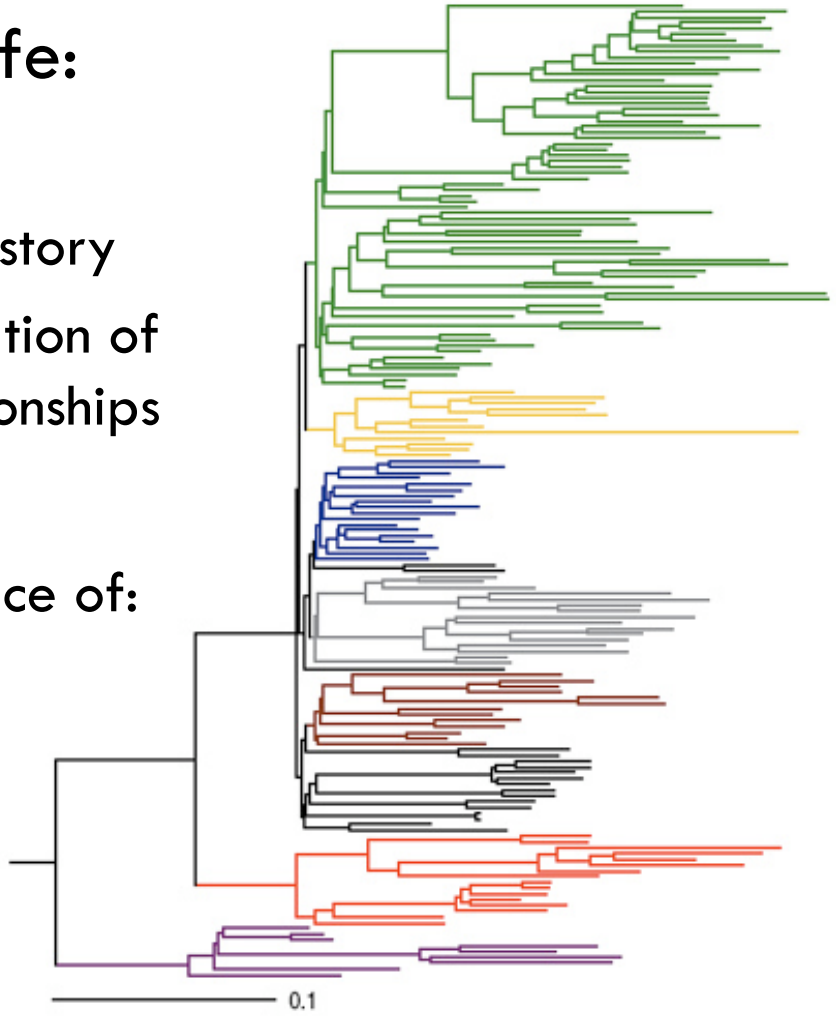
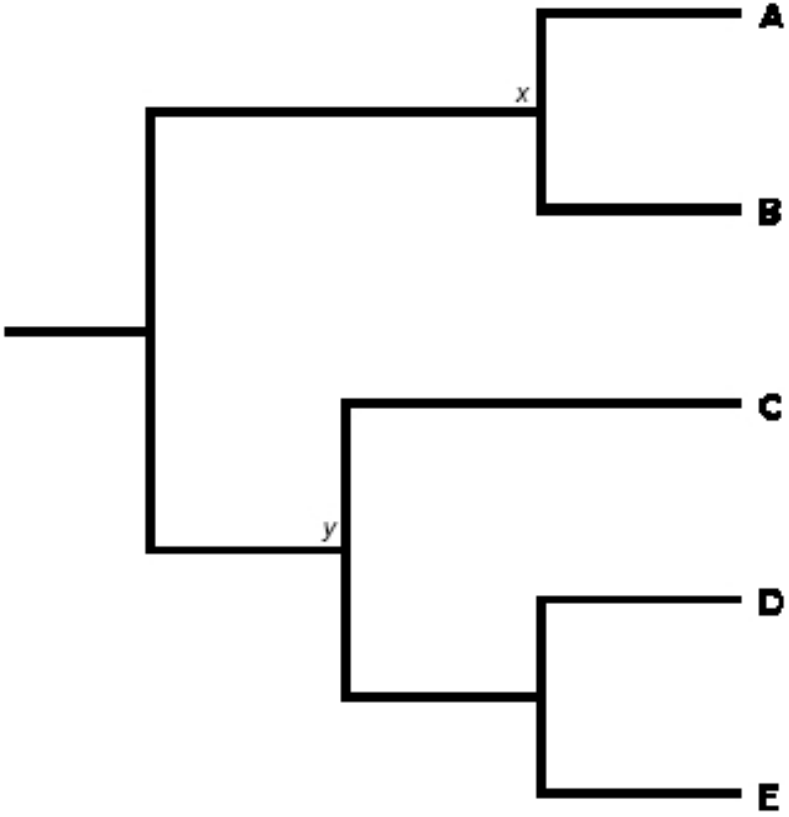
PHYLOGENIES

Tools of the trade

- To reconstruct history of life:
  - Phylogenetic trees
    - Phylogeny: evolutionary history
    - Phylogenetic tree: visualization of ancestor-descendant relationships
  - Fossil record
    - Provides only direct evidence of:
      - Physical morphologies
      - Where they lived
      - When they lived



Phylogenetic trees



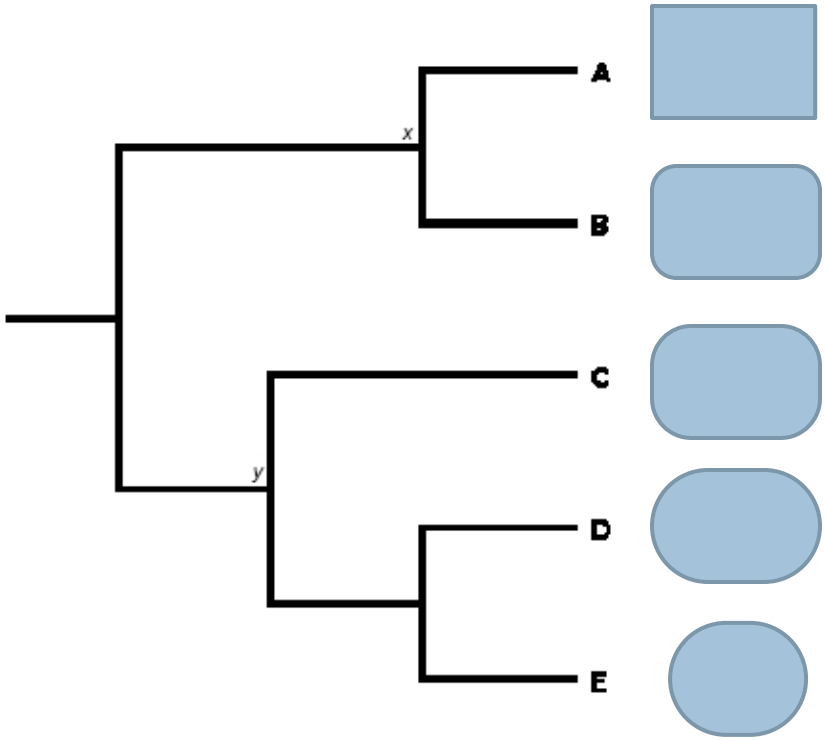
- Branch
  - Represent population through time
- Node (or fork)
  - Where 2 branches diverge
  - When ancestral species split
- Terminal node (or tip)
  - Living today or extinct

Estimating phylogenies

- Phylogenies summarize data on evolutionary history
  - Analyze morphological and/or genetic characteristics
- Two strategies
  - Phenetic approach
  - Cladistic approach

Parsimony

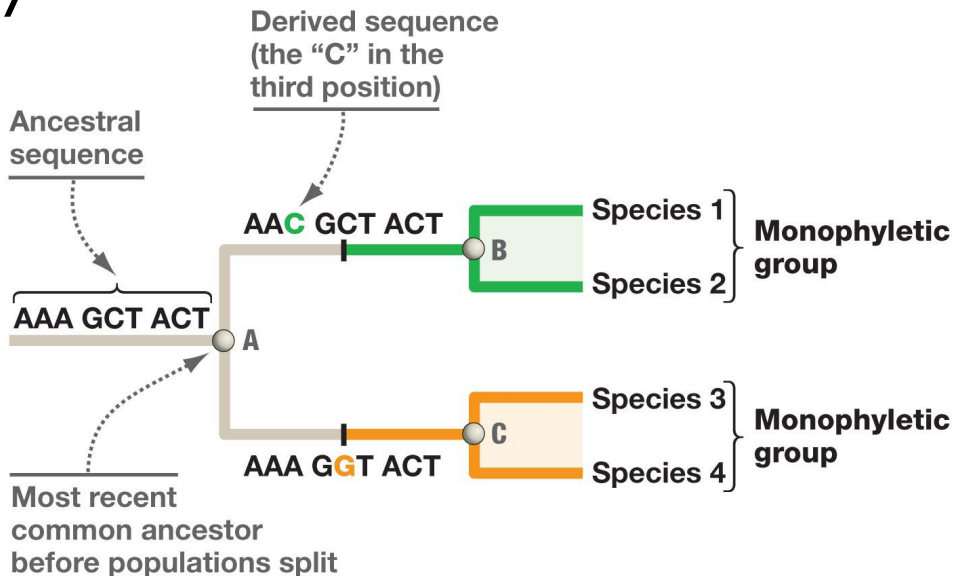
- Principle of logic
  - Most likely pattern implies least amount of change



- Assumption
  - Homoplasy is rare
- Best phylogenetic tree
  - Fewest evolutionary changes most accurately depicts reality

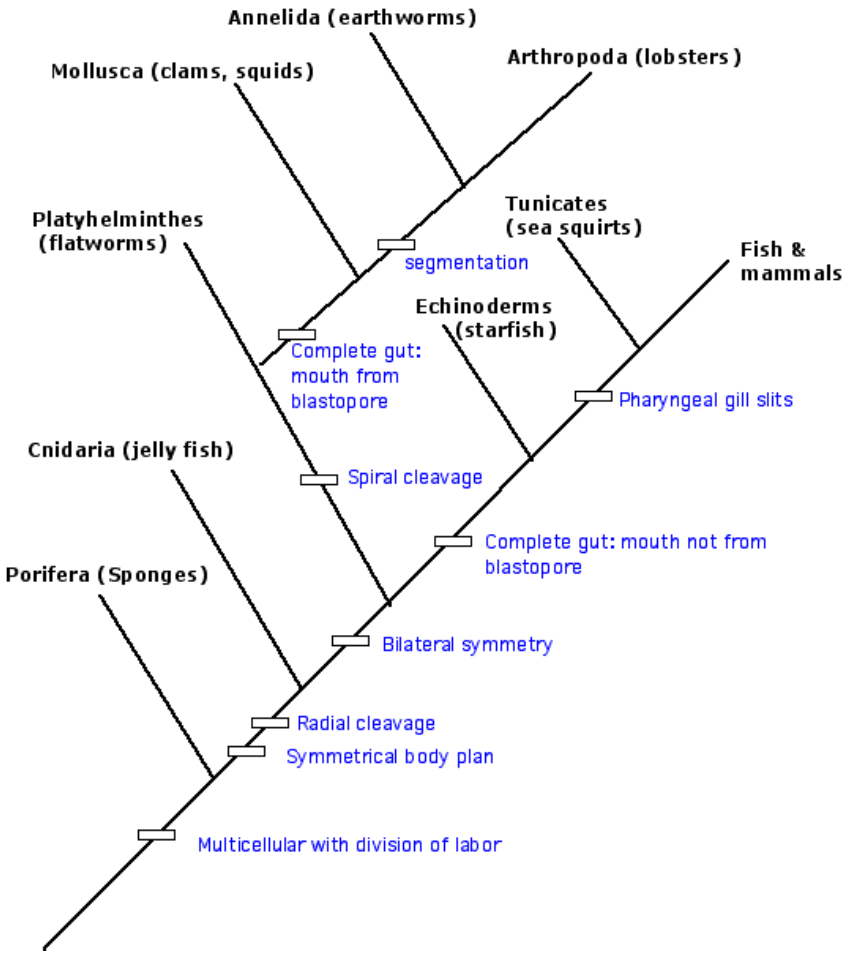
Phenetic approach

- Phylogenetic tree based on:
  - Computed statistic
    - Usually from DNA
  - Summarizing similarity among groups
- Clusters more similar groups
- Distances more divergent groups



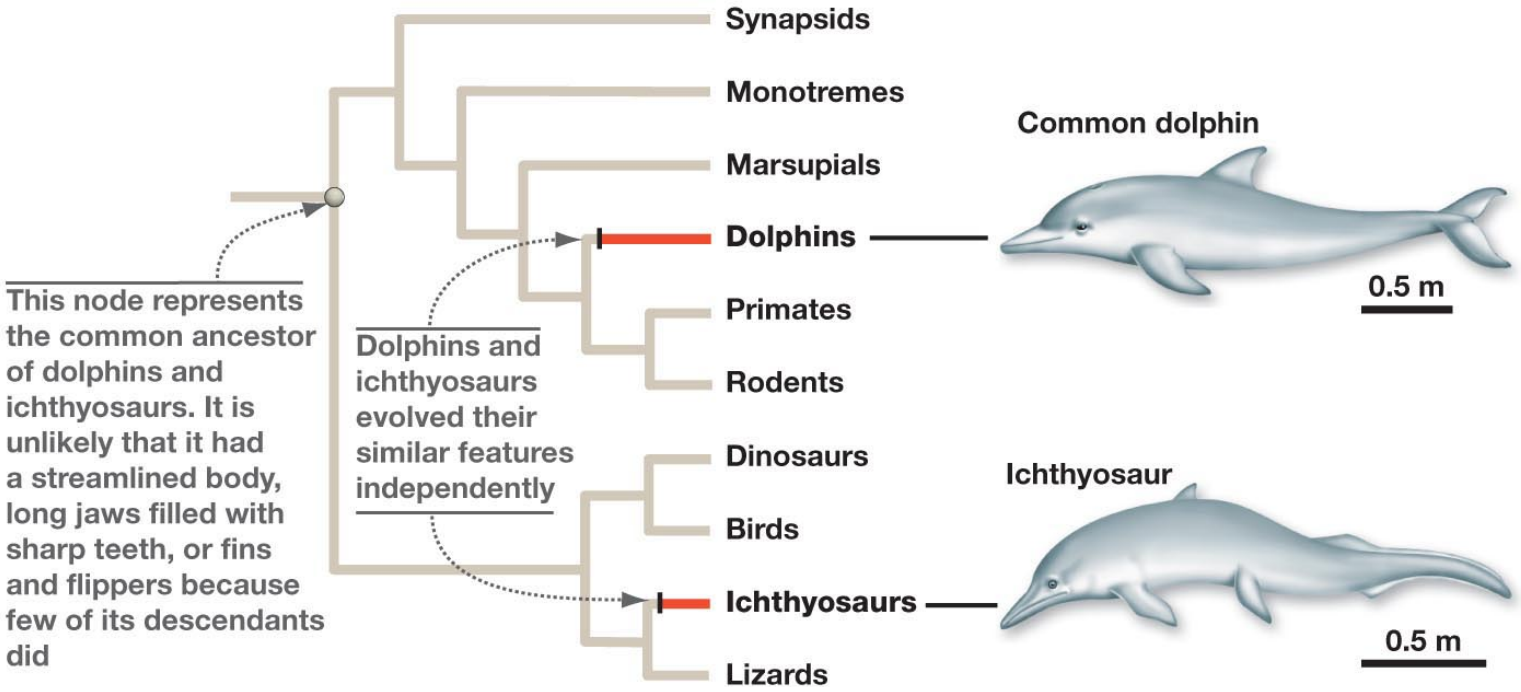
Cladistic approach

- Infers trees based on synapomorphies
  - Synapomorphies:
    - Similarities in derived characteristics
  - Clades:
    - Monophyletic groups that share common ancestors
    - aka lineages
- Based on fossils &/or DNA



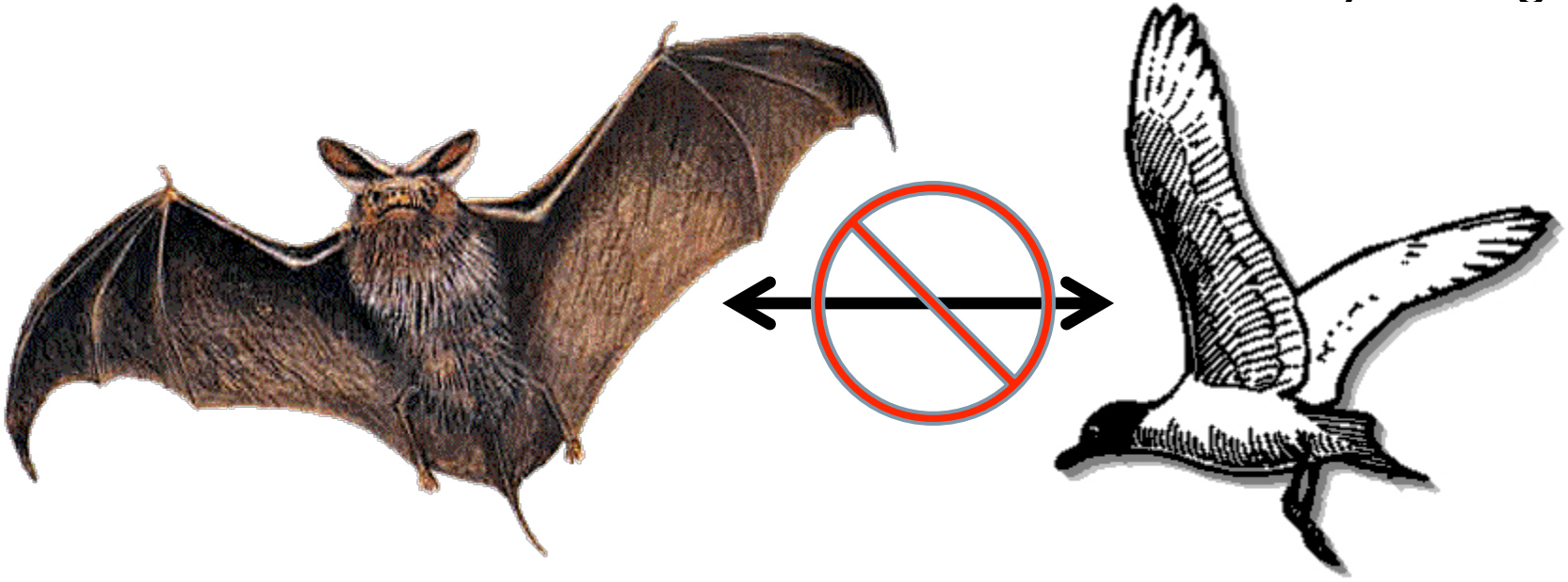
Homology vs. Homoplasy

- Problem: similar traits can evolve independently
- Homology: similar traits due to shared ancestry
- Homoplasy: similar traits not due to ancestry



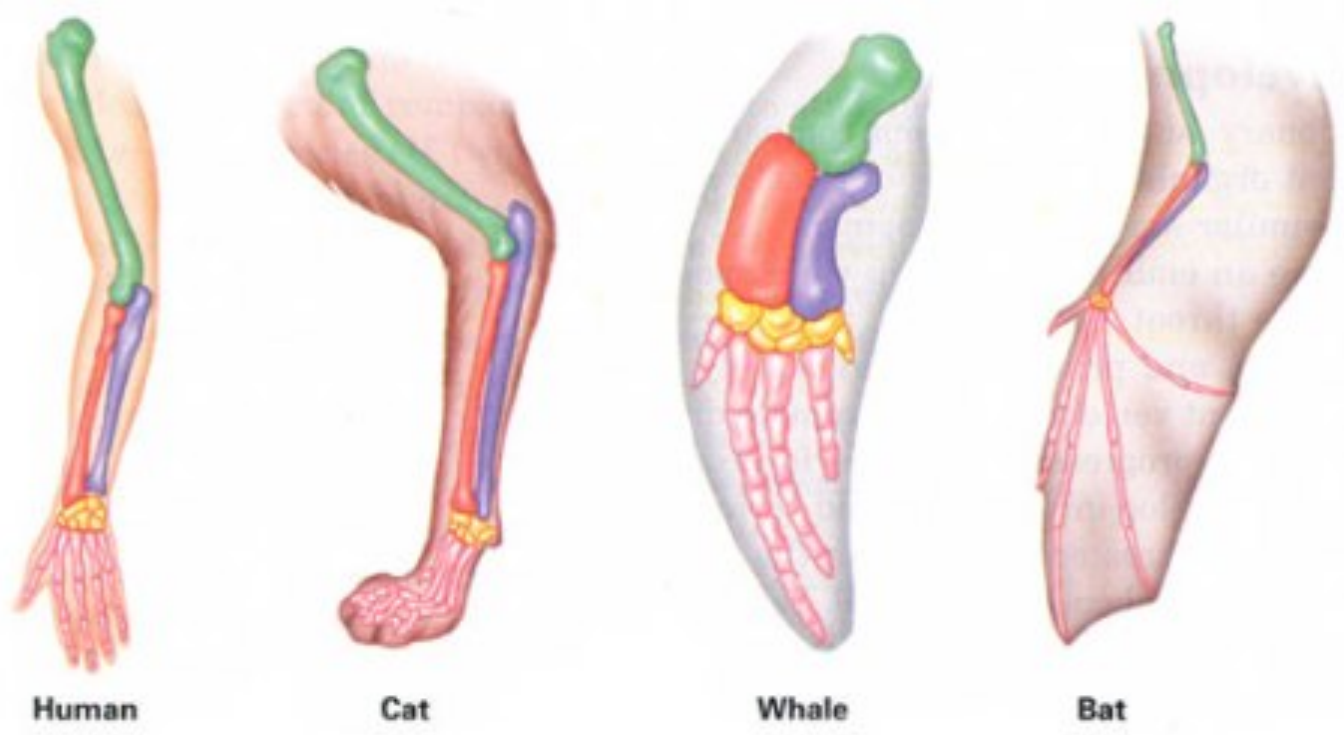
Convergent Evolution

- Cause of homoplasy
- Occurs when natural selection favors similar forms
- How do you know?
  - Similar traits should be found in intermediary lineages



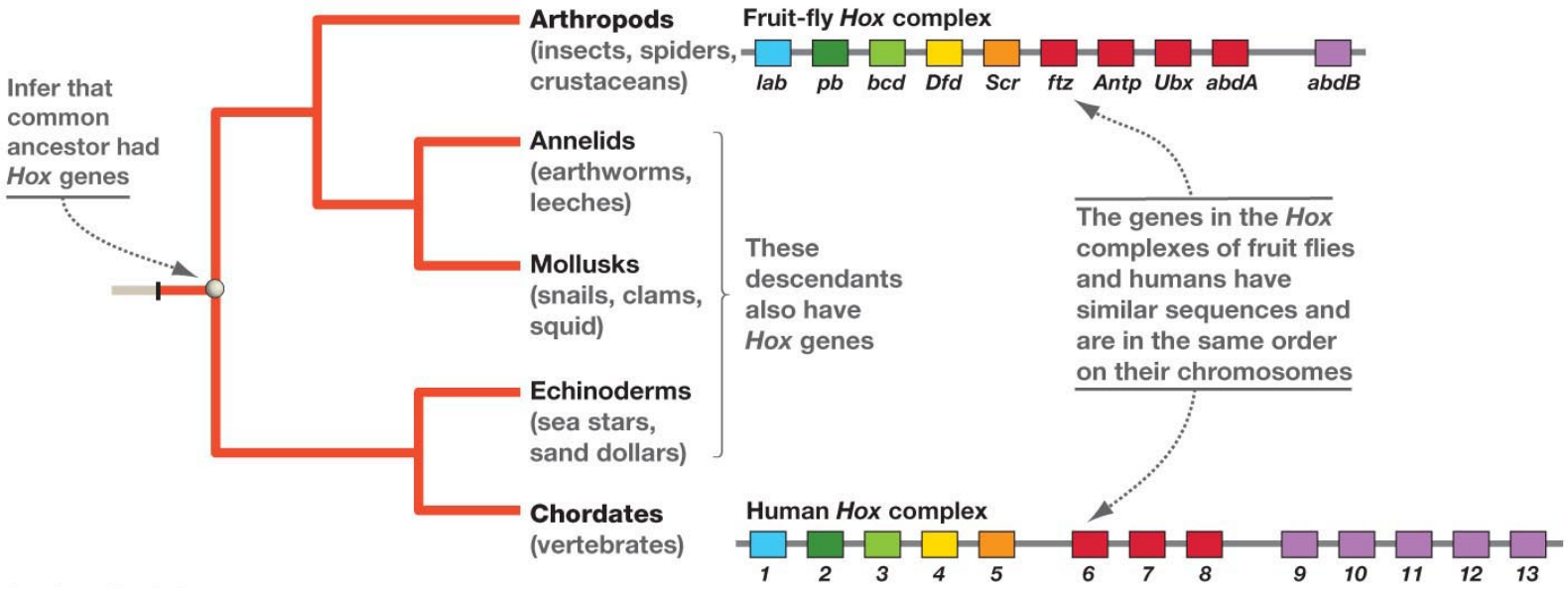
Evidence for homology: morphology

- Homologous structures
  - Physical similarities b/n different species



Evidence for homology

- Chromosomal
  - *Hox* genes on both insects and humans
    - *Hox* organized on chromosome same way
    - Share 180 base-pair sequence
    - Products of genes produce similar functions



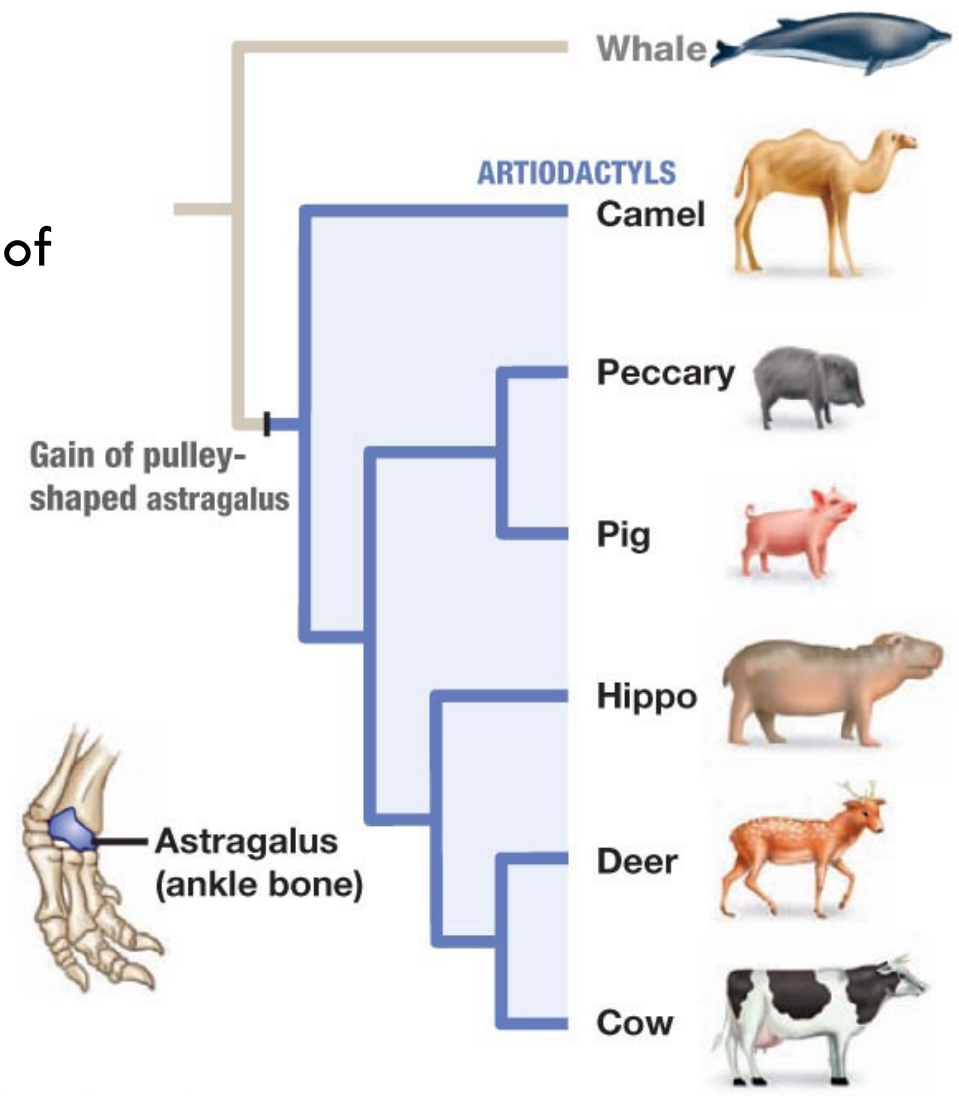
Whale evolution

- Artiodactyl
  - Hippos, cows, deer, pigs
  - Mammals with
    - Hooves
    - Even number toes
    - Pulley-shaped ankle bone
      - Astragalus

- Whales don't have astragalus

Whale evolution

- Morphologically
  - Whales are *outgroup*
    - Related, but not a part of



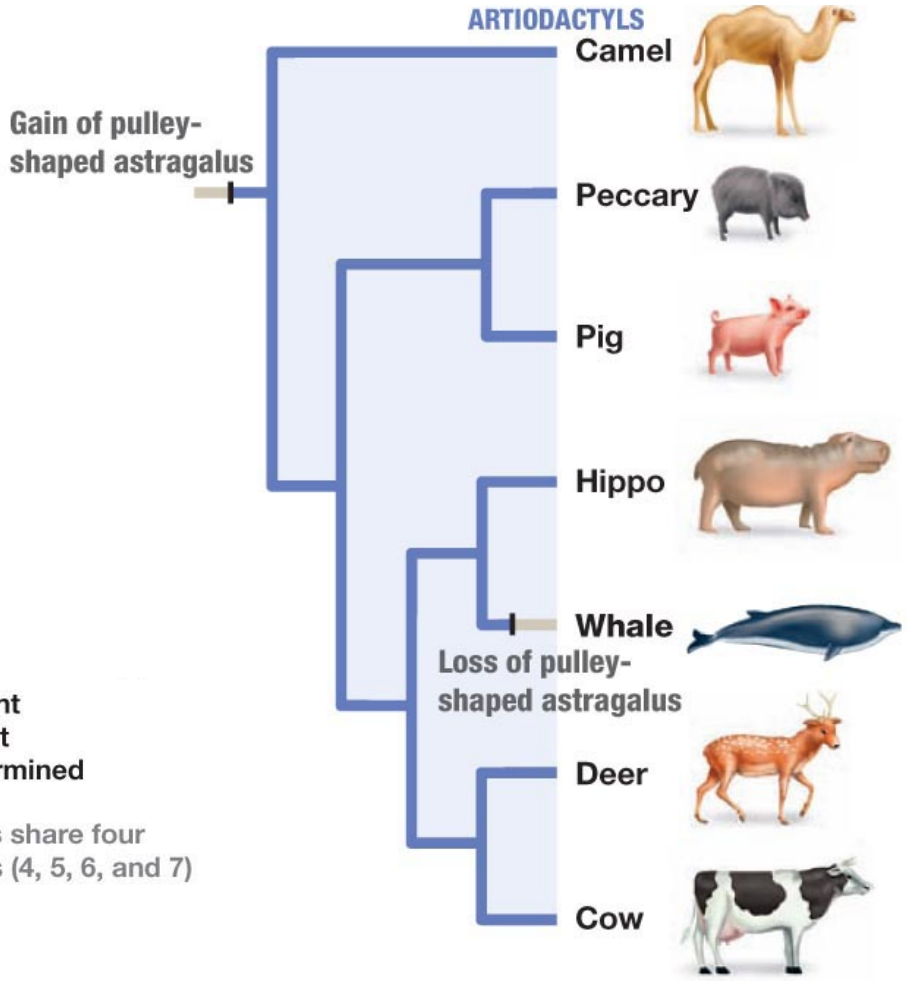
Whale evolution

- DNA suggest
  - close relationship b/n whale and hippo
- Requiring 2 changes to astragalus trait
- *Not* parsimonious

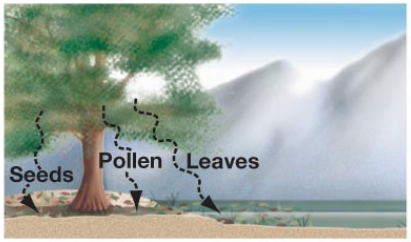
Locus	1	2	3	4	5	6	7	8
Cow	0	0	0	0	0	0	0	1
Deer	0	0	0	0	0	0	0	1
Whale	1	1	1	1	1	1	1	0
Hippo	0	?	0	1	1	1	1	0
Pig	0	0	0	?	0	0	0	0
Peccary	?	?	?	?	?	?	?	?
Camel	0	0	0	0	0	0	0	0

1 = gene present
0 = gene absent
? = still undetermined

Whales and hippos share four *unique* SINE genes (4, 5, 6, and 7)



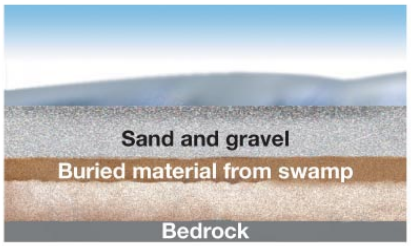
Fossils



1. Seeds, pollen, and leaves fall in swamp.

2. Tree falls.

3. Flood buries remains in sand and mud.



4. Over millions of years, remains are buried further.

- Preserved traces of organisms
- Provides only direct evidence
  - What looked like
  - Where they lived
  - When the existed

Types of fossils

- Intact fossils
  - No decomposition
- Compression fossils
  - Sediment compresses
- Cast fossils
  - Decomposition creates holes
- Permineralized fossils
  - Minerals infiltrate cells

(a) Intact fossil (pollen)

(b) Compression fossil (leaf)

(c) Cast fossil (bark)

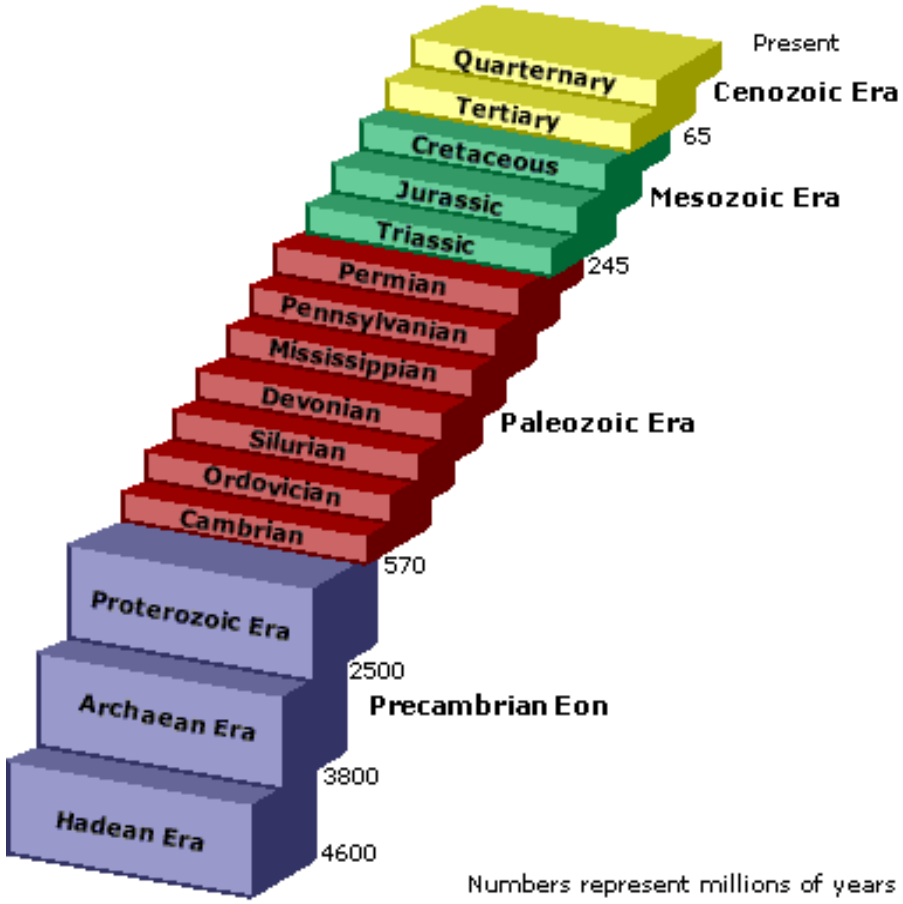
(d) Permineralized fossil (trunk)

Limitations of fossil record

- Fossilization is rare
  - Only 10 specimens of *Archaeopteryx*
  - 1 out of every 200,000,000
- Habitat bias
  - Active sedimentation
  - Low decomposition
- Taxonomic bias
  - Vertebrate-centric
- Temporal bias
  - More recent fossils are more common
- Abundance bias
  - More abundance species
  - Little to no knowledge of rare species

HISTORY OF LIFE

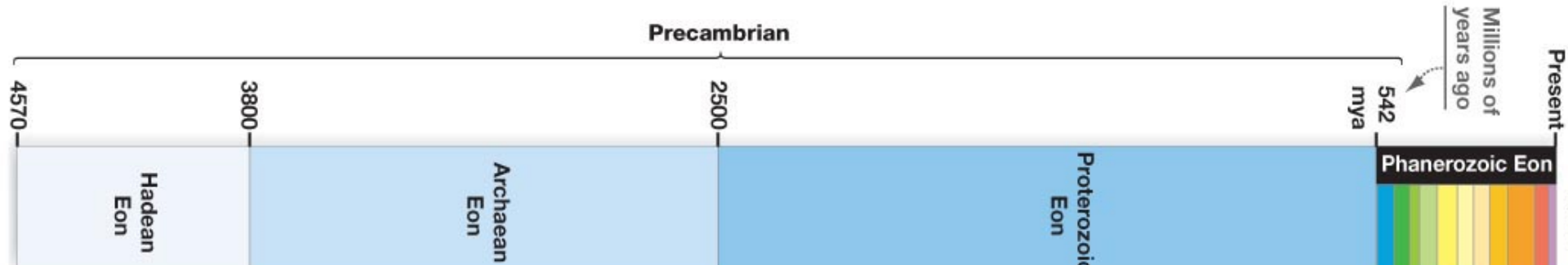
Life's timeline



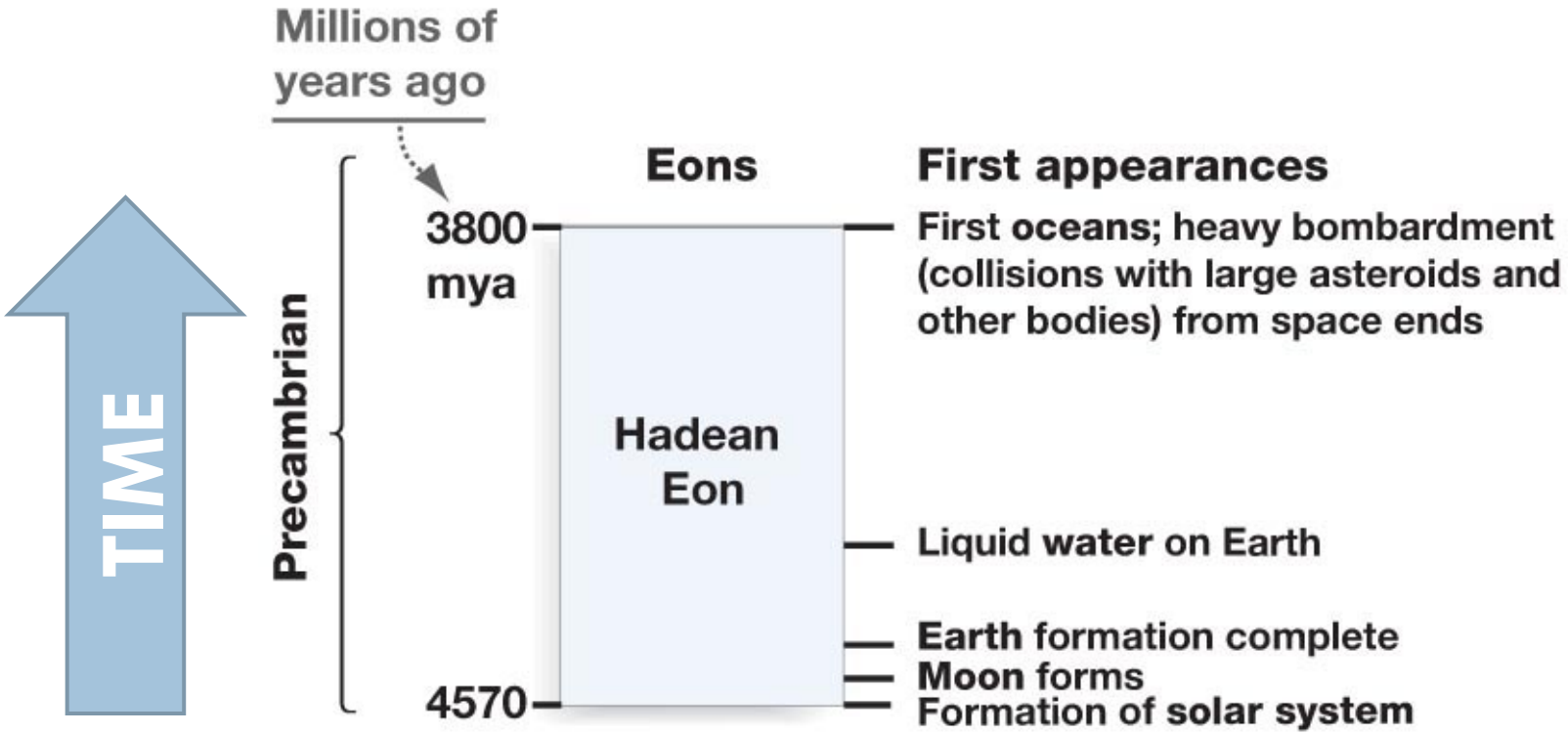
- Earth
  - Formed 4.6 billion
  - Life began 3.4 billion
- Geologic Time
  - Eons
  - Eras
  - Periods
- How do we know?
  - Radiometric dating
  - $^{40}P \rightarrow {}^{40}Ar$

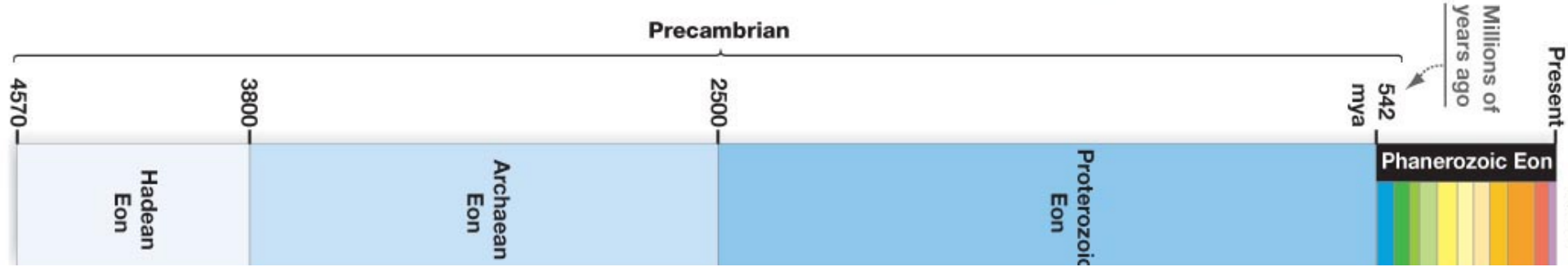
Precambrian

- 4.6 billion – 542 million years ago
- Life was unicellular
- Barely any oxygen present

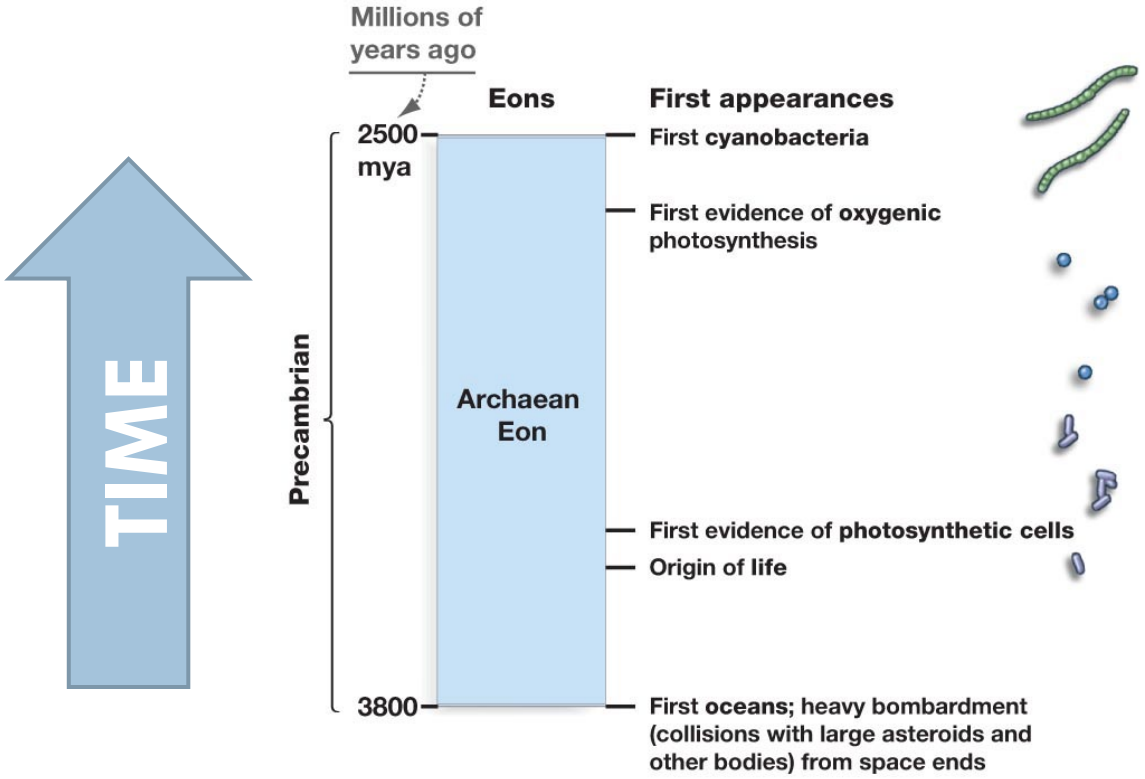


Precambrian

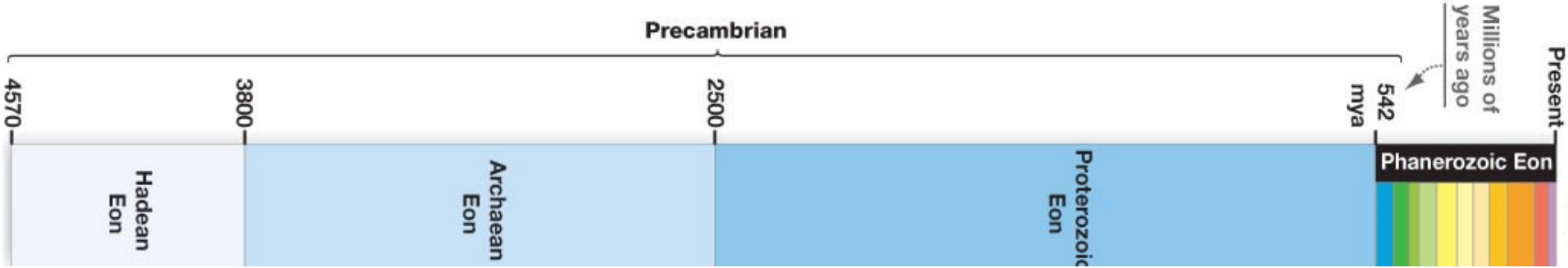




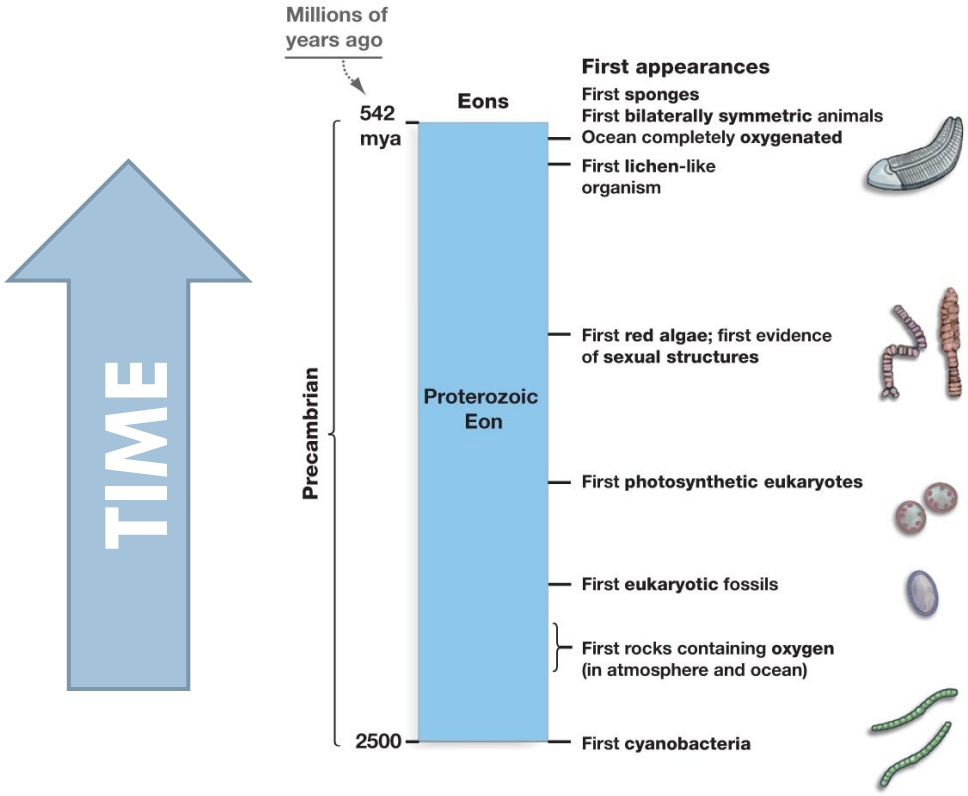
Precambrian



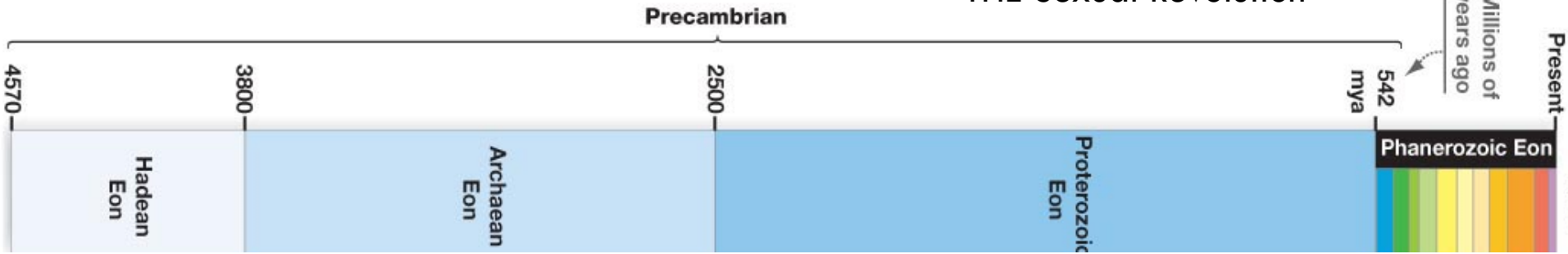
- 1st Chemical Evidence
  - ^{12}C:^{13}C
- 1st Physical Evidence
  - Stromatolites



Precambrian



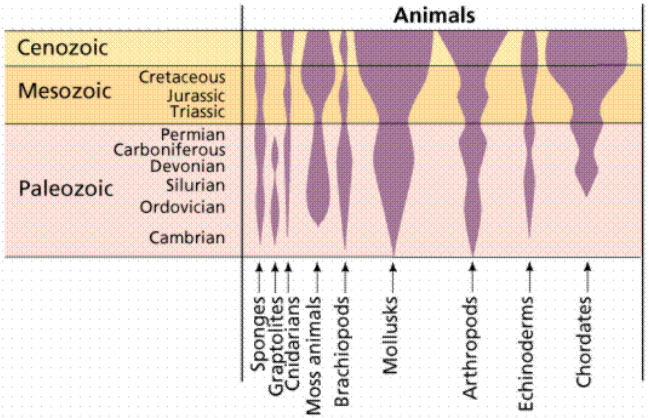
- Anaerobic respiration
  - Glucose → 2 ATP
- Aerobic respiration
  - Glucose → 32 ATP
- Endosymbiotic theory
  - Eukaryotes engulfed and retained beneficial prokaryotes
  - Each event thought to happen only once
    - Chloroplast
    - Mitochondria
- THE Sexual Revolution

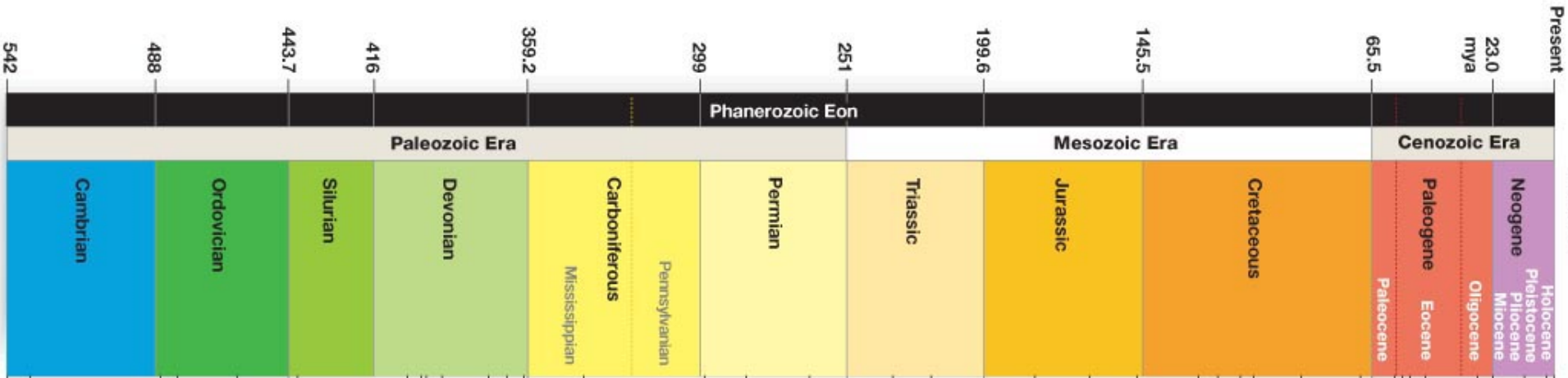


Phanerozoic Eon: Paleozoic Era

- Cambrian explosion
- Appeared
  - Fungi
  - Land plants
  - Land animals

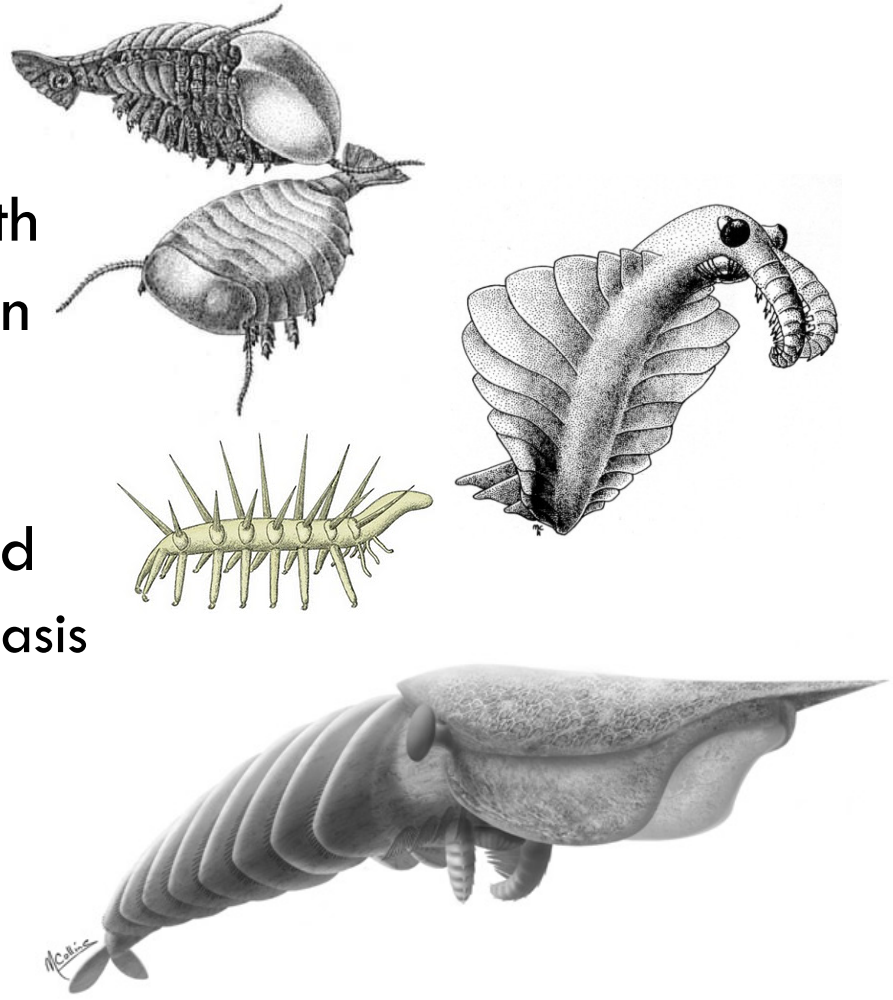
"Walk, hell—I gotta dance!"





Phanerozoic Eon: Paleozoic Era

- Cambrian Explosion
  - Fastest "radiation" of speciation in history of Earth
  - Darwin struggled to explain this in terms of natural selection
  - Niles Eldredge & Jay Gould
    - Evolution long-intervals of stasis
    - "punctuated" by periods of short rapid change
    - 1972

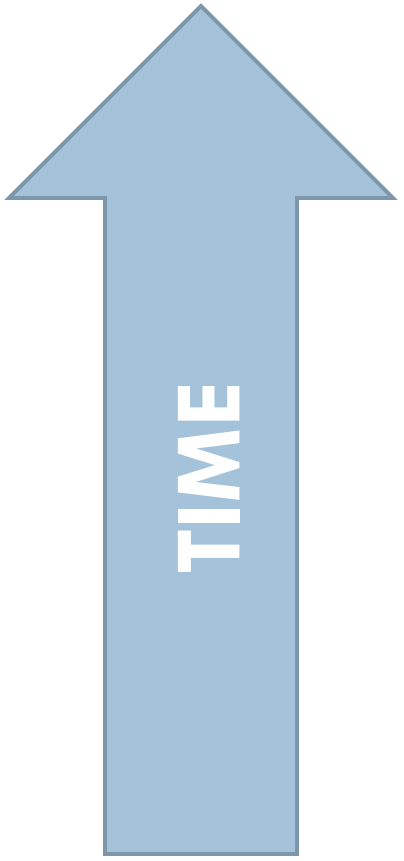


Phanerozoic Eon: Paleozoic Era

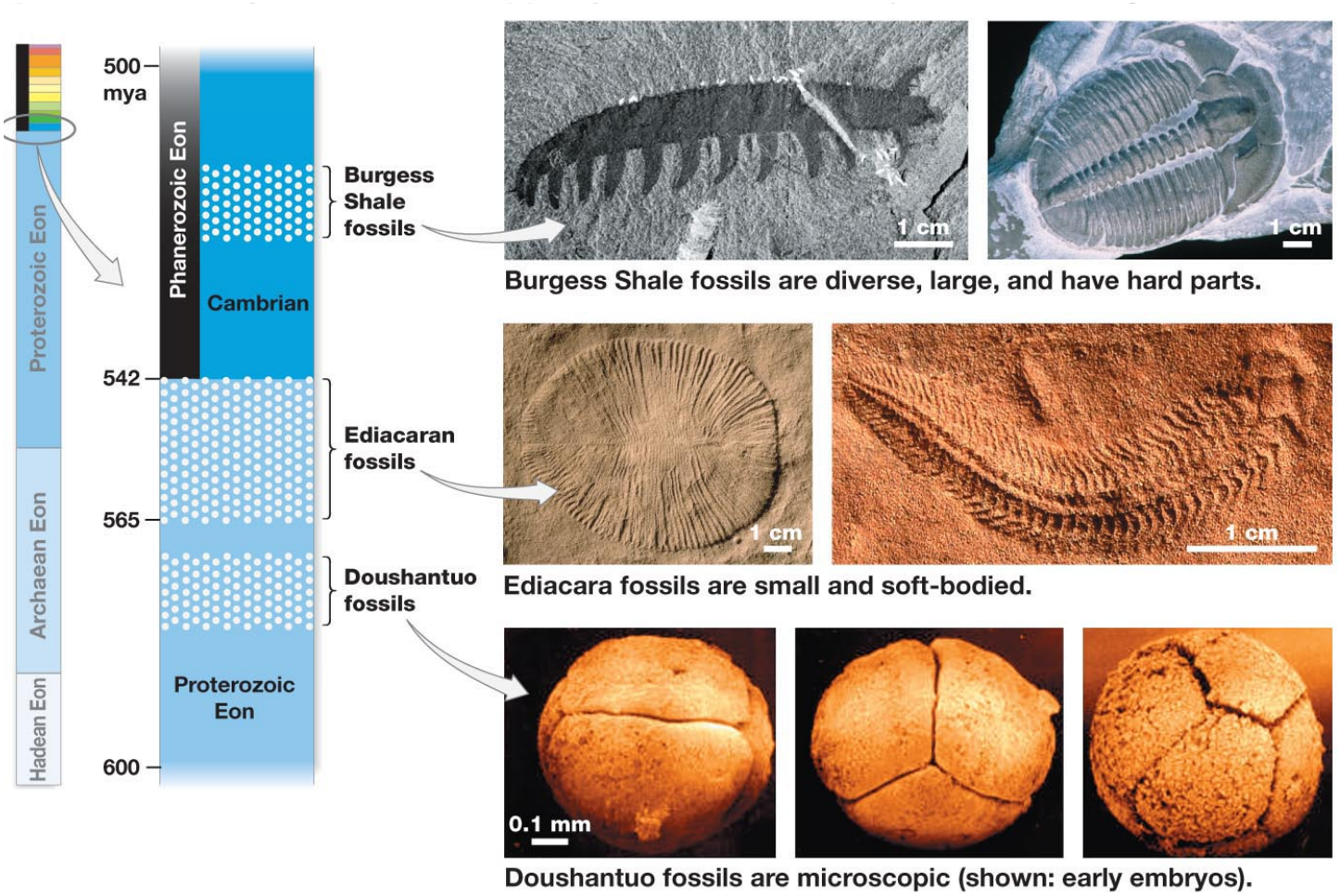
- Possible causes of Cambrian Explosion
  - Increased oxygen levels
    - Aerobic respiration more efficient
  - Origin of predation
    - Selection prey for defense ability
  - New genes, new bodies
    - Mutations allowed more complex bodies

Fossil evidence of Cambrian explosion

- Burgess Shale (Canada)
  - Nearly every major animal group
  - First indication of increased size and complexity
- Ediacara Hills (Australia)
  - Small, soft-bodied animals
  - Sponges, jellyfish
- Doushantuo (China)
  - Microfossils
  - Sponges, cyanobacteria, algae

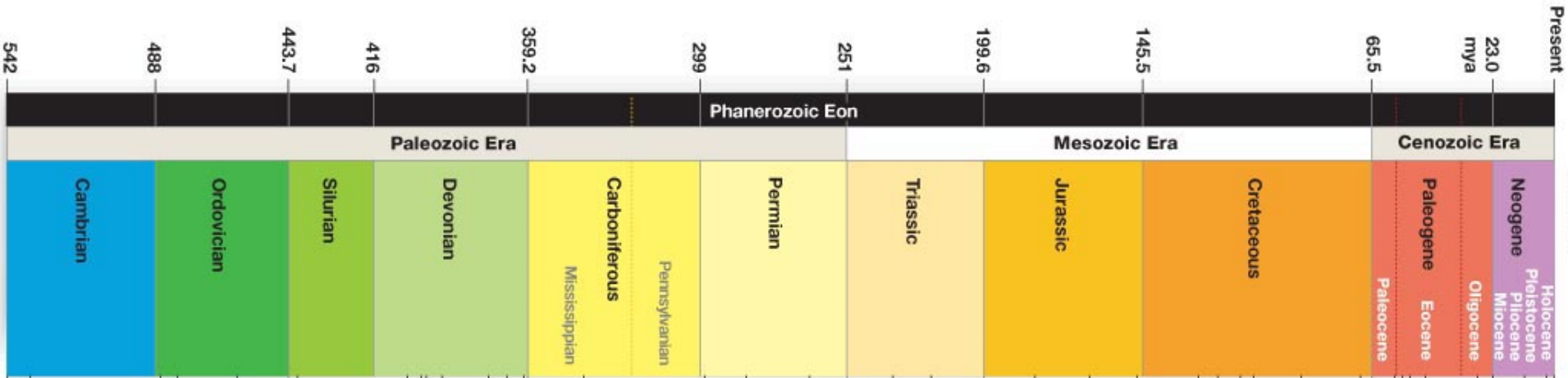


Fossil evidence of Cambrian explosion



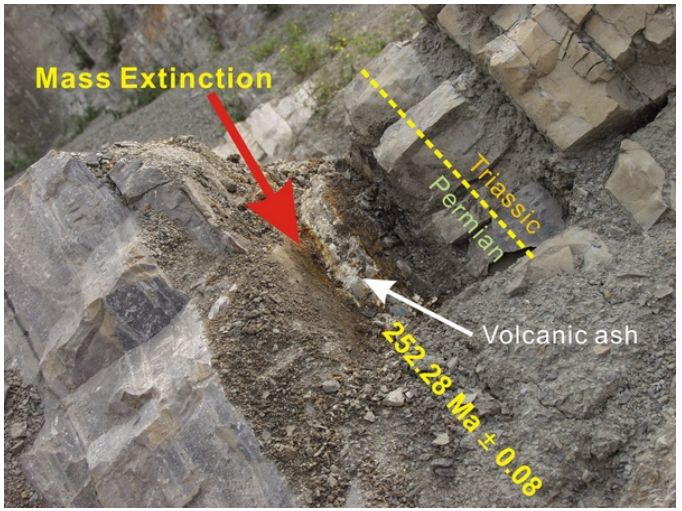
Phanerozoic Eon: Paleozoic Era

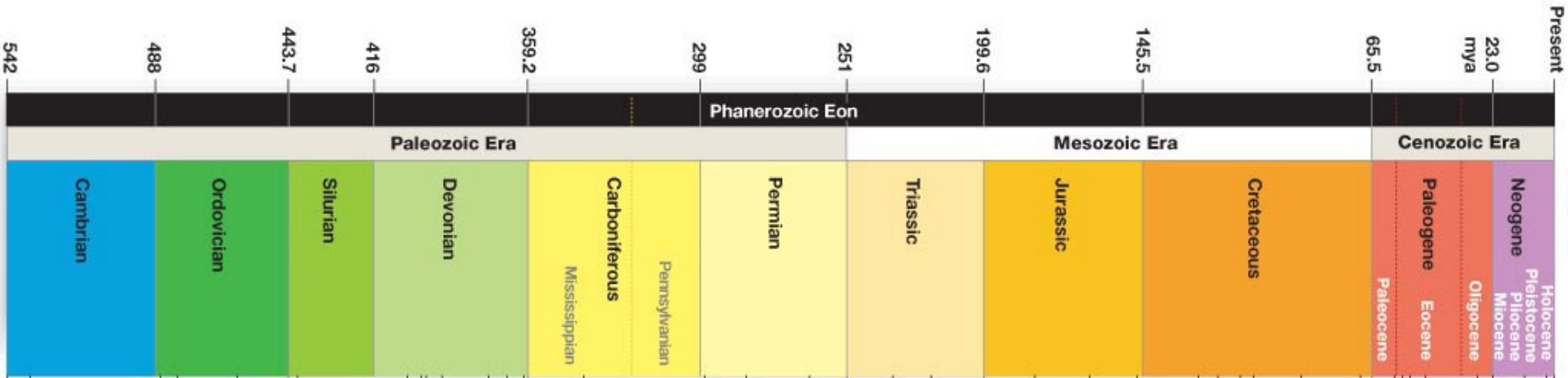
- Permian-Triassic extinction
  - Extinction of almost all multicellular life
  - Largest in Earth's history
  - 96% marine species
  - 70% terrestrial species



Phanerozoic Eon: Paleozoic Era

- Possible causes of Permian-Triassic Extinction
  - Impact event
  - Volcanism
  - Methane gas

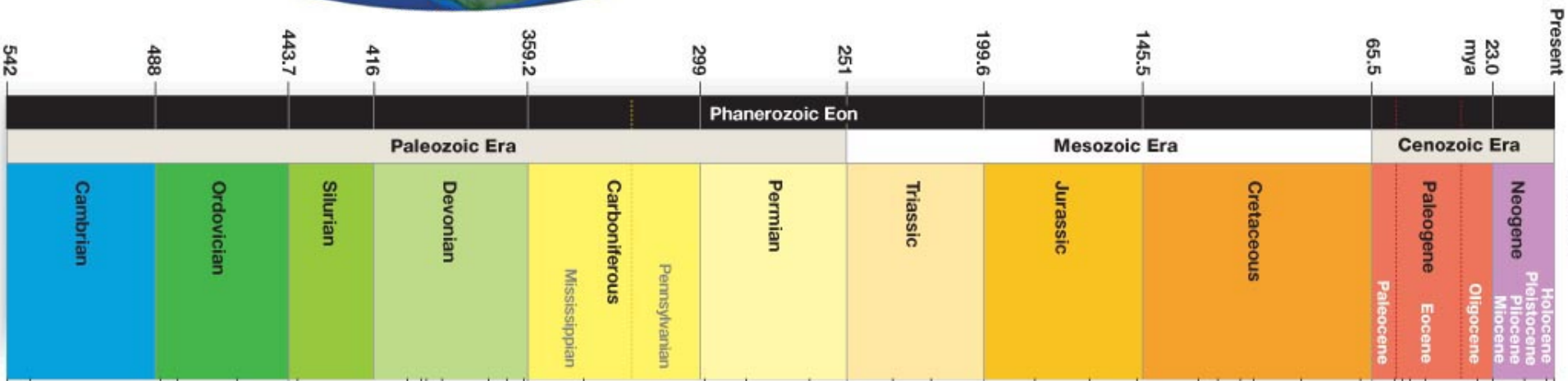




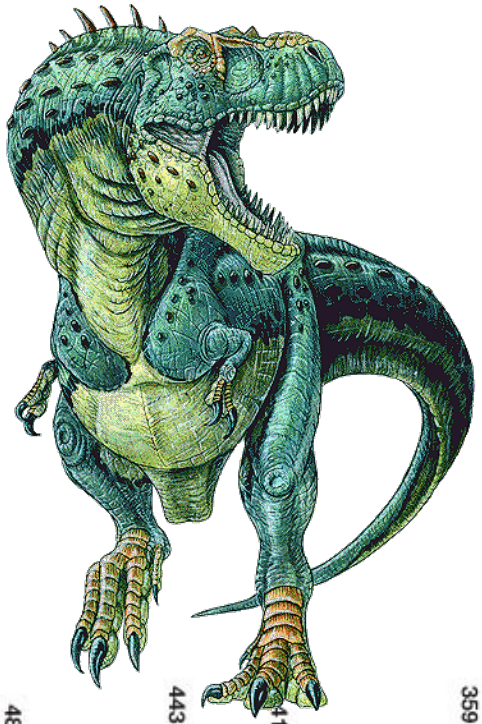
Phanerozoic Eon: Paleozoic Era

- Possible causes of Permian-Triassic Extinction

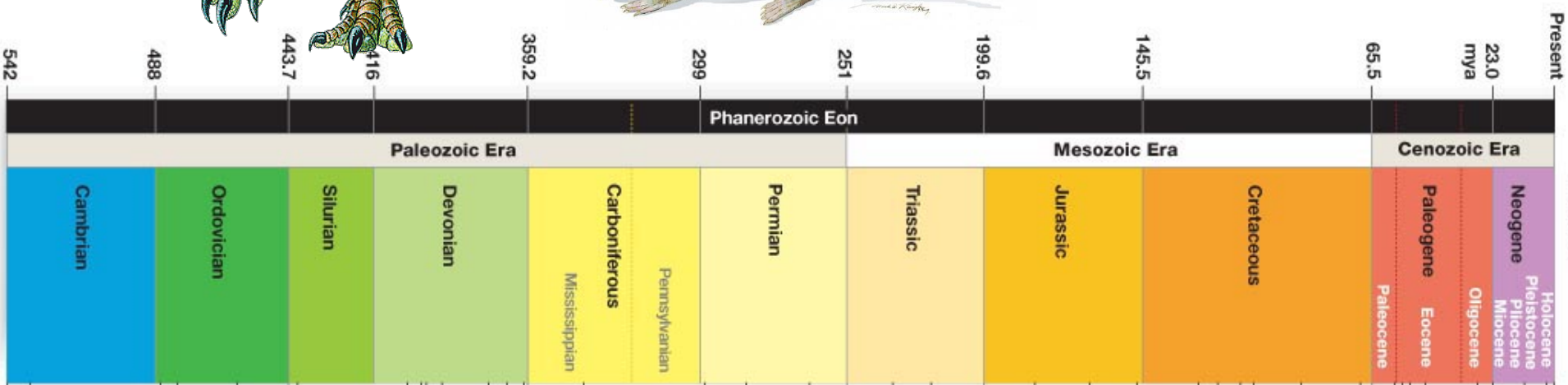
- Anoxic oceans
- Sea level decline
- Pangean Supercontinent
  - Decreased shoreline



Phanerozoic Eon: Mesozoic Era

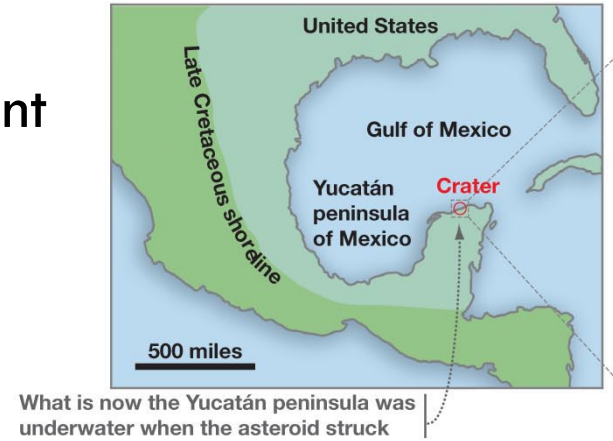


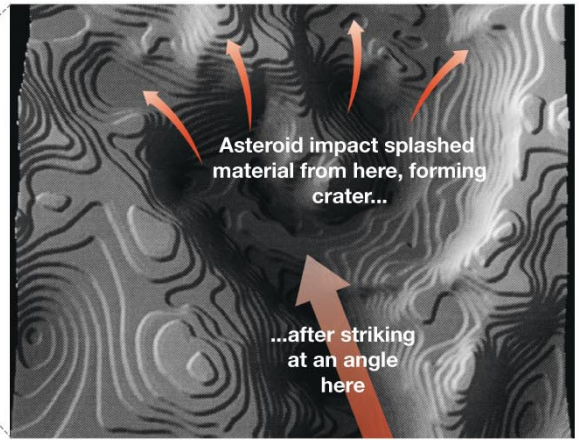
- Age of Reptiles
  - 251-65 mya
  - Rise, dominance, and extinction of dinosaurs
  - Mammals originated

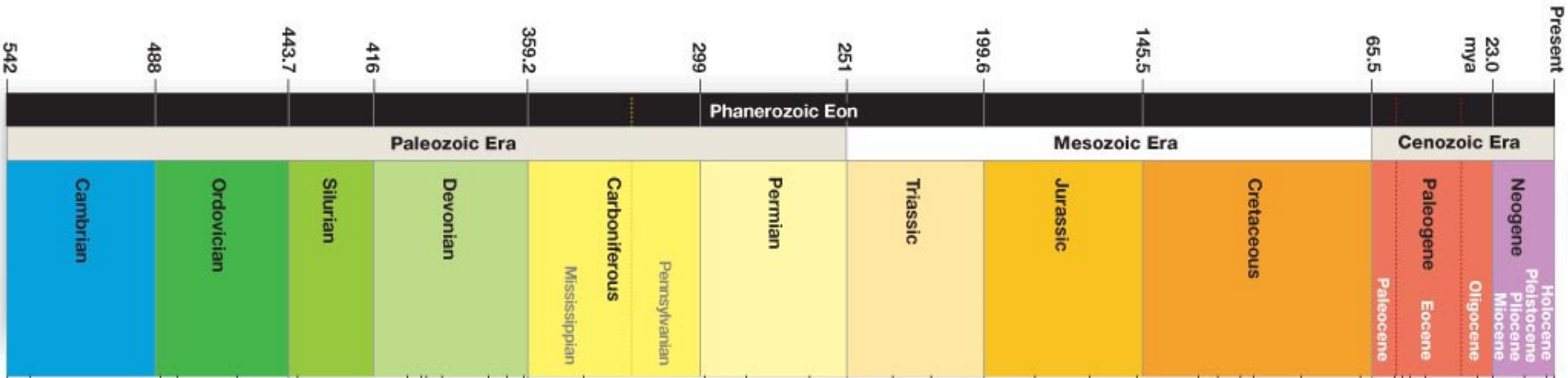


Phanerozoic Eon: Mesozoic Era

- Cretaceous-Paleogene extinction
  - Meteor impact
  - Band of sediment world-wide







Phanerozoic Eon: Cenozoic Era

- Age of Mammals
  - 65 mya to present
  - From generalists
  - Occupy many niches
    - Terrestrial
    - Marine
    - Flying
- Grass came to dominate
- Insect pollination