New Jersey Center for Teaching and Learning

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AP BIOLOGY

Big Idea 1
Part D

August 2012

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Big Idea 1: Part A

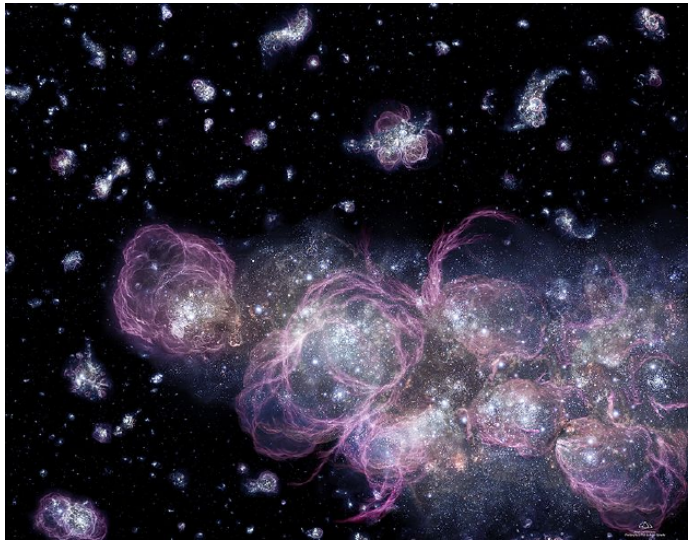
Click on the topic to go to that section

The Early Universe & Earth

Return to Table of Contents

The Beginning...

Many scientists have provided evidence of an event called the "Big Bang" which is said to have occurred about 14 billion years ago.



Big Bang Theory

This theory states that all of the mass in the universe was once compacted into one small point.

The universe was then created by a massive explosion and it has been expanding ever since.

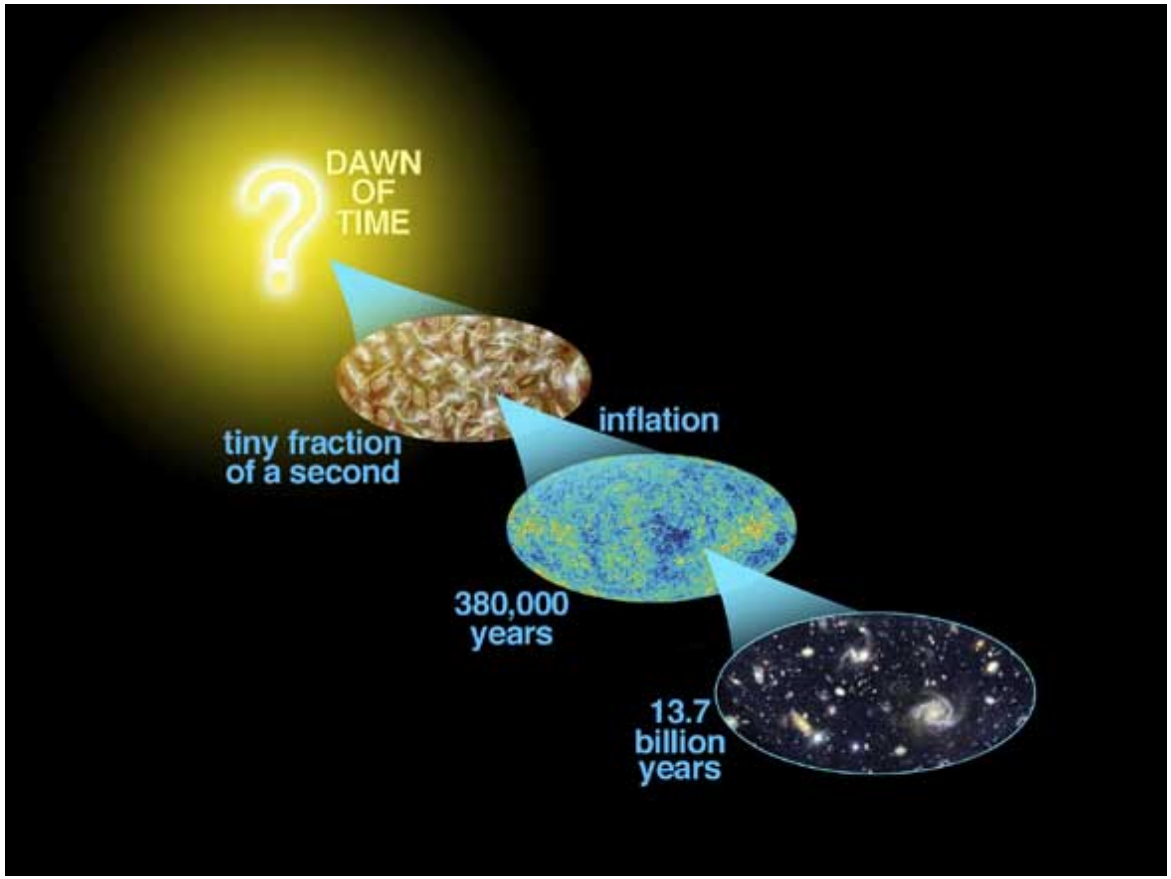


photo: NASA

Big Bang Theory

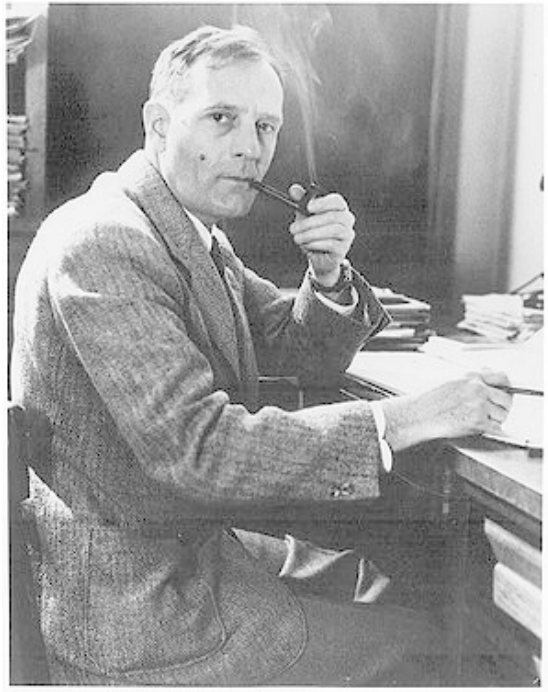
Every piece of matter in the universe came from this one point ... this one explosion.

Since everything is made of matter, this means that the stuff that makes up **everything** in the universe came from this one point in time.

Evidence Supporting the Big Bang Theory

If no one was around 15 billion years ago, then how did this theory come about?

In the early 1900's, an astronomer* named Edwin Hubble, discovered that various galaxies were spreading apart by measuring their location in the sky.



Due to this finding, he concluded the entire universe must be expanding.

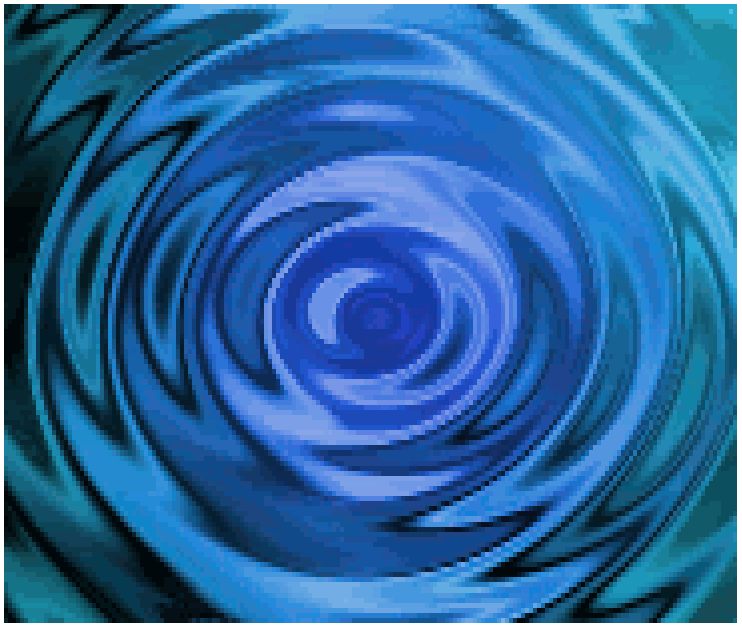
(astronomer: a scientist who studies planets, stars, and galaxies)

Evidence Supporting the Big Bang Theory

Scientists explain this phenomenon by claiming that the universe expanded from a single point.

To visualize this, think of a stone that hits the surface of the water...

The water will ripple out from that one point and expand larger and larger.



Our Expanding Universe

The universe will continue to expand, as it always has since the Big Bang occurred.

Stephen Hawking is one of the most famous physicists in the world today. He has researched and spoken on the expanding universe.

Click here to hear Stephen Hawking talk about this idea, the expanding universe

The Early Universe

The age of the universe is about 15 billion years.

The age of Earth is about 4.6 billion years.

The early universe was almost completely made of hydrogen (H_2) and helium (He).

None of the heavier elements (above helium) existed at the dawn of the universe.

Click here to see David Christian's explanation of the formation of the Universe

The Early Universe

Earth formed about 10 billion years after the start of the universe, about 4.6 billion years ago.

In those 10 billion years, generations of stars were born, and died.

All the heavier atoms on the periodic table were created by nuclear fusion inside those stars, or when they exploded.

The Early Universe

When the early stars died explosively (novae and supernovae), those heavier elements were scattered into space.

When Earth, and its solar system, formed, it was in a cloud of matter which included all the naturally occurring elements in the periodic table.

No new elements have been created since Earth formed.

This means that all the atoms in you and your world, other than hydrogen and helium, were once inside a star, long ago.

Early Earth

Studies of volcanos suggest the early atmosphere of Earth was composed of a mix of chemical compounds.

The most prevelant were:

- water vapor (H_2O),
- carbon dioxide (CO_2),
- nitrogen (N_2),
- hydrogen sulfide (H_2S),
- methane (CH_4), and
- ammonia (NH_3).

1 Where did all the elements heavier than hydrogen and helium come from?

- A the early universe
- B the sun
- C stars that we see at night
- D stars that exploded long ago
- E the other planets

answer

2 Scientists hypothesize that Earth's early atmosphere contained substances such as:

- A oxygen, carbon dioxide and hydrogen gas
- B nitrogen,oxygen, and water vapor
- C water vapor, methane, and oxygen
- D ammonia, water vapoor, and hydrogen gas

answer

3 Which of the following was probably not present in the atmosphere of the primitive Earth?

- A methane (CH_4)
- B oxygen (O_2)
- C water (H_2O)
- D carbon dioxide (CO_2)
- E ammonia (NH_3)

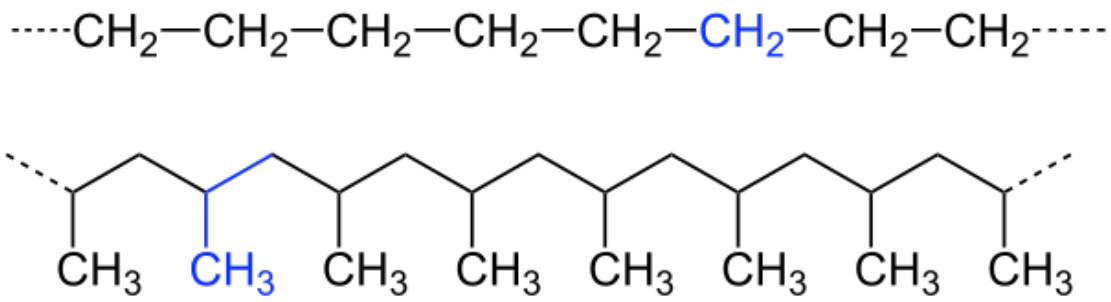
answer

Monomers to Polymers to Life

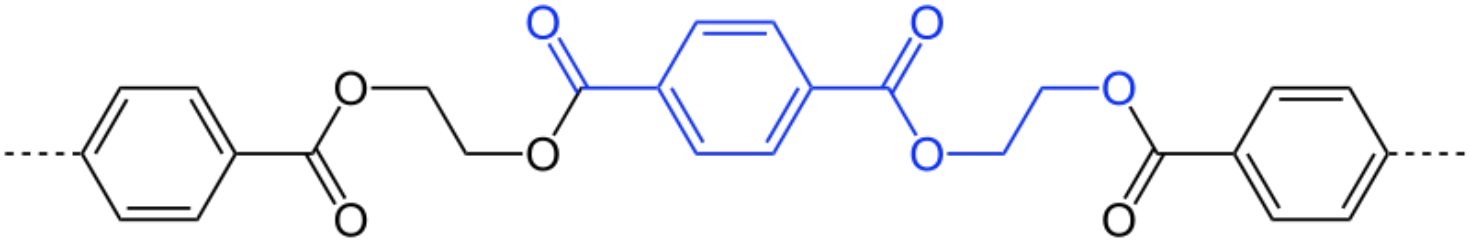
Return to Table of Contents

Organic Monomers Formed

Three of the four organic molecules necessary for life to form are **polymers,** chains of **monomers** linked together by covalent bonds.



Monomers are highlighted in blue



Organic Monomers Formed

Can you name the 3 organic molecules that are polymers?

Can you name the monomers for each of these?

Can you name the organic molecule that is not a polymer?

Organic Monomers Formed

There are two theories for the source of organic monomers:

- Arrival on Earth from space
- Creation on Earth through chemical reaction

Organic Monomers Formed

Which of these theories do you think is true?

- Arrival on Earth from space
- Creation on Earth through chemical reaction

How would you go about proving one of these theories?

Organic Monomers from Space

The dust in the solar system, from which Earth formed, was rich in organic chemicals.

Meteorites striking Earth would have hit with lower velocity since the atmosphere was thicker; organic components would have survived.

Organic Monomers from Space

We find organic chemicals in old meteorites discovered even today, such as this one.

Also, it's estimated that several million kg* (5,000,000 pounds) of organic chemicals fall as cosmic dust to Earth each year.

**The Story of Life , Richard Stockton, 2003, pg. 11*

Organic Monomers From Reactions

Two scientists (Oparin and Haldane), in the 1920's, proposed that organic chemistry could have evolved in the early Earth's atmosphere because it contained no oxygen.

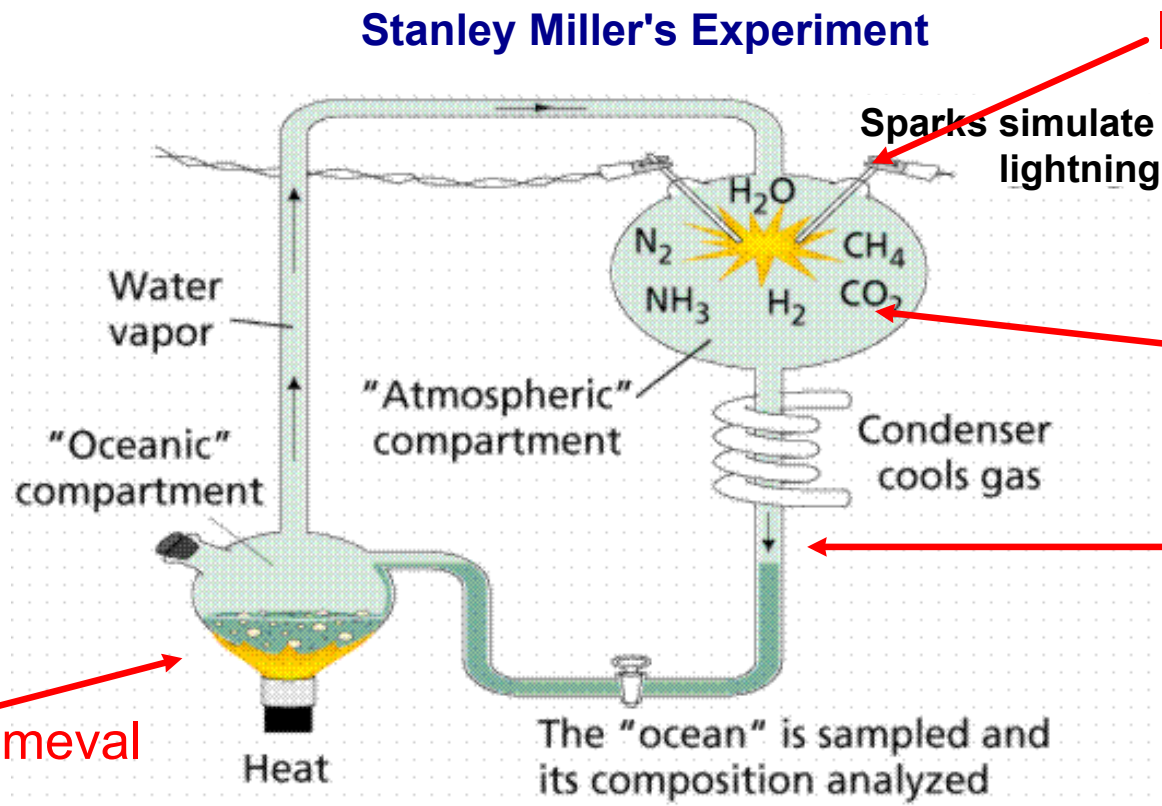
The oxygen-rich atmosphere of today is corrosive and breaks molecular bonds.

Organic Monomers From Reactions

In 1953, Stanley Miller used Oparin and Haldane's original idea and tested a hypothesis involving an artificial mixture of inorganic molecules while simulating the conditions thought to be found on primitive Earth.

Within days, the experiment produced some of the 20 amino acids presently found in organisms, as well as other organic molecules.

Organic Monomers From Reactions



Organic Monomers From Reactions

Recent experiments, improving on Miller's, have produced most of the naturally occurring organic molecules including:

- amino acids
- sugars
- lipids
- nucleotides

Four Conditions Required for Chemical Evolution

Absence of Oxygen in the atmosphere- O_2 would have broken down any large organic molecules by accepting electrons.

High energy input - at that point in time, the sun was producing massive amounts of ultraviolet radiation

Micromolecules- the inorganic molecules had to be in the atmosphere and primitive oceans

Time - adequate time had to pass to give the molecules a chance to form, react, and reform.

4 Miller and other scientists have shown that

A simple cells can be produced in a laboratory

B amino acids and sugars could be produced from inorganic molecules

C cells survived in the primitive atomosphere

D life on early earth required material from space

answer

5 Which of the following is not a condition for the formation of organic molecules?

- A a long period of time
- B inorganic micromolecules in the system
- C presence of oxygen in the atmosphere
- D high energy input

answer

6 Which of the following was Stanley Miller able to produce in his 1953 experiment?

- A proteins
- B prokaryotes
- C amino acids
- D carbohydrates

answer

Organic Monomers Combined to Form Polymers

Polymers are formed through a process called **dehydration synthesis**

word breakdown

Dehydration	the process of removing water from a compound or molecule
Synthesis	the combining of separate parts to make a new whole

Hydrolysis

The process of chemical evolution relies on molecules reacting with one another to form new molecules. .

Reacting together also involved breaking molecules apart.

This process is called **Hydrolysis**.

Hydro (water)

Lysis (splitting)

7 Which is true about dehydration synthesis?

- A one monomer loses a hydrogen atom, the other loses a hydroxyl group
- B electrons are shared between the joined monomers
- C water is formed when monomers join
- D covalent bonds are formed between monomers
- E all of the above are true

answer

8 the results of dehydration synthesis can be reversed by

- A condensation
- B hydrolysis
- C polymerization
- D adding an amino group

answer

From Micromolecules to Macromolecules

The chemical reactions in early cells would eventually create sugars, and then ribonucleic acid (RNA). RNA has been shown to be capable of some of the key functions enabling life:

- replication: making identical copies of itself
- metabolism: storing energy for chemical reactions
- catalyzation: dramatically speeding up favored chemical reactions

Once these three functions were developed, evolution accelerated.

Ambiogenesis

Abiogenesis is the study of how biological life could arise from organic molecules through natural processes. In particular, the term usually refers to the processes by which life on Earth may have arisen.

3.5 Billion year old cyanobacteria. The oldest and simplest life forms ever discovered.

Ambiogenesis

This topic is outside the scope of the AP test, but if you need further evidence for the formation of living things from chemical components you can view the work of Jack W. Szostak who has shown ways in which organic molecules could have assembled into a complex sphere capable of **self replication** and **producing energy.**

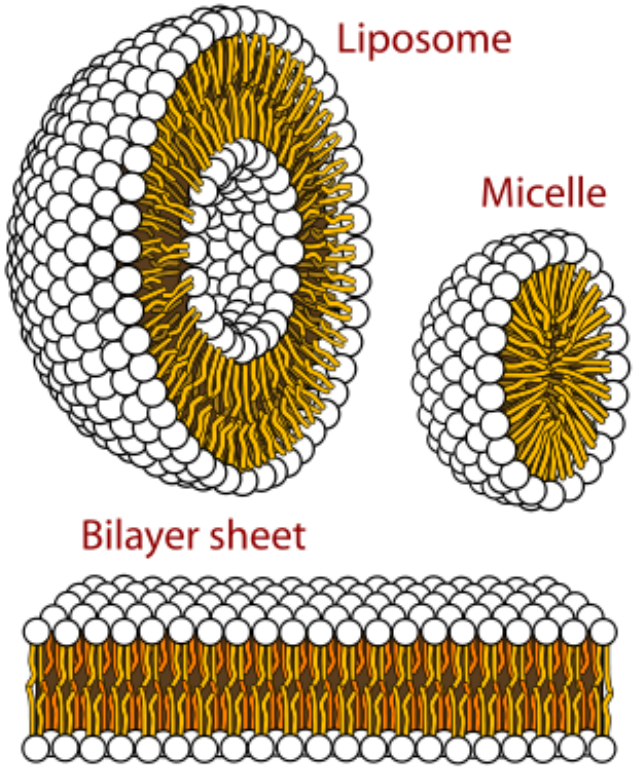
Click here to see Szostak Lab's animations that show the steps in forming a pre-biotic complex sphere

Jack Szostak
Harvard Medical School
Nobel Prize for Physiology 2009

Primitive Cells:
The Start of Animated Earth

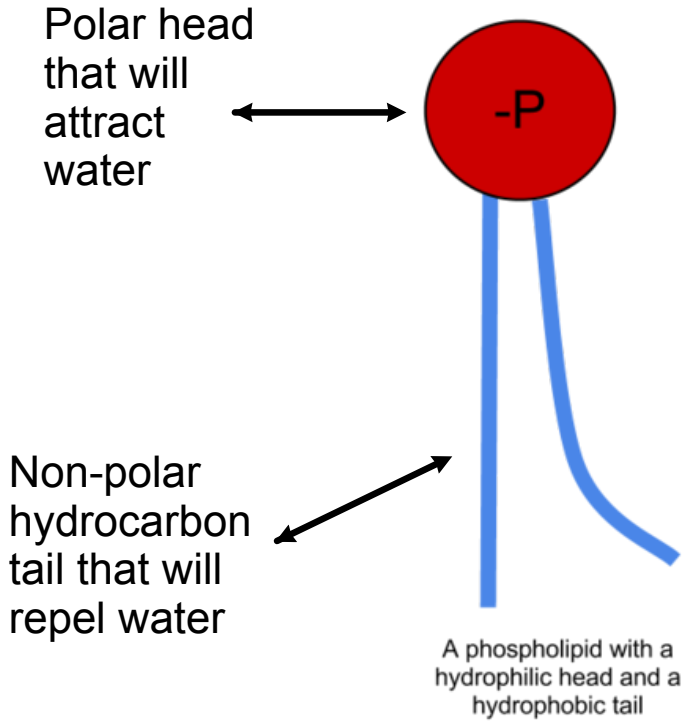
Membranes are an arrangement of **phospholipids** that gather together and make a closed shape. Membranes act as a wall or a barrier separating the outside and the inside of the closed shape.

This is the natural condition of phospholipids when placed in aqueous solution.

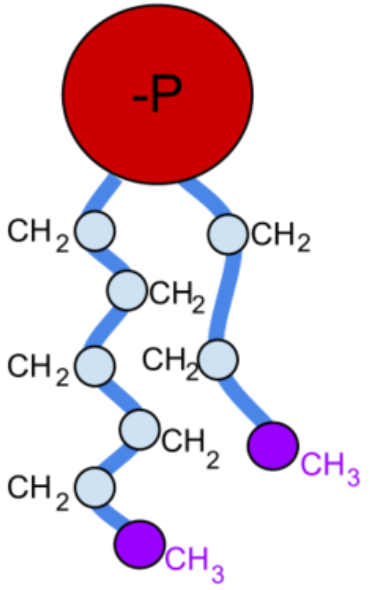


Primitive Cells: The Start of Animated Earth

This occurs because of the unique chemical properties of phospholipids. They are **amphiphilic**: containing a portion that is hydrophobic and a portion that is hydrophilic



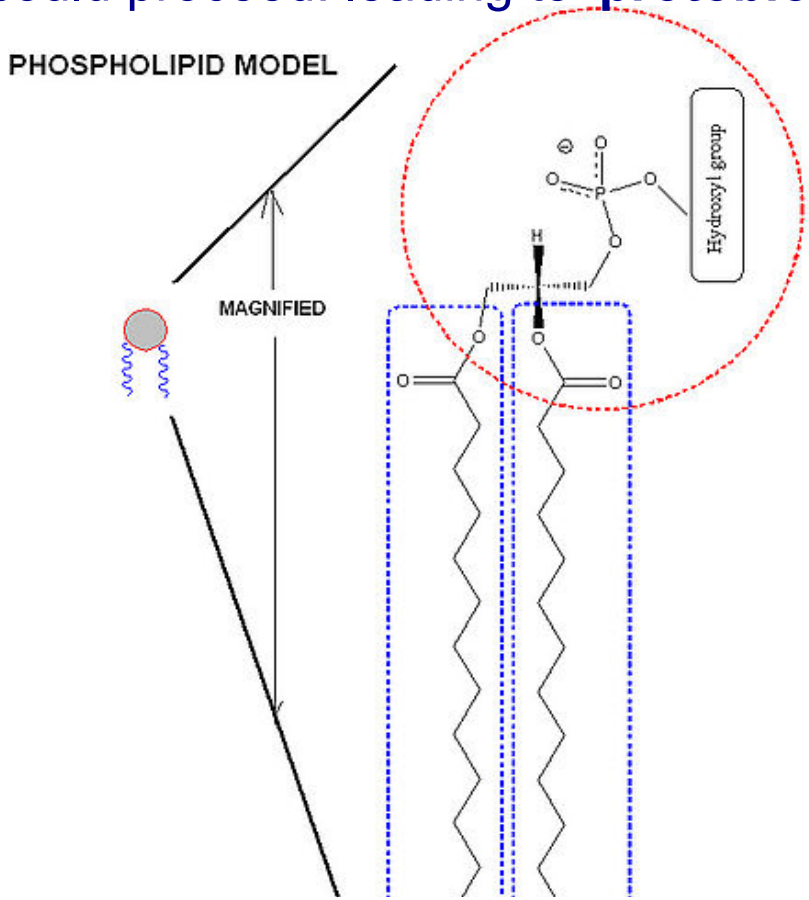
A phospholipid with a hydrophilic head and a hydrophobic tail

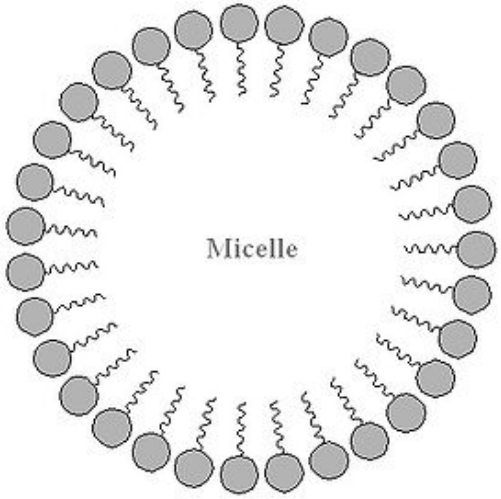


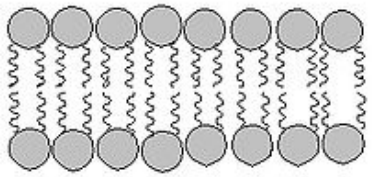
Chemical makeup of a single phospholipid

Primitive Cells: The Start of Animated Earth

Within that enclosed volume, more complex chemistry could proceed: leading to **protobionts: the precursors to life**







Bilayer

From Micromolecules to Macromolecules

Within the inner environment of the protobiont, theprocesses of chemistry created ever more complex:

- Proteins
- Carbohydrates
- Lipids
- Nucleic Acids

Simple metabolism evolved to increasingly complex levels based on the principles of organic chemistry.

Last Universal Common Ancestor (LUCA)

Protobionts became ever more complex until they included all the large biological molecules, including both RNA and DNA and the enzymes needed to maintain and use them.

This led to what is called **Last Universal Common Ancestor (LUCA)**. As you'll learn throughout this course, ***the common features of life on Earth are so profound that all life must have evolved from a single ancestor.***

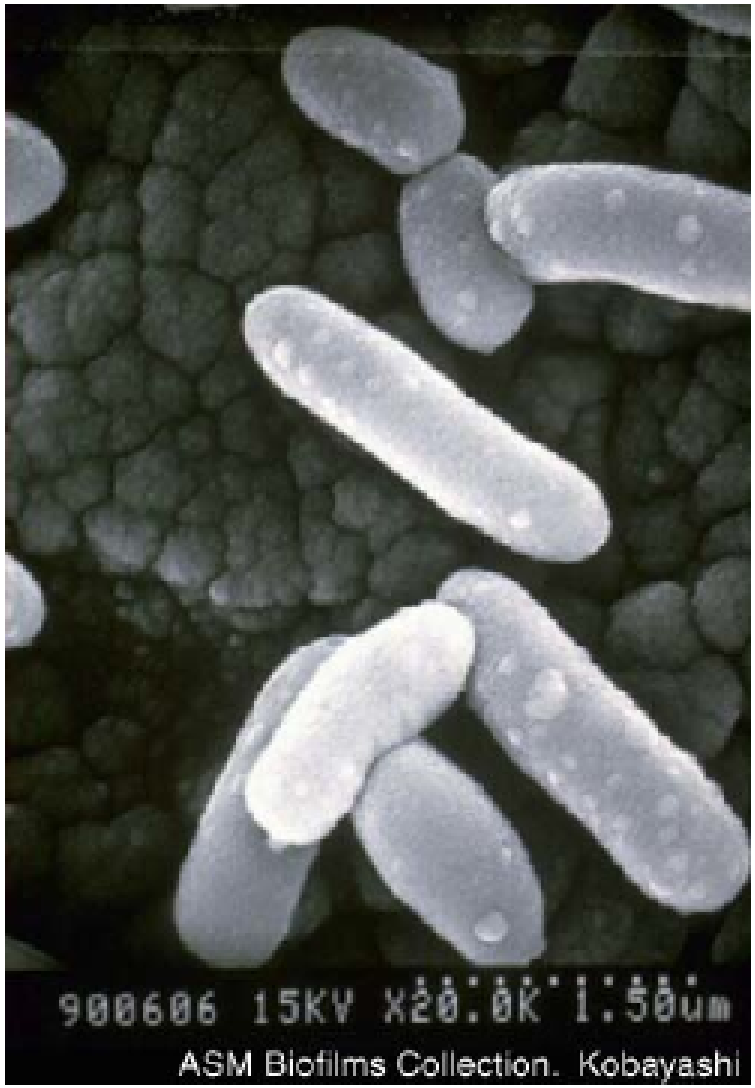
"A universal common ancestor is at least 10^{2860} times more probable than having multiple ancestors…"

Saey, Tina (5 June 2010). "Life has common ancestral source". Science News 177 (12): 12. doi:10.1038/465168a

Cells

The first organisms on earth were single, microscopic, simple chemical packets called cells. In particular they were **prokaryotic** cells.

These cells were/are very limited in their capabilities to perform the functions of life.



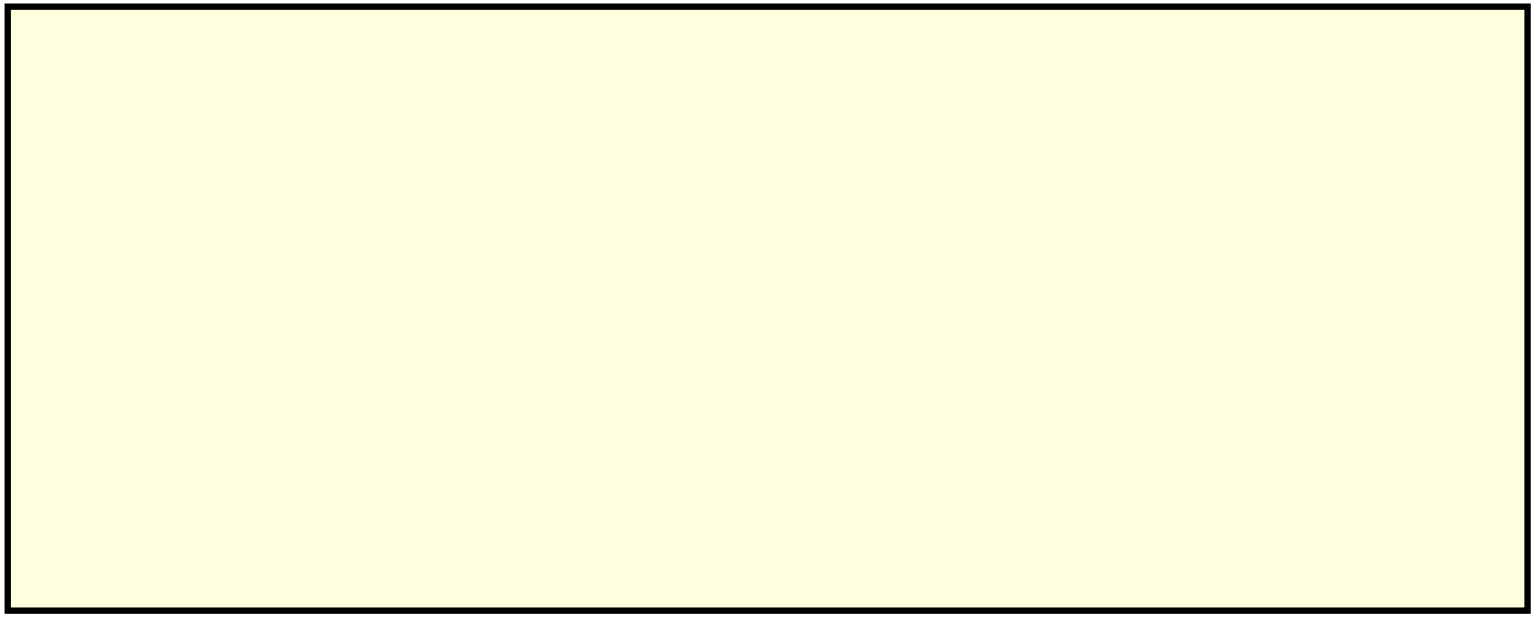
http://www.life.umd.edu/classroom/bsci124/img/bacteria.jpg

Cells

Early prokaryotic cells are the simplest packet of chemicals capable of doing all the functions that **define life**.

Life is defined as a set of conditions that separate **abiotic** (non-life) from the **biotic** (living).

There are 7 conditions. Can you name them?



LUCA

Some of the common features of all life on Earth that make a universal ancestor a logical necessity.

ALL LIFE on Earth uses the IDENTICAL:

Universal Genetic code that makes all life's structures possible
ATP as the "currency" of energy to power all their systems
Base pair coding in DNA (ATCG)and RNA (AUCG)
20 Amino acids that are used to build all proteins
DNA and RNA polymerases, enzymes that make polymers
mRNA for sending genetic messages
Sodium and Potassium ion pumps for creating potential
tRNA for gathering amino acids
L-isomers of amino acids
Ribosomes for assembling proteins
Glucose as the ultimate energy source (very few exceptions exist)
Lipid bilayer for making cell membranes
Cellular division for growth
ATP Synthase to power the production of ATP

AND MANY, MANY MORE SIMILARITIES

LUCA

None of these features of life on Earth had to be exactly this way. There are alternative ways to solve each problem.

Question:
How would it come to be that all life uses all these common features if there was not a universal ancestor?

Take a moment and come up with an alternate theory to LUCA.

LUCA

Knowing what you know about the physical world and universe, and Darwin's and Mendel's work, and population genetics, does your theory seem more likely than LUCA?

Do you think that the exact pattern of specific processes and molecules found in every life form on this planet were reinvented many times over or does it make more sense that it was derived in one organism that passed them to future generations?

LUCA

Earth is 4.6 billion years old

+

The environment is too hostile for life until 3.9 bya

+

The earliest fossil evidence for life is 3.5 bya

The evolution of LUCA occurred between 3.9 and 3.5 bya.

9 The creation of membranes from phospholipids _____.

- A allowed for a more complex chemistry
- B allowed bacteria to flourish
- C allowed lipids to make glycoproteins
- D allowed more amino acids to form

answer

10 Evidence for a last universal common ancestor among life on Earth is:

- A they all have the same synthesis pattern
- B they share the same biology
- C they all look the same
- D they are all aerobic

answer

11 The last universal common ancestor originates somewhere between around 4.5 BYA.

- True
- False

answer

Phylogenetics

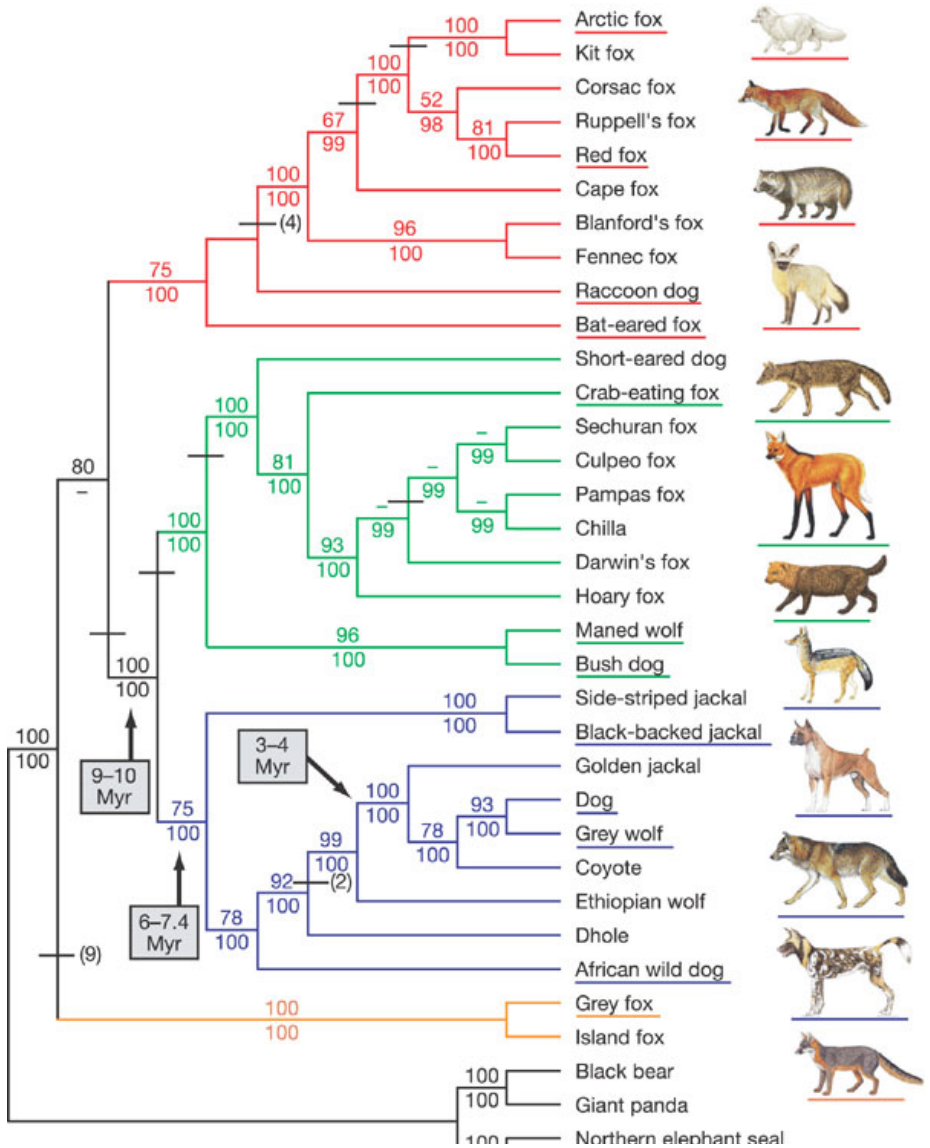
Return to Table of Contents

Phylogeny is Classification

As phylogeny shows history it also shows the relatedness of certain species to other species.

The closer two species are in a phylogeny the closer they are related.

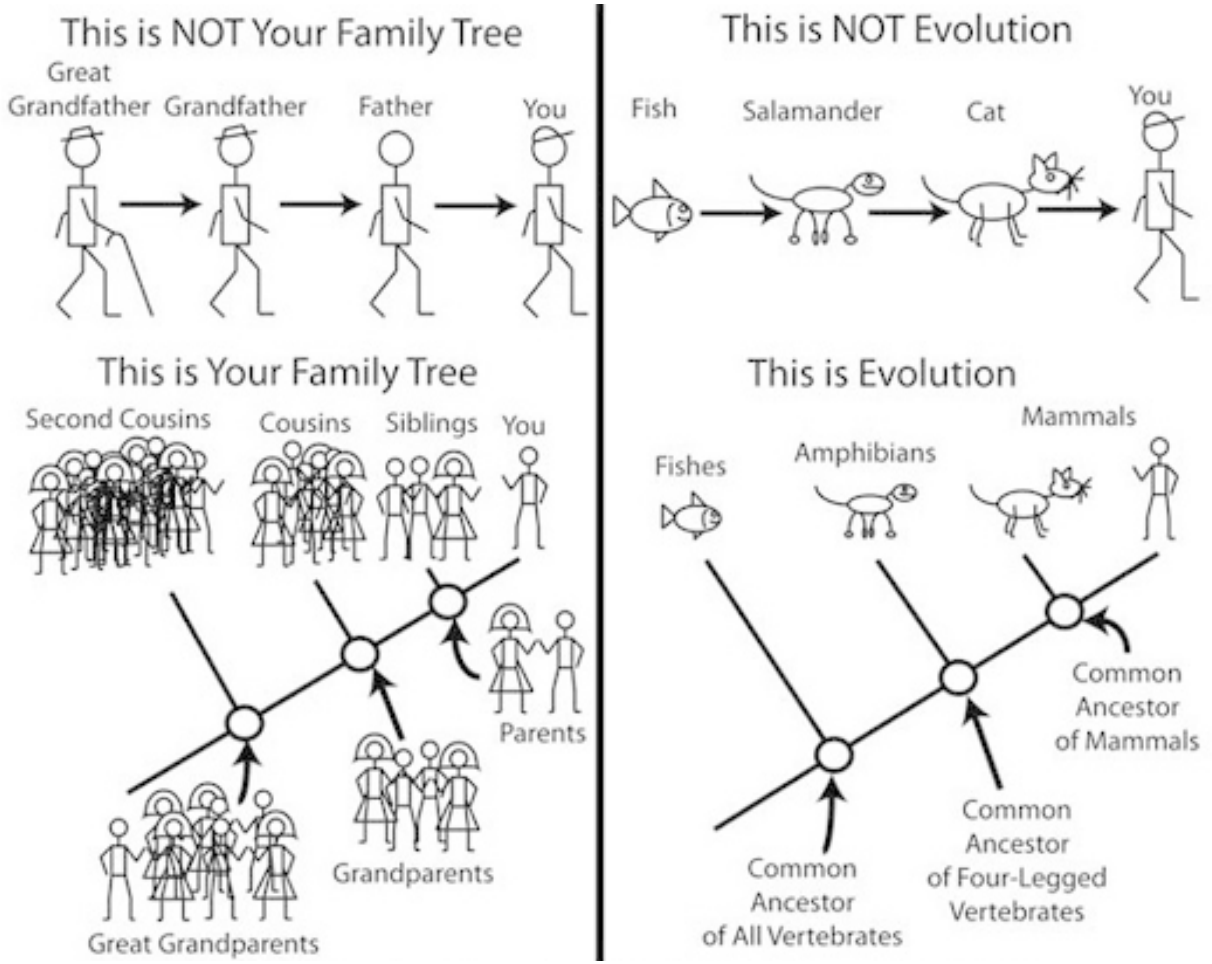
This is a **clade** of the Family Canidae, which includes meat eating, dog-like mammals.



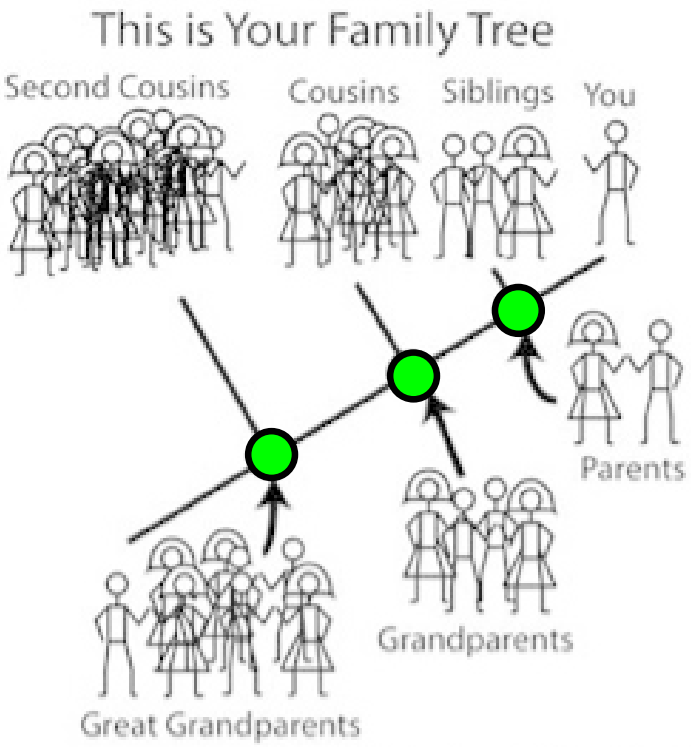
http://www.nature.com/nature/journal/v438/n7069/fig_tab/nature04338_F10.html

Phylogenetic Tree is a Family Tree

Phylogenetic trees can be viewed similar to family trees.



Phylogenetic Trees



Each node on the tree is representative of a common ancestor.

Your grandparents are a common ancestor between you and your cousins.

You share the most traits with your siblings, then your cousins, and then your second cousins.

How are we all connected?

Click here for a video of "Discovering the Greatest Tree of Life"

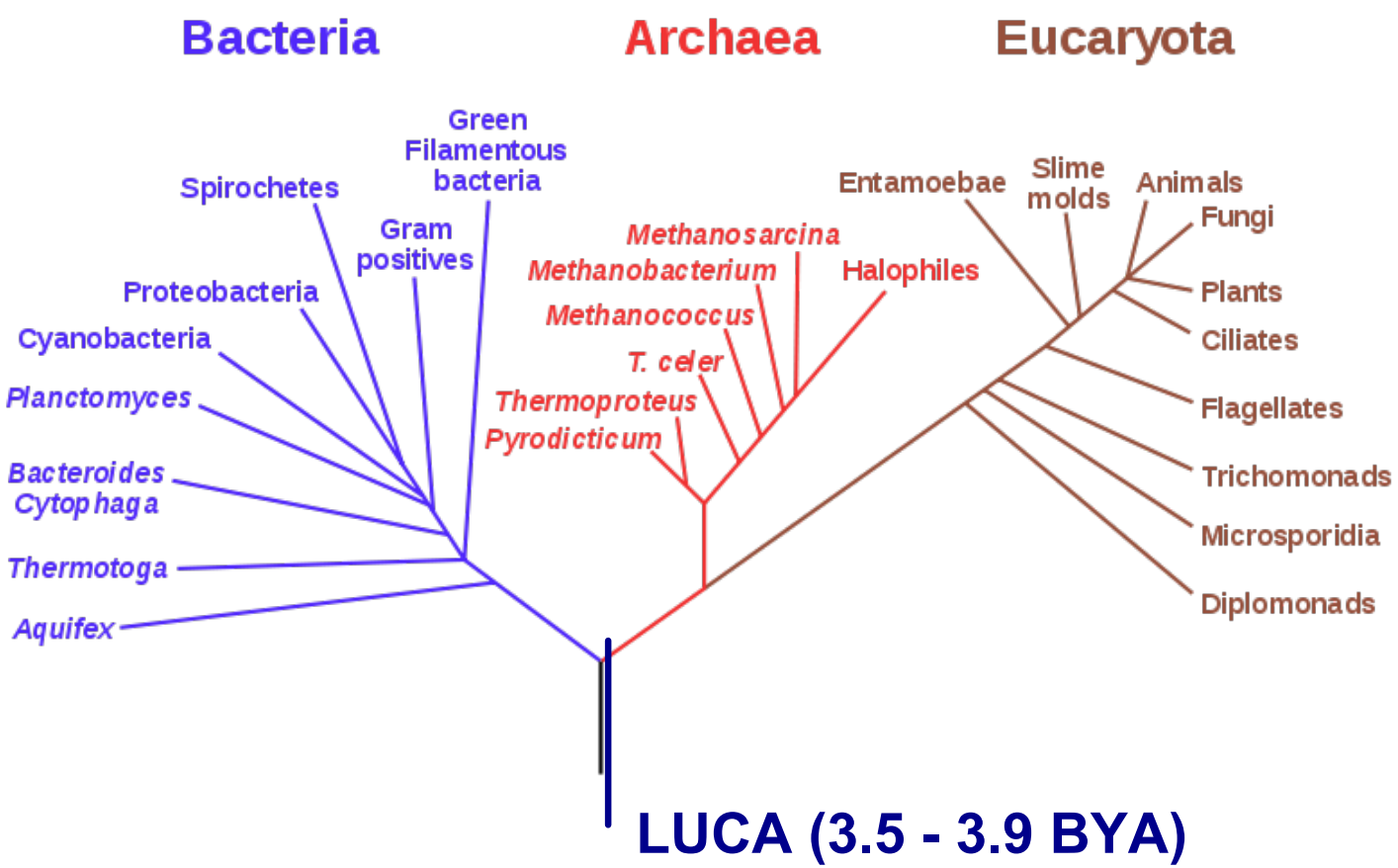
Phylogenetic Tree

Phylogenetic trees allow us to trace the evolutionary history of a species back farther and farther to common ancestors and related species.

They are produced through comparison of traits and the genetic code between modern day organisms and/or fossils.

Phylogenetic trees are constantly changing to fit in the new information that scientist learn.

Phylogenetic Tree of Life



Phylogenetic Tree of Life

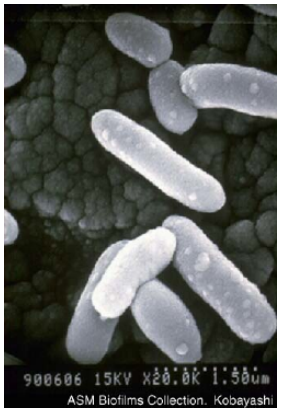
This tree represents the analytical approach to classifying the **diversity** of life. In doing so it also points out the organisms that show **unity** in particular groups.

The study of evolutionary relationships between species and the construction of phylogenetic trees is called **systematics**. It uses pieces of evidence provided by all the different disciplines we have talked about in Big Idea 1: homologies in structure and molecules, fossils in the record, biogeography, etc.

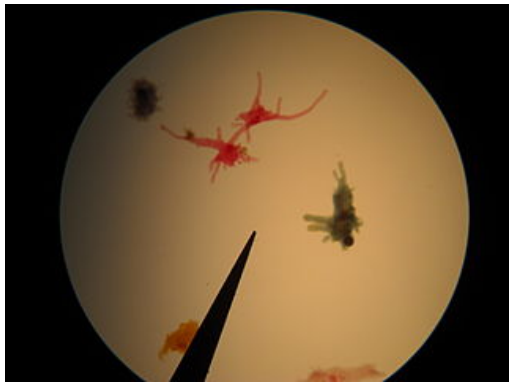
Phylogenetic Tree of Life

As a start to this tree... prokaryotic cells exist on the planet, they begin to mutate, become varied and replicate based on those variations (natural selection).

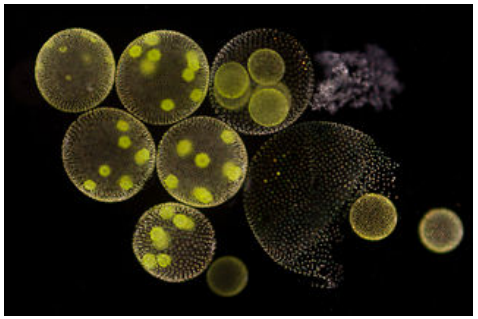
After billions of years of evolution more complex features arise. **Eukaryotes** which are defined by their large amount of genetic material contained in a nucleus, evolve even further to become multicellular organisms.



Prokaryotes



Single celled eukaryotes

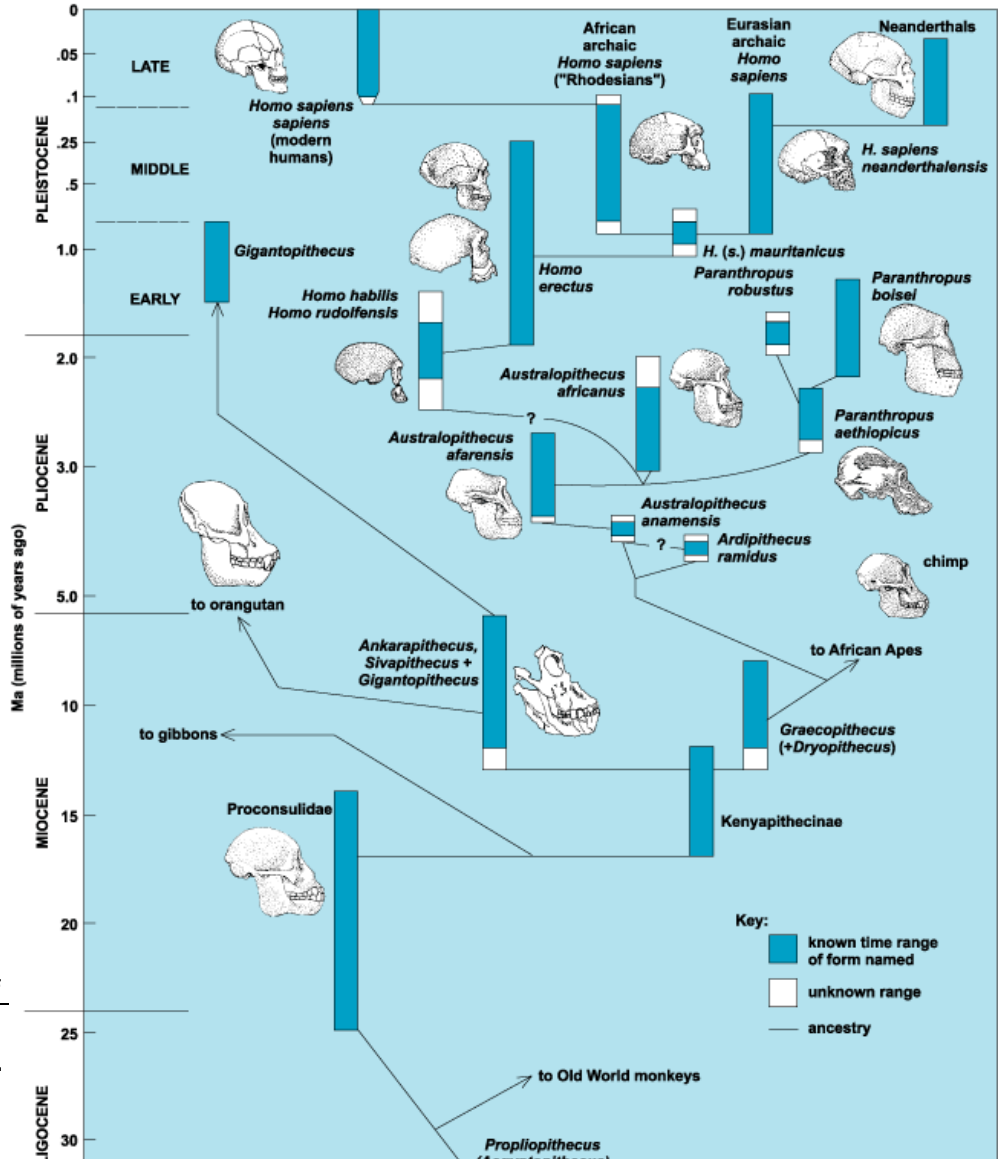


Multicelled Eukaryotes

Phylogeny is History

As a phylogenetic tree comes together it shows the heredity of species from the past and present.

This shows the relationship of hominid species as they evolved through time.



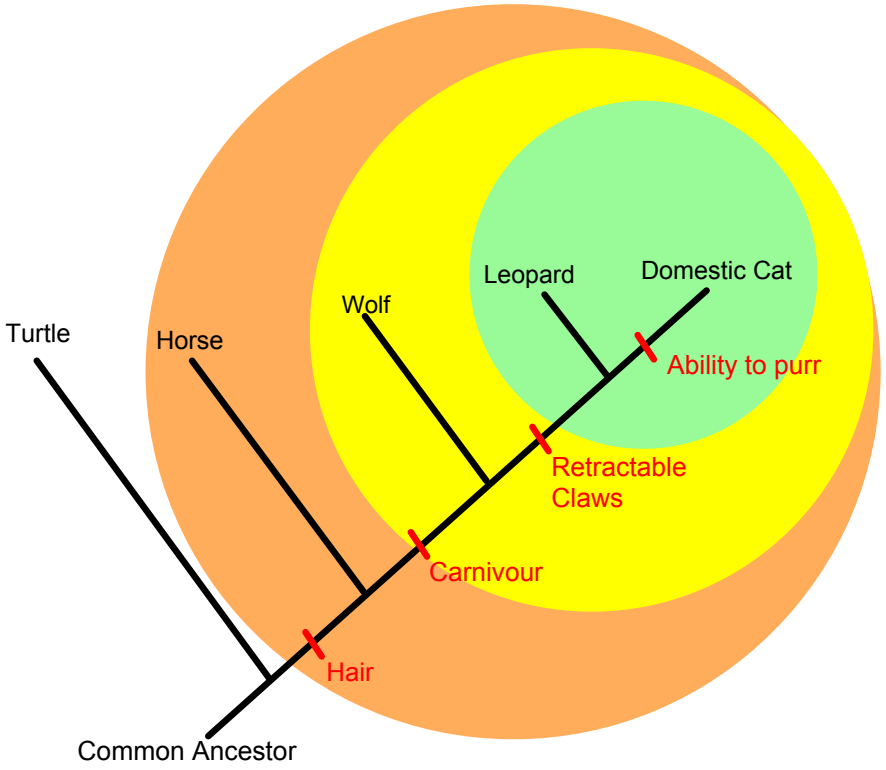
"Fossil humans." McGraw-Hill Encyclopedia of Science and Technology. The McGraw-Hill Companies, Inc., 2005. *Answers.com* 16 Aug. 2012. http://www.answers.com/topic/fossil-humans

Clade

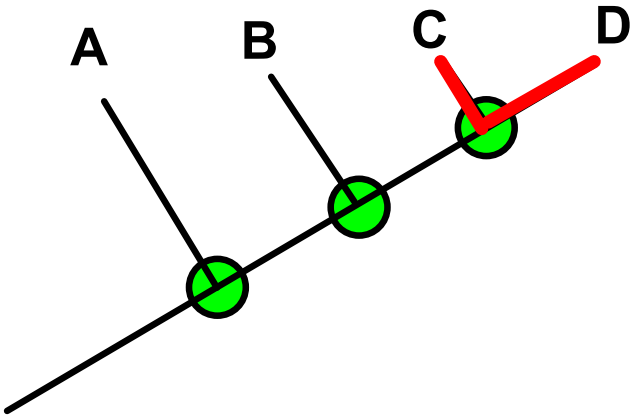
Sometimes the term clade is used to refer to smaller groups within a cladogram or phylogenetic tree.

A clade is representative of a group of organisms and all of its common descendants.

The colored highlighting is representative of 3 different clades within this 1 cladogram.

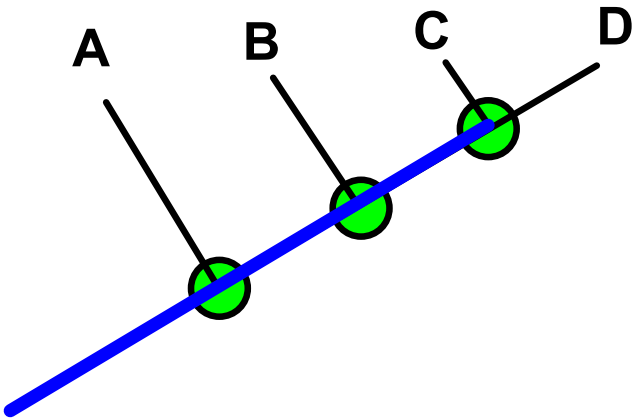


Phylogenetic Trees



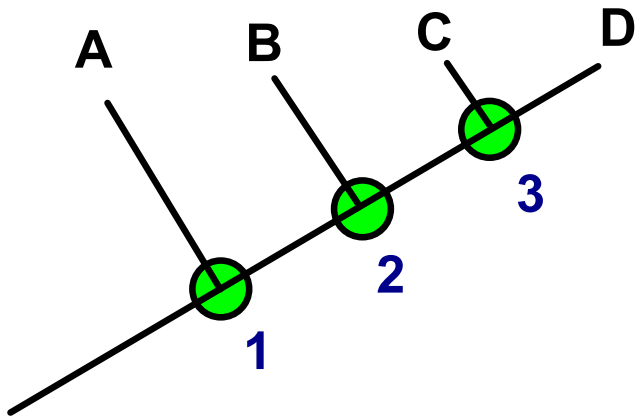
Each organism has a distinct history.

Phylogenetic Trees



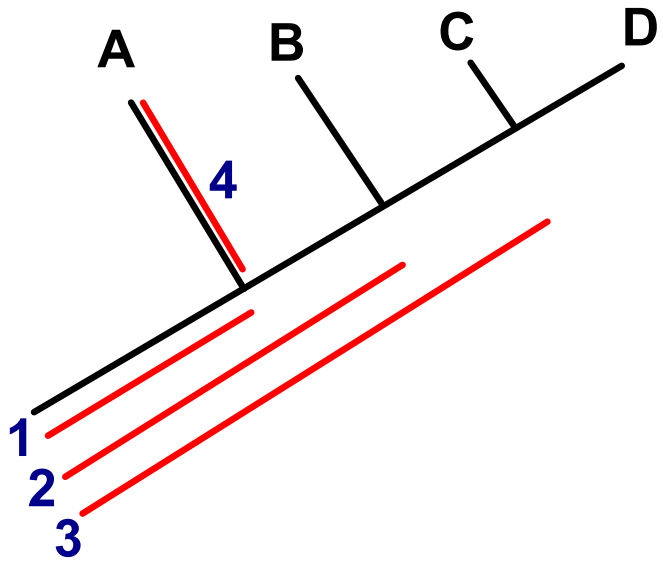
They also have shared histories.

12 Which number node represents the most recent common ancestor between organism B and C?



answer

13 Which number location represents the shared history between organism A, C, and D?



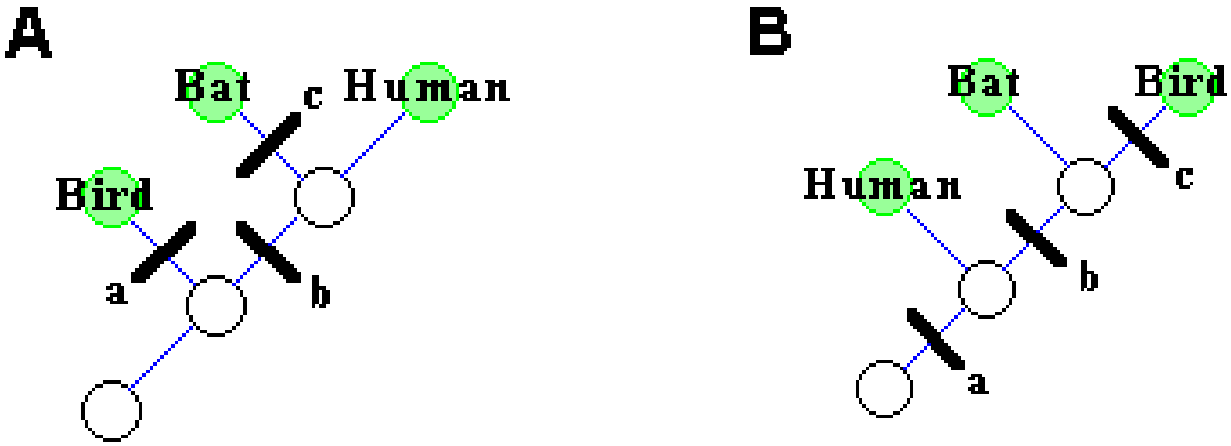
answer

Maximum Parsimony and Likelihood

Phylogeny relies on factual data being interpreted to produce a reasonable conclusion. In some cases the data could be interpereted in different ways. When this happens the principal of **maximum parsimony**, which states the simplest explanation that is consistent with the facts is more likely to be true.

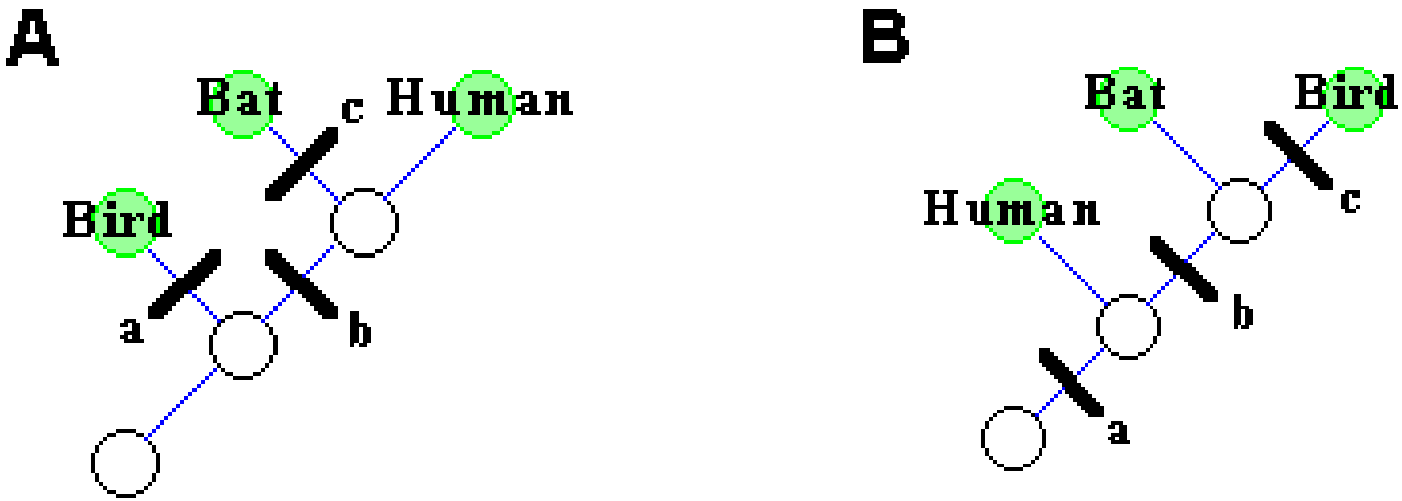
This is then combined with the principal of **maximum likelihood** which states a tree should be made that reflects the most likely sequence of evolutionary events. This can be determined using what we already know about DNA and how it changes over time.

Maximum Parsimony and Likelyhood



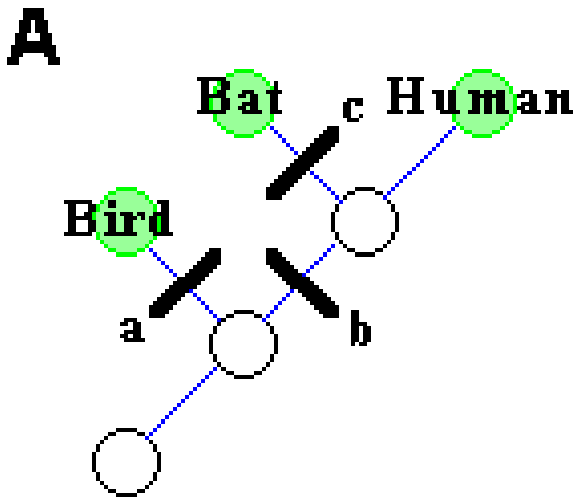
	Cladogram A	Cladogram B
Evolutionary event a	wing structures feathers	hair mammory glands
Evolutionary event b	hair mammory glands	wing structures
Evolutionary event c	wing structures	loss of hair mammory glands feathers

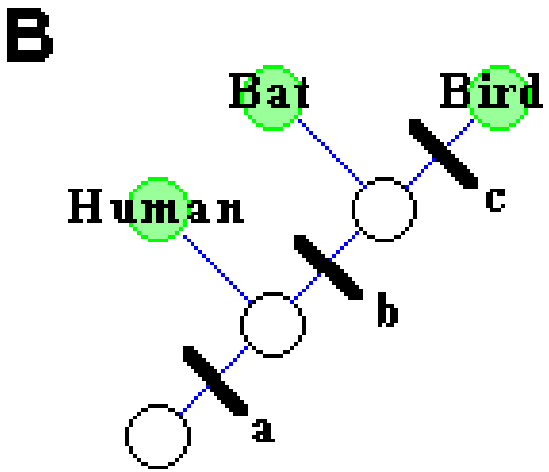
Maximum Parsimony and Likelyhood



Cladogram A requires five evolutionary steps while cladogram B requires six. Because cladogram A requires fewer evolutionary steps it is the simplest, and parsimony dictates that this is the preferred cladogram.

Maximum Parsimony and Likelyhood





The combination of the loss of hair, mammary glands and the evolution of feathers in one event would require that the laws of logic and DNA behavior must be ignored in order to allow cladogram B to be true.

Cladogram A does adhere to scientific logic, making it the parsimonious and likely cladogram.

T.rex Day 1

Return to Table of Contents

Understanding Cladistics: What Did T.rex Taste Like?

The following question slides are adapted from the http://www.ucmp.berkeley.edu/education/explorations/tours/Trex/navigation.html.

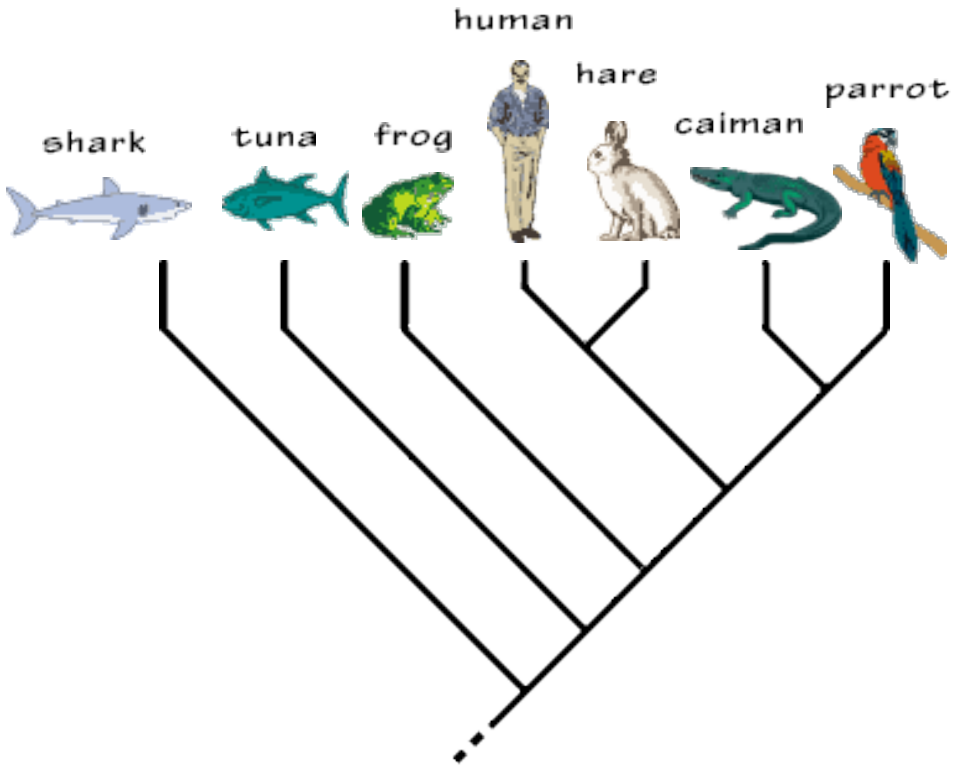
Teacher Note: You will proceed through folder 3 of the activity as a class. Anytime there is a question on the website, you should return to the notebook and allow students to use Smart Response to give their answers. Then put the class answers into the website activity to see if they are correct.

Click here for the activity: What did T.rex taste like?

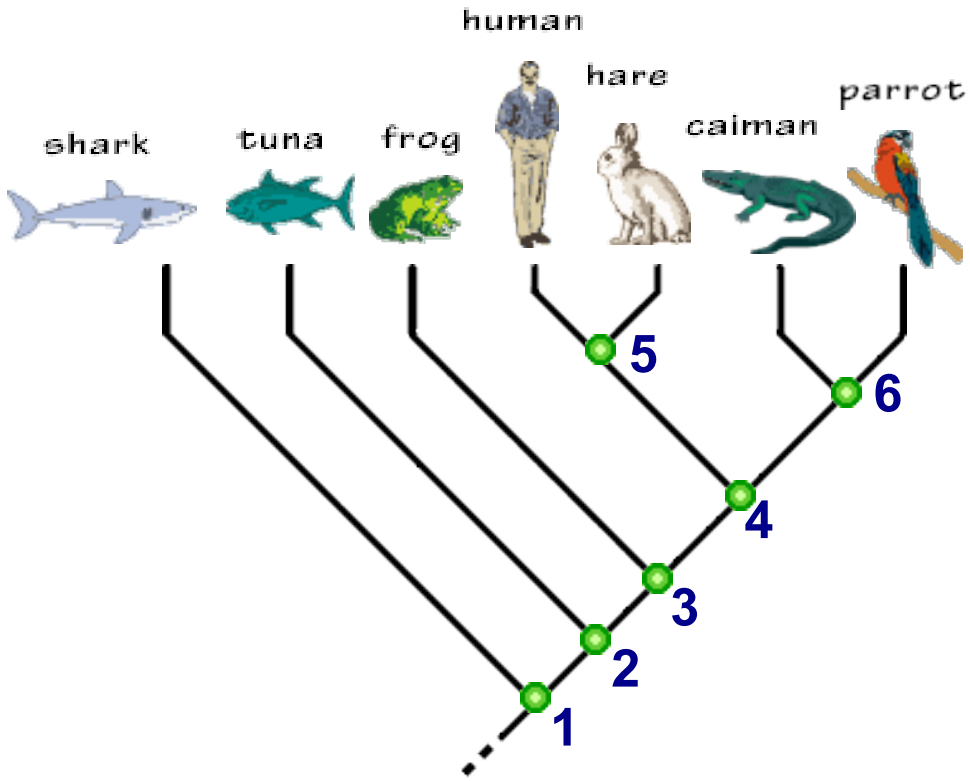
14 Which are more closely related to caimans?

A Hares

B Parrots

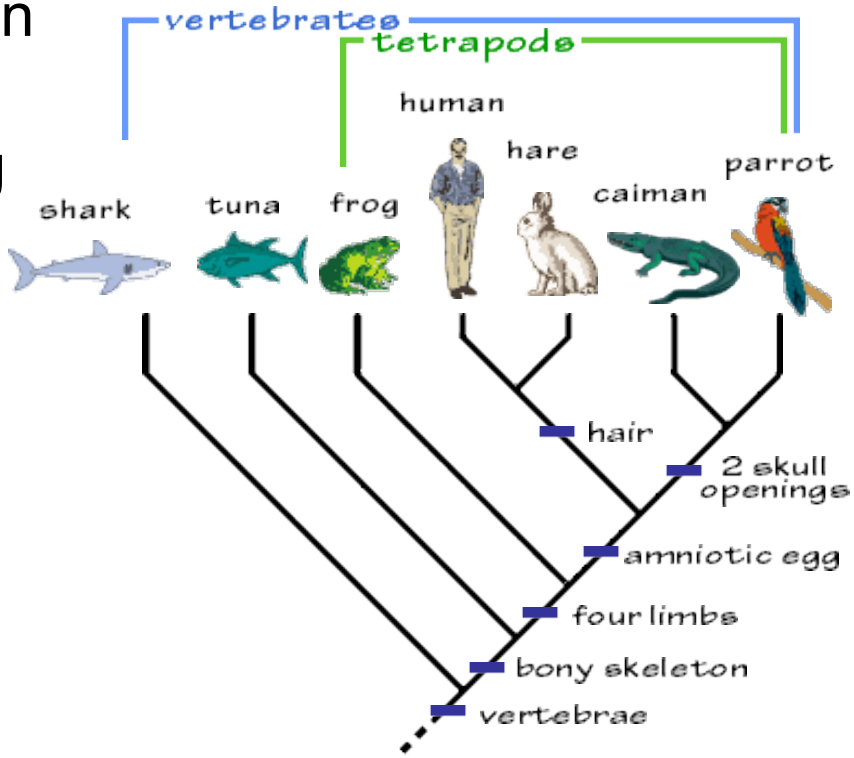


15 Which green dot best represents the common ancestor to the hare, parrot, and caiman?



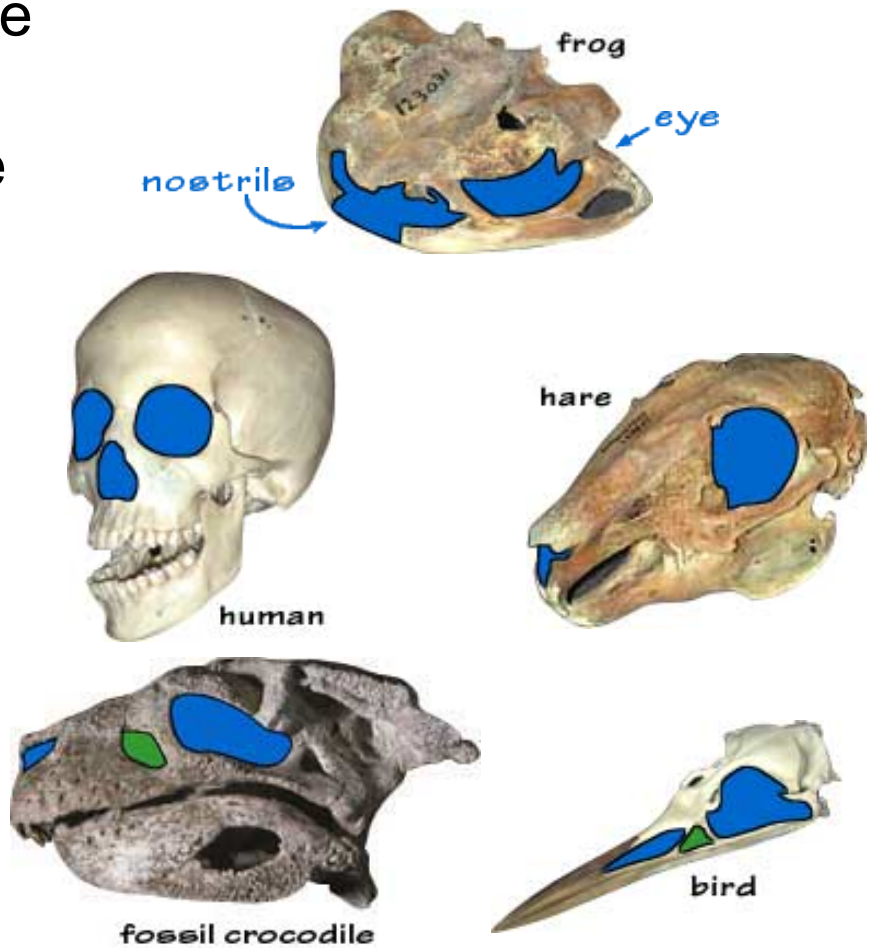
16 Which feature do humans, hares, caimans, and parrots share that the other three lineages did not inherit?

- A Bony skeleton
- B Hair
- C Amniotic egg

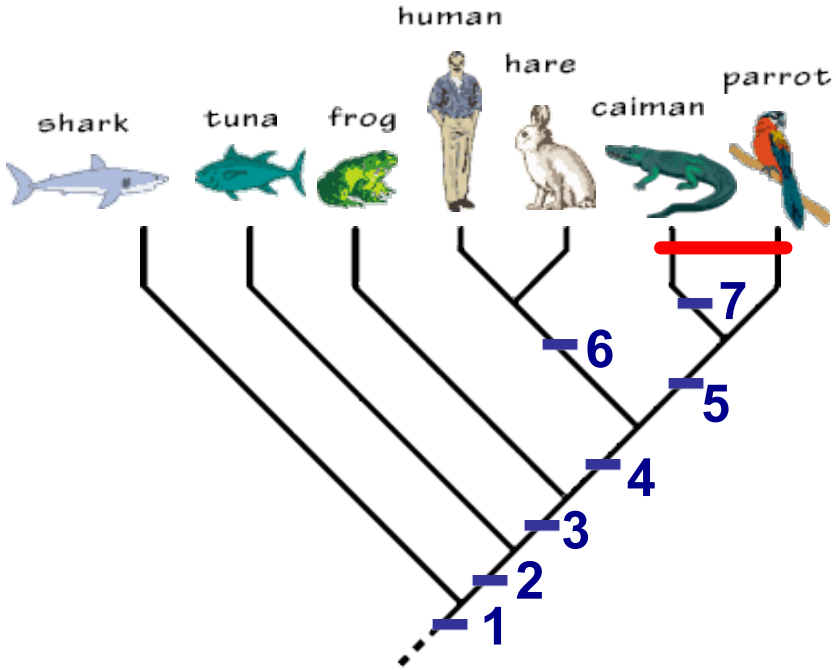


17 Which of the tetrapods have a skull opening in front of the

- A Hare and crocodile
- C Frog and hare
- B Bird and crocodile



18 Which number blue bar best represents when the skull opening in front of the eye evolved?



T.rex Day 2

Return to Table of Contents

What Did T.rex Taste Like?

Teacher Note: Students will now complete the folders 4 & 5 of the activity working with a partner. Each pair of students will need a computer and the appropriate handouts.

Click here for "What did T.rex taste like?" folder 4.

Phylogeny & DNA/ AP Lab 3

Return to Table of Contents

Ideas to Remember When Looking at Phylogenetic Trees

- **The trees are works in progress** - as new evidence arises updates are made.
  - The 3 Domain system we use today was introduced in 1990. It replaced a system known as the 5 Kingdom system that did not include Domains.

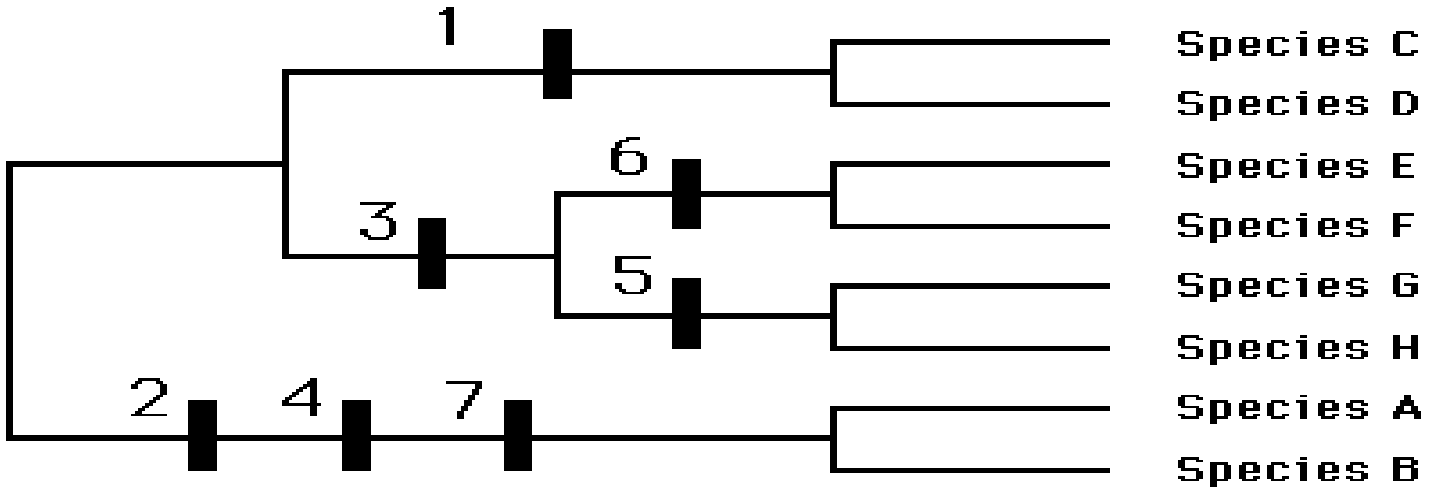
- **The diversity of organisms arose through evolution**- phylogeny is the history of life and its changes over time

- **All organisms exhibit characteristics similar to their ancestors**- All of the successful traits we see in life today have been fine
  tuned from traits that arose in the past

DNA Sequencing

Phylogeny looks at the differences of specific DNA sequences in living organisms and their extrapolated changes over time to confirm the relationship of species at a genetic level.

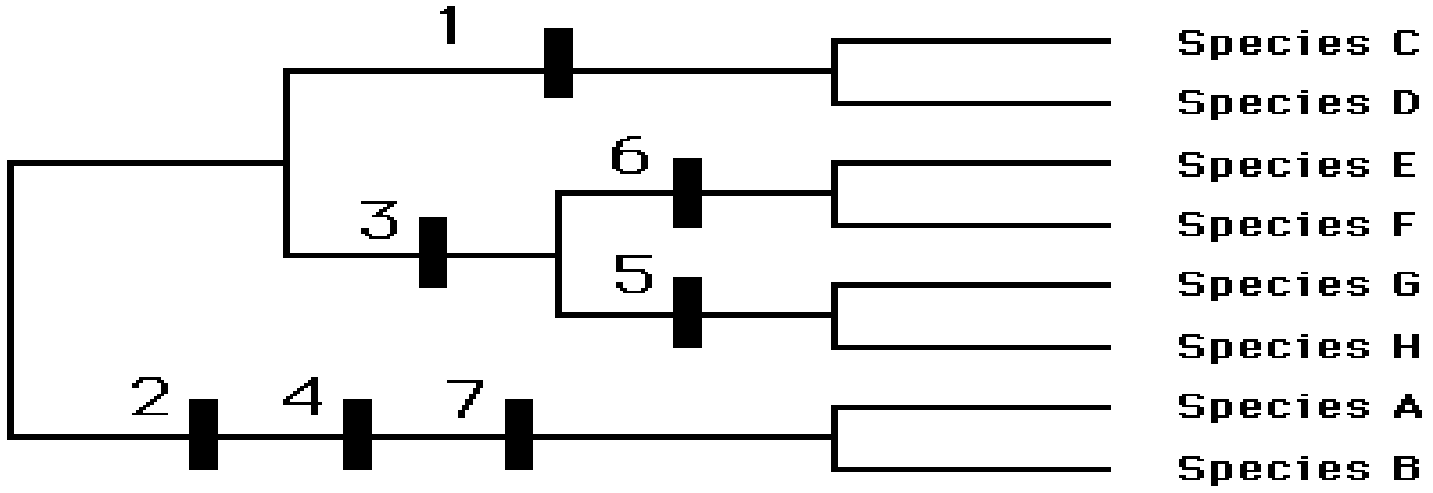
```
                 1   2    3        4              5      6  7
Species A   ACCAGCCTGTGCATCGATGACGACTAAGTGATACCATAAAGACT
Species B   ACCAGCCTGTGCATCGATGACGACTAAGTGATACCATAAAGACT
Species C   ACGAGCATGTGCATCGATGCCGACTAAGTGATACCATAATGACT
Species D   ACGAGCATGTGCATCGATGCCGACTAAGTGATACCATAATGACT
Species E   ACCAGCATGTGTATCGATGCCGACTAAGTGATACCAAAATGACT
Species F   ACCAGCATGTGTATCGATGCCGACTAAGTGATACCAAAATGACT
Species G   ACCAGCATGTGTATCGATGCCGACTAAGTGCTACCATAATGACT
Species H   ACCAGCATGTGTATCGATGCCGACTAAGTGCTACCATAATGACT
```



DNA Sequencing

The numbers below represent mutations that have happened in a group of species since their divergence from a common ancestor.

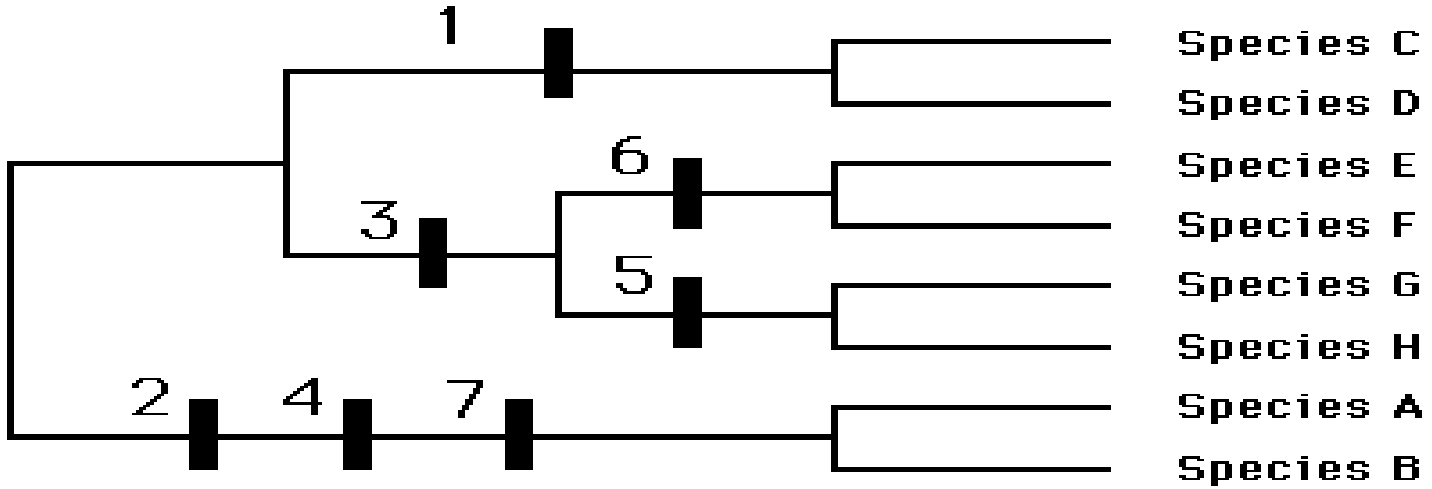
```
                 1   2    3        4              5      6  7
Species A   ACCAGCCTGTGCATCGATGACGACTAAGTGATACCATAAAGACT
Species B   ACCAGCCTGTGCATCGATGACGACTAAGTGATACCATAAAGACT
Species C   ACGAGCATGTGCATCGATGCCGACTAAGTGATACCATAATGACT
Species D   ACGAGCATGTGCATCGATGCCGACTAAGTGATACCATAATGACT
Species E   ACCAGCATGTGTATCGATGCCGACTAAGTGATACCAAAATGACT
Species F   ACCAGCATGTGTATCGATGCCGACTAAGTGATACCAAAATGACT
Species G   ACCAGCATGTGTATCGATGCCGACTAAGTGCTACCATAATGACT
Species H   ACCAGCATGTGTATCGATGCCGACTAAGTGCTACCATAATGACT
```



DNA Sequencing

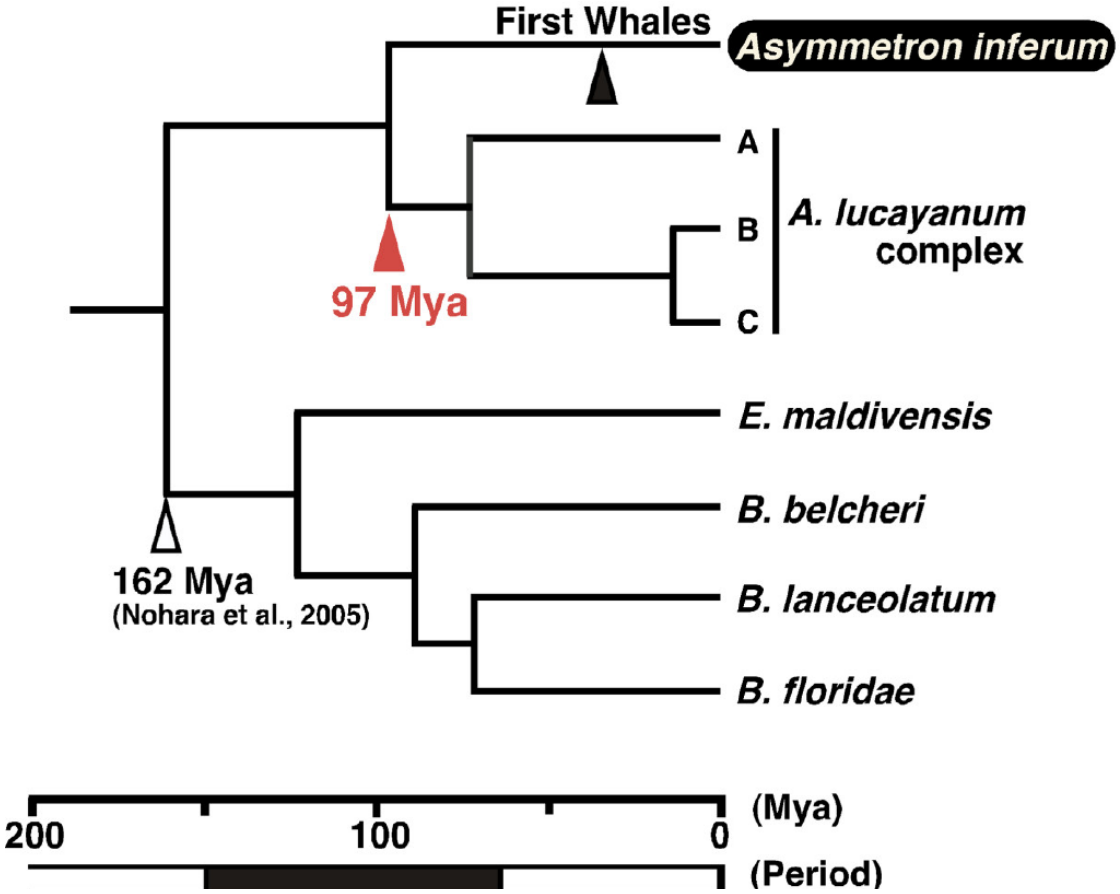
The mutations present in each of the species are compared and ordered to create a phylogenetic tree that represents the evolution of the group.

```
                  1   2    3        4              5      6  7
Species A   ACCAGCCTGTGCATCGATGACGACTAAGTGATACCATAAAGACT
Species B   ACCAGCCTGTGCATCGATGACGACTAAGTGATACCATAAAGACT
Species C   ACGAGCATGTGCATCGATGCCGACTAAGTGATACCATAATGACT
Species D   ACGAGCATGTGCATCGATGCCGACTAAGTGATACCATAATGACT
Species E   ACCAGCATGTGTATCGATGCCGACTAAGTGATACCAAAATGACT
Species F   ACCAGCATGTGTATCGATGCCGACTAAGTGATACCAAAATGACT
Species G   ACCAGCATGTGTATCGATGCCGACTAAGTGCTACCATAATGACT
Species H   ACCAGCATGTGTATCGATGCCGACTAAGTGCTACCATAATGACT
```



Ultrametric Trees

Combining time scale with changes in derived traits creates an ultrametric tree. The lines in this type of tree represent an amount of time from one divergence to another. (Mya = Millions of years ago)



Why Study the Tree of Life?

Click here for a video explanation

Lab Time

Please see:

College Board AP Biology Investigative Labs

Lab 3: Comparing DNA sequences to understand evolutionary relationships with BLAST

One last thought about LUCA

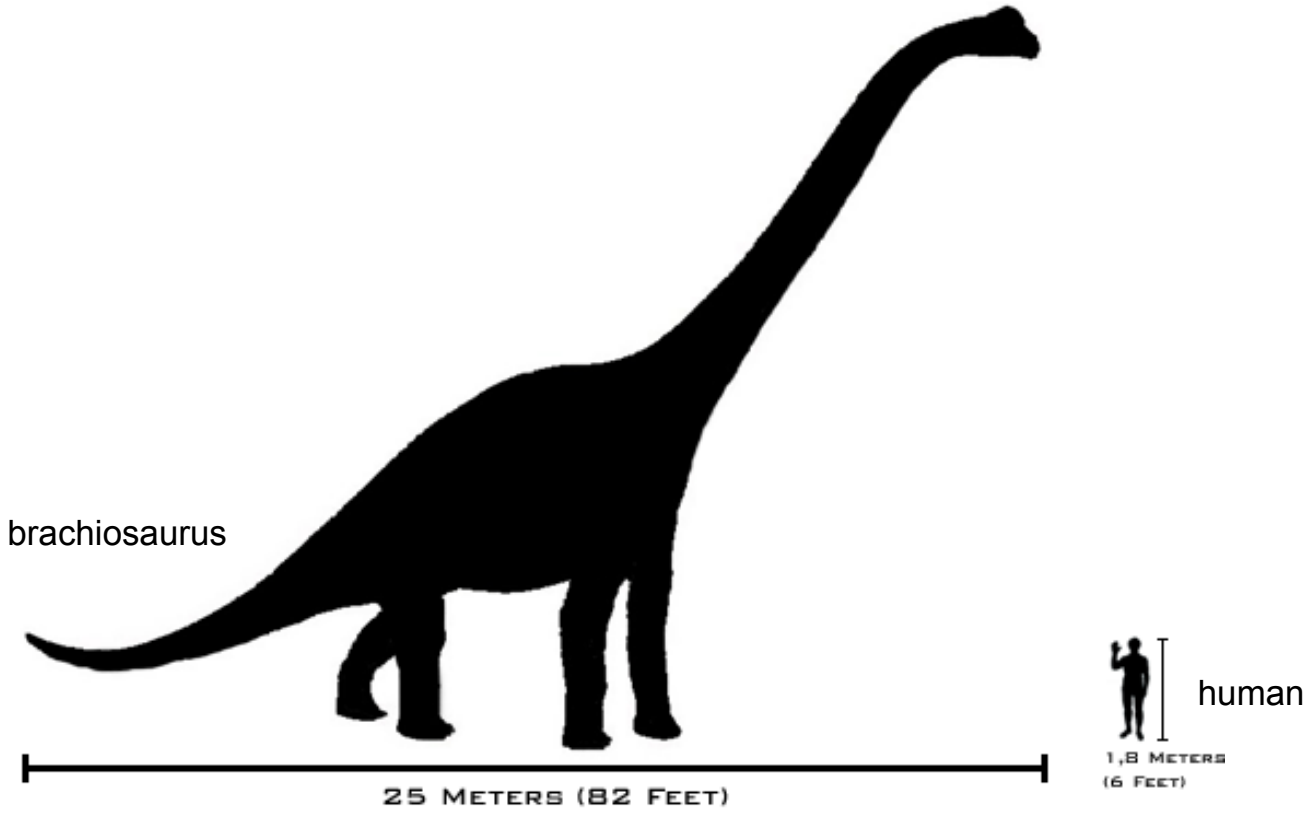
Remember the title of this unit:
The process of evolution drives the unity and diversity of life

Try not to think of LUCA as a thing, but a point in time when chemicals organized enough to do some basic functions. From that point critical processes came into existence and remain today, becoming the unity of life.

Other features evolved and succeeded or went extinct due to the environmental conditions at the time. These contribute to the diversity of life.

One last thought about LUCA

It is usually easy to see the differences in life forms but most living things have more in common then differences. What are the similarities of the below organisms?



One last thought about LUCA

The following unit will concentrate on the processes that life shares. The systems that are the most ancient to life, passed to us and all things living today from that early event known as LUCA.