ASTROBIOLOGY ALIVE!

Module 1: Life in Earth's Past

1. Introduction

This module will include creating a to-scale, generalized geologic timeline and guided stations that explore life in Earth's past through fossils. Stations will include fossils and rocks from four geologic timeframes: Pre-Cambrian (supereon), Paleozoic era, Mesozoic era, and Cenozoic era. Discussions topics will include 1) when the Earth was too hot to harbor life; 2) hypothesizing why light sensitive microbes produce stromatolite formations that grow upward toward the sun; 3) comparisons between present day life and prehistoric life. Students will move in groups from station to station to explore rock types and fossils through geologic history.

Astrobiology connection: Correlations will be made in regards to understanding life on Earth as a model in the search for life beyond Earth and the potential for fossilized life on Mars (e.g. Mars Rock ALH 84001).

Handouts: Students will take home a fossilized shark tooth to inspire student curiosity and act as a memory token.

Activity Add-on: Students can be encouraged to draw their own extraterrestrial life form based on the Earth life forms they learned about during the module.

Target Grades: K-6 (adapt discussions as appropriate for grade level)

2. Learning objectives:

1. Understand the geologic timescale and why it is divided into different eras
    a. Pre-Cambrian (supereon), Paleozoic era, Mesozoic era, and Cenozoic era; each timeframe represents major events and change in life forms (e.g. Cambrian explosion and extinction events)
2. Understand what rocks can tell us. For example:
    a. What the climate was like
    b. What type of life existed
    c. What environment it was deposited in (e.g. ocean, sand dunes, etc.)
3. Understand development and evolution of life and how we may use this information to look for past life on Mars
    a. Early Earth was sometimes very hot or cold, and without oxygen. During this time, life began in the form of microbes. As Mars has a similar climate and atmosphere, we would expect to find microbes if life ever existed.

3. Materials:

- Outreach volunteers (minimum 2)
- 10 m of Pre-cut butcher paper (for geologic time scale)
- ~ 10 m of (4) colored masking tape
- Precambrian rocks/fossils: stromatolite; ultramafic rock (very high temperature)
- Paleozoic fossils: trilobites, lobe-finned fish
- Mesozoic fossils: therapod, therapsid, bird
- Cenozoic fossils: mammoth molar fossil
- Anthropocene rocks: cement, concrete, asphalt, plastic, glass, metal etc.
- Illustrative fact cards and timeline guides
- Plush microbe models
- Colored markers/crayons
- *Handouts: Fossilized shark teeth*

4. In-Class guide (~ 1 h)

4.1. Introductory Discussion/Activity (10- 15 min)

Q: Can anyone tell me what a fossil is? Give some examples of fossils.

Q: Does anyone know why we study fossils?
The people who study rocks and fossils are called geologists.

Q: Does anyone have a guess how old the oldest fossil is? [3.5 billion year old Stromatolites]

Q: If the oldest fossils it 3.5 billion years old – can you guess how old the Earth is?

Q: Has anyone ever learned about the geologic timeline before?

You will build a basic geologic timeline with the entire class. Precut a piece of butcher paper 10 m long (1 mm = 1 million years; 1 m = 1 billion years). You will have a timeline spanning 4.6 m, by the end of the geologic timeline activity. Using 4 different colored masking tapes, have students tape out the length of each of the following timeframes:

a. Precambrian (supereon): 4.6 billion – 540 million years ago
   - 4.06 billion years total
   - OR 4.06 m (4 m + 6 cm) on your timeline

b. Paleozoic: 540 – 250 million years ago
   - 290 million years total
   - OR 29 cm on your timeline, adjacent to the Precambrian tape line

c. Mesozoic: 250 – 66 million years ago
   - 184 million years total
   - OR 18.4 cm on your timeline; adjacent to the Paleozoic tape line

d. Cenozoic: 66 million years ago - Present
   - 66 million years total
   - OR 6.6 cm on your timeline; adjacent to the Mesozoic tape line
   - Draw a (red) marker line at the very edge of the Cenozoic tape line- This is how long humans have been around. (1-2 mya)

Lead a brief 5-10 m introduction on the geologic timeline in the process of taping it out:

1. The Earth is 4.6 billion years old!
2. Precambrian time lasts ~ 90 % of Earth's history
3. Humans have only been around for a very short time (1-2 mya)! How can we learn about Earth's deep history?
4. Geologists study Earth's history by looking at rocks. Each rock can tell a story about what the Earth was like when it formed – [Water – Life – Volcanoes – Ice]

** You can add details to your timeline as you go through the fossils. See section 4.2 below.

4.2. Fossil Activity (25- 30 min, ~7 min ea. station)

Today we are going to be geologists and explore life in Earth's past by looking at fossils.

Break the class into 2 groups – outreach volunteers will guide each group. One group will go back in time, while the other moves forward in time. You do not need to cover every line item or detail provided below, rather present what topics you find most interesting and adapt as time allows. *Rock hand samples and fossils available from the UNLV geoscience department are outlined in boxes.*

1. Precambrian (supereon; 4.6 billion – 540 million years ago)

The Precambrian is a period of time called a supereon. It makes up about 90 % of Earth's history. During this time, Earth went through many major transitions, from its fiery formation to being completely covered in ice.

a. Hadean eon: 4.6 to 4.0 billion years ago
   - Earth formed
   - Volcanic activity
   - Meteor impacts
   - High radiation
   - VERY HOT

Ultramafic rock – very, very hot and molten, volcanic – no fossils in this rock
- What might have been on the earth to form so much of this rock?
- Do you think life could have survived this harsh environment?

b. Archean eon: 4.0 – 2.5 billion years ago
   - Earth cooled and continents formed
   - No oxygen in the atmosphere
   - Faint young sun (70-75 % of current solar strength)
   - First life! Stromatolies– 3.5 billion years ago (See Stromatolite fact card)

Stromatolites – Formed by cyanobacteria, microbes that use sunlight for energy and release oxygen (i.e. photosynthesis)
- What features do you see? [Layers] Why might they have made layers?
- See Stromatolite fact card

c. Proterozoic eon: 2.5 billion years to 540 million years ago
   - Means "early life" – time before complex life formed
   - Snowball Earth events
   - Rise of Oxygen in the atmosphere (eventually allowing for complex life to form)

2. Paleozoic era (540 – 250 mya)

The Paleozoic (meaning "ancient life") era is known as the age of invertebrates, amphibians and fishes. During this time life started to get more complex compared to the single celled, microbial life of the Precambrian. There were oceans and lakes, and abundant oxygen, making Earth a much more habitable planet for complex, multi-cellular life.

The beginning of the Paleozoic era was marked by the fastest diversification of life in Earth's history, called the Cambrian explosion (540 mya). This explosion of life began in the sea and eventually moved onto land. New life forms included fish, arthropods, and amphibians.

The Paleozoic era ended with the largest extinction on Earth – the Permian-Traissic extinction. This extinction event was potentially caused by a meteor impact event or major volcanism.

Bivalves – First appear in the Cambrian (500 mya)

- Do we have similar creatures today? Where do we find them?
- How are these life forms different from life in the Precambrian? [Multicellular, complex, form shells]

Trilobites –

Crinoids –

3. Mesozoic era (250 – 66 mya)

The Mesozoic era is known as the age of reptiles - dinosaurs, birds and the first mammals. The climate during this time period was warmer than it is now. At times it was humid and hot like the tropics are today. Tyrannosaurs and triceratops lived near the end of the Mesozoic, in the Late Cretaceous (100 – 65 mya).

The Mesozoic era ended with the Cretaceous-Paleogene, or Cretaceous-Tertiary (K-T), extinction event, which killed off dinosaurs, plants and other animals. This extinction event occurred when a massive meteor impacted the Earth.

Ammonite –

Thrinaxodon –

Tyrannosaurs Rex – This is a replica of a fossilized baby T-Rex skull

- Are there any ancestors of dinosaurs living today? Yes! birds

4. Cenozoic era (66 mya – Present)

The Cenozoic (meaning "new life") era is known as the age of mammals, apes, and humans! The extinction of most dinosaurs at the K-T boundary extinction event allowed mammals and birds to diversify and proliferate. Some mammals and birds grew very large. The climate cooled and became drier, with phases of glaciation. The continents moved into their current position, which included the formation of the Himalayan Mountains and Mt. Everest.

The first humans appeared 1 - 2 mya . Note how little time humans have been on the Earth! Did people live at the same time as dinosaurs? – Nope.

Some scientists call our current time period the Anthropocene – which refers to the major impact humans are having on the Earth.

Mammoths – This is a fossilized mammoth tooth! Notice how it is made for grinding grasses and shrubs – somewhat like your molar teeth!

Knightia – These small fresh water fish were abundant in the Eocene

Chicken skeleton – Chickens and other birds are descendants of dinosaurs. Chickens in particular are more closely related to T-Rex than alligators are.

This is a skeleton – (pre fossilization) –Talk about how fossils are formed.

Modern day "rock" and fossil formations – e.g. concrete and asphalt. "Non-native" plants and animals.

4.2. Wrap-up discussion (5- 10 min)

Bring the class back together and look over the timeline as a class.

Example discussion questions:

Q1. What are some of the clues rocks can give us to understand earth's history?
A1. [ultramafic] Volcanic rocks = very hot, volcano covered Earth; Fossils = life, microbial versis complex life.

Q2. How did life change from when earth started to today?
A1. It became more complex, organisms got bigger and more diverse

Q3. Did humans and dinosaurs ever live together?
A3. Nope! Humans have not been around very long, but we are leaving our mark on the rock record!

Q4. Ask the students what their favorite time-period was.

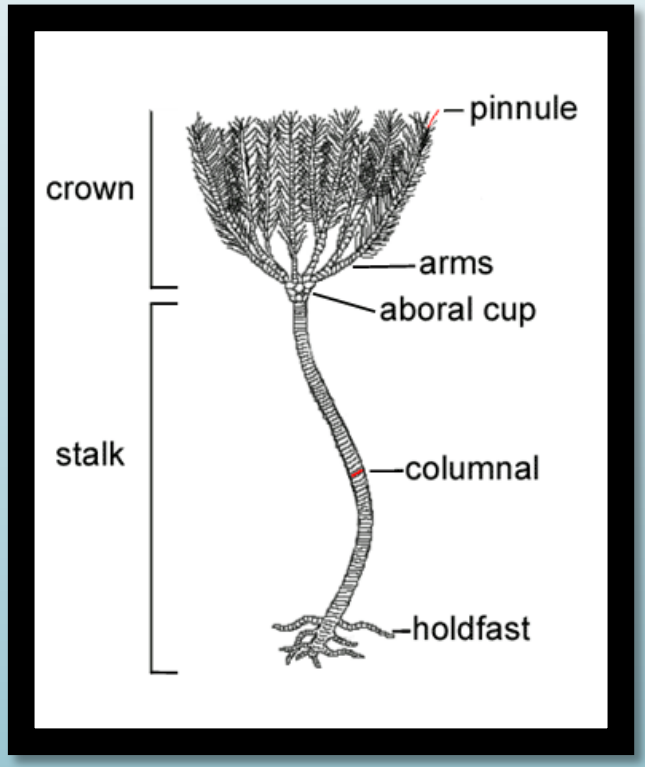
Don't forget to pass out fossil shark teeth at the end of the module!

4.4. Add on activity/ discussion

Mars is a lot like Early, Precambrian Earth: It gets very hot and very cold, and has no oxygen…If Mars has life, what kind of life would we expect to see? – Microbes!

Draw/ design a microbe that you think might live on Mars.

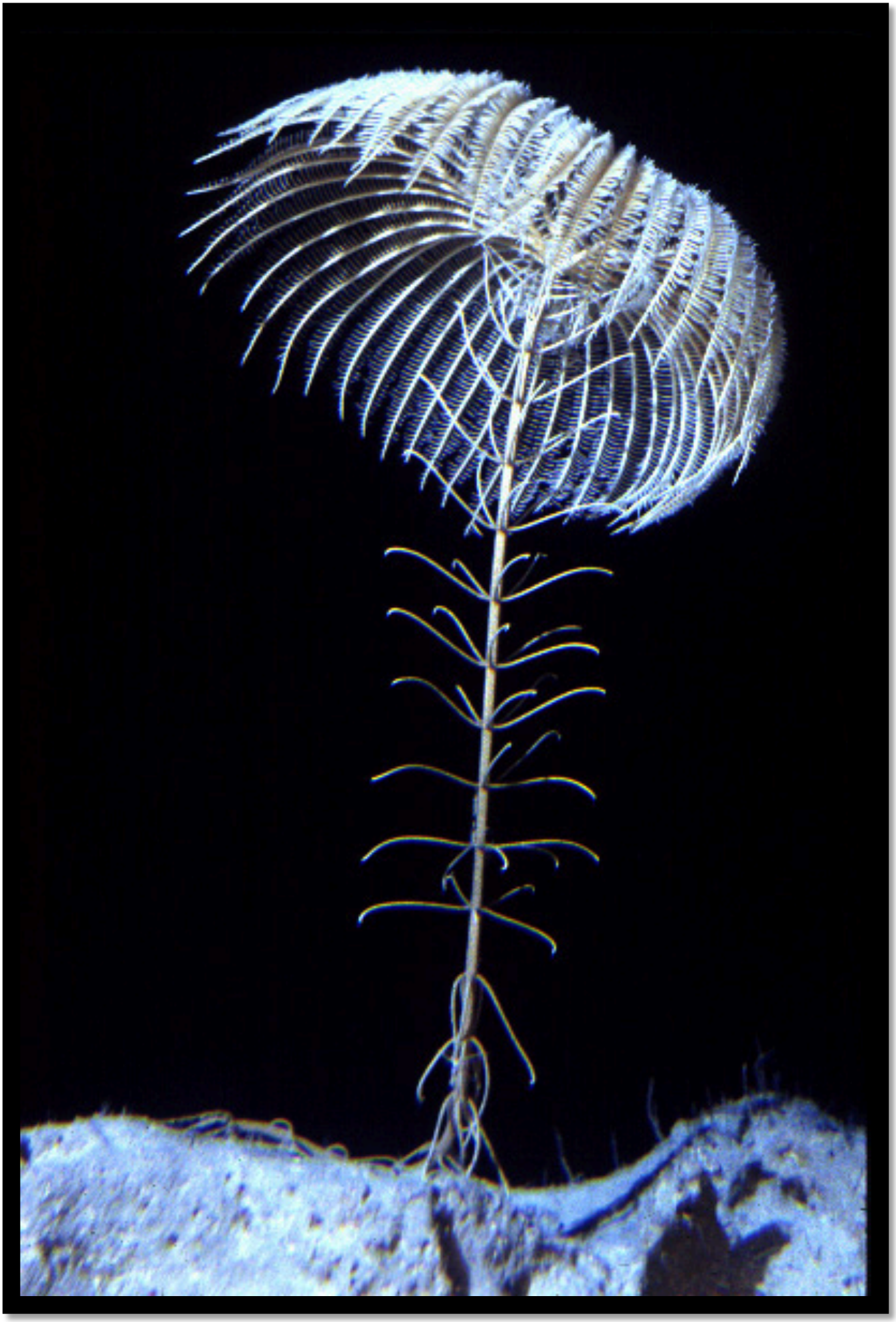
Crinoid Facts



- Also known as "sea lillies"
- Crinoids are animals!
- They capture food particles with their arms and put it in their mouths within their crown shaped body, or calyx.
- There are crinoids alive today!
- During the Paleozoic era, crinoids were very abundant. Geologists know this from limestone rocks that are made completely of crinoid fossils.

Imagine what an ancient sea of crinoids would have looked like!

http://www.giantsrib.ca/escarpment-origins-ancient-seas-and-fossils/crinoids/



http://www.usu.edu/geo/liddell/Photos/CRINOID.JPG

Ammonite Facts

- Ammonites were squid-like sea creatures with spiral shells
- Some ammonite shell fossils are over 3 feet across!
- They first appeared 240 million years ago, and disappeared with the dinosaurs around 65 million years ago.
- They are related to the living Nautilus and other cephalopods.

Imagine what a school of ammonites would have looked like!

http://www.discoveringfossils.co.uk/ammonites.htm
http://animals.nationalgeographic.com/animals/prehistoric/ammonites/
http://www.foreshorefossils.com/product/ammonite-promicroceras-multi-block/

Trilobite Facts

- Trilobites lived from 521 to 270 million years ago, during the Paleozoic era
- Some trilobites lived on the sea floor, while others swam!
- Paleontologists have identified 20,000 species of trilobites. These fossils can be used to help geologists determine when a rock formed

Do trilobite fossils remind you of any creatures on Earth today?

http://www.bbc.co.uk/nature/life/Trilobite

Mammoth Facts

- Mammoths live between 5 million to 4,500 years ago, during the Cenozoic era
- Humans and mammoths lived at the same time!
- The largest mammoths grew up to 13 ft. tall at the shoulder and weighed 8 to 13 tons.
- Mammoth molars were extra tough to allow them to eat grasses and shrubs.

http://www.pbs.org/wgbh/nova/next/nature/what-drove-wooly-mammoths-to-extinction/

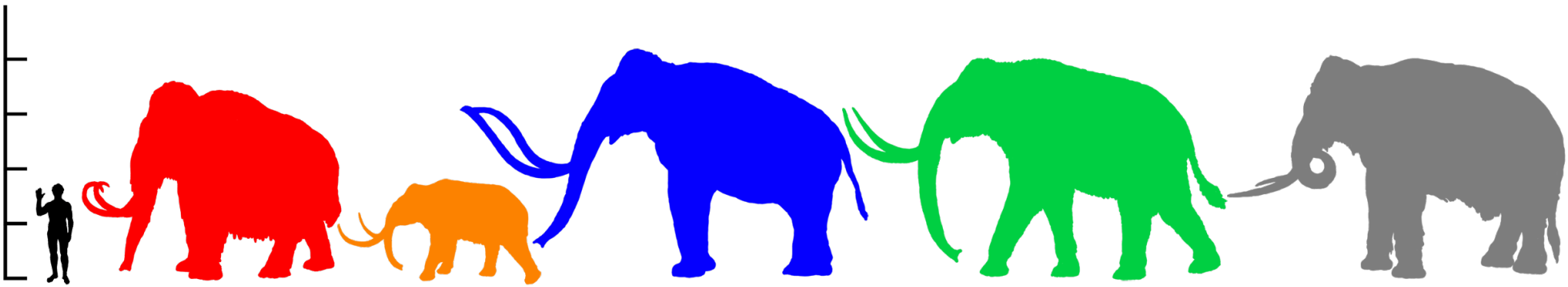
Mammuthus primigenius

Mammuthus exilis

Mammuthus columbi

Mammuthus trogontherii

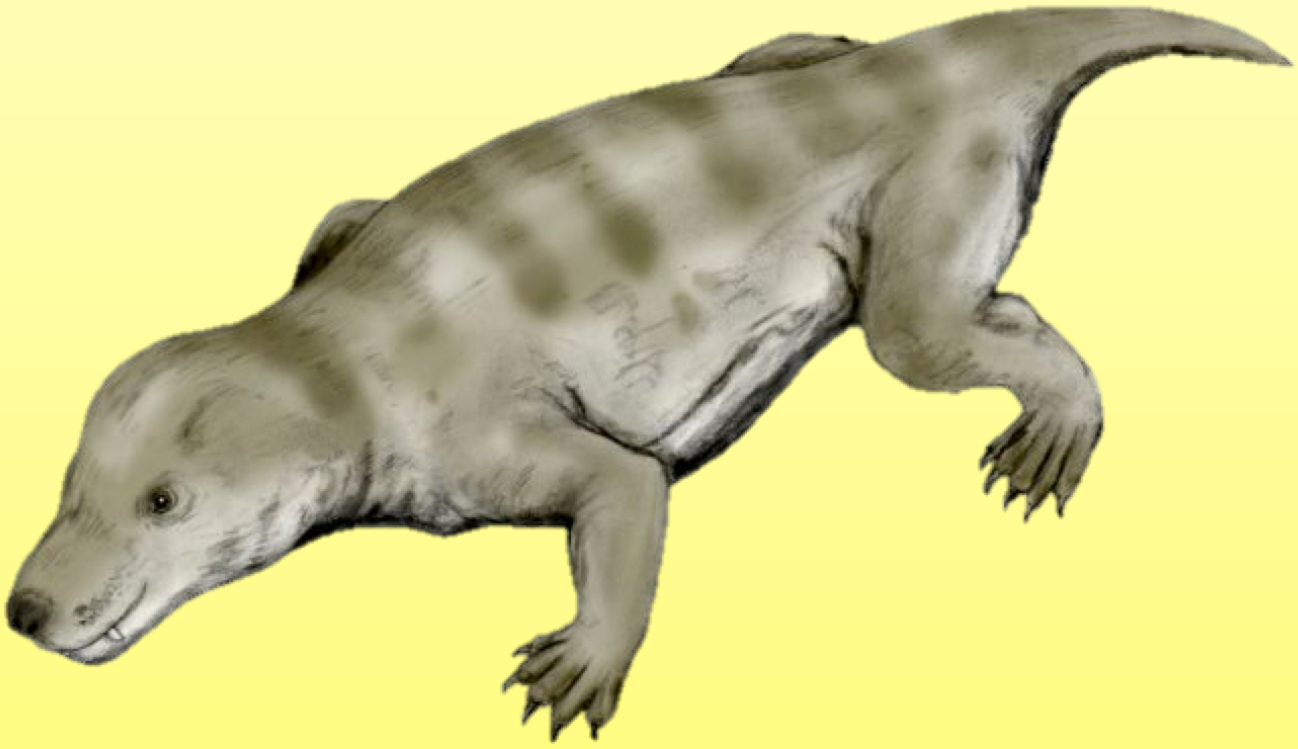
Mammuthus meridionalis



https://en.wikipedia.org/wiki/Mammoth#/media/File:Mammuthus_Size_comparison.png

Thrinaxodon Facts

- Thrinaxodon lived between 251- 247 million years ago, during the early Triassic (Mesozoic Era)
- Thrinaxodons were mammal like reptiles!
- These creatures burrowed in the ground – which may have helped them survive the Permian-Triassic mass extinction
- They were carnivores about the size of a fox, and may have had hair and whiskers!

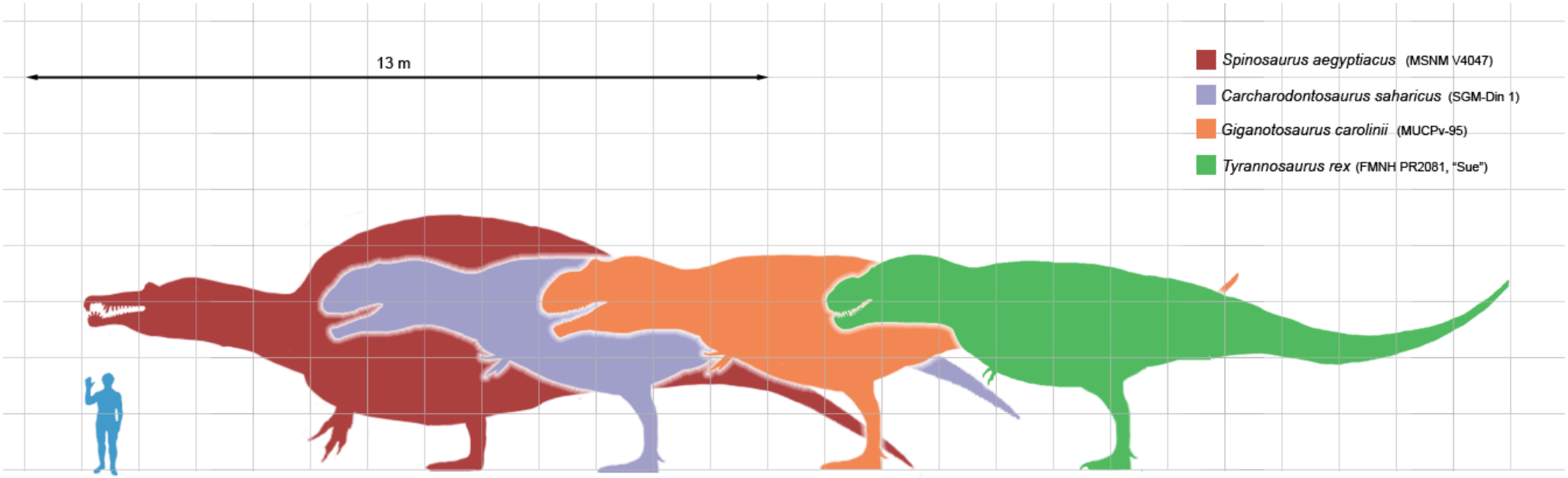


https://en.wikipedia.org/wiki/Cynodont
http://www.prehistoric-wildlife.com/species/t/thrinaxodon.html

Tyrannosaurs Rex Facts

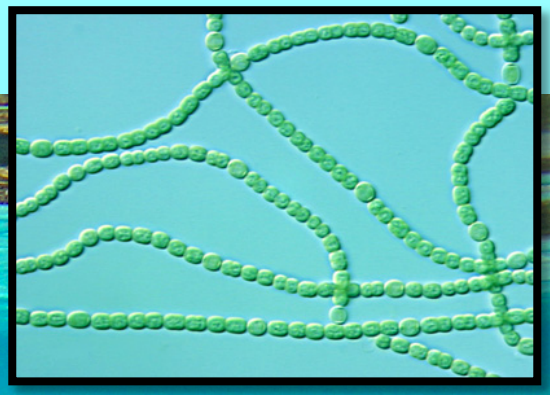
- T-Rex lived between 68 – 66 million years ago
- Scientists think T-Rex may have had feathers!
- The largest discovered T-rex is believed to weight up to 12,460 lbs.

Do you know if T-Rex has any living descendants?


13 m
Spinosaurus aegyptiacus (MSNM V4047)
Carcharodontosaurus saharicus (SGM-Din 1)
Giganotosaurus carolinii (MUCPv-95)
Tyrannosaurus rex (FMNH PR2081, "Sue")

Stromatolite Facts

- Formed by colonies of microbes, especially cyanobacteria, that catch and cement rock grains together
- Stromatolite formations "grow" towards sunlight because cyanobacteria require light to make energy.
- These structures may protect the microbes from harsh conditions
- The oldest stromatolite fossils are 3.5 billion years old!



https://uwaterloo.ca/peter-russell-rock-garden/rock-garden/rock-groups/proterozoic-rocks/stromatolite-marble

Knightia Facts

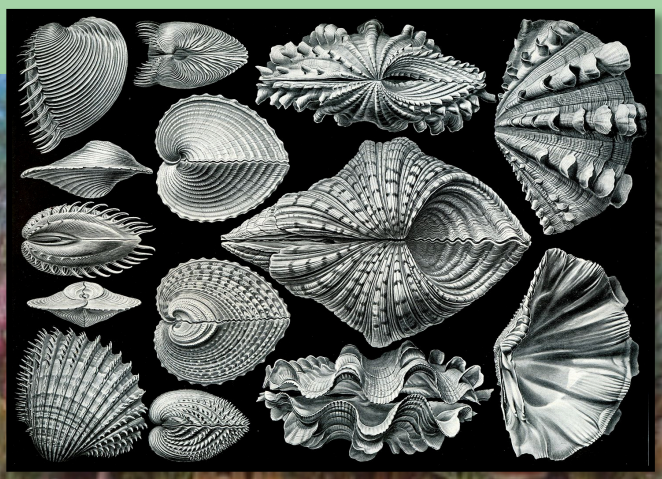
- This small fresh water fish moved in schools and was abundant in the Eocene (56 - 34 mya)
- They are related to herring and sardines
- Fossis of these fish have been found in the mouths and stomach of other larger fish of the time - indicating they were a favorite snack for sea life, just like sardines are now!

https://en.wikipedia.org/wiki/Knightia#/media/File:Knightia_BW.jpg

Bivalve Facts

- Bivalves first appeared in the Cambrian period (Paleozoic era) 500 mya
- They lived in both oceans and fresh water
- Bivavles still live today! They include clams, oysters, mussels and scallops

You can find bivalve fossils at Mt. Charleston!



http://www.columbia.edu/itc/eeeb/baker/N0316/Lecture%205/Images/ordovician.JPG

Chicken Facts

- Birds are descendants of dinosaurs!
- The first dinosaur fossil found with feathers was Archaeopteryx.
- Chickens, in particular, are the living relatives of T-Rex. They are more closely related to T-Rex than alligators

This is a skeleton of a chicken – How do you think the skeleton becomes a fossil?

http://img.burrard-lucas.com/india/full/red_jungle_fowl.jpg

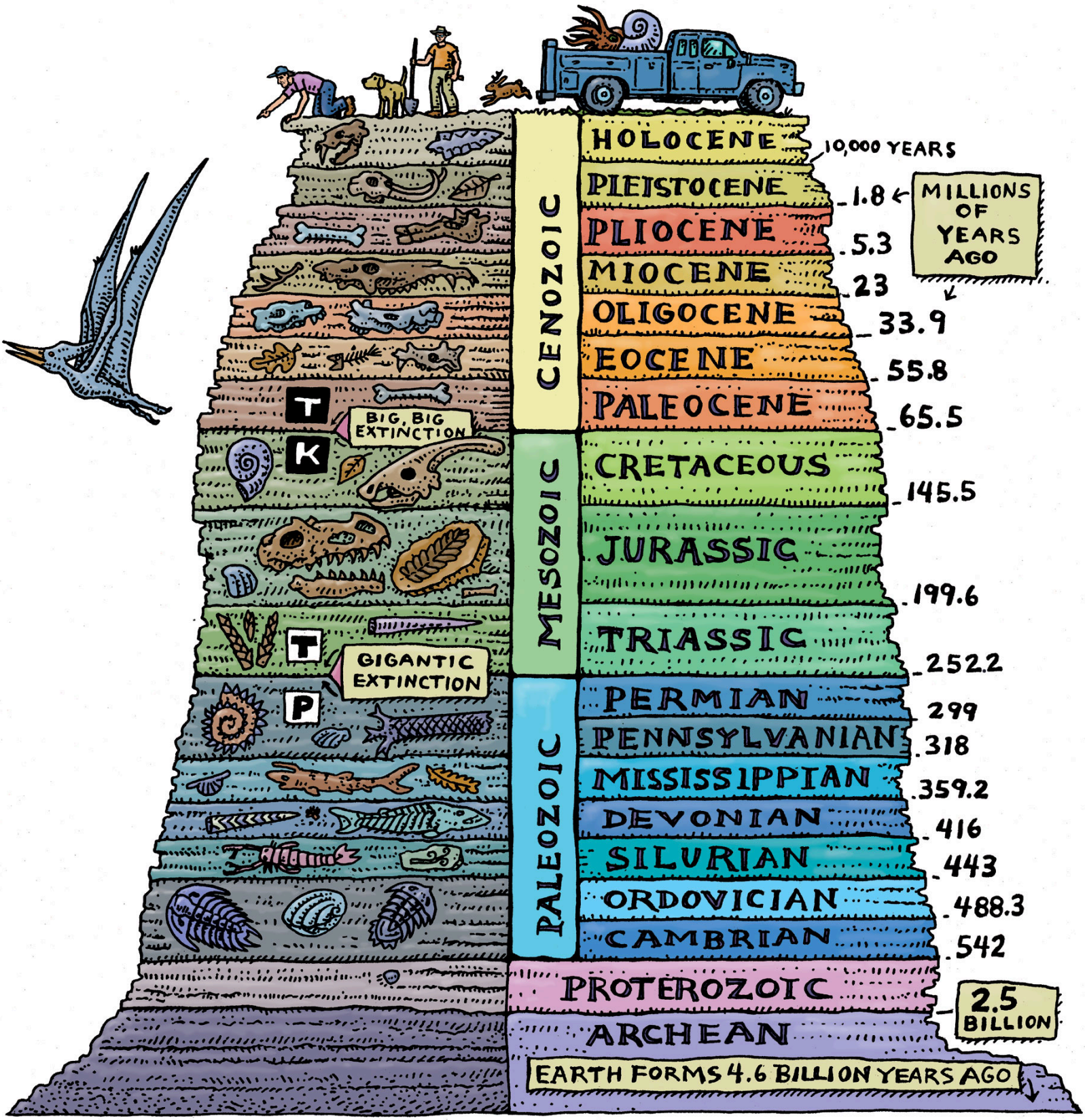


Image Credit: Ray Troll

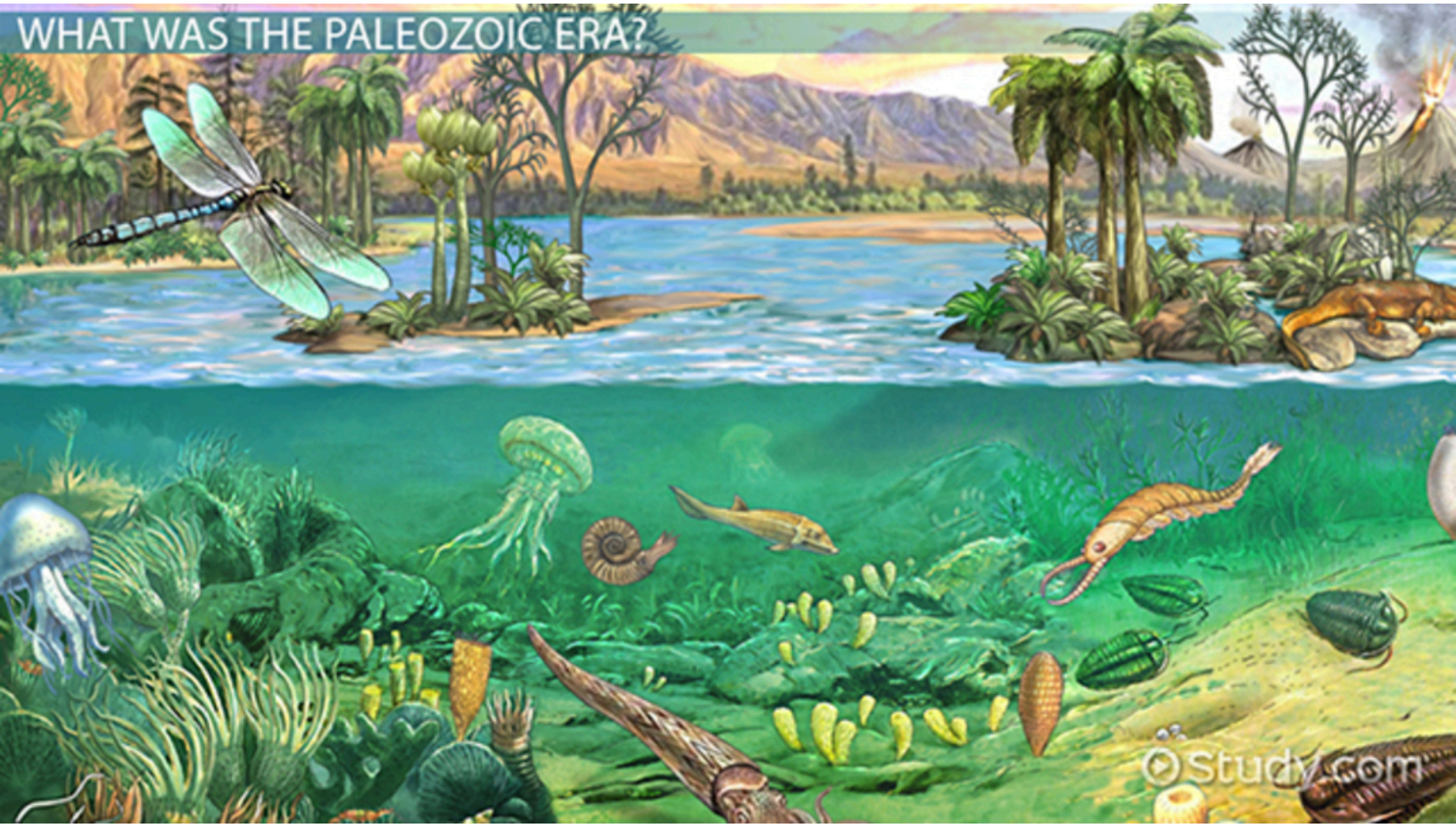
Precambrian

(supereon)

Paleozoic
(Era)

Cambrian Explosion!

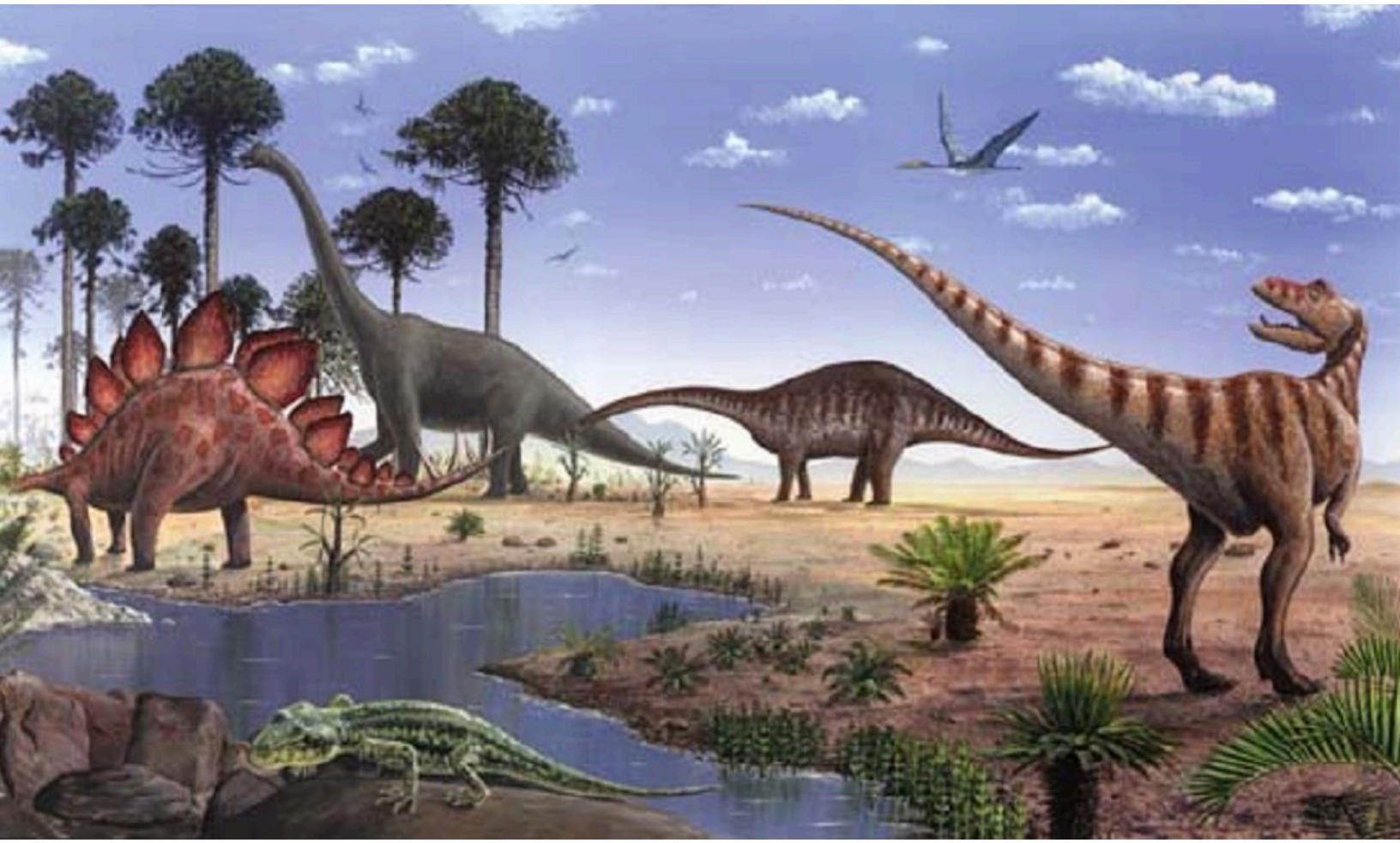
Extinction Events:
- End Ordovician (444 Ma)
- Late Devonian (375 Ma) – Trilobites wear nearly wiped out
- End Permian (251 Ma) – about 96% of marine species went extinct



Mesozoic
(Era)

Extinction Events:

- End Triassic (200 Ma)
- End Cretaceous (66 Ma) – Dinosaurs go extinct!



http://3.bp.blogspot.com/-3PBpalvhgFE/Vl2dtbGRvuI/AAAAAAAACdg/s0SUODl-U8s/s1600/11.15.jpg

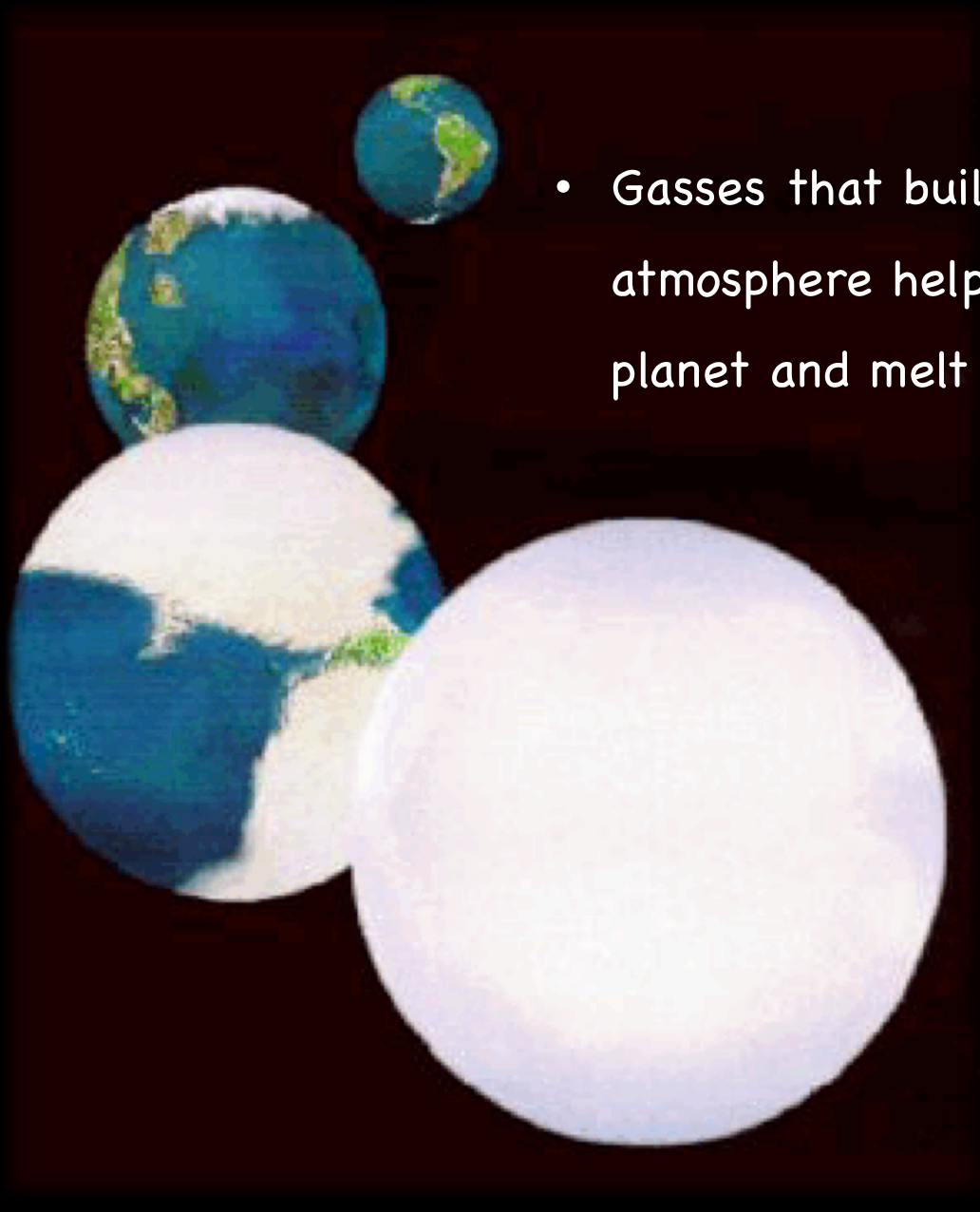
Cenozoic

(Era)

http://www.livescience.com/40352-cenozoic-era.html

Snowball Earth

- Evidence suggests Earth was completely covered in snow and ice, multiple times during the Precambrian
- Scientists still aren't sure how life survived these "snowball Earth" events!



- Gasses that built up in Earth's atmosphere helped warm the planet and melt the ice