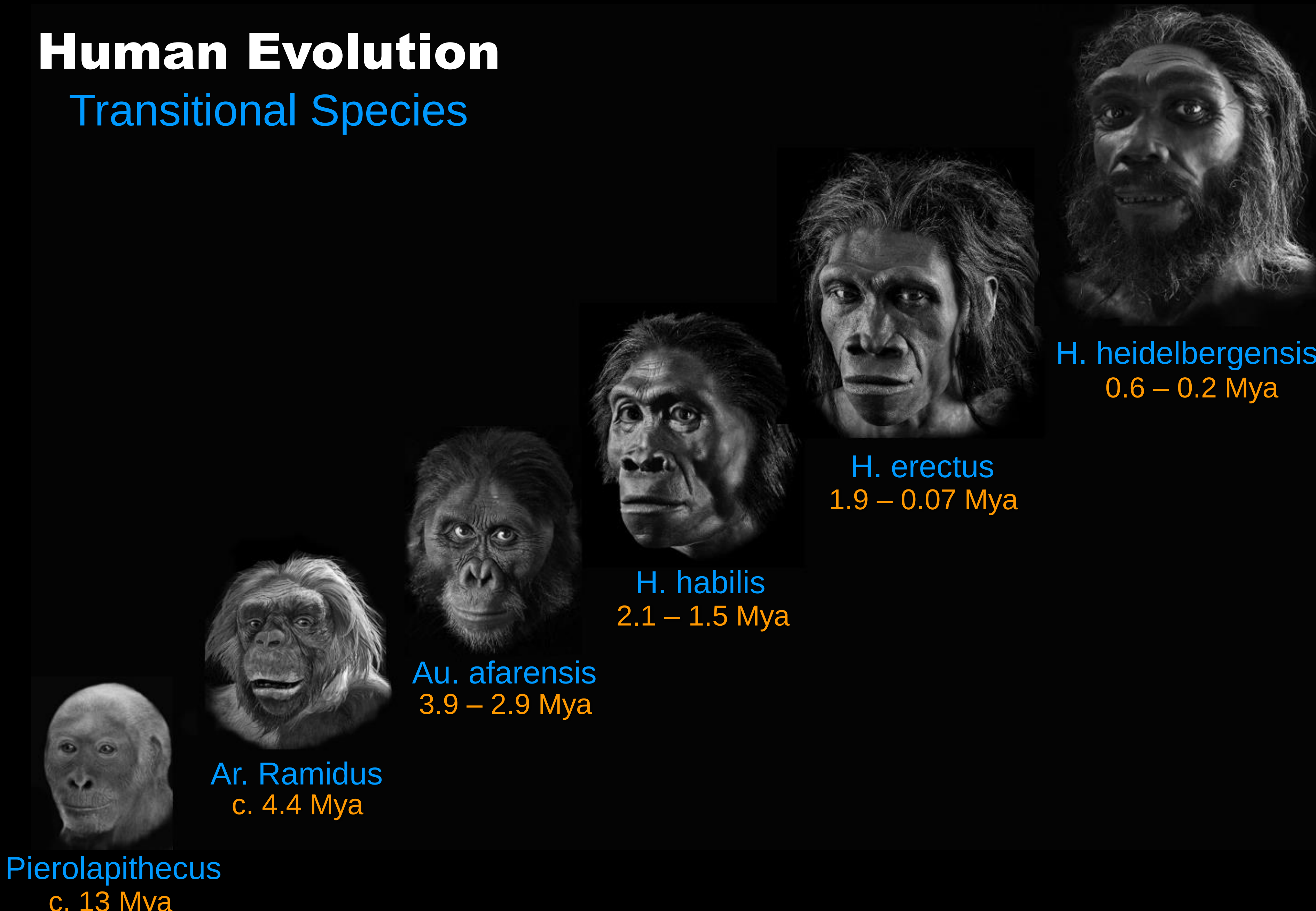
But which are in our line of descent?

Transitional Forms – Examples

- **Invertebrates to Fish (523 Mya – 419 Mya)**
  Pikaia → Conodont → Haikouichthys → Arandaspis → Birkenia → Guiya
- **Fish to Tetrapods (416 Mya – 210 Mya)**
  Osteolepis → Eusthenopteron → Panderichthys → Tiktaalik → Elginerpeton → Ventastega → Acanthostega → Ichthyostega → Hynerpeton → Tulerpeton → Pederpes → Eryops
- **Synapsids ("mammal-like reptiles") to Mammals (300 Mya – 125 Mya)**
  Protoclepsydrops → Archaeothyris → Haptodus → Dimetrodon → Biarmosuchus → Cynognathus → Thrinaxodon → Morganicodon → Yanoconodon
- **Dinosaurs to Birds (152 Mya – 75 Mya)**
  Juravenator → Pedopenna → Anchiornis → Archeopteryx → Confuciusoris → Eoalulavis → Icthyornis
- **Early Artiodactyla to Whales (56 Mya – 26 Mya)**
  Pakicetus → Ambulocetus → Kutchicetus → Artiocetus → Dorudon → Aetiocetus → Basilosaurus → Eurhinodelphis → Mammalodon
- **"Monkeys" to Humans (36 Mya – 300 kya)**
  Apidium → Aegyptopithecus → Proconsul → Pierolapithecus → Ardipithecus → Australopithecus → Homo habilis → Homo erectus → Homo heidelbergensis

Human Evolution

Transitional Species

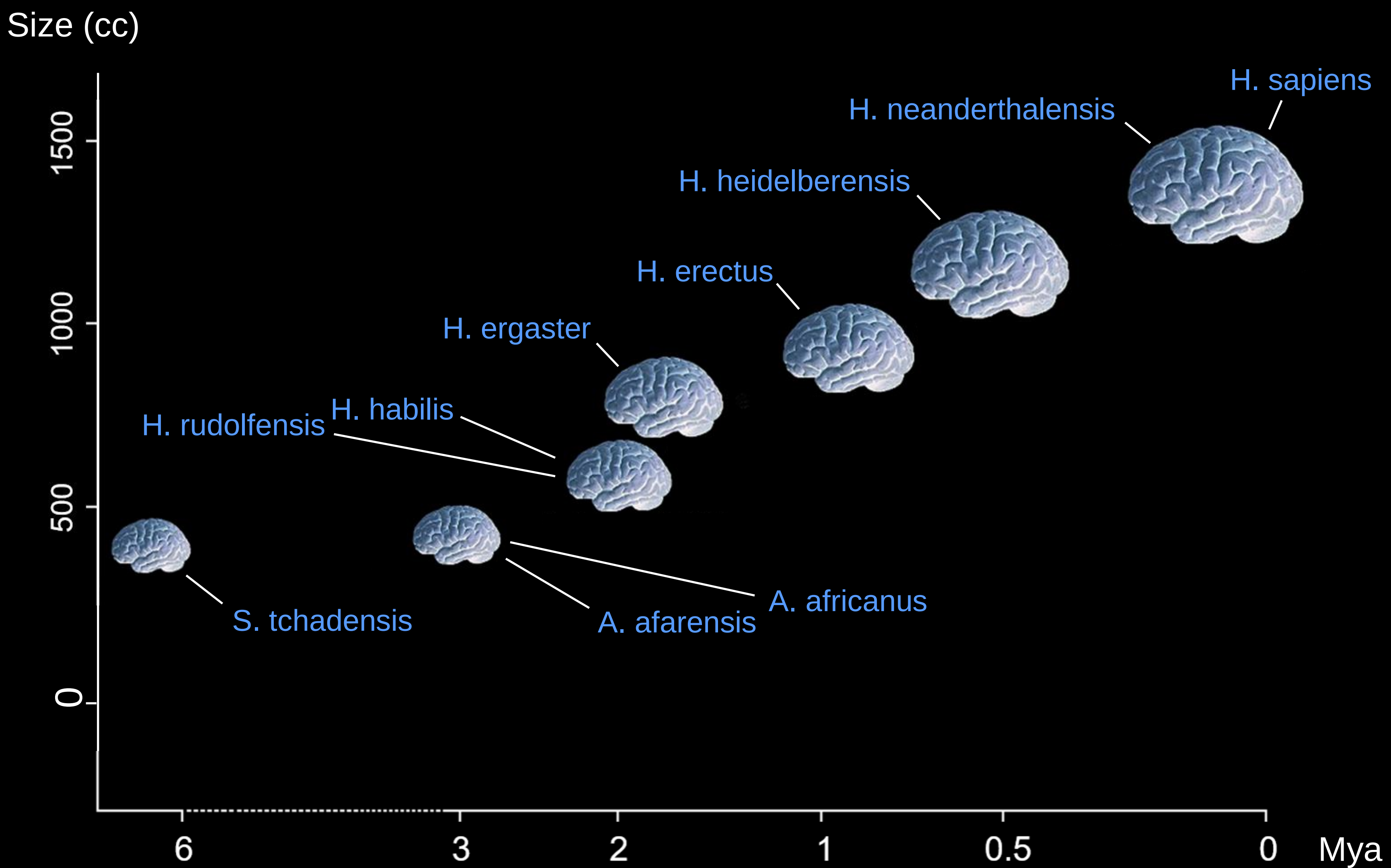


Subset from Wikipedia "List of Transitional Fossils" article. Top four paleo-sculptures by John Gurche. Ar. Ramidus by Roman Garcia Mora. Pierolapithecus (artist unknown) is an ancestor but not a hominin

Sequences like the last should not be viewed as final. New discoveries or insights could result in revisions

Hominin Brain Evolution

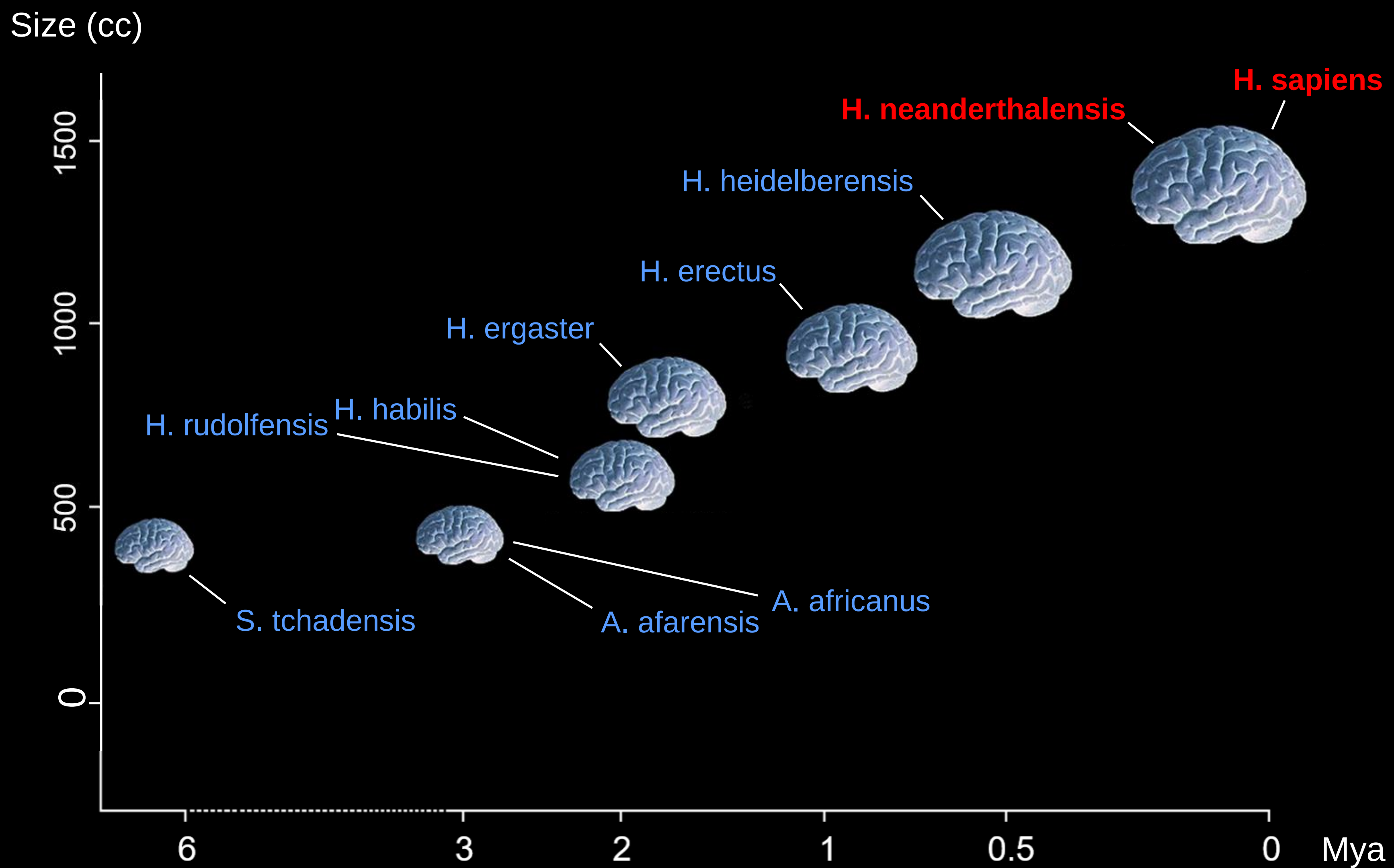
"Crude plot" of Brain Sizes



From "How Could Language Have Evolved" Bolhius, et al (2014), *PLOS Biology*

Hominin Brain Evolution

"Crude plot" of Brain Sizes



From "How Could Language Have Evolved" Bolhius, et al (2014), *PLOS Biology*

What About Neanderthals?

- Not in our direct line of descent, but interbred with Homo sapiens outside of Africa
- 1.5-2.1% of European, Asian and other non-African genomes is Neanderthal

"The complete genome sequence of a Neanderthal from the Altai Mountains"
Nature v 505, pp 43–49, Jan 2, 2014)

History of Life

Evolution

Evidence of Evolution

Morphological

Common structural unit: cell

Transitional forms via fossils

Homologous structures

Morphological remnants

Morphological trees of life

Molecular

Common genetic material (DNA) and near-universal genetic code

Homochirality (key biomolecules)

Molecular remnants

Molecular trees of life

Other

Biogeographical

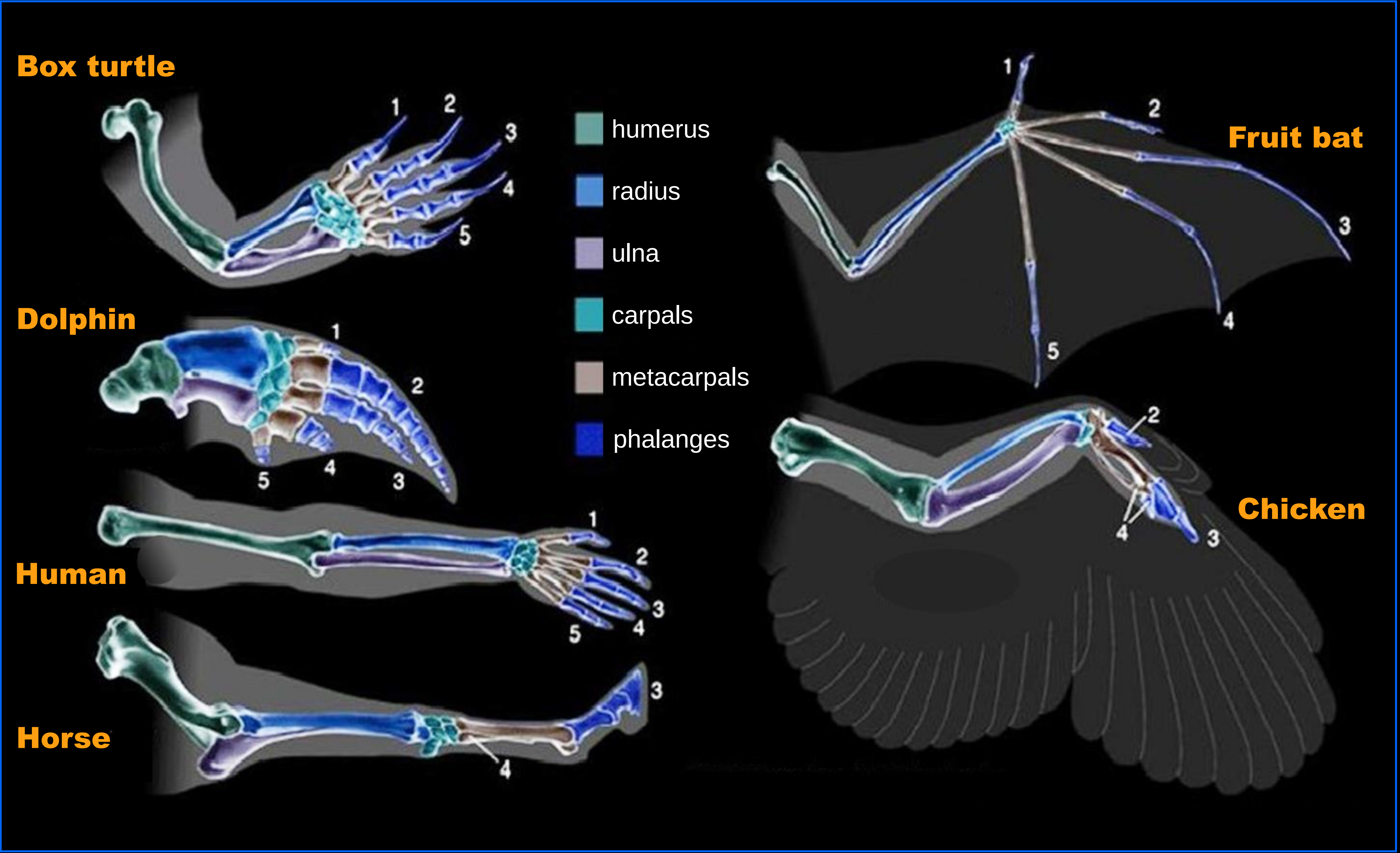
Real Time

Anthropogenic Damage to Biosphere

Homologous Structures

Organs or skeletal elements whose similarities suggest connection to a common ancestor

Homologous Structures – Pentadactyl Forelimb



History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

Homochirality of Key Biomolecules

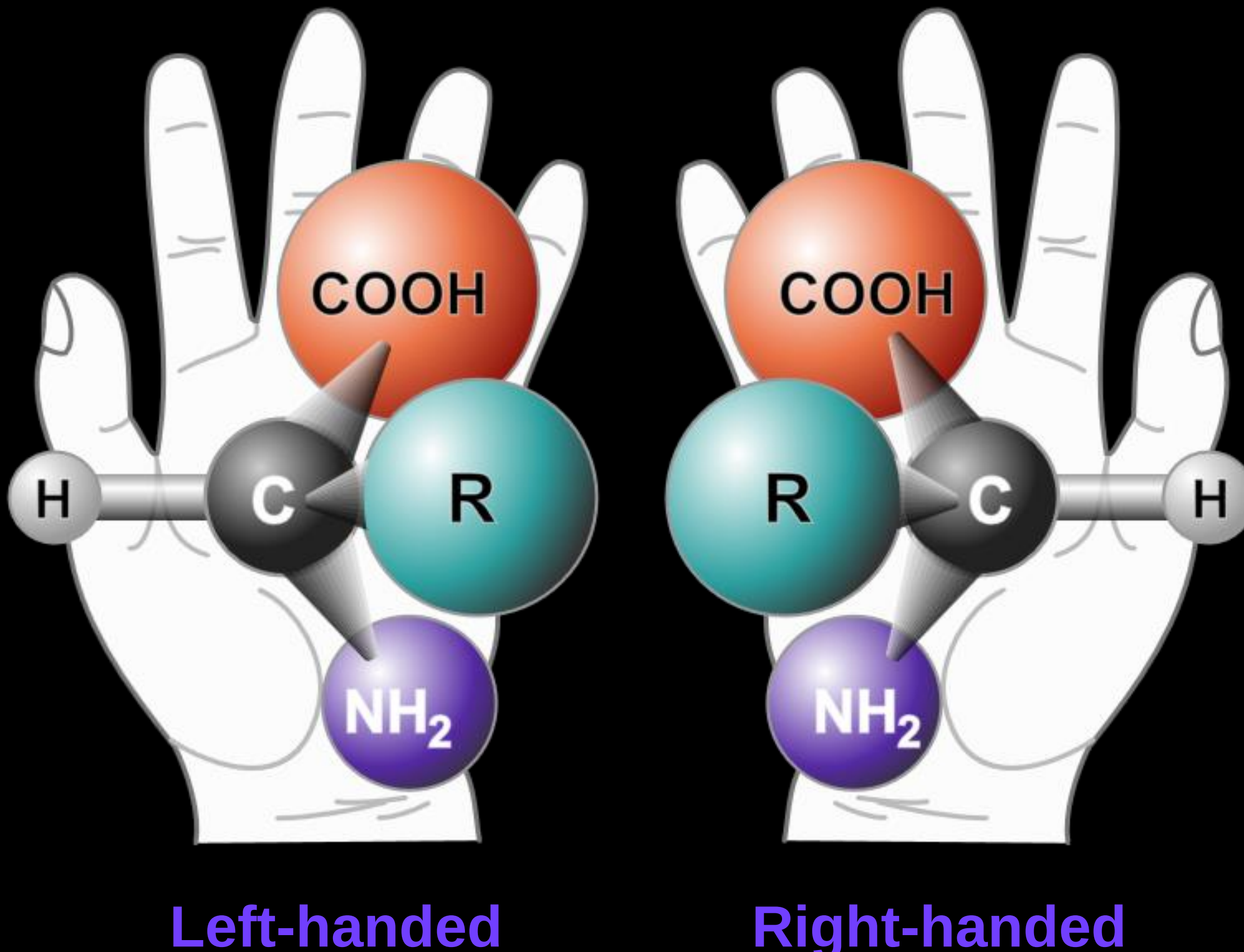
- Amino acids are exclusively left-handed and carbohydrates exclusively right-handed in living things
- Manufactured in the laboratory without special procedures, a 50-50 (racemic) mix of left- and right-handed types is obtained
- How homochirality in lifeforms came about is an unanswered question, but its existence seems strong evidence of common descent

Homochirality of Key Biomolecules

- Amino acids are exclusively left-handed and carbohydrates exclusively right-handed in living things
- Manufactured in the laboratory without special procedures, a 50-50 (racemic) mix of left- and right-handed types is obtained
- How homochirality in lifeforms came about is an unanswered question, but its existence seems strong evidence of common descent

Chirality or Handedness of Certain Molecules

Example: Generic Amino Acid



Left-handed and right-handed molecules can exhibit different chemical behavior. Thalidomide is an example. Left-handed version prevented morning sickness. Right-handed one caused severe birth defects. Marketed drug contained 50-50 (racemic) mix of the two, with tragic consequences. Image: Wikipedia "Chirality" article

Homochirality of Key Biomolecules

- Amino acids are exclusively left-handed and carbohydrates exclusively right-handed in living things
- Manufactured in the laboratory without special procedures, a 50-50 (racemic) mix of left- and right-handed types is obtained
- How homochirality in lifeforms came about is an unanswered question, but its existence seems strong evidence of common descent

History of Life

Evolution

Evidence of Evolution

Morphological

Common structural unit: cell

Transitional forms via fossils

Homologous structures

Morphological remnants

Morphological trees of life

Molecular

Common genetic material (DNA) and near-universal genetic code

Homochirality (key biomolecules)

Molecular remnants

Molecular trees of life

Other

Biogeographical

Real Time

Anthropogenic Damage to Biosphere

Morphological Remnants of Common Ancestry

- Similarities of young embryos
- Atavisms
- Vestiges
- Suboptimal "design"

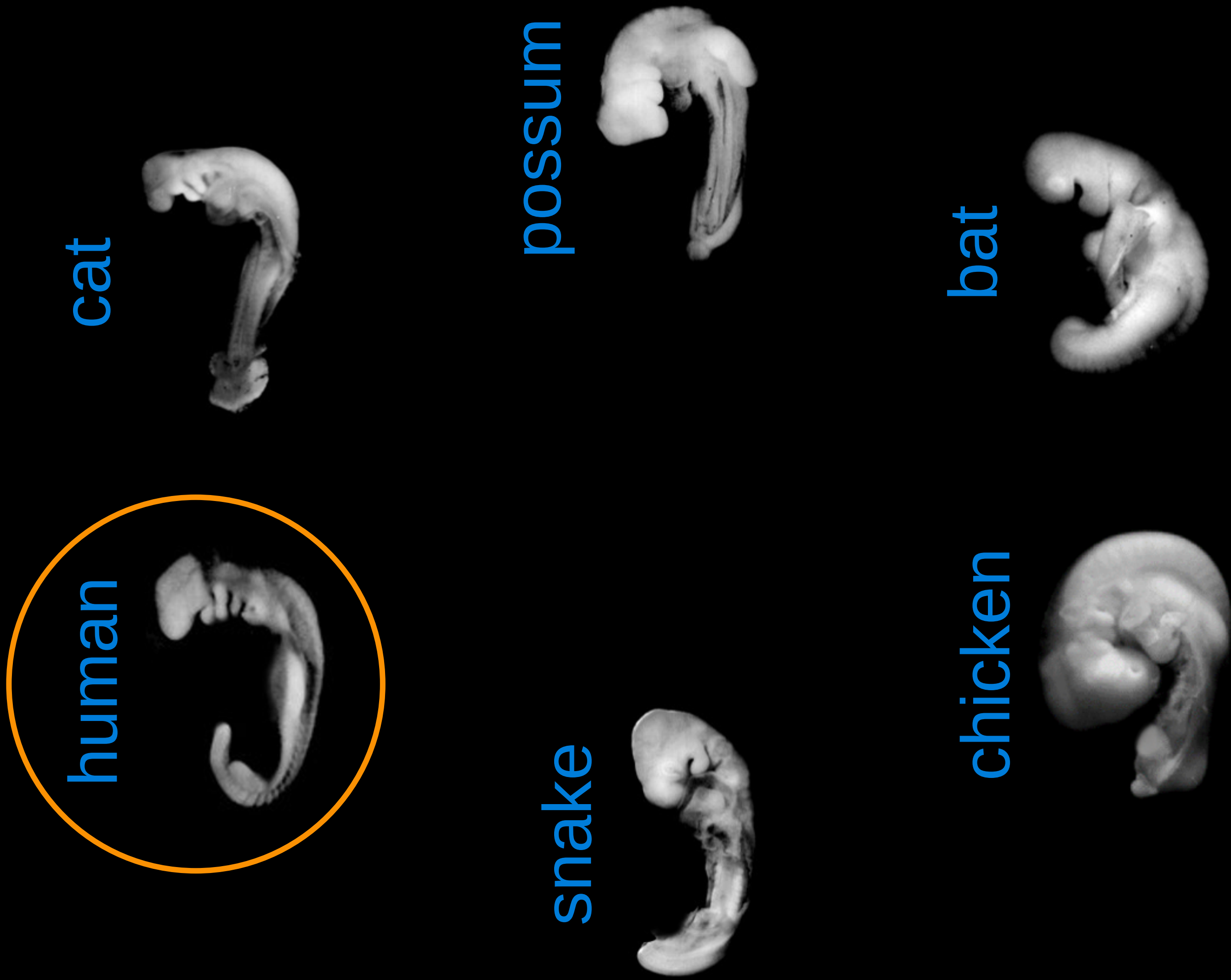
Similarity of Vertebrate Embryos – Tailbud Stage

Which one is human?

Photographs from Richardson et al (1997) https://www.ncbi.nlm.nih.gov/pubmed/9278154, with extraneous tissue removed

Similarity of Vertebrate Embryos – Tailbud Stage

Which one is human?



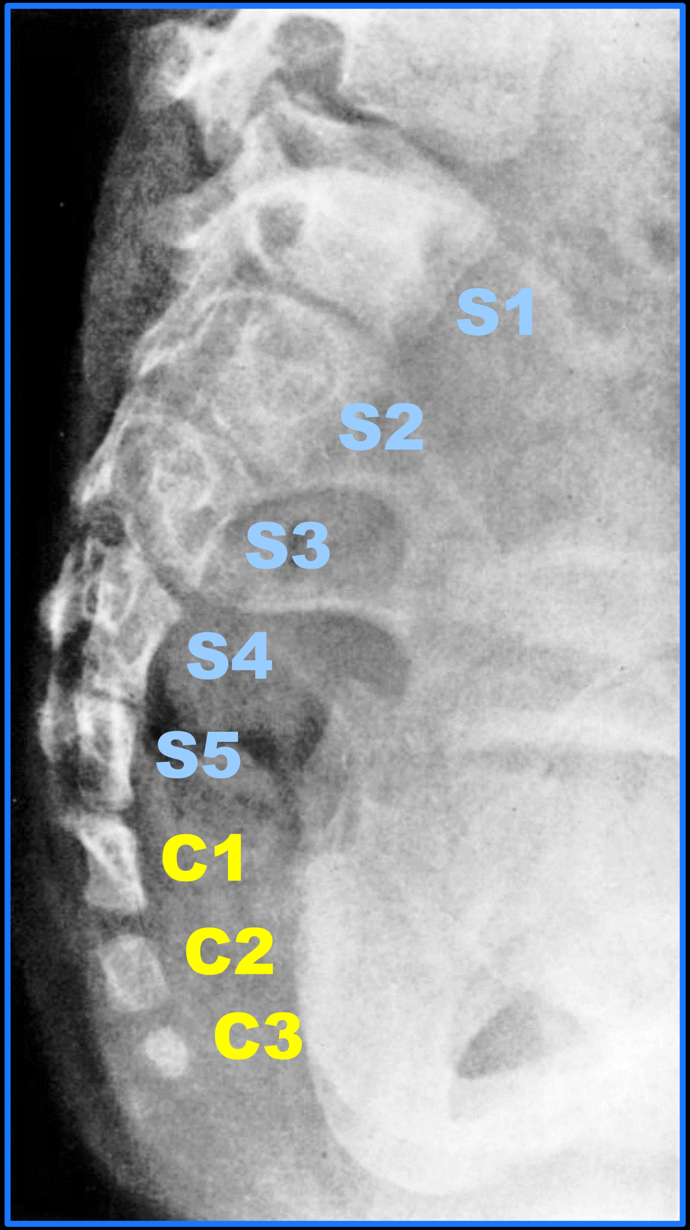
Point here is not that the embryos are indistinguishable, but that they are far more alike and primitive looking than adults of the species. It is far from obvious which embryo goes with which species

Morphological Remnants of Common Ancestry

- Similarities of young embryos
- Atavisms
- Vestiges
- Suboptimal "design"

Atavisms are sporadic occurrences

Atavism – Human Tail



X-ray image of atavistic tail found in a six-year old girl

The tail was perfectly midline and protruded form the lower back as a soft appendage. The five normal sacral vertebrae are indicated in light blue and numbered; the three coccygeal tail vertebrae are indicated in yellow. The entire coccyx (usually three or four tiny fused vertebrae) is normally the same size as the fifth sacral vertebrae. In this same study, the surgeons reported two other cases of an atavistic human tail, one with three tail vertebrae, one with five. All were benign, and only one was surgically "corrected" for cosmetic reasons

Description from Theobald "29+ Evidences for Macroevolution"

X-ray image (minus labels) from "Human Tails," Bar-Maor et al (1980), *Journal of Bone and Joint Surgery*

Atavism – Human Tail

3 month-old baby girl with 11 centimeter tail just prior to surgical removal. Shad and Biswas (2012) "An infant with caudal appendage" *BMJ Case Reports*

Morphological Remnants of Common Ancestry

- Similarities of young embryos
- Atavisms
- Vestiges
- Suboptimal "design"

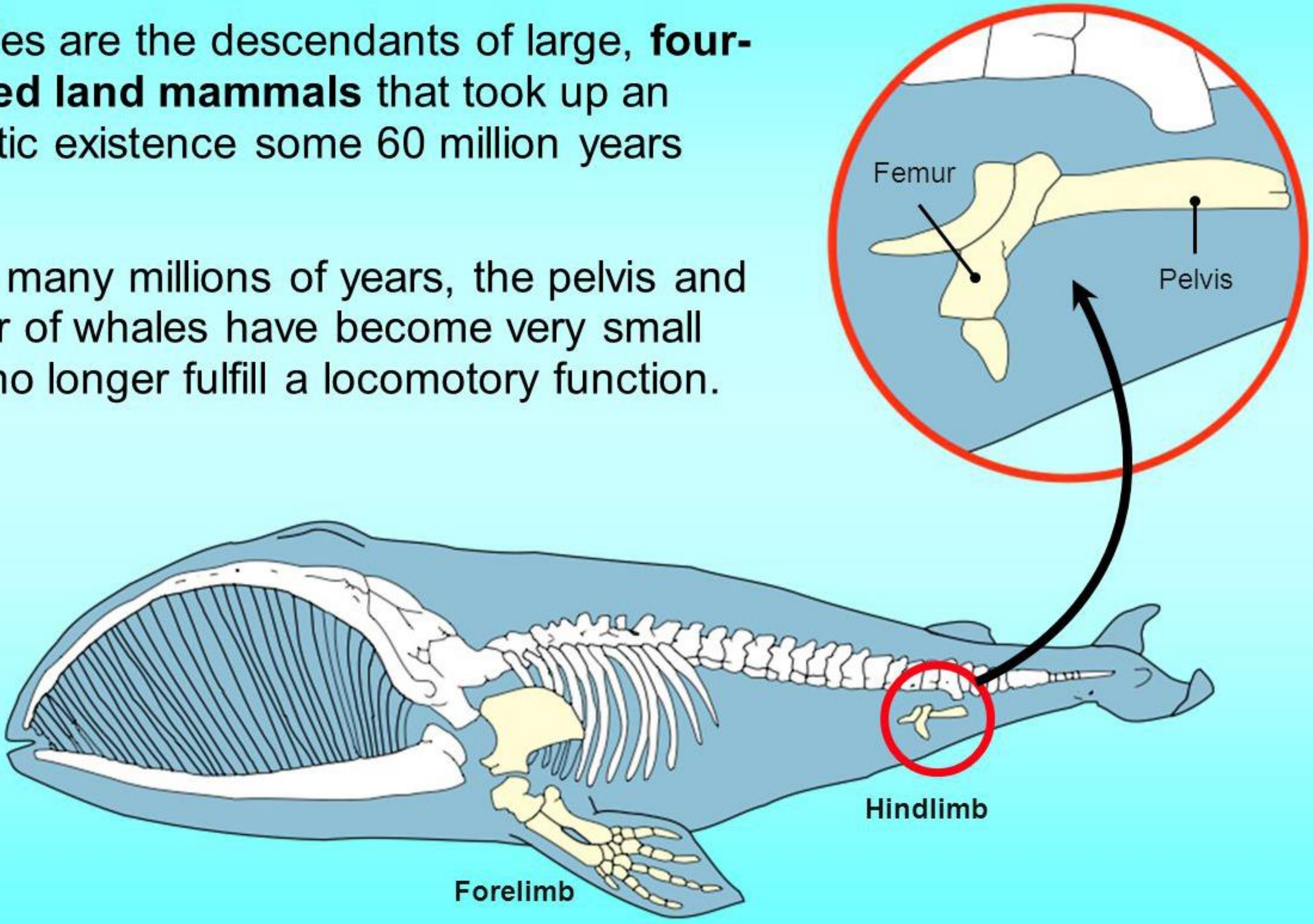
Vestiges, when they occur, are present in all members of the species

Vestige – Boa Constrictor Hindlimb Remnants

From Wikipedia "Vestigiality" article

Vestige – Whale Hind Limb Remnant

- Whales are the descendants of large, **four-legged land mammals** that took up an aquatic existence some 60 million years ago.
- Over many millions of years, the pelvis and femur of whales have become very small and no longer fulfill a locomotory function.



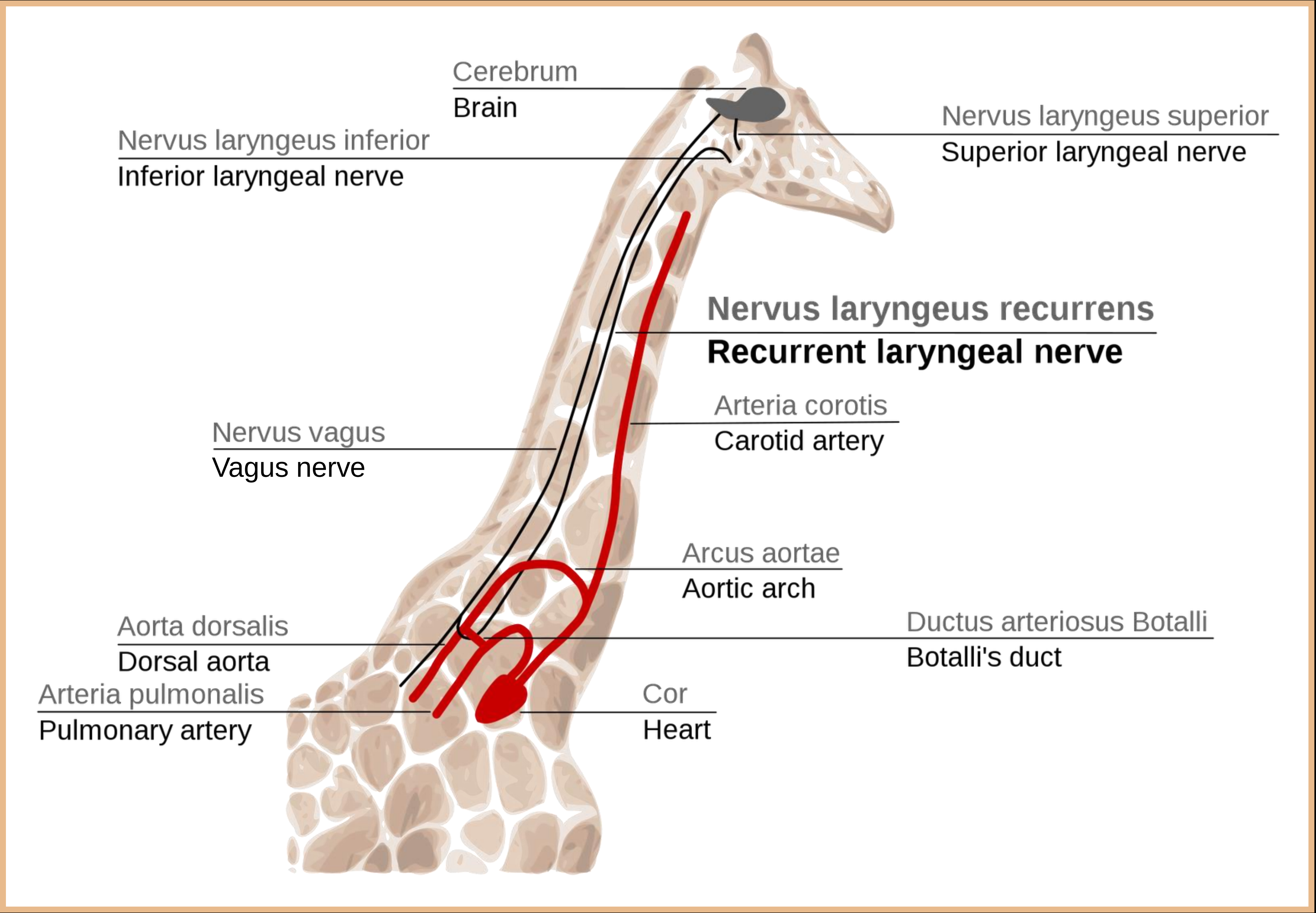
Notice also pentadactyl forelimb. Published by Anita Whitelow

Morphological Remnants of Common Ancestry

- Similarities of young embryos
- Atavisms
- Vestiges
- Suboptimal "design"

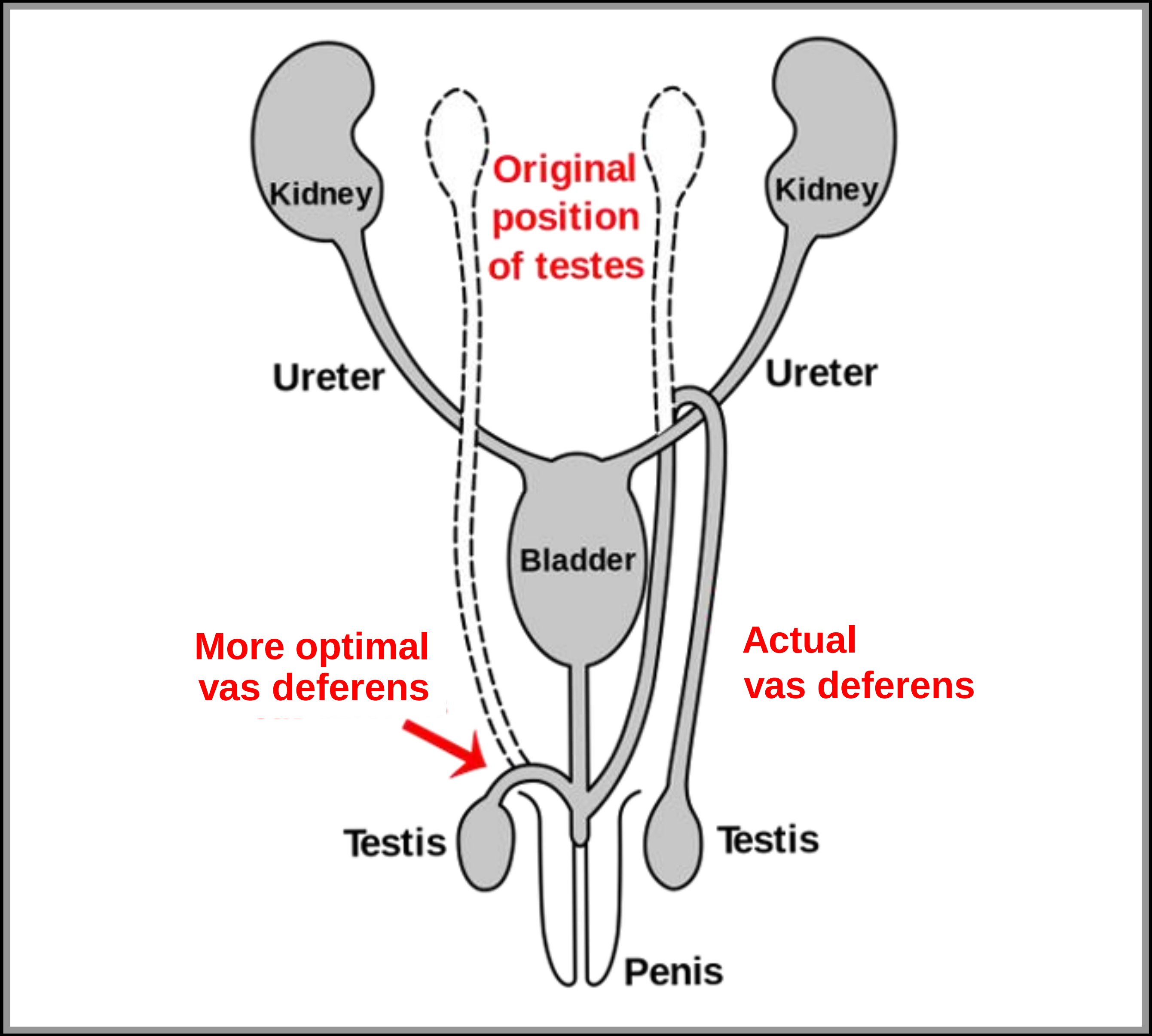
More precisely, lack of design

Suboptimal "Design"– Recurrent Laryngeal Nerve



Nerve has to loop around heart in humans too, but Giraffe represents extreme case. Source: Wikipedia

Suboptimal "Design"– Route of vas deferens



Human testicles initially in abdomen. In most cases they will have moved to their final position before birth. Sometimes they do not and require surgical correction. Clearly not an optimal design. Source: Wikipedia

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

Molecular Remnants of Common Ancestry

- Human endogenous retrovirus insertions. Vestiges of ancient viral infections that now reside stably in the human genome
- A mutated gene from some common ancestor that prevents primates (including humans) from making vitamin C. Most other animals can manufacture their own
- Any other DNA that is no longer necessary ("junk")

Molecular Remnants of Common Ancestry

- Human endogenous retrovirus insertions. Vestiges of ancient viral infections that now reside stably in the human genome
- A mutated gene from some common ancestor that prevents primates (including humans) from making vitamin C. Most other animals can manufacture their own
- Any other DNA that is no longer necessary ("junk")

Molecular Remnants of Common Ancestry

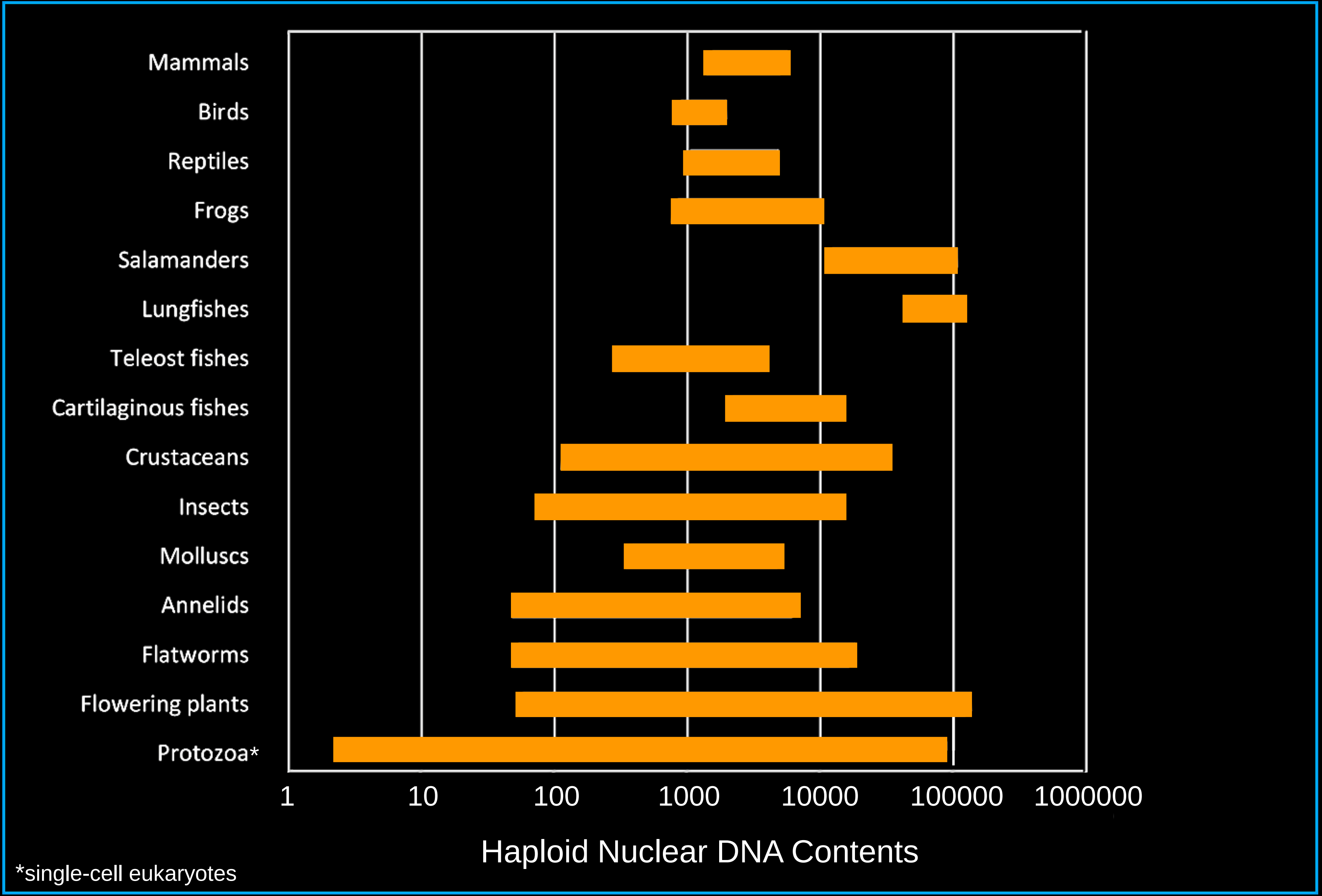
- Human endogenous retrovirus insertions. Vestiges of ancient viral infections that now reside stably in the human genome
- A mutated gene from some common ancestor that prevents primates (including humans) from making vitamin C. Most other animals can manufacture their own
- Any other DNA that is no longer necessary ("junk")

Junk DNA Dispute

- Evolutionary biologists tend to believe that a large fraction of DNA in many species – including humans – is junk
- Members of the ENCODE team, evaluating the human genome for active components, claim a large fraction of that genome is active and avoid use of word "junk"

Search "junk DNA" and/or "ENCODE" to find out more

Quantity of Genetic Material – Assorted Eukaryotes



From Palazzo and Gregory "The Case for Junk DNA" *PLOS Genetics* (2014)

With some of highest DNA content in oldest, simplest class of organism (protozoa), presence of junk DNA seems likely

As another example, an onion has 12 times more DNA than humans ("Why Onions Have More DNA Than You Do“ *Harvard Gazette*, 2000)

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

Trees of Life (Phylogenies)

- Common decent implies the existence of trees of life with branches delineating evolutionary relationships
- At ultimate root is LUCA, the Last Universal Common Ancestor* (not always shown)
- Trees can be inferred from both morphological and molecular data

*Exact nature of LUCA unknown, and might always be so. Also, LUCA was not necessarily the first lifeform

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

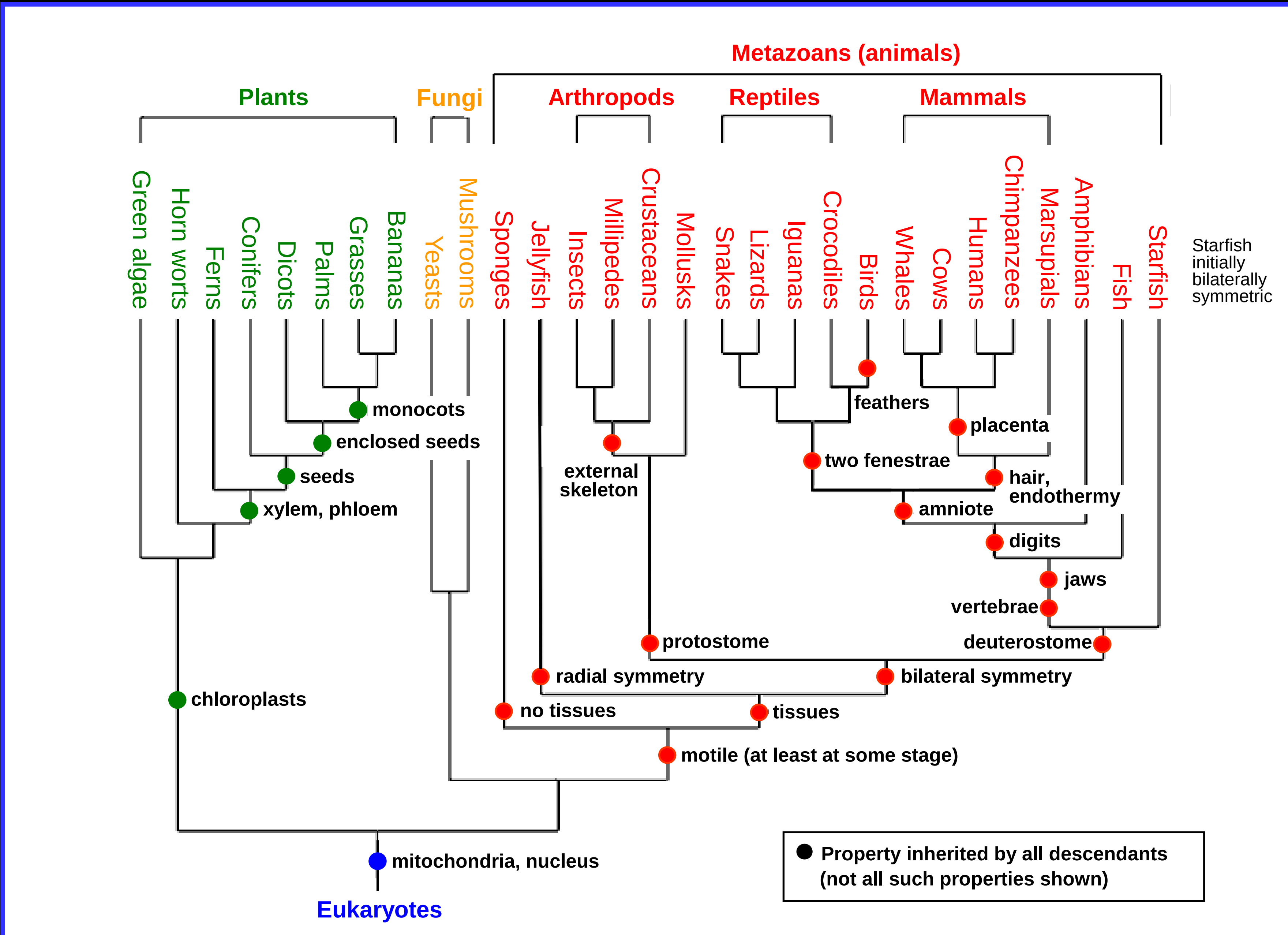
- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

Morphological Trees of Life

- Based on structure
- Only types employed from the first phylogenetic tree of Augustin Augier (1801) thru the early 1960s, when molecular techniques became available
- Only trees that can be constructed for extinct species (via fossils)

Eukaryote Morphological Tree of Life

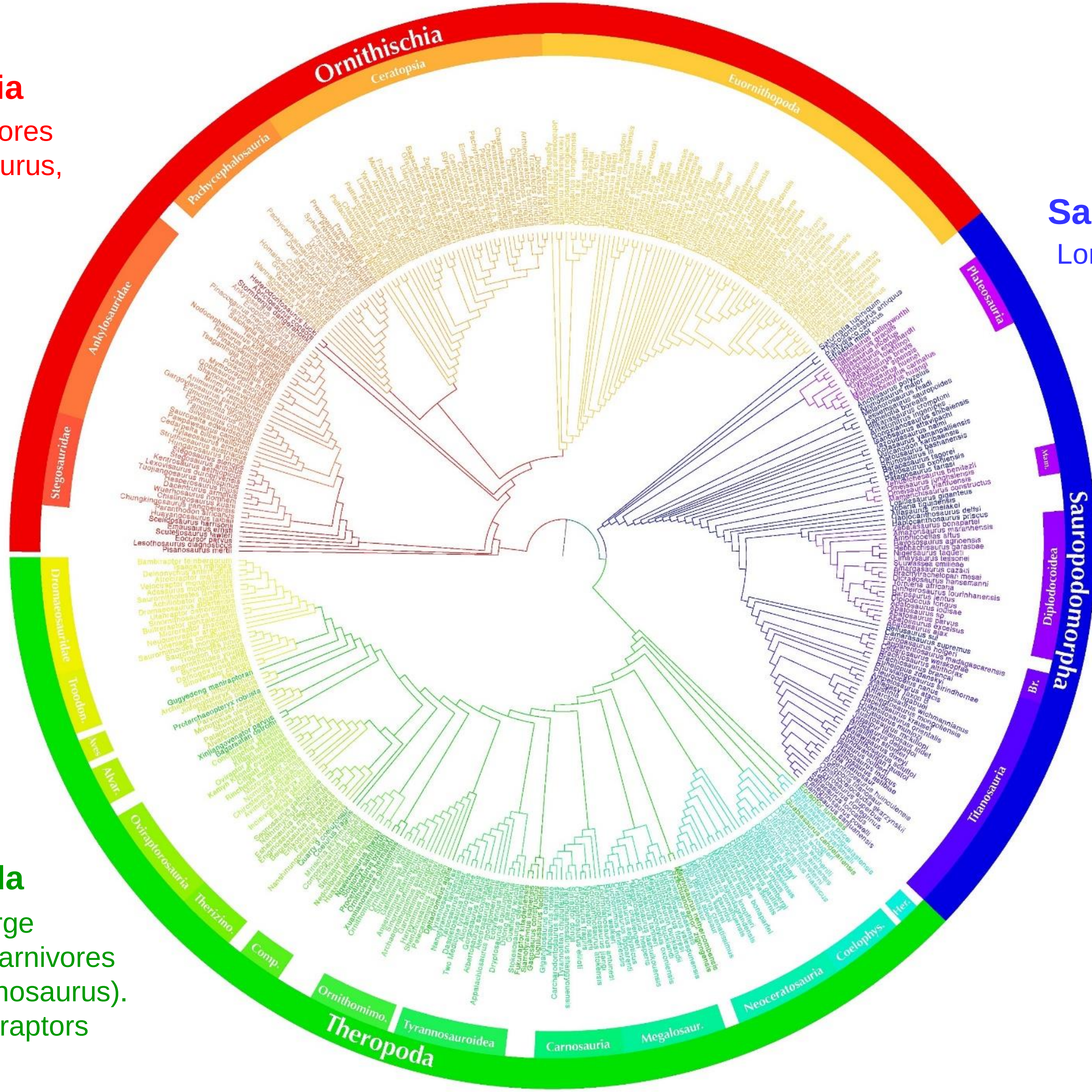


From Theobald "29+ Evidences for Macroevolution" www.talkorigins.org/faqs/comdesc/ (enhanced)

Dinosaur Morphological Tree of Life

Ornithischia

Mostly herbivores
(e.g. Stegosaurus,
Triceratops)



Sauropodomorpha

Long-necked herbivores
(e.g. Diplodocus)

Theropoda

Includes large
terrestrial carnivores
(e.g. Tyrannosaurus).
Also velociraptors

440 species. Lloyd et al, *Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2008.0715

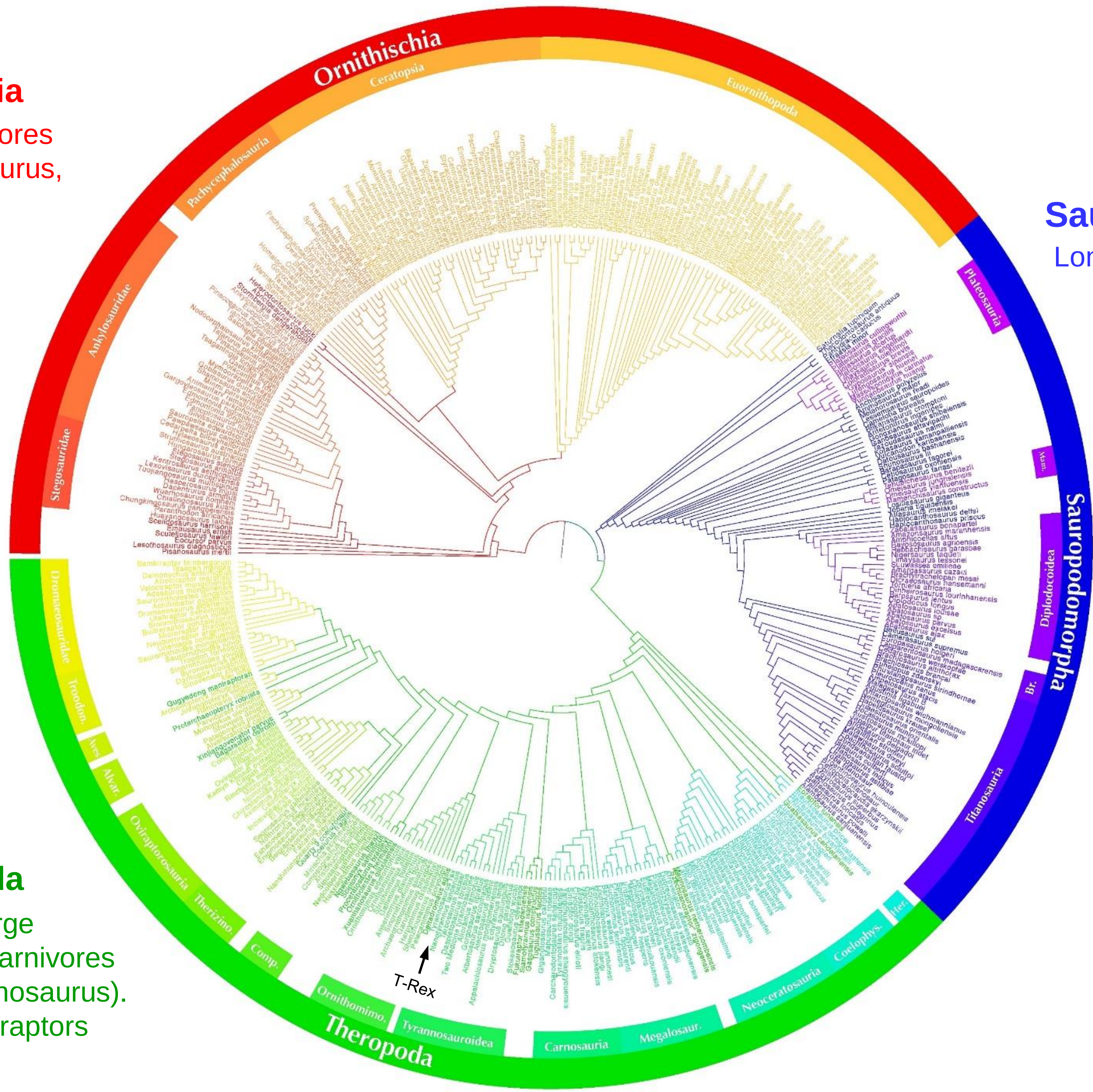
Dinosaur Morphological Tree of Life

Ornithischia

Mostly herbivores
(e.g. Stegosaurus,
Triceratops)

Sauropodomorpha

Long-necked herbivores
(e.g. Diplodocus)



Theropoda

Includes large
terrestrial carnivores
(e.g. Tyrannosaurus).
Also velociraptors

Yes . . . We have a T-Rex

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

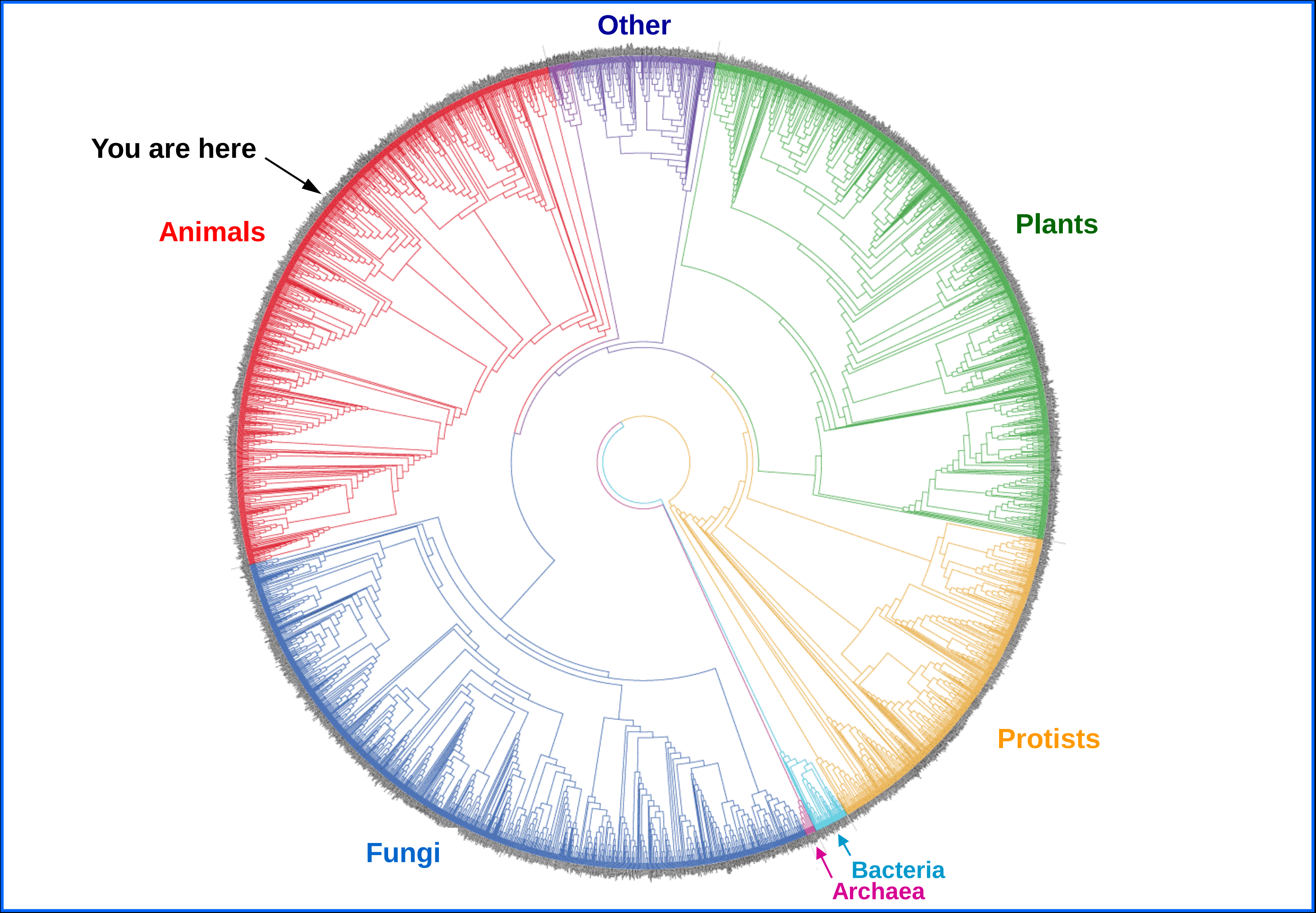
Anthropogenic Damage to Biosphere

Molecular Trees of Life

- Framework laid in 1960s
- Historical sequence of molecular trees studied: protein → ribosomal RNA → gene → genome*
- Constructed for species currently in existence

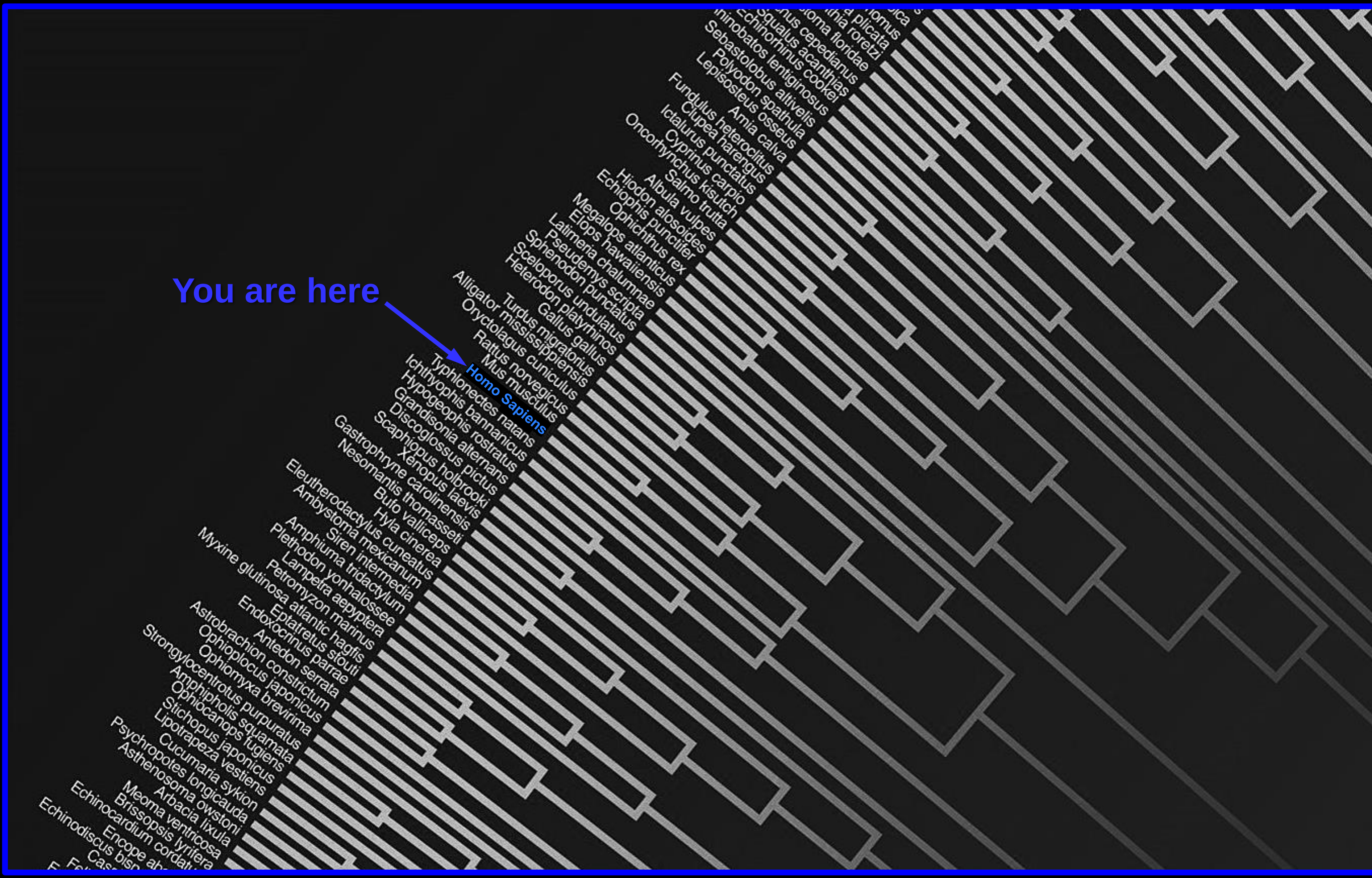
*Use of a significant portion of the genome (phylogenomics) reduces confounding effect of horizontal gene transfer. HGT, genes and genome defined below

Hillis Molecular Tree of Life



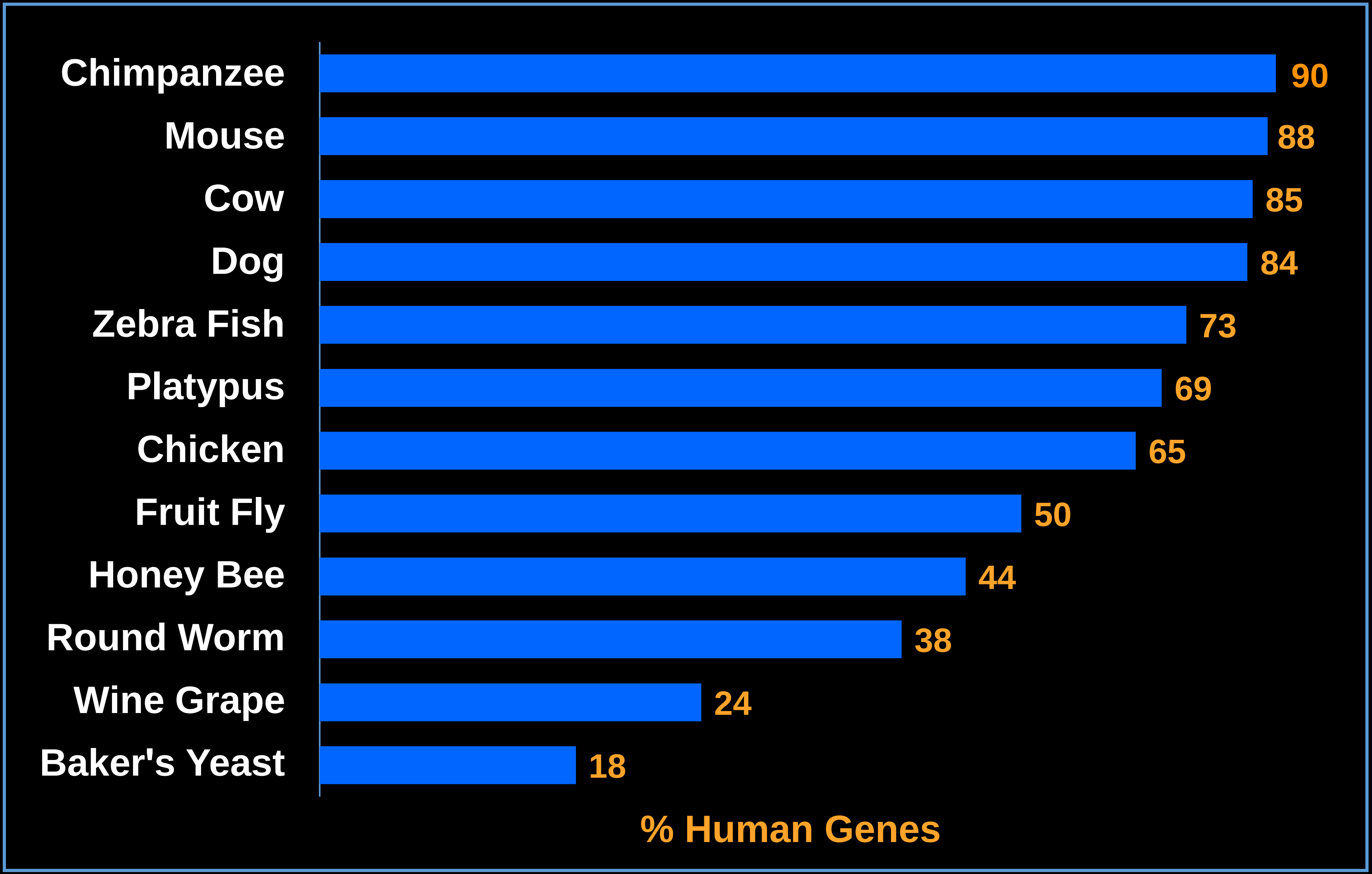
Current tree of life based on 18S rRNA from roughly 3000 species. David M. Hillis, Derrick Zwicki & Robin Gutell, University of Texas. Original B&W version in "Modernizing the Tree of Life" *Science* 13 Jun 2003

Hillis Tree – Detail



Source: Tom Bates: www.assortedscribbles.com/posts/The_Hillis_Plot

Human Genes in Other Lifeforms



Strange? More human genes in a mouse than in a dog. More in a zebra fish than in a chicken.
Data from Zimmer "Genes are Us. And Them" *National Geographic Magazine* (July 2013)

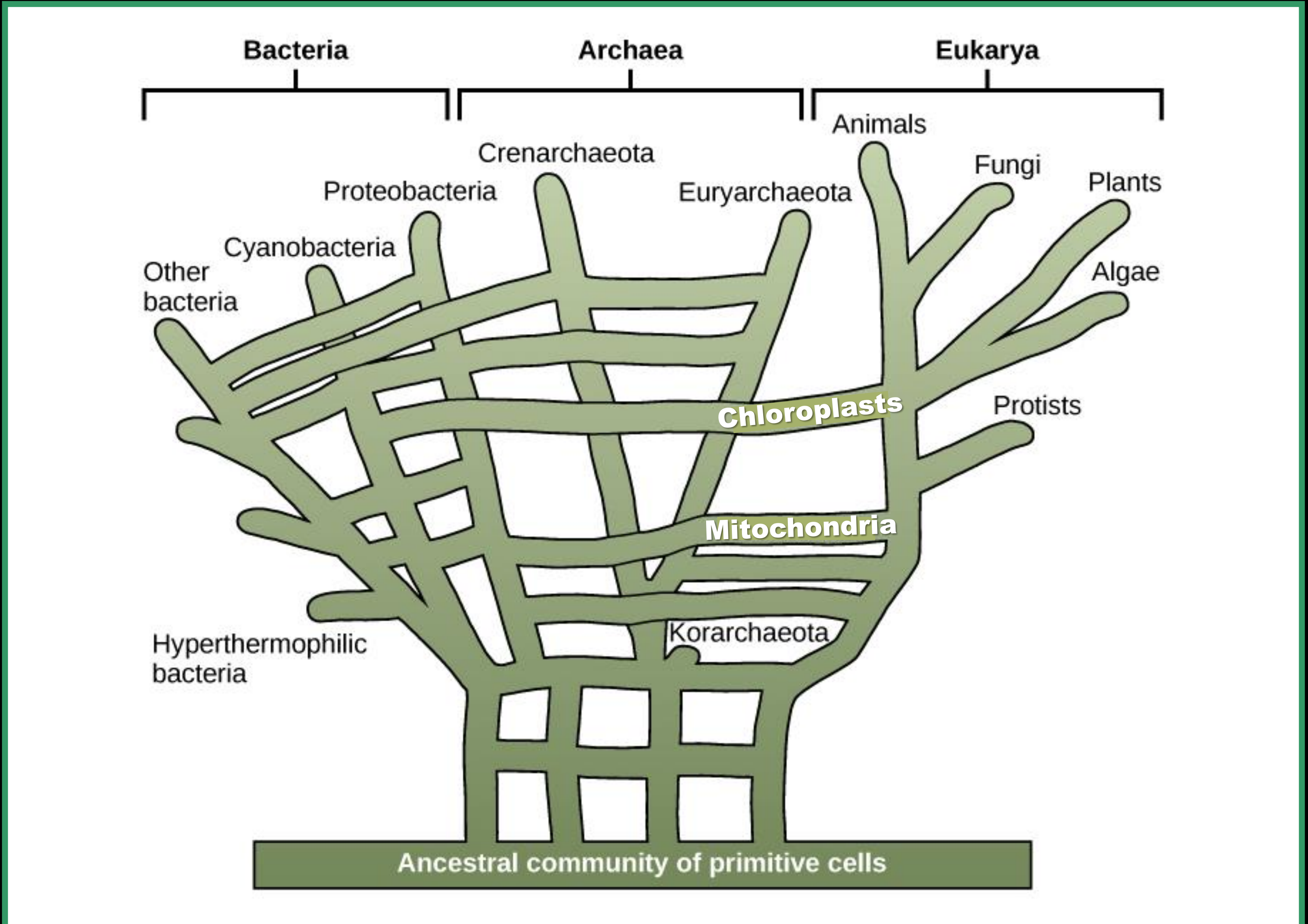
Horizontal Gene Transfer (HGT)

- Movement of genes between branches of tree of life (primarily, but not exclusively, among prokaryotes)
- Thought responsible for slightly different genetic codes in (i) some prokaryotes and (ii) chloroplasts / mitochondria of eukaryotes
- Confounds data used in molecular tree construction
- Impact can be minimized by using multiple genes in molecular tree construction – i.e. phylogenomics

Horizontal Gene Transfer (HGT)

- Movement of genes between branches of tree of life (primarily, but not exclusively, among prokaryotes)
- Thought responsible for slightly different genetic codes in (i) some prokaryotes and (ii) chloroplasts / mitochondria of eukaryotes
- Confounds data used in molecular tree construction
- Impact can be minimized by using multiple genes in molecular tree construction – i.e. phylogenomics

Web of Life – Alternative to Tree of Life



From Biology LibreTexts Project. Modification of work by "psyberartist"/Flickr

Horizontal Gene Transfer (HGT)

- Movement of genes between branches of tree of life (primarily, but not exclusively, among prokaryotes)
- Thought responsible for slightly different genetic codes in (i) some prokaryotes and (ii) chloroplasts / mitochondria of eukaryotes
- Confounds data used in molecular tree construction
- Impact can be minimized by using multiple genes in molecular tree construction – i.e. phylogenomics

Horizontal Gene Transfer (HGT)

- Movement of genes between branches of tree of life (primarily, but not exclusively, among prokaryotes)
- Thought responsible for slightly different genetic codes in (i) some prokaryotes and (ii) chloroplasts / mitochondria of eukaryotes
- Confounds data used in molecular tree construction
- Impact can be minimized by using multiple genes in molecular tree construction – i.e. phylogenomics

Genes to Genome

Increasing Information

- **Gene – DNA segment that codes for some aspect of a living thing. Humans have 20-25 thousand in total**
- **DNA – Large gene-containing molecule with double-helix structure**
- **Chromosome – Thread-like, gene-carrying structure made-up primarily of DNA and protein**
- **Genome – Full set of an organism's chromosomes. Contained in every cell. Includes all information needed for growth, maintenance and reproduction**

Genes to Genome

Increasing Information

- Gene – DNA segment that codes for some aspect of a living thing. Humans have 20-25 thousand in total
- DNA – Large gene-containing molecule with double-helix structure
- Chromosome – Thread-like, gene-carrying structure made-up primarily of DNA and protein
- Genome – Full set of an organism's chromosomes. Contained in every cell. Includes all information needed for growth, maintenance and reproduction

Genes to Genome

Increasing Information

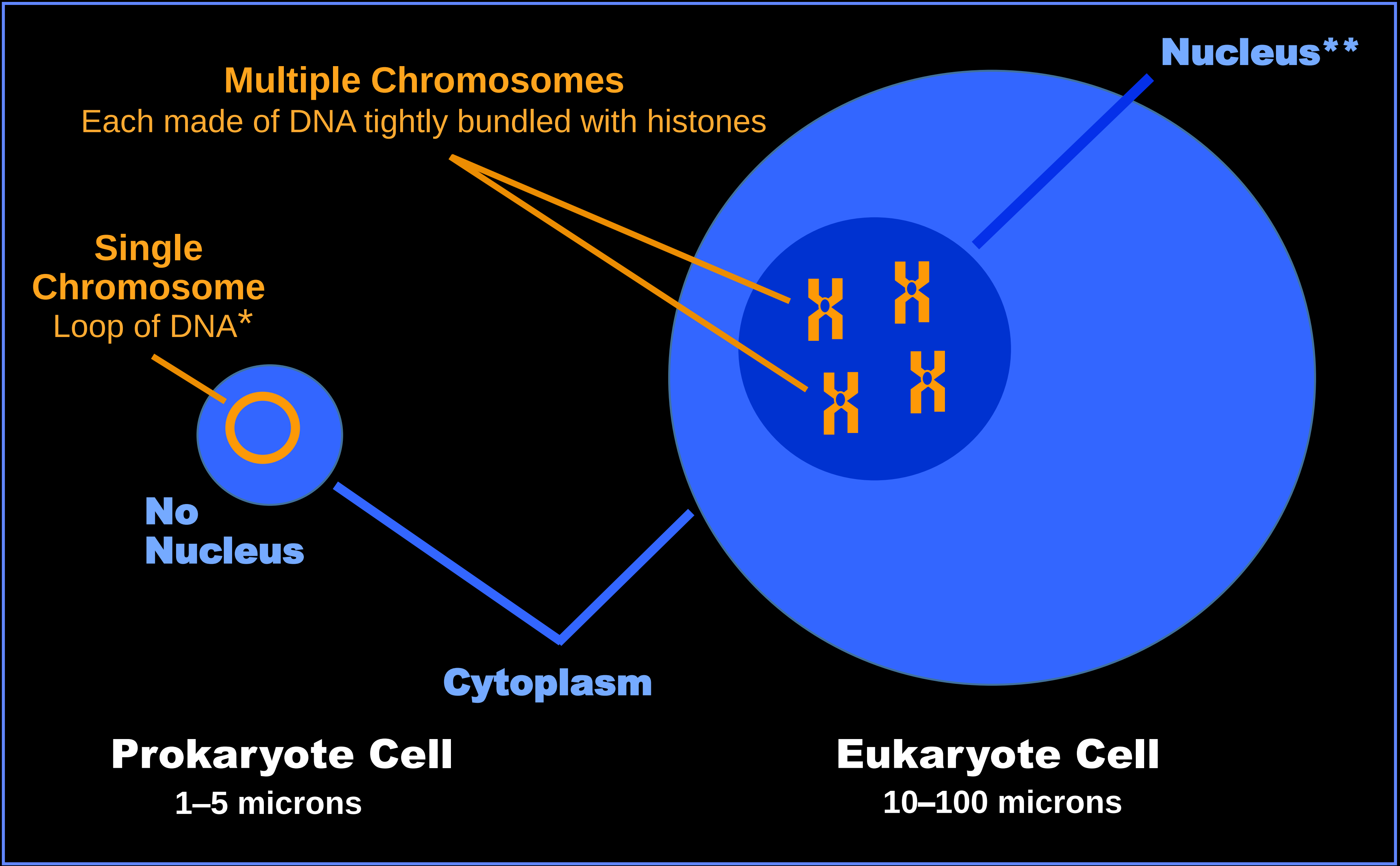
- **Gene – DNA segment that codes for some aspect of a living thing. Humans have 20-25 thousand in total**
- **DNA – Large gene-containing molecule with double-helix structure**
- **Chromosome – Thread-like, gene-carrying structure made-up primarily of DNA and protein**
- **Genome – Full set of an organism's chromosomes. Contained in every cell. Includes all information needed for growth, maintenance and reproduction**

Genes to Genome

Increasing Information

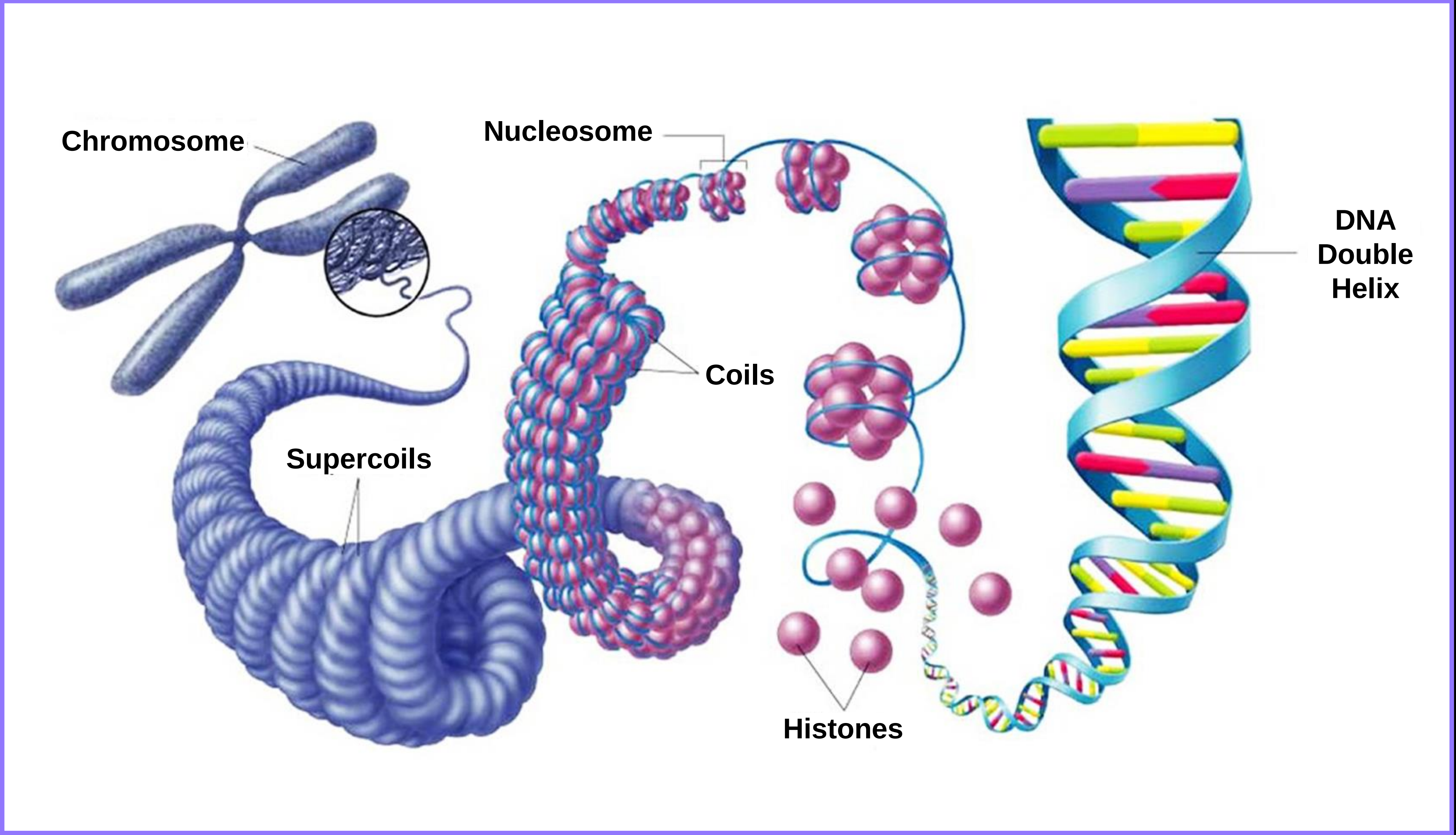
- Gene – DNA segment that codes for some aspect of a living thing. Humans have 20-25 thousand in total
- DNA – Large gene-containing molecule with double-helix structure
- Chromosome – Thread-like, gene-carrying structure made-up primarily of DNA and protein
- Genome – Full set of an organism's chromosomes. Contained in every cell. Includes all information needed for growth, maintenance and reproduction

Prokaryote vs Eukaryote Chromosomes



*****Loop not actually circular. ******Human cell nucleus is roughly 6 microns in diameter. Its 23 pairs of chromosomes occupy only a small fraction of it

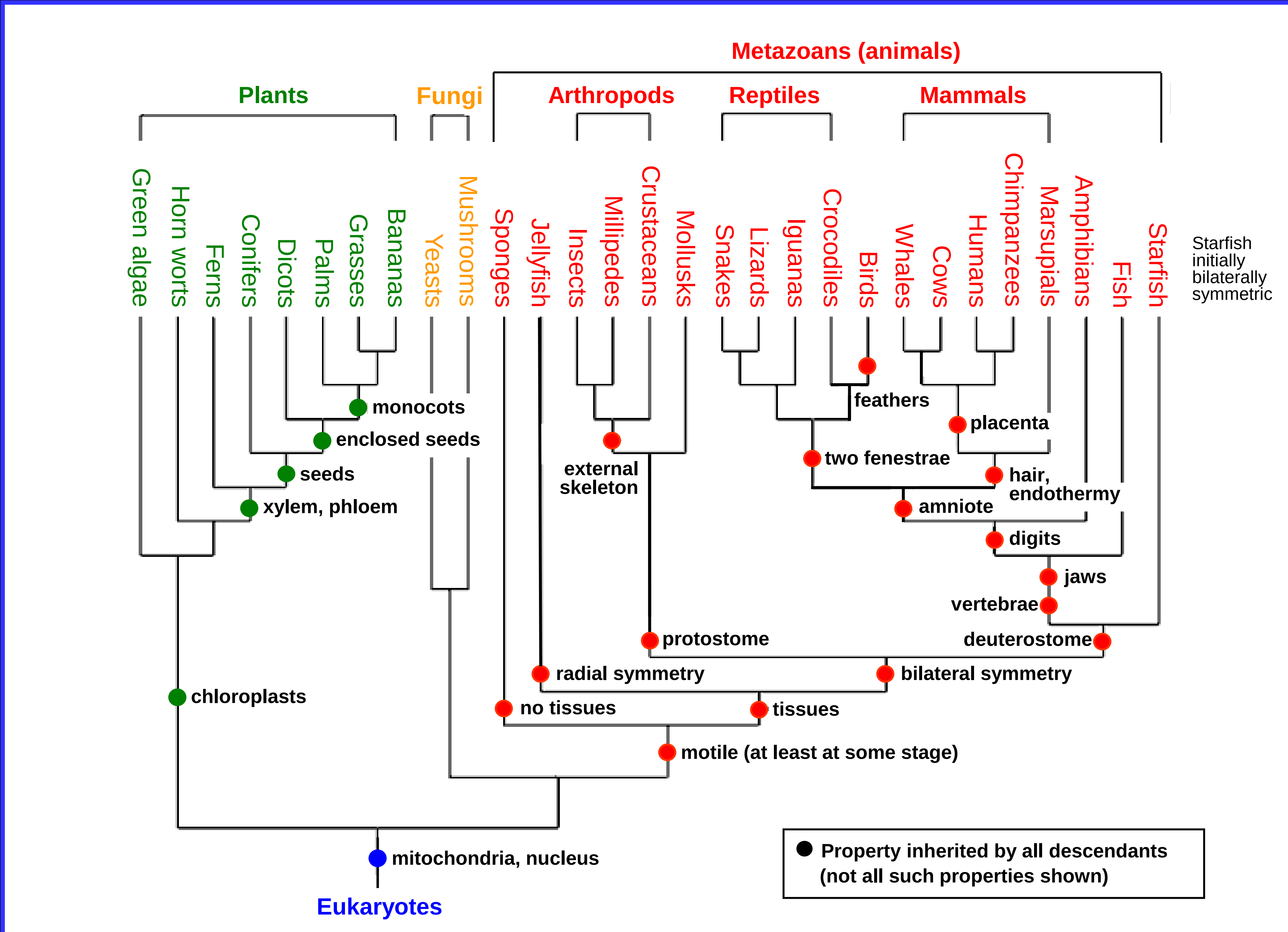
Eukaryote Chromosome – DNA Bundling



Unwound, human DNA molecule is roughly as long as a human is tall. Histones are proteins.

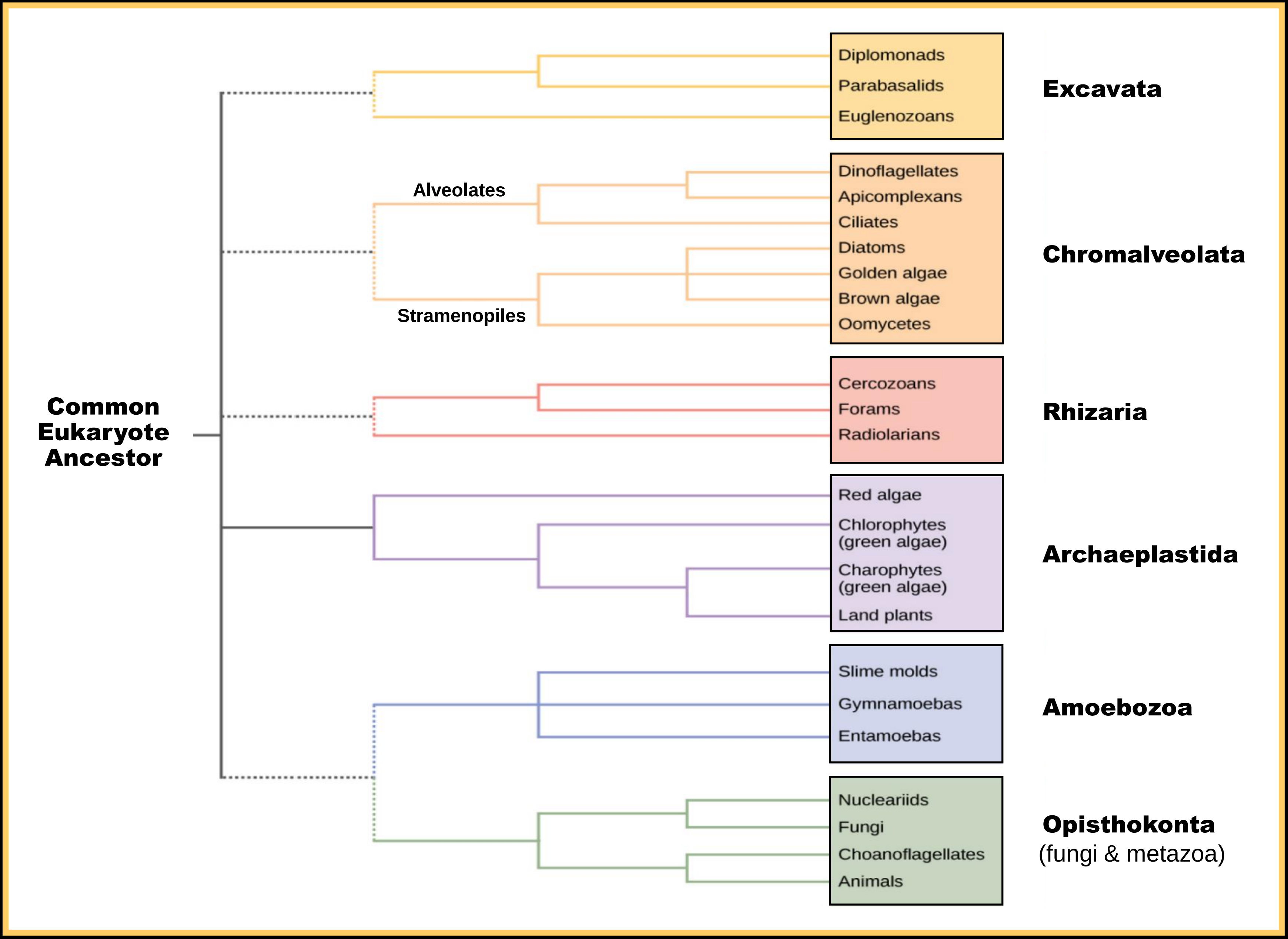
Phylogenomics has fine-tuned the Eukaryote tree of life

Recall Eukaryote Morphological Tree of Life



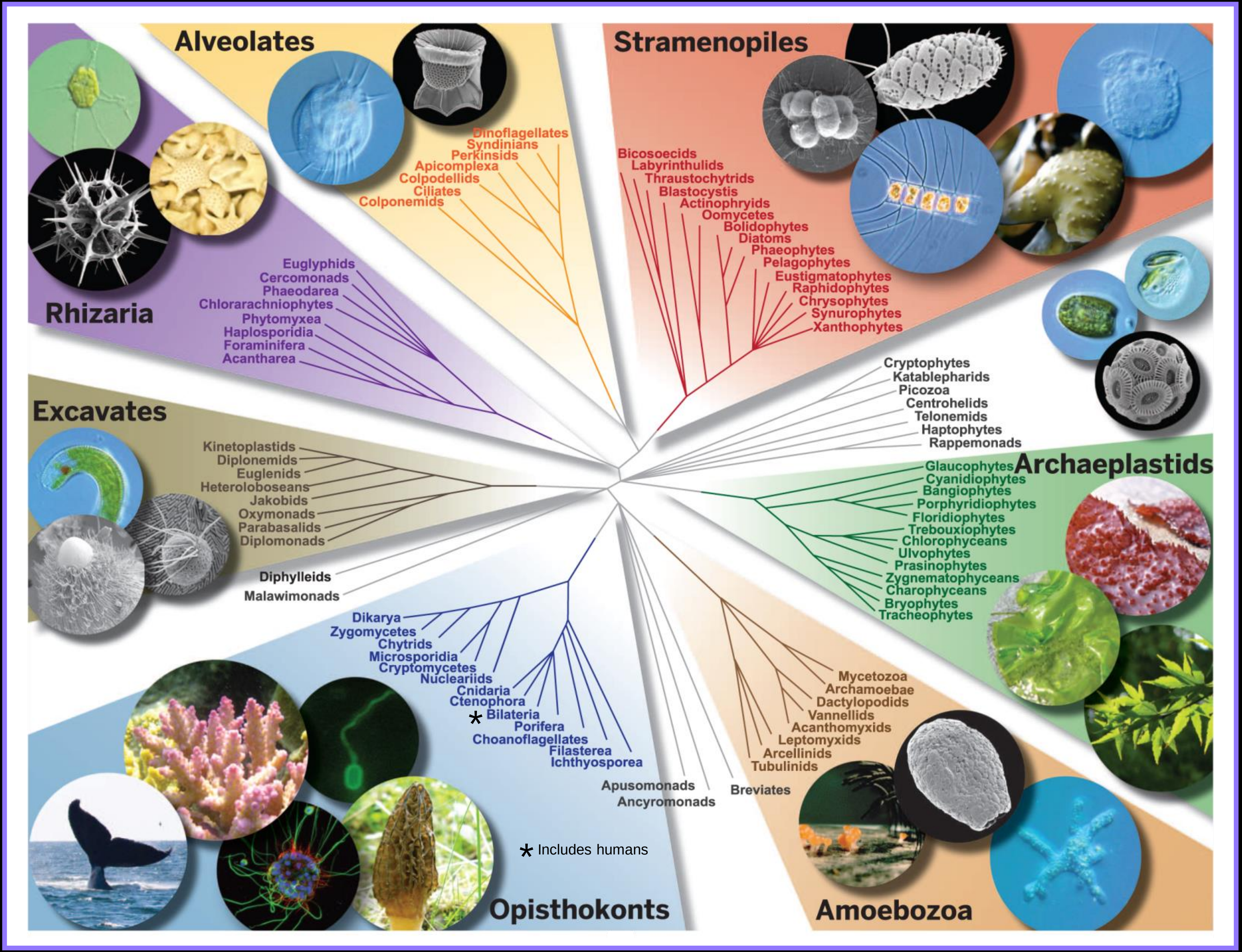
From Theobald "29+ Evidences for Macroevolution" www.talkorigins.org/faqs/comdesc/ (enhanced)

Eukaryote Phylogenomic Tree of Life



Based primarily on molecular evidence. From *Concepts of Biology*, OpenStax (2016)

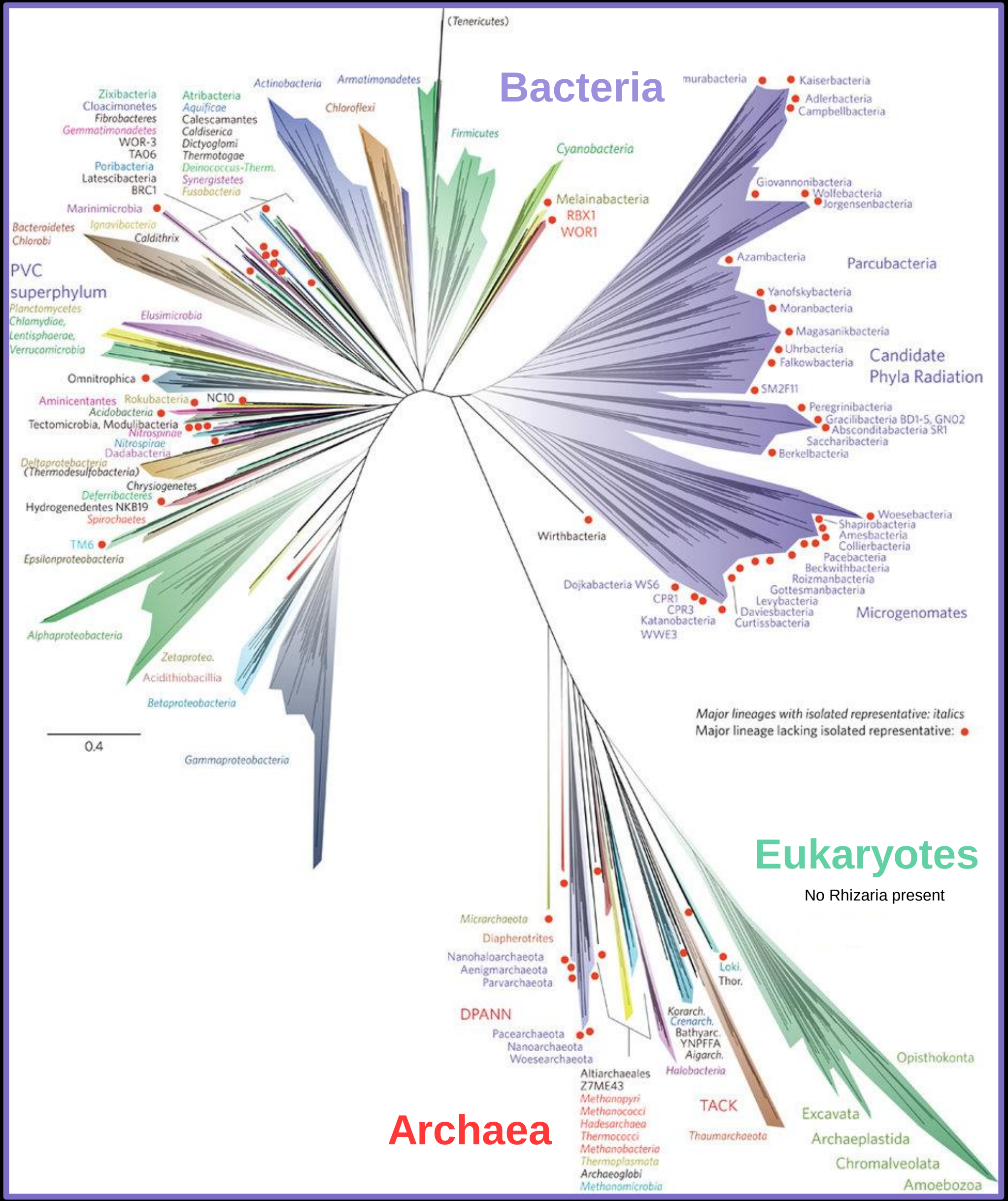
Eukaryote Phylogenomic Tree of Life



From Worden at al, *Science* (Feb 13, 2015) based on Burki (2014) "The Eukaryotic Tree of Life ..." Cold Springs Harbor. Eukaryotes in white area are orphans (no named group)

As for the whole shebang . . . . .

Phylogenomic Tree of All Life



Based on sixteen rRNA sequences from each of 3083 species. From Hug et al (2016), "A new view of the tree of life," *Nature Microbiology.* Dominated by bacteria

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

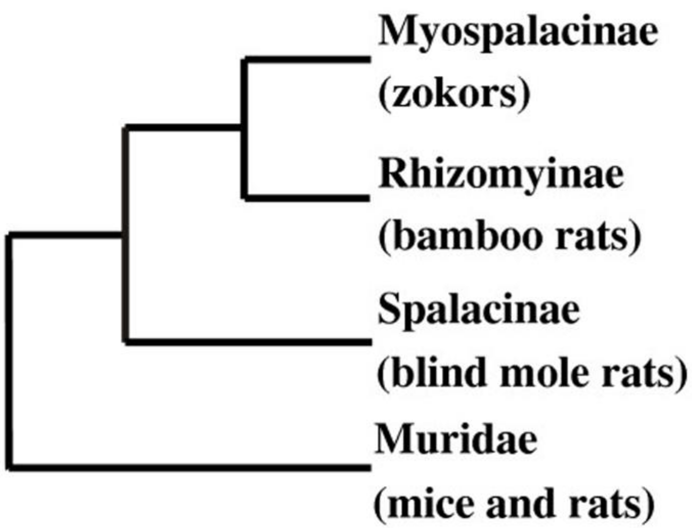
Other

- Biogeographical
- Real Time

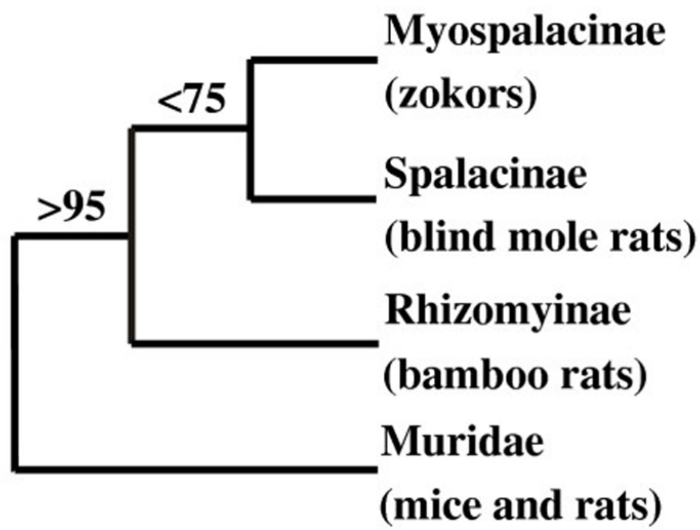
Anthropogenic Damage to Biosphere

Morphological vs Molecular Rodent Trees

Morphological



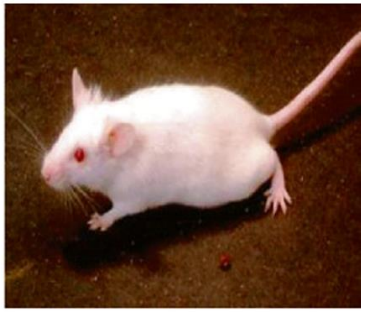
Molecular




zokor

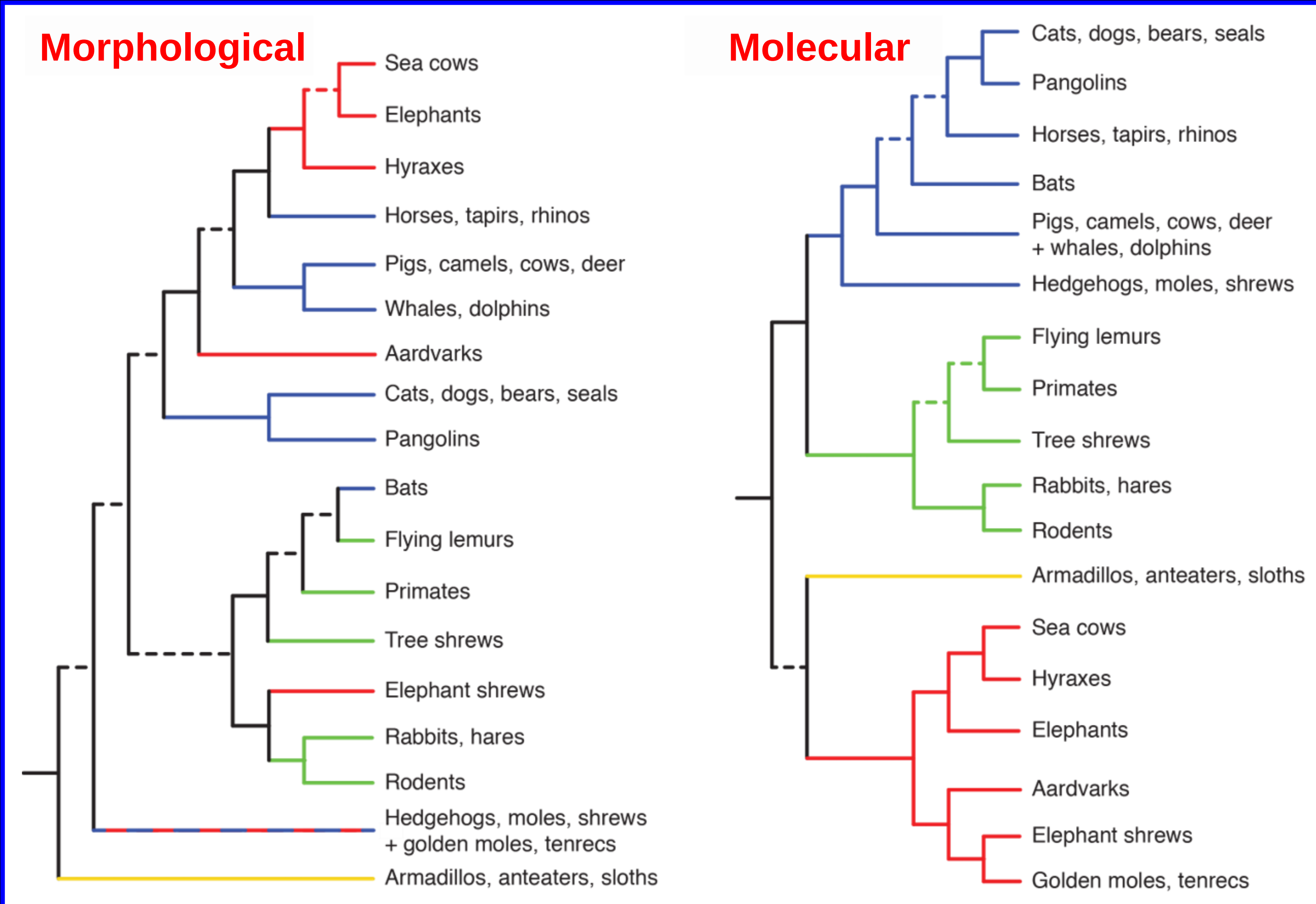

bamboo rat


blind mole rat


mouse

From Gong-Hua Lin, et al (2014) "Transcriptome sequencing and phylogenomic resolution within Spalacidae (Rodentia)" *BMC Genomics*. Molecular tree inferred from IRBP (interphotoreceptor retinoid-binding protein) and GHR (growth hormone receptor)

Morphological vs Molecular Mammal Trees



From Peter D. Heintzman "Tweaking the mammal family tree with ancient DNA and fossil proteins" 2015

Morphological vs Molecular Trees of Life

- As in above two examples, morphological and molecular trees generally disagree to some extent*
- Some discrepancies might be reduced (or not) through more extensive use of phylogenomics

*At least in 30+ random spot-checks

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

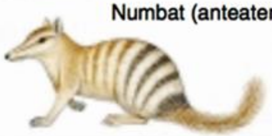
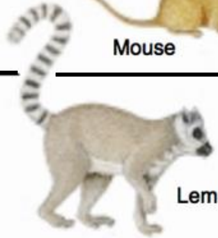
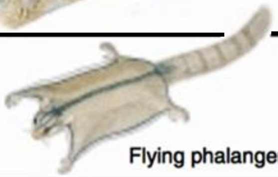
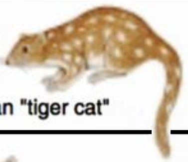
- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

Biogeographical Evidence of Evolution

- Geographically isolated regions produce unique species (e.g. Australia)
- Animals and plants on islands are most similar to species on the nearest mainland. On islands more than 300 miles from a mainland, mammals are almost never present

Homoplasy – Convergent Evolution

Niche	Placental Mammal	Australian Marsupial
Burrower	Mole 	Marsupial mole 
Anteater	Lesser anteater 	Numbat (anteater) 
Mouse	Mouse 	Marsupial mouse 
Climber	Lemur 	Spotted cuscus 
Glider	Flying squirrel 	Flying phalanger 
Cat	Ocelot 	Tasmanian "tiger cat" 
Wolf	Wolf 	Tasmanian wolf 

Above marsupials evolved in an isolated Australia without placentals. Source: Chegg Study

Biogeographical Evidence of Evolution

- Geographically isolated regions produce unique species (e.g. Australia)
- Animals and plants on islands are most similar to species on the nearest mainland. On islands more than 300 miles from a mainland, mammals are almost never present*

*Unless introduced by humans

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

Real-Time Evidence of Evolution

- Selective breeding (artificial selection)
- Evolved antibiotic resistance
- Evolved vaccine resistance (need for annual flu shots)
- Industrial melanism (peppered moth)
- Lenski long-term E. coli experiment

Real-Time Evidence of Evolution

- Selective breeding (artificial selection)
- Evolved antibiotic resistance
- Evolved vaccine resistance (need for annual flu shots)
- Industrial melanism (peppered moth)
- Lenski long-term E. coli experiment

Real-Time Evidence of Evolution

- Selective breeding (artificial selection)
- Evolved antibiotic resistance
- Evolved vaccine resistance (need for annual flu shots)
- Industrial melanism (peppered moth)
- Lenski long-term E. coli experiment

Real-Time Evidence of Evolution

- Selective breeding (artificial selection)
- Evolved antibiotic resistance
- Evolved vaccine resistance (need for annual flu shots)
- Industrial melanism (peppered moth)
- Lenski long-term E. coli experiment

Real Time Evolution – Industrial Melanism

Most Prevalent Before Industrial Revolution

Most Prevalent During Industrial Revolution

Industrial revolution pollution darkened surfaces where light colored peppered moths lived and were camouflaged. This favored reproduction of previously rare dark colored moths. After the revolution and the return of cleaner air, there was a return of the lighter colored moths

Criticisms of evidence – e.g. *Of Moths and Men* by Judith Hooper (2002) – have been discredited by research of Michael Majerus. See Cook et al, "Selective Bird Predation on the Peppered Moth: the Last Experiment of Michael Majerus" *Biology Letters* (2012)

Real-Time Evidence of Evolution

- Selective breeding (artificial selection)
- Evolved antibiotic resistance
- Evolved vaccine resistance (need for annual flu shots)
- Industrial melanism (peppered moth)
- Lenski long-term E. coli experiment

Lenski Long-Term E. coli Experiment

- Tracks changes in twelve initially identical asexually reproducing bacteria populations
- Begun in 1988
- Reached 66,000 generations in 2016
- Array of changes observed
- One population developed ability to digest citrate (not thought possible at outset)

Wikipedia article "E. coli long-term evolution experiment." Project of R. E. Lenski, MSU

History of Life

Evolution

Evidence of Evolution

Morphological

- Common structural unit: cell
- Transitional forms via fossils
- Homologous structures
- Morphological remnants
- Morphological trees of life

Molecular

- Common genetic material (DNA) and near-universal genetic code
- Homochirality (key biomolecules)
- Molecular remnants
- Molecular trees of life

Other

- Biogeographical
- Real Time

Anthropogenic Damage to Biosphere

An anthropogenic (human-caused) mass extinction event appears to be underway

Nature's Dangerous Decline "Unprecedented"; Species Extinction Rates "Accelerating"

Media Release

IPBES Report (2019)

IPBES = Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

Nature Declining at Rate Unprecedented in Human History*

- Human activities & natural trends have converged to severely alter natural world. Nature declining globally at rates unprecedented in human history. 75% of land-based environment and roughly 66% of marine environment significantly altered by human actions. Trends less severe or avoided in areas held or managed by indigenous peoples and local communities
- Nearly one million species at risk of extinction from human activities. Loss of clean air, drinkable water, pollinating insects, forests, and species pose a threat to life as great as climate change. Many experts believe a new mass extinction event is under way

*Based on Monica Dean (United Nations Foundation) summary of key findings of Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) 2019 Media Release

Nature Declining at Rate Unprecedented in Human History

- Loss of biodiversity increases challenge of curtailing climate change. Failure to protect natural world costs us our biggest asset, because healthy ecosystems absorb atmospheric carbon. Protecting / restoring natural carbon sinks & sustainable land management also improve biodiversity, water, and soil, as well as human health
- Climate change is intensifying biodiversity loss. In areas where ecosystems are vulnerable, impacts of climate change will be even more significant. It is more difficult for degraded systems to adapt to climate change, making impacts, such as flooding and wildfires, more damaging

IPCC Special Report on Global Warming of 1.5 °C

Summary for Policy Makers

Prepared for UNFCCC (2018)

IPCC = Intergovernmental Panel on Climate Change. UNFCCC = United Nations Framework Convention on Climate Change. 1.5 °C refers to rise above pre-industrial temperature levels

Impact of 1.5 & 2.0 °C Warming

Change	1.5°C over preindustrial	2.0°C over preindustrial
Global population experiencing extreme heat at least once every 5 years (%)	14	37
Vertebrate species losing at least half of range (%)	4	8
Plant species losing at least half of range (%)	8	16
Insect species losing at least half of range (%)	6	18
Land area with ecosystem biome shift (%)	7	13
Reduction in tropical maize harvest (%)	3	7
Further decline in coral reefs (%)	70-80	99
Decline in marine harvest (million tons)	1.5	3.0

IPCC Special Report results tabulated by Kelly Levin in "8 Things You Need to Know about the IPCC 1.5 °C Report" WRI (Oct 7, 2018). Impact on climate in Planet Earth presentation

Recall from Planet Earth presentation that world is on track to exceed 2.0 °C over preindustrial levels

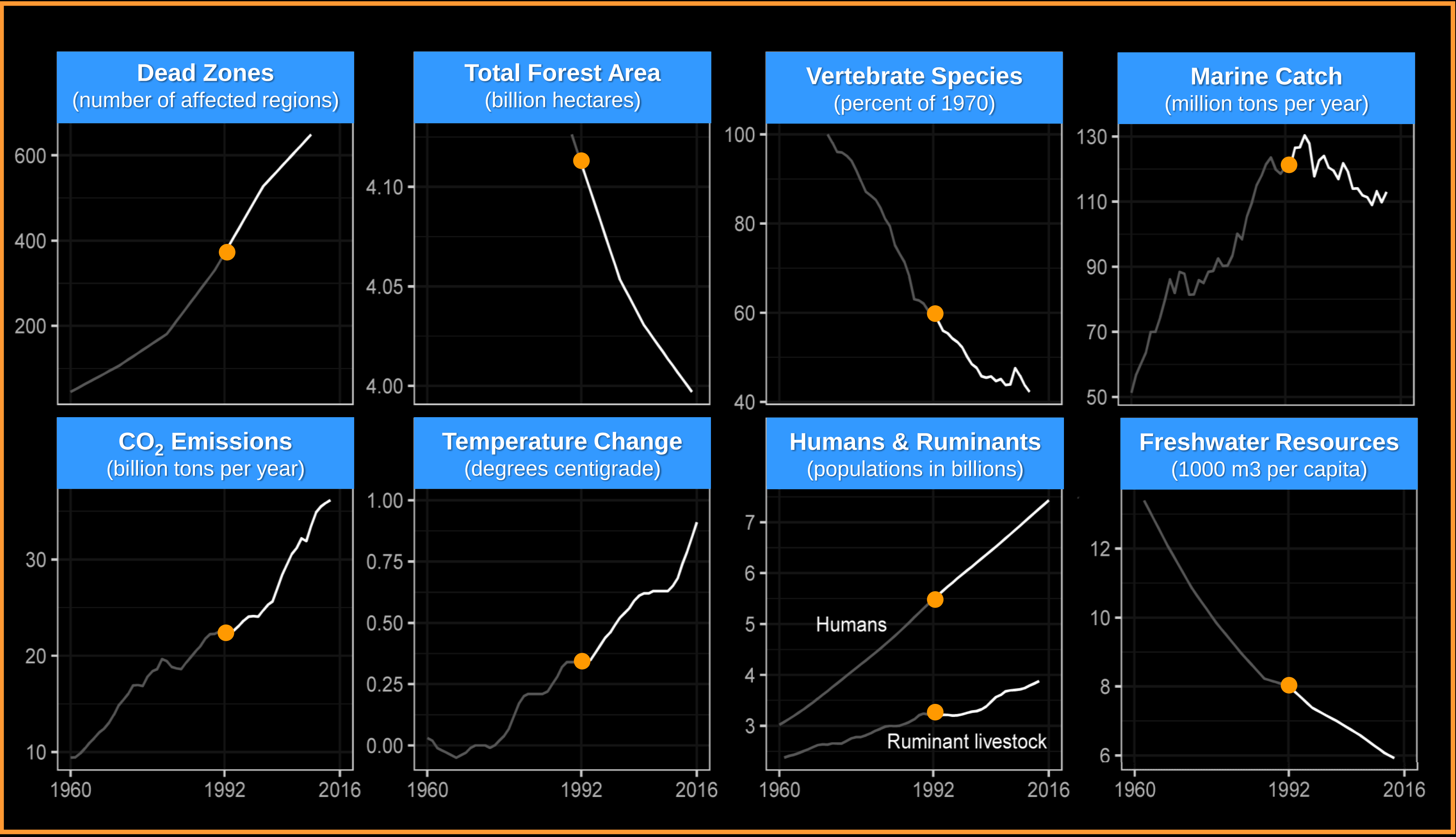
World Scientists' Warning to Humanity

Second Notice*

William J. Ripple, Christopher Wolf, Thomas M. Newsome, Mauro Galetti, Mohammed Alamgir, Eileen Crist, Mahmoud I. Mahmoud, William F. Laurance, and 15,364 scientist signatories from 184 countries, *Bioscience* (Dec 2017)

***First notice: 1992**

Things Continuing to Get Worse



Changes since first notice (1992) highlighted. Ozone graph (only positive result) excluded. Marine catch is decreasing even though fishing effort has increased, indicating resource is being depleted

Suggested Steps Toward Sustainability

- Prioritize enactment of connected well-funded & well-managed reserves for significant proportion of world's terrestrial, marine, freshwater, and aerial habitats
- Maintain nature's ecosystem services by halting conversion of forests, grasslands and other native habitats
- Restore native plant communities at large scales, particularly forest landscapes
- Rewild regions with native species – especially apex predators – to restore ecological processes and dynamics
- Develop and adopt adequate policy instruments to remedy defaunation, the poaching crisis, and the exploitation and trade of threatened species
- Reduce food waste through education and better infrastructure
- Promote dietary shifts towards mostly plant-based foods

Suggested Steps Toward Sustainability

- Further reduce fertility rates by ensuring women and men have access to education and voluntary family-planning services, especially where such are lacking
- Increase outdoor nature education for children as well as more general engagement of society in appreciation of nature
- Divest of monetary investments and purchases to encourage positive environmental change
- Devise and promote green technologies and massively adopt renewable energy sources while phasing out subsidies to fossil fuel production
- Revise our economy to reduce wealth inequality and ensure that prices, taxation, and incentive systems take into account real costs that consumption patterns impose on environment
- Estimate scientifically defensible, sustainable human population for long term while rallying nations and leaders to support that vital goal

How to Save Our Planet

2019

David Attenborough

From short film associated with Netflix nature series Our Planet

Problems

- Key underlying issue: Earth is becoming less wild. Humans now determine life's survival but are totally out of balance with nature
- We have cleared three trillion trees, cultivated half of the fertile land on the planet and now fish across most of the ocean
- In last fifty years, populations of wild animals have declined by 60%. We've replaced them with ourselves and our domesticated animals and plants
- Today we and the animals we raise account for 96% of the mass of mammals and 70% of the birds on earth
- This biodiversity loss is not only tragic, it is the single biggest problem we face. Without biodiversity, our planet does not work

Solutions

- Rewild the world by focusing on sustainability, by making sure that everything we do we can do forever
- Have fewer children (already happening, but keep it up)
- Invest in education (including that of women) & raising people out of poverty
- Phase out fossil fuels and replace them with renewables
- Upgrade to efficient food production and reduce consumption of meat, which will reduce deforestation, allow for more grass-lands, reduce use of fresh water for livestock and alleviate hunger by creating more affordable food
- Work together to properly manage ocean, including establish-ment of global network of no fish zones and a treaty on the use of international waters
- Work hard to keep hold of the wild populations we still have

A Global Deal for Nature

Guiding Principles, Milestones, and Targets

Dinerstein et al, *Science Advances* (2019)

Motivated by 2016 E. O. Wilson book, *Half-Earth*

All nations have signed on to the Paris agreement, but the Paris agreement is only a half-deal; it will not alone save the diversity of life on Earth or conserve ecosystem services upon which humanity depends*

The Global Deal for Nature (GDN) is a time-bound, science-based plan to save the diversity and abundance of life on Earth. Without the GDN, the goals of the Paris climate deal become unreachable; worse, we face the unraveling of the Earth's natural ecosystems that sustain human life. Achieving the milestones and targets of the GDN is the best gift we can offer to future generations – an environmental reset, a pathway to an Eden 2.0. We must seize this hopeful pathway

– Eric Dinnerstein

*Although President Trump has stated his intention to withdraw U.S.

Overarching Purpose of GDN

To tackle dangerous climate change or climate break-down and safeguard biodiversity to avoid worsening of ongoing anthropogenic extinction

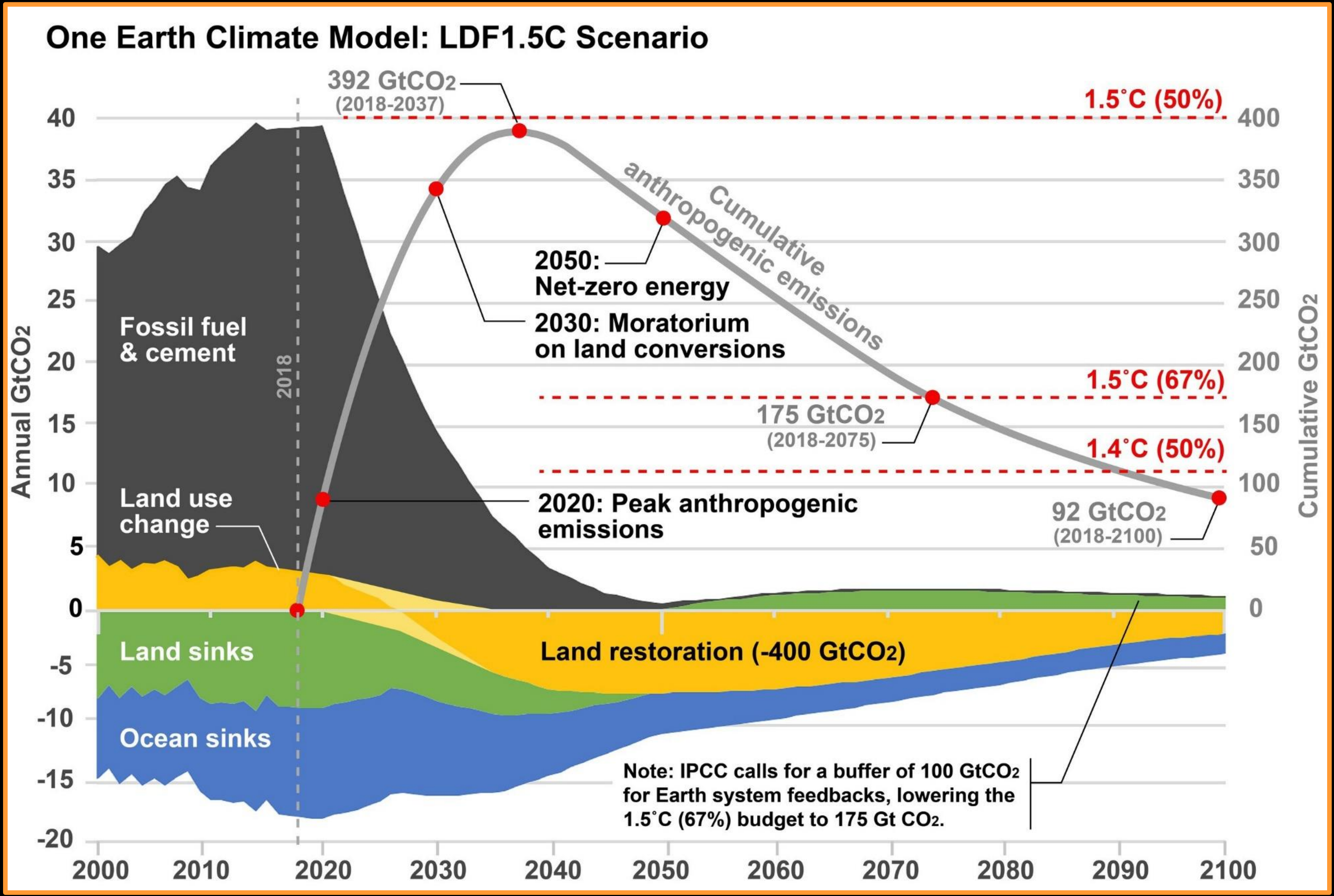
Most of GDN material here is based on an April 19, 2019 Newsweek interview with Eric Dinnerstein

Proposed Actions

- Fully protect 30 percent of world terrestrial, freshwater and marine environments by 2030
- Treat another 20 percent as "climate stabilization areas", not formally protected, but where land-based emissions of CO_2 would be reduced or eliminated
- The above should help greatly to prevent global warming from exceeding 1.5°C over preindustrial levels by letting natural processes (such as photosynthesis) remove CO_2 from the atmosphere
- Transition from fossil fuels to renewable energy
- Integrate the Paris Accord and Convention on Biological Diversity for greater focus and efficiency

Success Scenario

The One Earth climate model (LDF 1.5 scenario) documented in "Achieving the Paris Climate Agreement Goals" (Teske, ed. 2019) shows the possibility of staying below the 1.5˚C climate threshold. The IPCC special report "Global Warming of 1.5˚C" (SR1.5) calls for a carbon budget of 400 $GtCO_2$ to maintain a chance of staying below the threshold of 1.5˚C in global average temperature rise, adjusted to account for additional warming since the beginning of the industrial era (circa 1750). The budget for a good chance (>67%) of 1.5˚C is 175 $GtCO_2$, accounting for a buffer of 100 $GtCO_2$ for biosphere feedbacks in the second half of the century, such as melting permafrost, which is achieved by 2075. This is the first climate model to offer a chance of lowering global temperatures to 1.4˚C by the end of the century without geoengineering



Land use emissions (gold) become carbon-negative in 2027 and decline to zero in 2035. Roughly 400 Gt negative CO_2 emissions via land restoration required to achieve >67% chance of staying below 1.5˚C in 2075 with >50% chance of 1.4 ˚C by 2100. Carbon budgets derived from IPCC "Global Warming of 1.5˚C" (2018), starting in 2018 and adjusted downward to account for pre-industrial (before 1750) anthropogenic emissions

The End