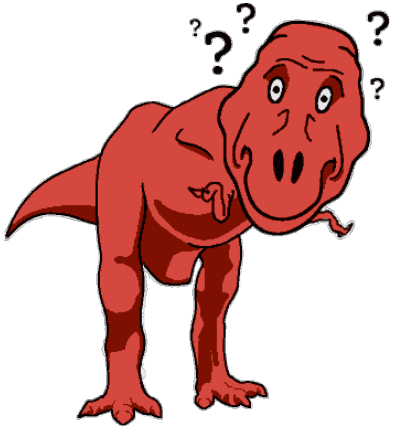


Understanding Evolution

Jennifer Skene, Ph.D.

The Lawrence Hall of Science

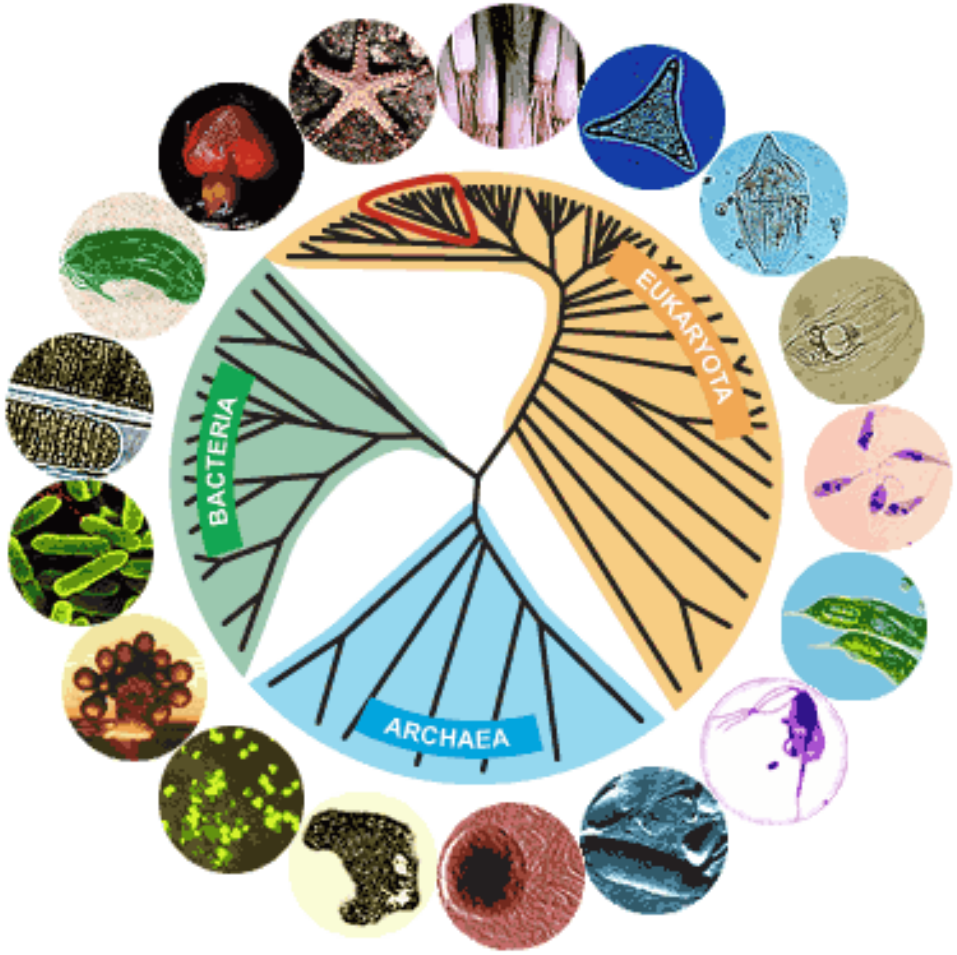
University of California Berkeley

University of California Museum of Paleontology

Understanding Evolution
your one-stop source for information on evolution

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Evolution Leads to Biodiversity

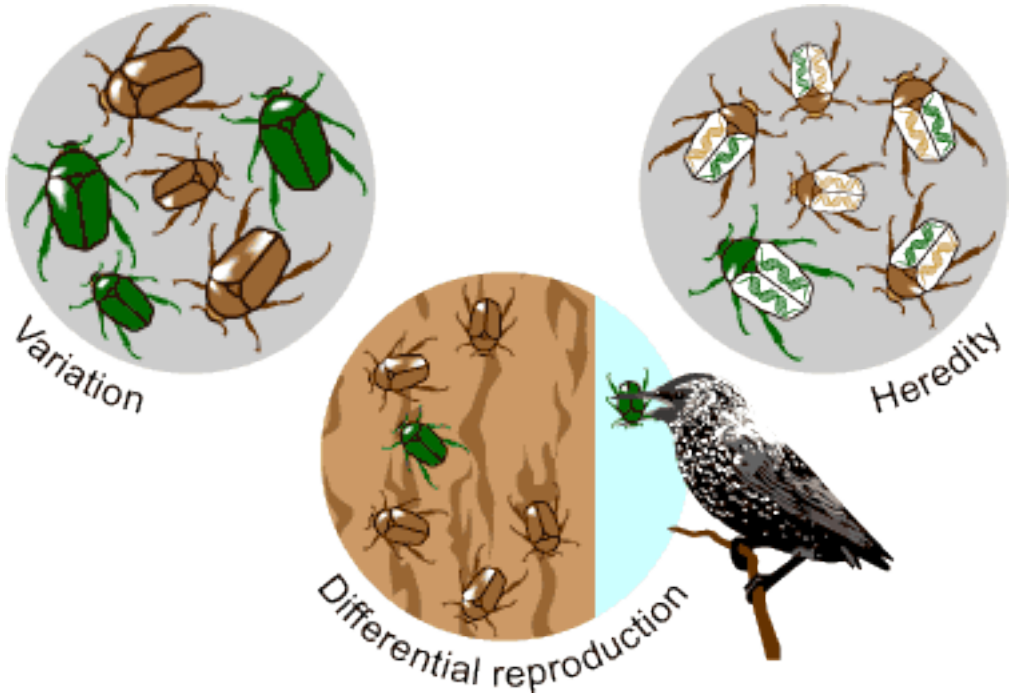


Understanding Evolution: Our plan for the morning

- Hands-on Activities:
  - Natural Selection Activity: Drawing Fish
  - What Did T. rex Taste Like?
- Coffee Break
- Resources from Understanding Evolution and Understanding Science

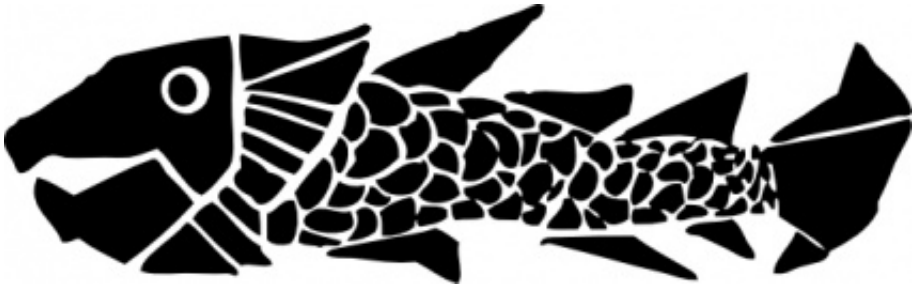
Ingredients for Natural Selection

1. Variation
2. Differential Reproduction
3. Heredity



Natural Selection: Drawing Fish

- Take 4 pieces of paper
- Divide into two groups
- Look at the fish and draw its offspring
- Look at the fish from your group's next generation and draw its offspring
- Repeat for 4 generations
- Discuss



What happened to the fish over time?

Questions:

- Why aren't all of the fish in each generation identical?

Questions:

- Why aren't all of the fish in each generation identical? VARIATION

Questions:

- Why aren't all of the fish in each generation identical? VARIATION
- Why are the copies similar to the parent fish?

Questions:

- Why aren't all of the fish in each generation identical? VARIATION
- Why are the copies similar to the parent fish? HEREDITY

Questions:

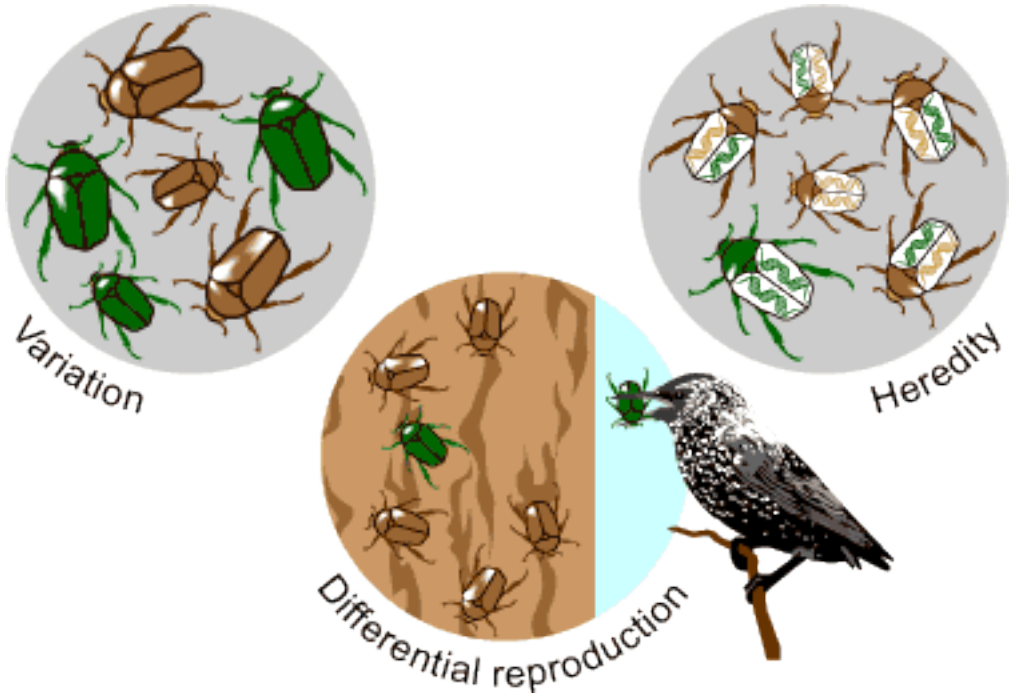
- Why aren't all of the fish in each generation identical? VARIATION
- Why are the copies similar to the parent fish? HEREDITY
- Why don't all the fish have offspring?

Questions:

- Why aren't all of the fish in each generation identical? VARIATION
- Why are the copies similar to the parent fish? HEREDITY
- Why don't all the fish have offspring? DIFFERENTIAL REPRODUCTION

Ingredients for Natural Selection

1. Variation
2. Differential Reproduction
3. Heredity



Let’s compare the fish in the two groups. Are they the same?

Let's compare the fish in the two groups. Are they the same?

No—because of SPECIATION

Adjust the activity for students of different ages:

- Simplify: no speciation. Do not divide the class into two groups.
- Make more advanced: include genetic drift. Randomly choose the parent fish.

Can you think of other ways
in which this exercise is similar to
evolution in the real world?

How is it different from evolution
in the real world?

What did T. rex taste like?

An introduction to how life is related

student START

teacher START

This educational module is sponsored by the National Science Foundation.

What Did T. rex Taste Like?

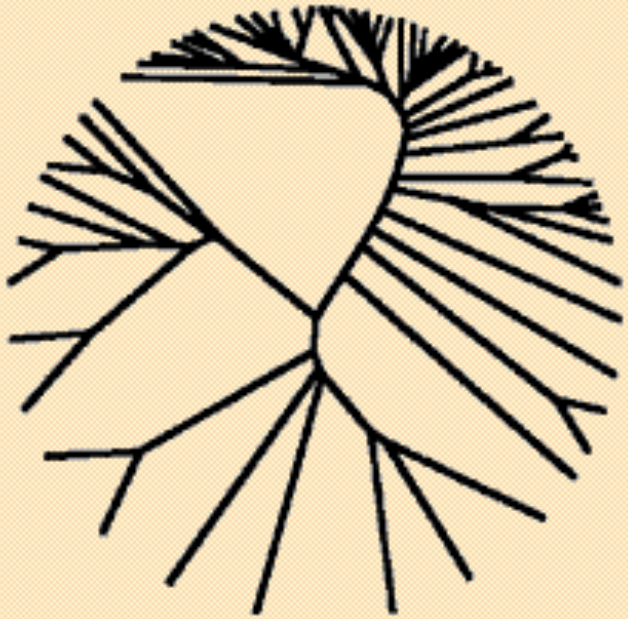
- Hands-on lesson adapted from a web-based module, on the website Understanding Evolution. www.evolution.berkeley.edu
- Introduces students to evolutionary trees (e.g., phylogenies or cladograms)
- Students use scientific evidence, from fossils and living taxa, to infer relatedness of taxa

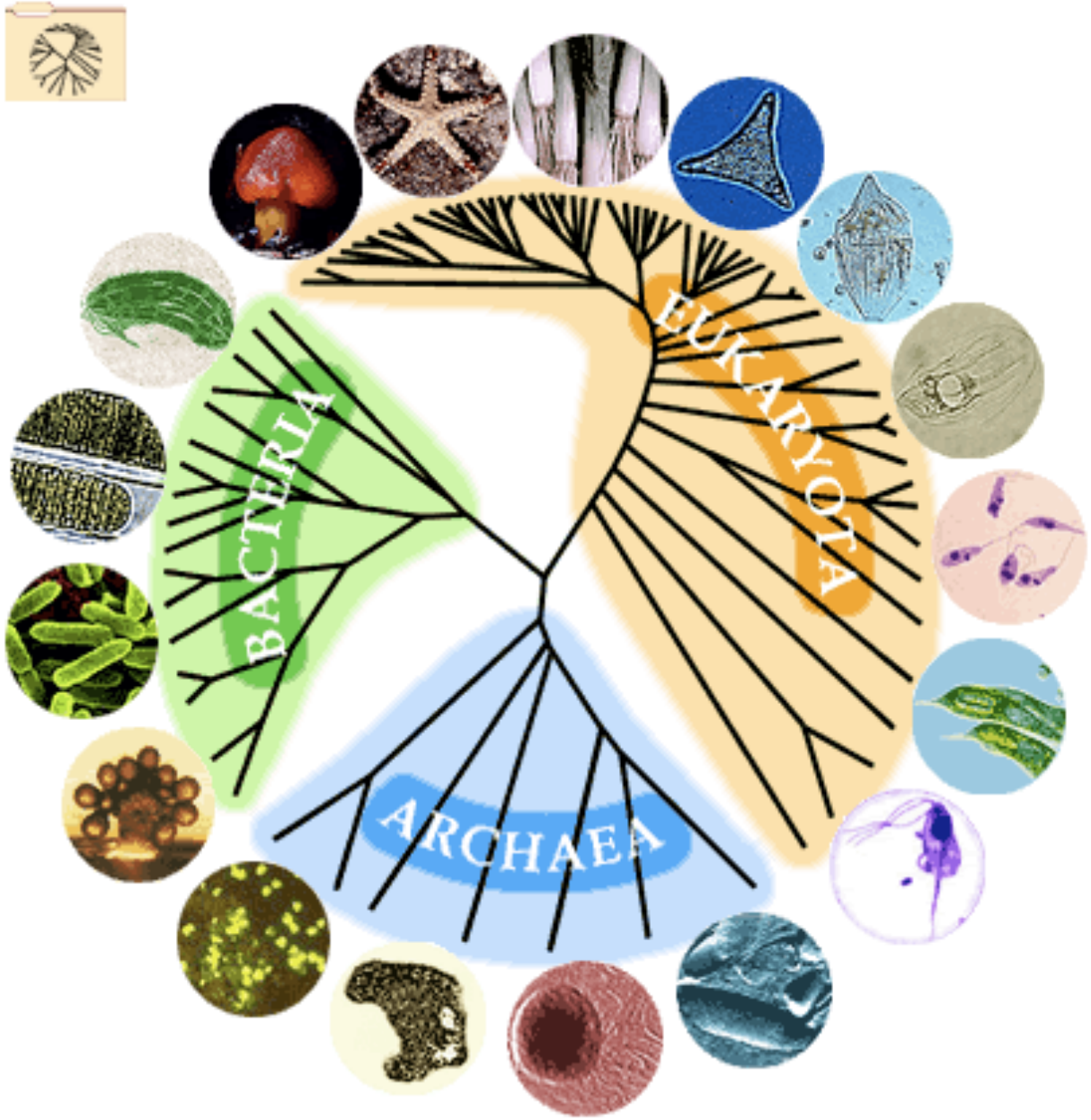
FOLDER 1:

Life is very diverse, yet all living things are related.

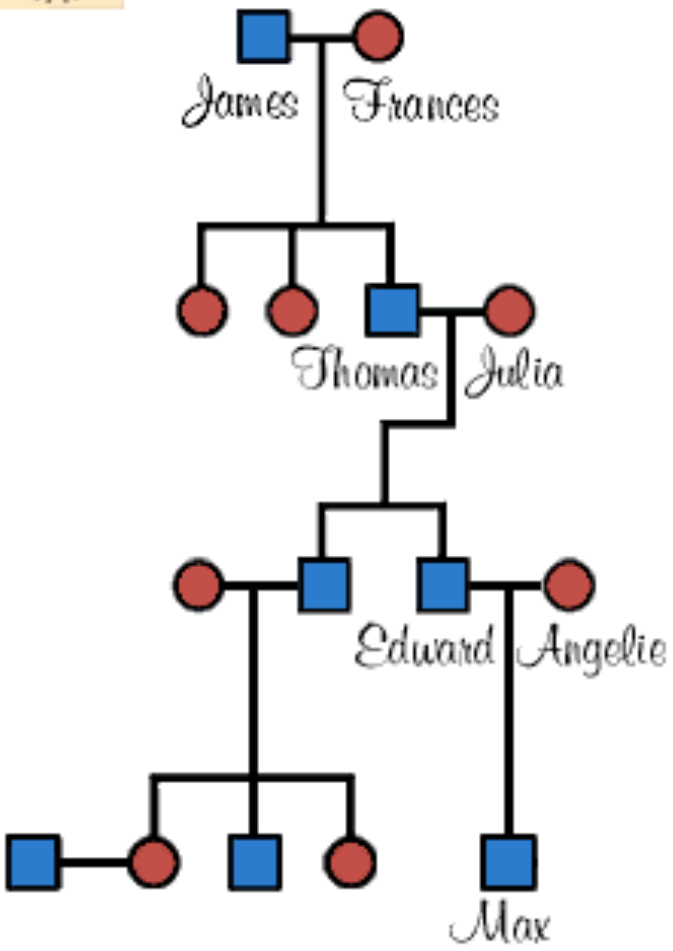
Branching diagrams show how living things are related to each other.

OPEN





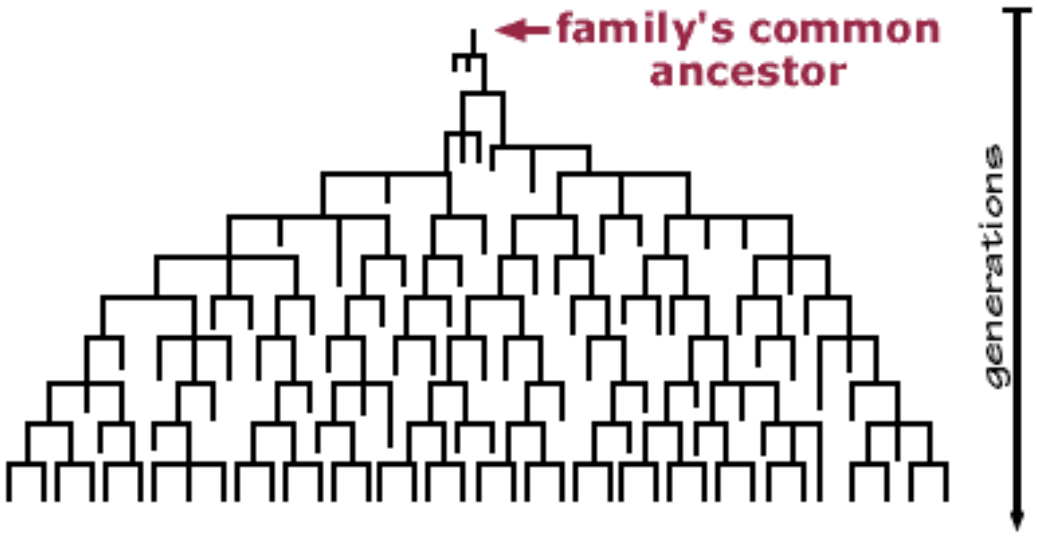
Click on the diagram to learn more about the organisms that are part of each group.



Resemblances to the "older ancestors" generally fade as the number of generations increases.

Max looks more like his parents than his great grandparents.

NEXT

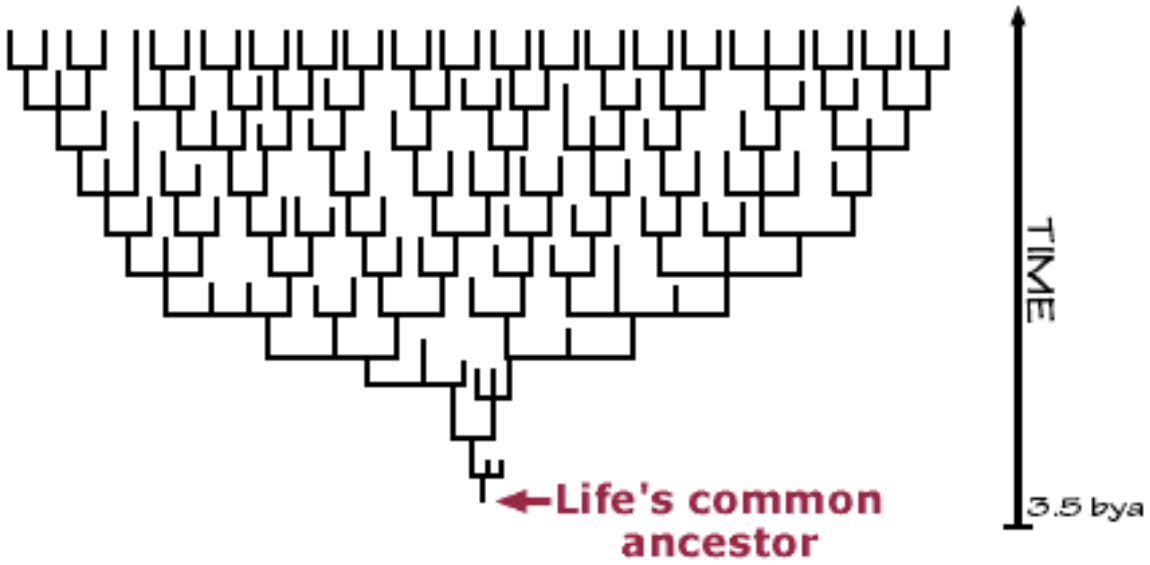


This diagram shows a larger part of the family history, or genealogy, all stemming from "an older common ancestor".

more . . .

Even though all life is related, resemblances fade over time, so those relationships are not always obvious.

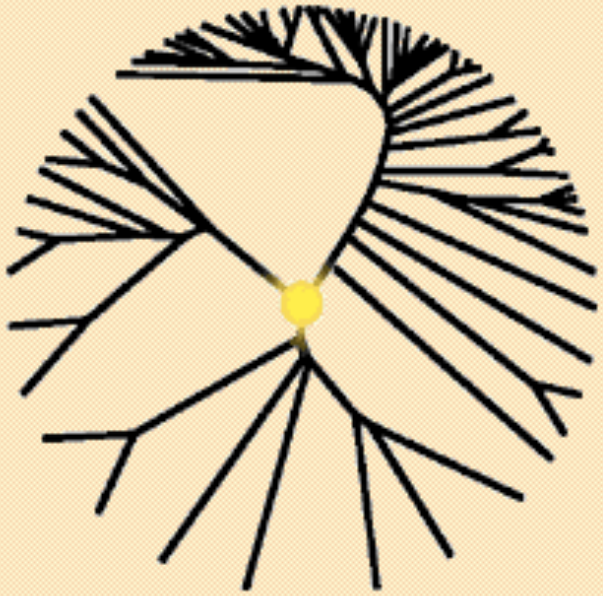
NEXT ►

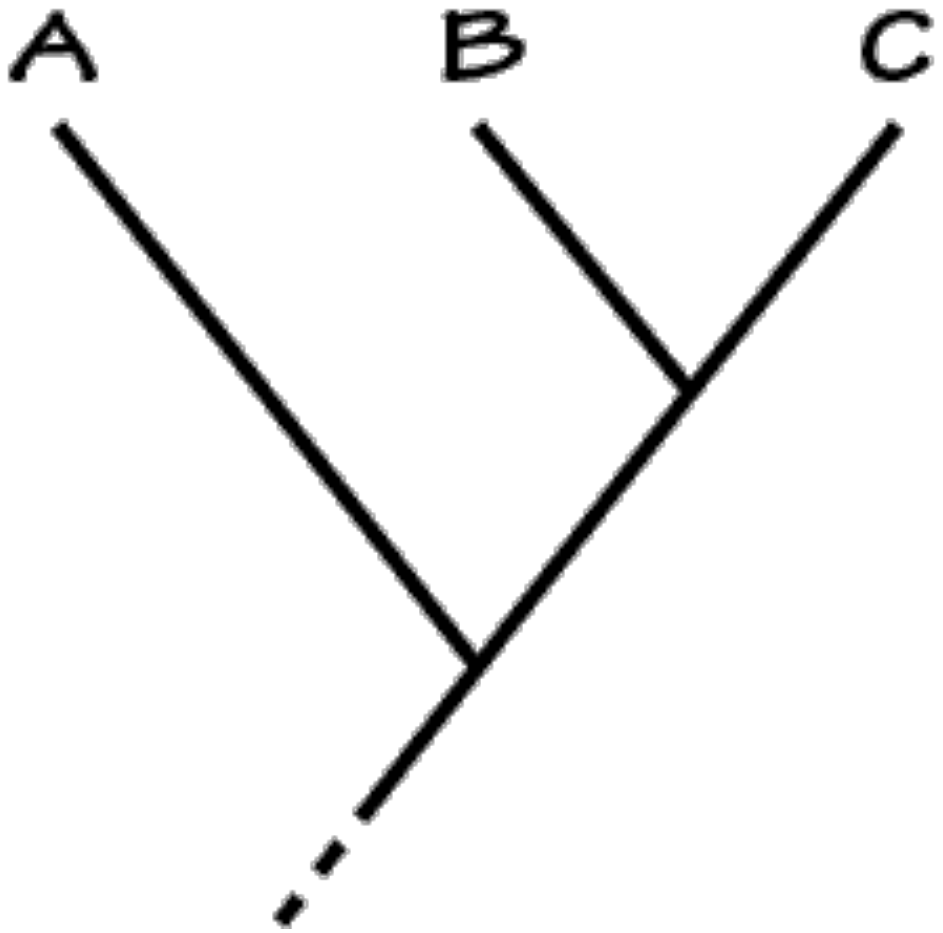


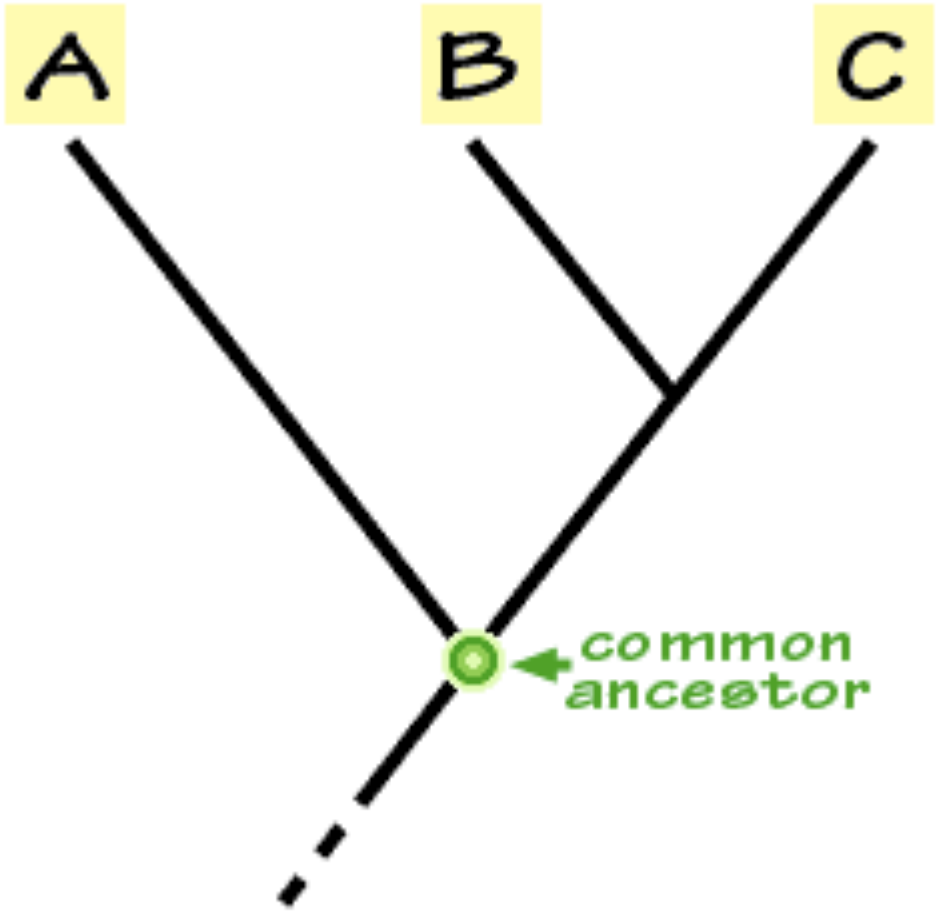
FOLDER 2:

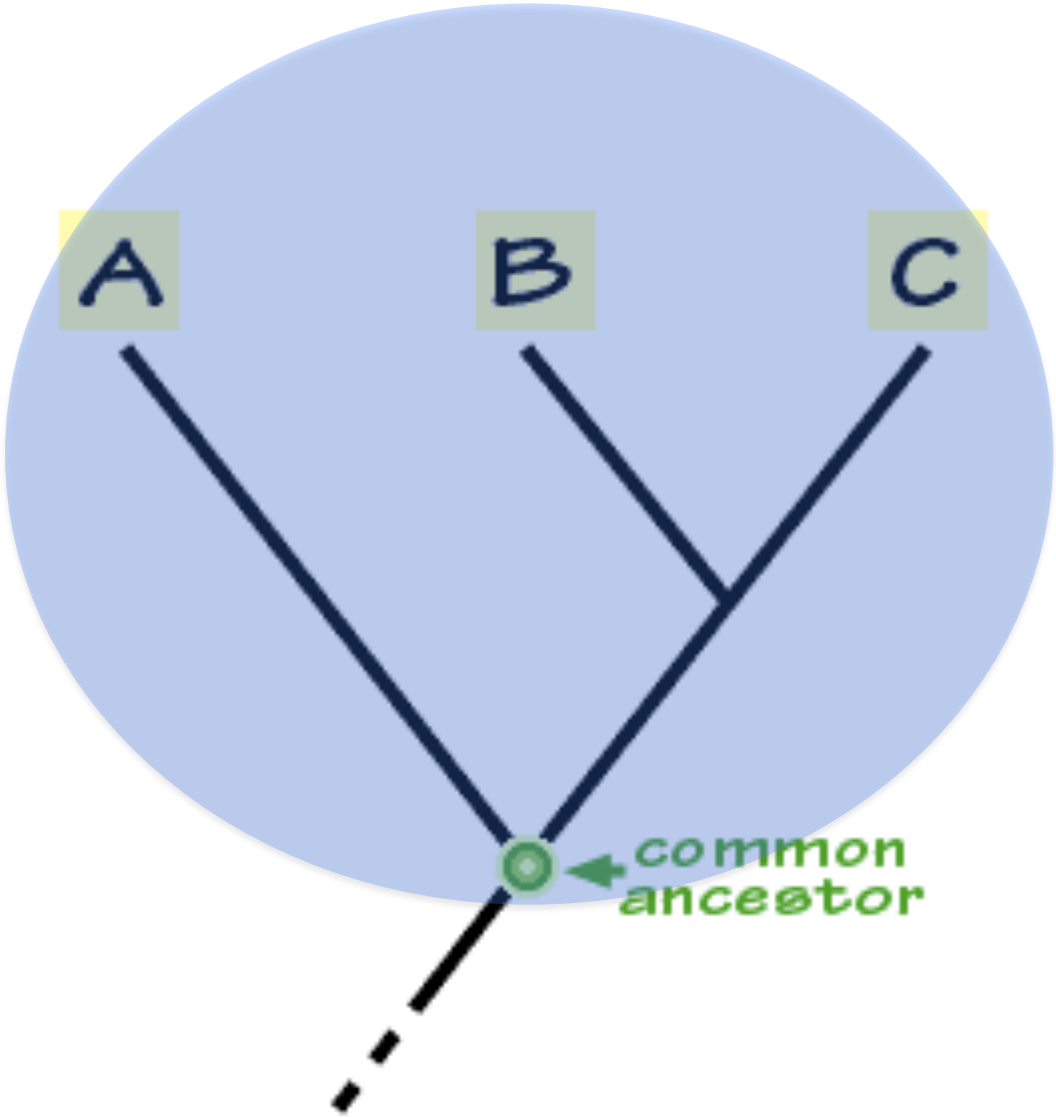
Lineages can be traced back in time to find a point of common ancestry.

OPEN



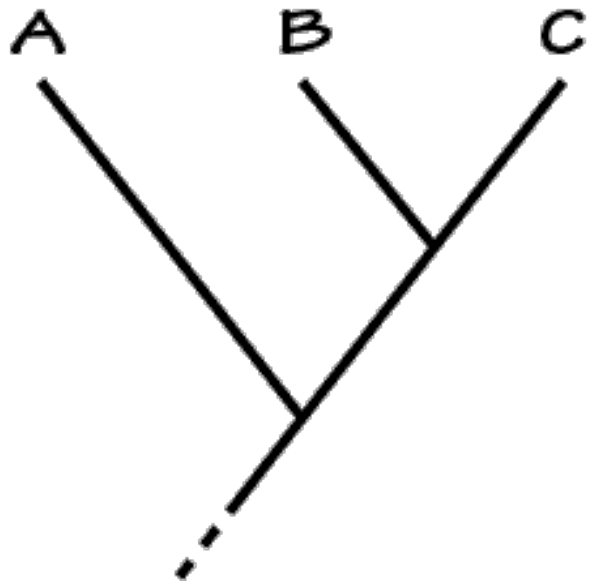

A
B
C


A
B
C
common
ancestor

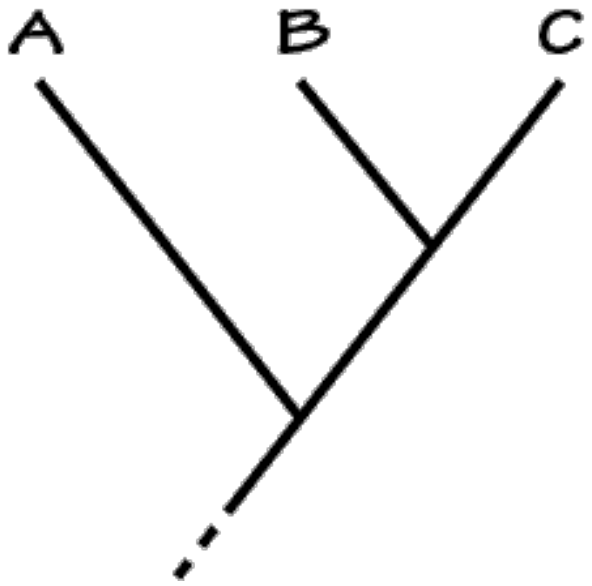


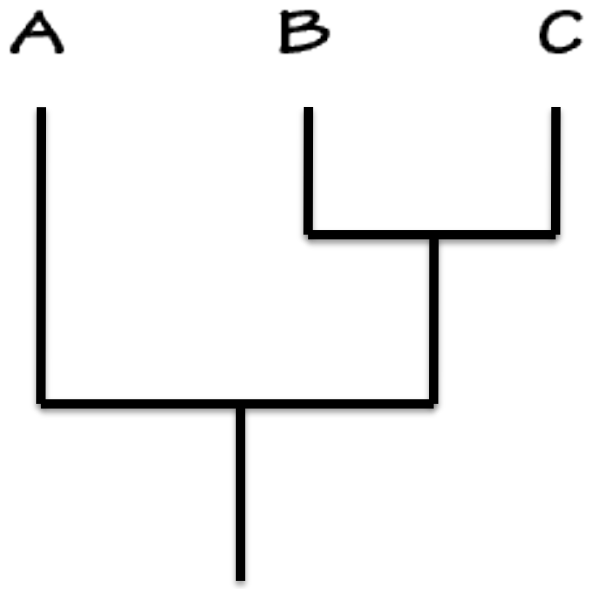
Clade:
an ancestor and all of its descendents

Evolutionary trees

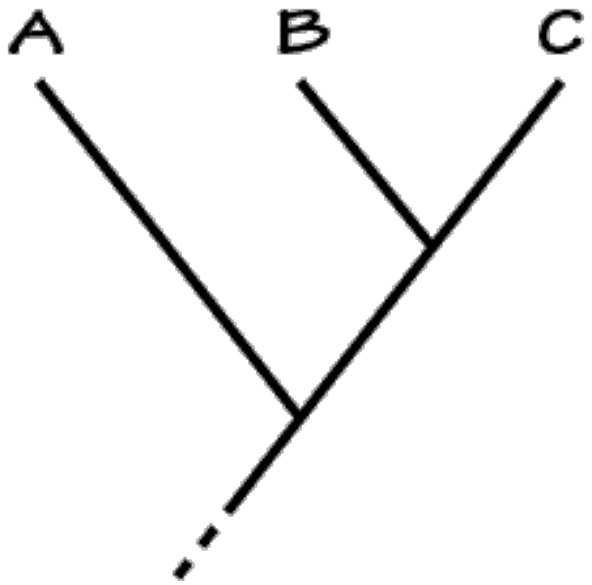


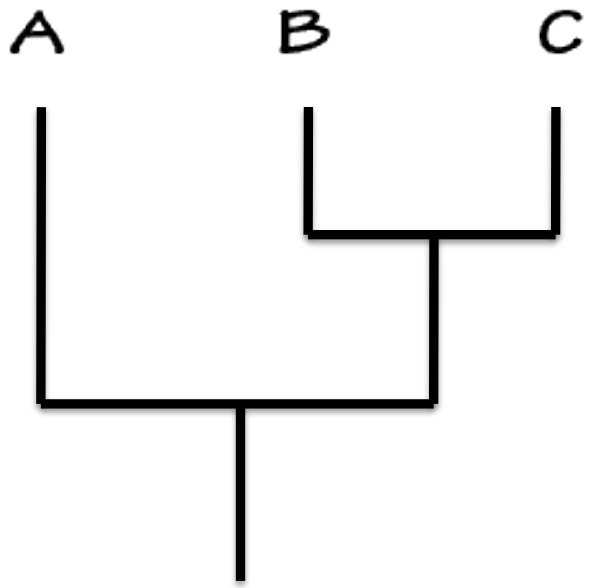
Evolutionary trees





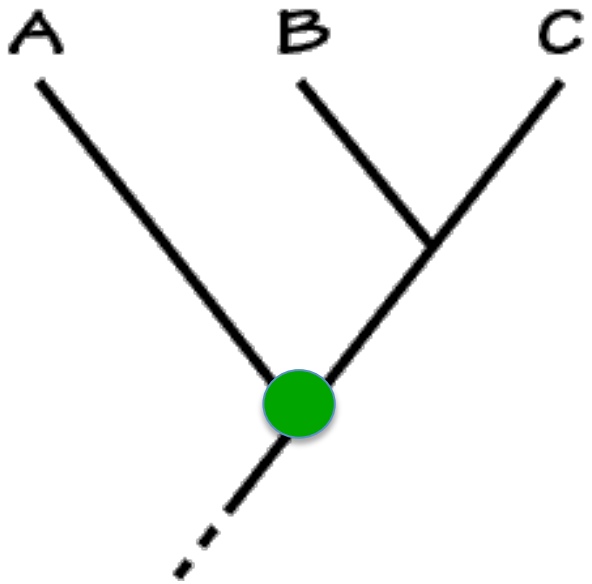
Evolutionary trees

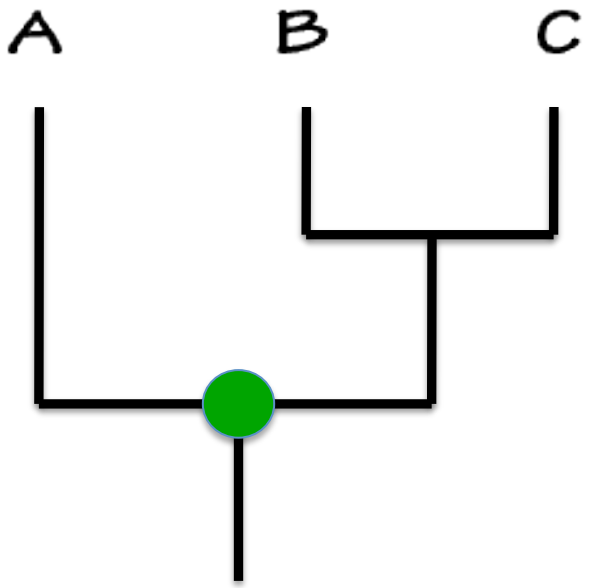




easier for students to understand

Evolutionary trees



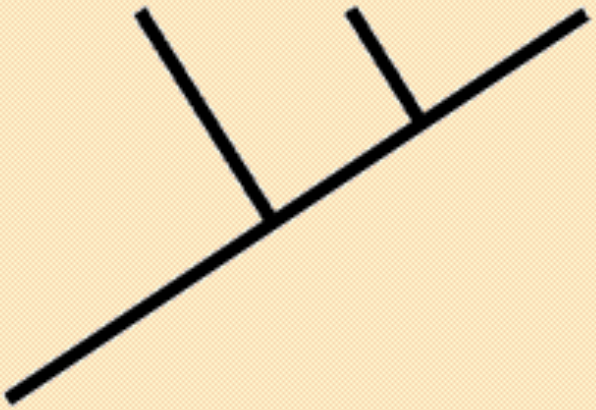


● = common ancestor

FOLDER 3:

Cladograms illustrate evolutionary relationships based upon shared inherited features.

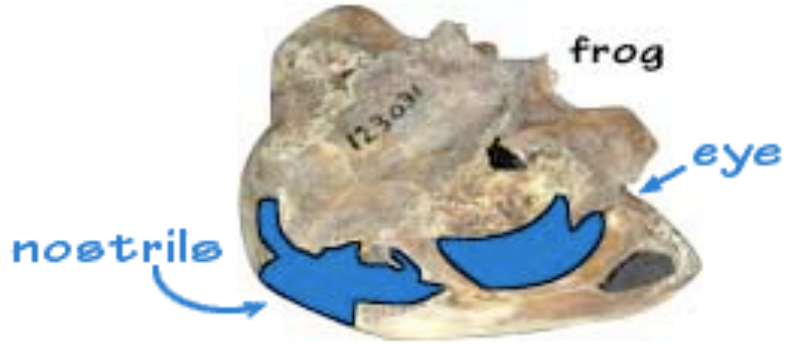
OPEN

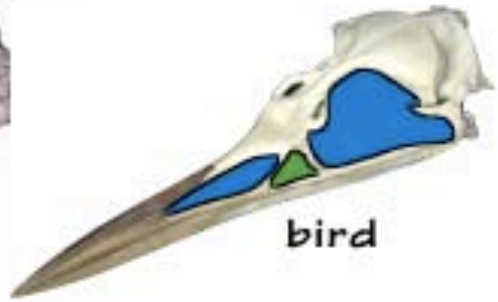



shark
tuna
frog
human
hare
caiman
parrot

The Taxa:
Their Shared Derived Characters

Features	Shark	Tuna	Frog	Human	Hare	Caiman	Parrot	T. rex
Vertebrae								
Bony Skeleton								
Four Limbs								
Amniotic Egg								
Hair								
Opening in front of eye								

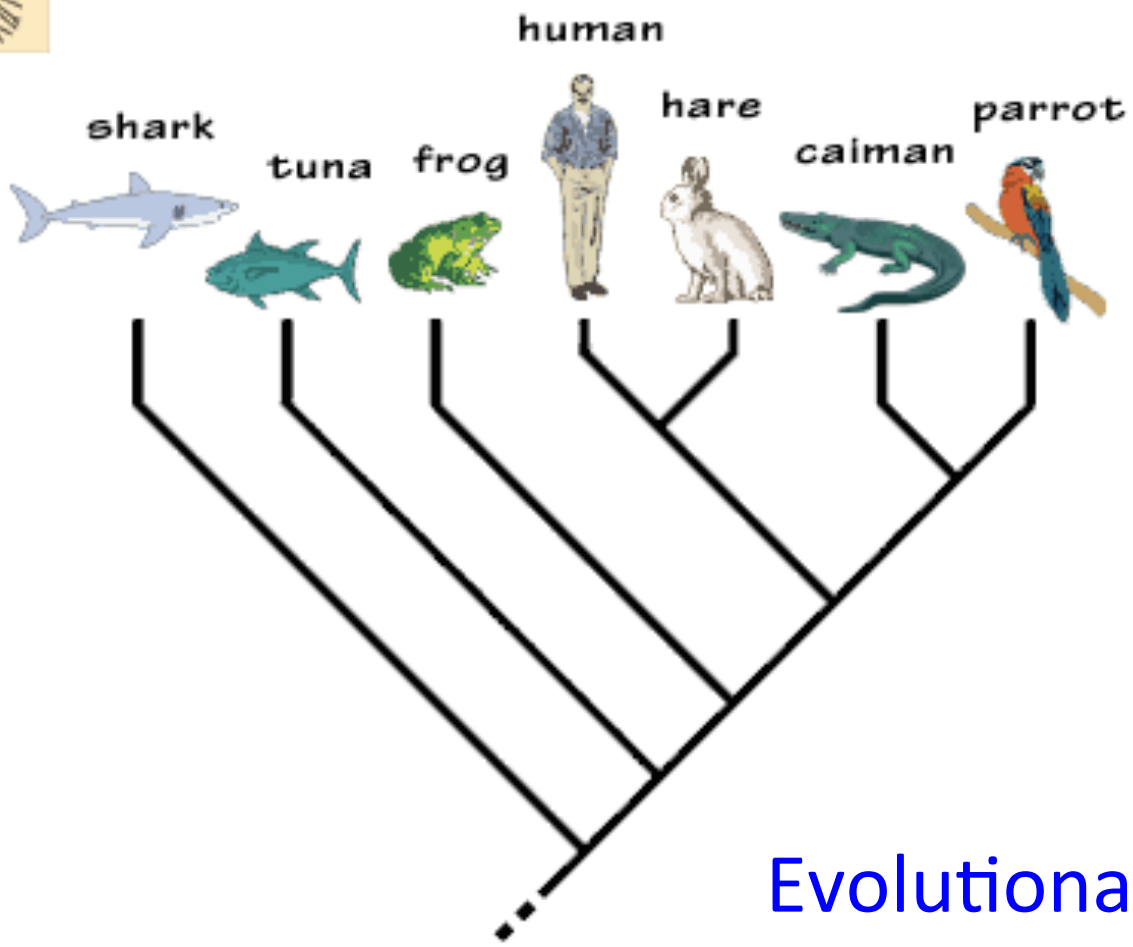




Look at the skulls of these tetrapods: the frog, human, hare, fossil crocodile, and bird.

Once again, all animals have openings for the eyes and nostrils.

more . . .

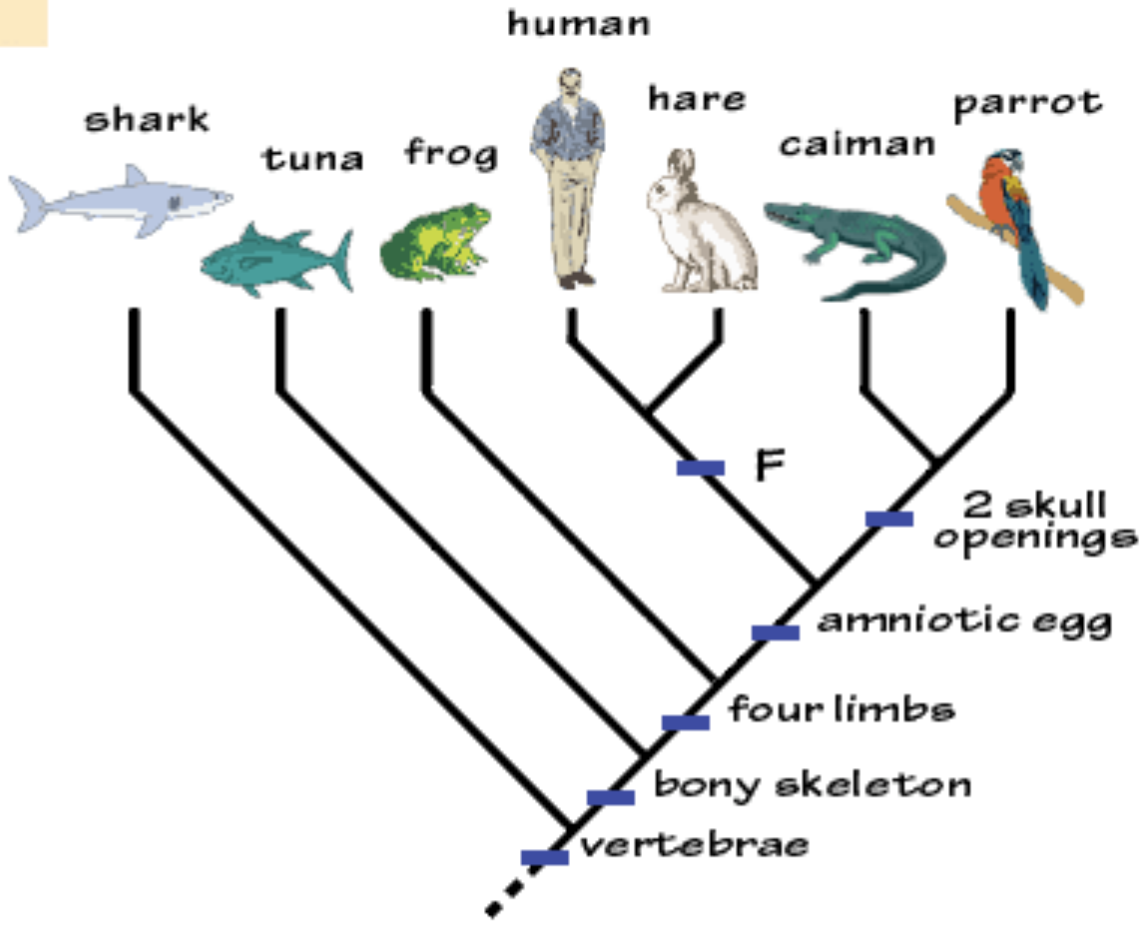


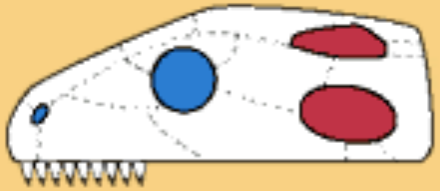
All of the animals, including the caiman and the parrot, are members of certain lineages, represented by the lines on the diagram.

We can trace each lineage back to where they intersect.

more . . .

Evolutionary Tree: A hypothesis about evolutionary relationships

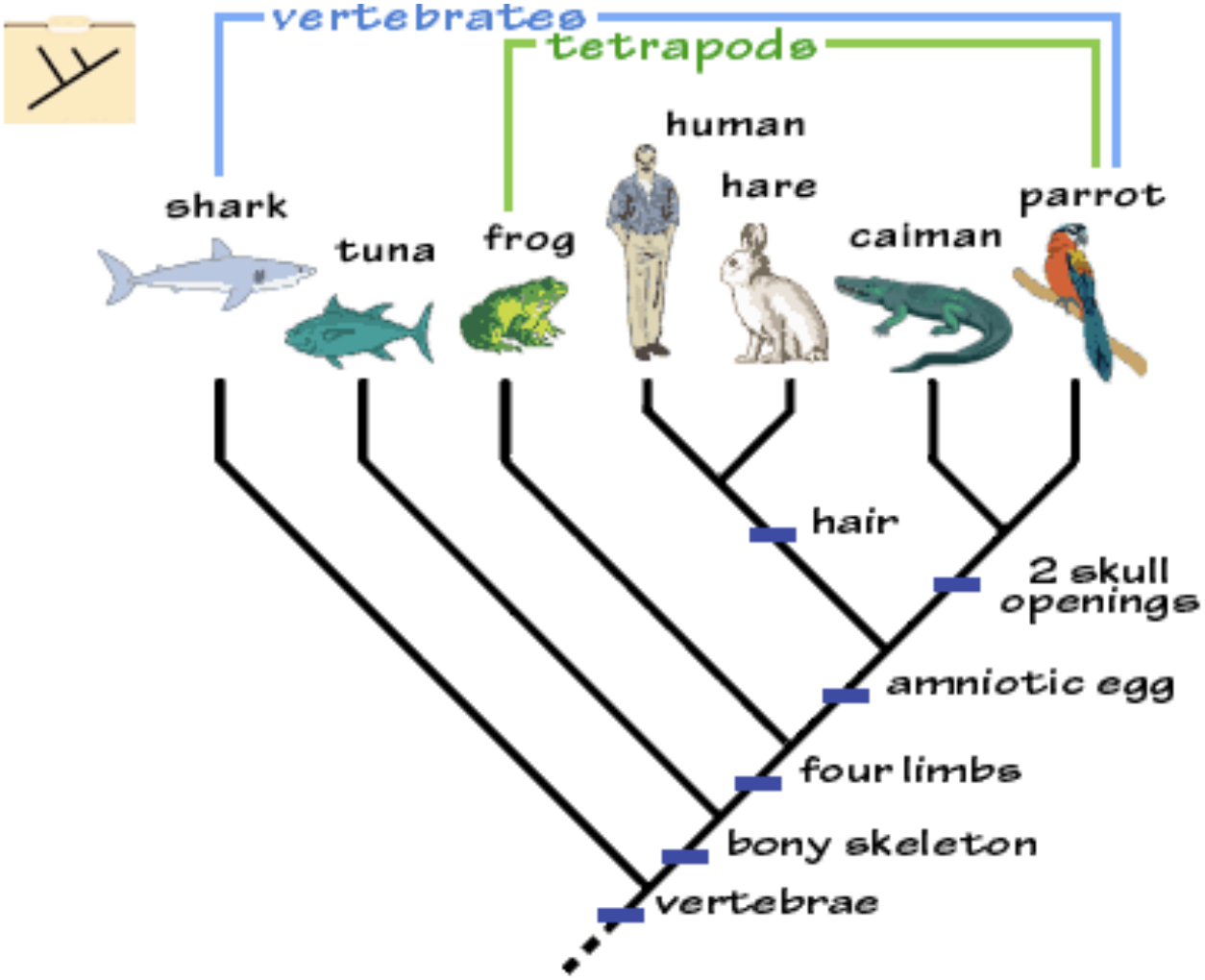




2 skull openings

Two additional openings (besides the eyes and nostrils) on the side of the skull behind the eyes. Animals with such openings are called "diapsids."

close



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

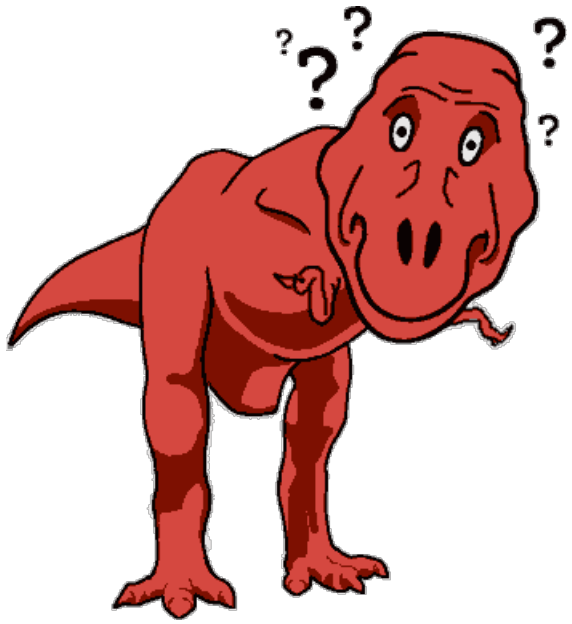
FOLDER 4:

Evolutionary relationships can be used to answer many kinds of questions about the history of life.

OPEN

What did T. rex taste like?

A. Chicken
B. Roast Beef
C. Tuna

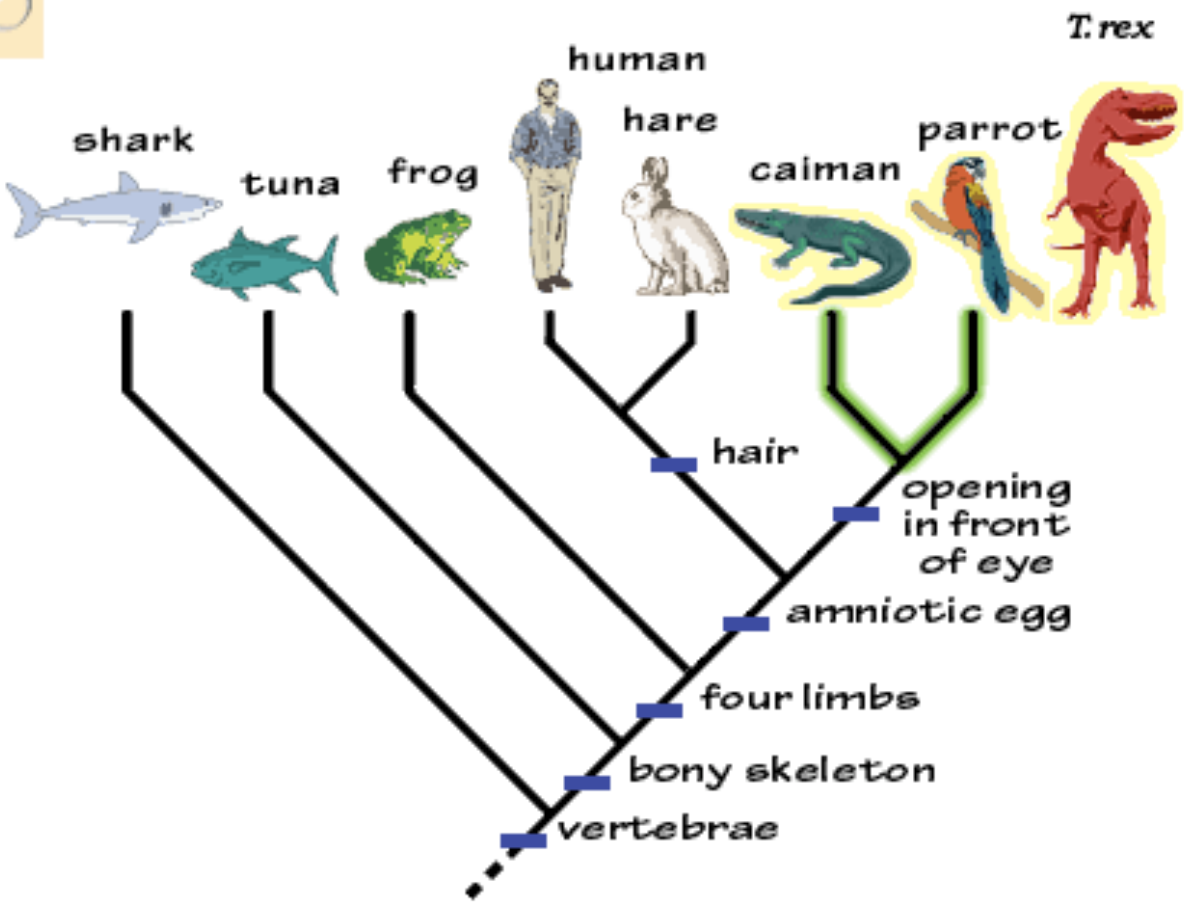


Who are T. rex's closest relatives?

Fill in the data for T. rex

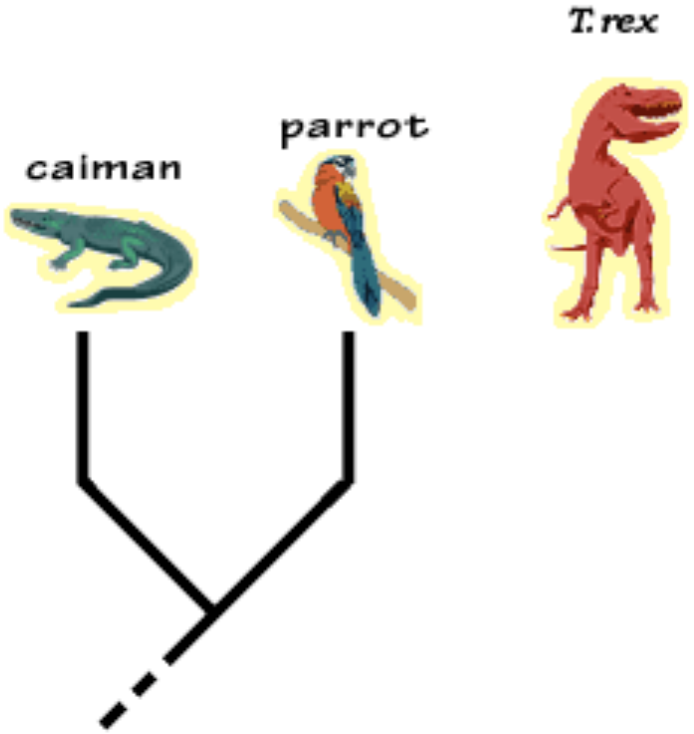
Features	Shark	Tuna	Frog	Human	Hare	Caiman	Parrot	T. rex
Vertebrae	+	+	+	+	+	+	+	
Bony Skeleton	0	+	+	+	+	+	+	
Four Limbs	0	0	+	+	+	+	+	
Amniotic Egg	0	0	0	+	+	+	+	
Hair	0	0	0	+	+	0	0	
Opening in front of eye	0	0	0	0	0	+	+	

Opening in front of eye



Now that we've narrowed it down, let's zoom in on this section of the cladogram.

more . . .



But is *T. rex* more closely related the caiman or to the parrot?

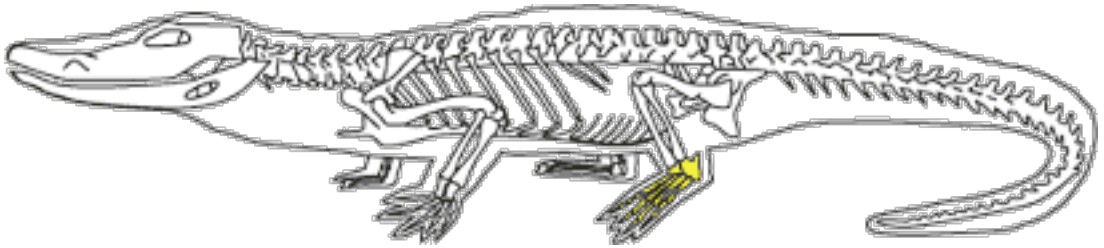
We don't have enough evidence yet.

more . . .

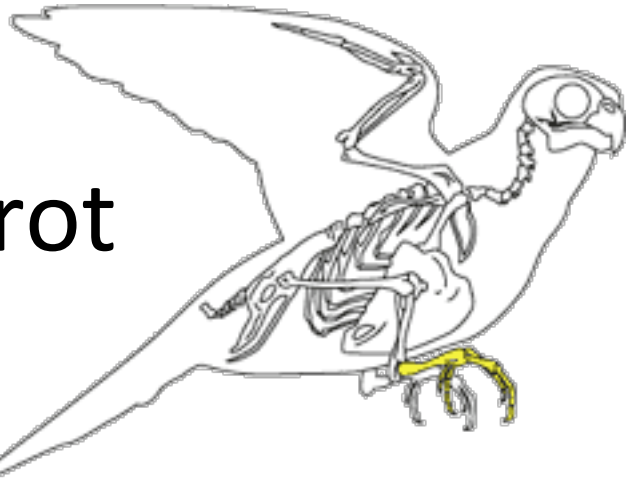
Let’s add some more characters

Features	Caiman	Parrot	T. rex
Vertebrae	+	+	+
Bony Skeleton	+	+	+
Four Limbs	+	+	+
Amniotic Egg	+	+	?
Hair	0	0	?
Opening in front of eye	+	+	+
Heel			
Bipedal			
4th and 5th finger lost			

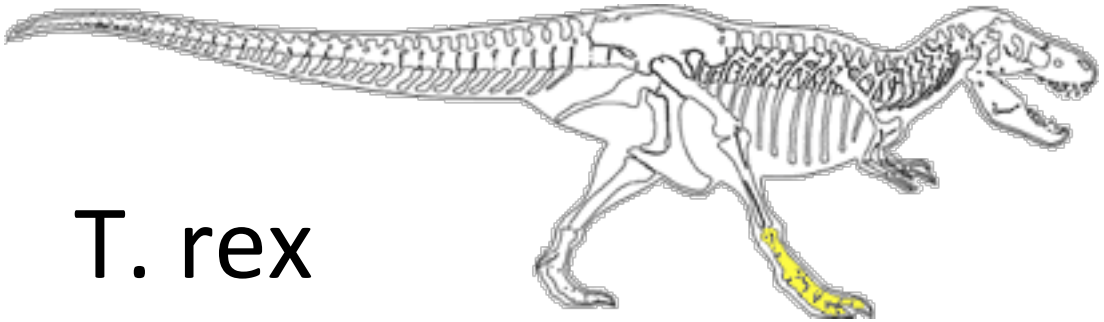
Caiman



Parrot



T. rex



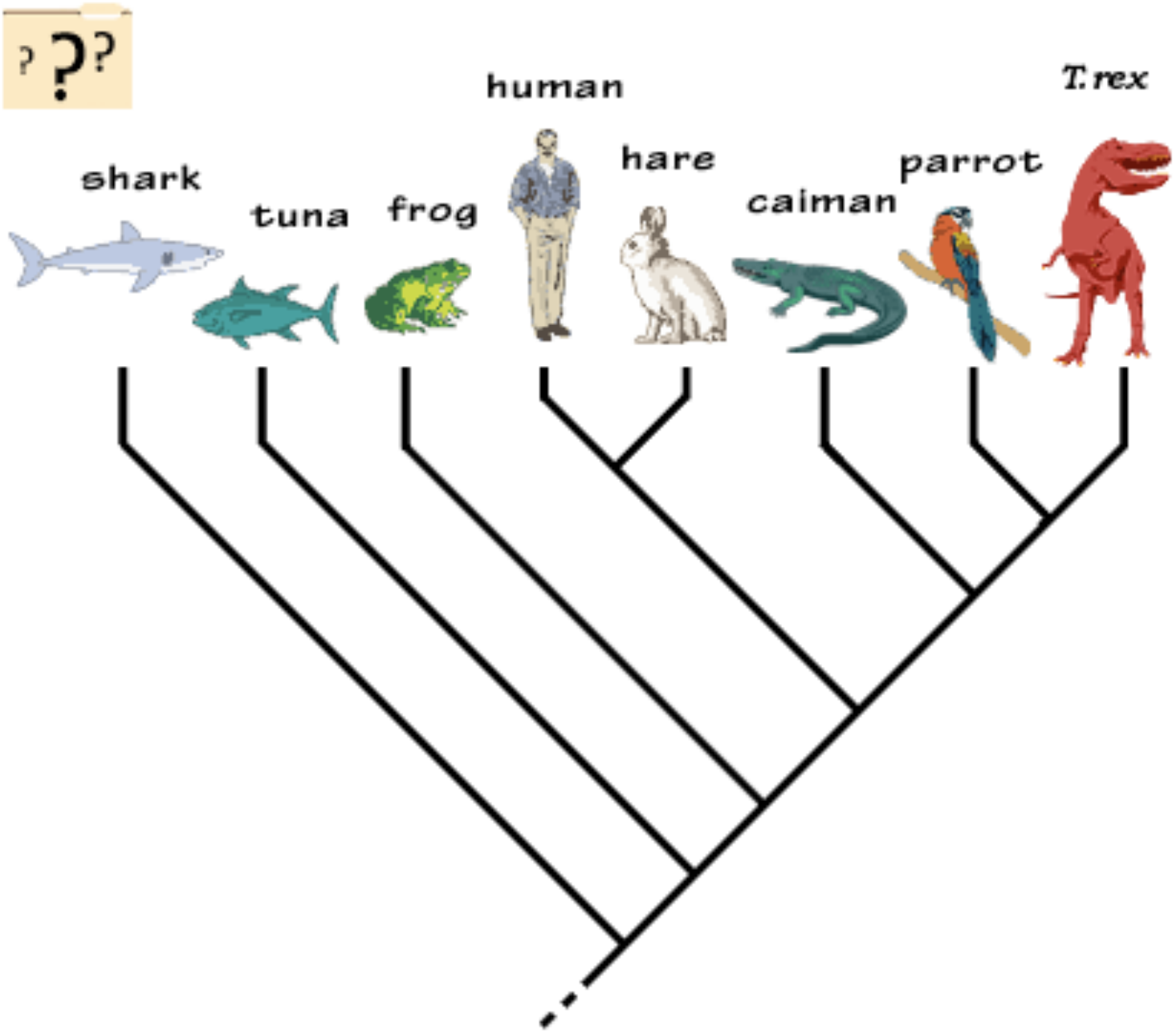
Caiman hand

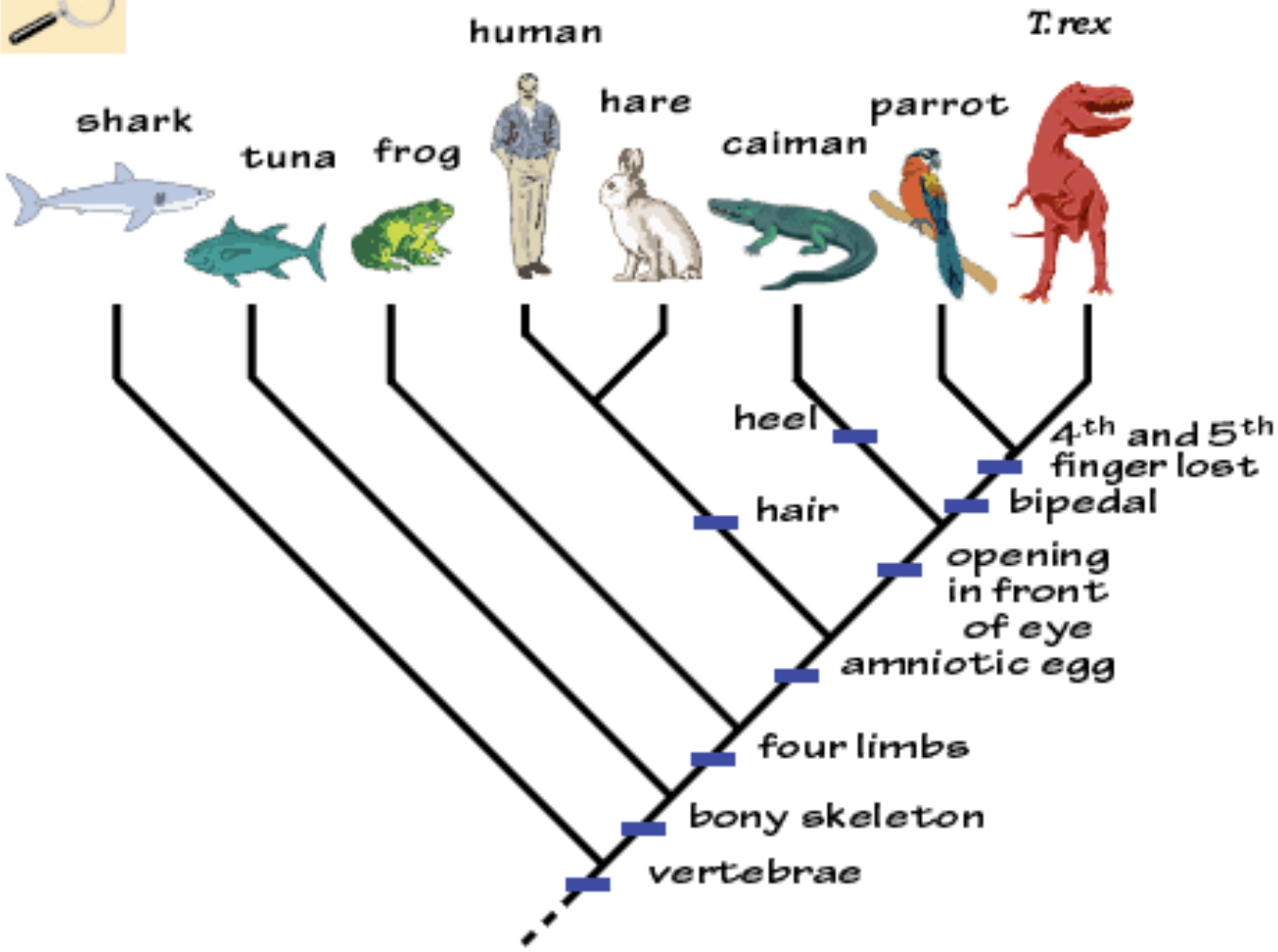
Parrot hand

T. rex hand

Let’s add some more characters

Features	Caiman	Parrot	T. rex
Vertebrae	+	+	+
Bony Skeleton	+	+	+
Four Limbs	+	+	+
Amniotic Egg	+	+	?
Hair	0	0	?
Opening in front of eye	+	+	+
Heel			
Bipedal			
4th and 5th finger lost			


?
?
?
human
T. rex
shark
tuna
frog
hare
caiman
parrot



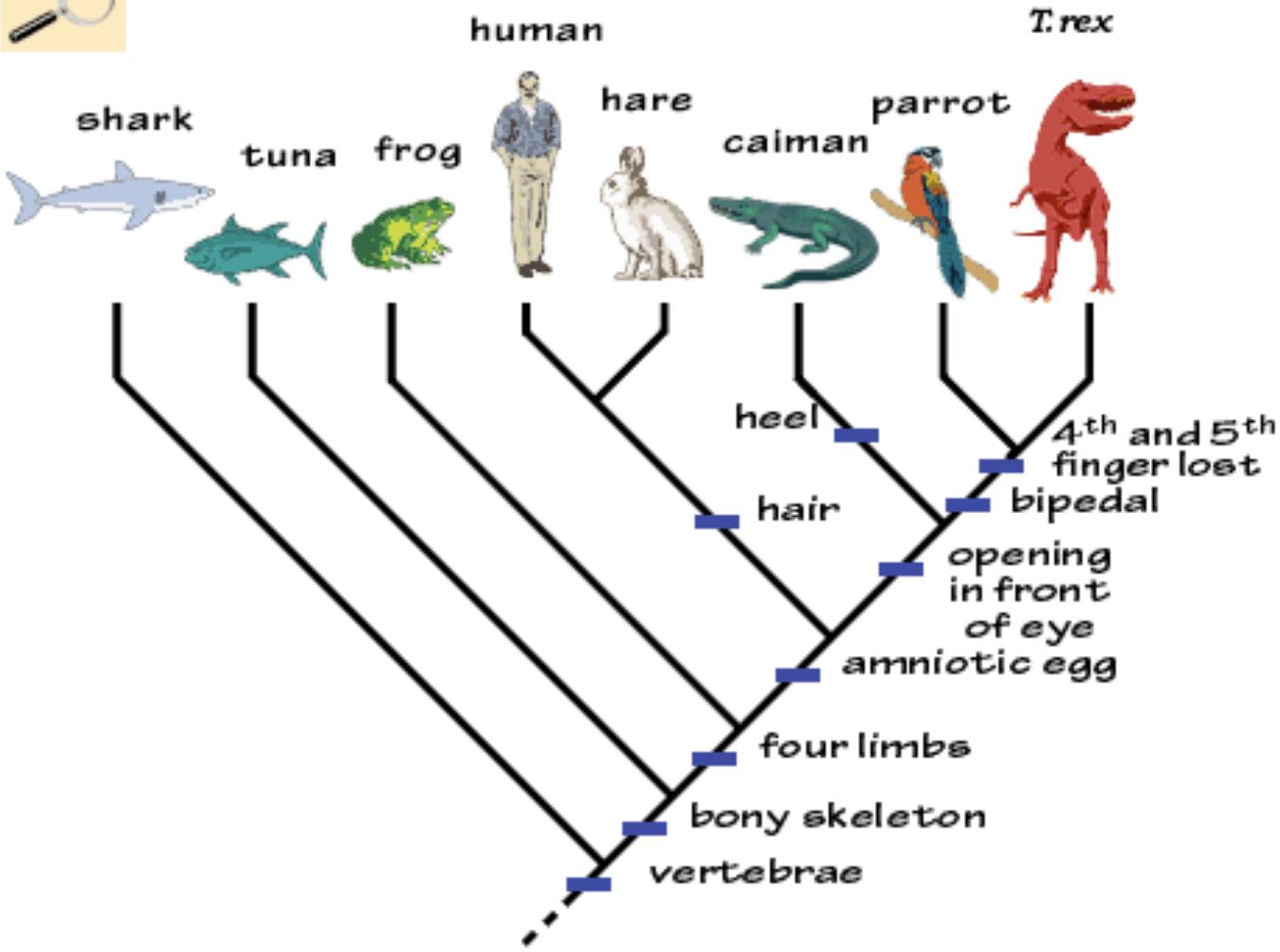
So back to our question:

What did *T. rex* taste like?

a) Chicken

b) Roast beef

b) Tuna



So back to our question:

What did *T. rex* taste like?

a) Chicken

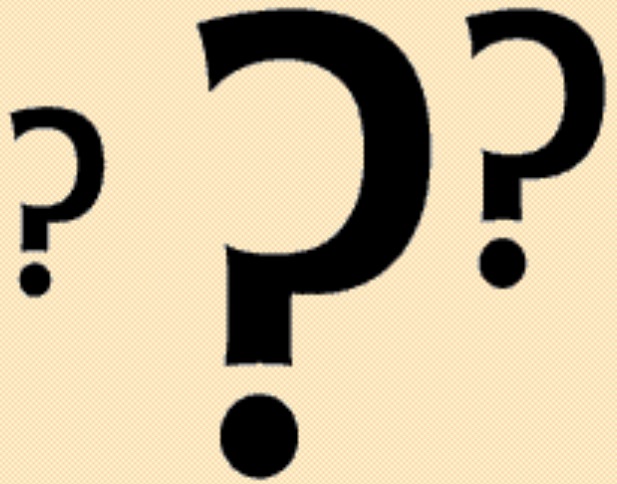
b) Roast beef

b) Tuna

FOLDER 5:

We can use cladograms to make inferences about past life, including *T. rex*.

OPEN



Special Assignment:

Solving *T. rex*'s Identity Crisis

Examine at least two of the questions below and make inferences about *T. rex*.

1) Did *T. rex* have an amniotic egg?
2) Was *T. rex* warm-blooded or cold-blooded?
3) Could *T. rex* have had feathers?
4) Did *T. rex* have color vision?
5) How many chambers were there in *T. rex*'s heart?
6) Did *T. rex* sing to its offspring?

Using your completed features table and the cladogram with additional data:

A) Decide if it is possible to answer the question with the data provided (the cladogram and data table).

B) If it is not possible, what information is needed to be able to answer the question?

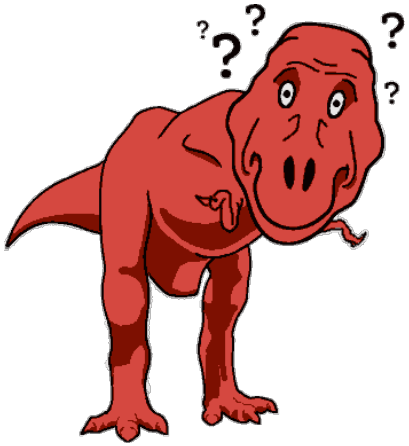
C) If it is possible, what kind of hypothesis would you make? What is the evidence for your statement? In your justification, make sure that you include information about common ancestors and shared inherited features. What other evidence would you look for that would support or refute your hypothesis?

BONUS: What other kinds of questions might be answered using the cladogram and data table?

Discussion:

What did you find surprising or interesting about the hands-on activities?

Do you think these or similar activities could work in your classroom?



Teaching Resources from Understanding Evolution & Understanding Science


Understanding Evolution
your one-stop source for information on evolution

- Produced by the University of California Museum of Paleontology
- Receives 60,000 page accesses per month
- Portions translated in to Spanish, Turkish, and Tibetan
- Winner of *Science* Magazine's *Science* Prize for Online Resources in Education (SPORE) award in 2010
- www.evolution.berkeley.edu

Teaching materials

Evolution is essential to our curriculum and to scientific literacy. Imagine teaching social science without teaching history; students would lack perspective on events going on today. Similarly, to understand the big picture of biology, students need to understand life on Earth in terms of its history and its future — the changing life forms and ecosystems that have arisen and changed over billions of years, as well as the mechanisms that have brought about those changes.

The *Understanding Evolution* project aims to help instructors develop student understanding of:

- Basic evolutionary patterns and processes
- Evolutionary theory's ability to explain phenomena across the many subdisciplines of biology
- The many applications of evolutionary theory, both in solving real world problems and in scientific research
- The evidence supporting evolutionary theory

As is true of any subject, to teach evolution successfully, teachers need to be prepared with a conceptual understanding of the topic and with effective curricular strategies. Teachers that develop a depth of knowledge beyond what is actually expected of students will be able to confidently adjust instruction in response to students' needs and inquiries. This is particularly true in the teaching of evolution, where students' questions can be numerous and challenging.

We've assembled a variety of resources to help you increase student understanding of evolution. To improve your own content knowledge, explore Evolution 101 and our

TEACHERS' LOUNGES
K-2 | 3-5 | 6-8 | 9-12 | UNDERGRAD

ALL-LEVEL RESOURCES
Guide to Evo 101
Teaching resource database
Image library
Dealing with objections to evolution
Correcting misconceptions

Lesson summary for:

What did T. Rex Taste Like?

Go to this lesson now! >>

Overview:
In this web-based module students are introduced to cladistics, which organizes living things by common ancestry and evolutionary relationships.

Author/Source:
UC Museum of Paleontology

Grade level:
9-12

Time:
Two to four class periods.

Concepts:

- Biological evolution accounts for diversity over long periods of time.
- An organism's features reflect its evolutionary history.
- Similarities among existing organisms provide evidence for evolution.
- Anatomical similarities of living things reflect common ancestry.

Lesson summary for:

Clipbirds

Go to this lesson now! >>

Overview:
Students learn about variation, reproductive isolation, natural selection, and adaptation through this version of the bird beak activity.

Author/Source:
UC Museum of Paleontology

Grade level:
9-12

Time:
One class period

Concepts:

- Evolution results from selection acting upon genetic variation within a population.
- Traits that confer an advantage may persist in the population and are called adaptations.
- Inherited characteristics affect the likelihood of an organism's survival and reproduction.
- Depending on environmental conditions, inherited characteristics may be advantageous, neutral, or

Toxic river means rapid evolution for one fish species

March 2011

Though we often think of evolution as occurring at a snail's pace, one fish species is highlighting just how quickly evolution occurs — in the right circumstances. Between 1947 and 1976, General Electric released more than a million pounds of PCBs into the Hudson River. PCBs can kill fish and seabirds and have been linked to cancer and other serious health problems in humans. PCBs were banned in 1979, but the toxins have remained at high levels in the Hudson because they settle into the sediments on the bottom of the river and don't break down. Now, scientists have discovered that, over the past 60 years, one bottom-feeding fish species, the Atlantic tomcod, has evolved resistance to PCBs. Though this evolutionary shift is good news for tomcod, it may put the rest of the food web, which depends on this species, in jeopardy.

Where's the evolution?

Hudson River tomcod evolved resistance to PCBs in the same way that a population of bacteria may evolve resistance to antibiotics over the course of a few hours and in the same way that a mammal species might evolve a camouflaged coat over the course of millennia: natural selection. Though the timescales involved are different, the basic process works the same way. Mutation generates random genetic variation (e.g., an individual with a mutation that happens to protect the organism from PCBs) in a population. When the population experiences a challenge (e.g., exposure to high levels of PCBs), individuals carrying genes that allow them to better survive and reproduce in that

Identify your learning goals

At the end of the school year, there are certain conceptual understandings that we want our students to have. Achieving these learning goals lays the groundwork for more sophisticated understandings as students proceed through their learning experiences. The *Understanding Evolution* Conceptual Framework is an effective tool for identifying a sequence of age-appropriate conceptual understandings (K-16) to guide your teaching. The Framework is divided into five strands, and a selection of teaching resources (i.e., lessons, activities, readers, and interactive online modules) targeting most concepts has been identified.

Jump to: History of Life | Evidence of Evolution | Mechanisms of Evolution | Nature of Science | Studying Evolution

Click here for a printable version.

History of Life concepts for undergraduates

1. **Biological evolution accounts for diversity over long periods of time. (See Lessons)**
   a. Through billions of years of evolution, life forms have continued to diversify in a branching pattern, from single-celled ancestors to the diversity of life on Earth today.
   b. Life forms of the past were in some ways very different from living forms of today, but in other ways very similar. (See Lessons)

Avoid common teaching pitfalls

Ever wonder if your students left class confused? Confusion can be a good thing if it causes students to think through ideas for themselves and find solutions. But sometimes confusion leads to persistent mistaken impressions or to major misconceptions. Here are a few things you can do to avoid unintentional confusion when it comes to teaching your students about evolution:

1. **Choosing your words carefully**
   - Function not purpose
   - Adaptation not design
   - Evolution not development
   - Accept not believe
   - Evidence not proof
2. **Clarifying misconceptions**
   - Adapt
   - Randomness
   - Ancestor versus relative
   - Neither primitive nor advanced
   - Confusing evidence with causation
   - Theory versus hypothesis
3. **Scientific terms that leave the wrong impression**
   - Survival of the fittest
   - Transitional features not missing links
   - The Cambrian explosion
4. **Handling bad press and sloppy science**

TEACHERS' LOUNGES
K-2 | 3-5 | 6
9-12 | UNDERGR
ALL-LEVEL RESOURC
Guide to Evo 101
Teaching resource database
Image library
Dealing with objecti to evolution
Correcting misconceptions

Misconceptions about evolution and the mechanisms of evolution

Unfortunately, people have misconceptions about evolution. Some are simple misunderstandings; ideas that develop in the course of learning about evolution, possibly from school experiences and/or from the media. Other misconceptions may stem from purposeful attempts to interfere with the understanding of evolution.

Below you will find a series of common misconceptions about evolution that link to responses which correct these misconceptions.

Misconceptions about evolution and how it works:

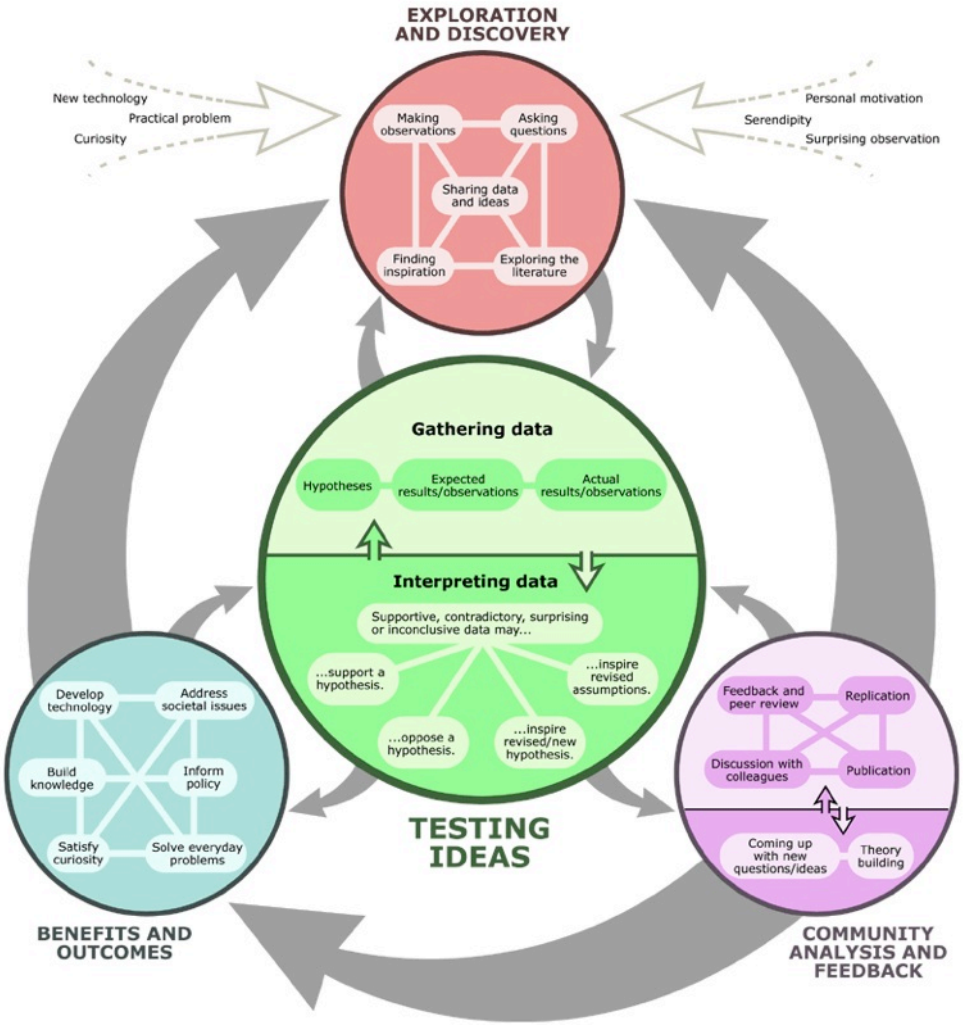
1. "Evolution is a theory about the origin of life."
2. "Evolution is like a climb up a ladder of progress; organisms are always getting better."
3. "Evolution means that life changed 'by chance.'"
4. "Natural selection involves organisms 'trying' to adapt."
5. "Natural selection gives organisms what they 'need.'"

Misconceptions about the evidence for evolution:

1. "Evolution is 'just' a theory."
2. "Evolution is a theory in crisis and is collapsing as scientists lose confidence in it."

- Developed because misconceptions about evolution stem from misconceptions about science
- Communicates what science really is and how it works
- Produced by the University of California Museum of Paleontology
- www.understandingscience.org

How science works: The flowchart



Asteroids and dinosaurs: Unexpected twists and an unfinished story

Plate tectonics might seem like a routine topic from a 7th grade textbook, but in the 1970s, plate tectonics was cutting-edge science. The theory had only gained widespread acceptance over the previous ten years and subsequently attracted scads of scientists looking to open up new intellectual frontiers. Walter Alvarez was one of them, but his research into plate tectonics was destined to be sidelined. An intriguing observation would eventually lead him, his collaborators, and the rest of science on an intellectual journey across geology, chemistry, paleontology, and atmospheric science — towards solving one of the great mysteries in Earth's history: What happened to the dinosaurs?

This entire section is available as a PDF download.

Are dinosaurs really completely extinct?

Well, most dinosaurs are. But one lesser known lineage of dinosaurs survived the KT extinction and might be fluttering outside your window at this moment: birds! Many separate lines of evidence suggest that modern birds are a branch off the dinosaur family tree — they're closely related to *T. rex* — which technically makes them dinosaurs. So the "dinosaur extinction" really refers to the

Science checklist:
How scientific is it?

- ☑ Focuses on the natural world
- ☑ Aims to explain the natural world
- ☑ Uses testable ideas
- ☑ Relies on evidence
- ☑ Involves the scientific community
- ☑ Leads to ongoing research
- ☑ Benefits from scientific behavior


Science
Everyone gets in, as long as they behave scientifically.
ALL PATRONS MUST EXPOSE THEIR IDEAS TO TESTING. THANK YOU.

Thank you!