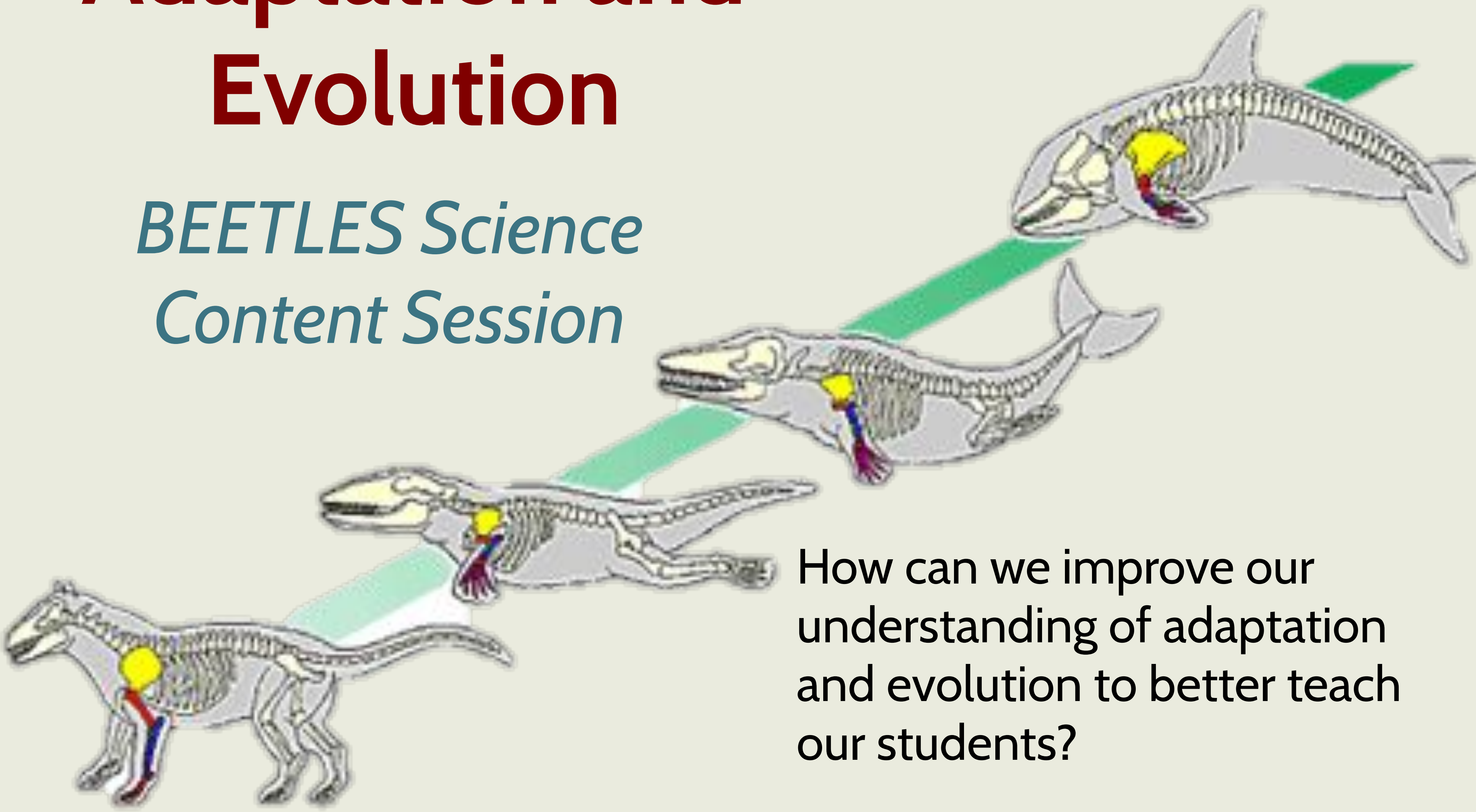
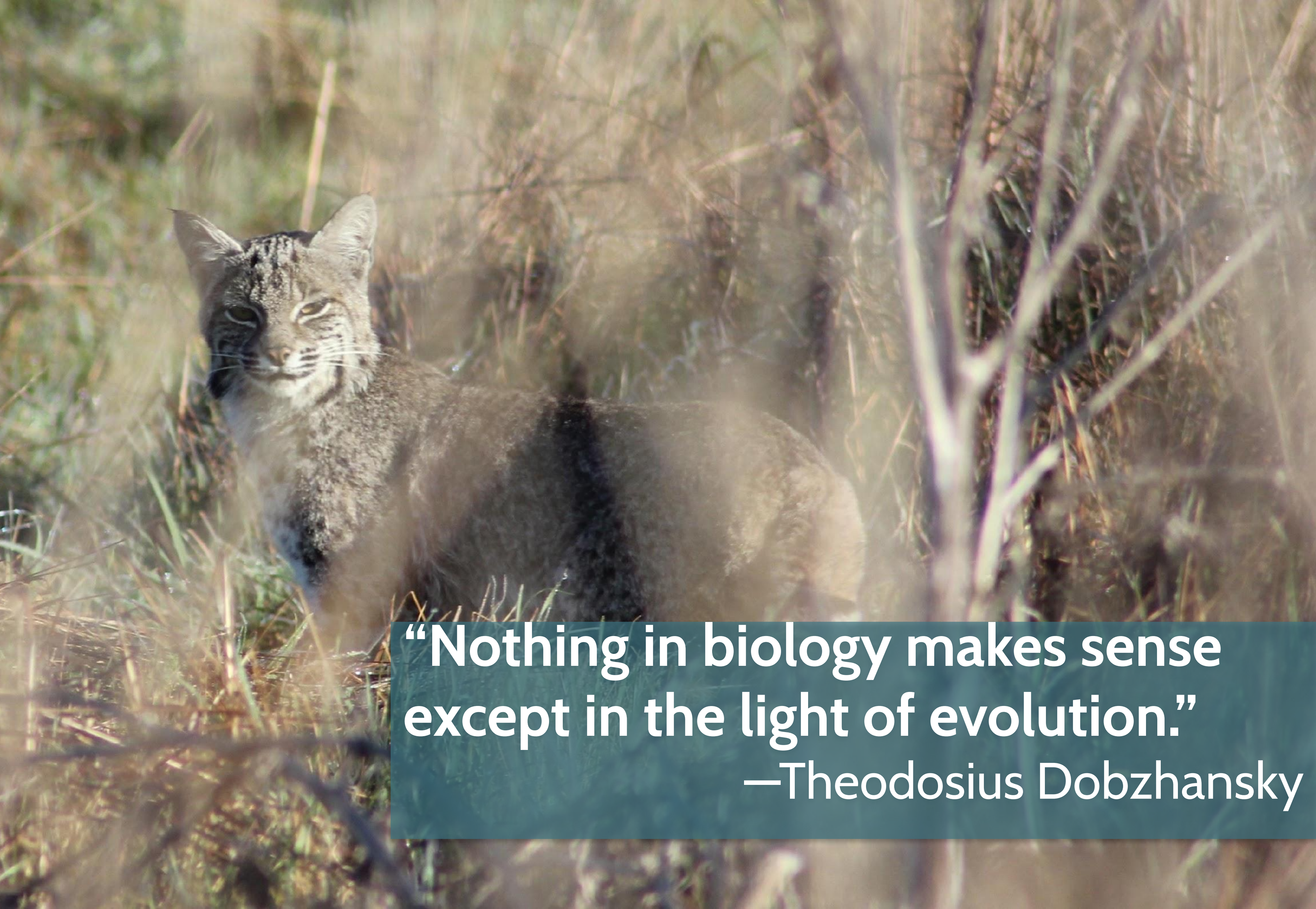
Adaptation and Evolution

BEETLES Science Content Session



How can we improve our understanding of adaptation and evolution to better teach our students?


"Nothing in biology makes sense except in the light of evolution."
—Theodosius Dobzhansky

“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 . . . as well as the mechanisms that have brought about those changes.”

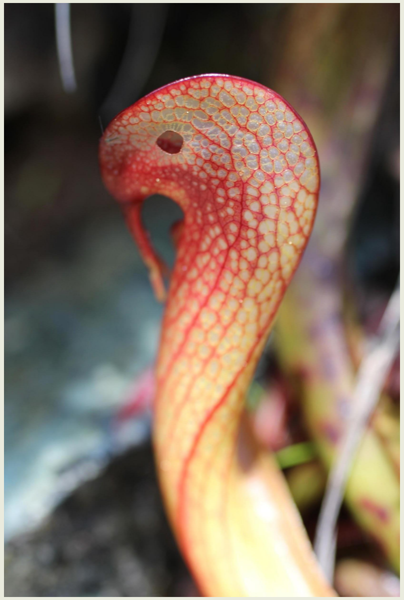
—University of California Museum of Pa

Understanding Evolution

Goals for the Session

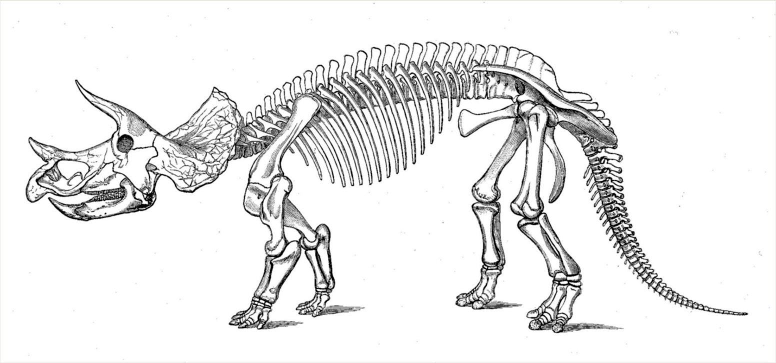
- Improve understanding of and increase curiosity about adaptation and evolution.
- Learn to use related scientific terms and refer to concepts accurately with students.
- Recognize some common misconceptions.
- Communicate understandings and engage in meaning-making conversations about evolutionary theory.
- Think about how to make choices about teaching students with different levels of understanding.

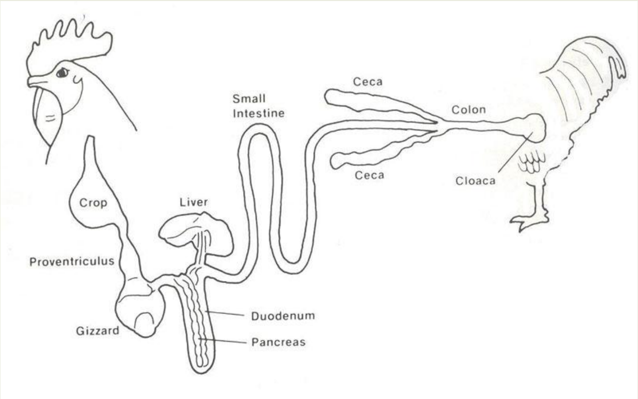
Explaining an Interesting Adaptation



What might have happened for this trait or feature of the organism to evolve?

Looking at Similarities and Differences in Organisms





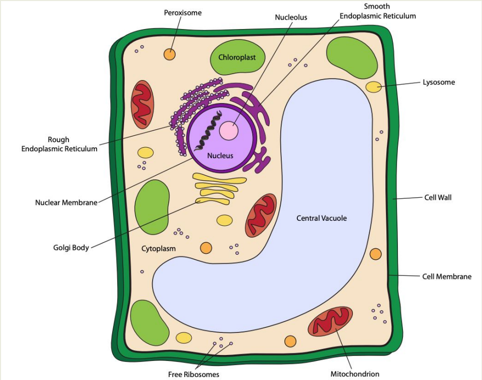
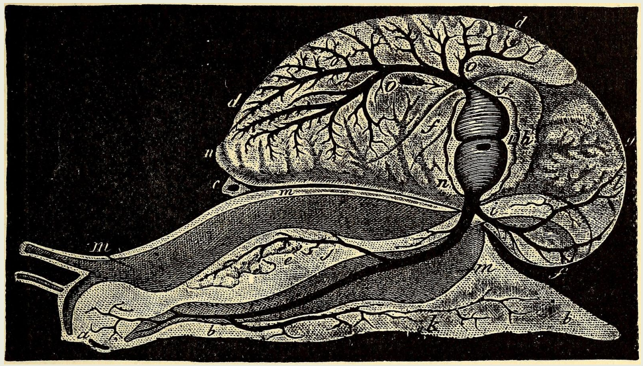
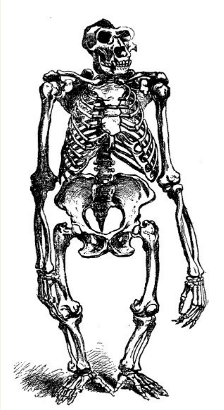


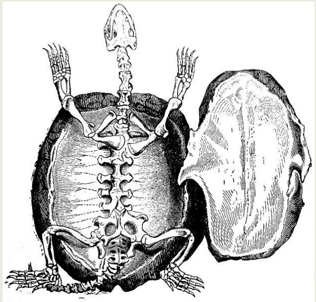
Figure 3. A typical plant cell.

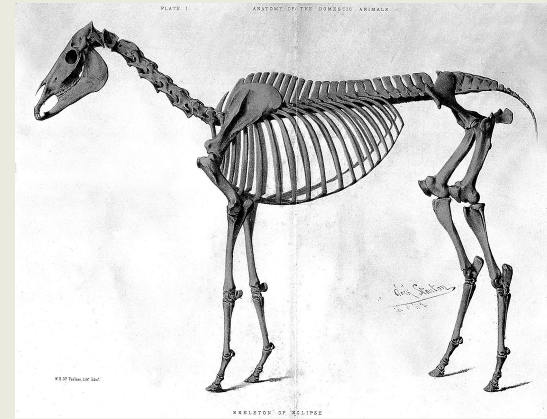


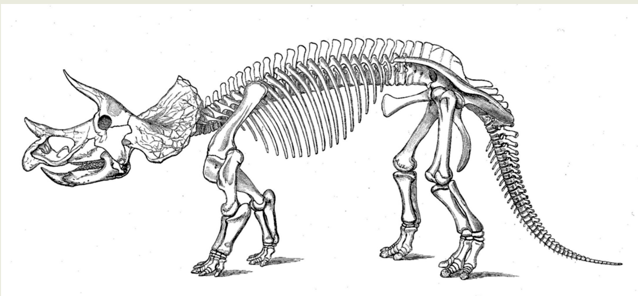
Vertebrate Skeletons

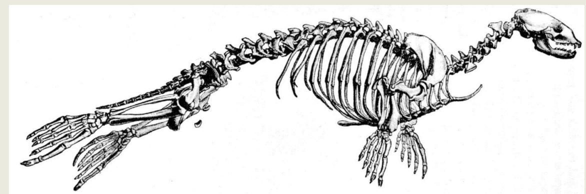
What are similarities and differences between skeletons of different kinds of vertebrates?

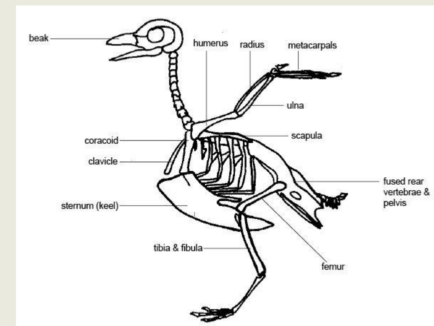












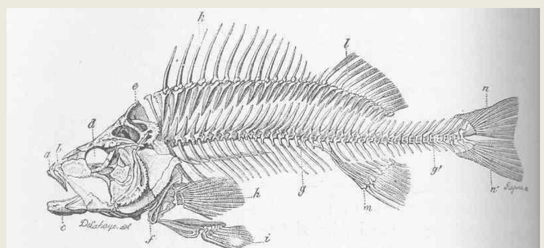
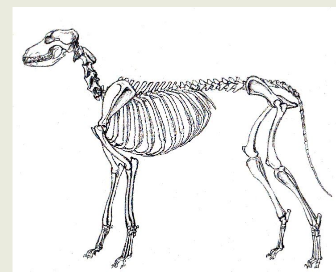
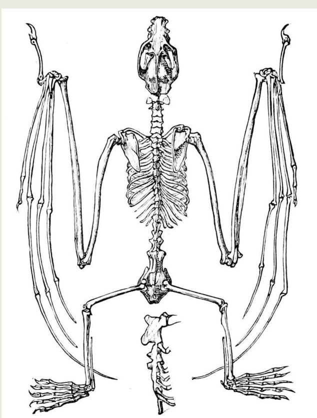
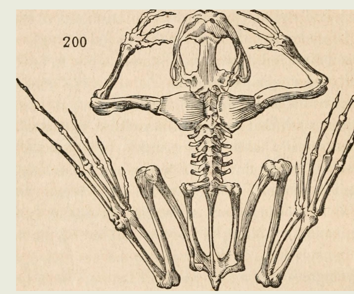


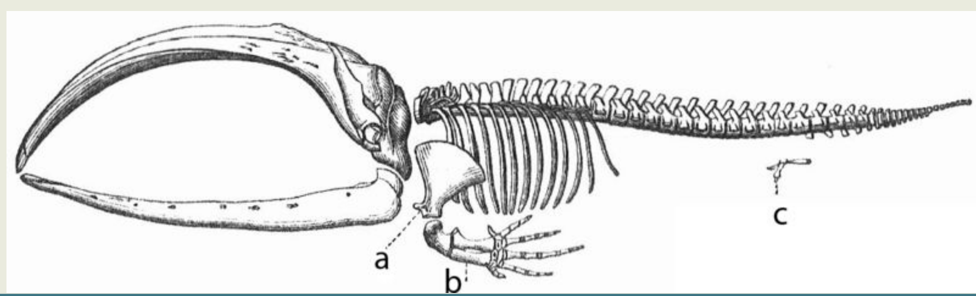
Fig. 339. Skeleton of the Common Perch



Dog Skeleton (after Ellenberger)



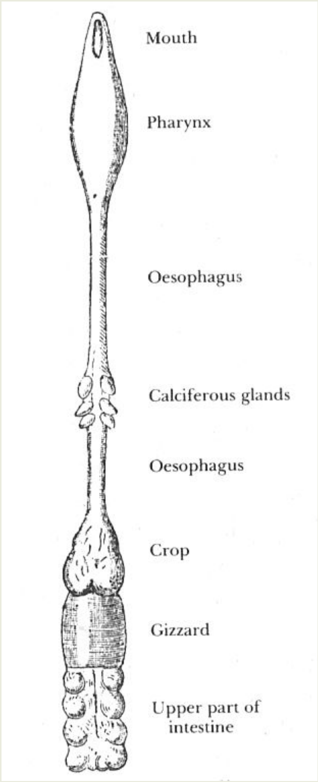




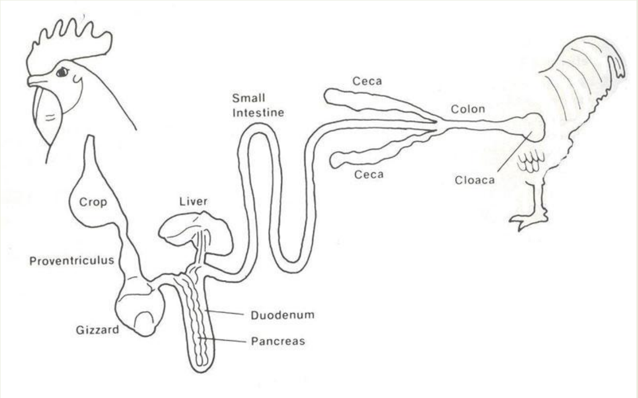
Digestive Systems

What are similarities and differences between digestive systems of invertebrates and vertebrates?

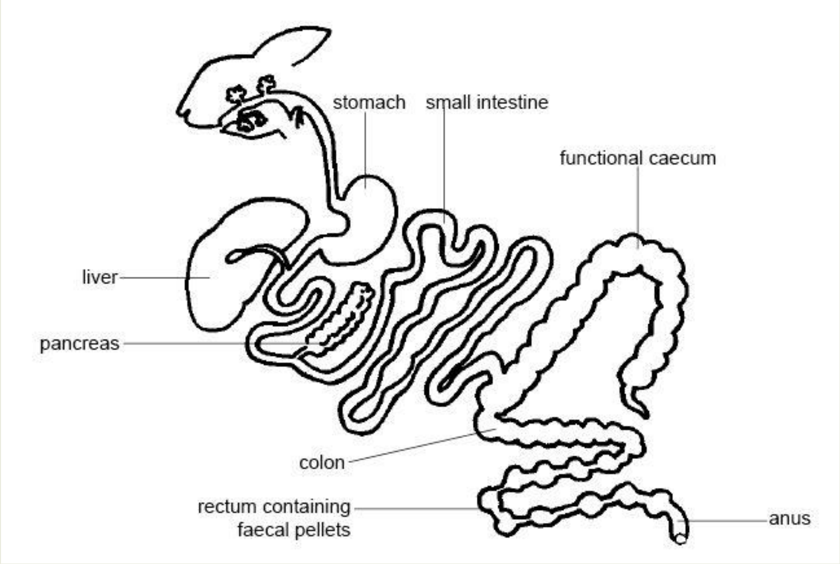
Worm



Bird



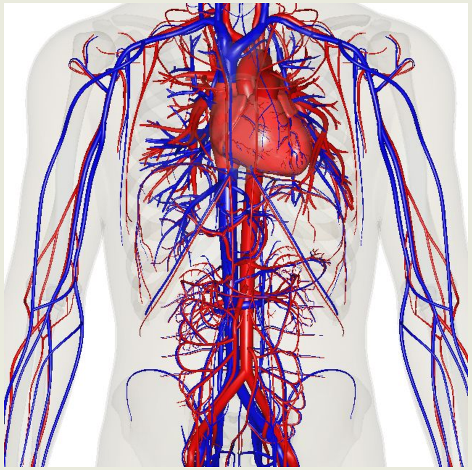
Rabbit



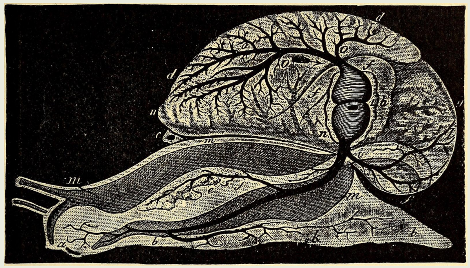
Vascular Systems

What are similarities and differences between vertebrate, invertebrate, and plant vascular systems?

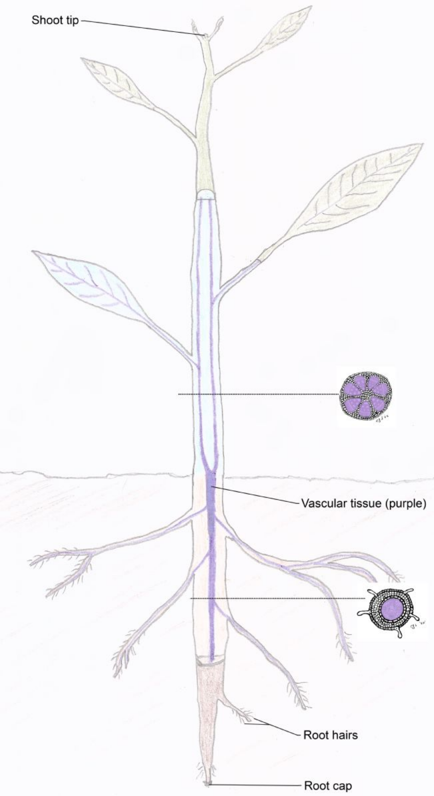
Vertebrate Vascular System



Invertebrate Vascular Systems



Plant Vascular System



Cells

What are similarities and differences between animal, plant, and bacterial cells?

Bacterial Cell

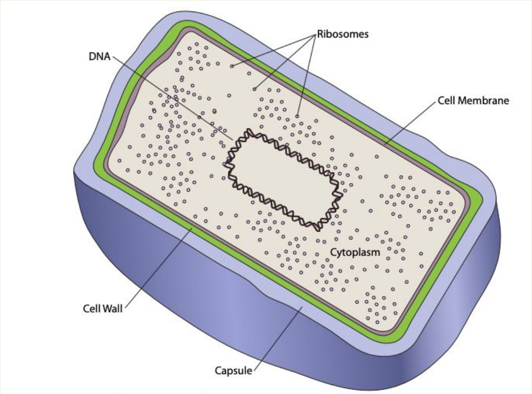


Figure 1. A Prokaryotic Cell.

Animal Cell

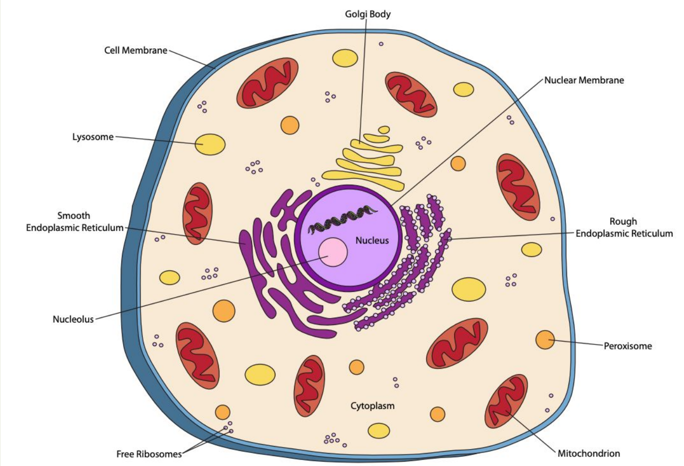


Figure 2. A prototypical animal cell.

Plant Cell

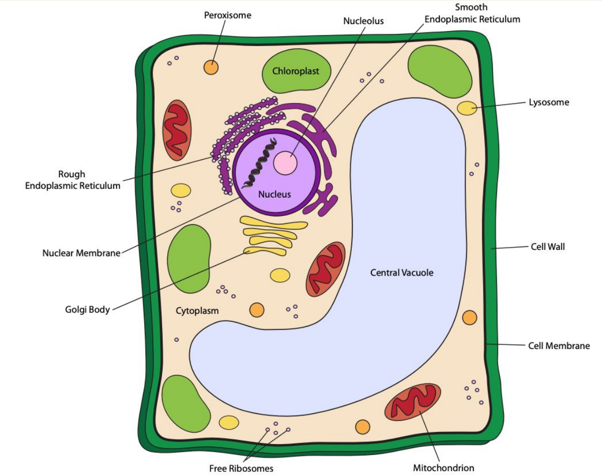
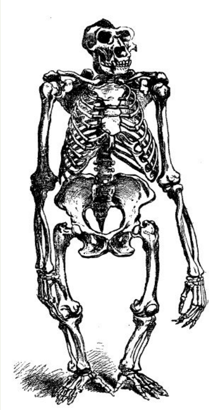
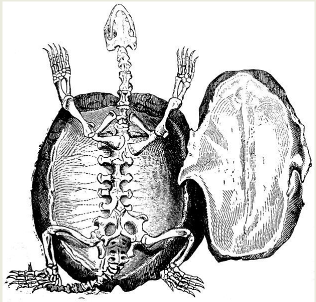


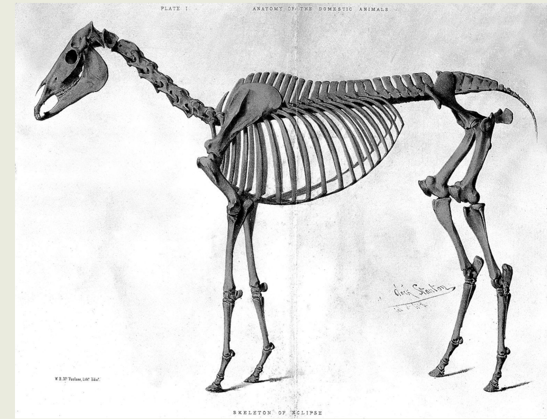
Figure 3. A typical plant cell.

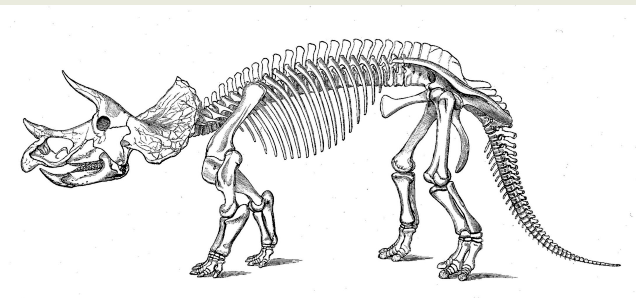
Homologous Structures

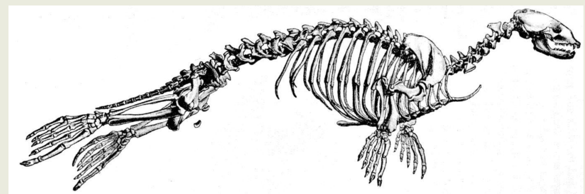
Similar structures in different organisms

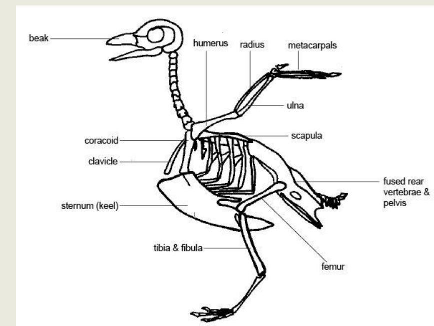


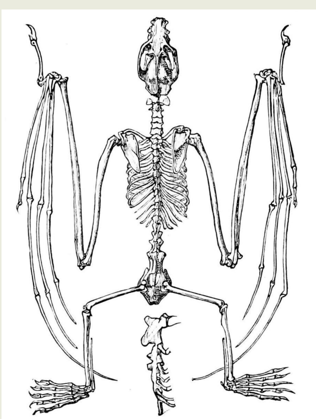












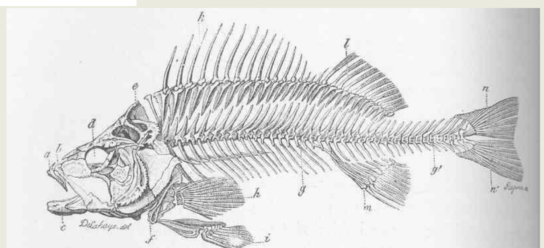
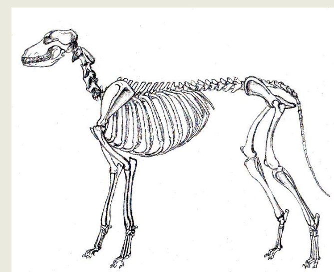


Fig. 339. Skeleton of the Common Perch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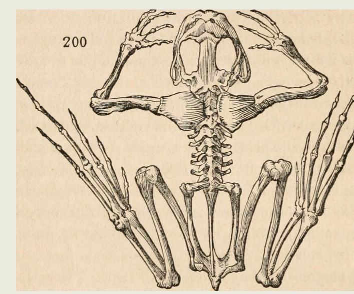
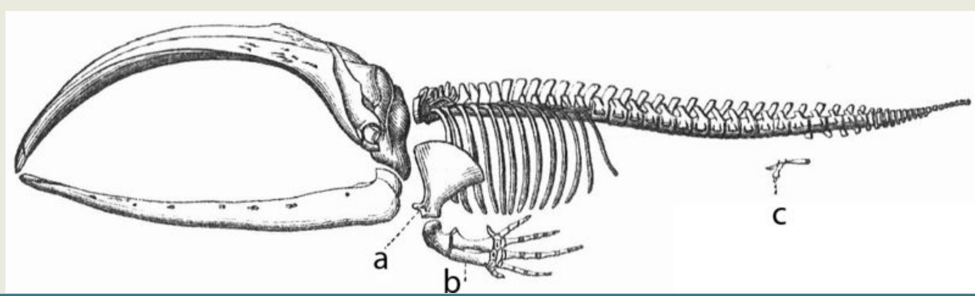
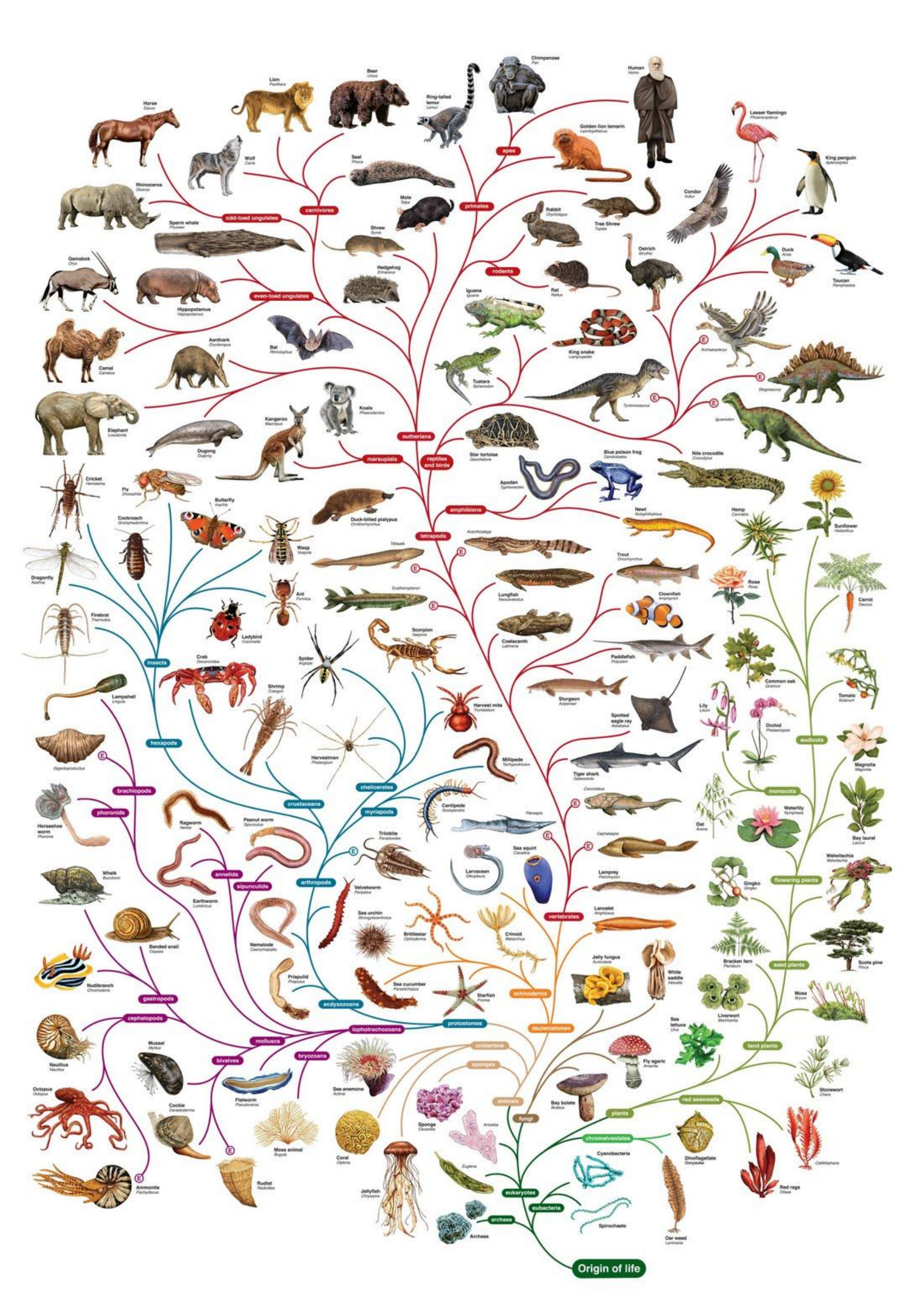




Tree of Life

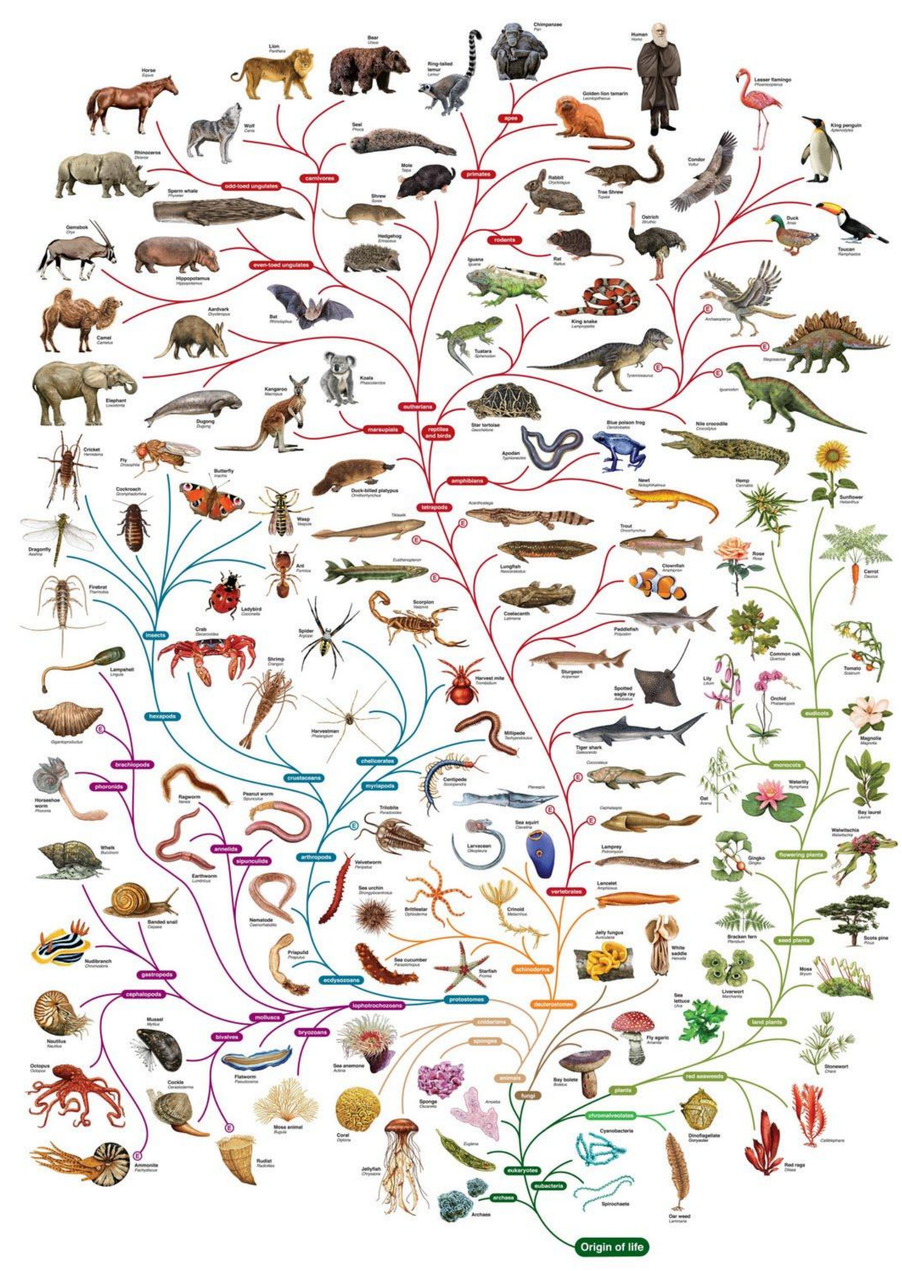
- All living things on Earth are related and share a common ancestor.



Tree of Life

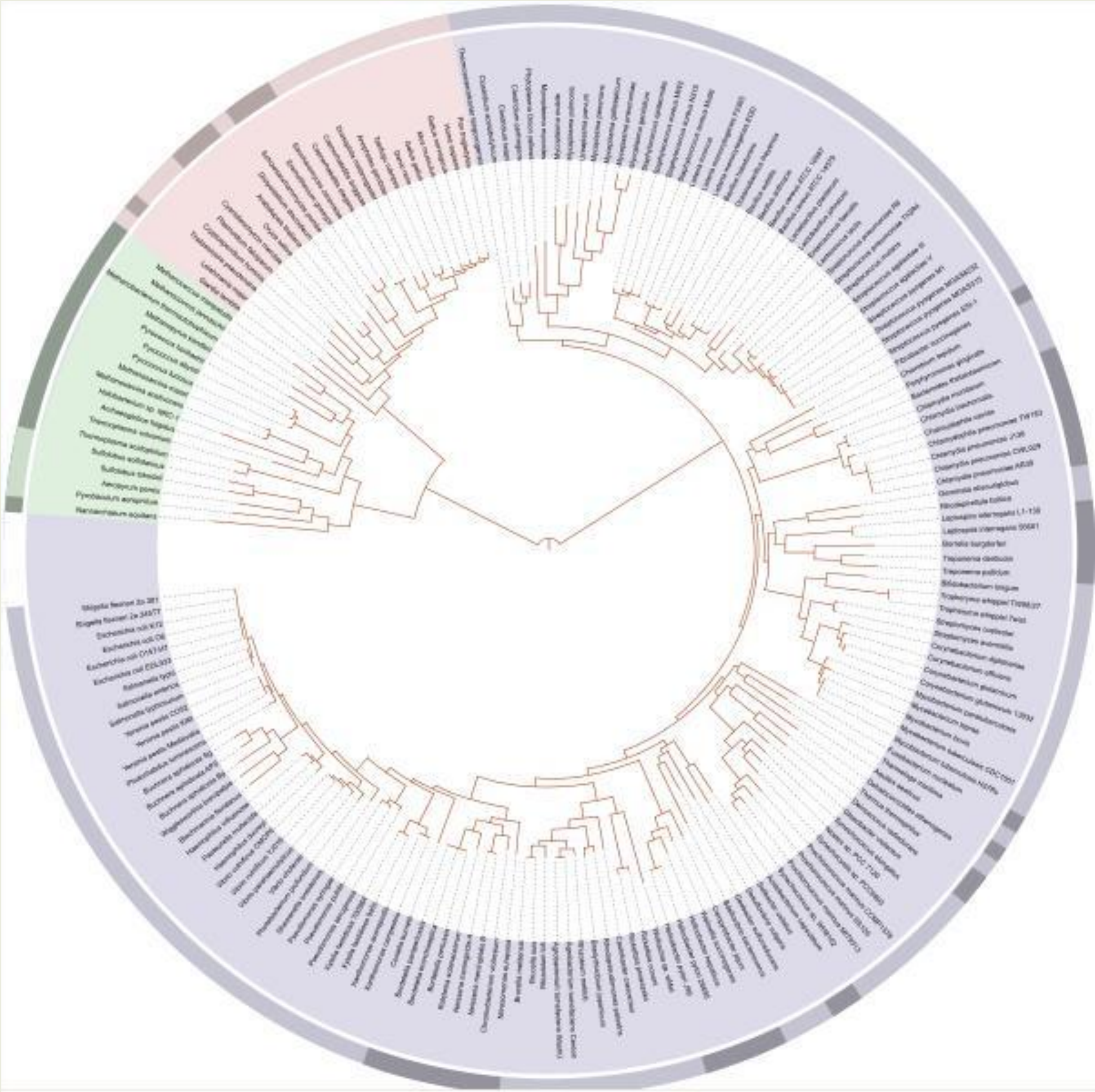
It's about change, *not* progress.

- Groups at the top do not represent a movement toward improvement of species.



Circular Phylogenetic Trees

- Are designed to show ancestral relationships, with all current organisms in outer ring and ancestors inside the ring.



Building Blocks for Understanding Adaptation and Evolution

Using the VISTA mnemonic:

- **V**ariation
- **I**nheritance
- **S**election
- **T**ime
- **A**daptation

VISTA

Variation: differences that occur among members of a species or population

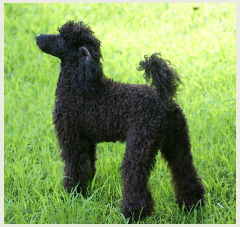
VISTA

Variation: differences that occur among members of a species or population

Genetic variation is the raw material for evolution.

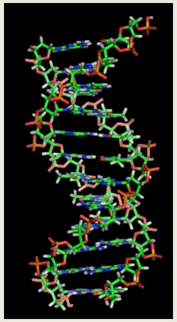

Woof woof! Bark bark!
Guau guau!

How did all these different strains come from this ancestor?



VISTA

- **Variation:** Genetic variation is the raw material for evolution.
- **Inheritance:** Parents pass on genes for traits to offspring.
- Selection
- Time
- Adaptation



Reading About Inheritance

- Alone or with a partner, read the handout.
- Use the cards to either:
  - make a "map" of the information as you read, showing how the ideas on the cards relate to one another, or
  - create a storyline based on the information as written.
- If partnered, share tasks and read out loud.

VI**S**TA

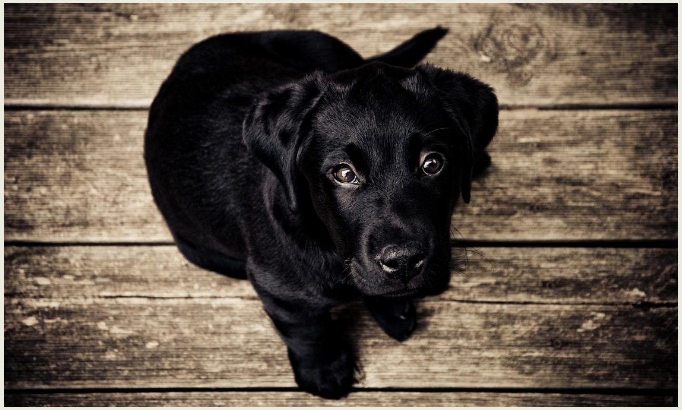
- Variation: Genetic variation is the raw material for evolution.
- Inheritance: Parents pass on genes for traits to offspring.
- **Selection**
- Time
- Adaptation

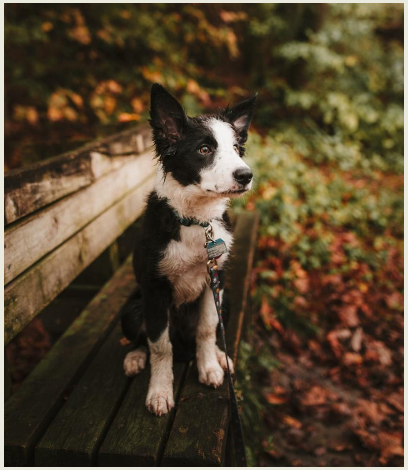
Short-Legged Mutation

Short-legged trait in dogs appeared and was selected for by humans.

Color in Dogs

People have artificially selected for color variations in dogs.





Shar-Pei

Its unusual wrinkling of skin was artificially selected for by humans.

VISTA

- **Variation:** Genetic variation is the raw material for evolution.
- **Inheritance:** Parents pass on genes for traits to offspring.
- **Selection:** A pressure that selects for certain traits in a population by providing a survival advantage to organisms with that trait
- Time
- Adaptation

Blowholes and Lamarck: Two Readings

Active Reading Strategy

1. Read carefully and underline parts that seem important: *I notice . . .*
2. Write questions you have in the margins: *I wonder . . .*
3. Write connections you think of in the margins: *It reminds me of . . .*
4. When you are ready, raise your hand and pair up with someone else whose hand is raised.
5. Together, discuss what seemed important, your questions, and the connections you made.

Explanation for Blowholes in Whales (Using VISTA)

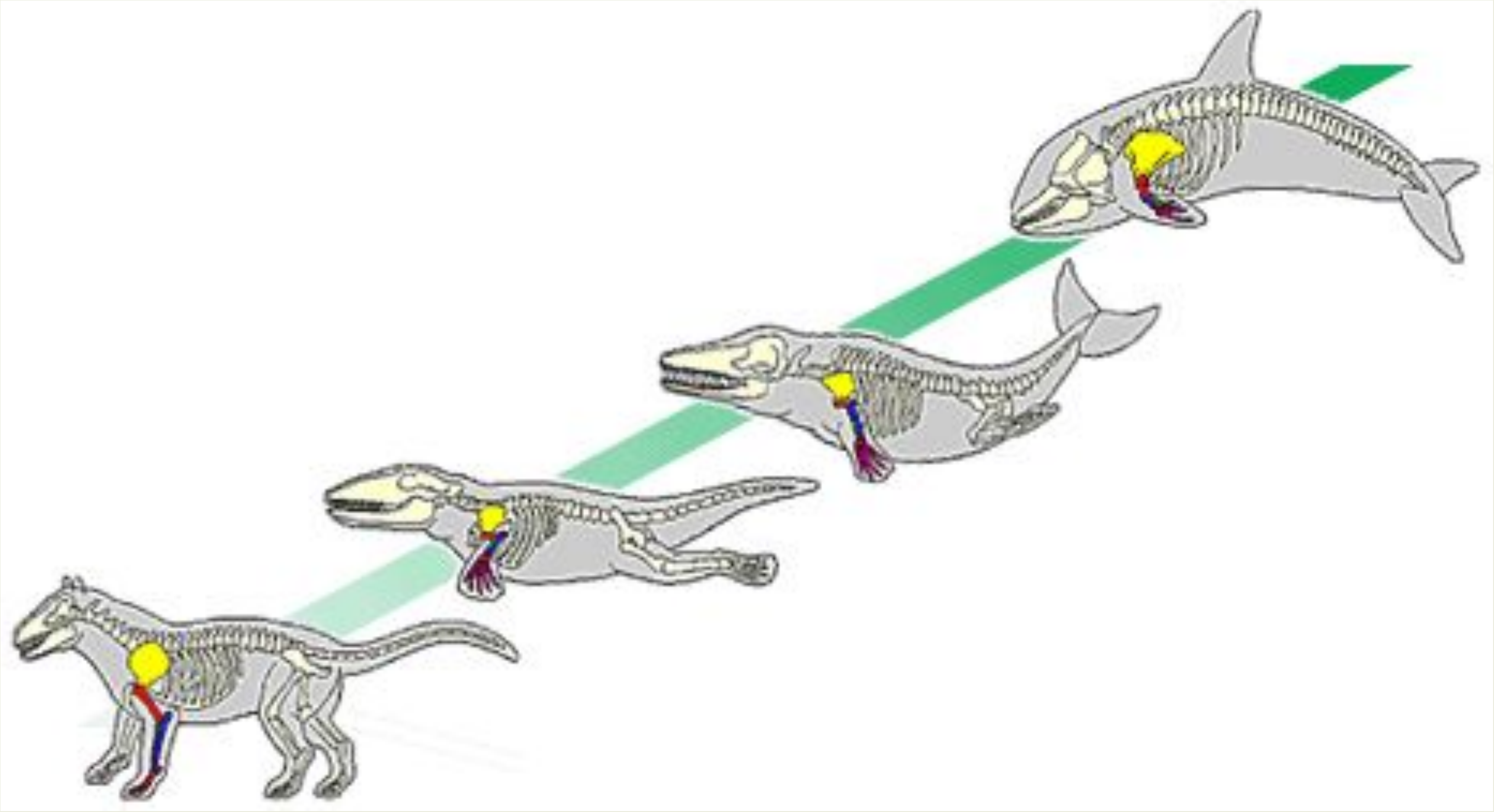
Whale blowholes allow air-breathing mammals (whales) to live full time in the ocean. They can pop up to the surface and breathe without lifting their heads out of the water and then smoothly dive back down. How did this adaptation evolve? When you look at blowholes in a series of ancient whale skulls, you can see the gradual movement over millions of years. In the earliest whale ancestor skull, the breathing hole is just a nostril where you might expect one to be on any land mammal. It took 35 million years for the breathing hole to move farther and farther back on the skull, ending up with today's whales having blowholes on the top of their skulls.

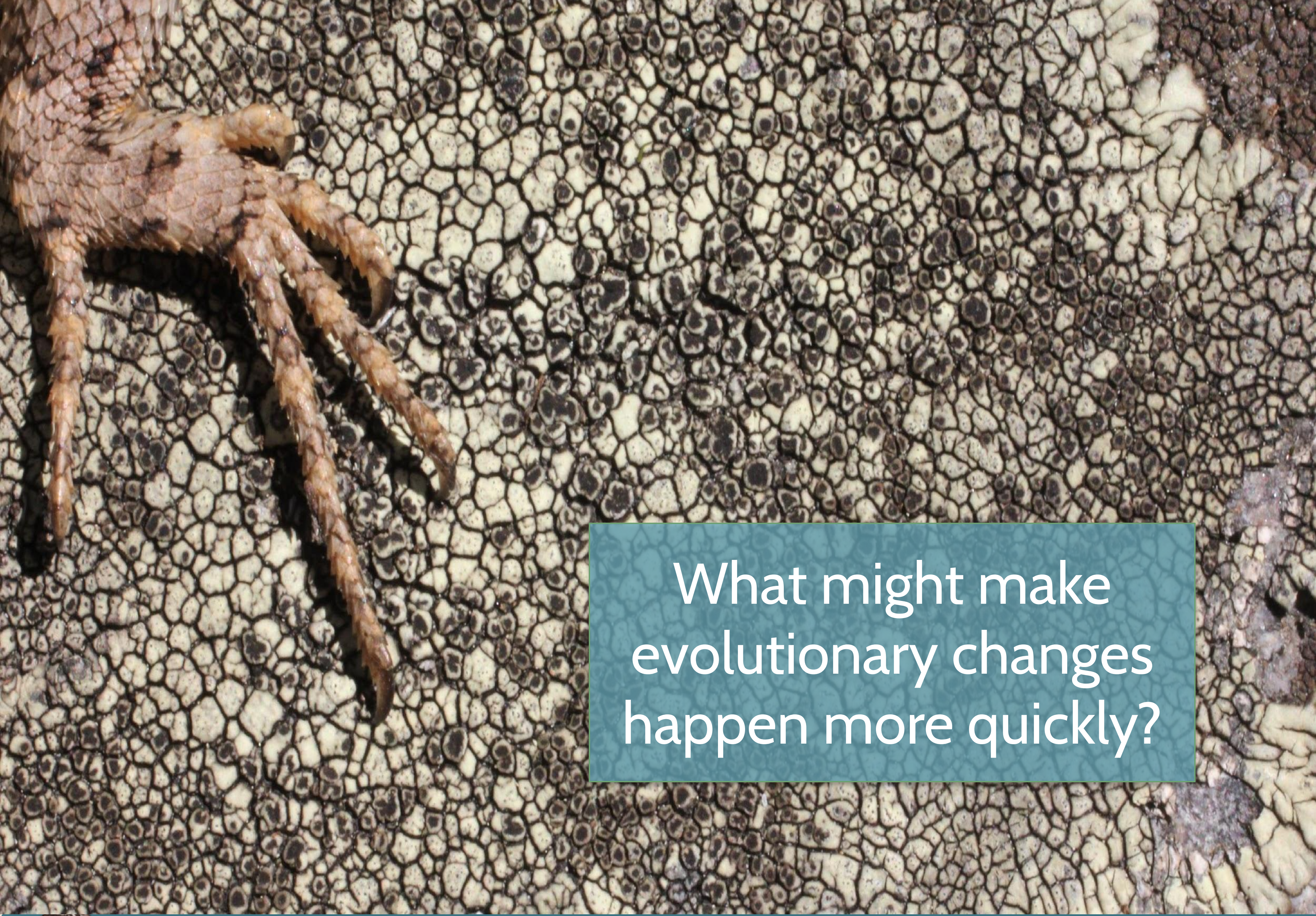
Using what we know about natural selection (VISTA: Variation, Inheritance, Selection, Time, Adaptation), we can explain that some whales may have been born with a mutation for a blowhole a little farther back on the skull (Variation). Environmental pressures then selected individuals with this trait to survive and reproduce more successfully (Selection). What were those pressures? Whale ancestors lived next to the ocean during warm times. The warm, salty seas were rich in marine life and also free of marine dinosaurs, which had become extinct. A breathing hole farther back on the skull could make it easier to breathe in water, allowing the whale to spend more time in the water, be more successful at feeding and escaping predation, and have more surviving young. Some of the offspring that had the same trait would be more successful, too; eventually, the trait would be widespread in the population (Inheritance). Over millions of years (Time), this process could happen again and again until the blowhole ended up where it is found today (Adaptation).

By adapting to live in water with the blowhole, along with other adaptations for living in a watery environment, early whales adapted to take advantage of a habitat that was closed off to most other mammals. This ecosystem had lots of food and shelter and few predators and competitors. These conditions were a powerful pressure to select for traits that could allow an organism to spend more time in the ocean.

Evolution Over DEEP Time

Gradualism




What might make evolutionary changes happen more quickly?

VISTA

- Variation: Genetic variation is the raw material for evolution.
- Inheritance: Parents pass on genes for traits to offspring.
- Selection: A pressure selects for certain traits in a population by providing a survival advantage to organisms with that trait.
- **Time:** It usually takes a very, very, very loooong (holy cow!) amount of time for significant evolutionary change to occur.
- Adaptation

Lamarckian Explanation for Giraffe Necks

Lamarck was a French naturalist in the early 1800s, before Darwin. He wrote what is now known to be an inaccurate explanation for how life evolved. However, exploring Lamarck's ideas can be useful for science educators because students and anyone who is new to evolution often have similar misconceptions. Today's common misconceptions are often similar to ideas held by brilliant people in the past! Just like our students, these smart scientists were thinking logically and using the best information available to them, but they didn't necessarily have access to all the evidence we now have.

A famous example of a Lamarckian explanation is related to how the giraffe got such a long neck. According to Lamarck, an individual giraffe was able to stretch its neck throughout its lifetime to reach food. Over time, its neck became longer, which caused its offspring to have longer necks. Knowing what you know about genes and traits, what is wrong with this explanation?

For traits to appear in a population and be passed on, they need to be caused by a change in genes. A population's genes are changed through reproduction (and sometimes by new individuals migrating into the population), not by events that happen during an individual lifespan.

- If you lose a finger, your children will not be born missing a finger.
- If you lift lots of weights, your children will not be born "buffed."
- If an individual giraffe managed to stretch its neck a bit during its life, its offspring would not have longer necks.

This is a common ongoing misconception about evolution and adaptation. We now know that *populations* adapt over time; individuals do not.

A More Reliable Natural Selection Explanation for Long Giraffe Necks

Using what we know about natural selection (Variation, Inheritance, Selection, Time, and Adaptation), we can hypothesize that giraffes with slightly longer necks appeared in a population through mutation or gene mixing (Variation). The giraffes with longer necks were able to be more successful than shorter-necked populations. Longer-necked giraffes may have been more successful at feeding during droughts and then had more offspring, some of which also had longer necks. From witnessing the "clubbing" behavior of male giraffes, some scientists think longer necks could also have been useful for competing over mates. In either case, this trait would make longer-necked giraffes more successful in reproducing (Selection), so they passed on the longer-neck trait to their offspring over generations (Inheritance). Over millions of years (Time), this process was repeated until giraffes evolved the long necks they have today (Adaptation).

Adapt

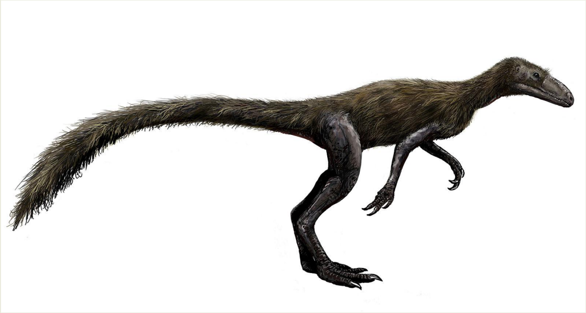
Everyday language:

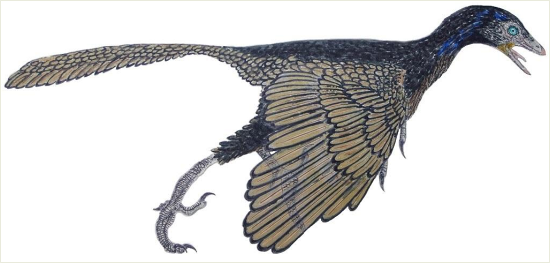
when individuals change due to events or conditions (e.g., Samantha moved to a different school and had to adapt.)

Science language:

when populations acquire traits through mutation and/or genetic mixing that provide a better chance of surviving and having offspring.

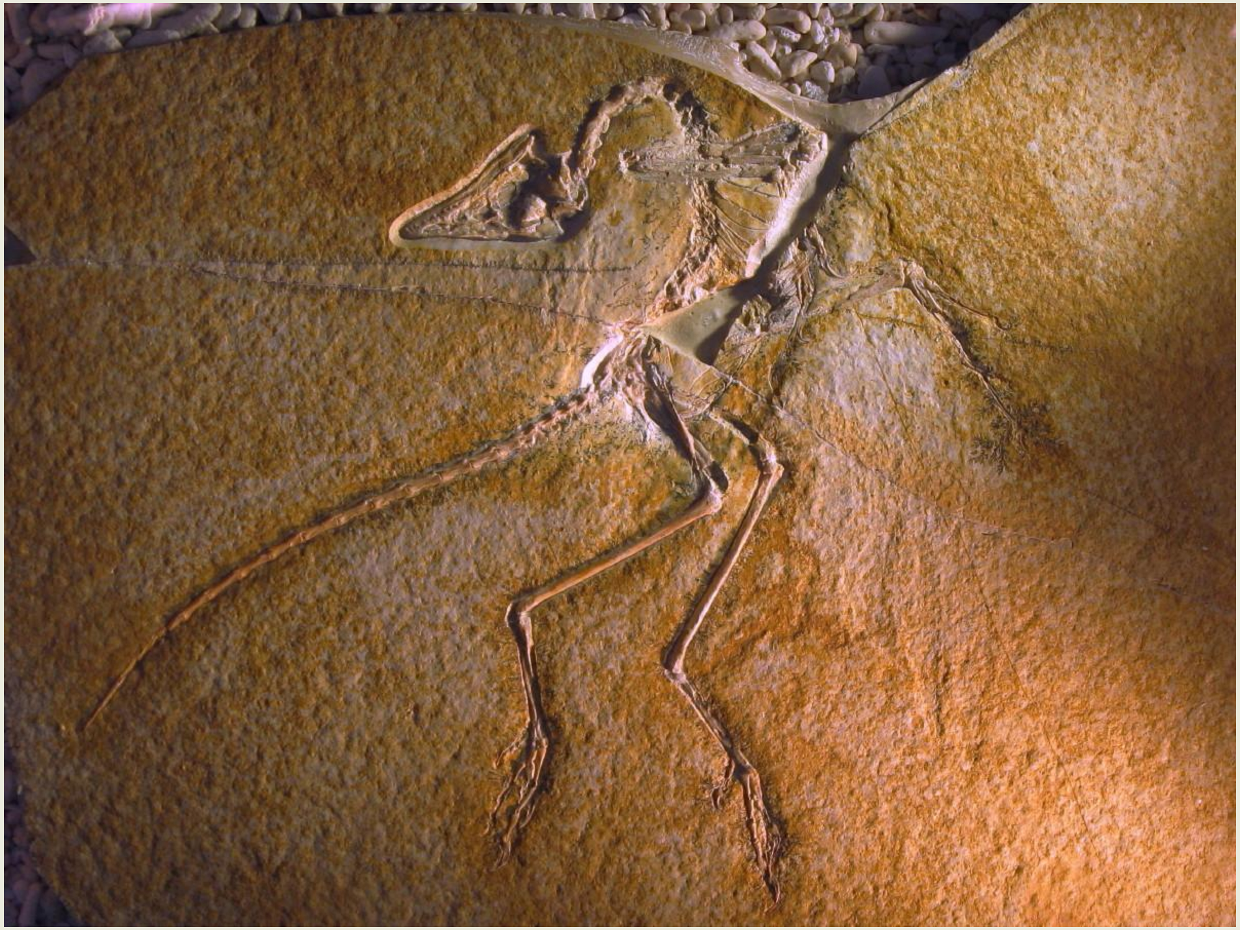
The Evolution of Flight in Birds





Archaeopteryx Fossil

In the early 1860s, fossils of the first known bird were found.



Archaeopteryx—CGI Model

How could bird feathers evolve from scales over deep time?

Variation: What kinds of new traits or characteristics could have given individuals within the population an advantage?

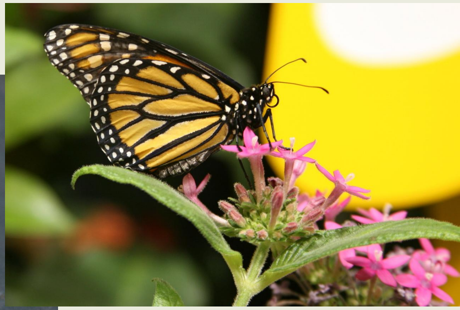
Selection: What kinds of environmental pressures could have selected for this trait by making those individuals more successful at passing on their genes?

Evolution Puzzler Stations







Station Instructions

- Go to a puzzler station with a partner. Try to explain how the trait (Adaptation) evolved over deep time.
- In your explanation, use these key evolutionary ideas: Variation, Inheritance, Selection, Time, and Adaptation.
- If you have time, go to a different station and do the same.

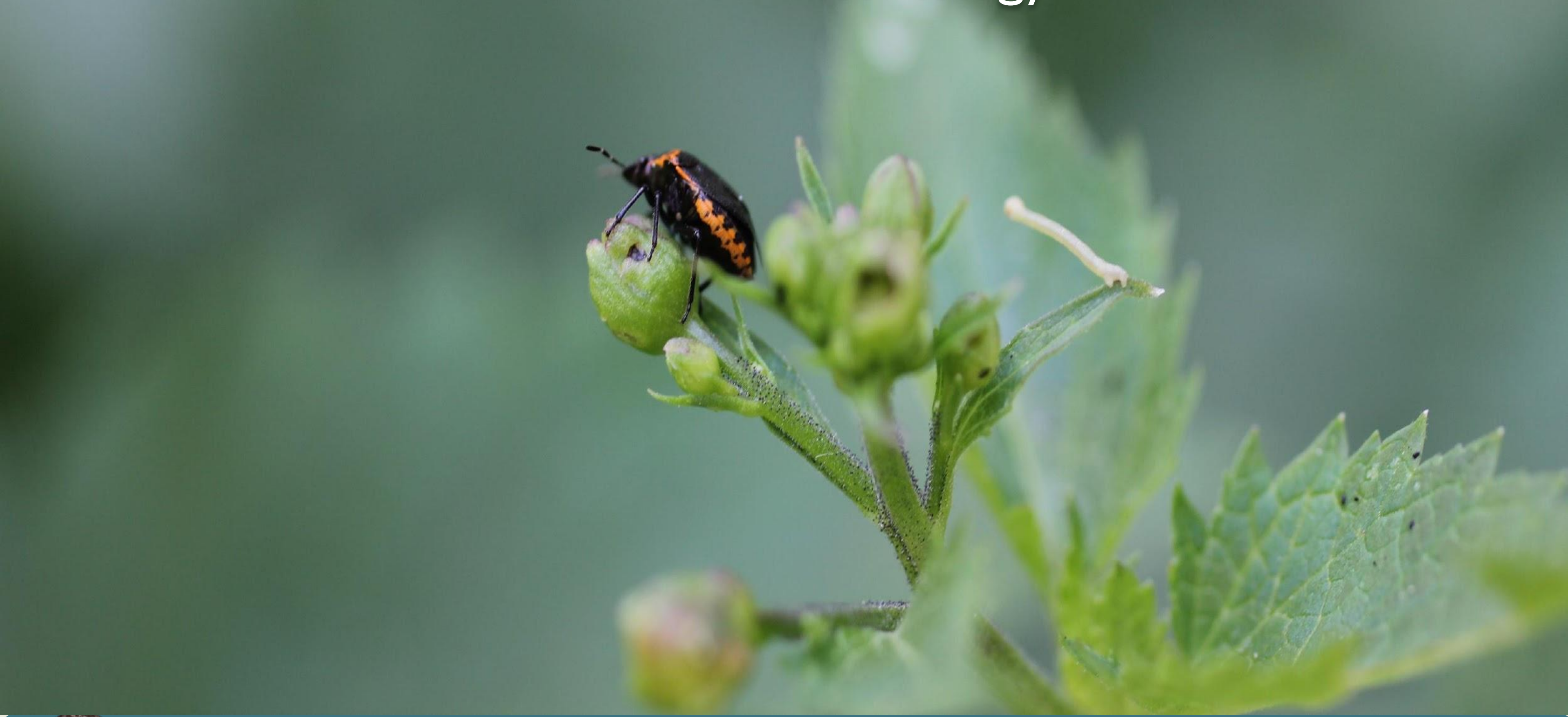
VISTA

- **Variation:** Variation is the raw material for evolution.
- **Inheritance:** Parents pass on genes for traits to their offspring.
- **Selection:** A pressure selects for certain traits in a population by providing a survival advantage to organisms that have that trait.
- **Time:** It usually takes an amazingly long amount of time for significant evolutionary change to occur.
- **Adaptation**

Adaptation

"A feature produced by natural selection for its current function."

—University of California Museum of Paleontology



Adaptation Definition #2
(for students unfamiliar with natural selection)

Adaptations are inheritable behaviors or structures that help a type of organism survive in its habitat.

VISTA

- **Variation:** Variation is the raw material for evolution.
- **Inheritance:** Parents pass on genes for traits to their offspring.
- **Selection:** A pressure selects for certain traits in a population by providing a survival advantage to organisms that have that trait.
- **Time:** It usually takes an amazingly long amount of time for significant evolutionary change to occur.
- **Adaptation:** Adaptations are inheritable behaviors or structures (traits) of a type of organism that result from natural selection and provide a survival advantage in its habitat.

NGSS *Adaptation and Evolution* Learning Progressions

	K-2	3-5	6-8	9-12
LS3.A Inheritance of traits	Young organisms are very much, but not exactly, like their parents and also resemble other organisms of the same kind.	Different organisms vary in how they look and function because they have different inherited information; the environment also affects the traits that an organism develops.	Genes chiefly regulate a specific protein, which affect an individual's traits.	DNA carries instructions for forming species' characteristics. Each cell in an organism has the same genetic content, but genes expressed by cells can differ
LS3.B Variation of traits			In sexual reproduction, each parent contributes half of the genes acquired by the offspring resulting in variation between parent and offspring. Genetic information can be altered because of mutations, which may result in beneficial, negative, or no change to proteins in or traits of an organism.	The variation and distribution of traits in a population depend on genetic and environmental factors. Genetic variation can result from mutations caused by environmental factors or errors in DNA replication, or from chromosomes swapping sections during meiosis.
LS4.A Evidence of common ancestry and diversity	N/A	Some living organisms resemble organisms that once lived on Earth. Fossils provide evidence about the types of organisms and environments that existed long ago.	The fossil record documents the existence, diversity, extinction, and change of many life forms and their environments through Earth's history. The fossil record and comparisons of anatomical similarities between organisms enables the inference of lines of evolutionary descent.	The ongoing branching that produces multiple lines of descent can be inferred by comparing DNA sequences, amino acid sequences, and anatomical and embryological evidence of different organisms.
LS4.B Natural selection	N/A	Differences in characteristics between individuals of the same species provide advantages in surviving and reproducing.	Both natural and artificial selection result from certain traits giving some individuals an advantage in surviving and reproducing, leading to predominance of certain traits in a population.	Natural selection occurs only if there is variation in the genes and traits between organisms in a population. Traits that positively affect survival can become more common in a population.
LS4.C Adaptation	N/A	Particular organisms can only survive in particular environments.	Species can change over time in response to changes in environmental conditions through adaptation by natural selection acting over generations. Traits that support successful survival and reproduction in the new environment become more common.	Evolution results primarily from genetic variation of individuals in a species, competition for resources, and proliferation of organisms better able to survive and reproduce. Adaptation means that the distribution of traits in a population, as well as species expansion, emergence or extinction, can change when conditions change.
LS4.D Biodiversity and humans	A range of different organisms lives in different places.	Populations of organisms live in a variety of habitats. Change in those habitats affects the organisms living there.	Changes in biodiversity can influence humans' resources and ecosystem services they rely on.	Biodiversity is increased by formation of new species and reduced by extinction. Humans depend on biodiversity but also have adverse impacts on it. Sustaining biodiversity is essential to supporting life on Earth.

Teaching About Adaptation and Evolution

- Look over the NGSS adaptation/evolution concepts recommended for different grade levels of students.
- Identify concepts taught in each student activity.
- Match up the student activities with the appropriate concepts for each grade level.

BEETLES Activities for Teaching Adaptation and Evolution

- *Whacky Adapty*
- *Adaptations Intro—Live!*
- *Blending In or Standing Out*
- *Structures and Behaviors*
- *Interview an Organism*
- *Discovery Swap*
- *Related and Different*
- *Mating and Cloning*
- *Card Hike*

UC Berkeley Museum of Paleontology

Understanding Evolution
your one-stop source for information on evolution

http://evolution.berkeley.edu/

Reflection:

- How have your ideas about adaptation and evolution changed?
- How can you incorporate these into your instruction?

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http://www.nextgenscience.org/sites/default/files/resource/files/AppendixE-ProgressionswithinNGSS-061617.pdf