

ST[EMpower]

PALEONTOLOGY 4: CHANGE

VOLUME 9, ISSUE 4, DECEMBER 2019



THIS MONTH

- Revisit Cladograms pg. 2
- Climate Change pg. 6
- Mass Extinction pg. 8
- Comparing Climate and Extinction Events pg. 11
- Complete Precambrian Timeline pg. 12

POWER WORDS

- **cosmos**: the universe seen as a well-ordered whole
- **Eon**: any of the four major divisions of this history of the Earth
- **fundamental**: forming a necessary base or core; of central importance
- **MYA**: million years ago
- **Precambrian**: a general term that includes the three **Eons** before multicellular life appeared in the fossil record—Hadean, Archean, and Proterozoic

CAREER CONNECTION

- You have taken a survey of your interests. This month, take a basic personality test. This will provide you with some information about how you perceive the world and make decisions. Pg. 14

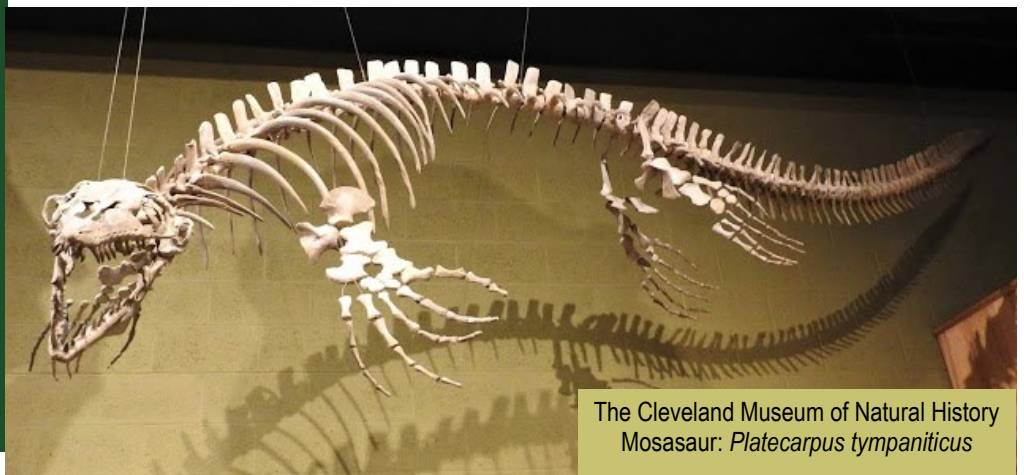
CHANGE THROUGH TIME

Change is the **fundamental** order of the **cosmos**. This ancient idea was first proposed 2,600 years ago by the Greek philosopher Heraclitus of Ephesus. This holds true for paleontology. Earth's record shows massive swings in climate from hot-house swamps of the Carboniferous 300 **MYA** to a snowball Earth 650 **MYA** in the **Precambrian Eons**.

The fossil record reflects these changes. Fossils that lived in oceans are found all over

Colorado, nowhere near oceans, 6,800 feet above sea level. For example, you can find mosasaur teeth in Archuleta County! Mosasaurs lived during Mesozoic (time of dinosaurs). They are aquatic reptiles (now called diapsids).

Major changes recorded in the fossil record are mass extinctions. Are they all related to climate? Are there other factors related to mass extinction? Let's figure this out! (Hooray for science!)



The Cleveland Museum of Natural History
Mosasaur: *Platecarpus tympaniticus*



SCIENCE, TECHNOLOGY,
ENGINEERING, AND MATH
COLORADO STATE UNIVERSITY
EXTENSION

COLORADO STATE UNIVERSITY EXTENSION
4-H PROGRAMS ARE AVAILABLE TO ALL WITHOUT DISCRIMINATION

Last month's ST[EMpower] newsletter included a whirlwind tour of cladograms. Before the activities on climate through Earth's history, I would like to revisit cladograms one more time.

In this activity, you will build a cladogram of your family. While cladograms generally depict how different organisms are related to each other, this might be a way to better explain how they work.

Cladograms are samples of related organisms. This is not a complete family tree. Instead, we are only looking at a snippet of your family. Just your mother, your mother's mother, one of your mother's siblings, and one of your cousins.

Directions:

- Complete the data table of a sampling of your mother's history, and then a sampling of your father's family history. You will not collect a complete family history, only a small sample of it.
- Sample of your mother's history
 - You and your siblings
 - Your mother
 - Your mother's mother
 - Your mother's sibling (either a brother or sister a **maternal** aunt or uncle)
 - Your mother's brother or sister's child (your **maternal** cousin)
- Sample of your father's history
 - You and your siblings
 - Your father
 - Your father's father
 - Your father's sibling (either a brother or

sister—a **paternal** aunt or uncle)

- Your father's brother or sister's child (your **paternal** cousin)
- If one of your parents is a single child, you will not have any information about an aunt/uncle and cousin. That is okay.
- Once you have completed the data table, fill in the blanks on your cladogram.

Results:

- A **cladogram** is a branching diagram of species. The **nodes** represent a shared common ancestor. For example, the orange circles on the page 3 example represents my shared common ancestor with my brothers (our mother), and my cousin, uncle and mother (our **maternal** grandmother). I am related to my cousin, and our common ancestor is our **maternal** grandmother.
- Look at your cladogram. If you were to add your **maternal** grandmother's mother (your mother's mother's mother), where would you add her?
- In the future, if you or your siblings have children, where would you add them?
- What can you say about this

POWER WORDS

- **cladogram**: branching showing the relationship among selected species
- **lineage**: lineal (in a line) descent from an ancestor
- **maternal**: related through the mother's side of the family
- **node**: a point at which lines or pathways intersect or branch; a central or connecting point
- **paternal**: related through the father's side of the family

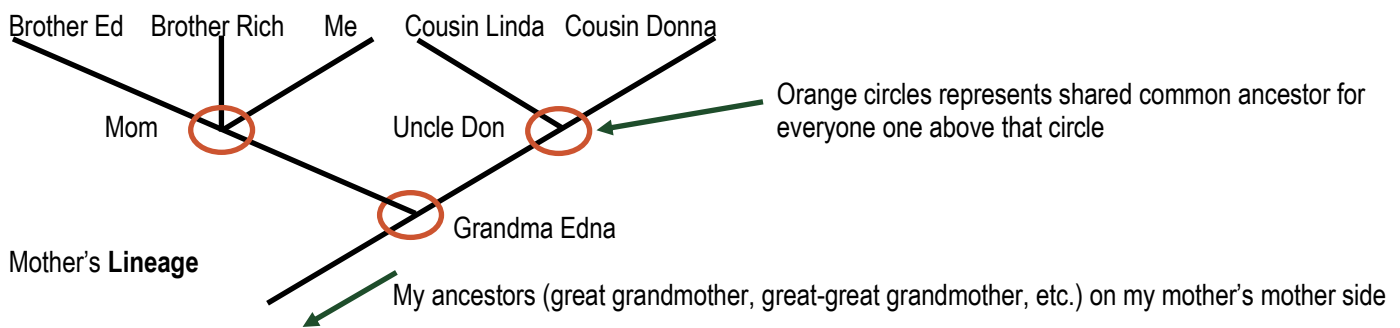
cladogram on dinosaurs? (Each node represents the shared common ancestor of every organism above that line.)

- Crocodiles are the first group listed on the cladogram. The node (circled in blue) shares a common ancestor with dinosaurs.

MATERIALS

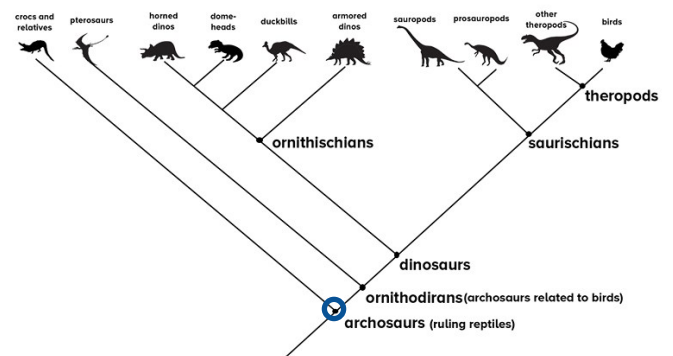
- computer with printer
- pencil or pen
- print page 3
- parents for information

You and your siblings	Your Mother/Father	Grandparents	Aunts and/or Uncles	Cousins
Example Mother's lineage : Barb (me), my brothers Ed and Rich	Dorothy (my mother)	Edna (my maternal grandmother)	Donald (my maternal uncle)	Linda and Donna (my maternal cousins, Uncle Don's daughters)
Mother Lineage				
Father Lineage				



Complete your **lineage** cladogram (keep it simple—you don't need to list everyone):

Your Mother's **Lineage**



Your Father's **Lineage**

Can you read this cladogram of dinosaur lineage?

What happens when you don't include every relative, but skip a **generation** or more? How does that change the cladogram? Would the basic information be different? This starts to look more like the information scientists use in their cladograms to evaluate how animals (or other **organisms**) are related.

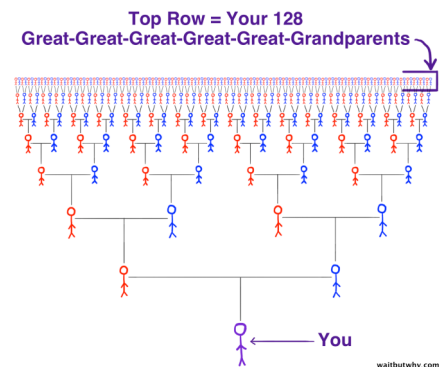
This time, you are going to not include your grandmother on your mother's side, or your aunt or uncle on your father's side. As the example, I used my mother's lineage without my mother listed. Examine your two cladograms, and compare it to the example. Then you will have a final challenge!

Directions:

- Start with your slanted line from lower left to upper right. Lower left represents back in time. Upper right will be the most recent ancestor.
- Think of each node as a hinge that can swivel. If you compare the two examples (on page 3 and on page 5), note that "me" is switched on the left to the right. It was swiveled at the node. The information remains the same. What is your first node (your oldest shared common ancestor)?
- Each node continues to represent the common ancestor with everyone one above the line directly related to your share common ancestor at the node.
- How many nodes are there between you and your cousin?
- Repeat for your father's line, but this time, you do not include your uncle or aunt.
- Finally, make a cladogram of your family with ancestors you never met, and probably don't know even their names. You will follow the lineage on your mother's side of your family with:
 - you
 - your great-great-great-great grandfather
 - his great-great-great-great grandmother
 - her great-great-great-great grandmother
 - her great-great-great-great grandfather
- Figure out how many generations between you (listed on the upper right) and your great-great-great-great-great-great-great-great-great-great-great-great-great-great-great-great grandfather
- When you have all your cladograms, examine each of them. What information is lost, and what information is retained? Your last cladogram is most similar to what scientists use when looking at organism relationships, like dinosaurs or ground sloths!
- If each of your ancestors lived an average of 90 years, what century did your great (x 16) grandfather live? (Answer on the last page.)

POWER WORDS

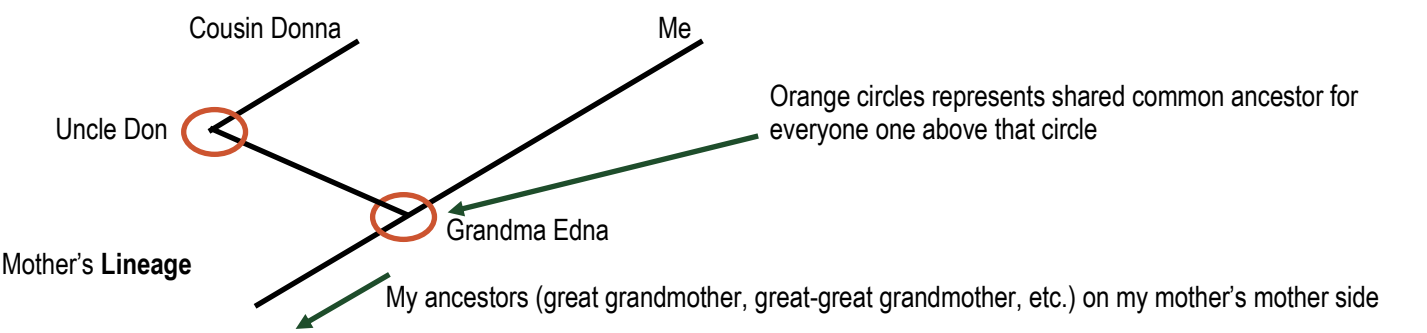
- **generation**: all of the people born and living at about the same time
- **organism**: an individual animal, plant, or single-celled life form



MATERIALS

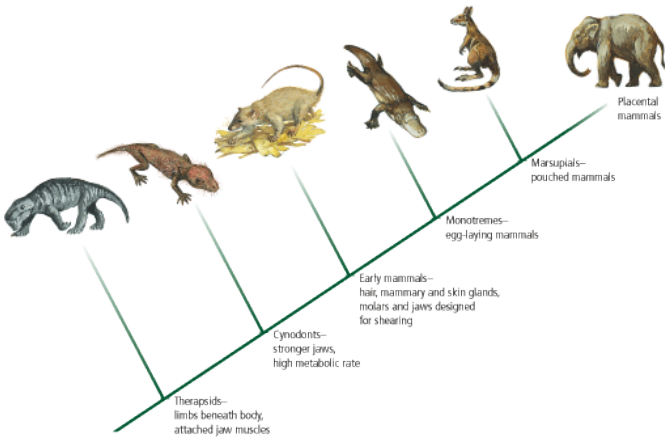
- computer with printer and calculator
- pencil or pen
- print page 5
- parents for information

You and your siblings	Your Mother/Father	Grandparents	Aunts and/or Uncles	Cousins
Example Mother's lineage: Barb (me)		Edna (my <i>maternal</i> grandmother)	Donald (my <i>maternal</i> uncle)	Donna (my <i>maternal</i> cousin, Uncle Don's daughter)
Mother Lineage				
Father Lineage				



Complete your **lineage** cladogram (keep it simple—you don't need to list everyone):

Your Mother's **Lineage**



Your Father's **Lineage**

Can you read this cladogram of mammal lineage?

Scientists are not concerned that climate is changing, but the rapid rate of change. Human activities (**e.g.** cars using gasoline, coal power plants) are releasing carbon trapped in trees, coal, and gasoline. Carbon traps solar energy in our atmosphere. From data we glean from the Earth's history, this is the most rapid change we have seen. **

Our Earth has been much warmer in the past. In fact, the Earth during the past 2.5 million years of Ice Ages is much colder than it has been for about 650 million years! When changes are slow, organisms have time to adapt to cooling or warming world. Too fast, organisms will go extinct.

Directions:



- Open the Smithsonian website (green box below), and explore how our planet looked like during different times in the past. For example, 650 MYA, the Earth was almost entirely encased in snow and ice, called "Snowball Earth."
- Open Word (or similar program). On the menu bar, click "Layout." Set page:
 - orientation to "landscape"
 - custom margins to 0.15"

- top and bottom
- custom margins to 0.25" left and right
- Open the Scotese website. This is the same website you explored in the two prior issues. Dr. Scotese also has climate information, and the link will take you directly to the climate pages. You will copy and paste selected maps (listed below) on your timeline. You need to match the Period of the map to the your timeline's period (example, Devonian map will be pasted to the Devonian timeline).
- Be sure that your maps are pasted next to the left margin labels as possible. Each month will add more information to your timeline, so you want to make sure to leave room to the right.
- On the Scotese website's left menu bar, note that there are links to different Periods from Early Cambrian to Miocene.
- You do not need all 26 maps, only a sampling to follow how climate changes through time. On the website, or press control key and place cursor over each map, click on the following 14 maps:
 - [Miocene Climate](#)
 - [Oligocene Climate](#)
 - [Late Eocene Climate](#)
 - [Paleocene Climate](#)

POWER WORDS

- **e.g.:** exempli gratia, Latin means "for example"
- **quadrant:** any of the four quarters into which something is divided by two real or imaginary lines that intersect each other at right angles

** If interested in activities related to weather, climate, and climate change, see the ST[EMpower] issues 46—51 at <https://tra.extension.colostate.edu/stem-k12/stem-resources/>

- [Late Cretaceous Climate](#)
- [Late Jurassic Climate](#)
- [Middle Triassic Climate](#)
- [Late Permian Climate](#)
- [Late Carboniferous Climate](#)
- [Early Carboniferous Climate](#)
- [Middle Devonian Climate](#)
- [Silurian Climate](#)
- [Middle & Late Ordovician](#)
- [Middle and Upper Cambrian](#)

MATERIALS

- computer with internet and printer
- your timelines *
- markers
- glue stick
- scissors

WEBSITES

- Smithsonian: <https://www.smithsonianmag.com/science-nature/travel-through-deep-time-interactive-earth-180952886/>
- Scotese: <http://scotese.com/climate.htm>

* See 53.Paleontology1 for directions to make a timeline: <https://tra.extension.colostate.edu/stem-k12/stem-resources/>

- Note that a description of the climate is below the map. Right click on the map, copy the map, and paste it in a word document.
- Click on the picture. In Word's top menu bar, click:
 - "Picture Format."
 - * Resize image to 5.25" width, 3.00" height.
 - * Click "Position" and select top/left, top/right, bottom/left, or bottom/right to move the picture into a different **quadrant** of the paper. You will fit 4 maps per page.
- Continue copy/pasting/resizing/placing each map until you have copied all 14 maps listed in blue in the middle column.
- You will have 4 pages, with the last page only half used. On the Scotese website, on any map page, click "MAP LEGEND." Copy/paste/resize, and place in the 4th page, and resize to fit in the area that isn't used by maps.
- Print all 4 pages single sided.
- Cut out each map and glue on the appropriate Period in a column on the left side next to labeling of each Period.
- Glue the legend at the top, above all the maps.
- There is a description of the climate under each map. Go back to the Scotese website, and note that you did not copy all the maps, only about half of them. For example:

- China and Australia during early Devonian. South America and Africa were covered by cool, temperate seas.
- Middle Devonian:** During the Middle Devonian the Equator ran through Arctic Canada. Coals began to accumulate as land plants flourished in the equatorial rainy belt. Warm shallow seas, under cloudless skies, covered much of North America, Siberia and Australia.
- Late Devonian:** During the Late Devonian, Pangea began to assemble. Thick coals formed for the first time in the tropical rainforests in the Canadian Arctic and in Southern China. Glaciers covered parts of the Amazon Basin, which was located close to the South Pole.

- Include all three descriptions of the Devonian climate, even though you only printed one map of Middle Devonian.
- The Carboniferous is divided into two major subdivisions, Pennsylvanian (Upper Carboniferous) and Mississippian (Lower Carboniferous). The Late Carboniferous Climate map is Pennsylvanian and the Early Carboniferous Climate map is

LEGEND

WARM		COOL	
WET	Tropical	Coal	Cool Temperate
	Coal	Coal	Coal & Tillites
	Bauxite		
	Laterite		
DRY	Warm Temperate		
	Kaolinite (& coal & evaporite)		
	Crocodiles		
	Palms & Mangroves		
	Arid		
	Evaporite		
	Calcrete		
	Cold		
		Tillite	
		Dropstone	
		Glendonite	

"Paratropical" = High Latitude Bauxites

TIMELINE

Below is a to-scale model of your timeline for the Era Paleozoic.

If you have not yet made your timeline, you can find the instructions on Paleontology 1: Basics, pages 16-19 located at this website:

<https://tra.extension.colostate.edu/wp-content/uploads/sites/9/2019/08/53.-Paleontology-1.pdf>

Paleozoic	Permian 252 - 299 MYA	
	Carboniferous Upper (Pennsylvanian) 299 - 323 MYA	
	Carboniferous Lower (Mississippian) 323 - 359 MYA	
	Devonian 359 - 419 MYA	
	Silurian 417 - 443 MYA	
	Ordovician 443 - 485 MYA	
	Carbonian 485 - 540 MYA	

Example of Paleozoic Timeline:

Map

Description of climate during that Period found with each map on the Scotese.com climate map pages

Lion King's song "Circle of Life" plays softly in the background...

Nants ingonyama bagithi Baba
(Sithi uhm ingonyama) yeah,
ingonyama

Nants ingonyama bagithi baba
(Sithi uhm ingonyama)
Ingonyama (Ingonyama)
Siyo Nqoba (Ingonyama)

<https://www.youtube.com/watch?v=GibiNy4d4gc>)

Mood set—check!

Scientists recognize 5 mass extinction events in the Phanerozoic **Eon** (defined on pg. 1):

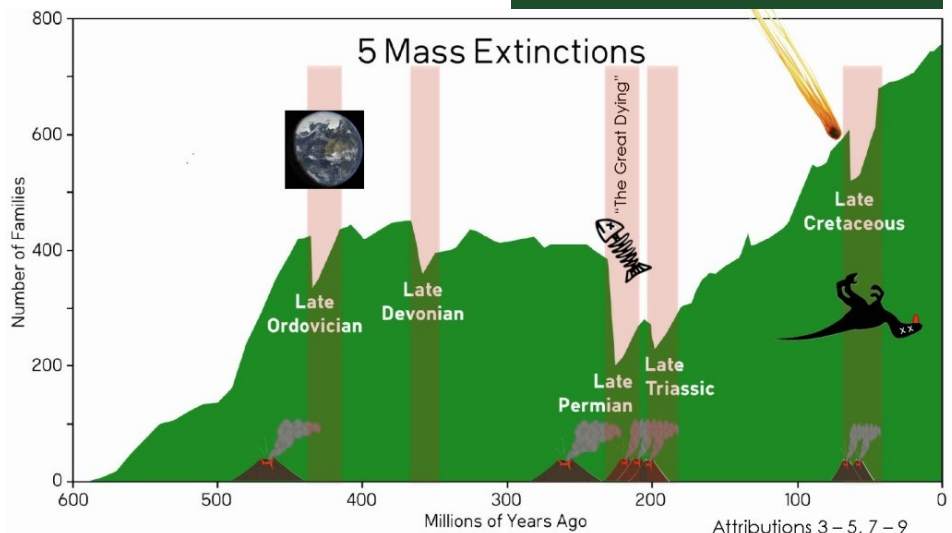
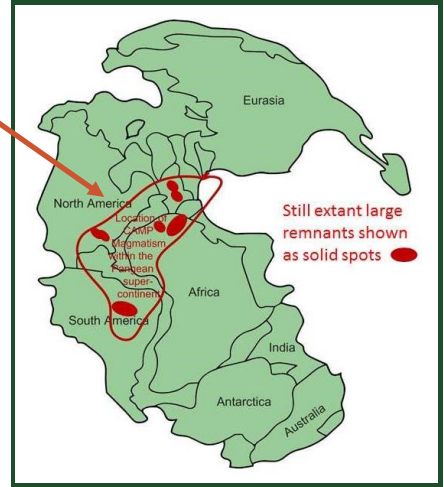
- **Late Ordovician:**
 - 445 **MYA**
 - 86% of all species extinct
 - possible causes: volcanic activity, intense ice age followed shortly by a warm period 1 million years later
- **Late Devonian:**
 - 360 **MYA**
 - 75% of all species extinct
 - possible causes: rapid environmental and climatic changes
- **Late Permian** also known as the Great Dying:
 - 250 **MYA**
 - 85% of all species extinct (estimated that 95% of marine life went extinct)
 - possible causes: formation of **Pangaea**, vast inland deserts, shorelines disappeared, ocean chemistry disrupted, atmosphere crashed, oxygen levels dropped, and, the second largest known volcanic eruptions (Siberian **Traps**) lasted for one million years, and covered an area of 3 million square miles!

- **Late Triassic**
 - 200 **MYA**
 - 85% of all species extinct
 - possible causes: changes in the ocean's chemistry and the largest known volcanic eruptions, Central Atlantic magmatic province (CAMP; see map to the lower right), covered an area of 9 million square miles!
- **Late Cretaceous**
 - 65 **MYA**
 - 76% of all species extinct (end of dinosaurs)
 - possible causes: meteor impact and one of the largest volcanic eruptions (Deccan **Traps**) located in India covered 600,000 square miles up to 6,600 feet thick!

Examine the graph on page 11.

POWER WORDS

- **MYA:** acronym for Million Years Ago
- **Pangaea:** supercontinent that included all current land masses
- **trap:** geologic term for rock formation with step like hills



MATERIALS

- computer with internet access and printer
- color pencils or markers
- scissors
- print datasheet on page 10
- your timeline
- page 11 graphs (optional to print)

Directions:

- This is an internet scavenger hunt for information! Start by watching: https://www.youtube.com/watch?v=FIUes_NPa6M
- Print the table on page 10. Use it to collect information about each of the 5 major extinction events during the Phanerozoic **Eon** (definition pg. 1). You are looking for evidence of what caused each event. You may have one, some, or all the causes listed.
- Look for information from universities or museums. Other sources may not be based in science and peer-reviewed literature. Universities and museums hire scientists who move science forward. Other sites may have good information. Then again, they may not. People are sometimes convinced of an idea and promote it as fact. While you are learning about the concepts behind paleontology, it helps you to know that the information is supported by research. For example:
 - University of California, Berkeley's Museum of Paleontology
- Record the causes in the table. For example, if the extinction event had volcanoes, climate change (the more abrupt, the more catastrophic), ocean and atmospheric chemistry changes, check those boxes. There is enough room to jot a few notes, too. You can keep additional notes on the back of your table.
- Find images of organisms

- that died during that event. For example, trilobites, which were extremely successful throughout the Paleozoic, died out at the end of the Permian.
- Copy/paste the images in a Word document. Size them about 2-3" inches.
 - Print the images, cut them out and paste them on your timeline just below the extinction event boundary. Record the causes for that extinction event with the images.
 - What are the most common causes of triggering extinct events?
 - Sometimes these causes do not trigger an extinction event. Can you develop an hypothesis why it did not trigger an extinction event?
 - What do you notice about Eras (Paleozoic, Mesozoic, and Cenozoic), the Periods (Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian) and extinction events?
 - Why have scientists divided time with **Eons**, **Eras**, and **Periods**?
 - Why did scientists divide the Paleozoic from the Mesozoic, and the Mesozoic from the Cenozoic?
 - Are all of the five extinction events correlated with climate change?

POWER WORDS

- chronostratigraphy:** the branch of geology concerned with establishing the absolute ages of strata
- correlated:** have a mutual relationship or connection, in which one thing affects or depends on another.
- era:** a major division of time that is a subdivision of an eon and is itself subdivided into periods
- period:** a major division of geological time that is a subdivision of an era and is itself subdivided into epochs, corresponding to a system in chronostratigraphy



Gorgonopsis sp. died out in Permian

- What other trends do you notice?

Example of the Permian Extinction Event on your timeline



Event Cause	Late Ordovician	Late Devonian	Late Permian “The Great Dying”	Late Triassic	Late Cretaceous	Today
Global Cycles / Sea Level Changes						
Ocean Chemistry						
Atmospheric Chemistry						
Climate						
Oceanic Oxygen Levels						
Volcanic Activity						
Asteroid Impact						

Geologists estimate past climate through indirect methods. For example, specific conditions must exist for various rocks to form. Glaciation events leave a specific signature. Dating igneous rocks in that strata (layer deposited at the same time) provides how old the rock. Eventually a picture emerges of different climates throughout the world, and the picture of world climate begins to emerge.

Late Cretaceous

Just like in the “who dunnit” stories, scientists search for clues and develop a hypotheses based on those clues. As more clues emerge, we modify our hypothesis to best explain what happened with all the clues.

ORANGE ARROWS INDICATE A MASS EXTINCTION EVENT.

Late Triassic

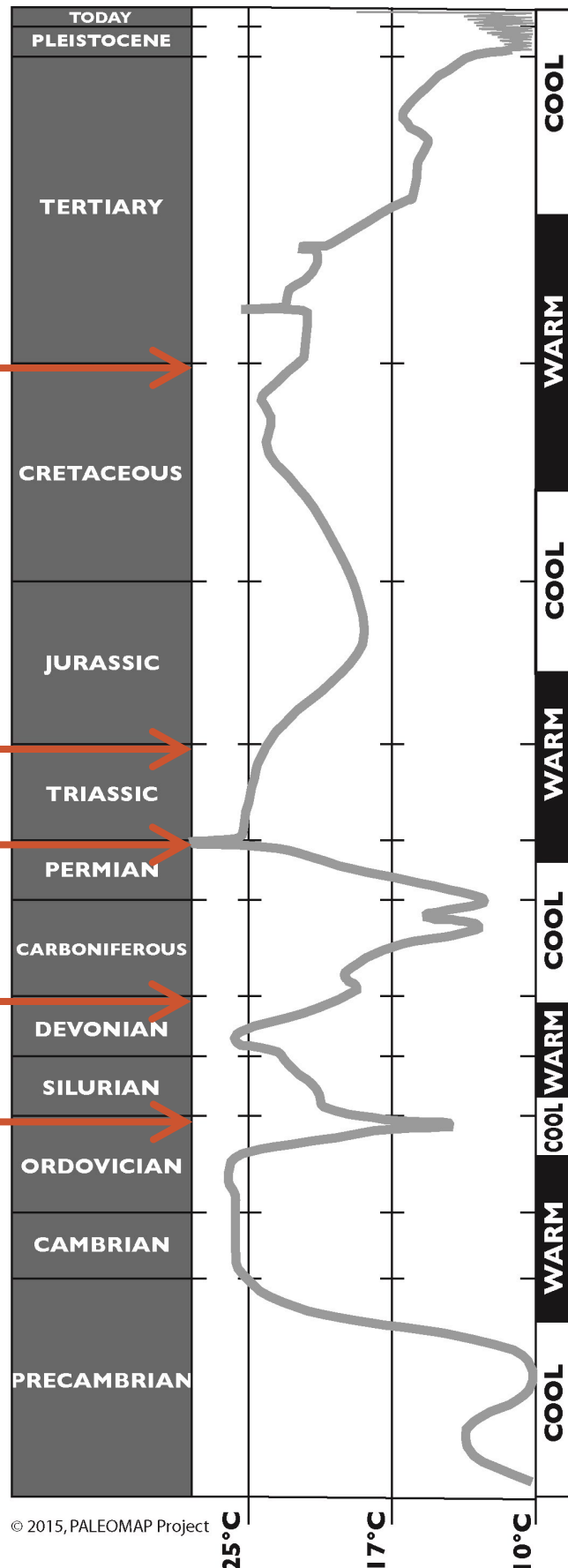
Late Permian

Late Devonian

Late Ordovician

In the Earth’s infancy, 4.6 billion years ago, the sun’s output was also different. Astronomers’ evidence supports that solar irradiance (radiant energy in light and heat) was about 1/3 lower than it is today.

The most accurate climate reconstructions are preserved in glaciers found in Greenland and Antarctica. We are much more confident of recent past climates because of the trapped gases. The oldest glacier (Antarctica) is 1,000,000 years.



The Precambrian would have had many devastating events, but the early fossil record is very spotty. About 4 **BYA**, the Late Heavy Bombardment was a time when asteroids collided with everything in the inner solar system (from the Sun to Mars). This debris ranged from tiny to planet sized. Scars from these impacts are clear to see on Mercury and our Moon. With only a trace atmosphere, these two bodies do not have winds to erode their record.

Any bacterial life would have been obliterated in large-scale collisions. The oldest known fossil is from about 3.5 **BYA** when the Earth was about 1 billion years old. It looks very similar to a bacterium today called cyanobacteria. This organism produces sugar from sunlight (photosynthesis). In 2015, scientists described 4.1 billion year old rock in Australia with remains of life in the form of carbon.

Another major occurrence was the poisoning of the atmosphere. This is hypothesized to have been the greatest extinction event of all times, but only bacteria and **archaea** were present on Earth.

It is possible to use **mutations** in DNA to clock time. It is a

rough measure, since different species have different rates of **mutation**. Geneticists have estimated the last universal common ancestor possibly from deep thermal vents to 3.5—3.8 BYA. That does roughly agree with the oldest known fossil cyanobacterium (image below left). A living cyanobacteria species is imaged below.



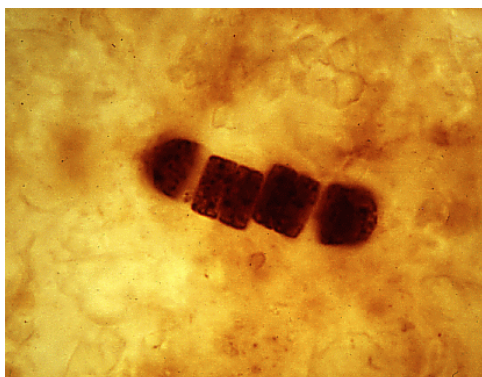
In this activity, you will complete your Precambrian timeline.

Directions:

- When you first made your timeline templates, you did basic divisions of time. You should have indicated the major Eon Divisions of Hadean (3 meters), Archean (7.5 meters), and Proterozoic (9.8 meters). If necessary, measure and draw a line making each division of those Eons.
 - 1 cm = 2 million years.**
- Start at the bottom, the formation of the Earth, the Hadean. It is 3 meters long (4.6 to 4 BYA).
 - Hadean Eon**
 - 4.6 BYA (*At the bottom of your timeline*) Formation of the Solar System from a large cloud of gas and dust around the

POWER WORDS

- archaea:** microorganisms similar to bacteria in size and simplicity of structure but radically different in molecular organization
- BYA:** Billion Years Ago
- mutation:** a mistake or change in DNA by deleting, inserting, or rearranging a section of a gene (See [https://tra.extension.colostate.edu/stem-k12/stem-resources/Paleontology 3: Time/ Kin](https://tra.extension.colostate.edu/stem-k12/stem-resources/Paleontology%203%20Time%20Kin), pages 18 for more information on DNA)
- nucleotide:** the basic structural unit of DNA that has 4 molecules, adenine, thymine, guanine, and cytosine, the “letters” in DNA that code an organism



MATERIALS

- Precambrian timeline (adding machine tape—see <https://tra.extension.colostate.edu/stem-k12/stem-resources/>, 53.Paleonotology 1, pgs. 16-19 for directions)
- markers
- metric tape measure or meter stick

We have been exploring ideas of a rewarding, fun career for you.

<https://tra.extension.colostate.edu/stem-k12/stem-resources/>

- 53.Paleontology 1: Take an interest survey (what do you like to do?) pages 31-33
- 54.Paleontology 2: Score your interest survey, pages 50-51
- 55.Paleontology 3: Explore your interests by developing a project, page 22.

This month, you will take a personality test. Personality tests provide insight in how you **perceive** the world, and how those **perceptions** influence your decisions. One of the first and most famous tests is Myer-Briggs, that evaluates responses on a scale of 4 different criteria:
 “E” Extraversion—“I” Introversion
 “S” Sensing—“N” Intuition
 “T” Thinking—“F” Feeling
 “J” Judgement—“P” Perception

The tests then provides a 4 letter code with 16 different combinations:

ESTJ	ENTJ	ISTJ	INTJ
ESTP	ENTP	ISTP	INTP
ESFJ	ENFJ	ISFJ	INFJ
ESFP	ENFP	ISFP	INFP

Each “type” has different strengths and weaknesses. It doesn’t mean that you are just that trait, but it means you rely

on it more than the opposite trait. For example, when I make decisions, I am rational and use logic. I am a “T” rather than a “F”. I am, however, also very empathetic. I make better decisions when I do not rely just on my feelings.

Most personality tests use similar criteria as the Myers Briggs test, like the one you can take. It is free and online.

Directions:

- Click on the link in the green box to the right. This will take you to 16 Personalities Free Personality Test. It is similar to the Myer Briggs test.
- Answer as honestly as you can, even when the answer is embarrassing. No one will see the test except for you. The more honestly you answer, the more accurate the results.
- Answer each question. Try not to use the center button, the neutral answer. Even slightly liking or disliking will give you better results.
- When you have completed the test, it will give you an answer of your traits.
- Try taking the test once a day for several days. You may be surprised that your answers will change, and you could get different results.

POWER WORDS

- **empathy:** the ability to understand and share the feelings of another
- **perceive:** become aware or conscious of (something); come to realize or understand
- **perception:** the ability to see, hear, or become aware of something through the senses

MATERIALS

- computer with internet access
- <https://www.16personalities.com/free-personality-test>
- <https://careerinstem.com/personality/>
- Over several days, you will see similar traits emerge. Capture those results and keep them in your career journal.
- Check out one more website after you are done. This site connects different STEM careers with your personality.
- Have fun! After all, you are exploring the most interesting person in the world—YOU!

Extraverting	Introverting	Sensing	Intuiting	Thinking	Feeling	Judging	Perceiving
Initiating	Receiving	Concrete	Abstract	Logical	Empathetic	Systematic	Casual
Expressive	Contained	Realistic	Imaginative	Reasonable	Compassionate	Planful	Open-ended
Gregarious	Intimate	Practical	Conceptual	Questioning	Accommodating	Early Starting	Prompted
Active	Reflective	Experiential	Theoretical	Critical	Accepting	Scheduled	Spontaneous
Enthusiastic	Quiet	Traditional	Original	Tough	Tender	Methodical	Emergent

AUTHORS

- Dr. Barbara J. Shaw, Colorado State University Extension Western Region Youth Development 4-H STEM K/12 Specialist
- Tom Lindsay, retired Portland State University instructor (geology and paleontology); HS science teacher (AP and IB Chemistry, Physics, Biology, and Calculus)

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CITATIONS

Information:

- Climate through time: <http://scotese.com/climate.htm>
- Mass Extinctions: <https://www.mtcares.org/science-of-warming/denialist-myths-debunked/global-warming-is-causing-extinction-of-some-life/>; https://en.wikipedia.org/wiki/Central_Atlantic_magmatic_province; https://evolution.berkeley.edu/evolibrary/article/massextinct_08;
- Career Explorations: <https://careerinstem.com/>

Images:

- Mosasaur: <http://bonerooms.blogspot.com/2018/07/cleveland-museum-of-natural-history.html>
- Cladograms: <https://www.sciencefriday.com/wp-content/uploads/2017/09/Cladogram.jpg>; <https://s3.amazonaws.com/user-media.venngage.com/387319-4f3fd5053ff2e8aa6cc81abebbd521a8.gif>
- Timeline temperature: <http://scotese.com/climate.htm>
- Timeline mass extinction events: <https://skepticalscience.com/Earths-five-mass-extinction-events.html>
- Smithsonian Hadean Earth: <https://www.smithsonianmag.com/science-nature/travel-through-deep-time-interactive-earth-180952886/>
- Climate Legend: <http://scotese.com/legend.htm>
- 5 Mass Extinctions: <https://www.mtcares.org/science-of-warming/denialist-myths-debunked/global-warming-is-causing-extinction-of-some-life/>
- CAMP: https://en.wikipedia.org/wiki/Central_Atlantic_magmatic_province
- Cyanobacteria: <https://ucmp.berkeley.edu/bacteria/cyanofr.html>; <https://mounikakalwa33.files.wordpress.com/2012/12/cyanobacteria.jpg?w=300&h=240>
- Earth timeline: https://en.wikipedia.org/wiki/Late_Heavy_Bombardment
- Permian Extinction: <https://www.washington.edu/news/2018/12/06/biggest-extinction-in-earths-history-caused-by-global-warming-leaving-ocean-animals-gasping-for-breath/> ; <https://www.nationalgeographic.com/content/dam/science/photos/000/009/923.ngsversion.1509199279224.adapt.1900.1.jpg>
- Ediacaran biota: <https://www.sciencemag.org/news/2016/10/how-earth-s-oldest-animals-were-fossilized>

Answer from page 4 :

- you, your mother, your grandmother, and 16 greats = 19 generations
- 19 generations x average 90 years = 1,710 years
- 2019 (this year) - 1,710 years = the year 309, or the 4th Century (it is now the 21st Century)