ST[EMpower]

PALEONTOLOGY 6: PALEOZOIC ERA

VOLUME 9, ISSUE 6, FEBRUARY 2020

THIS MONTH

POWER WORDS

- **dynamic**: characterized by constant change, activity, or progress
- **eon**: a major division of geological time, subdivided into eras
- **MYA**: million years ago
- **Phanerozoic Eon**: current eon in geologic time scale, covering the past 541 million years
- **systematic**: done to a fixed plan or system

CAREER CONNECTION

WEIRD AND WONDERFUL DIVERSITY OF LIFE

The root words of **Phanerozoic**:

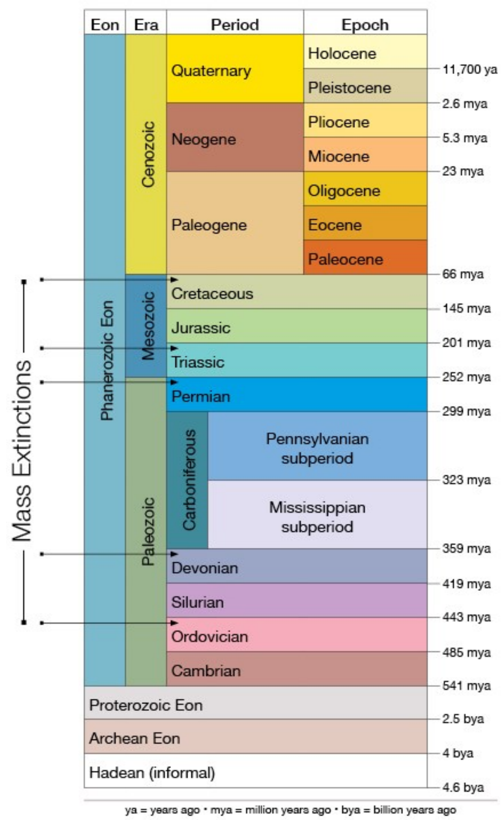
- phaneros (Greek) visible, evident
- zoion (Greek) animal

In the 1950s, geologists developed the **systematic** study of animal fossils. With the Cambrian Explosion (the burst of fossils from the Early Cambrian 541 **MYA**), scientists thought they had identified the origins of animals. Later, additional fauna was found in the Precambrian. Oops! We still recognize the start of the Cambrian Period in the Paleozoic Era as the beginning of the **Phanerozoic Eon**.

As you know from making your own timeline of Earth's history, the Hadean, Archean, and Proterozoic Eons are not to scale in the image to the right. The Phanerozoic Eon is scaled.

With this issue, you will begin the survey of life during the Paleozoic Era as revealed by the fossil record. Science is **dynamic** knowledge, constantly changing with new information. New finds will reveal new information. Fossils are hard evidence. Scientists can say that this did occur. New fossils may tell a deeper and richer story.

Science is amazing!



Cambrian (485-540 MYA):
At the beginning of the Paleozoic Era, weird and wonderful **invertebrate** animals squirmed, wiggled, and swam. Land, however, was barren. No plant had edged its way to cover the bare bedrock.

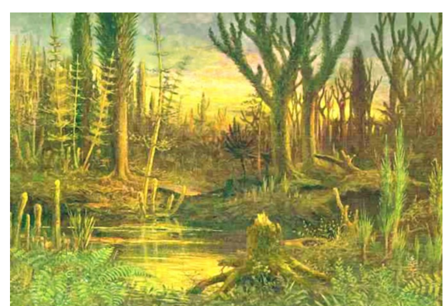
What do you think the land looked like before plants? The image below is a NASA image of Mars. While Mars may have had oceans, lakes, and rivers in the past, now the only water is deep underground or frozen. It would have been different on Earth, with our oceans teeming with life. The image could have been what Earth looked like before plants invaded the land.

Ordovician (443-485 MYA):
The first fossil evidence of plants on land is from 470 MYA. The first plants were seedless and nonvascular, like moss, hornworts and liverworts, called bryophytes. (52.Springtime, pages 2-7 for activities on the 4 major groups of plants: https://tra.extension.colostate.edu/stem-k12/stem-resources/). That would have provided a carpet of green hugging the exposed rock. Further away from water, these early plants would not be able to live. There may be a connection to the first land plants and the ice age at the end of the Ordovician. Below is an image of a carpet of moss.

Silurian (419-443 MYA):
The fossil *Cooksonia* (drawing below) is the first known land plant with **vascular** tissue (like ferns). It was just a inch tall with an upright stalk. The bryophytes were still the dominant plant. Apparently the low-lying carpet of plants provided enough protection for the first air-breathing animals on land, the arthropods. The oldest known **terrestrial** animals found are a scorpion found in rock 350 MYA and a millipede from 428 MYA.

POWER WORDS
- **bryophyte**: small, non-vascular
- **invertebrate**: an animal lacking a backbone
- **terrestrial**: of, on, or relating to land on Earth; inhabitant of Earth
- **tetrapod**: means “four foot” vertebrate animals other than fish (amphibians, reptiles, birds, and mammals)
- **vascular**: relating to or denoting the plant tissues (xylem and phloem) which conduct water, sap, and nutrients in flowering plants, conifers, ferns, and their relatives.

Devonian (359-419 MYA):
First forests (image below) of **vascular** plants, lycophytes (club mosses), horsetails,



MATERIALS
- computer with internet
- 7 sturdy shoeboxes with separate lids
- playdough, plaster of Paris, or papier mâché
- art supplies (**e.g.** tape, scissors, markers, glue, poster paint, tissue paper, etc.)
- craft knife or box cutter (& parent supervision)
- cellophane wrap (party section of store)
- lots of creativity and imagination

and ferns grew to enormous sizes, towering almost 100 feet into the air. The first fossil insects are found during the Devonian Period. **Tetrapods** took their first steps onto land. The earliest know tetrapod is *Tiktaalik rosae* (drawing below).

This animal is between lobe-finned fish and amphibian. The hind limbs were stronger and larger than the front limbs. It would pull itself along the bottom of its aquatic environment, but also propel on land.

Carboniferous (299-359 MYA): Humid tropical swamps dominated this Period. Most of our oil and coal deposits were laid down during this time from the massive vegetation. The first fossil evidence of conifers (**e.g.** pine trees) is 300 MYA.

Animals grew to enormous sizes. Dragonflies had a 2.5 foot wingspan, millipedes were 6 feet long, 2.5 feet wide, and amphibians (frogs, and salamanders) were 20 feet! The Period also has the fossil evidence of the first **amniote** egg. Birds, reptiles, and egg-laying mammals have **amniote** eggs. Non-**amniote** eggs must be laid in water or damp places. **Amniote** eggs are water proof, and also allow oxygen and carbon dioxide gas exchange. Pretty neat!

Permian (252-299 MYA): The continents were on their slow march towards colliding and forming the Supercontinent Pangaea. The climate was drying, and the swamps gave way to more desert-like landscapes. Conifers are not dependent on water for reproduction, like ferns are. The plants shifted from former fern forests to conifer dominant land.

Insects continued to diversify, and the first fossil evidence of piercing and sucking mouthparts are found.

Most amazing are the **synapsids** and **sauropsids**. These are **tetrapods** that lead to two different lines. The **synapsids** (formerly mammal-like reptiles) are the lineage to (eventually) mammals, and the **sauropsids** (formerly reptiles)are the lineage to dinosaurs, turtles, lizards, crocodiles, and birds.

The Paleozoic Era ended at the end of Permian with the mass extinction event, the Great Dying.

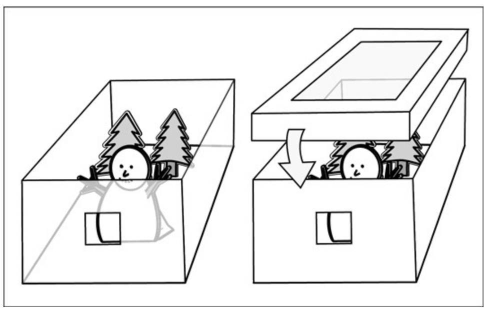
POWER WORDS

- **amniote**: an animal whose embryo develops in an amnion and chorion and has an allantois; a mammal, bird, or reptile
- **e.g.**: Latin *exempli gratia*, for example
- **Sauropsida**: group of **amniote**s that includes all existing reptiles and birds and their fossil ancestors, including the dinosaurs, the immediate ancestors of birds
- **Synapsida**: group of **amniote**s that includes all existing mammals and their fossil ancestors, including the "mammal-like reptiles (**e.g.** *Dimetrodon* sp. and *Gorgonops* sp.)

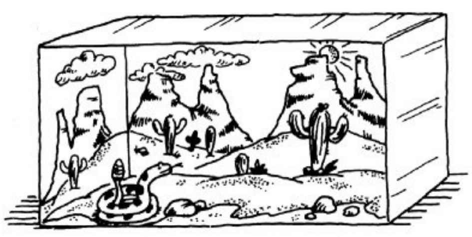
SOME MAMMAL ANCESTORS:

Building **dioramas** are the next best thing to building a time machine! See for yourself what the Paleozoic Era looked like. Here's how!

There are two types of **dioramas**, each using a different **orientation** of the box. One is the peephole **diorama**. The advantage is a truly 3D world.



The other type of **diorama** is the open box scene. It provides



interest in the full scape. Using everyday materials, like paper, paint, and pebbles, you can create wonderful **dioramas**!

Directions:

- Each shoebox represents a different Period in the Paleozoic Era:
    - Permian
    - Carboniferous
    - Devonian
    - Silurian
    - Ordovician
    - Cambrian Terrestrial
    - Cambrian Ocean
- Research information about each Period online. The prior two pages are very brief summaries of the major features of the land during the Paleozoic. Fill in with more specific information.
- Verify that your website is from either a university or natural history museum to ensure that your information is authentic. For example, the University of Michigan, the Smithsonian and the American Museum of Natural History have great information.
- The websites below were selected to give you ideas for building each **diorama's** landscape, for example, trees (website 8), horsetails (very similar to bamboo website 9), mountains (website 3, 4, and 5), or water (website 6 and 7). The first website has complete directions for how to build a **diorama**, including selecting good boxes, and the second takes you from beginning to end on a Sierra Mountain **diorama**. It has lots of great tips for you.
- The basic steps to building a **diorama**:
    1. select a simple sturdy shoe box with a lid
    2. paint the outside and label what will be inside
    3. Paint the interior of the shoe box with the background
    4. build the topography, the hills, mountains, streams, etc.
    5. add water to streams, lakes, or oceans
    6. add vegetation
    7. add animals
- Start with the Cambrian. Take notes and make sketches of the information as you find it. When you have enough

POWER WORDS

- **contrast**: strikingly different from something else
- **diorama**: a model representing a scene with three-dimensional figures, either in miniature or as a large-scale museum exhibit; a scenic painting, viewed through a peephole, in which changes in color and direction of illumination simulate changes in the weather, time of day, etc.
- **orientation**: relative position of something

WEBSITES

How to:

1. https://www.youtube.com/results?search_query=Stephanie+Barnett+diorama
2. https://www.youtube.com/watch?v=6ganUXUa0sw

Topography:

3. https://www.youtube.com/watch?v=os1SA2ZpVdE
4. https://www.youtube.com/watch?v=uK0XcoUX9u0
5. https://www.youtube.com/watch?v=pm-wEpu1yBo

information about the climate, landscape, plants and animals, sketch what you would like your final **diorama** for that Period to look like.

- You can either complete each **diorama** one at a time, or work on all six of them in stages. For example, paint all of the boxes on the outside, and allow them to dry. Label each of them a different Period. Paint the interior of the boxes. Build the topography in all 7. We all approach creativity differently, so approach these dioramas with what makes sense to you.
- Select sturdy, simple shoeboxes with lids. If possible, use 7 identical boxes. Shoe stores have

extra boxes, and will save them for you if you ask.

- Paint the outside of the shoebox with spray paint, poster (tempera) paint, or wrap with paper, like a present. Allow the paint to dry completely. Using a **contrasting** color marker or poster paint, write the name of the Period (**e.g.** “Cambrian”).
- The directions are for the open box **diorama**. If you want to make a peephole **diorama**, you need to constantly refer to close and far from the peephole. You don’t want something large in front blocking the view.
- Paint the inside of the box with the distant scene. Perhaps you are overlooking the ocean from a cliff. The background would be the ocean, horizon, and sky. If you are looking inland, it could be a distant mountain range.
- Create your **topography** for each scene. For example, website 2 uses plastic cups that are then covered with paper mâché. You can use recycled **corrugated** cardboard boxes cut to give the overall shape (image on left; see https://tra.extension.colostate.edu/stem-k12/stem-resources/ 47.Here Comes the Sun pages 19 -22 for directions), which can then be covered with paper mâché, aluminum foil, or homemade

POWER WORDS

- **corrugated** : material, surface, or structure shaped into alternate ridges and grooves
- **topography**: the arrangement of the natural and artificial physical features of an area

Water:

6. https://www.youtube.com/watch?v=NwXBvc-FmhU
7. https://www.youtube.com/watch?v=MbjF4oaZ6hQ

Vegetation:

8. https://www.youtube.com/watch?v=UdvwhJoYqAM
9. https://www.youtube.com/watch?v=Jw-CaMe6ltE

Paper Mâché Clay

10. https://www.youtube.com/watch?v=1YQ6eUqcEh8

playdough (see https://tra.extension.colostate.edu/stem-k12/stem-resources/ 57.Paleontology 5, page 6 for directions to make playdough). You can carve your terrain from recycled foam (website 11).

- Allow the paper mâché or playdough to dry completely before painting.
- Paint your **terrain**. Websites 3, 6, and 10 have ideas. Also https://tra.extension.colostate.edu/stem-k12/stem-resources/ 42.Pigments has ideas for making your own paint pigments from natural sources, like our red rock mountains. There is also a Munsell color chart that you can use to get more realistic soil colors.
- For the Cambrian terrestrial, you would stop here, since there were no land plants yet. Cambrian oceans **teemed** with life: trilobites hunted by *Anomalocaris,* the meter-long top predator of the distant oceans, or *Opabinia* with 5 eyes, and

  Hallucigenia, all spikes.
- The other Periods had plants, and you would continue your terrestrial **dioramas** with adding the vegetation models that were present, like the enormous horse tail forests of the Carboniferous and the conifer forests during the Permian.
- Add animals that were found during that time, sculped from homemade playdough or paper mâché covered aluminum foil shaped like these organisms. The websites below will get you started with fauna and flora.

POWER WORDS

- **foreground**: the part of a view that is nearest to the observer
- **teem**: be full of or swarming with
- **terrain**: a stretch of land, especially with regard to its physical features

The diorama below is from the Carnegie Museum in Pittsburgh, Pennsylvania. It depicts the Permian with a Dimetrodon in

the **foreground**.

For your Carboniferous Period diorama, can you have a dragonfly suspended, as if it were flying?

What colors were the animals from the Paleozoic? No one knows. They could have had similar colors to similar animals found today.

Have fun! Learn lots!

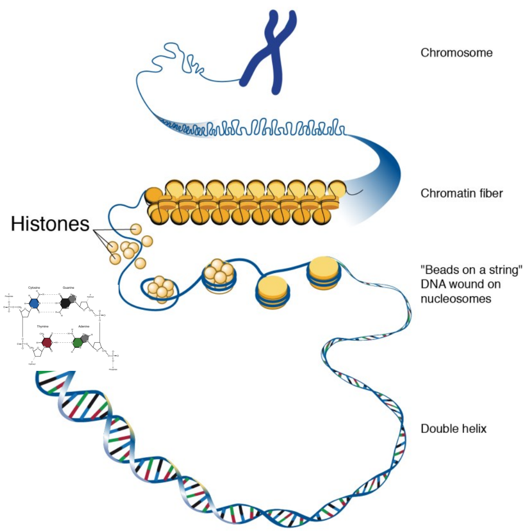
WEBSITES OF PALEOZOIC FAUNA

- https://ucmp.berkeley.edu/paleozoic/paleozoic.php
- https://ucmp.berkeley.edu/paleozoic/paleozoiclife.html
- https://www.livescience.com/37584-paleozoic-era.html
- https://www.geol.umd.edu/~tholtz/G102/102epal2.htm (these are lecture notes from Dr. Thomas Holtz. More about him next month when we cover the Mesozoic, the time of dinosaurs!)

This month covers the basics of DNA and RNA. It is necessary background before exploring how **mutations** are caused, and their impact.

Variation within a species is contained in the DNA of each individual. The total population of a species, with all the variation in that population is called the **gene pool**. For example, you can only inherit two **alleles** for a blood type, but there are three alleles. The human population **gene pool** contains all three **alleles**. The same is true for all **genes**.

DNA is highly organized, and packed inside the membrane



bound nucleus within the cell. All life needs water and has DNA (some viruses have RNA instead of DNA, and biologists argue if viruses are alive).

- DNA is copied to RNA
- RNA makes proteins
- Proteins build organelles
- Organelles are found in cells that help the cell function
- Cells build organisms

DNA's code is like an alphabet that only has 4 letters. These 4 letters, in different sequences, can spell out all the proteins that are needed to make a tree, bread mold, or even you!

Directions:

- Fill your glass half full with water (~1-1.5 ounces). Add 2 pinches of salt and mix with the spoon until the salt is dissolved. DNA and water are both polar. The salt neutralized the water.
- Rub the swab on the inside of your cheeks, tongue, and gums for 1 minute.
- Swish water in your mouth, then spit it back into the cup.
- Put the cotton swab in spit water and stir to remove the cells on your swab.
- Add 2 drops of liquid dish soap and GENTLY and SLOWLY mix with the spoon to dissolve the dish soap into the solution without making any bubbles. The dish soap breaks the cell and nucleus membranes apart.
- Add 2 pinches of meat tenderizer and GENTLY and SLOWLY mix with the spoon to dissolve it into the solution. The meat tenderizer breaks the histones apart.
- Let the cup rest undisturbed for 10 minutes.
- Tilt the cup at an angle, and add about 1 ounce of ice cold isopropyl alcohol (rubbing alcohol) by GENTLY pouring it along the sides of the cup.
- Look carefully at the point where the water and alcohol meet— you will start to see something — that is your DNA!
- You can pull your DNA out of the liquid with a toothpick.

POWER WORDS

- **allele**: one of two or more alternative forms of a **gene** that arise by mutation and are found at the same place on a chromosome—e.g. A, B, AB, and O blood types are alleles for blood
- **gene pool**: the collection of all alleles for each **gene** in an interbreeding population
- **mutation**: changing the structure of a gene, resulting in a variant form that may be transmitted to offspring

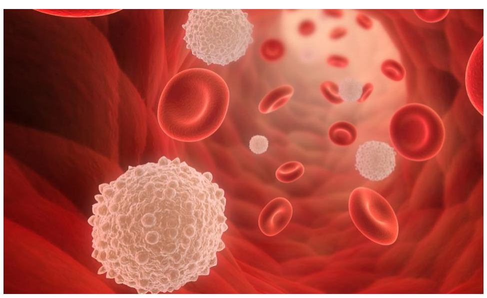
DNA = **D**eoxyribo**n**ucleic **A**cid

RNA = **R**ibo**n**ucleic **A**cid

MATERIALS

- Small clear glass or plastic cup 2-3 oz
- Spoon (plastic or metal)
- Water
- Cotton swab
- Salt
- Drop of liquid dish soap
- Meat tenderizer
- 90 to 99% isopropyl alcohol in freezer (ice cold)
- toothpick

DNA is in every cell in your body with one exception. Your red blood cells (**RBC**) have a nucleus with DNA while being made in your bone marrow. Before they enter your blood stream, the nucleus with the DNA is removed. Awesome! DNA needs a lot of energy to function. Energy requires lots of oxygen molecules. If the **RBCs** do not have DNA, they don't need to use the oxygen. Instead, the **RBC** can carry that oxygen to all the other cells in your body to function. The white blood cells (WBC) have DNA in the nucleus. WBC fight diseases and parasites. When you look at them in a microscope, the **RBCs** look like a frisbee, and the WBCs look like a ball.



Every cell in your body has two copies of the DNA: one from your mother and the other from your father. There is one exception: eggs and sperm only have one copy of your DNA, inherited from both parents randomly. A very special process of making reproductive cells helps to mix up the DNA and place only one set of **chromosomes** into the nucleus of those cells.

If you didn't make the DNA double helix model in with marshmallows and licorice sticks, do that now. The website is listed in the Materials green box to the right.

Directions:

- Tear a large piece of wax paper (the cell) and do all your work on it.
- Make a large circle on the wax paper with the string. This represents the nucleus membrane. Your Twizzler chromosomes will be placed inside the membrane.
- Pick 3 red Twizzlers. Cut 1 Twizzler in half. You have 4 red Twizzler pieces, 2 whole and 2 half sticks. Use 1 long and 1 short, and set the others aside for later.
- Pick 3 blue Twizzlers. Cut 1 Twizzler in half. You have 4 blue Twizzler pieces, 2 whole and 2 half sticks. Use 1 long and 1 short, and set the others aside for later.
- Red Twizzlers represent your mother's chromosomes, and the blue Twizzlers represent your father's chromosomes. The long Twizzlers are Chromosome 1 and short Twizzlers represent Chromosome 2.
- Interphase: The cell spends most of its time in Interphase. Very little time is spent replicating. The cell cannot function during replication, so that happens quickly. The cell returns to a functioning state, but with two copies of the chromosomes.
  - Page 10, Image 1.
  - Match the identical length and color of Twizzlers; place them together. You now have 2 long blue, 2

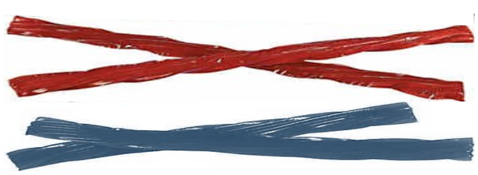
POWER WORDS

- **centromere**: the region on a chromosome that links sister chromatids during cell division
- **chromatid**: a replicated **chromosome** containing two identical double strands of DNA— **sister chromatids** joined at their **centromere**
- **chromosome**: a threadlike structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of **genes** (diagram and image on bottom of page 10).
- **mitosis**: cell division that results in two daughter cells each having the same number and kind of chromosomes as the parent nucleus
- **RBC**: acronym for Red Blood Cell

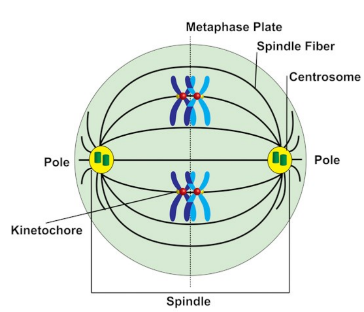
MATERIALS

- Twizzlers Rainbow Twists
- Scissors—wash with soap and water
- Wax paper
- String
- small rod-shaped candy like Mike and Ike or Good and Plenty
- Optional: copy of page 10
- 55.Paleonotology 3 page 18, https://tra.extension.colostate.edu/stem-k12/stem-resources/

long red, 2 short blue and 2 short red chromosomes.
  - Although not visible in a microscope because the strands are too thin, the DNA has doubled. Each chromosome is attached to the copy chromosome. The two chromosomes are now called **sister chromatids**. Cut 4 pieces of string about 6" long. Tie the 2 long red together. Tie the 2 long blue together. Tie the 2 short red together. Tie the 2 short blue together. The string represents the **centromeres**, or the place where the **sister**



chromatids are joined.
- Prophase: DNA condenses and the nucleus dissolves.
  - Page 10, Image 2. The chromosomes contract and become visible in a microscope. Place the Twizzlers in the shape of an "X".
  - The membrane begins to dissolve. Cut your string into tiny pieces and remove.
- Metaphase: DNA lines up along the center of the cell.
  - Page 10, Image 3.
  - Line all paired Twizzlers across the center of the wax paper with one **sister**



chromatid pointing right, and the other pointing left.
  - **Centrioles** appear and **spindles** attach to each **sister chromatid**.
  - Place 2 rod-shaped candy at right angles at each pole (left and right). Attach another piece of string from the candy to each Twizzler where the string ties the sister Twizzlers together.
- Anaphase: Sister chromatids break at the **centromere**, and the spindles pull each chromatid to the opposite pole.
  - Page 10, Image 4.
  - Pulling on the string, move 1 long and 1 short red and 1 long and 1 short blue to one side of the wax paper, and move the remaining Twizzlers on the opposite side.
- Telophase: Each side of the cell has identical DNA. The Cell begins to pinch in the center, called a cleavage furrow, until it pinches the cell into two cells.
  - Page 10, Image 5.
  - Notice that both sides have exactly the same color and length of Twizzlers—they match.
- Cytokinesis: The cell divides into two cells.
  - Page 10, Image 6.
  - Tear the wax paper in half between the Twizzlers at each end of the wax paper. You now have two pieces of wax paper (two cells) each with a complete set of chromosomes (long mother, long father, short mother and short father).
- Interphase: The 2 cells

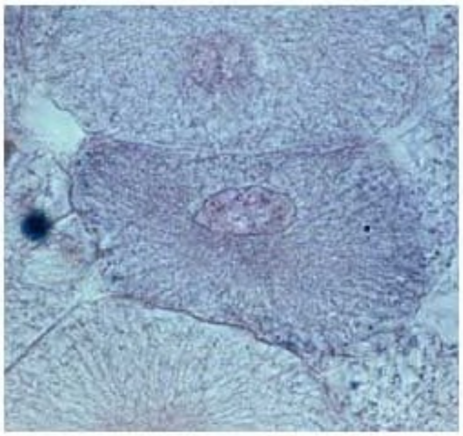
POWER WORDS
- **centriole**: a rod-shaped organelle in animal cells involved in the development of spindle fibers in cell division
- **centromere**: the region of a chromosome to which the microtubules of the spindle attach, during cell division
- **daughter cell**: two cells formed when a cell undergoes cell division by **mitosis**
- **sister chromatids**: identical copies formed by the DNA replication of a chromosome, joined together by a common **centromere**
- **spindle**: rope-like structure separating chromosomes into the daughter cells during **mitosis**

FUN FACTS:
- **Genes** make up only about 3 percent of your DNA. **Genes** are short segments of DNA, but not all DNA is genes. All told, **genes** are only about 3 percent of your DNA. The rest of your DNA controls the activity of your genes.

are now identical to each other, and the cells spend most of their time in Interphase. Very little time is spent replicating.

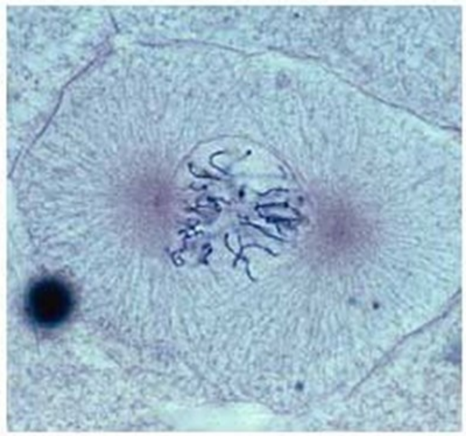
- Page 10, Image 1 (You are done with modeling Cell Division and Mitosis. Eat and Enjoy!)

Image 1: The cell functions normally. When the cell receives a message, the DNA is replicated very quickly, and the cell returns to normal functions.



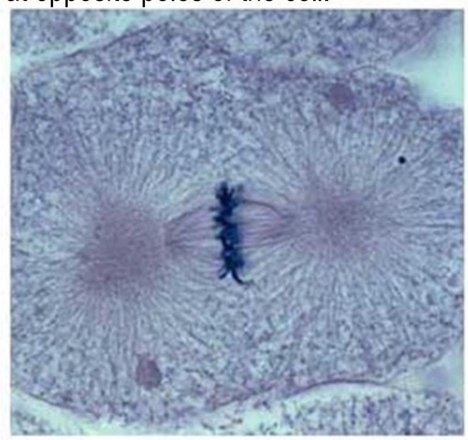
Interphase

Image 2: The DNA chromosomes condense, and are now visible. Nucleus membrane dissolves.



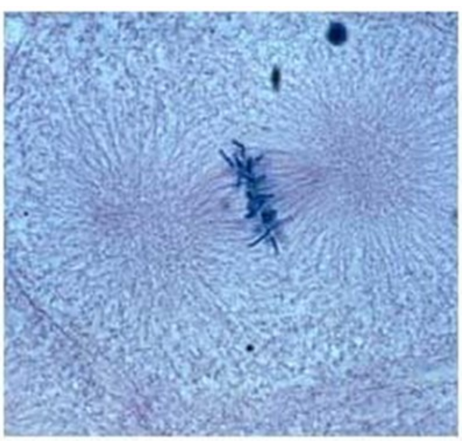
Prophase

Image 3: Chromosomes line up in the center of the cell. Sister chromatids (the replicated chromosomes) attach to spindles, controlled by centrioles at opposite poles of the cell.



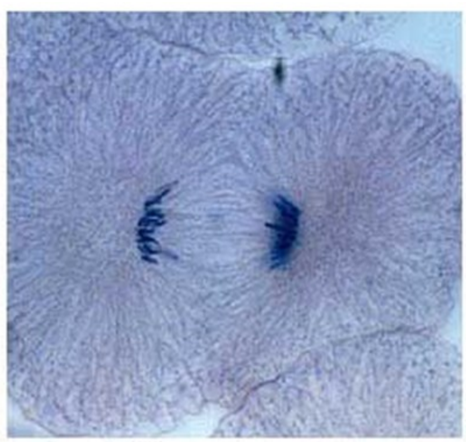
Metaphase

Image 4: The sister chromosomes break their connection at **centromeres**, and each is pulled in the opposite directions by the centrioles attached to the spindles. Similar to a winch (centrioles) and cable (spindles).



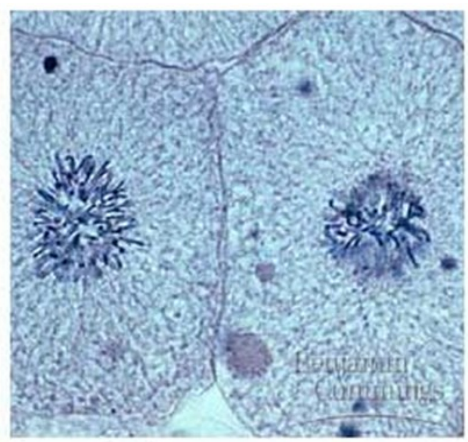
Anaphase

Image 5: Telophase completes cell division. During this phase, the complete set of chromosomes are now on opposites sides of the cell. The cell begins to pinch between the two poles.



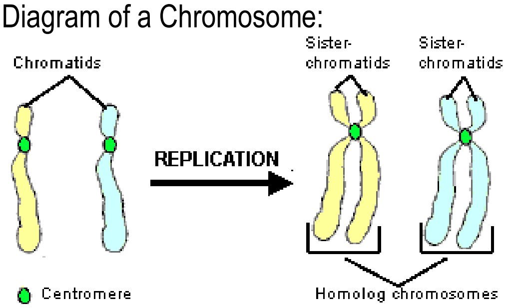
Early Telophase

Image 6: Late Telophase is also called Cytokinesis. The nucleus membrane reforms around the DNA, and the two cells enter Interphase. Most of the life of the cell is spent in Interphase.



Late Telophase

Diagram of a Chromosome:



Scanning Electron Microscope:

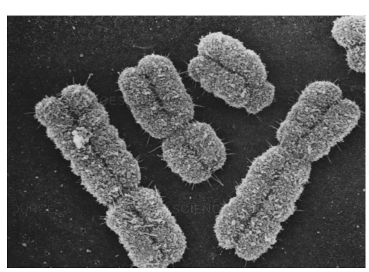
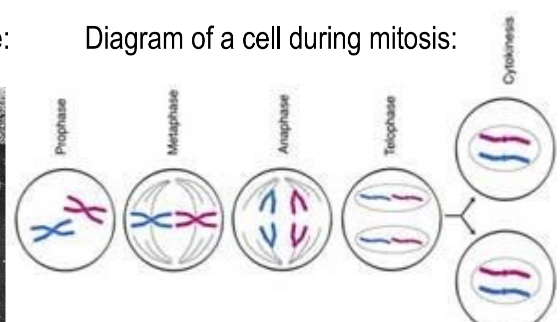


Diagram of a cell during mitosis:



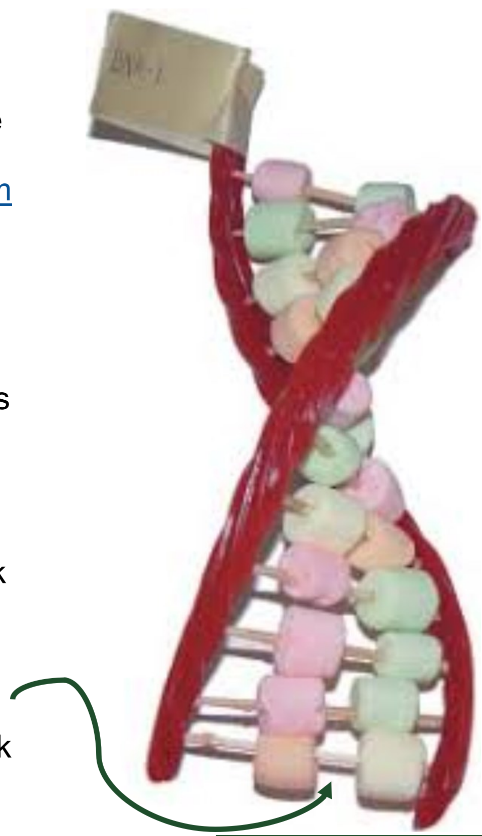
Paleontologists, **systematic** biologists, and **forensic** scientists use DNA sequences to compare organisms.

The first activity on DNA sequences simulates how a forensic scientist prepares two suspects' DNA to compare to DNA found at a crime scene. **Forensic** scientists do not need to know the specific sequence of **nucleobases**. The second activity simulates how scientists code DNA to actually read the sequence of **nucleobases** ATGC (adenine, thymine, guanine, and cytosine).
Look at your model of DNA made from toothpicks, colored mini marshmallows, and licorice sticks (https://tra.extension.colostate.edu/stem-k12/stem-resources/ 55.Paleonotology 3, page 18). The business end of DNA is between the two marshmallows on a single toothpick. The backbone is the licorice. DNA is called a double helix structure because there are two strands of DNA that weakly bind together with hydrogen bonds (double), and it twists like a cork screw (helix). **Transcription** or **replication** (first step in **mitosis**) in DNA starts by separating the weak bonds. These bonds are similar to weak magnets. Large molecules insert between the two strands and read the sequence of **nucleobases**. The weak hydrogen bonds then zip back together.

We inherit our parent's DNA, including junk DNA. Junk DNA doesn't code for anything. Identical twins have exactly the same DNA, but over time, their junk DNA will become slightly different. The fewer differences in these regions of DNA, the more closely related two people are, and the more mutations, the more distantly related.

Scientists collect, extract, and isolate specific sites of DNA. If there is only a single sample (for example a single skin cell) they use a process called PCR (Polymerase Chain Reaction) that works like a photocopier making millions of DNA copies.

After extracting DNA, scientists add a restriction enzyme. When bacteria are infected with viruses, they make **restriction enzymes**. These enzymes recognize specific sequences of **nucleobases** (the DNA molecules ATGC), and cut viral DNA into pieces, protecting the bacteria. Scientists use bacteria **restriction enzymes** to cut the DNA at specific spots all along the



POWER WORDS

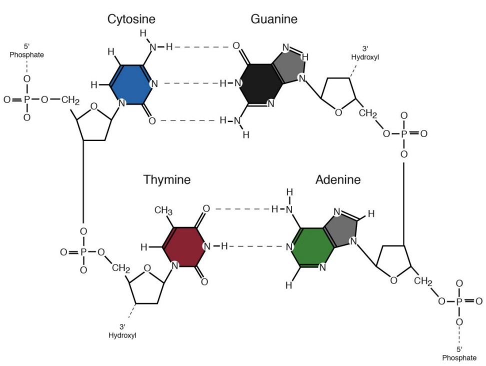
- **forensic**: relating to scientific methods in criminal investigations
- **nucleobase**: the basic structural unit of DNA, comprised of four molecules: adenine (A), thymine (T), guanine (G), and cytosine (C)
- **replication**: the action of copying or reproducing something
- **restriction enzyme**: bacterial enzyme that cuts specific DNA sites
- **systematics**: study of the diversification of past and present living forms and relationships through time
- **transcription**: the process which information in a DNA strand is copied into a new molecule RNA

MATERIALS

- Scissors
- Print page 13 and 14
- Tape

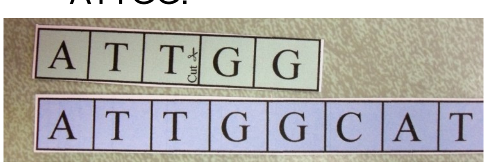
strand. After the DNA is cut into fragments, scientists load each sample of DNA into a well on a gel. Using electricity, the different fragments separate. The larger the fragment, the harder it is to move through the gel, and it will remain closer to the well. The smaller fragments of DNA move much more quickly through the gel, and they will be further from the well. (see image in the green box below).

Because each person's junk DNA has a different sequences, the **restriction enzymes** will cut it differently forming different length fragments. The DNA fingerprint is the pattern those fragments form on the gel.

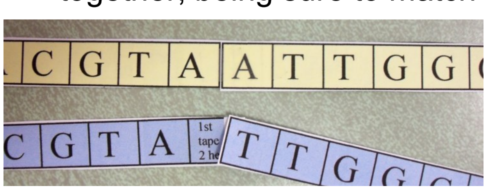


Directions:

- Cut the strips of paper that represent DNA sequences blue, yellow, purple, and grey. Cut out the green **restriction enzymes** "ATTGG."

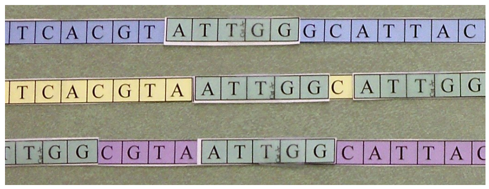


- Tape the same color strips together, being sure to match



the ends together correctly. These represent the same junk DNA for 3 people.

- Match a restriction enzyme **EXACTLY** to the junk DNA strand and tape the restriction enzyme on top of the matching sequence. For example, the yellow strand sequence begins with GGTGCCATTGGG. The restriction enzyme ATTGG matches the underlined

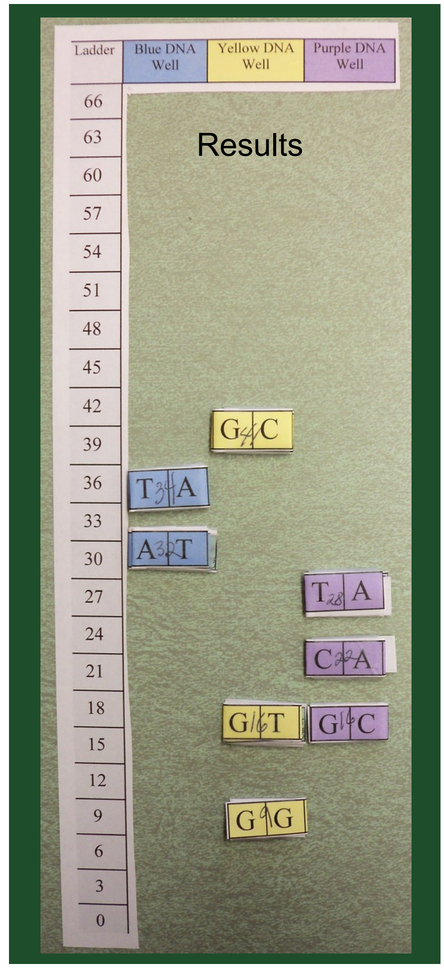


portion of that sequence.

- Tape the restriction enzyme over the ATTGG on the yellow DNA strand.
- Cut where indicated on the restriction enzyme between

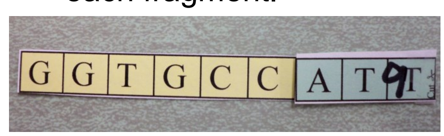
the T and G. For example, the first yellow fragment is 9 **nucleobases** long.

- Continue to tape the **restriction enzymes** over all the yellow, blue, purple, and grey DNA strands.
- Cut the restriction enzyme (and the DNA) between the T



and G (ATT cut GG).

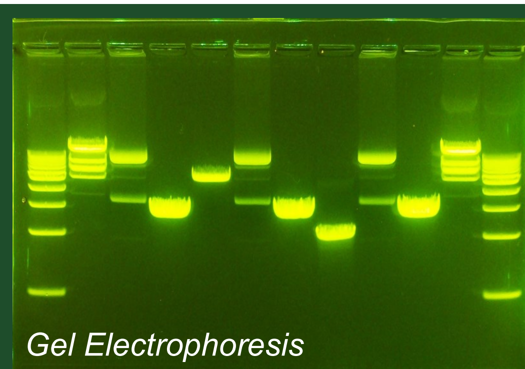
- Count the number of **nucleobases** you have on each fragment and record the number on each fragment.



- Fold the fragments to fit (picture labeled "results" above) and tape closed.

DNA is too small to see. This activity models how scientists make DNA fingerprints. In this image, we can see the DNA bands in each column, dyed to make them visible.

The first column is the ladder, and the top row holds the wells where DNA is deposited. DNA in each well moves down from the negative charge at the top, separating by segment length.



Electrophoresis Rig

Ladder	Crime Scene DNA	Blue DNA Well	Yellow DNA Well	Purple DNA Well
66				
63				
60				
57				
54				
51				
48				
45				
42				
39				
36				
33				
30				
27				
24				
21				
18				
15				
12				
9				
9				
3				

- DNA is loaded on a gel in wells at the top. The paper gel has the ladder on the left and the four wells (grey, blue, yellow, and purple) on top.
- DNA travels from the well down towards the bottom of the gel, depending on the number of **nucleobases** in each fragment.
- The ladder indicates how far fragments will travel. Grey fragments will be in the grey column, blue fragments in the blue column, yellow fragments in the yellow column, and the purple fragments in the purple column.
- Each fragment travels down its column, and ends where indicated on the ladder. Notice the 9 **nucleobase** yellow fragment aligns to the 9 on the ladder.
- The DNA at the crime scene is in column 1, the grey DNA. Which suspect, yellow or purple, matched the crime scene DNA?
- DNA fingerprint that matches the crime scene DNA is still a suspect. The others are eliminated.

Suspect 1

G	C	T	G	G	C	A	T	T	G	C	G	A	T	A	T	C	G	C	G	T	A	1st tape
T	T	A	G	G	C	A	A	T	T	G	G	A	T	A	T	C	A	C	G	T	A	2nd tape 3
T	T	T	G	G	C	A	C	T	A	C	G	A	T	A	T	C	A	T	A	G	G	3rd cut

Suspect 2

G	G	T	G	C	C	A	T	T	G	G	G	A	T	A	T	C	G	C	G	T	A	1st tape
A	T	T	G	G	C	A	T	A	A	G	C	A	T	A	T	C	A	C	G	T	A	2nd tape 3
A	T	A	G	G	C	A	C	T	A	C	G	A	T	A	T	C	A	C	G	T	A	3rd cut

Suspect 3

C	C	T	G	G	C	A	T	T	G	C	G	A	A	T	T	G	G	C	G	T	A	1st tape
T	T	T	G	G	C	A	T	A	T	C	C	A	A	T	T	G	G	C	G	T	A	2nd tape 3
T	T	T	G	G	C	A	G	T	A	T	A	G	G	A	T	C	A	C	G	T	A	3rd cut

Crime Scene DNA

G	G	T	G	C	C	A	T	T	G	G	G	A	T	A	T	C	G	C	G	T	A	1st tape
A	T	T	G	G	C	A	T	A	A	G	C	A	T	A	T	C	A	C	G	T	A	2nd tape 3
A	T	A	G	G	C	A	C	T	A	C	G	A	T	A	T	C	A	C	G	T	A	3rd cut

Restriction Enzymes—Total 8 enzymes 5 nucleobases long

A	T	T Cut	G	G	A	T	T Cut	G	G	A	T	T Cut	G	G	A	T	T Cut	G	G
A	T	T Cut	G	G	A	T	T Cut	G	G	A	T	T Cut	G	G	A	T	T Cut	G	G

Forensic scientists use sections of DNA that are not **genes**. They are **minisatellites**. These sections of DNA can freely mutate with no ill effects. Even identical twins, with identical DNA, can eventually have their **minisatellites** vary differently. Forensics scientists call this a DNA fingerprint.

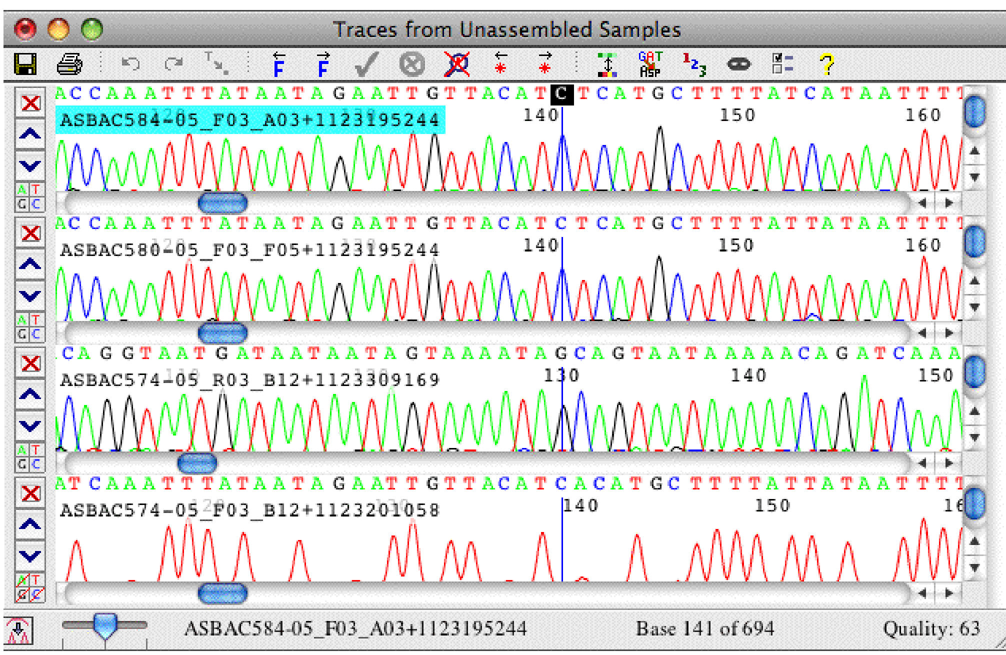
Phylogenetic scientists are looking for deep relationships among the organisms they study. They select **genes that** may mutate occasionally, or ones that are parts of the genome that are extremely stable, depending on their questions. Instead of short fragments, phylogenetic scientists use long sequences to better align different organisms. The double helix is separated. Dye is added to the solution, and each **nucleobase** attaches to a different color dye:

- adenine—green dye
- thymine—red dye
- guanine—black dye
- cytosine—blue dye

The DNA sample is put into a machine that reads the sequence of the dyes. Below is an image of the **chromatogram** results. The bumps are colored. The higher the bump, the more confidence that the color is correct. A read-out of the ATGC sequences is above the bumps. It starts with ACCAAA…

The sequences are then loaded into a computer program that analyzes them to each other. The more differences in the **nucleobases**, the more time has passed, and the more distantly related they are. The results are then produced as phylogenetic trees (more details than cladograms but the same basic technique). Both phylogenetic tree and cladogram graphs were covered in earlier issues (https://tra.extension.colostate.edu/stem-k12/stem-resources/, 55.Paleontology 3 and 56.Paleontology 4).

The last step is to interpret the graph, answering the question posed at the beginning of this experiment.



POWER WORDS

- **chromatogram**: visible record (e.g. series of colored bands) showing the result of separation of the components of a mixture chromatography
- **homologous**: similar in position, structure, and origin but not necessarily in function
- **minisatellite**: section of DNA with a high mutation rate, a specific sequence of between 10-60 base pairs, and repeating 5-50 times
- **phylogenetic**: relating to the gradual development and diversification of a species or group of organisms, or of a particular feature of an organism

MATERIALS

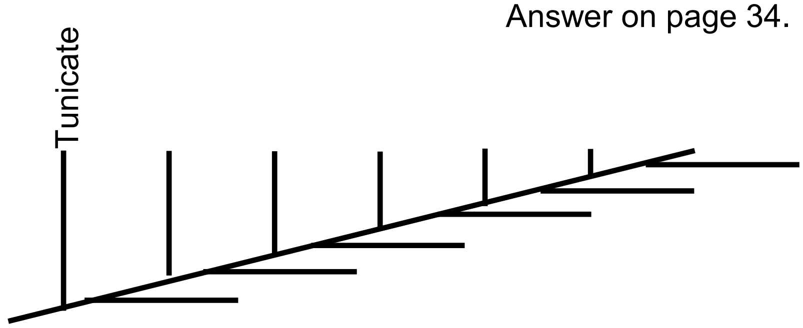
- print page 16
- pencil

Organism	DNA Sequences	#	Rank
Tunicate Ancestor	G T A A G C C G T T T A G C G T T A A C G T C C G T A G C T A A G G T C C G T A G C	0	1
Coqui frog	G T A A A A T T A A A A G C G T T A A T T C A T G T A G C T A A G G T C C G G C G C		
Green sea turtle	G T A T A A T T A A A A G C G T T A A T T C A T G T A G C T T C C G T C C G G C G C		
Hoary bat	G T T T A A T T A A A A G A T T T C C T T C A T G T A G C T T C C A C G C G G C G C		
Human	G T T T A A T T A A A A G A T T T C C T T C A T G T G G C T T C C A C G C G G C G C		
Wallaby	G T T T A A T T A A A A G C G T T C C T T C A T G T A G C T T C C A C G C G G C G C		
Yellowfin tuna	G T A A A A T T T T T A G C G T T A A T T C A T G T A G C T A A G G T C C G T A G C		

Directions:

- Chromatograms were developed for the seven species, and the following **nucleobases** were aligned and placed in a table (to the left).
- Each row is a different species, and each column are the **homologous nucleobases**.
- The blue shaded row is the tunicate, an organism that shares the common ancestor with vertebrates.
- Go through each column and compare the **homologous nucleobases** of the other 6 species (coqui frog, green hoary bat, human, sea turtle, wallaby, and yellowfin tuna). If the **nucleobase** is different, circle it with a pencil. As an example, the green sea turtle's fourth **nucleobase**, circled in gold, is different than the Tunicate **nucleobase**.
- When you have circled the **nucleobases** that are different, count the total changes for each species in the row, and record in the table.
- Complete the cladogram below. If you don't remember how, directions are located in https://tra.extension.colostate.edu/stem-k12/stem-resources/, 55.Paleontology 3, pg. 12-17.

Answer on page 34.



Number Different Nucleotides

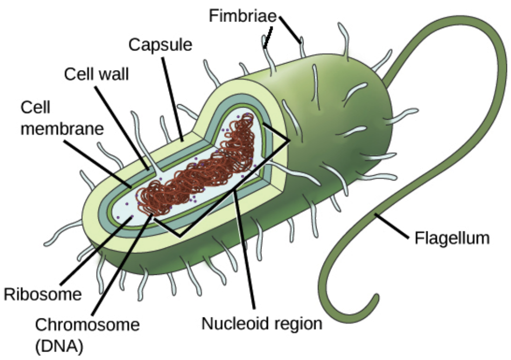
Organism	Number Different Nucleobases	Rank (low to high)
Tunicate (Ancestor)	0	1
Coqui frog		
Green sea turtle		
Hoary bat		
Human		
Wallaby		
Yellowfin tuna		

DNA Structure:

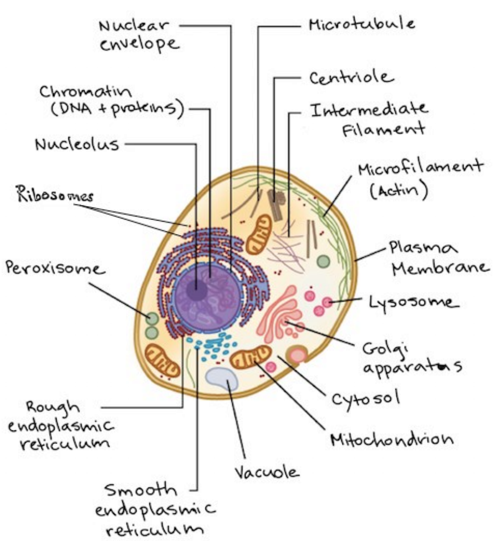
Molecular biology studies DNA and cellular functions. This is a quick guide to the scientific concepts and vocabulary. You can use this as a reference.

DNA is the key to life. It is vital for paleontologists to understand. DNA, unfortunately, is very fragile. It breaks down, and the oldest known DNA sequences are 700,000 years old from a horse.

Two cell types are prokaryote (bacteria and archaea)



and eukaryote (protists, fungi, plants and animals).



The bacterial chromosome is circular, and there is only one copy of it. Bacterial cells are **clones** of all their ancestor cells. They can swap some of their DNA (**horizontal gene transfer)** with another bacterium, but that is an infrequent process. A bacterium's **genome** has about 5% that is foreign DNA. Compare that to your DNA, and half is from your mother, and half is from your father.

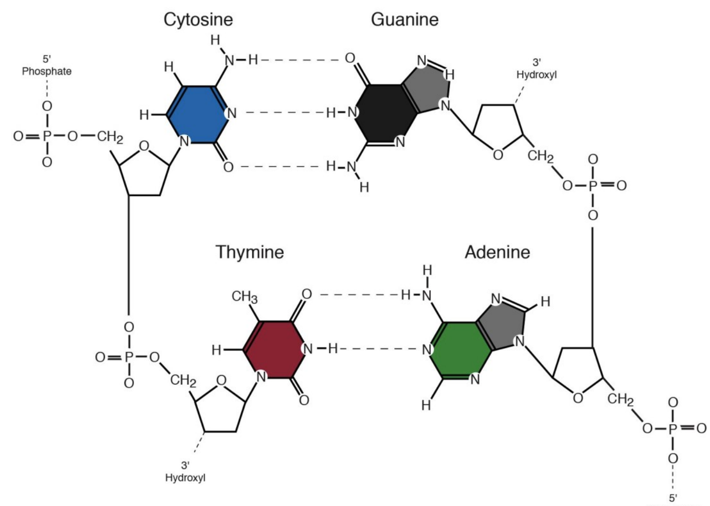
The eukaryote chromosome is linear, and there are two copies of chromosomes, one from the mother and the other from the father. Organisms with eukaryote cells have sexual reproduction, so there are two sets of chromosomes in every cell. What do you think are the advantages of this system?

Bacteria and archaea are fascinating, and have the exact same 4 **nucleobases**, adenine, thymine, guanine, and cytosine (ATGC) as organisms with eukaryote cells.

Structure of DNA:

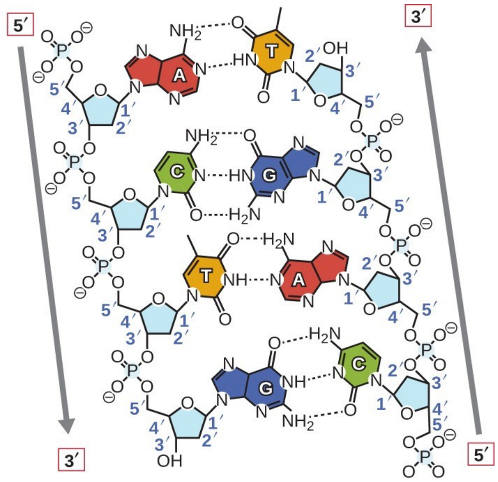
These 4 **nucleobases** always pair: adenine pairs only with thymine (AT), and guanine pairs only with cytosine (GC). The pairs are held together by **hydrogen bonds**. These are weak bonds that act like weak magnets.

On the diagram below, notice that there are three dotted lines between cytosine and guanine, and two dotted lines between thymine and adenine. That represents 3 hydrogen bonds between G and C, but only two hydrogen bonds between A and T. DNA is called a **double**

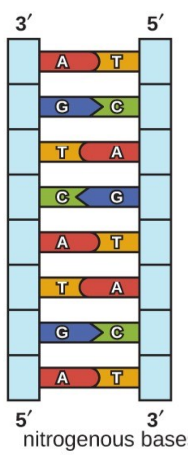


COMPARISON	PROKARYOTE CELL	EUKARYOTE CELL
Size	0.5-5.0µm	10-100µm
DNA	circular chromosome 1 set	linear chromosome 2 sets (mom & dad)
Organized	naked	bound by histones
Replication	binary fission	mitosis/miosis
Nucleus	no	present
Cell Wall	yes	yes, but not for all cells
Ribosomes	yes	yes
Organelles	no	present

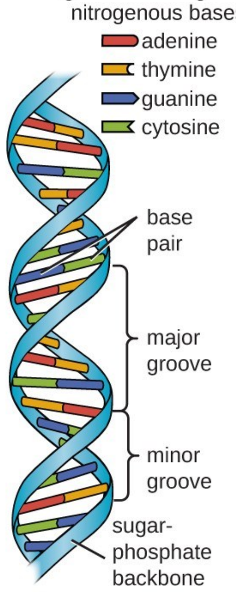
helix. It has two strands of DNA bound by the hydrogen bonds. The **nucleobases** ATGC are in the center. Each strand has a backbone. to protect it. The sugar phosphate backbone is directional. The side that



starts is called 5' (5 prime), and the end of the backbone is 3' (3 prime). The DNA is always read from 5' to 3', just like we read from left to right. It looks like a ladder, with ATGC **nucleobases** forming the steps, and the backbone forms the rails.



Finally, DNA twists, so the entire structure is spiraled. Helix means spiraled.



(a)

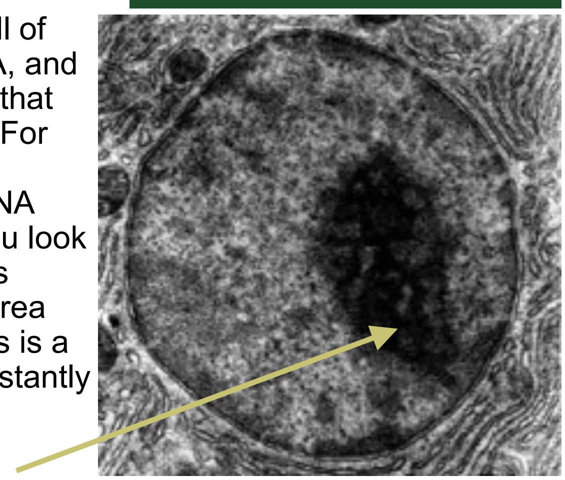
DNA

Transcription to RNA:

For DNA to be used in **replication** (in preparation of making a new cell, the first step is to copy all of the DNA) or **transcription** (making the **complementary** copy of the DNA) the **hydrogen bonds** unzip, and the **nucleobases** are exposed.

ATGC are like letters in an alphabet. They spell out directions for making all the organisms on Earth. DNA is fragile. To help protect it, only copies are made from it. It is like the **genome** is the reference book and the nucleus is the library. Just like a library, you cannot check out a reference book. This helps to protect the DNA from being damaged. Instead you can make a copy to take with you. That is exactly what your cell does.

The nucleus is packed full of DNA, **nucleobases**, RNA, and different huge molecules that have different functions. For example, there are many molecules maintaining DNA and making repairs. If you look in a microscope at a cell's nucleus, there is a dark area called the nucleolus. This is a region of DNA that is constantly being **transcribed**.
Adenine pairs only with



SUGAR PHOSPHATE BACKBONE

- DNA is composed of atoms that form specific structures. The sugar phosphate backbone refers to the atomic structure of DNA that does not contain genes.
- In chemistry, sugar refers to a group of molecules that contain carbon, oxygen, and hydrogen. There are many different kinds of sugar. The sugar in the sugar phosphate backbone is a 5 carbon sugar.
- Phosphate is another element. The phosphate is bonded with several oxygen atoms.

Human Karyotype: Chromosomes paired: Note the last chromosome pair identify as XY. That means a male. Females are XX.

thymine, and guanine pairs only with cytosine in DNA? One side of the DNA is (for example):
A T G G C C A T C C T T G
and the **complementary** side is:
T A C C G G T A G G A A C.

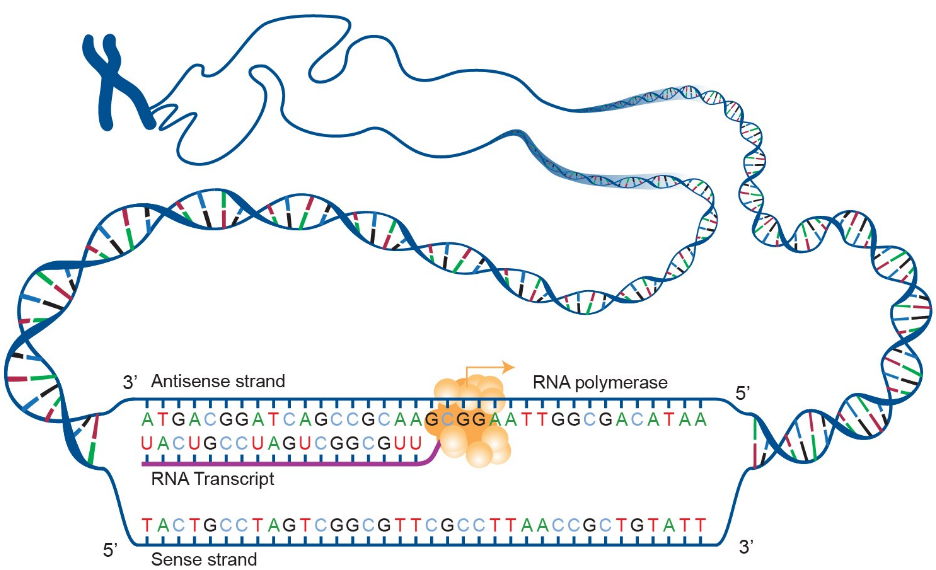
A paper from 2017 by Dan Graur found at least 75% of the human **genome** was **junk DNA**. Less than 25% of the **genome** contains **genes**. The **genes** can be located on either strand of the double helix.

RNA has a slight variation. Guanine and cytosine still pair, but adenine pairs with a different **nucleobase** uracil (U) instead of thymine. Uracil is less stable than thymine. That makes sense.

DNA is stable (thymine is more stable), and mRNA needs to break down quickly (uracil is less stable). RNA has 4 **nucleobases**, G pairs with C, however A pairs with U. In this example, the DNA is:
A T G G C C A C C T T G
and the **complementary** RNA is:
U A C C G G U G G A A C
The A is paired with U, and the G is paired with C.

RNA polymerase (**RNAP**) is a **macromolecule** that finds the **recognition site** at the start of a **gene**. The **RNA polymerase** lands, unwinds the DNA helix about one twist, and unzips the DNA. It only reads one strand of the DNA from 5' to 3'. The other strand can be **junk DNA,** part or all the DNA of another gene. The growing strand of **pre-RNA** is the compliment of DNA strand being read by **RNAP**.

The **mRNA** is edited. Some sections of **nucleobases** are removed and the RNA is spliced together. The front end of mRNA is "capped" (**5' cap** or **RNA cap**), and the 3' end has a **poly-A tail** added (100 -250 adenine **nucleobases**). After editing, the strand is now **mRNA.**



HOW EXPERIMENTS BECOME SCIENCE

- Scientists read peer-reviewed journal articles, and their work must incorporate those articles. This brings up questions.
- They design and conduct an experiment to answer their testable questions.
- When the collection portion is complete, they analyze the data to answer their questions.
- They write the entire study with the answers they found as a article.
- They submit it to a scientific journal to be published.
- The journal's editors send the article to other scientists who work in the same field (i.e., the "peers" of peer review).
- The peers accept, accept with revisions, or reject the article.
- If accepted, the article is published.

FUN FACTS:

- Your DNA could stretch from the Earth to the Sun and back ~600 times. If unwound and linked together, the strands of DNA in each of your cells would be 6 feet long. With 100 trillion cells in your body, that means if all your DNA were put end-to-end, it would stretch over 110 billion miles.

POWER WORDS

- **5' cap**: (said as "5 prime cap") also RNA cap; specially altered **nucleotide** to the 5' end of pre-mRNA vital to developing the mature mRNA which is then able to undergo translation
- **amino acid**: the building blocks of proteins; a simple organic compound containing both a carboxyl (—COOH), an amino (—NH_2) group, and a unique side chain
- **chromosome**: a threadlike structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of **genes**
- **clone**: an organism or cell, or group of organisms or cells, produced asexually from one ancestor or stock, to which they are genetically identical
- **codon**: a sequence of three nucleotides which together form a unit of genetic code in a DNA or RNA molecule
- **complementary**: (of **gene** sequences, nucleotides, etc.) related by the rules of base pairing
- **cytoplasm**: the material or **protoplasm** within a living cell, excluding the nucleus
- **diploid**: containing two complete sets of chromosomes, one from each parent.
- **double helix**: a pair of parallel spirals intertwined about a common axis, especially that in the structure of the DNA molecule
- **gene**: a unit of heredity which is transferred from a parent to offspring and is held to determine some characteristic of the offspring; a distinct sequence of nucleotides forming part of a chromosome, the order of which determines the order of monomers in a polypeptide or nucleic acid molecule which a cell (or virus) may synthesize.
- **genome**: the **haploid** set of chromosomes in a gamete or microorganism, or in each cell of a multicellular organism
- **haploid:** having a single set of unpaired chromosomes
- **horizontal gene transfer**: also called lateral **gene** transfer; the process of swapping genetic material between neighboring "contemporary" bacteria
- **hydrogen bond**: a weak bond between two molecules resulting from an electrostatic attraction between a proton in one molecule and an electronegative atom in the other
- **junk DNA**: genomic DNA that does not encode proteins, and whose function, if it has one, is not well understood
- **macromolecule**: a molecule containing a very large number of atoms, such as a protein, nucleic acid, or synthetic polymer
- **messenger RNA**: the form of RNA in which genetic information transcribed from DNA as a sequence of bases is transferred to a ribosome
- **molecular**: relating to or consisting of **molecules**
- **molecule**: a group of atoms bonded together, representing the smallest fundamental unit of a

FUN FACTS:

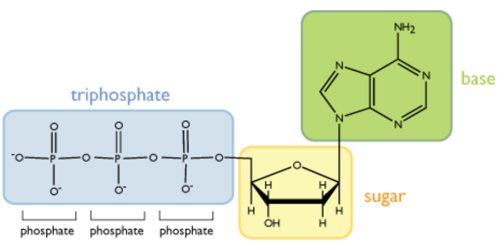
- The human genome contains 3 billion base pairs of DNA. DNA molecules are shaped like twisted ladders. And the rungs on that ladder are made of bases – adenine (A), cytosine (C), guanine (G), and thymine (T) – locked together in pairs with hydrogen bonds. The really cool part is, they pair up in a very specific way: 'A' always pairs with 'T,' and 'C' always pairs with 'G.'

FUN FACTS:

- We're all 99.9 percent alike. Of the 3 billion base pairs in the human genome, only 0.1% are unique to us. While that 0.1% is still what makes us unique, it means we're all more similar than we are different.

chemical compound that can take part in a chemical reaction

- **mRNA**: acronym for messenger RNA
- **nucleobase**: also known as nitrogenous bases or often simply bases, are nitrogen-containing biological compounds Adenine, Thymine, Guanine, Thymine, and Uracil (the **nucleobase** is green in the image below)
- **nucleoside**: a **nucleobase** linked to a sugar molecule (the sugar molecule is yellow in the image below, so both the green and blue comprise the nucleoside)
- **nucleotide**: a compound consisting of a nucleoside linked to a phosphate group. Nucleotides form the basic structural unit of nucleic acids such as DNA (the phosphate group is blue in the image below—the entire structure is the nucleotide)



- **organelle**: any of a number of organized or specialized structures within a living cell
- **poly-A tail**: also called polyadenylation; addition of 100-250 adenine bases (A) to the 3’ end of pre-RNA
- **pre-RNA**: the rough draft of RNA—the direct complementary copy of RNA from DNA during **transcription**
- **protein**: organic compounds that consist of large molecules composed of one or more long chains of amino acids and are an essential part of all living organisms, especially as structural components of body tissues such as muscle, hair, collagen, etc., and as enzymes and antibodies
- **protoplasm**: the colorless material comprising the living part of a cell, including the cytoplasm, nucleus, and other organelles
- **recognition site**: also called recognition sequence; located on DNA chromosomes at the beginning of genes, it has a specific sequence of **nucleobases** recognized by the RNA polymerase for the beginning of transcription
- **replication**: the action of copying or reproducing something
- **ribosome**: consisting of RNA and proteins found in large numbers in the cytoplasm of living cells. They bind messenger RNA and transfer RNA to synthesize polypeptides and proteins
- **RNA cap**: see **5’ cap**
- **RNA polymerase**: macromolecule that transcribes DNA to pre-RNA
- **RNAP**: acronym for RNA polymerase
- **transcription**: process by which the information in a strand of *DNA* is copied into a new molecule of messenger RNA
- **translation**: process by which a protein is synthesized from the information contained in a molecule of mRNA
- **transport RNA**: RNA molecule that helps decode a messenger RNA (mRNA) sequence into a protein
- **tRNA**: acronym for **transport RNA**

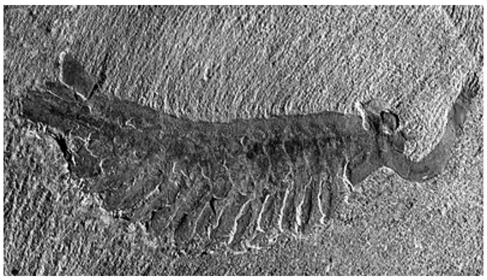
FUN FACTS

- **Proteins**, lipids, carbohydrates, and **nucleotides** are the 4 **macromolecules** that are necessary to build any organism
  - carbohydrates are used for energy, and can be broken down to glucose, a simple sugar
  - lipids make membranes, and are similar to vegetable oil in **molecular** structure
  - **nucleotides**: DNA and RNA
  - **proteins** provide cellular structure and function

FUN FACTS

- A parent and child share 99.5% of the same DNA.
- You have 98% of your DNA in common with a chimpanzee.
- Humans and cabbage share about 40-50% common DNA.
- If you could type 60 words per minute, eight hours a day, it would take approximately 50 years to type the human genome.

This is the final step in developing your Paleozoic Era timeline. In this activity, you will explore the internet to locate the oldest record known of various organisms from this time period. You will find out some basic information about them, and track the range of time (if you can find it) that they lived.



Opabinia fossil and computer generated image

The diversity of life is truly wondrous. Every Era has amazing, weird and wonderful (even terrifying) animals. It seems that during the Cambrian Explosion, there were amazing experiments in body plans, like the 5-eyed *Opabinia*. Some were very successful, and others disappeared, not even leaving a fossil.

Anomalocaris canadensis meter long predator

You certainly do not need to find every single organism on this list, but you may...just may...get pulled into this incredible time! It is, after all, the closest thing we do have to a time machine. So, get ready for wonder!

This list does not include trilobites, because they were the focus of last month's activities on speciation. They are amazing animals. If you touch a trilobite, you are probably holding an animal that lived at least 250 million years ago! It does not include bacteria, archaea, protists (organisms with eukaryote cells, but they are mostly single celled organisms), or fungi. These organisms were certainly there in abundance. There are some plants in the table, but most of the organisms are animals.

Put on your "This is Truly Amazing" hat, and get ready for wonder!

<u>Directions</u>:

- Hopefully you still have room on your timeline between climate, continental formations, and trilobite speciation to include the amazing organisms that lived during the Paleozoic Era. If not, you could:
    - Use additional paper and tape or glue it on the right edge of the timeline (best option to keep all the information easy to access)
    - Redraw the Paleozoic Era's Periods on the back of the timeline (Cambrian, Ordovician, Silurian, Devonian,

FASCINATING FACTS

- *Anomalocaris* was originally found as separate pieces. The claws by the mouth were thought to be shrimp.

The tail was similar to a lobster tail. The mouthpart is unique. It was first identified as a jellyfish (below)! Scientists think that the mouth closed like the drawstring on a bag. Scary!

MATERIALS

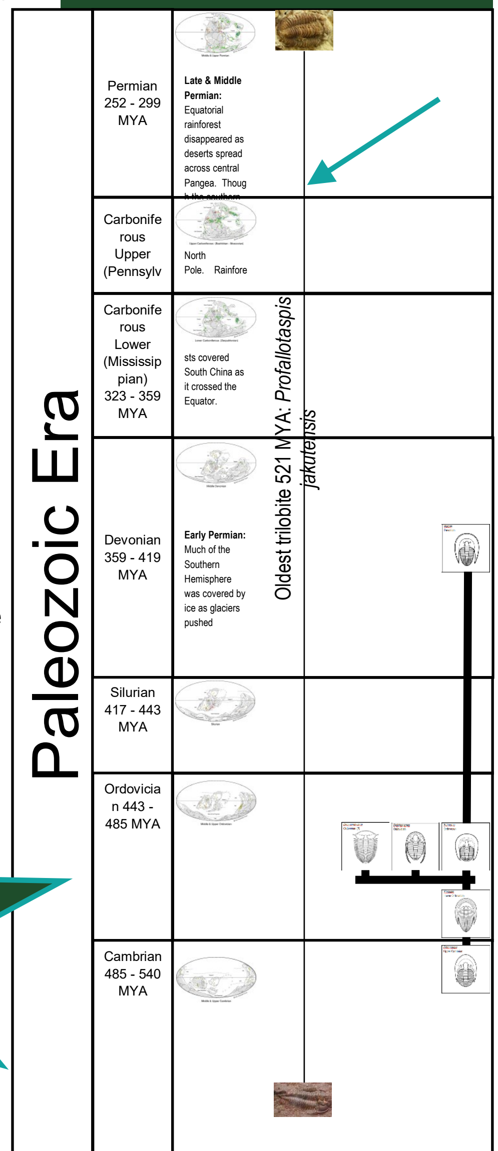
- your Phanerozoic Eon timeline
- sharpies or markers in a variety of colors
- pencil
- yardstick or meterstick
- computer with internet
- printer (color optional)
- glue stick or tape
- print pages 24-29 double-sided
- art supplies (optional)

Carboniferous, Permian; not the best solution, but it will work)

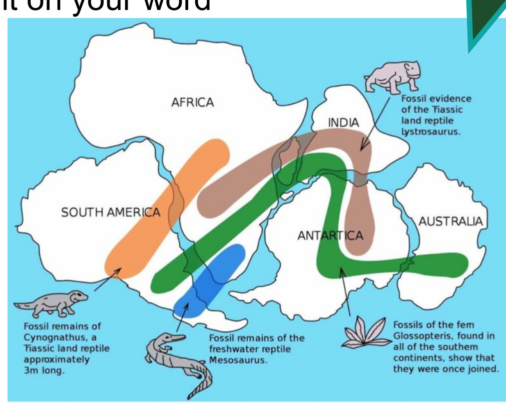
- The list of organisms is not comprehensive by any means, but it includes a variety of animals and plants.
- The table on page 24 has one of the first fossils found for representatives of the vertebrate groups and some invertebrate groups. Include each of those on your timeline.
- The table includes additional species. Select at least 2 organisms from each group. Complete the table.
- Search the internet to locate an image and information about each organism.
- Copy / paste the image to a word document, and resize it to fit on your timeline. For example, you could make your images each 3" x 3" (or so). Since that does not convey the proper scale, note the size next to the image. Examples:
    - *Anomalocaris* was the major predator of the Cambrian oceans, and almost 1 meter (1 yard).
    - *Marrella splendens* (the lace crab; not a crab or even a crustacean) was 2 cm (less than an inch).
- As you collect images of each organism, be sure to identify it on your word document. Do not tape or glue down anything yet. Wait until you have completed your table and images of all the organisms you are adding to your timeline.
- Once you are done, place all the images in the correct Period. Arrange them until you like how it looks. Tape or glue all your images.
- Include information (like size) by each image.
- If you found the range the species fossils lived, you can indicate that with a **vertical** line that starts at their first (origin) fossil occurrence, and their last (extinction) fossil occurrence. Use the yard or meter stick to connect the origin and extinction points. The diagram of the timeline has the Class Trilobita origin and extinction indicated by the green-blue arrow.

POWER WORDS

- **vertical**: up and down line; a right angle to the horizontal plane; in a direction such that the top is directly below the bottom



Keep your timeline until next month. You will be completing the Mesozoic Era.



FUN FACTS

Fossil evidence for Pangaea includes the presence of similar and identical species on continents that are now great distances apart. For example, fossils of the therapsid Lystrosaurus have been found in South Africa, India and Antarctica, alongside members of the Glossopteris flora, whose distribution would have ranged from the polar circle to the equator if the continents had been in their present position; similarly, the freshwater reptile Mesosaurus has been found in only localized regions of the coasts of Brazil and West Africa.

- Include all of the organisms in this table on your timeline. They represent the some of the oldest fossils in the major **phyla** (plural of phylum). Search for as much information as you can find to complete your table. You may not be able to find everything. Leave that cell blank.
- On the back of your table, include interesting information about each species; e.g. *Haikouichthys* had at least 6, and perhaps 9 gills.

Power Words:

- **botanist**: an expert or student in the scientific study of plants
- **phylum**: a principal taxonomic category that ranks above class and below kingdom (botanists use the word "division" instead)

First Fossil Evidence in the Paleozoic Era

Organism	Period	Time Range	Phylum	Class	Size
Example: jawless fish: H*aikouichthys*	Cambrian	525 MYA (no range given)	Chordata	Agnatha	2.5 cm (1 inch)
shark: *Cladoselache*					
bony fish ray-finned: *Entelognathus*					
bony fish lobe-finned: *Luckeus*					
Amphibia: *Ichthyostega*					
Sauropsida (reptile): *Isisfordia*					
Synapsida (mammal-like reptile): *Ophiacodon*					
Plants: *Archaefructus*					
Plants: *Glossopteris*					
Plants: *Calamites*					
Plants: *Cordaites*					

First Fossil Evidence in the Paleozoic Era

Organism	Interesting Facts
Example: jawless fish: H*aikouichthys*	Found in the Chengjiang fauna in China. Animal has at least 6 (perhaps 9) bills. Had fins similar to hagfish and lampreys.
shark: *Cladoselache*	
bony fish ray-finned: *Entelognathus*	
bony fish lobe-finned: *Luckeus*	
Amphibia: *Ichthyostega*	
Sauropsida (reptile): *Isisfordia*	
Synapsida (mammal-like reptile): *Ophiacodon*	
Plants: *Archaefructus*	
Plants: *Glossopteris*	
Plants: *Calamites*	
Plants: *Cordaites*	

First Fossil Evidence in the Paleozoic Era

Organism	Period	Time Range	Phylum	Class	Size

First Fossil Evidence in the Paleozoic Era

Organism	Interesting Facts

First Fossil Evidence in the Paleozoic Era

Organism	Period	Time Range	Phylum	Class	Size

First Fossil Evidence in the Paleozoic Era

Organism	Interesting Facts

On the right is a list of color-coded animals. Each color represents a different group. Pick at least two animals in each color group to include in your timeline. Write their name in the first column, research, and complete the table. Include a small image of either a rendition drawing or the fossil to add to the timeline. Decorate the remaining space with images you made in your dioramas.

When you have completed your Paleozoic Era, tape your tables to the back of your timeline. Since they are two sided, only tape a single side of the table, so you can look at the backside of the paper without removing any tape.

Before ending this issue, I ran across the two most awesome 3D paper models of Cambrian animals!

Trilobite from the British Geological Survey (includes a how-to video): https://www.bgs.ac.uk/discoveringGeology/time/puppets/trilobite.html

Anomalocaris (directions are in Japanese, but with the pictures, you can make this! :)

Directions:

- Copy the name of the fossil, and paste into your search engine. That will begin your journey into the life of the Paleozoic!
- To gain a better understanding of the wonderful and bizarre animals and plants from the past, check them all out.
- Add at least two of these species for each Period on your time line.
- HAVE FUN!

Cambrian—select at least two of the following:

- *Anomalocaris*
- *Burgessochaeta*
- *Eoconodontus*
- *Hallucigenia*
- *Lingula* (WOW!)
- *Marrella*
- *Opabinia*
- *Pikaia*
- *Wiwaxia*
- Cambrian trilobite

Ordovician—select at least two of the following:

- *Astraspis*
- *Discoceras*
- *Eocarcinosoma*
- *Hiscobeccus*
- *Iocrinus*
- liverwort (fossil evidence are 473-471 MYA spore from Argentina)
- *Orthoceras*
- *Protaraea*
- Ordovician trilobite

Silurian—select at least two of the following:

- *Baragwanathia*
- *Cooksonia*
- *Distomodus*
- *Eurypterus*
- *Herrmannina*
- *Parioscorpio*
- *Pneumodesmus*
- *Poraspis*
- *Romundina*
- Silurian trilobite

Devonian—select at least two of the following:

- *Asteroxylon* (formerly *Thursophyton*)
- *Doliodus*
- *Dunkleosteus*
- *Maldybulakia*
- *Pseudobornia*
- *Stereolasma*
- *Tiktaalik*
- *Trigonotarbia*
- Devonian trilobite

Carboniferous—select at least two of the following:

- *Amphibiamus*
- *Archimedes*
- *Arthropleura*
- *Fenestella*
- *Hylonomus*
- *Lebachia*
- *Meganeura*
- *Pseudostaffella*
- Carboniferous trilobite

Permian—select at least two of the following:

- *Actinocrinites*
- *Alexandrinia*
- *Dimetrodon*
- *Goniatites*
- *Gorgonops* (WOW!)
- *Hollinella*
- *Moschops*
- *Permarachne*
- a Permian trilobite

In this year's ST[EMpower] issues, you took and analyzed an interest survey. You also took a personality test. You can keep all your information in a career journal. You need your career information and your journal for this activity.

If you haven't completed these yet, the are located here: https://tra.extension.colostate.edu/stem-k12/stem-resources/

- 53 Paleontology 1: Interest Survey starting on page 31
- 54 Paleontology 2: Interest Survey Results starting on page 50
- 55 Paleontology 3: Military Career Interest Survey on page 22 (optional for this activity)
- 56 Paleontology 4: Personality Test on page 14
- 57 Paleontology 5: Career Satisfaction on page 24

The interest survey analyzed twelve broad categories:

- Adventure
- Animals and Nature
- Art
- Business
- Computers
- Math
- Music and Dance
- Science
- Sports
- Talking
- Travel
- Writing

What are your four top ranked interests from your quiz results:

1.

2.

3.

4.

Look at your ranking. What are your top 3 or 4 categories? For example, my top 4 are Animals and Nature, Math, Science, and Travel. I love my job, and it incorporates all four of those interests. I am a paleontologist and I travel throughout the USA and South America to collect data on how a variety of different ancient mammals walked.

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

What is your personality test result?

____

This month's career project is to further incorporate both your personality and interests.

IINTERESTING CAREER FACTS

- Nearly 80% of American workers are dissatisfied with their jobs.
- For every 1,470 resumes, an employer will hire one person.
- The career of "data scientist" has been judged one of the most lucrative and attractive careers of the 21st century. Data scientists analyze information, such as market and statistical trends, in order to help their companies make sound decisions and investments.
- Physicians, pharmacists, nurse practitioners, and physician's assistants are some of the highest paid jobs in the United States.

Believe it or not, this is the first step in exploring a satisfying career! In this activity, you will select a project (or develop your own) to explore these aspects of who you are.

Awesome!

Pick at least one of the following and explore the ideas further.

IINTERESTING CAREER FACTS

- Teachers in the United States make around $58,000 per year, on average.
- Around 2.05 million farms are in operation in the United States (2017) with 3.2 million farmers.
- Approximately 99% of American farms are run by farming families. Farming and ranching families make up around 2% of the US population.
- Around 15.2% of the American workforce works for the public sector.

- What are your very favorite books, movies, and TV shows? Why? What are the common threads? Write them down. Look at your top interest categories, and how do they relate to each other?
- Write a story about yourself set in 2030. What are you doing? How are you doing it? Be as wildly creative as you like in your story.
- Design something using recycled materials. This project can be anything from designing artwork to a robot that plays with your cat. How did this project relate to your top interests?
- Keep a journal to track your activities over the course of the month. Set it up with the amount of time at each task (including your chores). At the end of the month, add up the time it takes for each (i.e. 143 hours for school). Even with the tasks we have to do, some are enjoyable. Note the activities that you enjoyed doing during the "have to" time. Next look at your free time. How did you spend it? What was the most enjoyable to you? Do you see a pattern emerge?
- You can work with 3 other friends on this idea. Develop a themed day for younger 4-H members. For example, present the 4-H day with one activity from each of the Head, Hand, Heart, and Health. Each one of you presents your activity to younger members. What did you like best about this?
- Some of your favorite activities may not happen weekly, or even monthly. They can include the annual family camping trip, or traveling to other states or foreign countries. Plan the perfect vacation. Where would you go? What would you do? How much does it cost? How does this relate to your top interest categories?
- Design your own adventure! Be sure that what you do really is exciting to you. How does it relate to your top interest categories?

Is your favorite place in wild Colorado camping, hiking, or hunting?

IINTERESTING CAREER FACTS

- What are the common criteria for a great career? People who rate job satisfaction high have these in common:
    - Work that is engaging
    - Work that benefits other people
    - Work that you are good at
    - Flexibility in how and where you work
    - Chance for meaning collaborations
    - Low number of negatives like:
        - A long commute
        - Unpredictable or long work hours
        - No recognition
        - Feeling like you are in danger

Which section of the library is your favorite? That is a clue!

IINTERESTING CAREER FACTS

Ten traits for career success:

- Positive Attitude
- Enthusiastic
- Ethical
- Goal Focused
- Good Listener
- Adaptability
- Persistent
- Self-Aware
- Self-Disciplined
- Self-Confident

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- Doug Garcia, Colorado State University Creative Services Communication Coordinator/ Designer

CITATIONS

Information:

- First plants / ice age: https://www.newscientist.com/article/dn21417-first-land-plants-plunged-earth-into-ice-age/
- Paleozoic Dioramas: https://www.newscientist.com/article/dn21417-first-land-plants-plunged-earth-into-ice-age/; https://www.livescience.com/43514-silurian-period.html; https://www.astrobio.net/also-in-news/oldest-land-animal-fossil-found/; https://www.livescience.com/43596-devonian-period.html ; https://ucmp.berkeley.edu/carboniferous/carboniferous.php; https://www.livescience.com/43219-permian-period-climate-animals-plants.html: https://www.dummies.com/crafts/holiday-crafts/christmas-crafts-for-kids-shoebox-diorama-with-peephole/: http://www.californiapapergoods.com/shoe_box.shtml
- DNA: Extracting DNA by Dr. Shaw, Barbara J., Boone, Jane, (2003) Portland State University; https://www.smithsonianmag.com/smart-news/million-year-old-rhino-tooth-provides-oldest-dna-data-180973117/ ; Dan Graur, An Upper Limit on the Functional Fraction of the Human Genome, *Genome Biology and Evolution*, Volume 9, Issue 7, July 2017, Pages 1880–1885, https://doi.org/10.1093/gbe/evx121; https://www.genome.gov/: Elena A. Ponomarenko, Ekaterina V. Poverennaya, Ekaterina V. Ilgisonis, Mikhail A. Pyatnitskiy, Arthur T. Kopylov, Victor G. Zgoda, Andrey V. Lisitsa, and Alexander I. Archakov (2016) The Size of the Human Proteome: The Width and Depth. International Journal of Analytical Chemistry. Institute of Biomedical Chemistry, Moscow 119121, Russia.
- Definitions used or modified: https://www.dictionary.com/;
- Career facts: https://www.factretriever.com/usa-jobs-facts

Images:

- Geologic Time Scale: http://geokansas.ku.edu/mass-extinctions
- Images for dioramas: https://www.nasa.gov/feature/jpl/nasas-curiosity-rover-team-confirms-ancient-lakes-on-mars; https://www.finegardening.com/article/moss-makes-a-lush-carpet; https://en.wikipedia.org/wiki/Cooksonia; https://upload.wikimedia.org/wikipedia/commons/b/ba/Devonianscene-green.jpg; https://en.wikipedia.org/wiki/Tiktaalik; University of Michigan Museum of Natural History, Carboniferous Diorama; http://waikatomuseum.co.nz/exhibitions-and-events/view/2145882920; http://ayay.co.uk/backgrounds/dinosaurs/mammal_like/mammal-like-reptiles.jpg
- Making dioramas: https://www.dummies.com/crafts/holiday-crafts/christmas-crafts-for-kids-shoebox-diorama-with-peephole/; https://lifestyle.howstuffworks.com/crafts/nature-crafts/nature-craft-projects-for-kids7.htm
- DNA: https://www.sciencesource.com/archive/Human-Chromosomes--SEM-SS2449143.html; https://socratic.org/questions/5a4d01757c014945be3cecd2; https://www.livingoceansfoundation.org/education/portal/course/life-cycle/figure-6-13/; https://knowgenetics.org/nucleotides-and-bases/ ; https://teach.genetics.utah.edu/content/dna/HaveYourDNAandEatItToo.pdf; https://theminione.com/gel-electrophoresis/; https://www.genome.gov/genetics-glossary/histone; https://www.khanacademy.org/science/high-school-biology/hs-cells/hs-prokaryotes-and-eukaryotes/v/prokaryotic-and-eukaryotic-cells; https://askabiologist.asu.edu/venom/building-blocks-protein; https://www.genome.gov/genetics-glossary/Transcription; https://www.ncbi.nlm.nih.gov/Class/MLACourse/Original8Hour/Genetics/structure.html; http://cyberbridge.mcb.harvard.edu/dna_1.html; https://www.vcbio.science.ru.nl/en/virtuallessons/cellcycle/chromosome/; https://www.fi.edu/heart/white-blood-cells
- Paleozoic: http://www.fossilmall.com/EDCOPE_Enterprises/trilobites/trilobite-3/Trilobite-3.htm; https://www.facebook.com/pg/%D0%A4%D0%BE%D1%81%D1%81%D0%B8%D0%BB%D1%81%D1%82%D0%BE%D0%BA-%D0%A2%D1%80%D0%B8%D0%BB%D0%BE%D0%B1%D0%B0%D0%B9%D1%82%D1%81-823462924398137/photos/?tab=album&album_id=823463931064703; http://sapientfridge.org/cambrian/animals/opabinia_f_smith.html; http://www.geologyin.com/2018/02/facts-about-pangaea-most-recent.html
- Career: https://moore.libraries.cam.ac.uk/sites/moore.libraries.cam.ac.uk/files/styles/leading/public/001.jpg?itok=X-uYFfbc; https://www.5280.com/2017/06/the-5280-guide-to-camping-in-colorado-2/

Organism	DNA Sequences																																									#	Rank
Tunicate Ancestor	G	T	A	A	G	C	C	G	T	T	T	A	G	C	G	T	T	A	A	C	G	T	C	C	G	T	A	G	C	T	A	A	G	G	T	C	C	G	T	A	G	C	0	1
Coqui frog	G	T	A	A	A	A	T	T	A	A	A	A	G	C	G	T	T	A	A	T	T	C	A	T	G	T	A	G	C	T	A	A	G	G	T	C	C	G	G	C	G	C	14	3
Green sea turtle	G	T	A	T	A	A	T	T	A	A	A	A	G	C	G	T	T	A	A	T	T	C	A	T	G	T	A	G	C	T	T	C	C	G	T	C	C	G	G	C	G	C	18	4
Hoary bat	G	T	T	T	A	A	T	T	A	A	A	A	G	A	T	T	T	C	C	T	T	C	A	T	G	T	A	G	C	T	T	C	C	A	C	G	C	G	G	C	G	C	26	6
Human	G	T	T	T	A	A	T	T	A	A	A	A	G	A	T	T	T	C	C	T	T	C	A	T	G	T	G	G	C	T	T	C	C	A	C	G	C	G	G	C	G	C	27	7
Wallaby	G	T	T	T	A	A	T	T	A	A	A	A	G	C	G	T	T	C	C	T	T	C	A	T	G	T	A	G	C	T	T	C	C	A	C	G	C	G	G	C	G	C	24	5
Yellowfin tuna	G	T	A	A	A	A	T	T	T	T	T	A	G	C	G	T	T	A	A	T	T	C	A	T	G	T	A	G	C	T	A	A	G	G	T	C	C	G	T	A	G	C	9	2

Answer:

- The **nucleobases** that are different from the Tunicate ancestor (and you circled) are highlighted in yellow. To find them, you need to go down each column and compare the **nucleobase** of the tunicate to each of the other animals. The green rectangle in the third column has the tunicate **nucleobase** A. The coqui frog, green sea turtle, and yellowfin tuna have an A, but the hoary bat, human and wallaby have a T instead.
- After you have gone down each row and circled the **nucleobases** that are different than the tunicate, count the number of changes between that species and the tunicate. For example, the tunicate is 0, and the coqui frog has 14 **nucleobases** that are different.
- After counting the different nucleotides in each row, rank them from 1 to 7 according to the increasing number of different nucleotides.
- Fill in the cladogram. The tunicate is not a vertebrate animal, but it has characteristics with vertebrates. It therefore shares a common ancestor with vertebrates. The remaining animals are placed by rank from left to right, each with a higher number of **nucleobases** different than the tunicate.
- Last, place the number of different **nucleobases** between each species. That indicates that the animals above the number all share the same number of **nucleobases** that are different than the tunicate.

You now have the foundation in DNA and RNA. Next month, we will explore how mutations in the DNA can modify an organism.