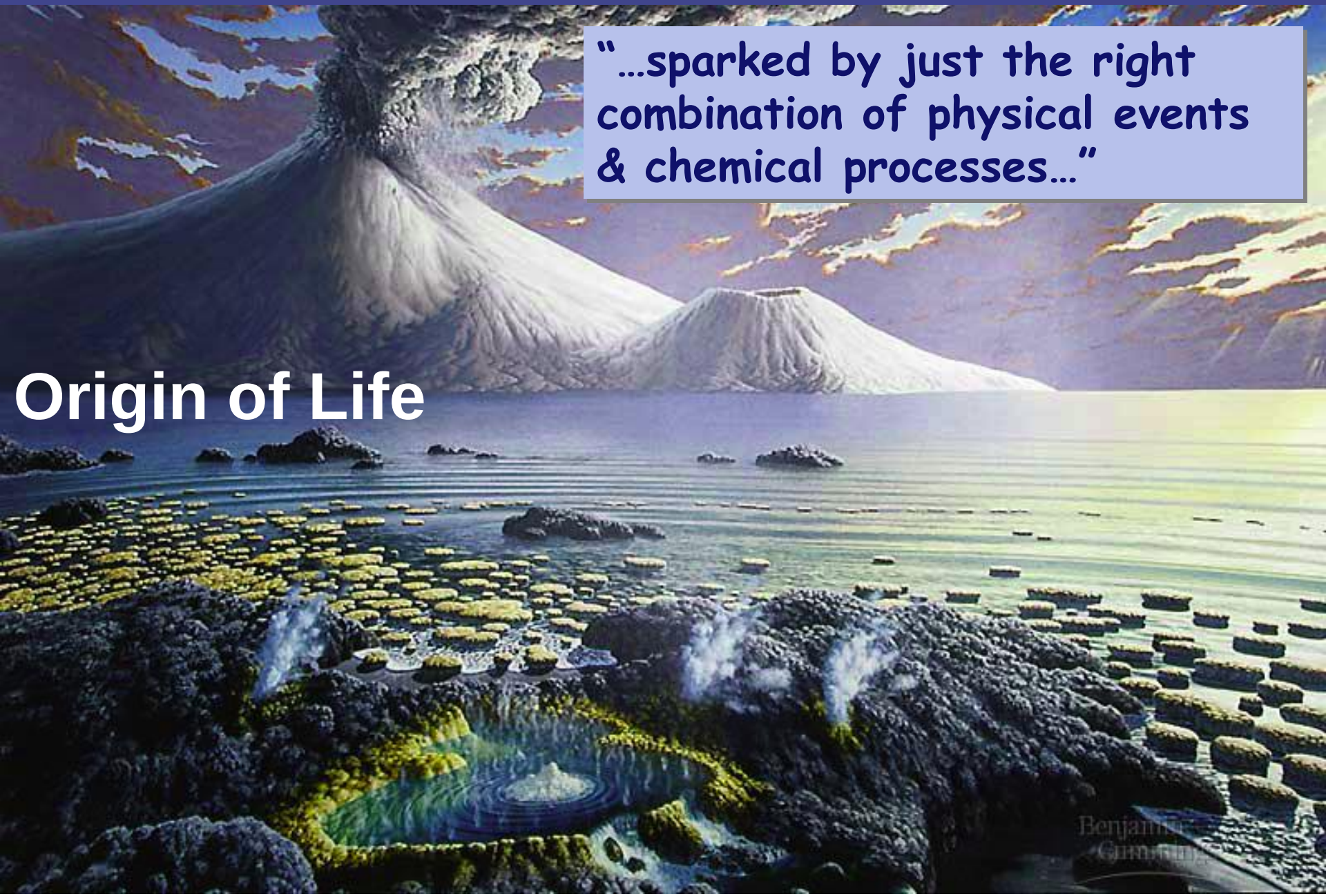
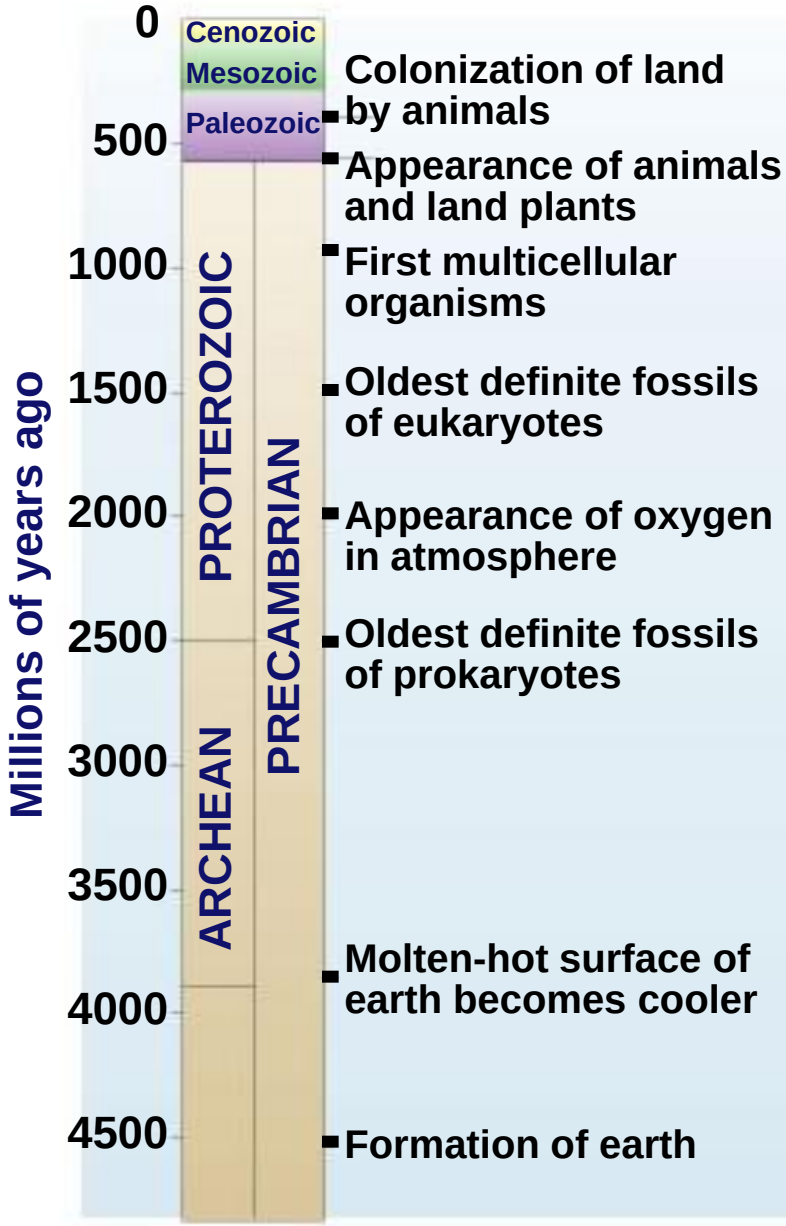
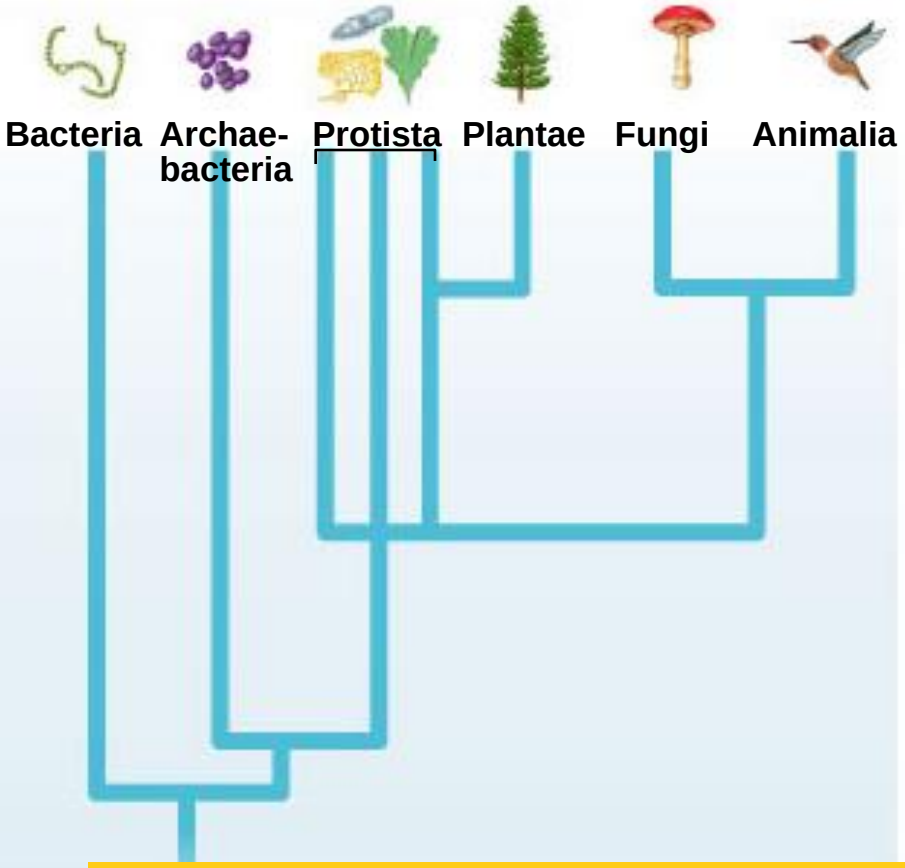


Origin of Life

"…sparked by just the right combination of physical events & chemical processes…"



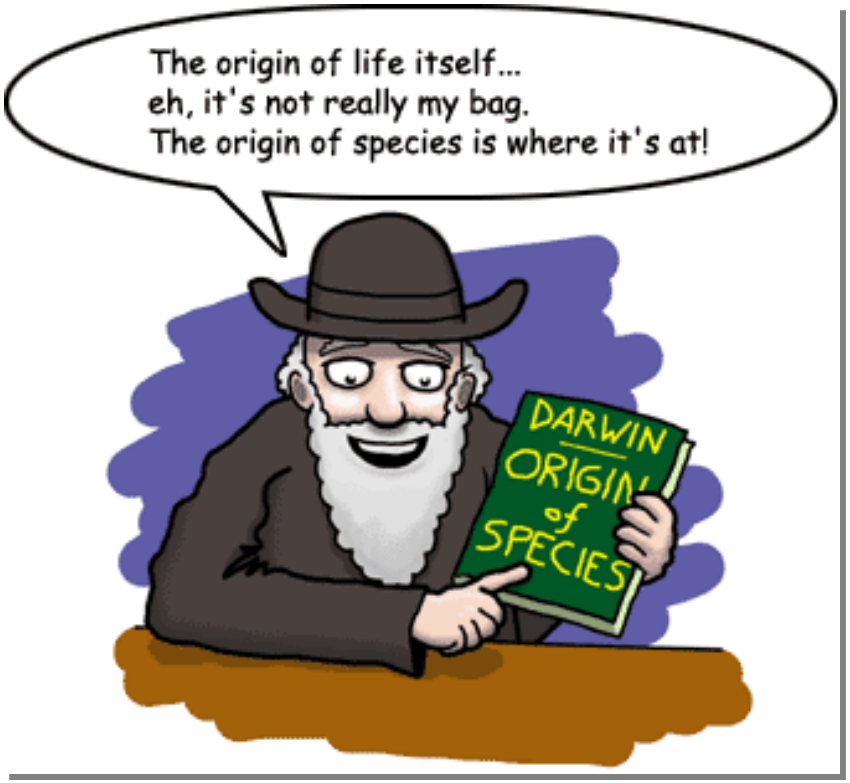


The evolutionary tree of life can be documented with evidence.

The Origin of Life on Earth is another story…

What is Life?

- First we have to define LIFE…
  - organized as cells
  - respond to stimuli
  - regulate internal processes
    - homeostasis
  - use energy to grow
    - metabolism
  - develop
    - change & mature within lifetime
  - reproduce
    - heredity
      - DNA / RNA
    - adaptation & evolution



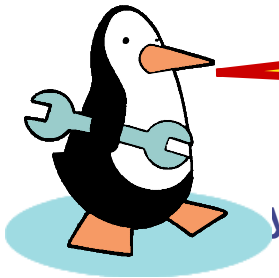
The Origin of Life is Hypothesis

- **Special Creation**
  - *Was life created by a supernatural or divine force?*
  - **not testable**
- **Extraterrestrial Origin**
  - *Was the original source of organic (carbon) materials comets & meteorites striking early Earth?*
  - **testable**
- **Spontaneous Abiotic Origin**
  - *Did life evolve spontaneously from inorganic molecules?*
  - **testable**

Conditions on early Earth

- **Reducing atmosphere**
  - water vapor (H_2O), CO_2, N_2, NO_x, H_2, NH_3, CH_4, H_2S
  - lots of available H & its electron
  - no free oxygen
- **Energy source**
  - lightning, UV radiation, volcanic

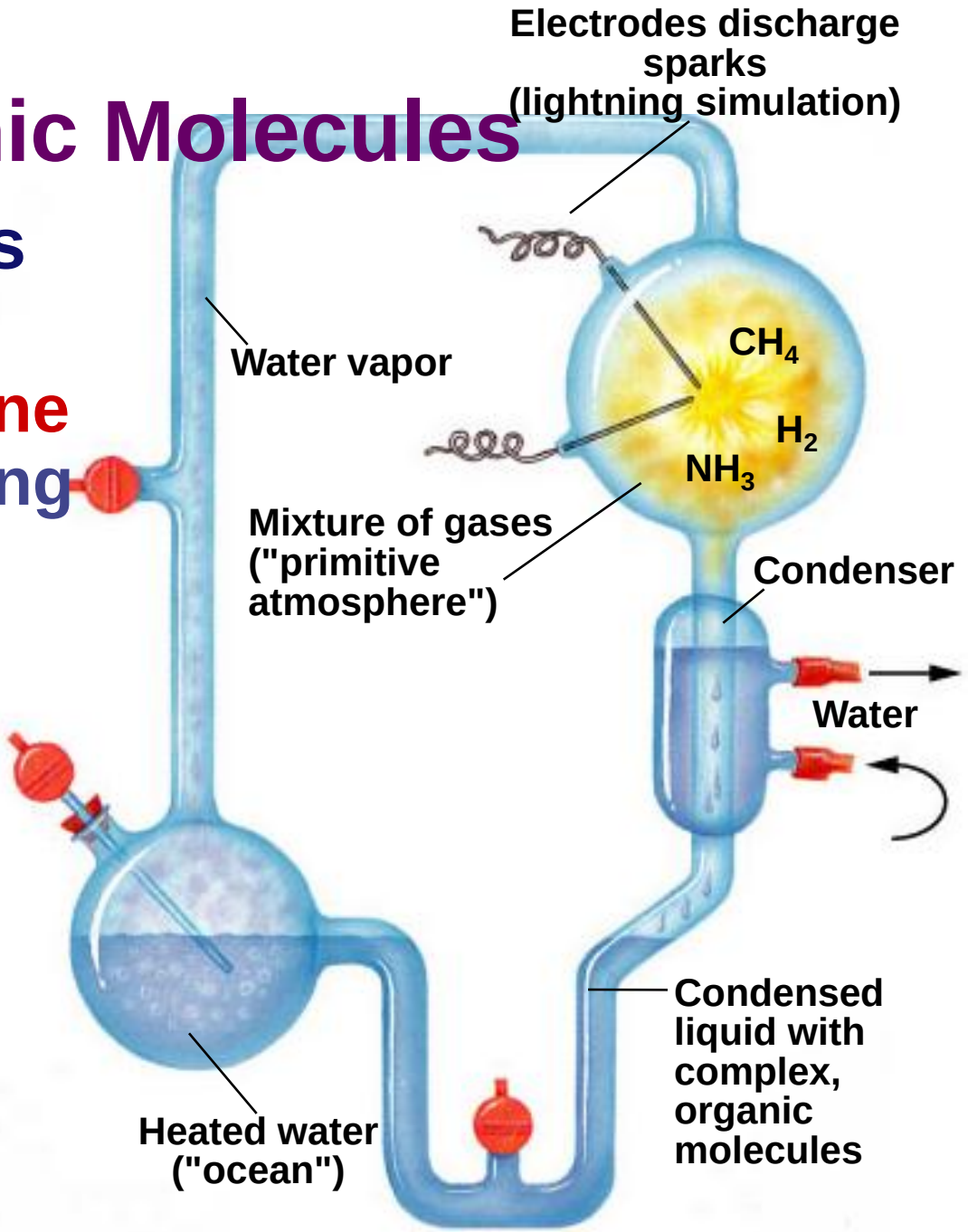
low O_2 = organic molecules do not breakdown as quickly



What's missing from that atmosphere?

Origin of Organic Molecules

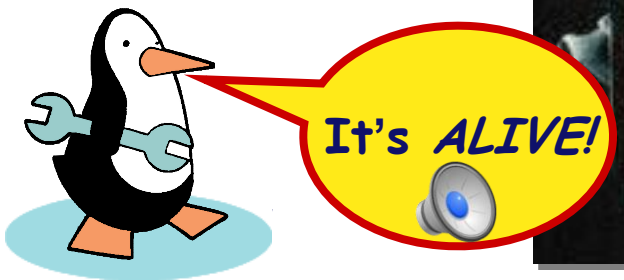
- Abiotic synthesis
  - 1920 Oparin & Haldane propose reducing atmosphere hypothesis
  - 1953 Miller & Urey test hypothesis
    - formed organic compounds
      - amino acids
      - adenine



Stanley Miller

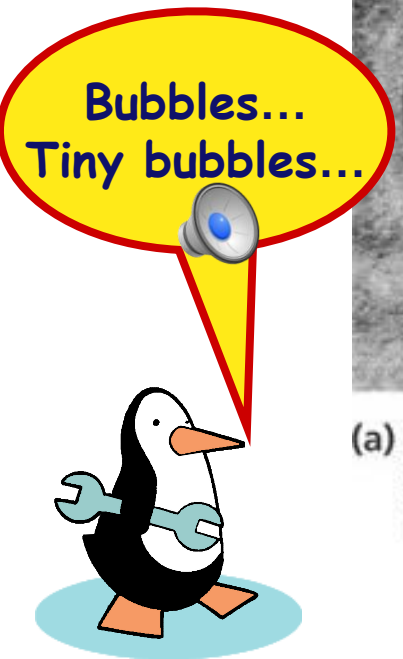
University of Chicago

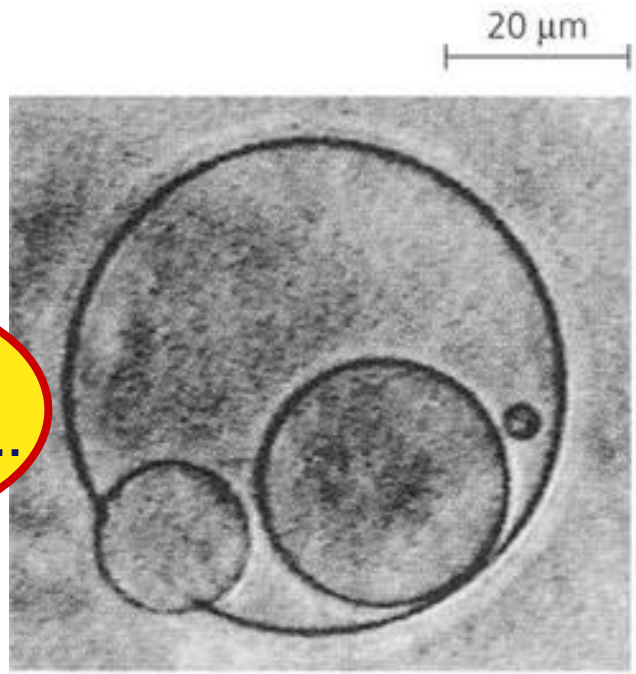
produced
-amino acids
-hydrocarbons
-nitrogen bases
-other organics



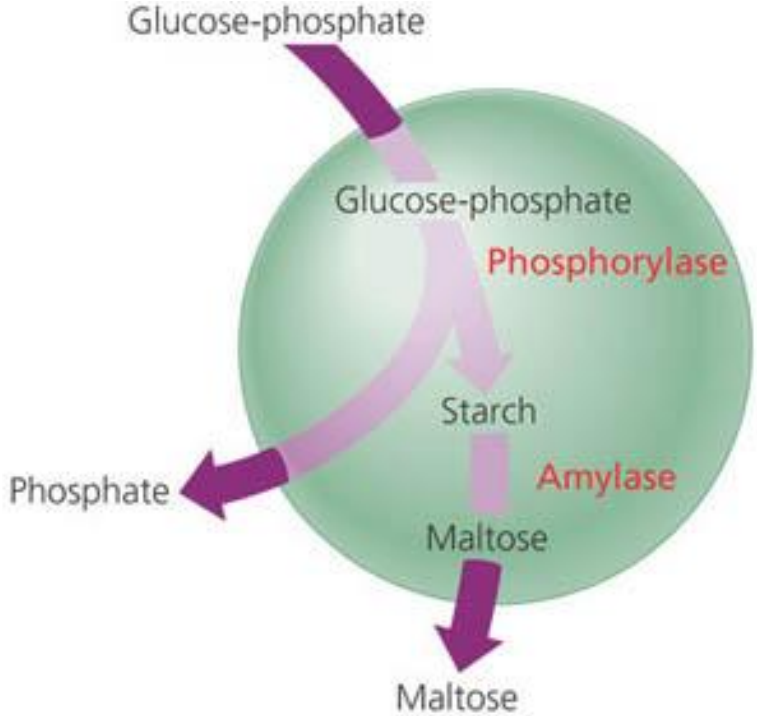
Origin of Cells (Protobionts)

- **Bubbles → separate inside from outside**
  → metabolism & reproduction





(a) Simple reproduction. This liposome is "giving birth" to smaller liposomes (LM).

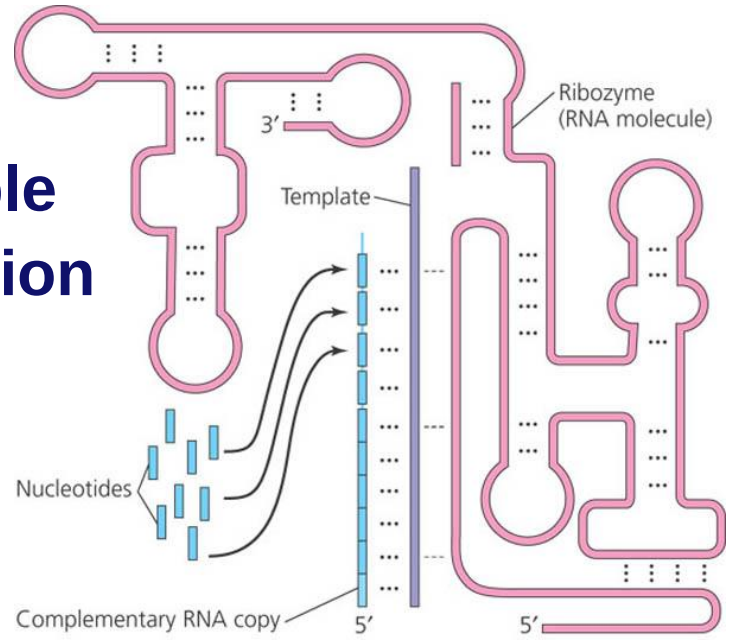


(b) Simple metabolism. If enzymes—in this case, phosphorylase and amylase—are included in the solution from which the droplets self-assemble, some liposomes can carry out simple metabolic reactions and export the products.

Dawn of natural selection

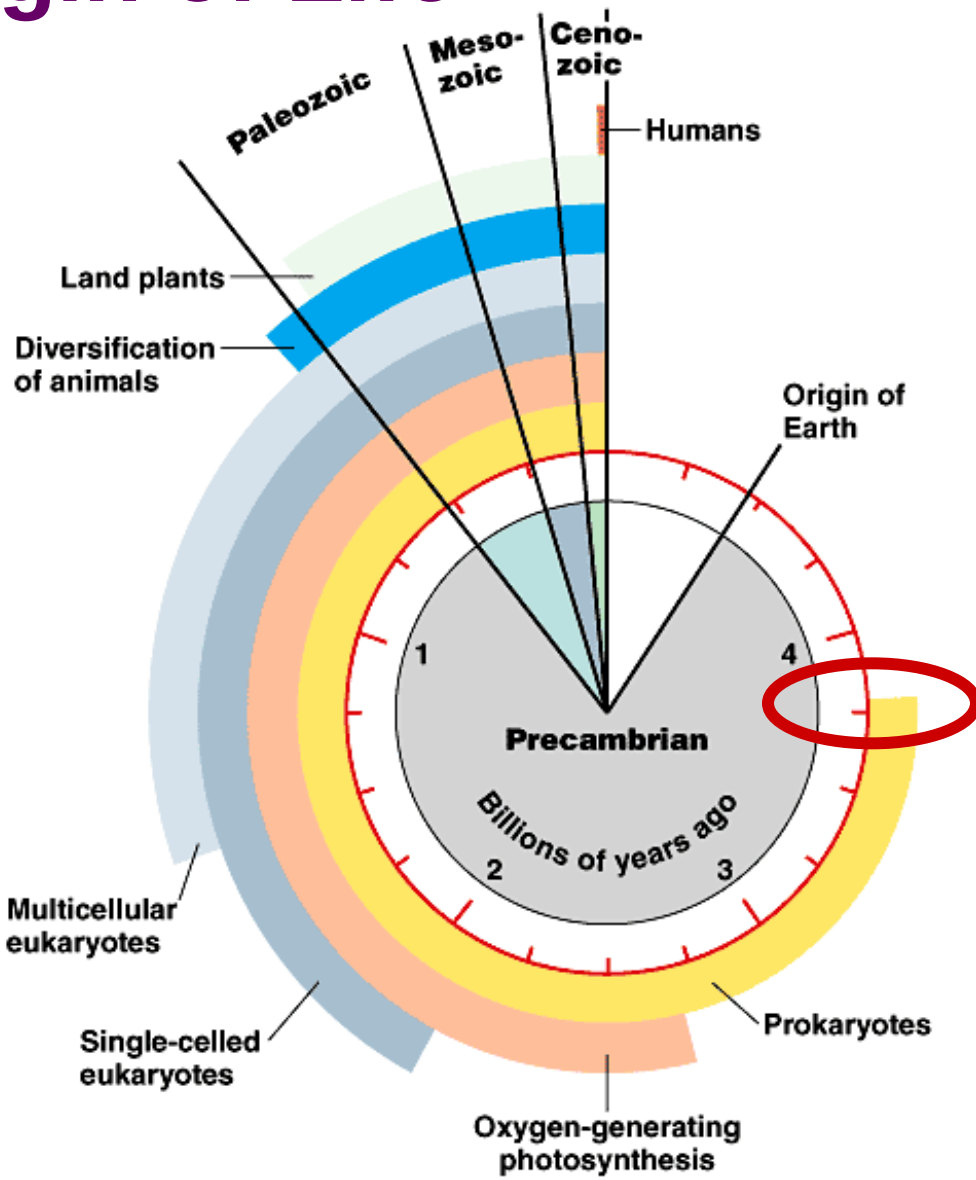
Origin of Genetics

- RNA is likely first genetic material
  - multi-functional
  - codes information
    - self-replicating molecule
    - makes inheritance possible
    - natural selection & evolution
  - enzyme functions
    - ribozymes
    - replication
  - regulatory molecule
  - transport molecule
    - tRNA & mRNA



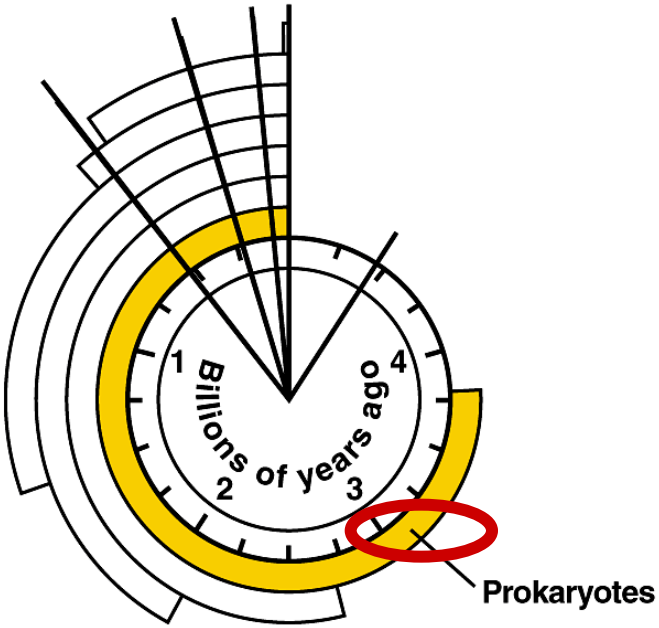
Key Events in Origin of Life

- Key events in evolutionary history of life on Earth
  - life originated 3.5–4.0 bya

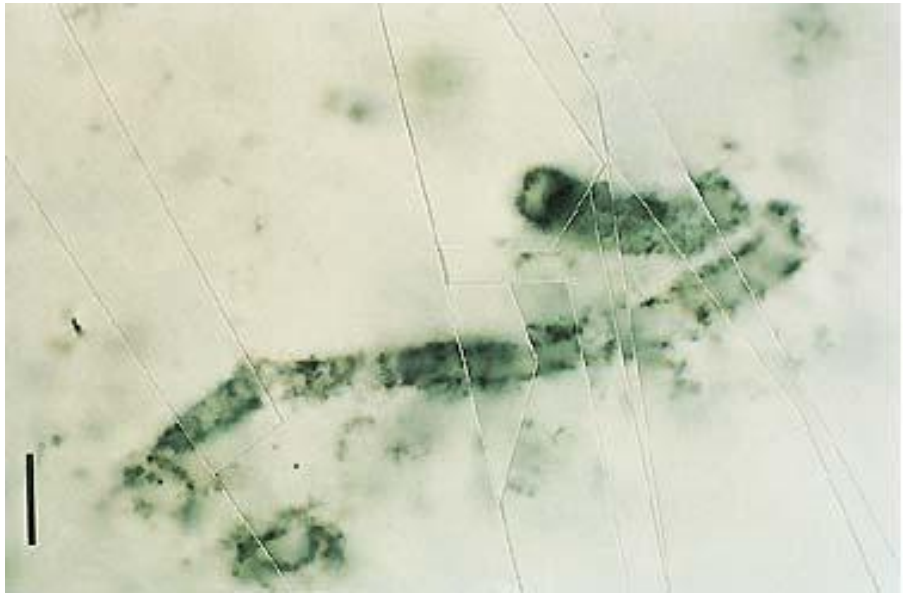


Prokaryotes

- Prokaryotes dominated life on Earth from 3.5–2.0 bya



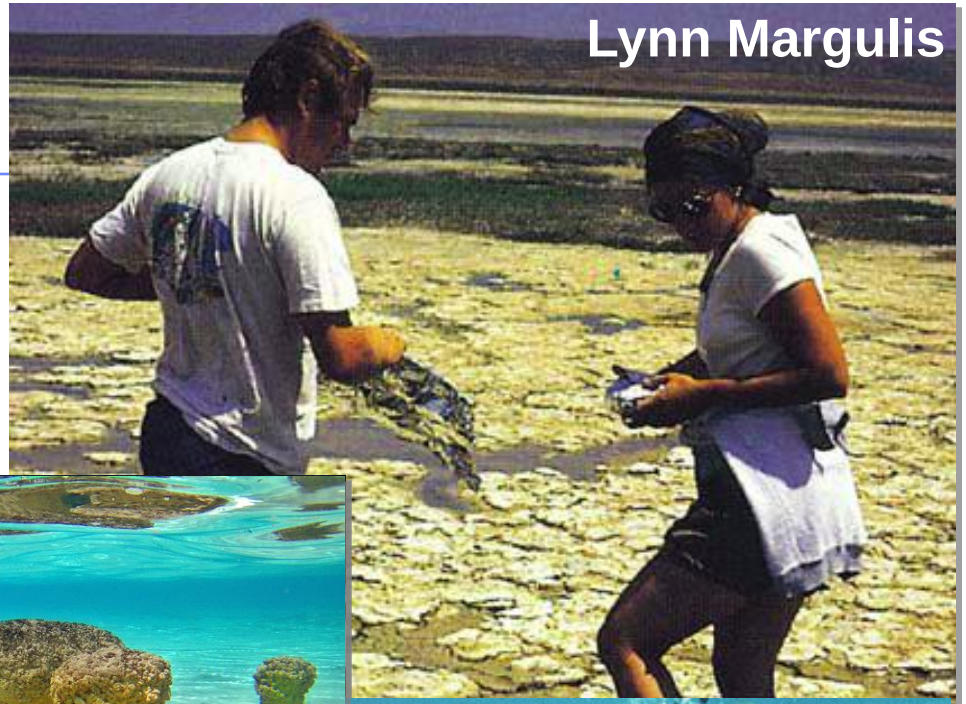
3.5 billion year old fossil of bacteria

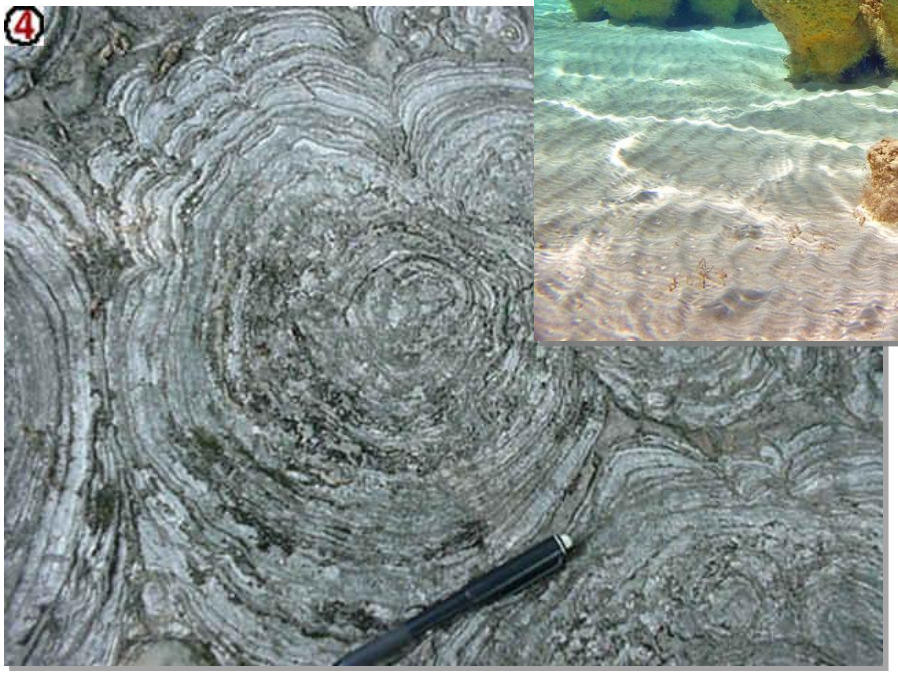


modern bacteria

Stromatolites

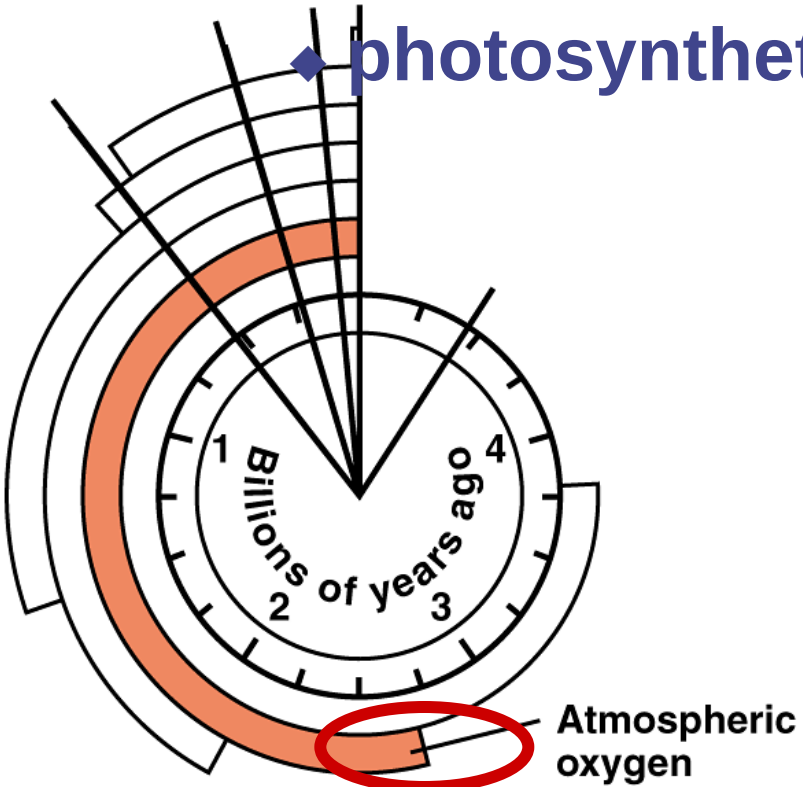
Fossilized mats of prokaryotes resemble modern microbial colonies

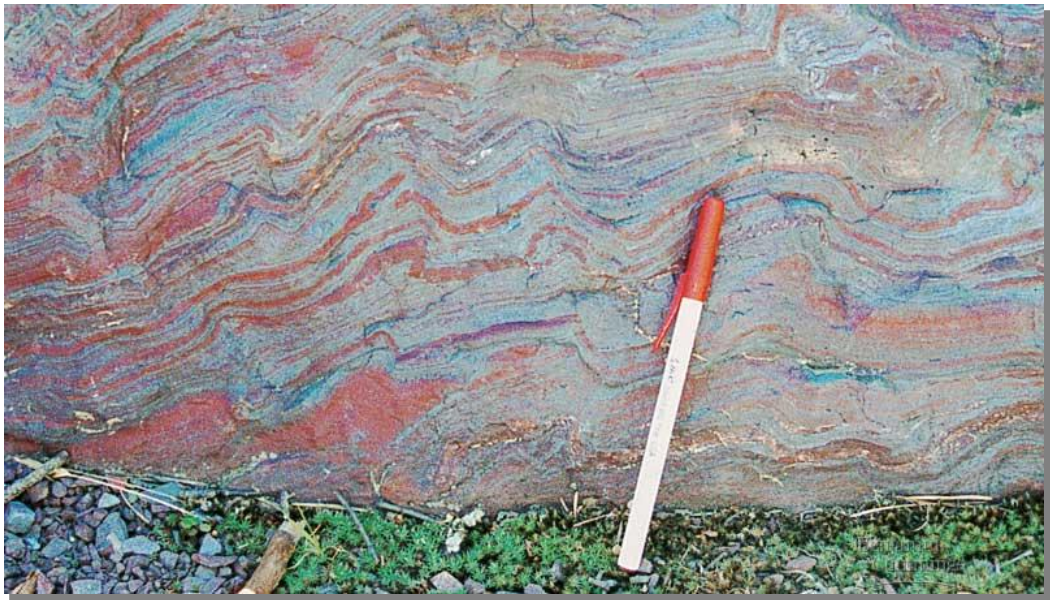




Oxygen atmosphere

- Oxygen begins to accumulate 2.7 bya
  - reducing → <u>oxidizing</u> atmosphere
    - evidence in banded iron in rocks = rusting
    - makes aerobic respiration possible
  - photosynthetic bacteria (blue-green algae)

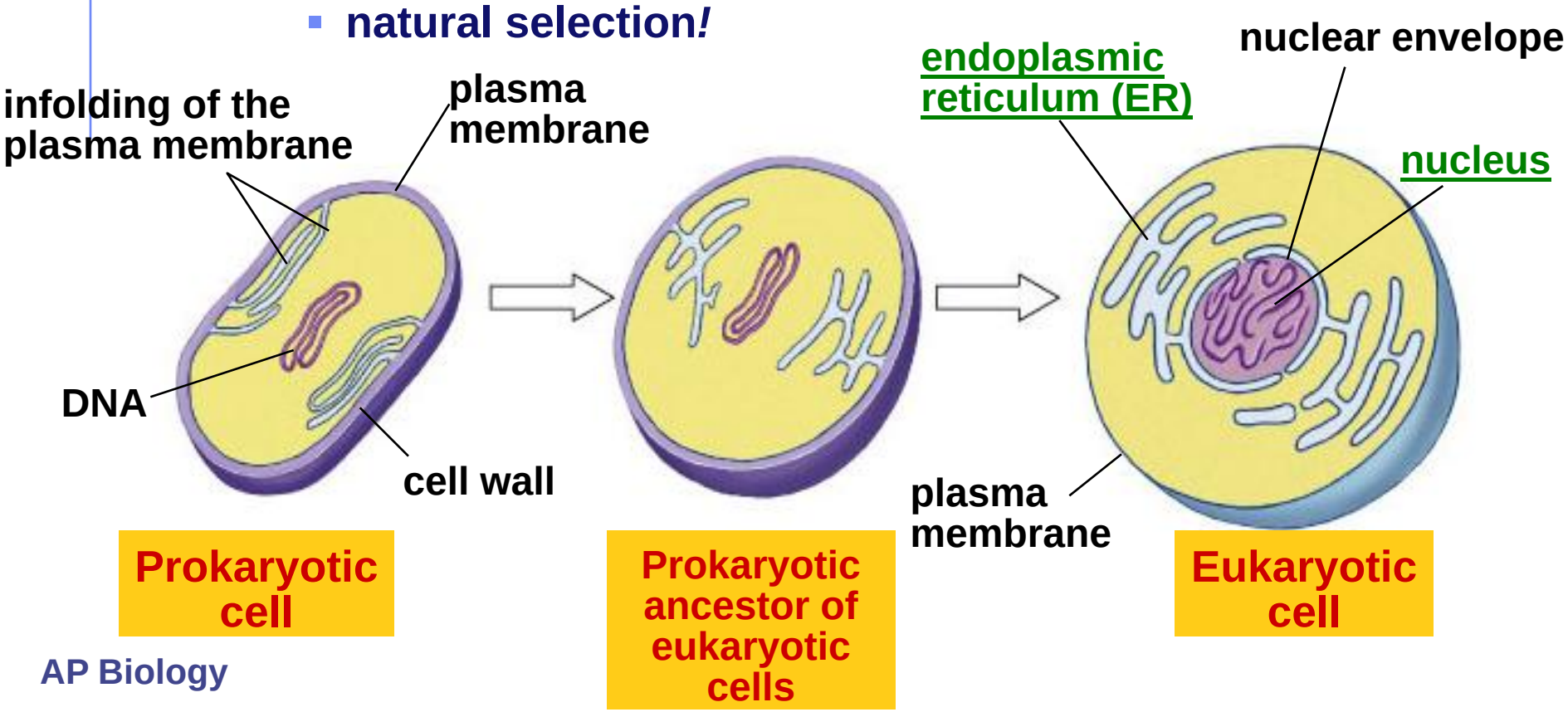




~2 bya

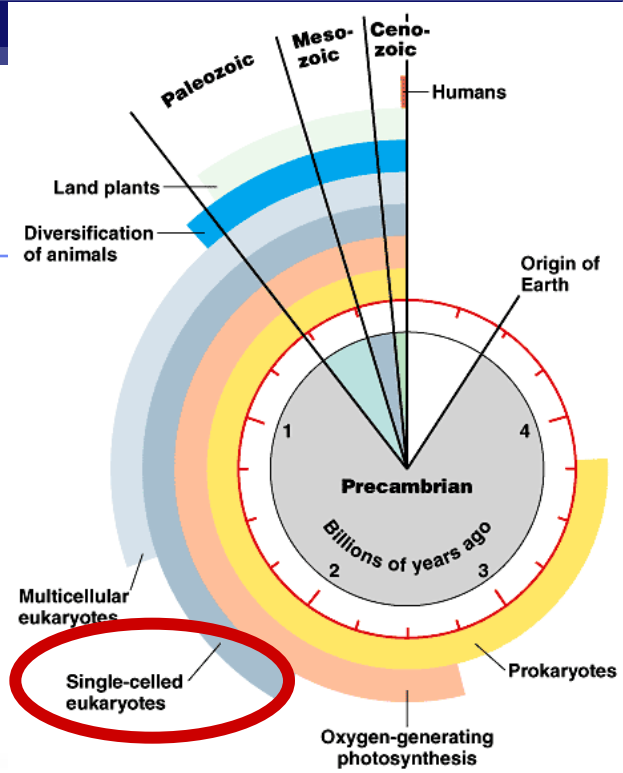
First Eukaryotes

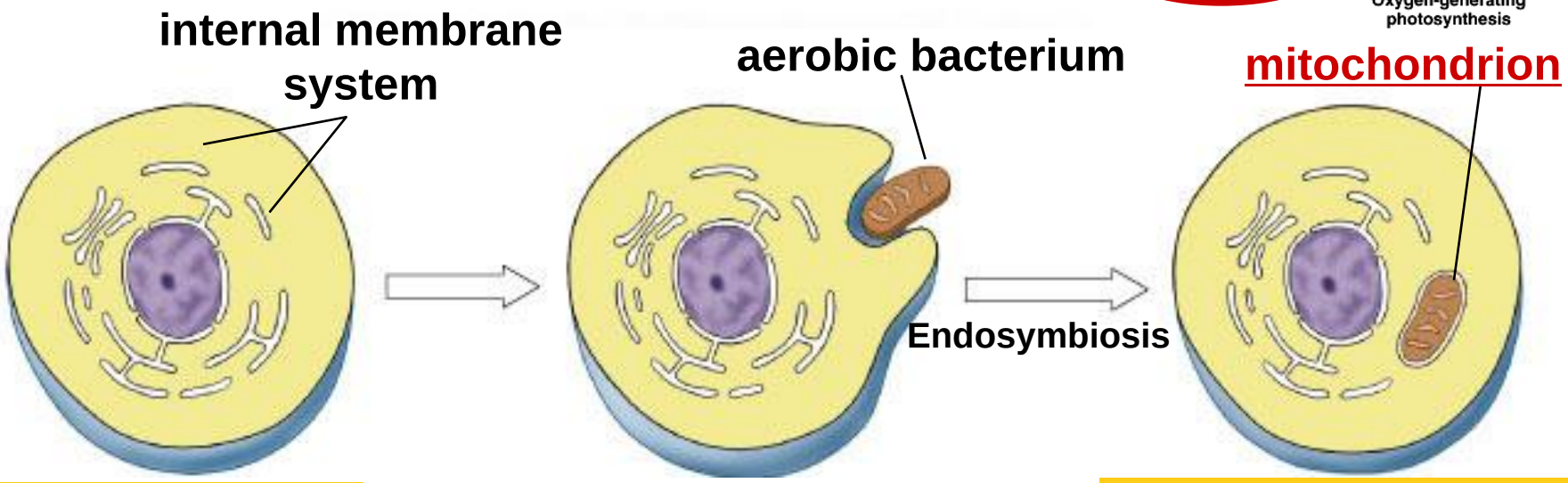
- **Development of internal membranes**
  - create internal micro-environments
  - advantage: specialization = increase efficiency
    - natural selection!



Endosymbiosis

- **Evolution of eukaryotes**
  - origin of <u>mitochondria</u>
  - engulfed aerobic bacteria, but did not digest them
  - mutually beneficial relationship
    - natural selection*!*



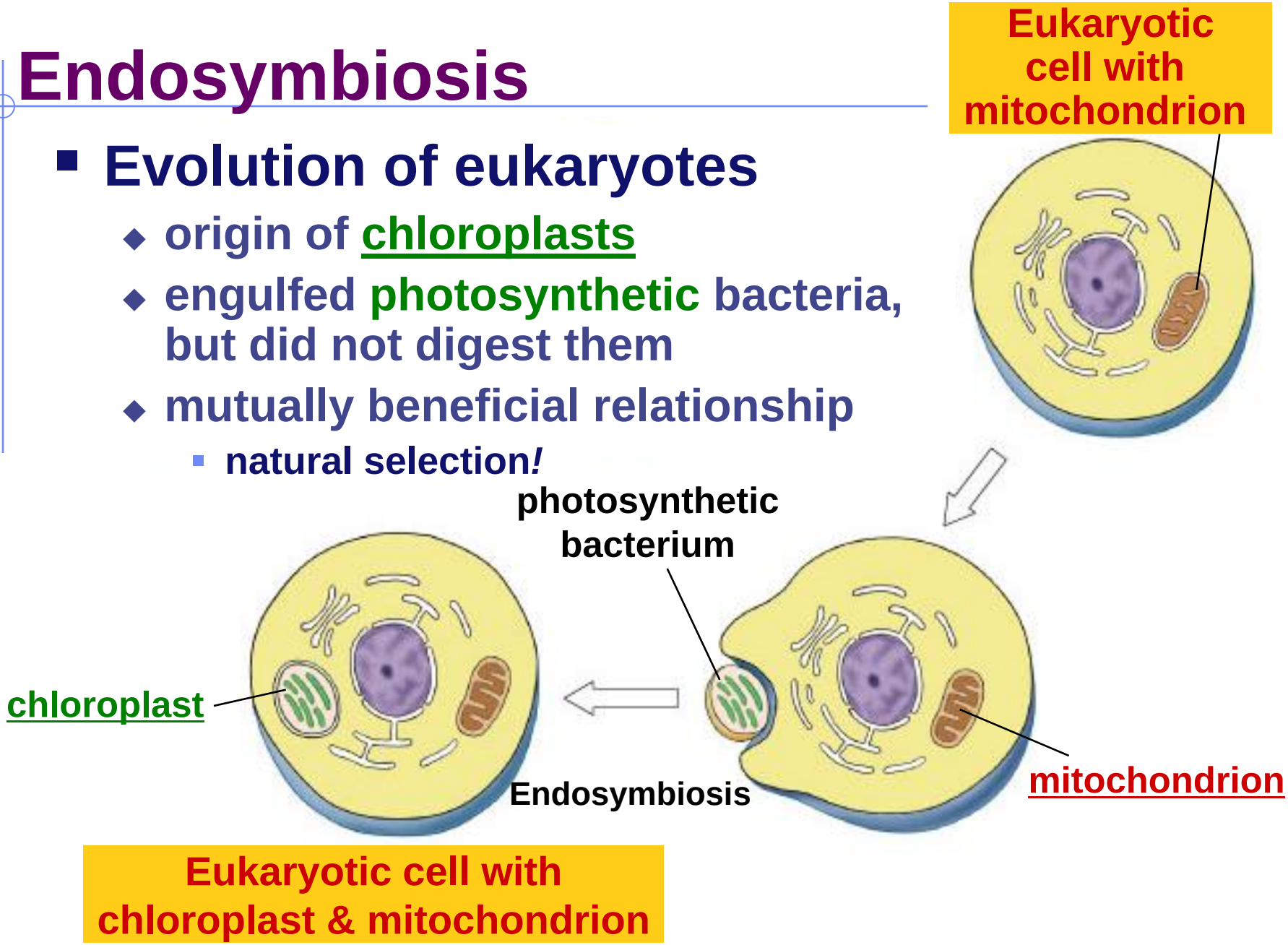


Ancestral eukaryotic cell

Eukaryotic cell with mitochondrion

Endosymbiosis

- **Evolution of eukaryotes**
  - origin of chloroplasts
  - engulfed photosynthetic bacteria, but did not digest them
  - mutually beneficial relationship
    - natural selection*!*



Theory of Endosymbiosis

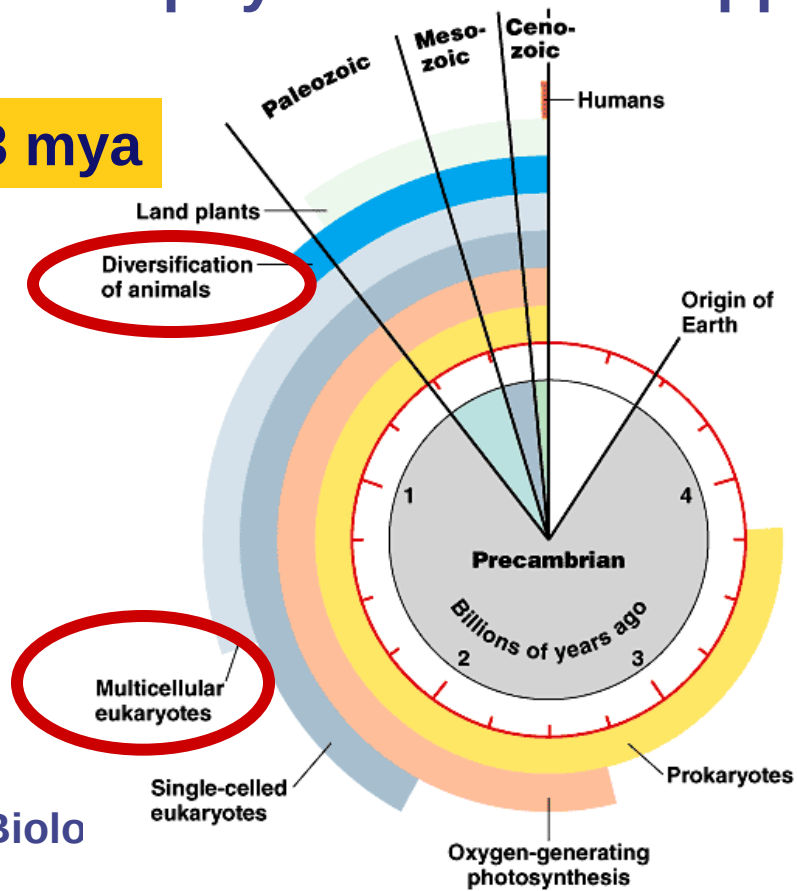
- Evidence
  - structural
    - mitochondria & chloroplasts resemble bacterial structure
  - genetic
    - mitochondria & chloroplasts have their own circular DNA, like bacteria
  - functional
    - mitochondria & chloroplasts move freely within the cell
    - mitochondria & chloroplasts reproduce independently from the cell

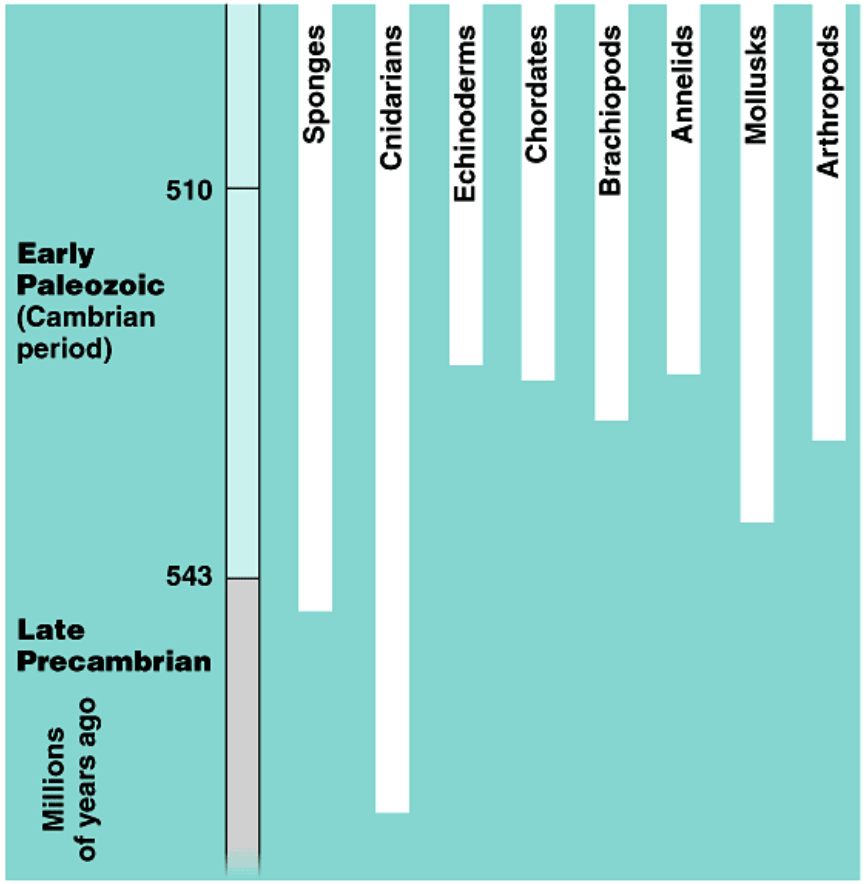
Lynn Margulis

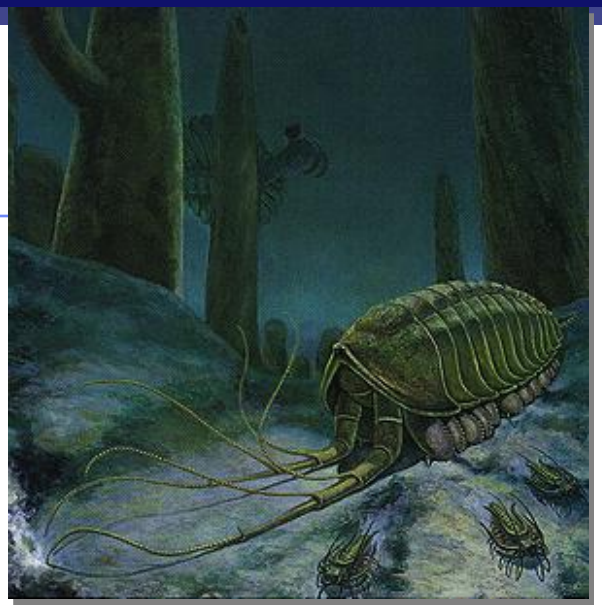
Cambrian explosion

- **Diversification of Animals**
  - within 10–20 million years most of the major phyla of animals appear in fossil record

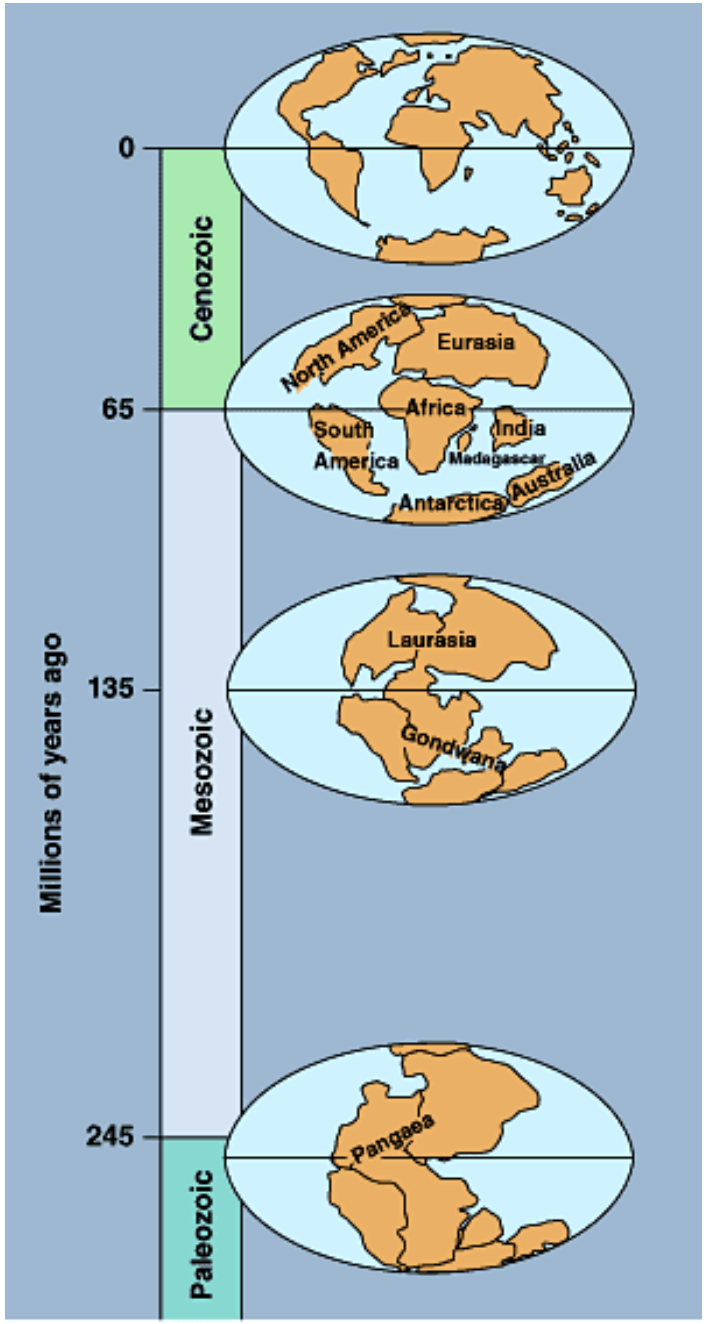
543 mya





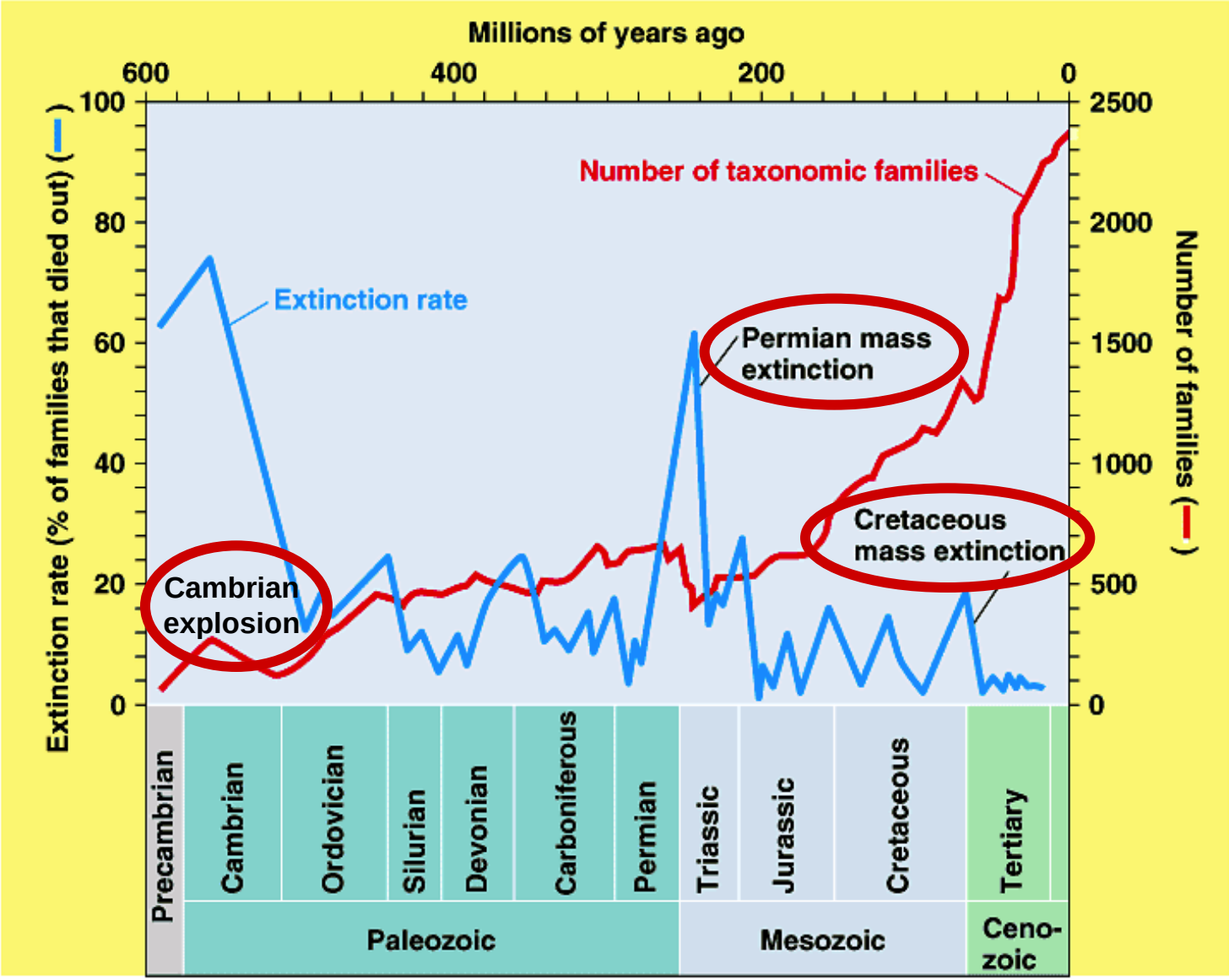


CAMBRIAN EXPLOSION was characterized by the sudden and roughly simultaneous appearance of many diverse animal forms almost 600 million years ago. No other period in the history of animal life can match this remarkable burst of evolutionary creativity. Most of the Cambrian creatures shown here were reconstructed from fossils by Simon Conway Morris and Harry Whittington of the University of Cambridge.

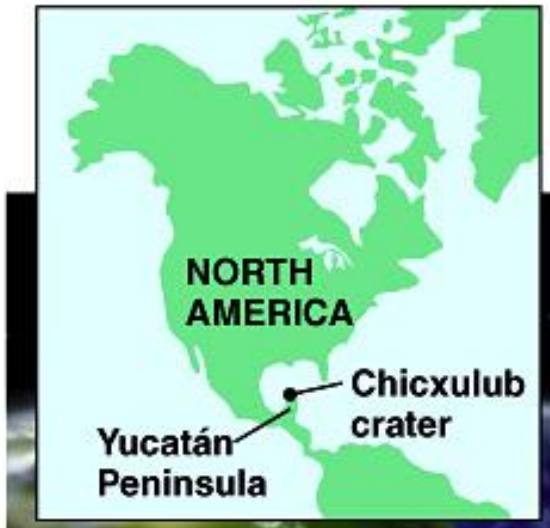


Relative Time Span of Eras	Era	Period	Epoch	Age (Millions of Years Ago)	Some Important Events in the History of Life
Cenozoic	Cenozoic	Quaternary	Recent		Historical time
				0.01	
Mesozoic			Pleistocene		Ice ages; humans appear
				1.8	
Paleozoic		Tertiary	Pliocene		Apelike ancestors of humans appear
				5	
			Miocene		Continued radiation of mammals and angiosperms
				23	
			Oligocene		Origins of many primate groups, including apes
				35	
			Eocene		Angiosperm dominance increases; continued radiation of most modern mammalian orders
				57	
			Paleocene		Major radiation of mammals, birds, and pollinating insects
				65	
Pre-cambrian	Mesozoic	Cretaceous			Flowering plants (angiosperms) appear; many groups of organisms, including dinosaurs, become extinct at end of period (Cretaceous extinctions)
				144	
		Jurassic			Gymnosperms continue as dominant plants; dinosaurs abundant and diverse
				206	
		Triassic			Cone-bearing plants (gymnosperms) dominate landscape; radiation of dinosaurs
				245	
	Paleozoic	Permian			Extinction of many marine and terrestrial organisms (Permian mass extinction); radiation of reptiles; origins of mammal-like reptiles and most modern orders of insects
				290	
		Carboniferous			Extensive forests of vascular plants; first seed plants; origin of reptiles; amphibians dominant
				363	
		Devonian			Diversification of bony fishes; first amphibians and insects
				409	
		Silurian			Diversity of jawless fishes; first jawed fishes; diversification of early vascular plants
				439	
		Ordovician			Marine algae abundant; colonization of land by plants and arthropods
				510	
		Cambrian			Radiation of most modern animal phyla (Cambrian explosion)
				543	
	Precambrian			600	Diverse soft-bodied invertebrate animals; diverse algae
				2,200	Oldest fossils of eukaryotic cells
				2,700	Atmospheric oxygen begins to increase
				3,500	Oldest fossils of cells (prokaryotes)
				3,800	Earliest traces of life
				4,600	Approximate time of origin of Earth

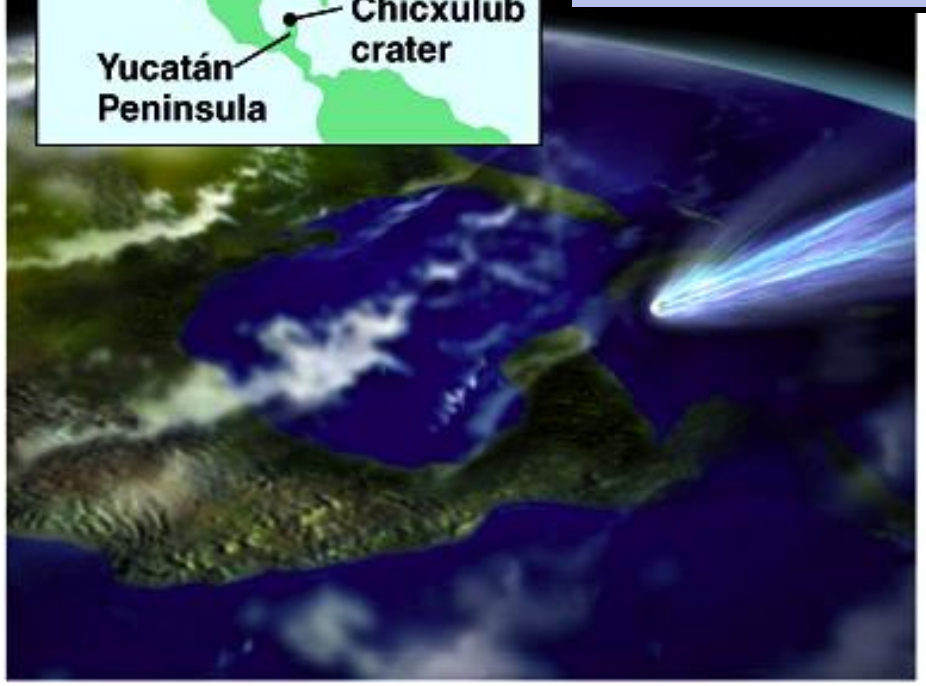
Diversity of life & periods of mass extinction



Cretaceous extinction

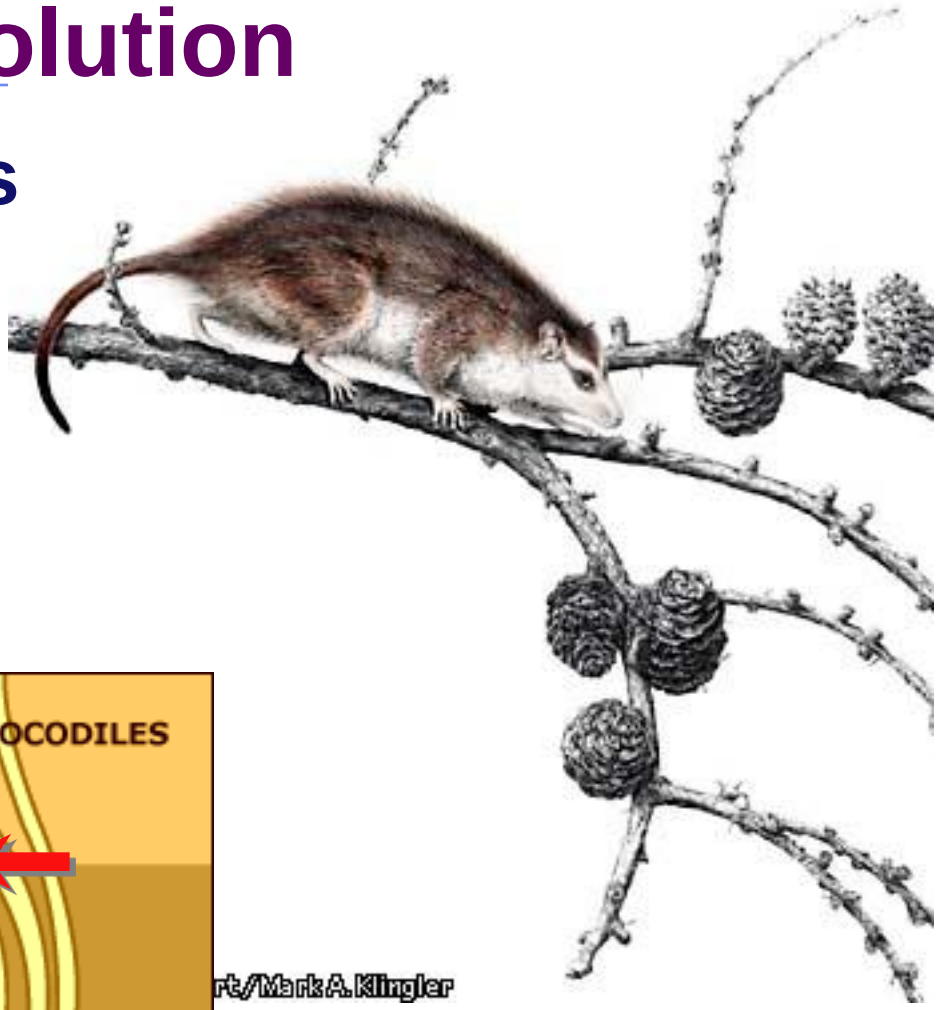


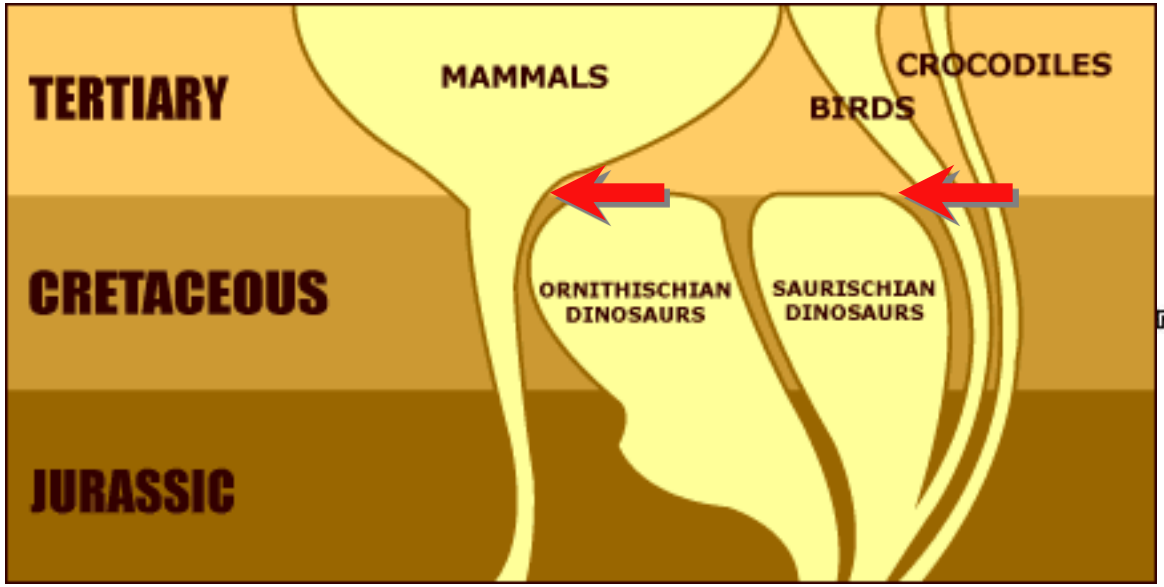
The Chicxulub impact crater in the Caribbean Sea near the Yucatan Peninsula of Mexico indicates an asteroid or comet struck the earth and changed conditions 65 million years ago



Early mammal evolution

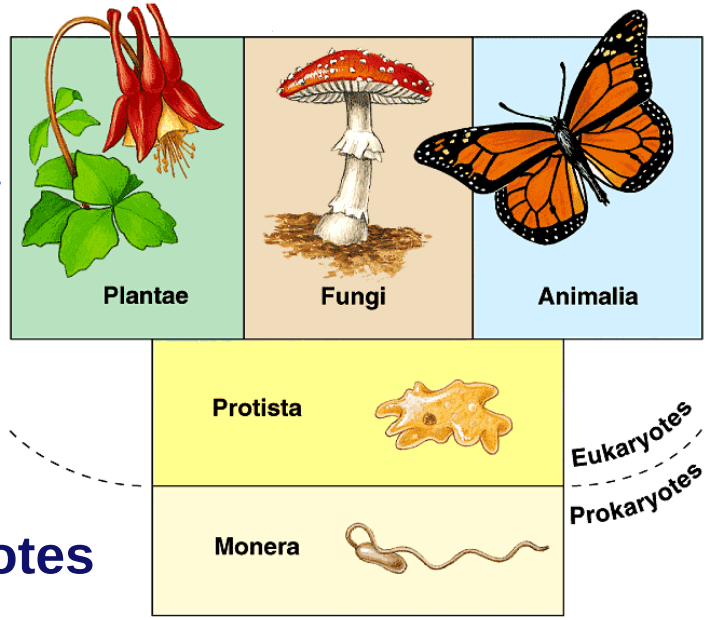
- 125 mya mammals began to radiate out & fill niches

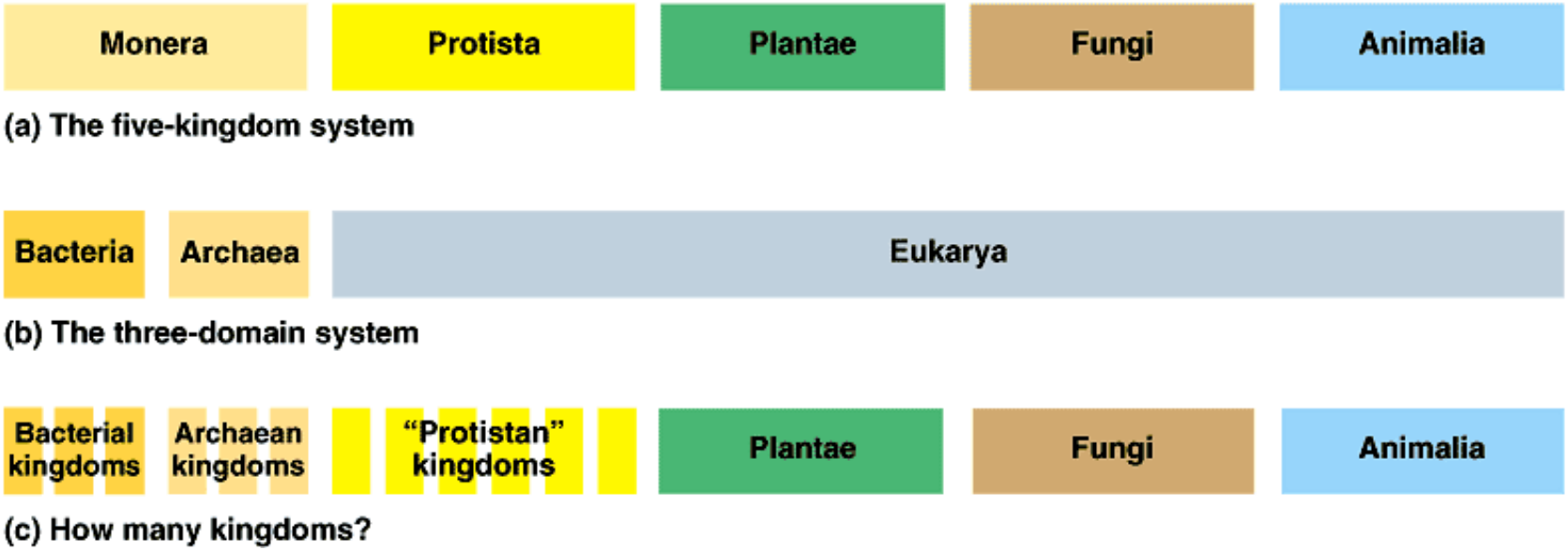




Classifying Life

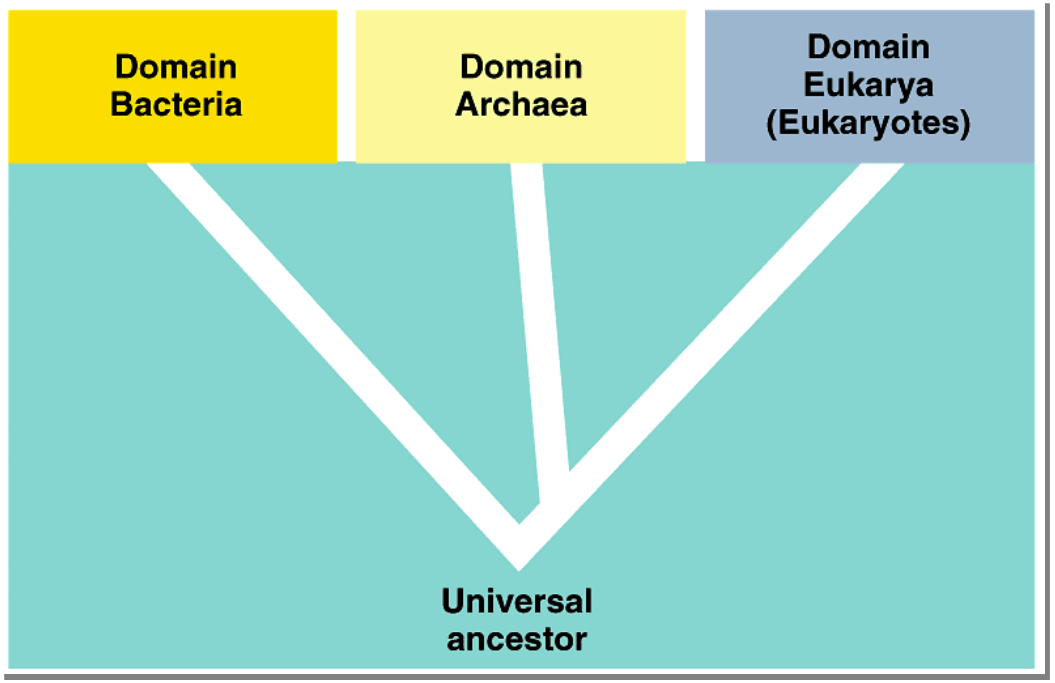
- **Molecular data** challenges 5 Kingdoms
  - Monera was too diverse
    - 2 distinct lineages of prokaryotes
  - Protists are still too diverse
    - not yet sorted out



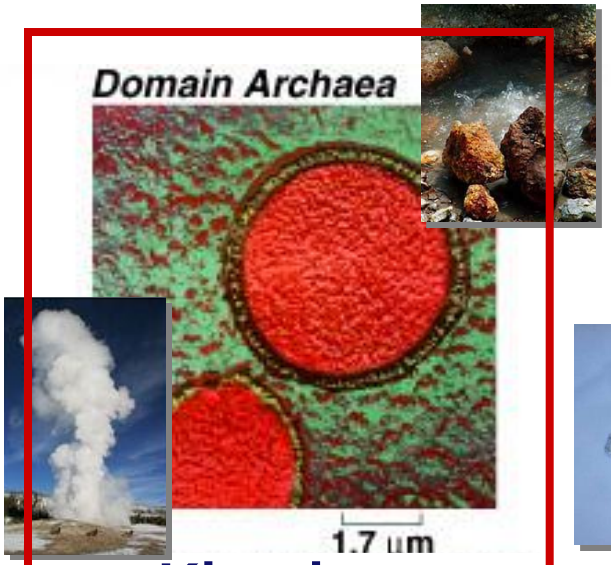


3 Domain system

- Domains = "Super" Kingdoms
  - Bacteria
  - Archaea
    - extremophiles = live in extreme environments
      - methanogens
      - halogens
      - thermophiles
  - Eukarya
    - eukaryotes
      - protists
      - fungi
      - plants
      - animals



Kingdom Bacteria



Kingdom Archaebacteria

Kingdom Protista

Kingdom Fungi

Kingdom Plantae

Kingdom Animalia

Any Questions??

Is there life elsewhere?

Does it look like life on Earth?