Geologic Time

Current Florida Standards Addressed

- SC.912.N.1.1: Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: (reference 1-11)
- SC.912.N.1.6: Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.
- SC.912.N.2.4 *Explain that scientific knowledge is both durable and robust and open to change. Scientific knowledge can change because it is often examined and re-examined by new investigations and scientific argumentation. Because of these frequent examinations, scientific knowledge becomes stronger, leading to its durability.*
- SC.912.L.14.5 *Explain the evidence supporting the scientific theory of the origin of eukaryotic cells (endosymbiosis).*
- SC.912.L.15.3: *Describe how biological diversity is increased by the origin of new species and how it is decreased by the natural process of extinction.*
- SC.912.L.15.8: *Describe the scientific explanations of the origin of life on Earth.*
- *SC.912.L.16.5: Explain the basic processes of transcription and translation, and how they result in the expression of genes.*
- SC.912.L.18.1-4: *Describe the basic molecular structures and primary functions of the four major categories of biological macromolecules.*
- SC.912.E.5.1 *Cite evidence used to develop and verify the scientific theory of the Big Bang (also known as the Big Bang Theory) of the origin of the universe.*
- SC.912.E.5.5 *Explain the formation of planetary systems based on our knowledge of our Solar System and apply this knowledge to newly discovered planetary systems*
- SC.912.E.6.1 *Describe and differentiate the layers of Earth and the interactions among them*
- *(SC.912.E.6.3: Analyze the scientific theory of plate tectonics and identify related major processes and features as a result of moving plates.)*
- *SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure*
- SC.912.P.8.10 *Describe oxidation-reduction reactions in living and non-living systems*
- *LA.910.2.2.3 The student will organize information to show understanding or relationships among facts, ideas, and events (e.g., representing key points within text through charting, mapping, paraphrasing, summarizing, comparing, contrasting, or outlining)*
- MACC.912.N-Q.1.1 *Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.*
- MACC.912.A-CED.1.1*Create equations and inequalities in one variable and use them to solve problems.*
- MA.912.S.1.2 *Determine appropriate and consistent standards of measurement for the data to be collected in a survey or experiment.*

NGSS Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

- 1. Patterns.
- 2. Cause and effect
- 3. Scale, proportion, and quantity
- 4. Systems and system models
- 5. Energy and matter:
- 6. Structure and function.
- 7. Stability and change.

Geologic Time Scale Activity

How Vast is Geologic Time?

Table 1. The development of life through time.

Million years before present	Era, System, or Event	Relative to a calendar year
	Precambrian	
4600	**Earth formed from planetary nebula**	**1/1/04 12:00 AM**
3900	Inferred origin of life (first cells)	2/25/04 4:41 PM
3800	Oldest age-dated rocks on Earth	3/4/04 3:39 PM
3600	Fossil blue-green algae and stromatolites (prokaryots)	3/20/04 1:33 PM
3250	First fossil evidence of bacteria	4/17/04 9:54 AM
2100	First fossil evidence of cells with a nucleus	7/17/04 9:54 PM
1500	First multi-celled organisms (seaweed and algae)	9/3/04 3:39 PM
670	Oldest marine worms and jellyfish	11/8/04 4:35 PM
600	Vendian period begins: Edicarian fossils	11/14/04 6:15 AM
	Paleozoic	
544	**Cambrian system begins**	**11/18/04 5:11 PM**
515	Burgess Shale organisms: first animals with a	11/21/04 12:34 AM
505	**Ordovician system begins**	**11/21/04 7:40 PM**
505	First fish	11/21/04 7:40 PM
470	First fossil evidence of land plants	11/24/04 2:30 PM
438	**Silurian system begins**	**11/27/04 3:36 AM**
430	First vascular land plants	11/27/04 6:53 PM
414	Oldest lung fish fossils	11/29/04 1:26 AM
408	**Devonian system begins**	**11/29/04 12:53 PM**
408	Oldest fossil evidence of mosses	11/29/04 12:53 PM
385	First insects (beetles), scorpions, and centipedes	12/1/04 8:49 AM
380	First lobe-finned fish	12/1/04 6:21 PM
375	First land animals (amphibians)	12/2/04 3:54 AM
370	First sharks	12/2/04 1:27 PM
365	First seed plants (ferns)	12/2/04 11:00 PM
360	**Mississippian system begins**	**12/3/04 8:33 AM**
330	First possible reptiles	12/5/04 5:50 PM
320	**Pennsylvanian system (Kentucky coal)**	**12/6/04 12:56 PM**
286	Permian system begins	12/9/04 5:51 AM
260	Sail-backed reptiles (Dimetrodon)	12/11/04 7:30 AM
245	End of Paleozoic, 96% of all life on Earth perishes	12/12/04 12:09 PM
	Mesozoic, the "Age of Reptiles"	
245	**Triassic system begins**	**12/12/04 12:09 PM**
240	First crocodiles	12/12/04 9:42 PM
228	First dinosaurs (Eoraptor and Saltoposuchus)	12/13/04 8:37 PM
221	First mammals (shrew-like)	12/14/04 9:59 AM
210	First turtles	12/15/04 6:59 AM
208	**Jurassic system begins**	**12/15/04 10:48 AM**
195	Dilophosaurus, an early Jurassic dinosaur	12/16/04 11:38 AM
155	First bird, Archeopteryx	12/19/04 4:01 PM
152	Apatosaurus and Brachiosaurus (long-necked	12/19/04 9:44 PM
150	Allosaurus, (meat-eating dinosaur)	12/20/04 1:33 AM
148	Stegosaurus, (plate-backed dinosaur)	12/20/04 5:23 AM
144	**Cretaceous system begins**	**12/20/04 1:01 PM**
115	First flowering plants	12/22/04 8:24 PM
82	Duck-billed dinosaurs (Maiasaurus)	12/25/04 11:24 AM
80	Protoceratops (first dinosaur eggs discovered)	12/25/04 3:14 PM
75	Triceratops	12/26/04 12:46 AM
70	Tyrannosaurus rex and Velociraptor	12/26/04 10:19 AM
65	End of Mesozoic, probably meteor or comet impact	12/26/04 7:52 PM
	Cenozoic, the "Age of Mammals"	
65	**Tertiary system begins**	**12/26/04 7:52 PM**
64	First ancestors of dogs and cats	12/26/04 9:47 PM
60	Grasses become widespread	12/27/04 5:25 AM
57	First ancestors of pigs and deer	12/27/04 11:09 AM
55	First horses (Eohippus)	12/27/04 2:58 PM
45	First ancestors of rabbits	12/28/04 10:04 AM
39	First monkeys	12/28/04 9:31 PM
4	Oldest human like ancestors (hominids)	12/31/04 5:18 PM
2	**Quaternary system begins**	**12/31/04 8:56 PM**
1	First of four ice ages	12/31/04 10:05 PM
1	Oldest direct human-ancestor fossil, Homo habilis	12/31/04 11:02 PM
0.1	First modern man, Homo sapiens	12/31/04 11:48 PM
0.05	Mammoth and mastodon bones, Big Bone Lick, KY	12/31/04 11:54 PM
228 years	Revolutionary War	12/31/04 11:59 PM
63 years	World War II	1/1/05 12:00 AM

The scale of geologic time is vast, currently estimated at nearly 4.6 billion years. During that time, life evolved into the familiar forms we see today. These materials are provided to assist in understanding time relationships and how life on Earth changed through time.

The dates shown were compiled from several available sources. Table 1 shows some important events in Earth history, presented in the order in which they occurred. The data are also shown on the scale of a calendar year. When geologic time is compressed to the scale of a calendar year, 1 second equals about 146 years. At this scale, World War II began about 0.4 second before midnight on December 31; because of rounding, this is shown as midnight of the new year.

On the back of this sheet is a chart showing the geologic eras, systems, and series; the oldest is at the bottom. On the chart, each dot, number, or letter represents 1 million years. The dots get "older" as you read down the chart, or to the right along a row. Thus, they represent millions of years before present ("mybp") and show the ages of the oldest known fossils of selected animals or the time of an event. Not all of the items shown in Table 1 are shown on the chart because of space limitations.

For more information on the geologic time scale, see:

- www.uky.edu/KGS/education/activities.html
- Dinosaurs: Fact & Fiction pubs.usgs.gov/gip/dinosaurs/
- Fossils, Rocks, and Time: pubs.usgs.gov/gip/fossils/
- Geologic Time: pubs.usgs.gov/gip/geotime/
- Teaching About Evolution and the Nature of Science: books.nap.edu/books/0309063647/html/index.html
- Learning from the Fossil Record www.ucmp.berkeley.edu/fosrec/fosrec.html
- Understanding Evolution: evolution.berkeley.edu/
- National Center for Science Education: www.natcenscied.org/

The dot scale of geologic time is adapted from an idea by Charly Zuppann of the Indiana Geological Survey, Bloomington, Indiana.

Lets plot the Highlights!

- Earth Forms
- Origin of life
- First multi-cell orgs
- First land animals (amphibians)
- First seed plants (ferns)
- First Reptiles
- Ordovician Extinction (438 mya)
- Devonian Extinction (365 mya)
- Permian Extinction (245mya)
- First dinosaurs
- First mammals
- First bird, Archaeopteryx
- Triassic Extinction (208 mya)
- First Flowering Plants
- T-Rex
- K-T Extinction (65mya)
- Ancestors of Dogs and Cats
- Grasses widespread
- First monkeys
- Hominids
- First of 4 ice ages
- Homo habilis
- Homo sapiens

Use the Calendar Chart to find the highlights listed above and plot them on the calendar provided. This will give you a good idea as to what order major events happened in Life's history and the time relationships between those events.

Group Work

- Use the Calendar Chart and Dot Chart of the Geologic Time Scales to Complete the Activity in Groups.

SC.912.L.15.3: *Describe how biological diversity is increased by the origin of new species and how it is decreased by the natural process of extinction.*
SC.912.L.15.8: *Describe the scientific explanations of the origin of life on Earth.*
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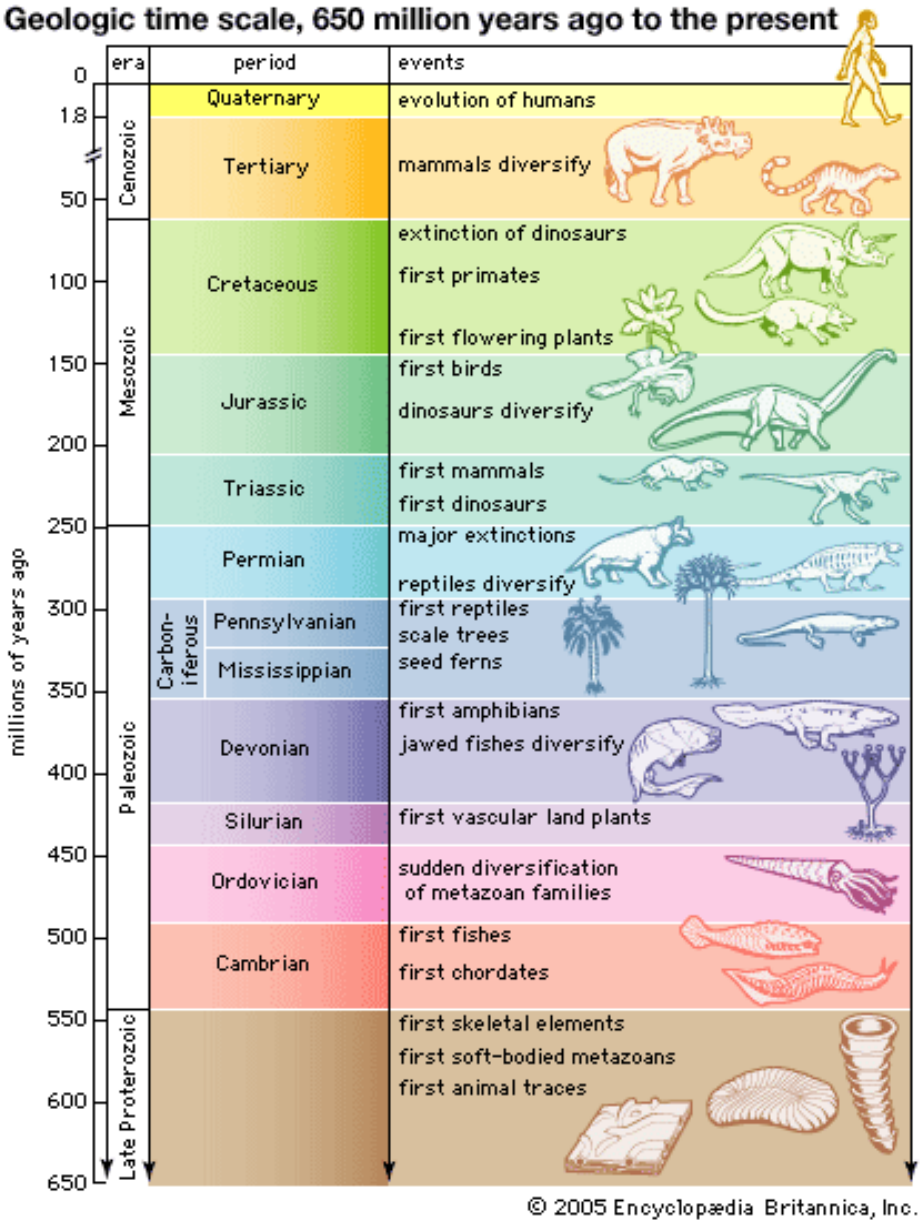
MACC.912.A-CED.1.1 *Create equations and inequalities in one variable and use them to solve problems.*

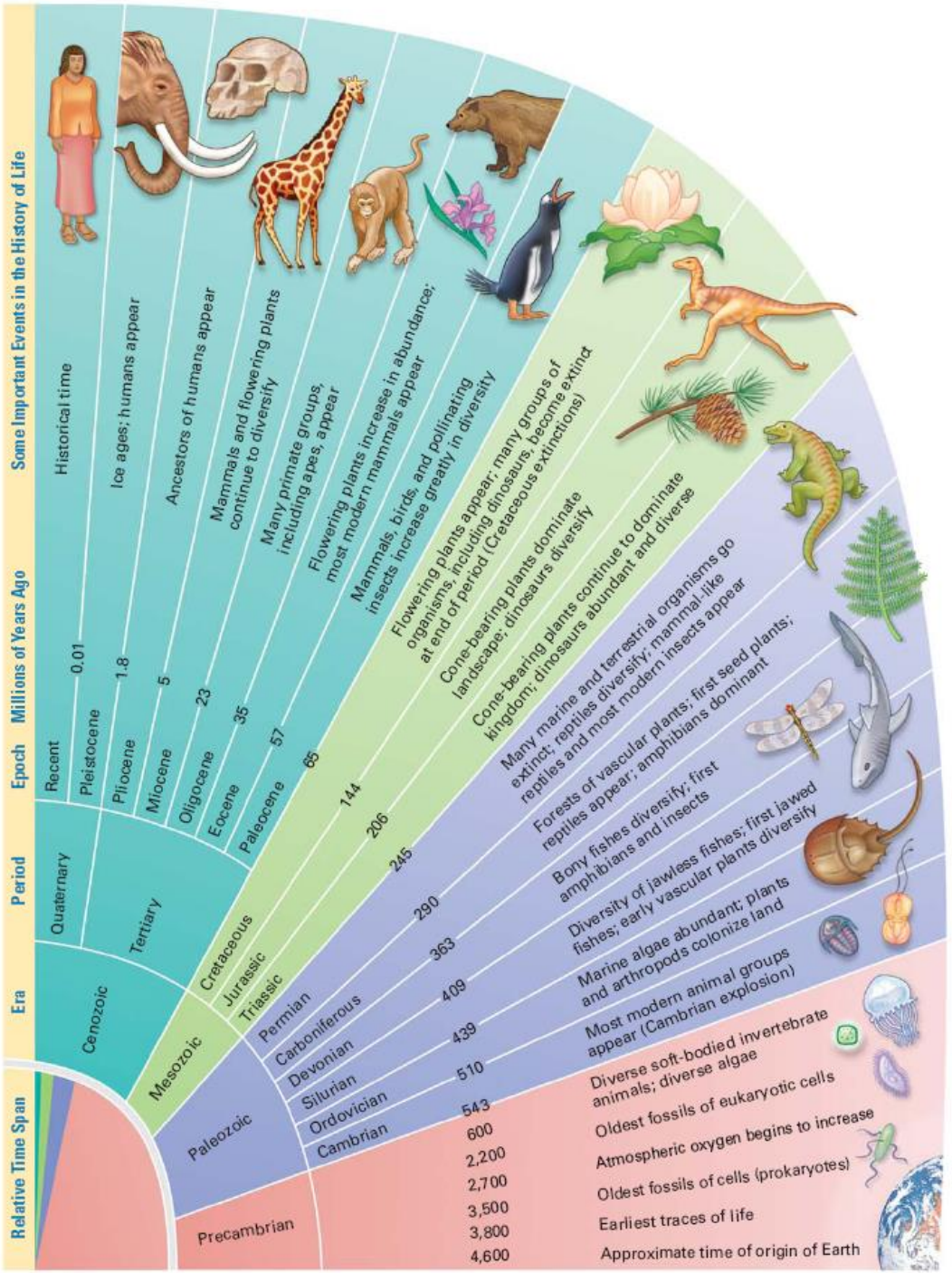
Geologic Time Scale

- geologic time scale : organizes Earth's history into four distinct eras:
  - Precambrian
  - Paleozoic
  - Mesozoic
  - Cenozoic
  - **eras** are divided into shorter time spans called periods
  - **periods** are divided into epochs



Boundaries in Time

- Boundaries between Eras and Periods are marked in the fossil record by:
  1. Major changes (or turnovers) in the forms of life
  2. Widespread or mass extinctions



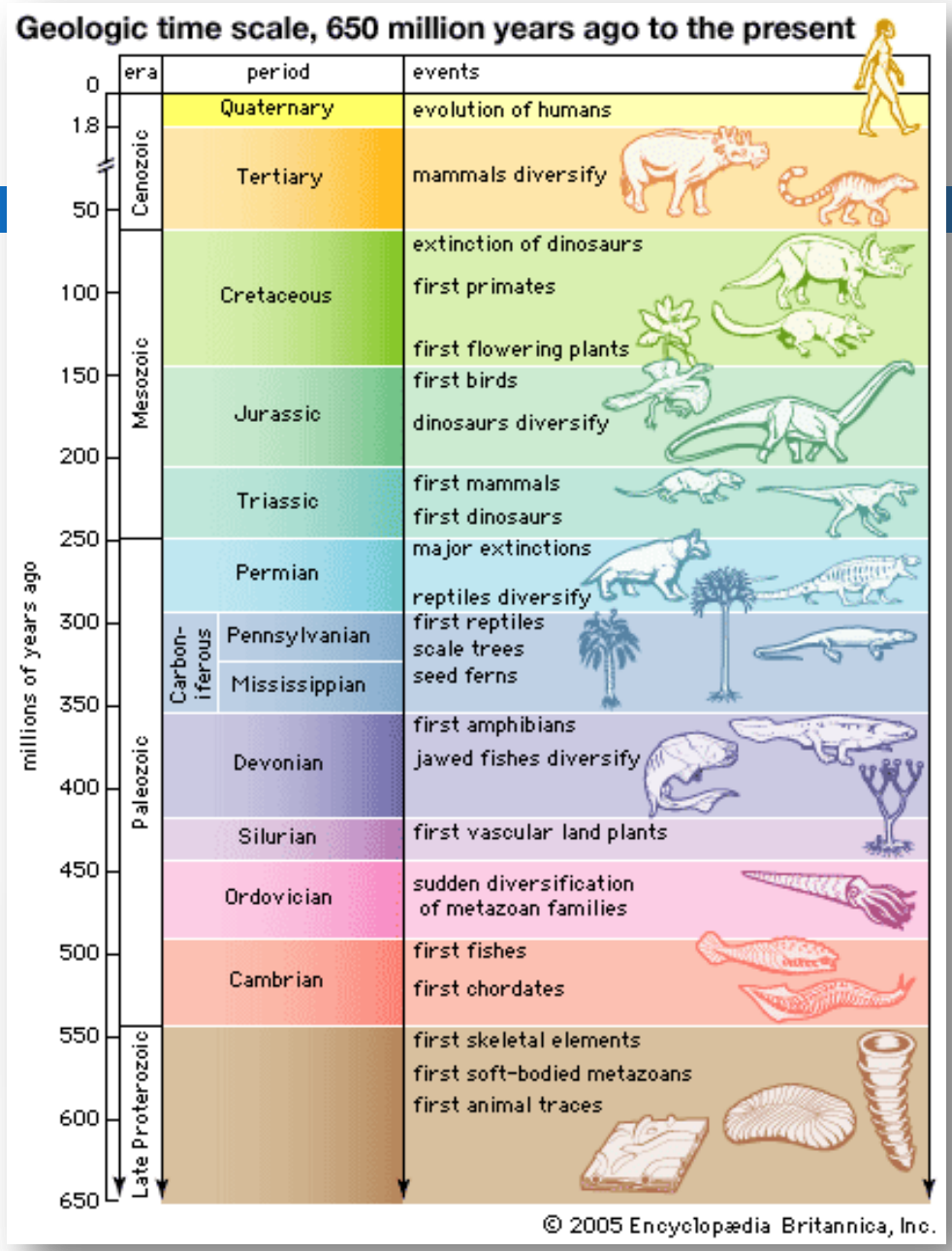
Mass Extinctions

- **mass extinction**: episode of great species loss
  - Cretaceous-Tertiary
    - 65 MYA
    - world lost an enormous number of species
    - dinosaurs thrived on Earth for 150 my
    - <10 million years later—a brief period in geologic time—all the dinosaurs were gone

"Big Five"

- End Ordovician
- Late Devonian
- End Permian
- End Triassic
- End Cretaceous

Extension Opportunity
(SC.912.E.6.3: Analyze the scientific theory of plate tectonics and identify related major processes and features as a result of moving plates.)



Analyzing Data

SC.912.N.1.1, SC.912.N.1.6, SC.912.L.17.8, MA.912.S.3.2

Extinctions Through Time

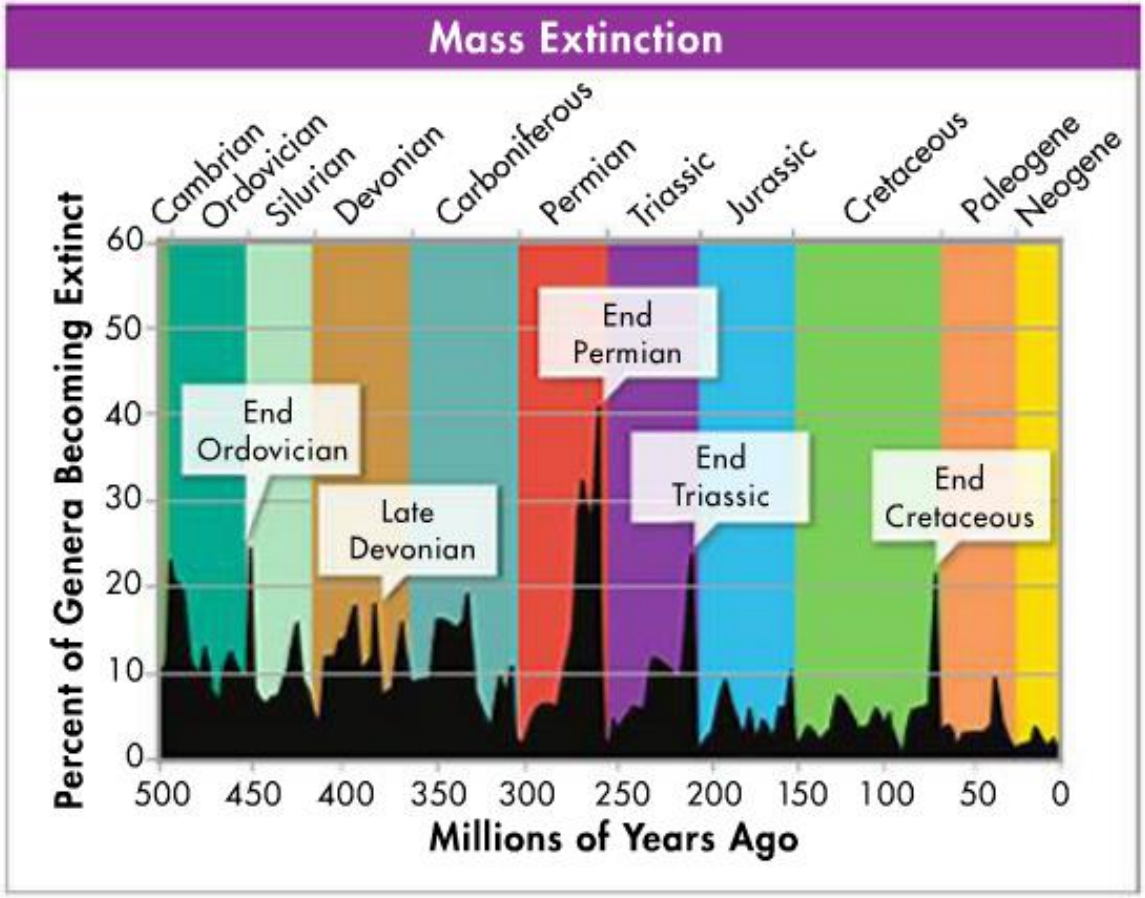
The graph shows how the rate of extinction has changed over time. Study the graph, and then answer the questions.

1. Interpret Graphs What is plotted on the *y*-axis?

2. Analyze Data Which mass extinction killed off the highest percentage of genera?

3. Draw Conclusions Describe the overall pattern of extinction shown on the graph.

4. Infer What evidence is this graph probably based on?



Essential Questions:

✓ What are three scientific hypotheses about how and where life began on earth?

Origin of Life

SC.912.L.15.8: ***Describe the scientific explanations of the origin of life on Earth.***

Prokaryotic life begins life on Earth.

Enduring Understanding: ***The scientific theory of evolution is supported by multiple forms of scientific evidence and organisms are classified based on their evolutionary history.***

Origin of Life on Earth

1. Earth forms (Big Bang)
   - SC.912.E.5.1 *Cite evidence used to develop and verify the scientific theory of the Big Bang (also known as the Big Bang Theory) of the origin of the universe.*
2. Reducing Atmosphere
   - SC.912.P.8.10 *Describe oxidation-reduction reactions in living and non-living systems*
3. Formation of Organic Molecules
   - SC.912.L.18.1: *Describe the basic molecular structures and primary functions of the four major categories of biological macromolecules.*
4. Formation of Complex Polymers
   - SC.912.L.18.1-4: *Describe the basic molecular structures and primary functions of the four major categories of biological macromolecules.*
5. Origin of Cells (Life)
   - SC.912.L.14.5: Explain the evidence supporting the scientific theory of the origin of eukaryotic cells (endosymbiosis).

HISTORY OF THE UNIVERSE

- 12 – 15 billion years ago
  - "Time zero"
  - Everything compressed into volume of sun
    - Incredibly dense, incredibly hot
  - **Big bang**
    - **Origin of the Universe**
    - Matter and energy very rapidly distributed throughout universe

SC.912.E.5.1 *Cite evidence used to develop and verify the scientific theory of the Big Bang (also known as the Big Bang Theory) of the origin of the universe.*

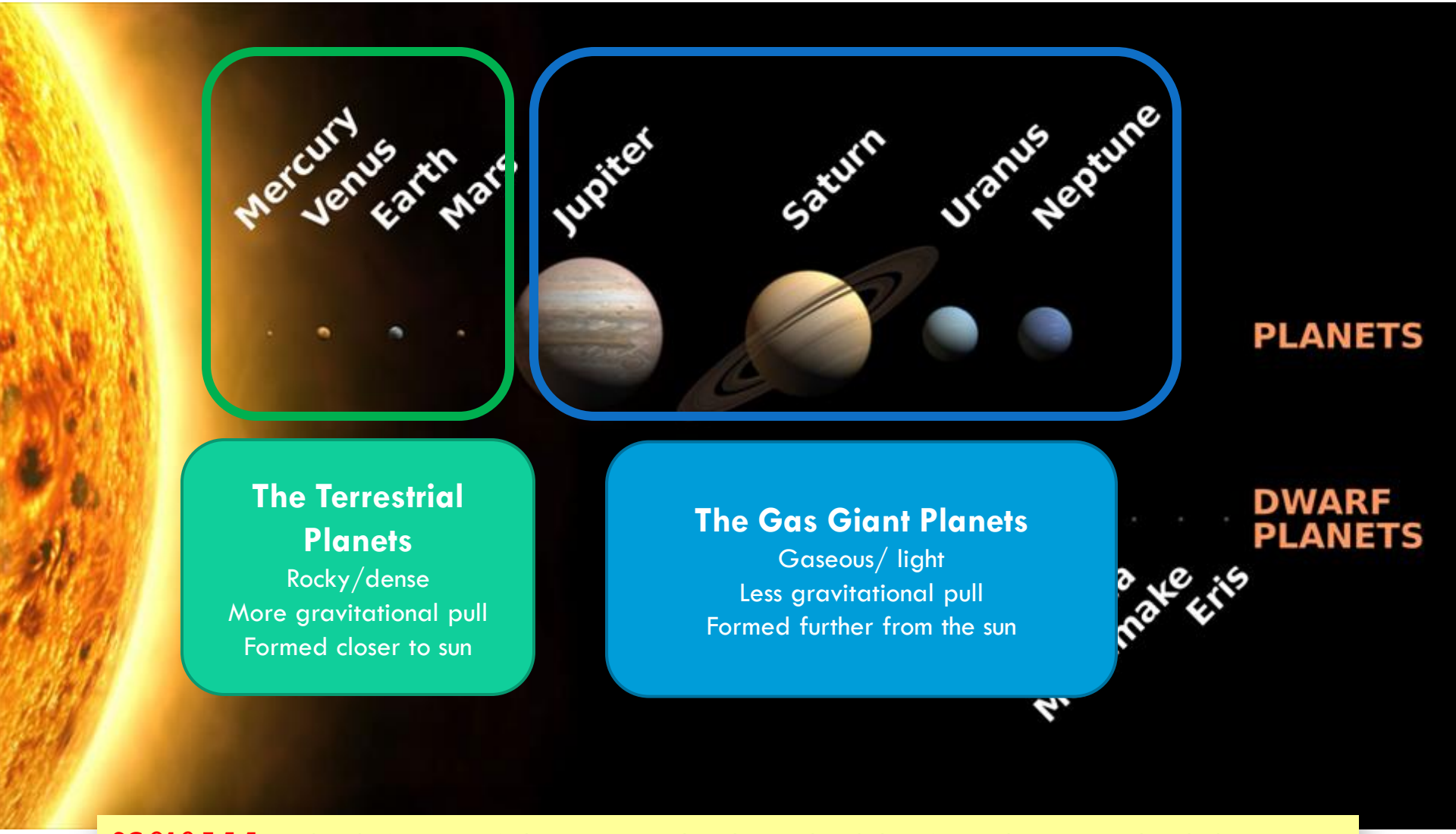
EARTH FORMS

Could life exist here on this brand new Earth?

- Contracting cloud formed our solar system
  - H_2, H_2O, Fe, Silicates, HCN, NH_3, CH_4, H_2CO
  - Planets formed ~ 4.6 – 4.5 billion years ago
- Earth was hot
  - Asteroid impacts, internal compression, radioactive decay of minerals
  - Much of rocky interior melted
  - Many heavier elements moved toward interior
  - Lighter elements floated toward surface

SC.912.E.5.2 *Identify patterns in the organization and distribution of matter in the universe and the forces that determine them.*

Formation of Our Solar System

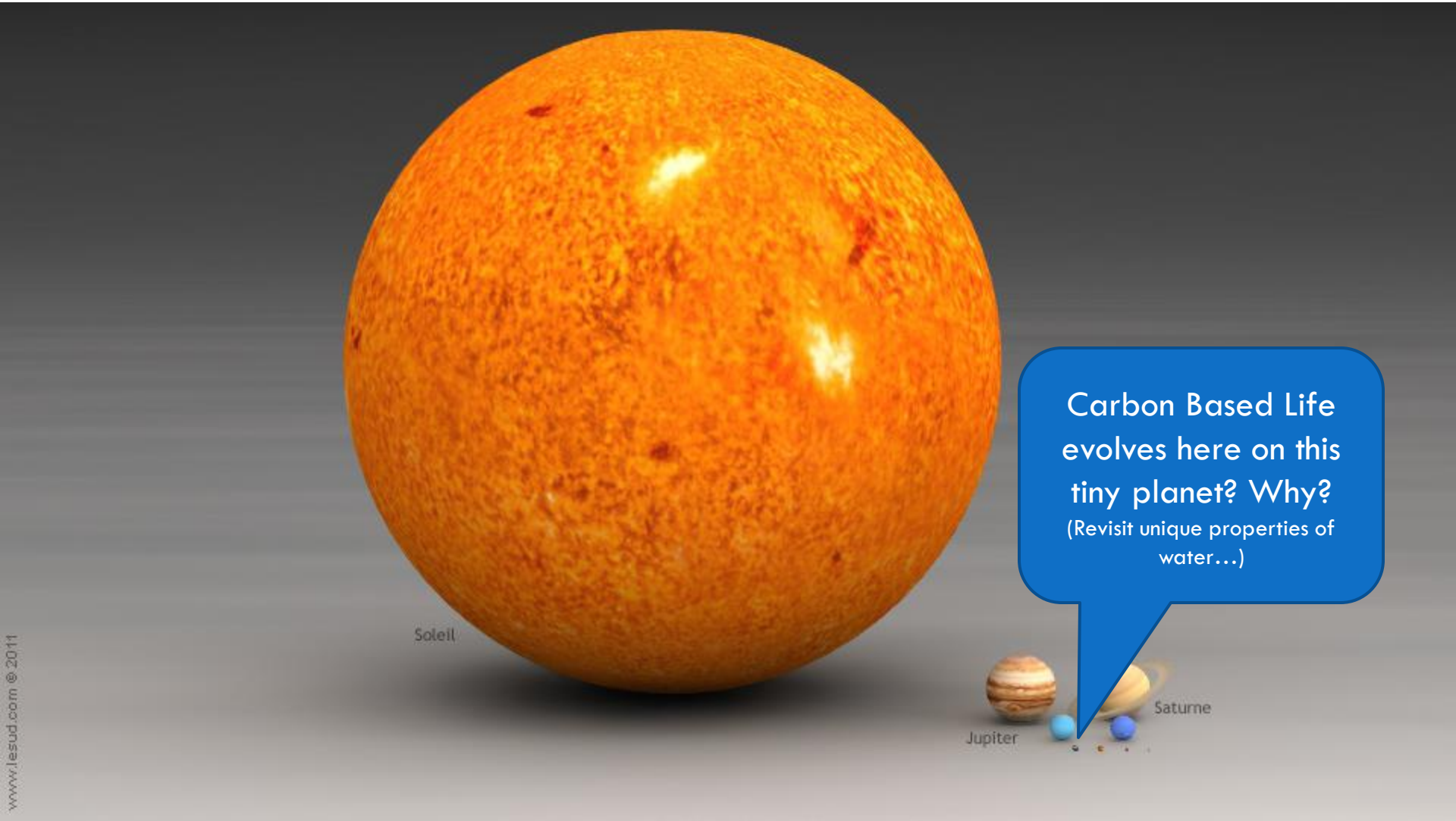


The Terrestrial Planets
Rocky/dense
More gravitational pull
Formed closer to sun

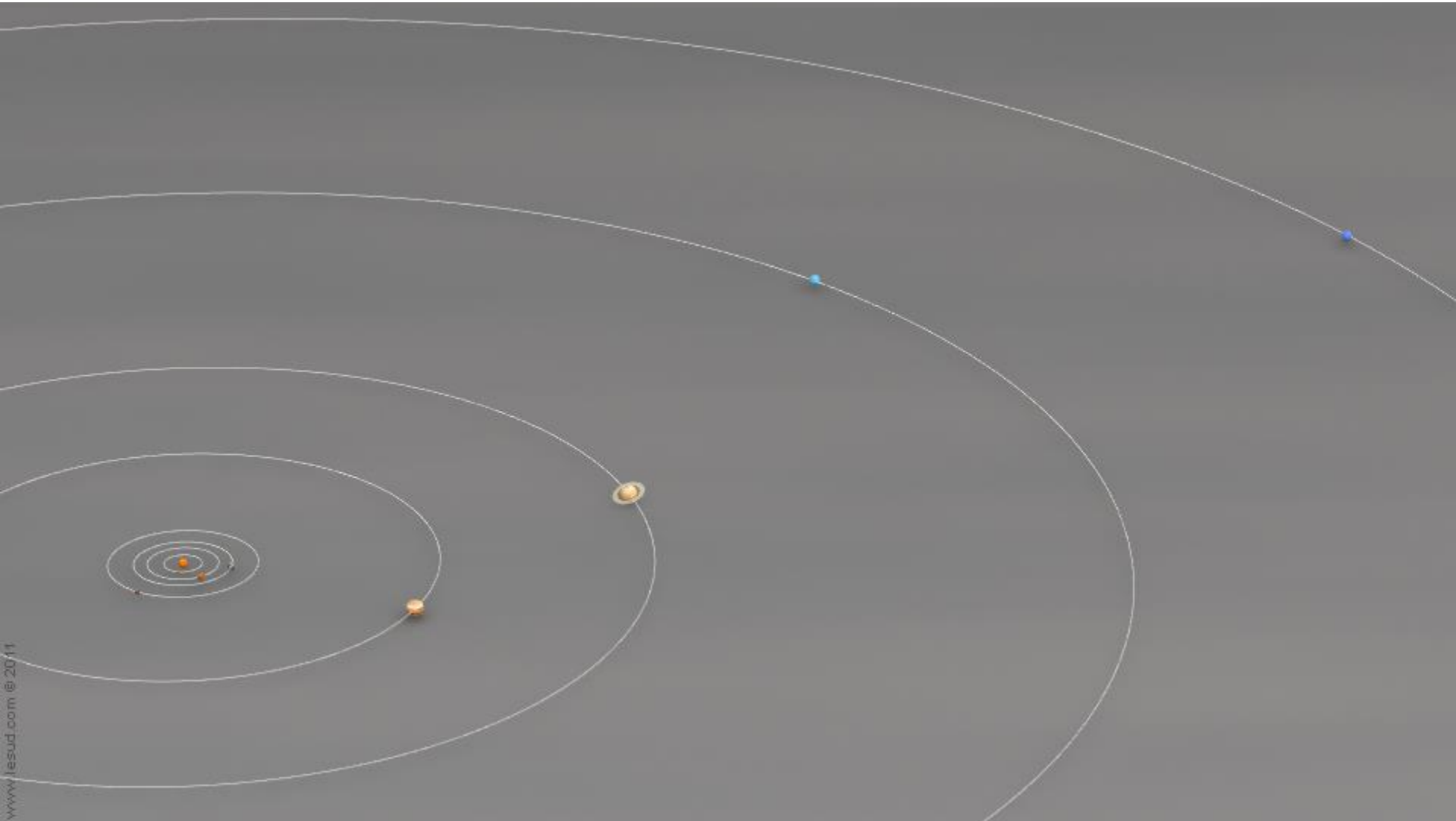
The Gas Giant Planets
Gaseous/ light
Less gravitational pull
Formed further from the sun

SC.912.E.5.5 *Explain the formation of planetary systems based on our knowledge of our Solar System and apply this knowledge to newly discovered planetary systems*

Planet Size Comparisons



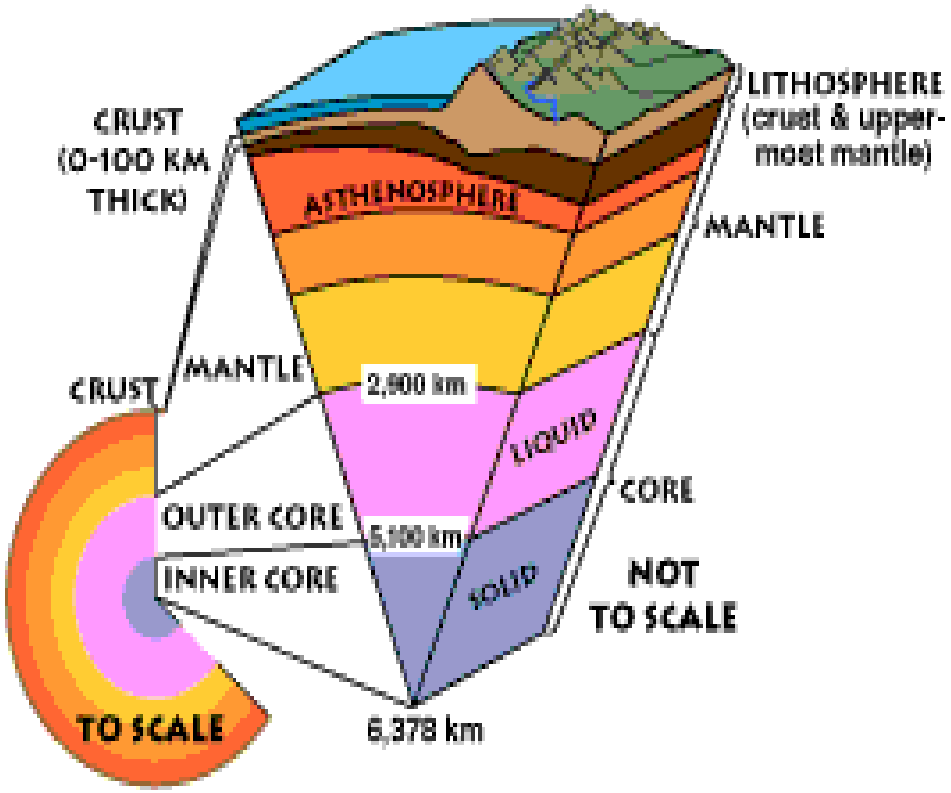
Orbit Distance Comparisions



EARTH

Think Pair Share: In which layer do you think life originated on our planet? Why? Defend your answer!

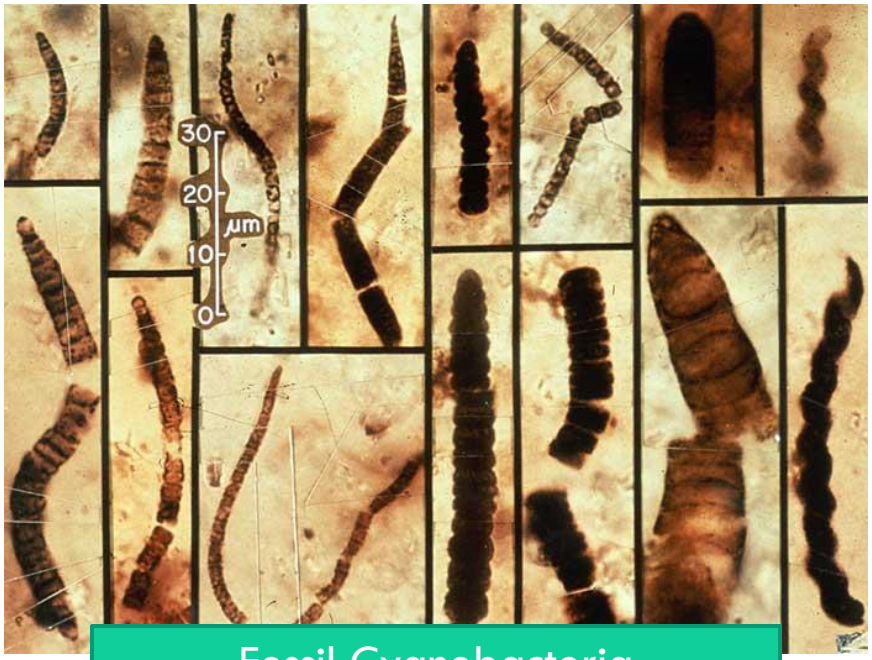
- Crust
  - Surface zone
  - Basalt, granite, and other low-density rocks
- Mantle
  - Interior to crust
  - Intermediate-density rocks
- Core
  - High-density, partially molten nickel and iron



SC.912.E.6.1 *Describe and differentiate the layers of Earth and the interactions among them.*

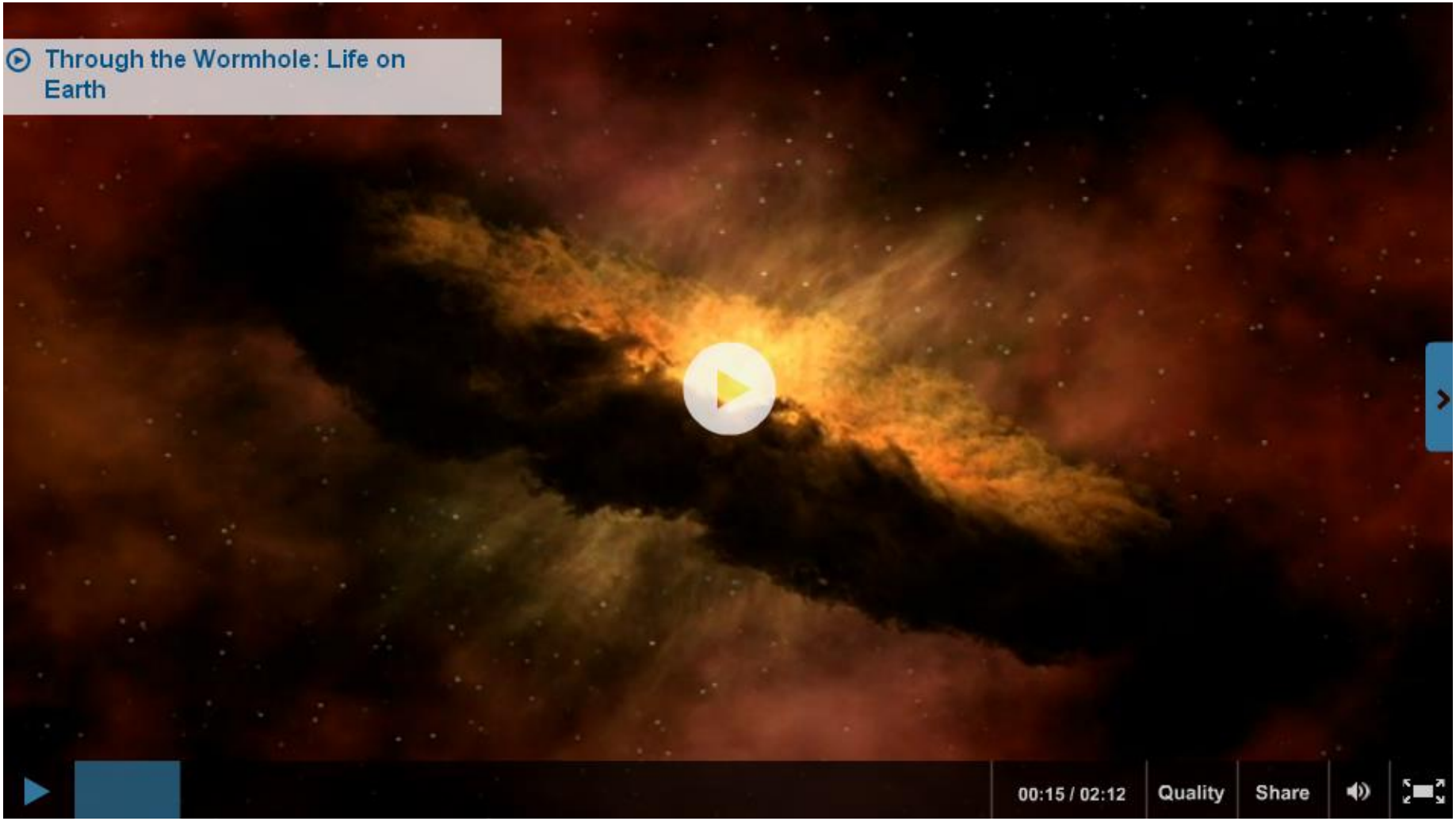
EARTH TO LIFE

- Earth 4 billion years ago
  - Thin-crusted inferno
- Earth ~3.8 billion years ago
  - Life arose, but how did this happen?



Fossil Cyanobacteria

Early Earth

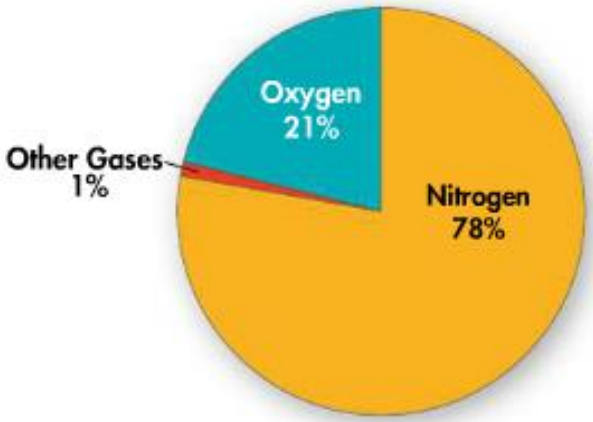


EARLY REDUCING ATMOSPHERE

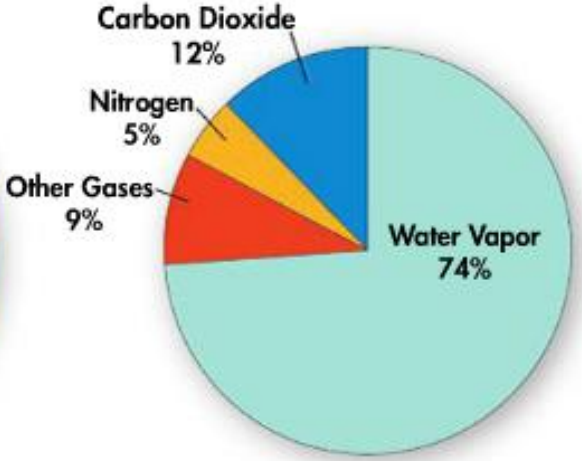
Analyzing Data

Comparing Atmospheres

Many scientists think that Earth's early atmosphere may have been similar to the gases released by a volcano today. The graphs show the composition of the atmosphere today and the composition of gases released by a volcano.



Composition of Earth's Atmosphere Today



Composition of Gases From Volcanoes

1. **Interpret Graphs** Which gas is most abundant in Earth's atmosphere today? What percentage of that gas may have been present in the early atmosphere?

2. **Interpret Graphs** Which gas was probably most abundant in the early atmosphere?

3. **Infer** Where did the water in today's oceans probably come from?

EARLY REDUCING ATMOSPHERE

LEO goes GER!

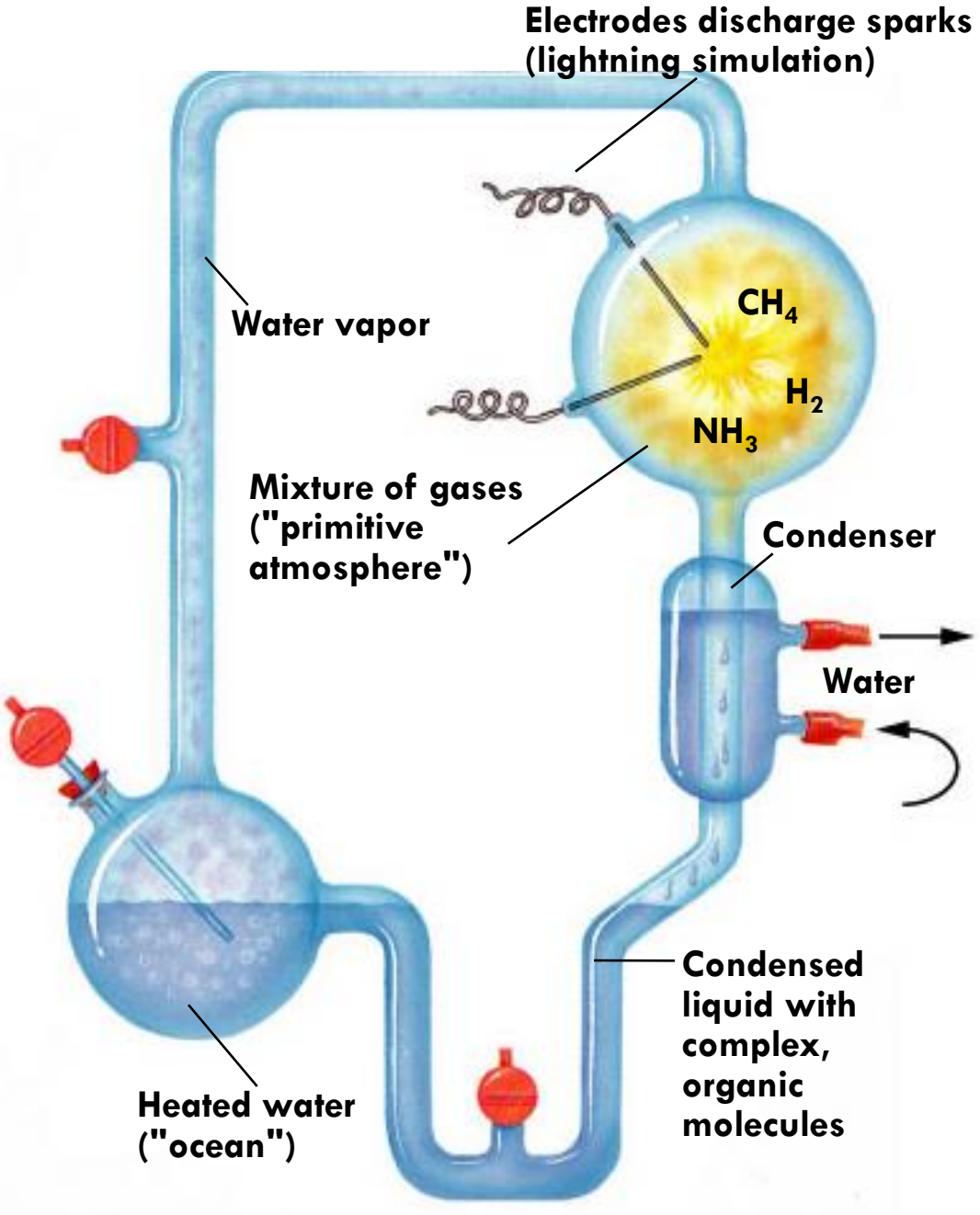
- Earth's early atmosphere had a composition very different than today's atmosphere
  - No free O_2
  - More reducing than present atmosphere
  - Inorganic Compounds H_2O, H_2, CH_4, NH_3
- Energy Sources
  - *lightning, UV radiation, volcanic
- Can we recreate this environment?

low O_2 = organic molecules do not breakdown as quickly

SC.912.P.8.10 *Describe oxidation-reduction reactions in living and non-living systems*

FORMATION OF ORGANIC MOLECULES

- Abiogenesis
  - 1920 Oparin & Haldane
    - propose reducing atmosphere hypothesis
  - 1953 Miller & Urey
    - test hypothesis
- Miller Urey Experiment
  - recreated early atmosphere
    - Inorganic compounds (H_2O, H_2, CH_4, NH_3)
    - No free O_2
    - Energy sources- heat and electrical sparks
      - Mimic geothermal heat and lightning
    - Made organic compounds
      - *amino acids
      - *adenine



Stanley Miller

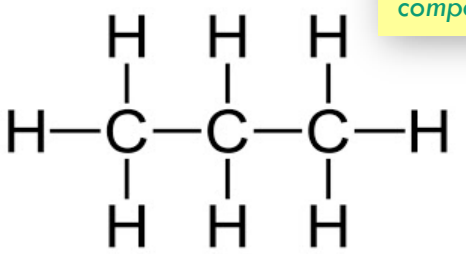
University of Chicago

Produced:

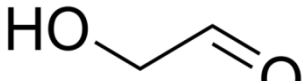
- All 20 amino acids
- Several sugars
- Lipids
- Purines and pyrimidines
- ATP (when phosphate was added)

Biomolecules (or Precursors) Produced by Abiogenesis Experiments

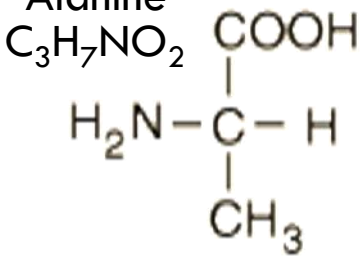
SC.912.P.8.7 *Interpret formula representations of molecules and compounds in terms of composition and structure*



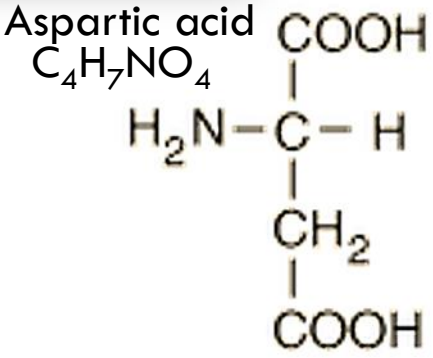
Propane
C_3H_8



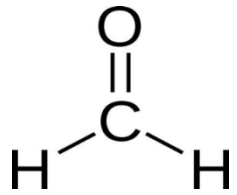
Glycolaldehyde
$C_2H_6O_2$



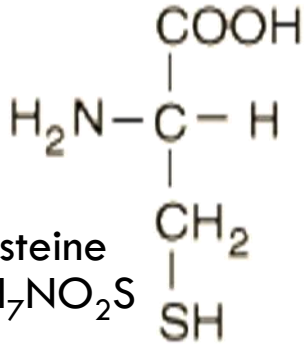
Alanine
$C_3H_7NO_2$



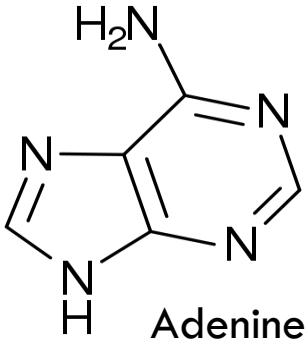
Aspartic acid
$C_4H_7NO_4$



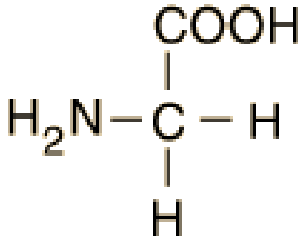
Formaldehyde
CH_2O



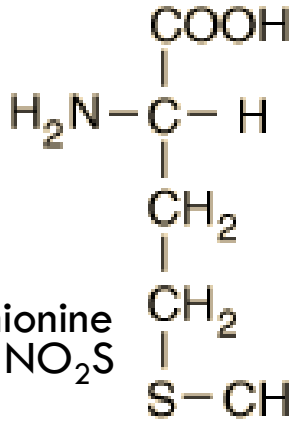
Cysteine
$C_3H_7NO_2S$



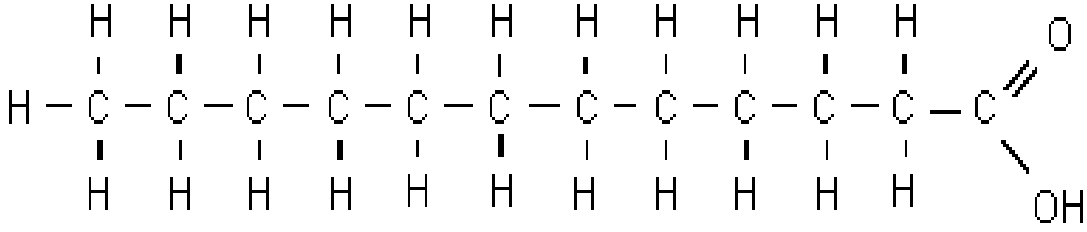
Adenine
$C_5H_5N_5$



Glycine
$C_2H_5NO_2$



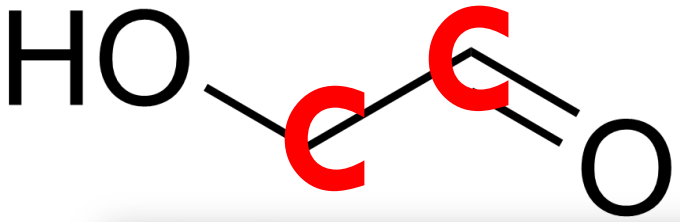
Methionine
$C_5H_{11}NO_2S$

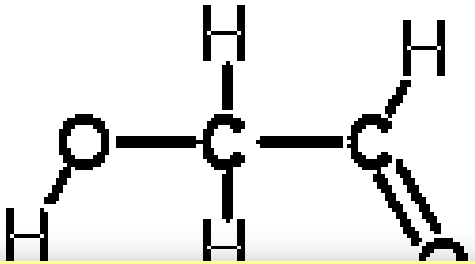


Fatty Acid $CH_3(CH_2)_{10}COOH$

Glycolaldehyde

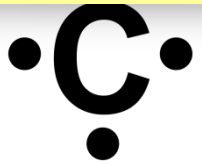
$C_2H_6O_2$





SC.912.P.8.7 *Interpret formula representations of molecules and compounds in terms of composition and structure*

SC.912.P.8.12 *Describe the properties of the carbon atom that make the diversity of carbon compounds possible.*



Periodic Table of the Elements

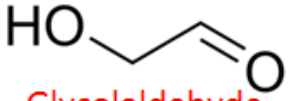
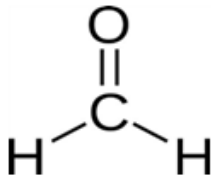
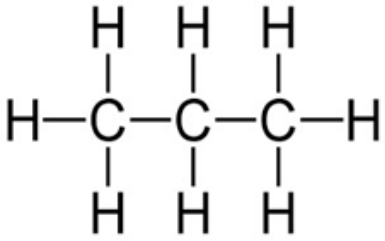
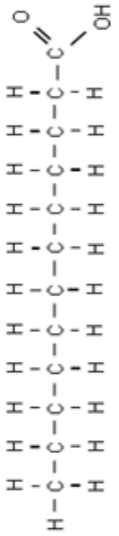
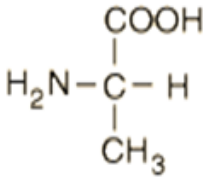
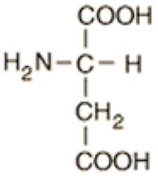
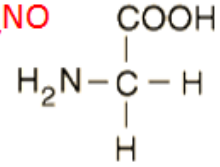
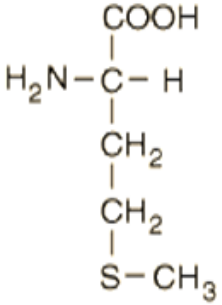
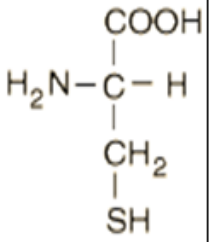
1 1IA 11A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.0079																	2 He Helium 4.00260
3 Li Lithium 6.941	4 Be Beryllium 9.01218											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.989768	12 Mg Magnesium 24.305											13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.64	33 As Arsenic 74.92159	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [208.9824]	85 At Astatine 209.9871	86 Rn Radon 222.0176
87 Fr Francium 223.0197	88 Ra Radium 226.0254	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Uuq Ununquadium [289]	115 Uup Ununpentium unknown	116 Uuh Ununhexium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0796	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]

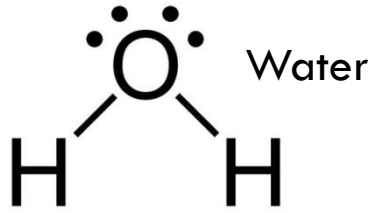
Alkali Metal | Alkaline Earth | Transition Metal | Basic Metal | Semimetals | Nonmetals | Halogens | Noble Gas | Lanthanides | Actinides

Examine the molecules produced in the Abiogenesis experiments. Categorize their importance to life into the chart below based on the structure of each.
*Hints have been inserted into each column to help you.

Carbohydrates ($C_xH_2O_x$)	**Lipids** (Hydrocarbons: C backbone bonded to many H's)	**Proteins** (Amino Acids: Central Carbon bonded to H, NH2, COOH and variable group)	**Nucleic Acids** (nitrogenous bases: purines- double C & N ring, Pyrimidines- single C & N ring)

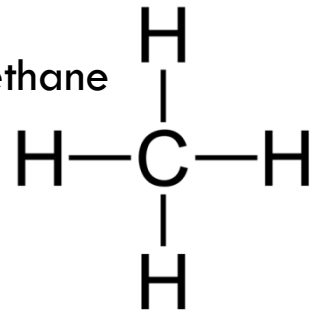
Carbohydrates ($C_xH_2O_x$)	Lipids (Hydrocarbons: C backbone bonded to many H's)	Proteins (Amino Acids: Central Carbon bonded to H, NH2, COOH and variable group)	Nucleic Acids (Nitrogenous bases: purines- double C & N ring, Pyrimidines- single C & N ring)
 Glycolaldehyde $C_2H_6O_2$  Formaldehyde CH_2O	 Propane C_3H_8  Fatty Acid $CH_3(CH_2)_{10}COO$	 Alanine $C_3H_7NO_2$  Aspartic acid C_4H_7NO  Glycine $C_2H_5NO_2$  Methionine $C_5H_{11}NO_2S$  Cysteine $C_3H_7NO_2S$	 Adenine $C_5H_5N_5$

Classic Urey-Miller

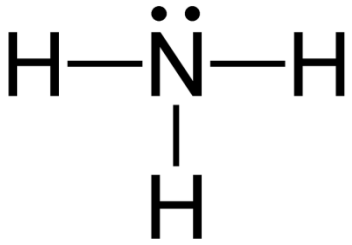


Hydrogen gas

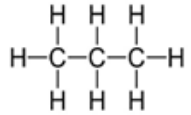
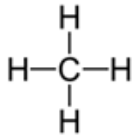
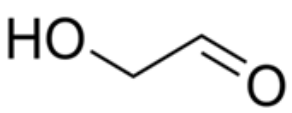
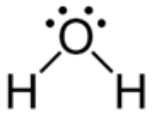
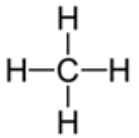
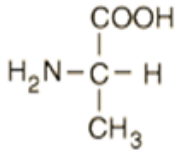
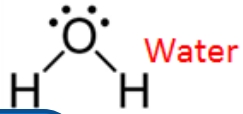
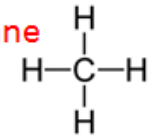
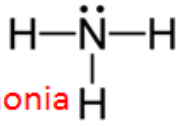
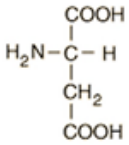
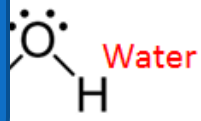
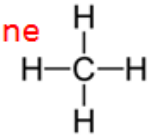
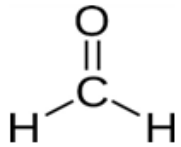
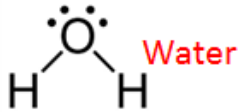
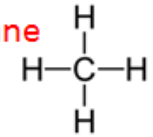
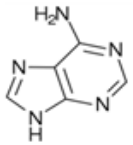
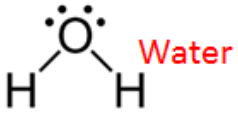
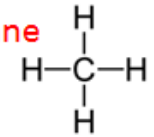
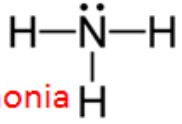
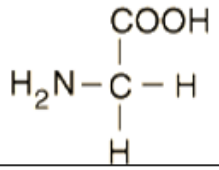
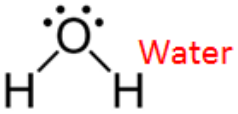
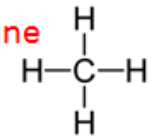
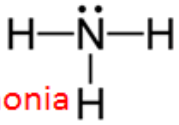
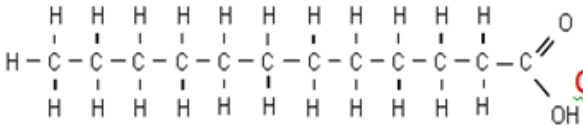
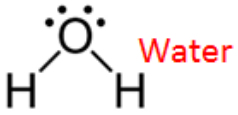
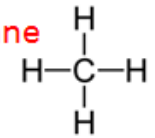
Methane



Ammonia



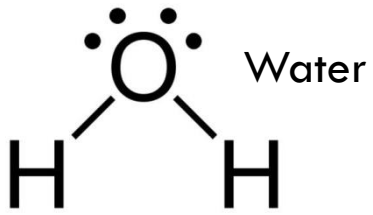
Examine the chart "Biomolecules Produced by Abiogenesis Experiments" and determine for each molecule listed which molecules in Miller's laboratory atmosphere would have come together to create these biomolecules.

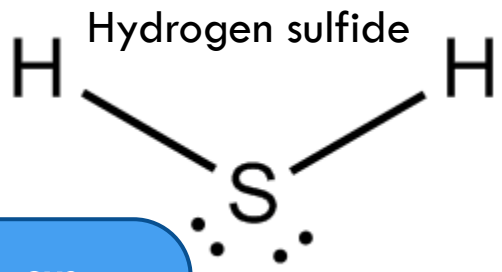
Biomolecule Produced	Possible Inorganic Molecules Needed to Build Biomolecule
 Propane C_3H_8	**H-H** Hydrogen gas; Methane 
 Glycolaldehyde $C_2H_6O_2$	 Water; Methane 
 Alanine $C_3H_7NO_2$	 Water; Methane   Ammonia
 Aspartic acid C_4H_7NO	 Water; Methane 
 Formaldehyde CH_2O	 Water; Methane 
 Adenine $C_5H_5N_5$	 Water; Methane   Ammonia
 Glycine $C_2H_5NO_2$	 Water; Methane   Ammonia
 Fatty Acid $CH_3(CH_2)_{10}COOH$	 Water; Methane 

Reduced or Oxidized? Why?

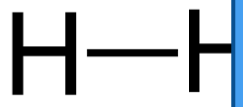
Classic Urey-Miller

Volcanic Eruptions

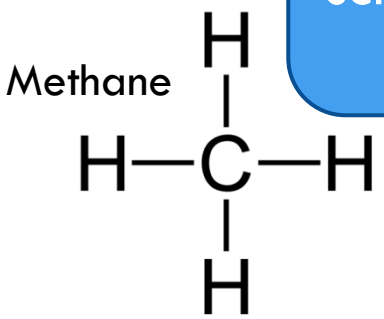


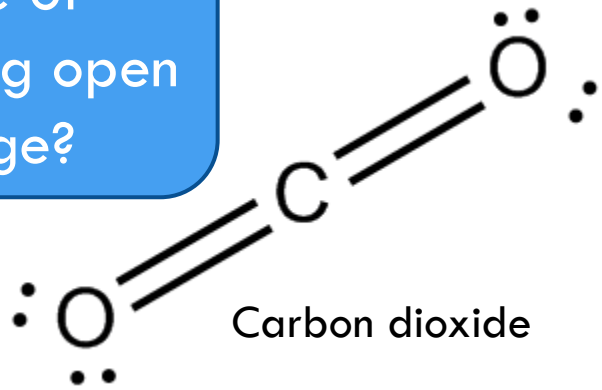


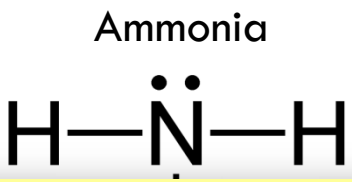
Hydrogen gc

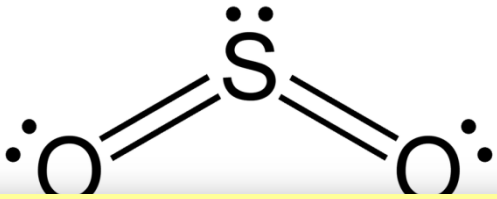


How is this an example of science being open to change?



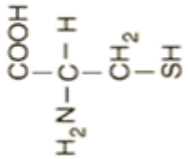
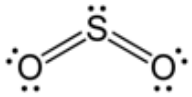
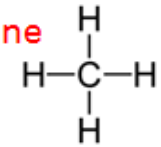
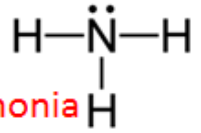
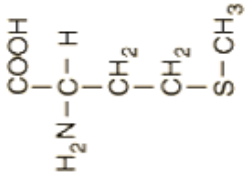
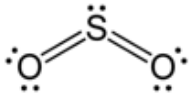
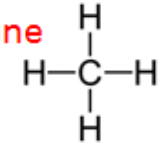
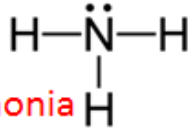






Examine the molecules left on the "Biomolecules Produced by Abiogenesis Experiments" chart and determine if the molecules available in this revised atmosphere could have played a part in their formation. Complete the chart for these molecules as before.

SC.912.N.2.4 *Explain that scientific knowledge is both durable and robust and open to change. Scientific knowledge can change because it is often examined and re-examined by new investigations and scientific argumentation. Because of these frequent examinations, scientific knowledge becomes stronger, leading to its durability.*

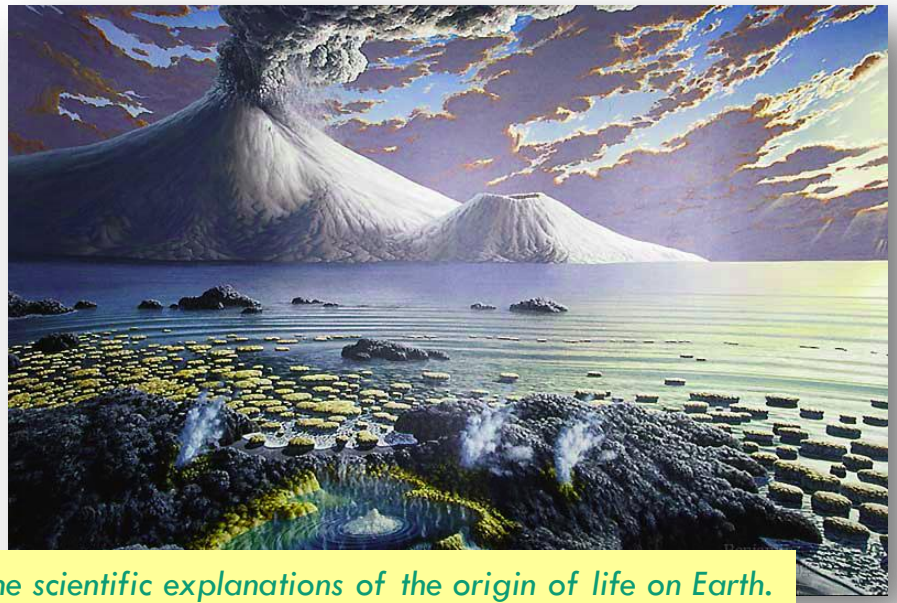
Biomolecule Produced	Possible Inorganic Molecules Needed to Build Biomolecule
 Cysteine $C_3H_7NO_2S$	 Sulfur dioxide Methane   Ammonia
 Methionine $C_5H_{11}NO_2S$	 Sulfur dioxide Methane   Ammonia

Recreating the Early Atmosphere

SITES OF ABIOGENESIS

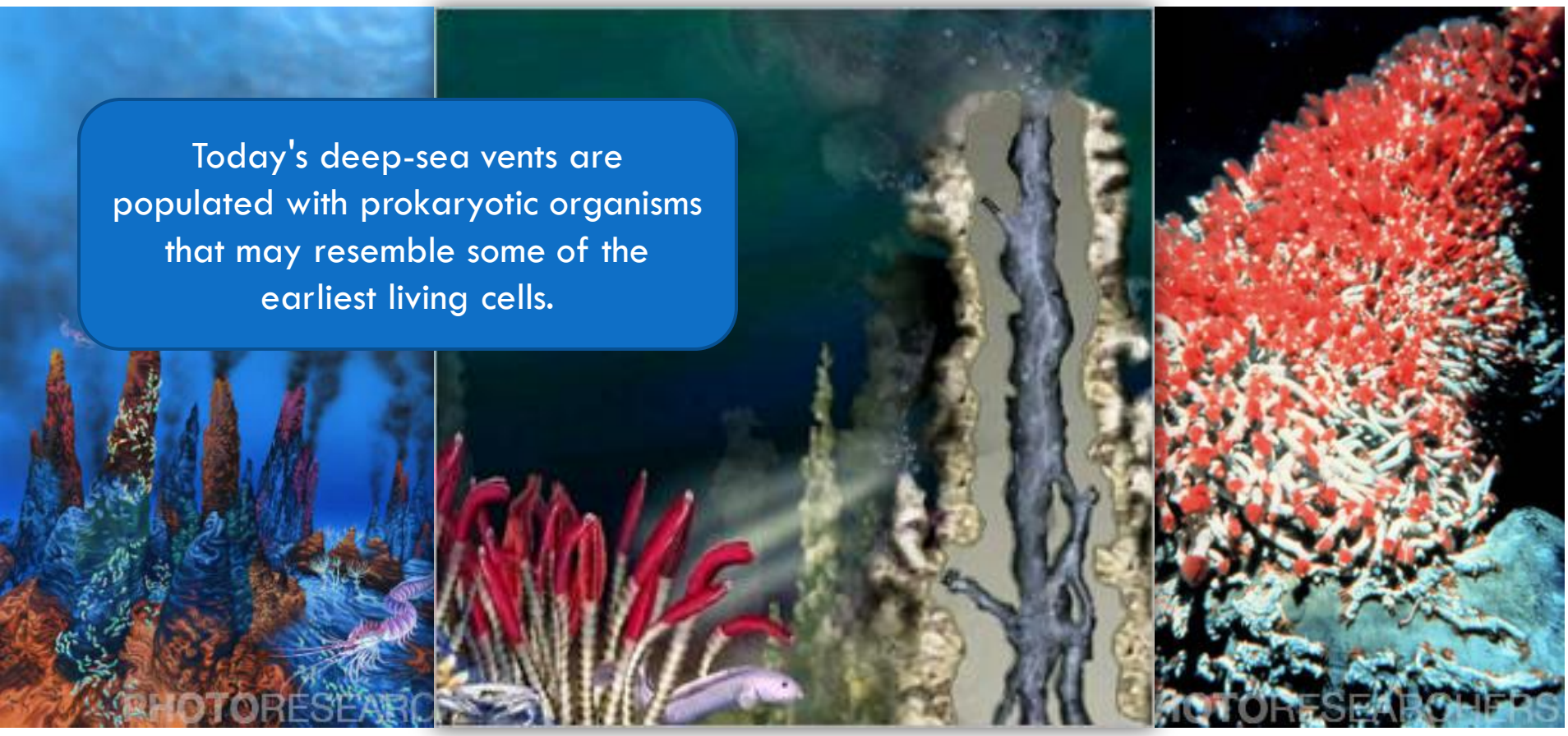
- Where would these key molecules have been created on early earth?
  - Shallow water or moist sediments such as clay
  - Mineral-rich deep sea vents/underwater volcanoes

Today's deep-sea vents are populated with prokaryotic organisms that may resemble some of the earliest living cells.



SC.912.L.15.8: Describe the scientific explanations of the origin of life on Earth.

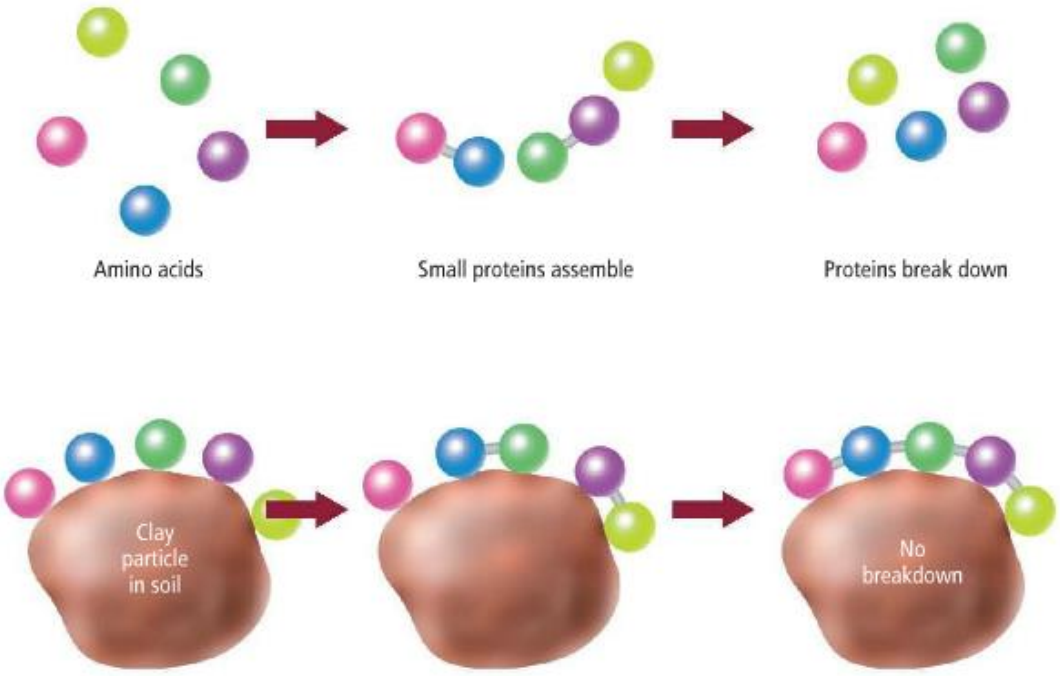
Hydrothermal Vents



Today's deep-sea vents are populated with prokaryotic organisms that may resemble some of the earliest living cells.

FORMATION OF COMPLEX POLYMERS

- Once these small organic molecules accumulated, polymers began to form.
  - Chemical attractions



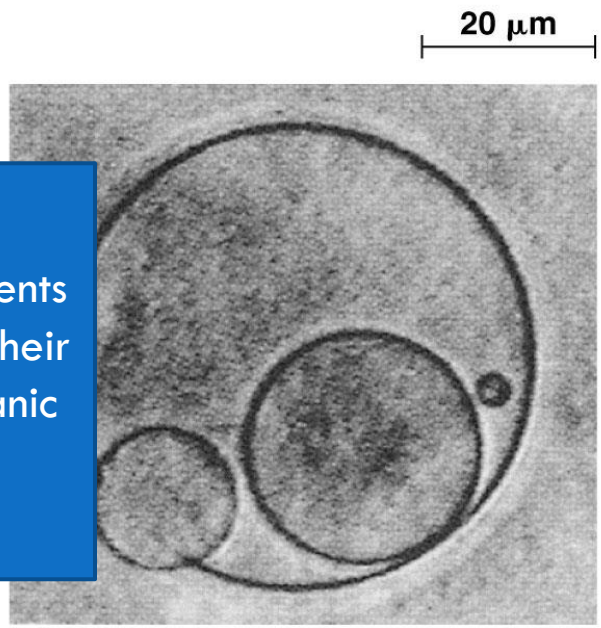
For example: Proteins are polymers of amino acids, they may have been brought together by clay particles common in sediments of early oceans

SC.912.L.18.1-4: *Describe the basic molecular structures and primary functions of the four major categories of biological macromolecules.*

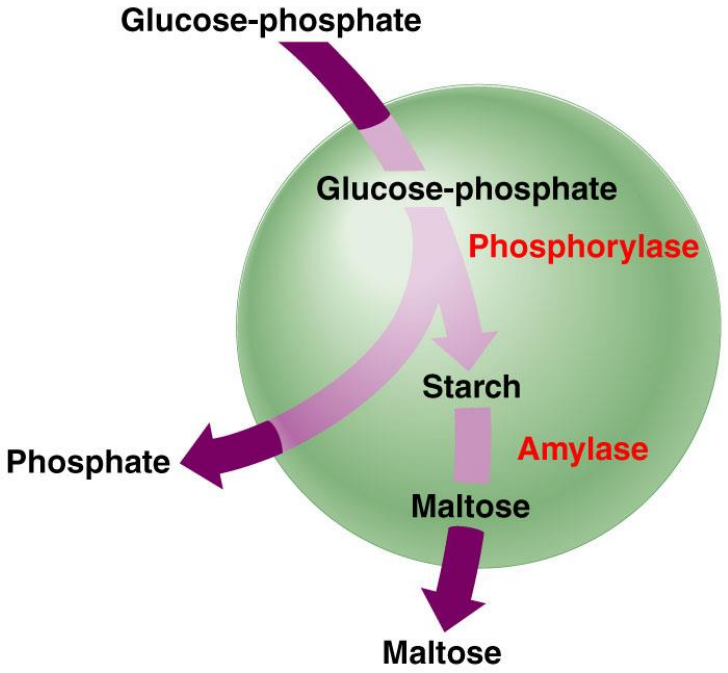
Origin of Cells: Protobionts

- Fatty Bubbles
- Clusters of abiotically produced molecules that came before living cells
- separate inside from outside
- capable of simple metabolism & reproduction

Laboratory experiments have demonstrated their formation from organic compounds



(a) Simple reproduction



(b) Simple metabolism

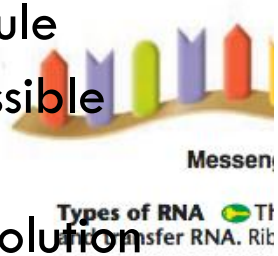
Creating Life

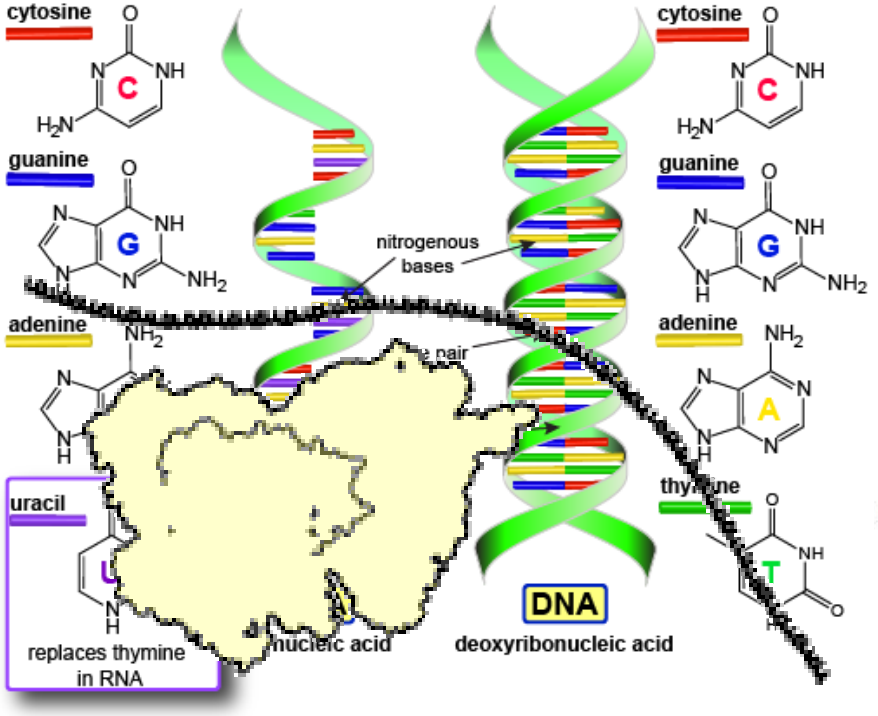
Lab: Creating Protobionts

SC.912.L.15.8: Describe the scientific explanations of the origin of life on Earth.
MA.912.S.1.2 Determine appropriate and consistent standards of measurement for the data to be collected in a survey or experiment.

Origin of Genetics

- RNA is likely first genetic material
  - Simpler than DNA
  - multi-functional
  - Some RNA behave like enzymes
  - codes information
    - self-replicating molecule
    - makes inheritance possible
      - Codes for proteins
    - natural selection & evolution
  - RNA sequences have changed little over time





SC.912.L.18.1: *Describe the basic molecular structures and primary functions of the four major categories of biological macromolecules.*
SC.912.L.16.5: *Explain the basic processes of transcription and translation, and how they result in the expression of genes.*

From RNA to DNA

Panspermia

Group Activity: In Groups, evaluate the strengths and weaknesses of the Abiogenesis and Panspermia Hypotheses with regards to the Origin of Life.

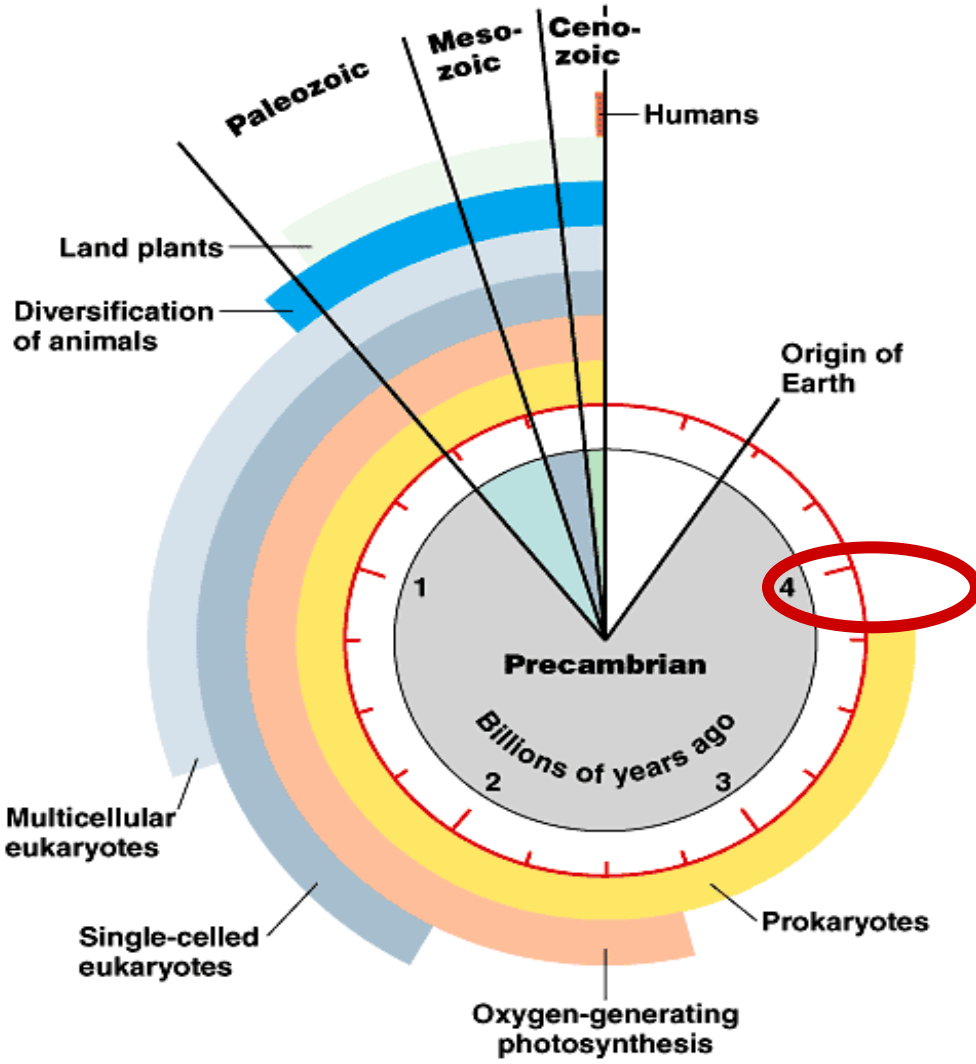
- Proposes that life that can survive the effects of space
  - extremophile bacteria
  - trapped in debris that is ejected into space after collisions between planets that harbor life
  - Bacteria may travel dormant for an extended amount of time before colliding randomly with other planets
  - If met with ideal conditions on a new planet's surfaces, the bacteria become active and the process of evolution begins.
- **NOT** meant to address how life began, just the method that may cause its sustenance.

SC.912.L.15.8: Describe the scientific explanations of the origin of life on Earth.
LA.910.2.2.3: The student will organize information to show understanding or relationships among facts, ideas, and events (e.g., representing key points within text through charting, mapping, paraphrasing, summarizing, comparing, contrasting, or outlining)

Ok, so we now have an idea of how life came to be on our planet but what happens next?

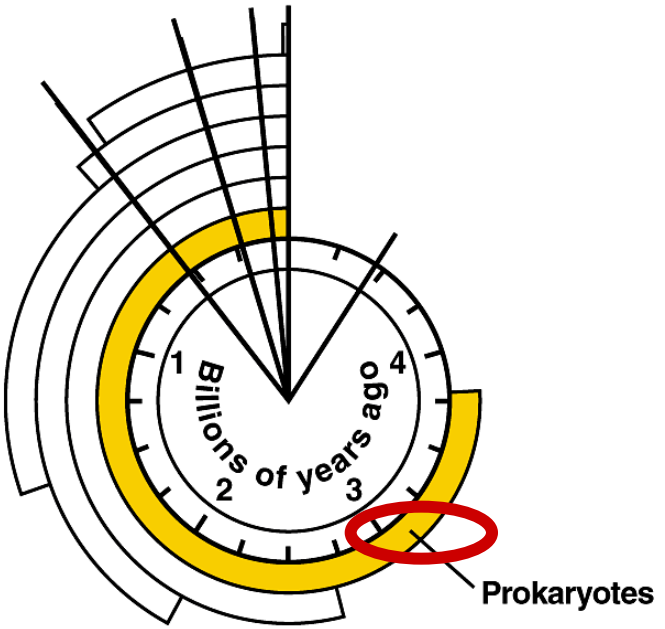
Key Events in Origin of Life

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

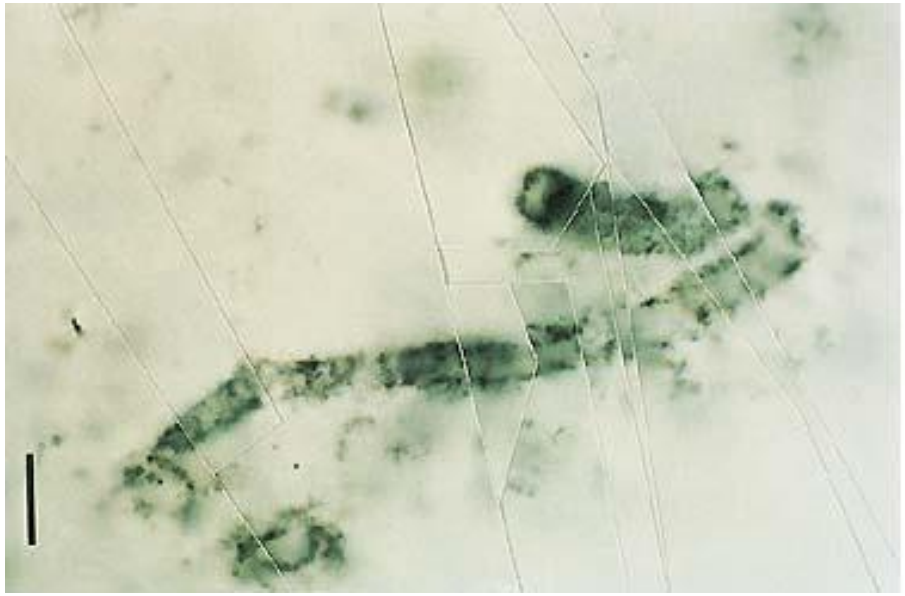


First Living Cells

- Prokaryotes dominated life on Earth from 3.5–2.0 bya



3.5 billion year old fossil of bacteria



modern bacteria

Stromatolites

- provide the most ancient records of life on Earth by fossil remains which date from more than 3.5 billion years ago
- composed of thin layers of sediment pressed tightly together that has trapped clumps of microorganisms (cyanobacteria)

Stromatolites

Modern vs. Fossil Stromatolite

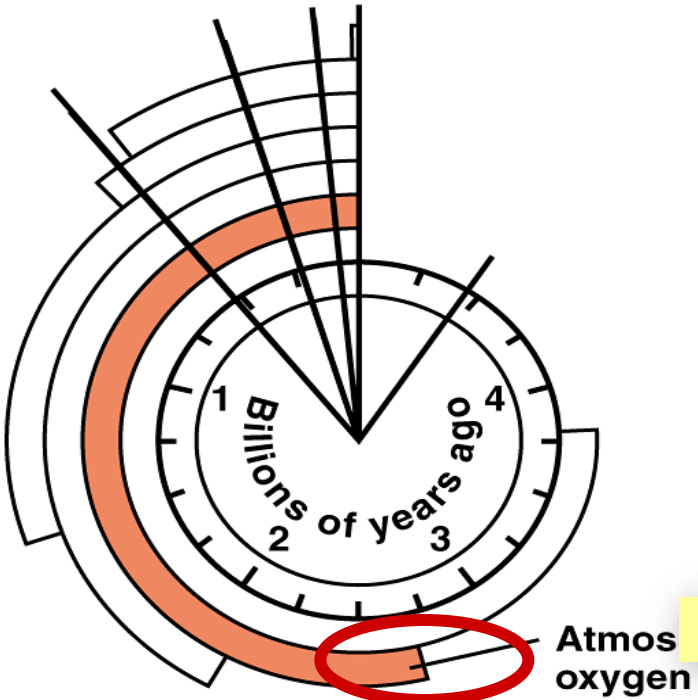
- Resembles layered mats formed by colonies of photosynthetic prokaryotes living today in salty marshes

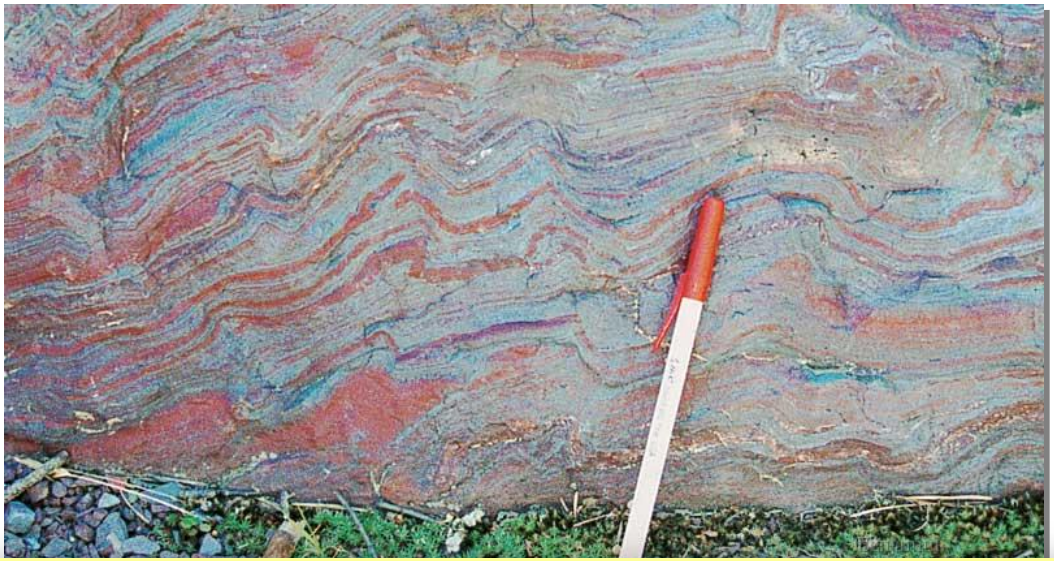
From Big Bang to Life

Scroll down on playlist to “Assignment Discovery: The Big Bang”

Oxygen atmosphere

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

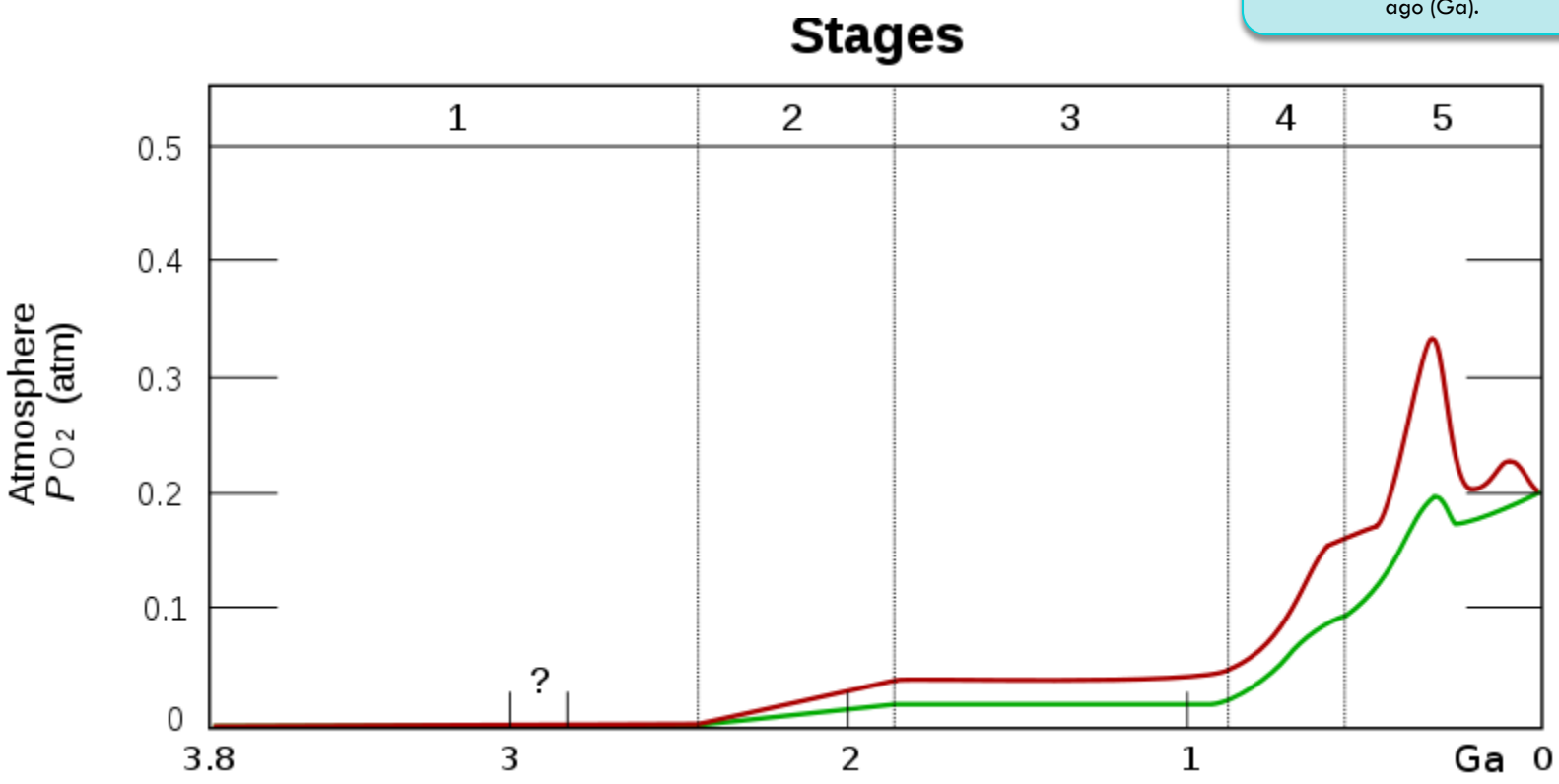




SC.912.P.8.10 *Describe oxidation-reduction reactions in living and non-living systems*

Estimated Evolution of Atmospheric Oxygen

Red and green lines represent the range of the estimates while time is measured in billions of years ago (Ga).

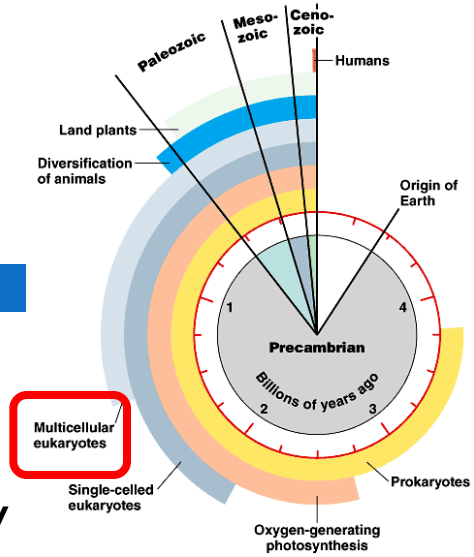


1. Analyze and interpret what is occurring in Stages 1 and 2 in the graph.

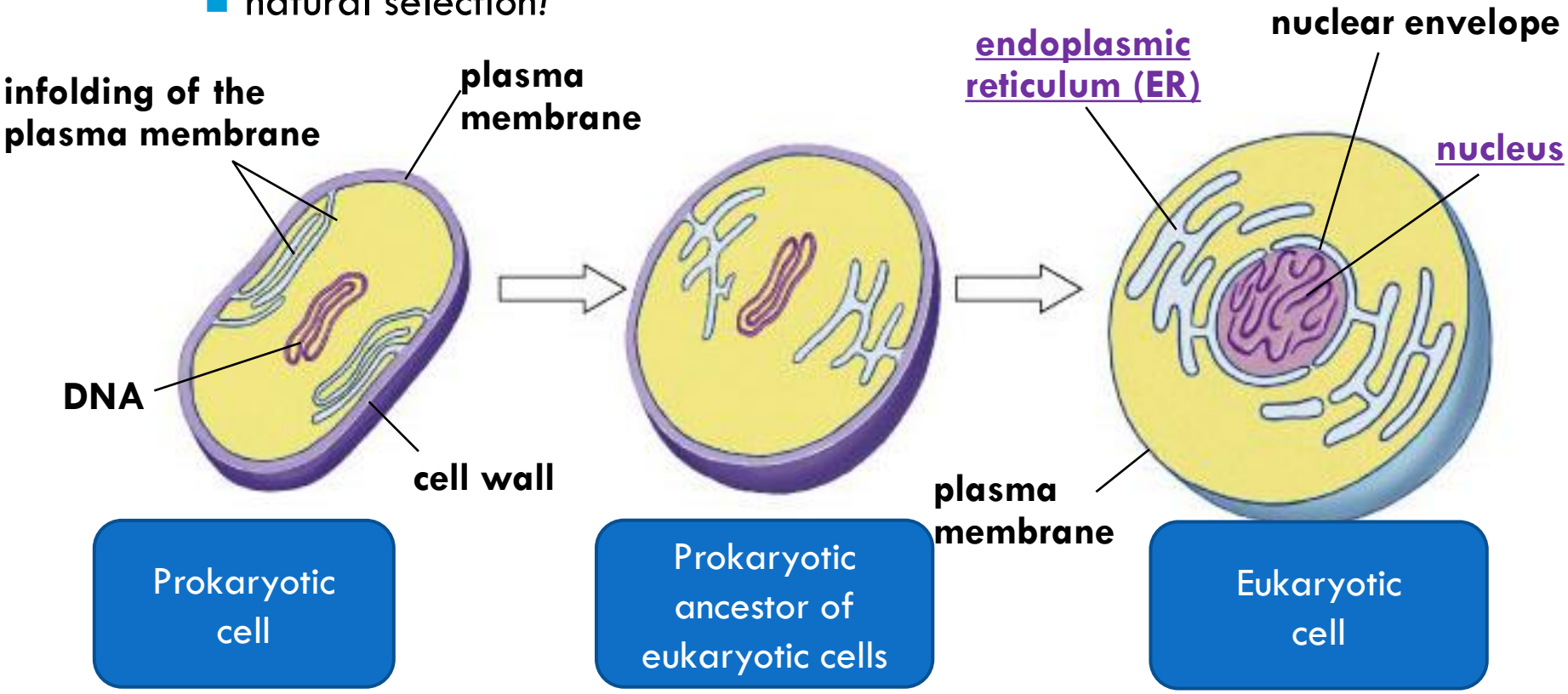
2. Analyze and interpret the trends occurring in Stages 2 and 5 in the graph.

First Eukaryotes

~2 bya



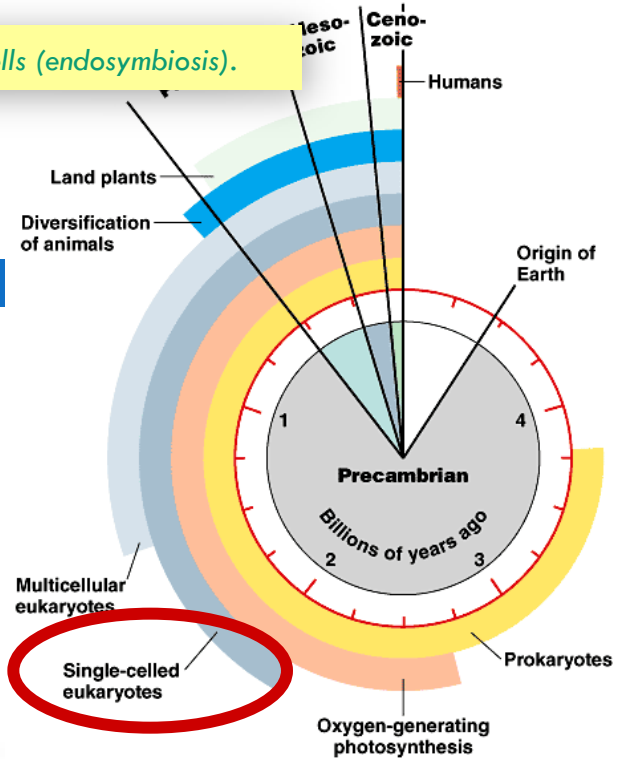
- Development of internal membranes
  - create internal micro-environments
  - advantage: specialization = increase efficiency
    - natural selection!

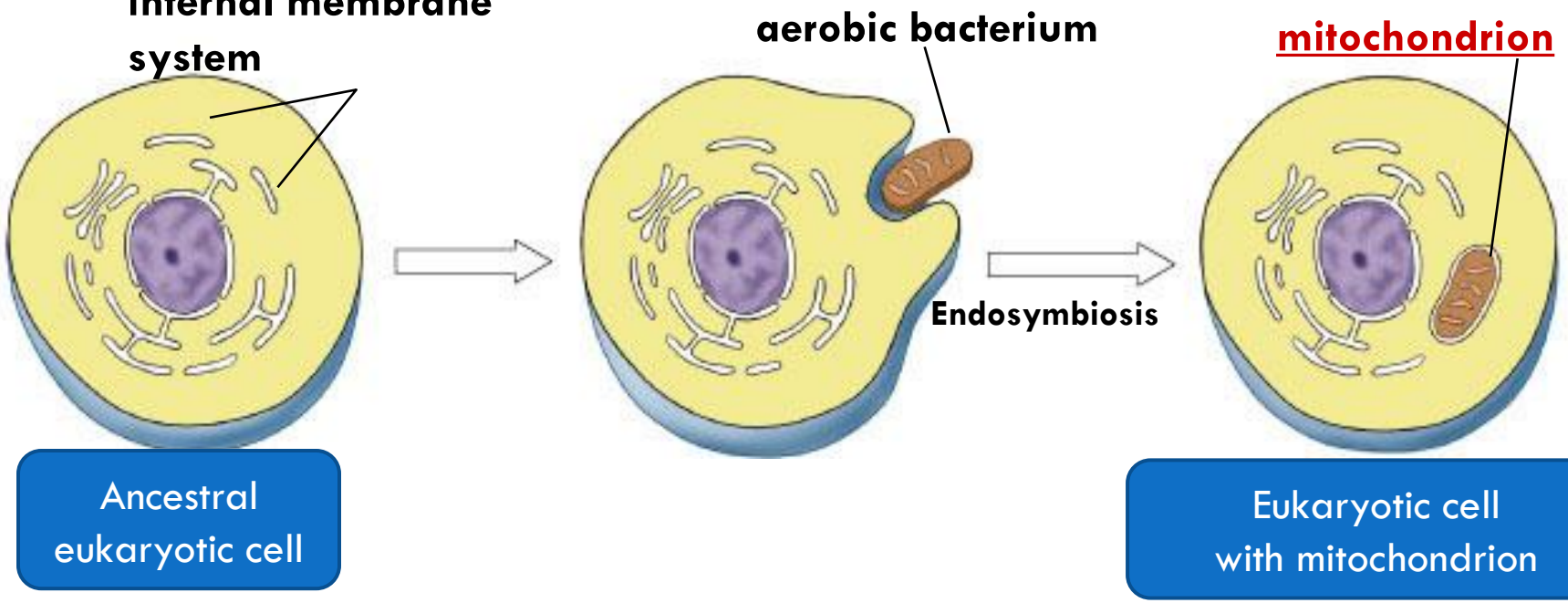


SC.912.L.14.5 *Explain the evidence supporting the scientific theory of the origin of eukaryotic cells (endosymbiosis).*

1st Endosymbiosis

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





DATA ANALYSIS LAB 1

SC.912.L.15.8: Describe the scientific explanations of the origin of life on Earth.

Based on Real Data*

Analyze Scientific Illustrations

How did plastids evolve?

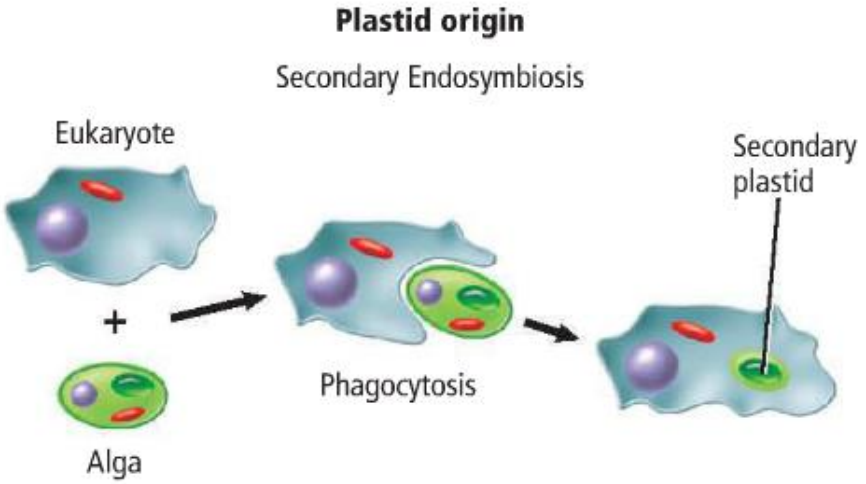
Chloroplasts belong to a group of organelles called plastids, which are found in plants and algae. Chloroplasts perform photosynthesis. Other plastids store starch and make substances needed as cellular building blocks or for plant function.

Think Critically

1. **Summarize** the process described in the diagram. Include the definition of phagocytosis in your description.
2. **Compare** secondary endosymbiosis to the endosymbiont theory described in **Figure 17.**

Data and Observations

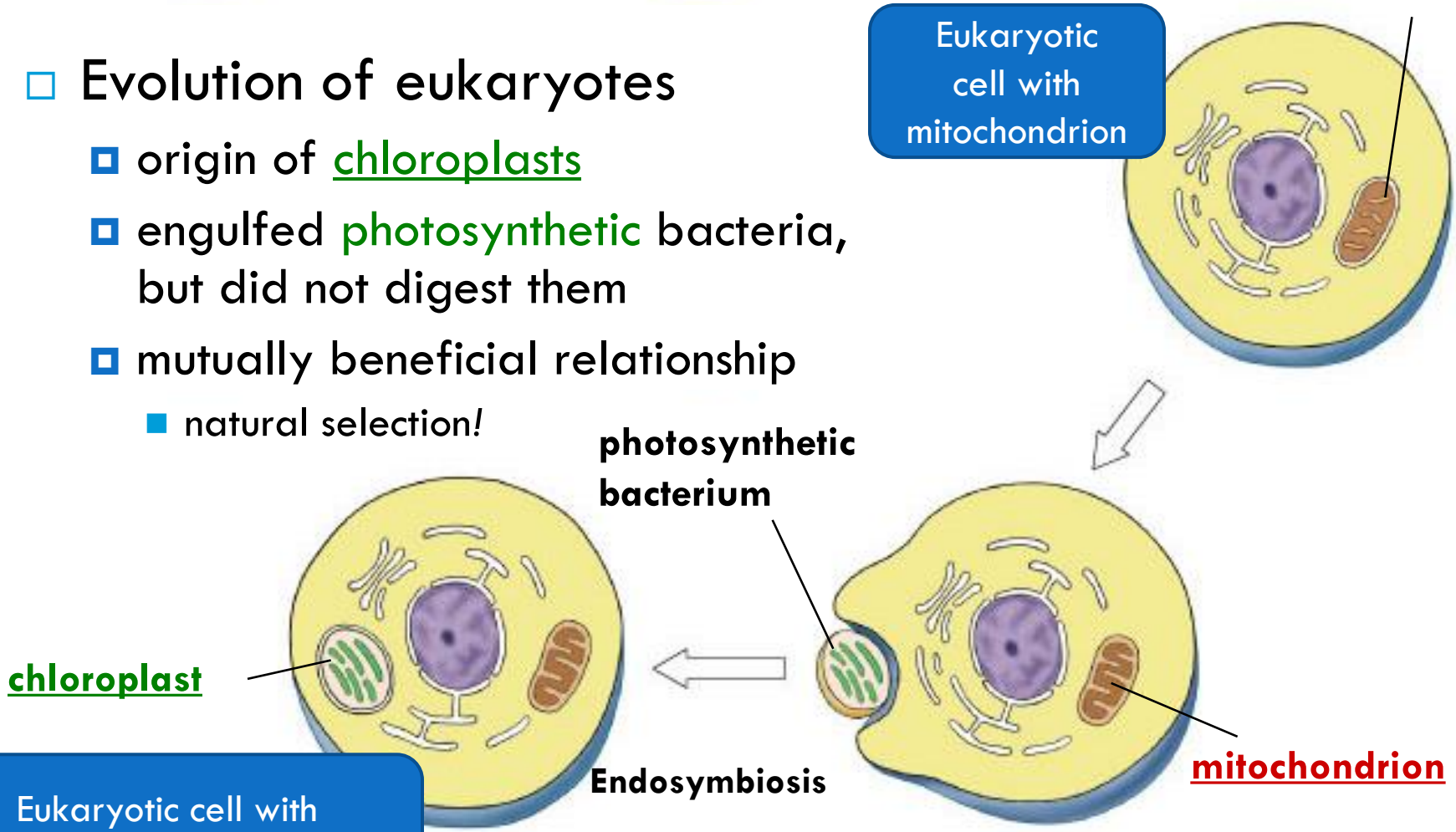
The illustration shows a way these plastids might have evolved.



*Data obtained from: Dyall, S.D., et al. 2004. Ancient invasions: from endosymbionts to organelles. *Science* 304: 253–257.

2nd Endosymbiosis

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

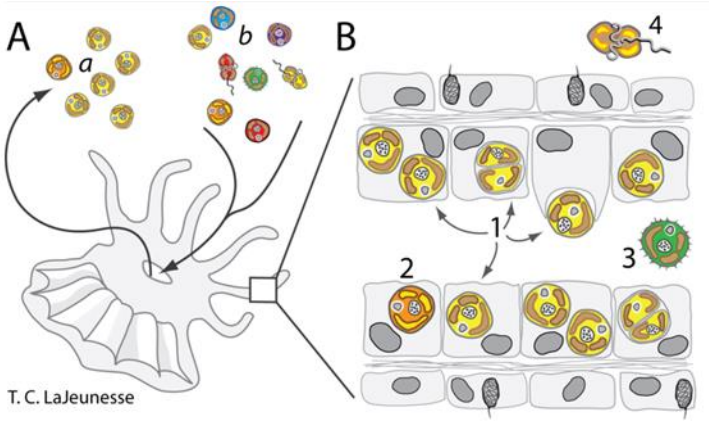


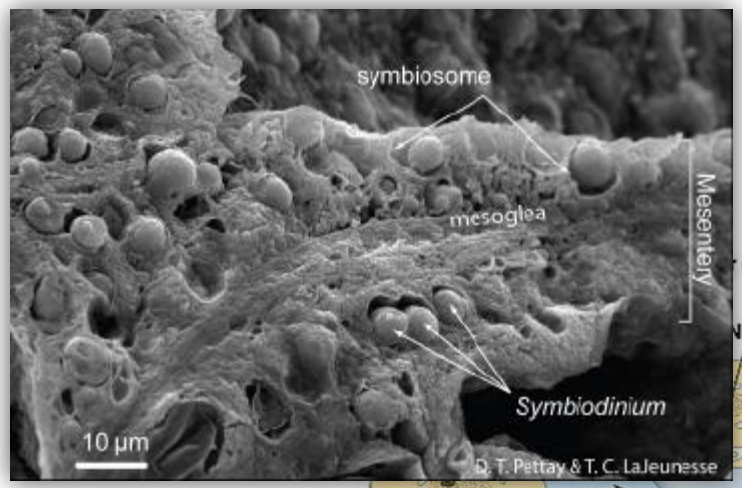
Theory of Endosymbiosis

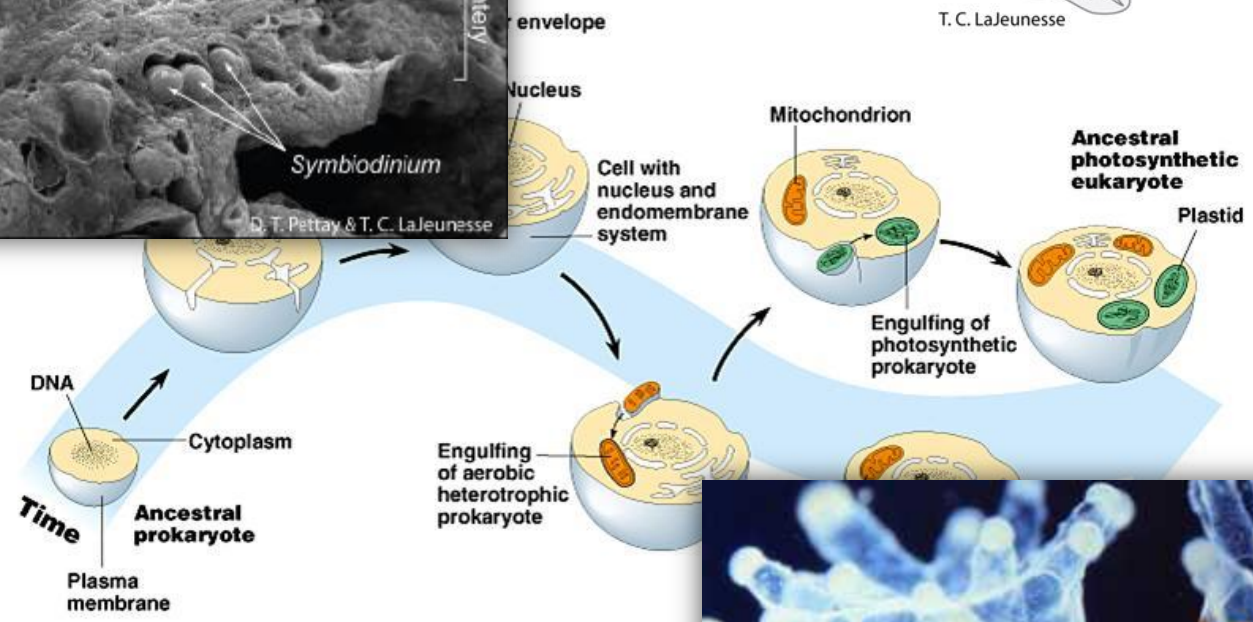
Lynn Margulis

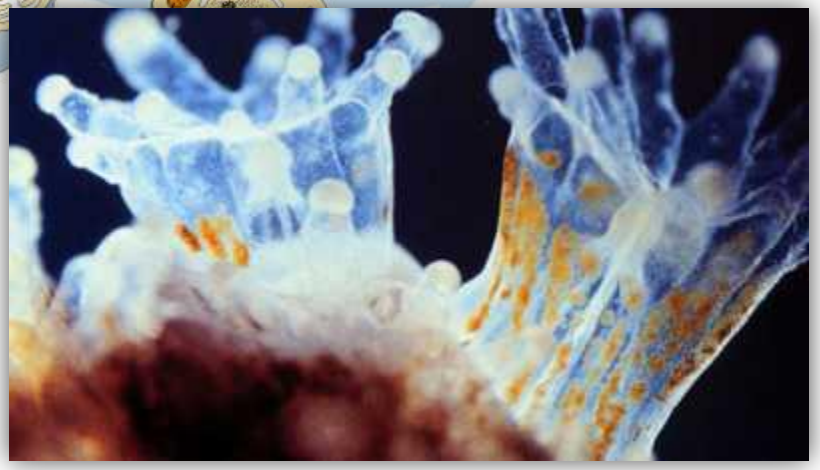
- Evidence
  - structural
    - mitochondria & chloroplasts resemble bacterial structure
  - genetic
    - mitochondria & chloroplasts have their own circular DNA, like bacteria
  - functional
    - mitochondria & chloroplasts move freely within the cell
    - mitochondria & chloroplasts reproduce independently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

Are there any modern day examples to investigate?



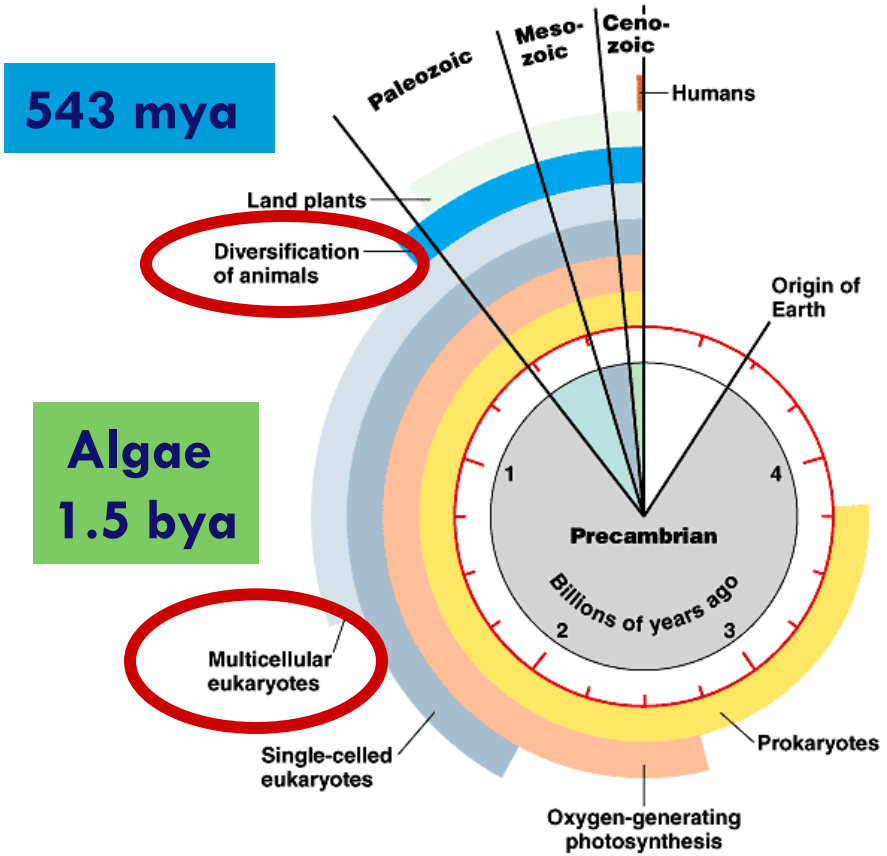


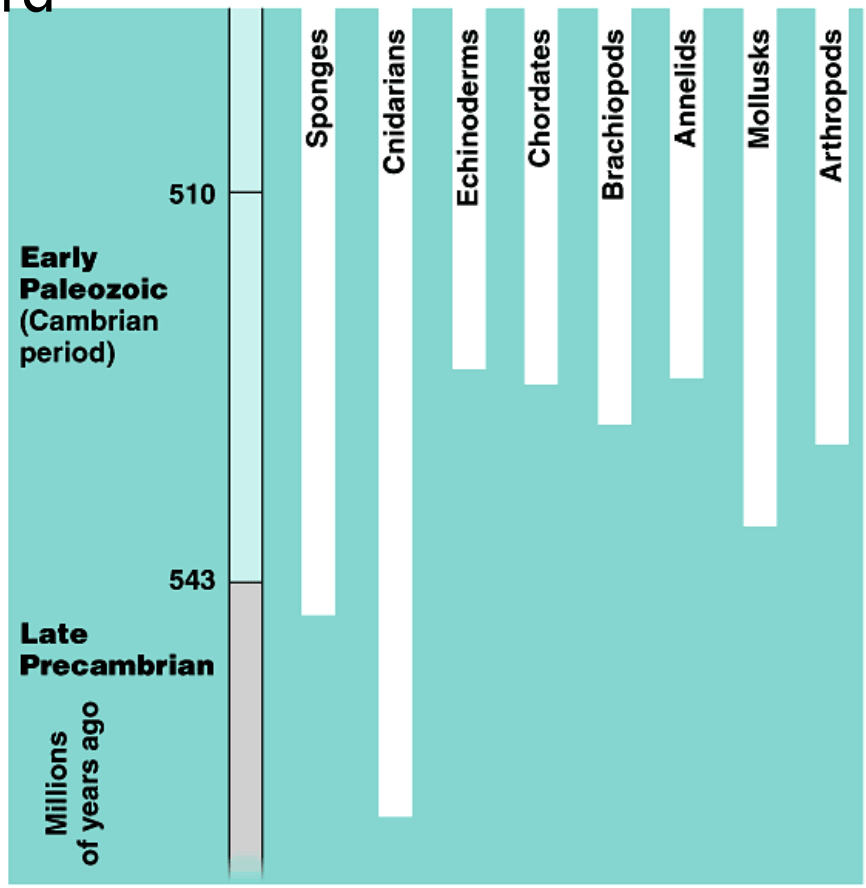




Diversification of Life

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



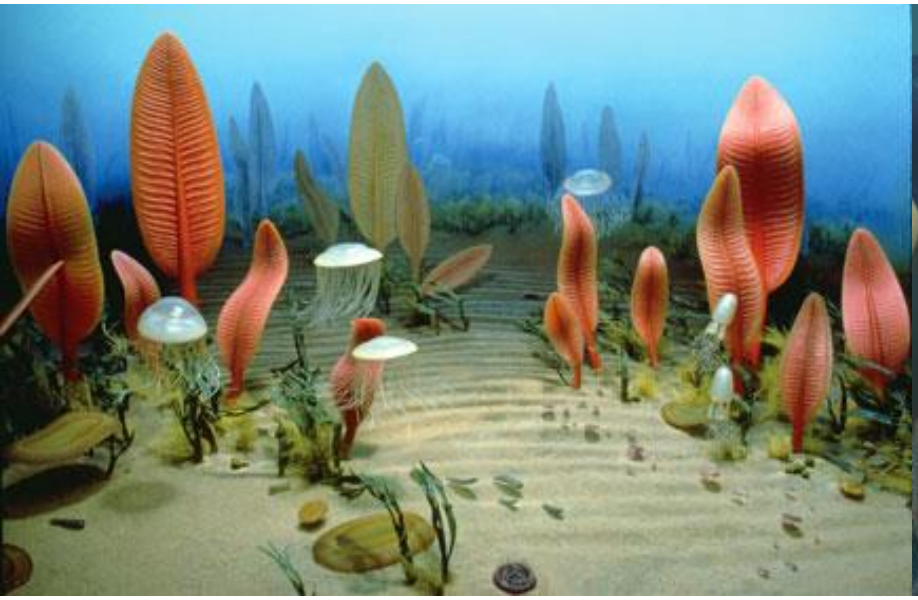


Origin of Invertebrates

- Fossils that shed light of the origins of invertebrates have been found in 3 places:
  - Edicara Hills, Australia
  - Chengjiang, China
  - Burgess Shale, Canadian Rockies

SC.912.L.15.1 *Explain how the scientific theory of evolution is supported by the fossil record, comparative anatomy, comparative embryology, biogeography, molecular biology, and observed evolutionary change.*

Origin of Invertebrates



Edicarian Fossils

Burgess Shale

Origin of Invertebrates

- Cambiran Explosion
  - Animals evolved
    - complex body plans
    - shells, skeletons, and other hard parts were evolving
    - Specialized cells, tissues, and organs
  - Animal Diversity "exploded"
    - Ancestors to modern organisms were appearing

SC.912.L.15.3: *Describe how biological diversity is increased by the origin of new species and how it is decreased by the natural process of extinction.*