

### 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 itself...  
eh, it's not really my bag.  
The origin of species is where it's at!

### 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<sub>2</sub>O), CO<sub>2</sub>, N<sub>2</sub>, NO<sub>x</sub>, H<sub>2</sub>, NH<sub>3</sub>, CH<sub>4</sub>, H<sub>2</sub>S
  - ♦ lots of available H & its electron
  - ♦ no free oxygen
- **Energy source**
  - ♦ lightning, UV radiation, volcanic

### 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**

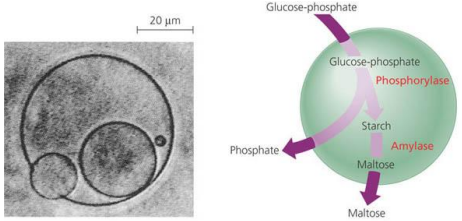
University of Chicago

produced:

- amino acids
- hydrocarbons
- nitrogen bases
- other organics

### Origin of Cells (protobionts)

- Bubbles → separate inside from outside
- metabolism & reproduction

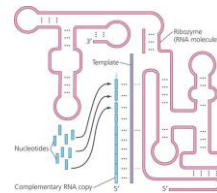


(a) Simple reproduction. This liposome is "giving birth" to smaller liposomes (LM).

(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.

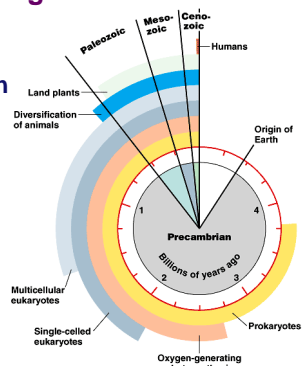
### Origin of Genetics Dawn of natural selection

- 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



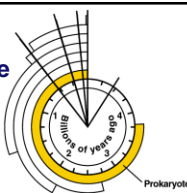
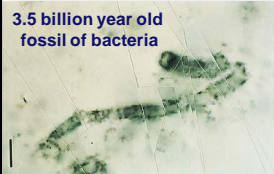
### Key Events in Origin of Life

- 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

chains of one-celled cyanobacteria

### Stromatolites

Fossilized mats of prokaryotes resemble modern microbial colonies

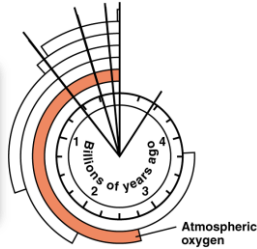


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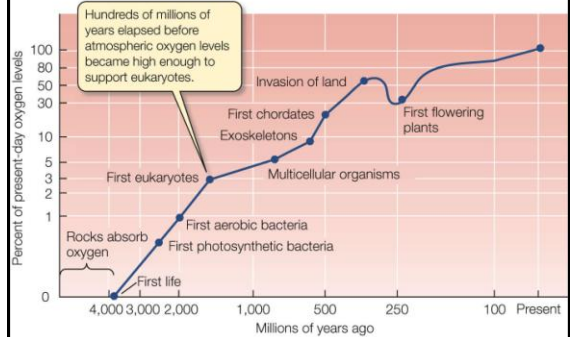


### Oxygen in the Atmosphere

- Oxygen begins to accumulate 2.7 bya
  - ◆ reducing → **oxidizing** atmosphere
    - evidence in banded iron in rocks = rusting
    - makes aerobic respiration possible
  - ◆ photosynthetic
    - algae



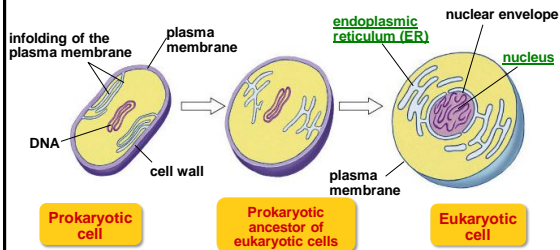
### Life has changed & changed the Earth!



### First Eukaryotes

~2 bya

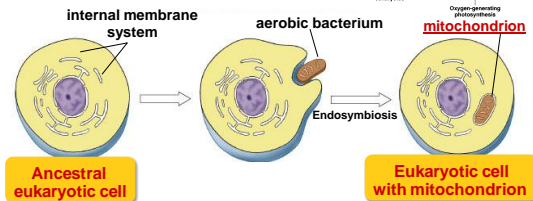
- Development of internal membranes
  - ◆ create internal micro-environments
  - ◆ advantage: specialization = increase efficiency



### Endosymbiosis

- Evolution of eukaryotes

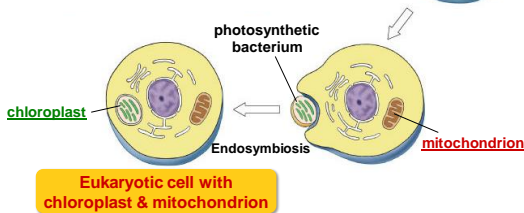
- ◆ origin of **mitochondria**
- ◆ engulfed aerobic bacteria, but did not digest them
- ◆ mutually beneficial relationship



### Endosymbiosis

- Evolution of eukaryotes

- ◆ origin of **chloroplasts**
- ◆ engulfed **photosynthetic bacteria**, but did not digest them
- ◆ mutually beneficial relationship



### 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



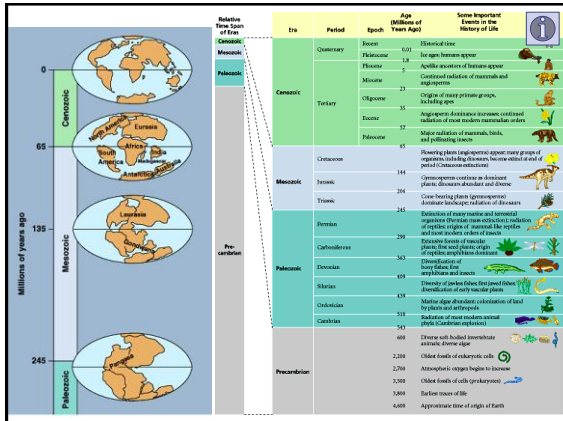
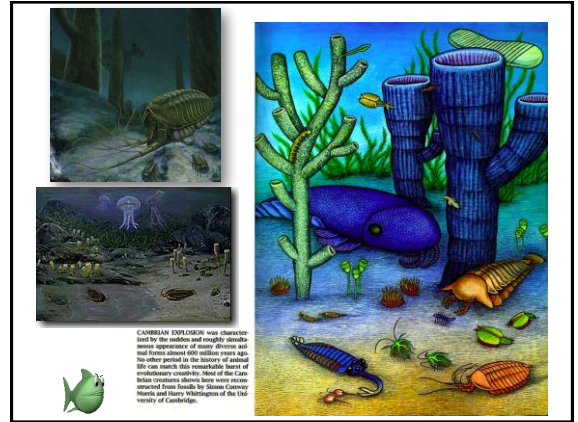
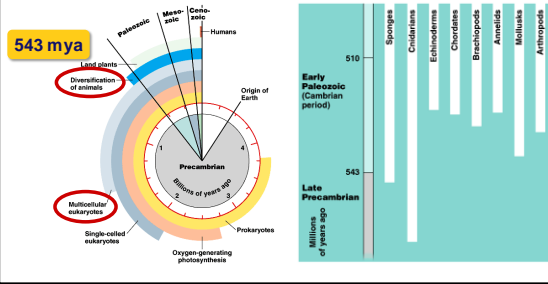
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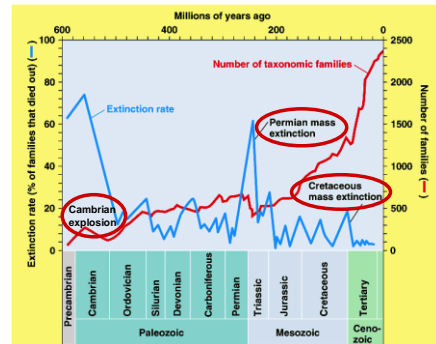
## Cambrian Explosion

### Diversification of Animals

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

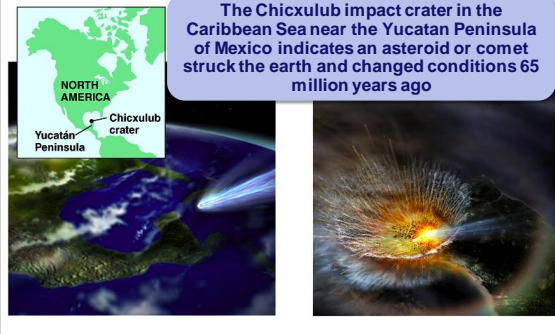


## Diversity of life & periods of mass extinction



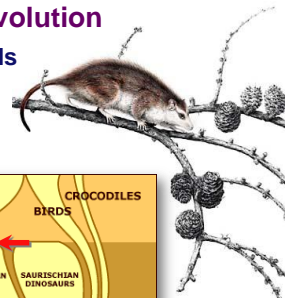
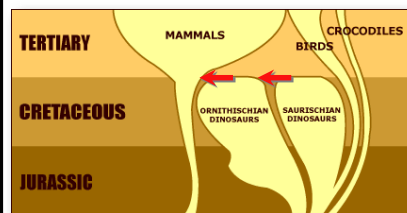
## Cretaceous Extinction

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

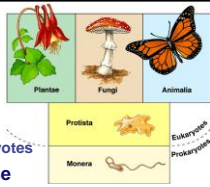
- 125 mya mammals began to radiate out & fill niches



### 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



(a) The five-kingdom system



(b) The three-domain system

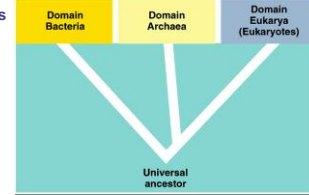


(c) How many kingdoms?

### 3 Domain System

▀ Domains = "Super" Kingdoms

- ♦ Bacteria
- ♦ Archaea
  - ▀ extremophiles = live in extreme environments
    - ♦ methanogens
    - ♦ halogens
    - ♦ thermophiles
- ♦ Eukarya
  - ▀ eukaryotes
    - ♦ protists
    - ♦ fungi
    - ♦ plants
    - ♦ animals



<p><i>Domain Bacteria</i></p> <p><b>Kingdom Bacteria</b></p>	<p><i>Domain Archaea</i></p> <p><b>Kingdom Archaeobacteria</b></p>	<p><i>Domain Eukarya</i></p> <p><b>Kingdom Protista</b></p>
<p><b>Kingdom Fungi</b></p>	<p><b>Kingdom Plantae</b></p>	<p><b>Kingdom Animalia</b></p>