Evidence of Evolution

GRADE LEVELS	7^{th}-12^{th}; California Content Standards for 7^{th} and High School Biology
SUBJECTS	Life Sciences, Earth Sciences
DURATION	Preparation: 10 minutes Academy: 60 minutes Post-Visit: 45 minutes
SETTING	Classroom; *Islands of Evolution* exhibit; *Earthquake* exhibit

Objectives

In this scavenger hunt and post-visit activity, students will

1. be introduced to the types of evidence that scientists use to determine evolutionary relationship of species.
2. evaluate how DNA, fossils, and comparative anatomy are evidence of evolutionary relationships.
3. learn about the evolution of four example groups of living organisms (marsupials, Proteaceae, flightless birds, and Galápagos finches).
4. practice creating branching diagrams to describe evolutionary relationships.

Materials

Evidence of Evolution Scavenger Hunt (one per student)
pencils
Teacher Answer Keys
clipboard (optional)

Vocabulary

- **anatomy**: the shape and structure of a living organism
- **ancestor**: an earlier organism from which others are derived; a relative from the past
- **cladogram**: a type of branching diagram that shows evolutionary relationships
- **convergent evolution**: the independent development of similar structures in organisms that are not directly related
- **diverge**: when two lineages branch off in two directions
- **DNA (deoxyribonucleic acid)**: the molecule that carries genetic information in living systems
- **fossil**: the remains or imprints of an organism from a previous time
- **lineage**: a continuous line of descent from a particular ancestor
- **speciation**: the evolutionary formation of new biological species by the branching of one species into two or more distinct ones
- **species**: a group of organisms that share their most recent common ancestor and can produce viable offspring

Teacher Background

When scientists study how different species are related to each other, they use a number of lines of evidence to understand their evolutionary history. These types of data include the geographic distribution of species, fossil evidence, and shared anatomical characteristics (comparative anatomy). More recently, the use of DNA has helped scientists better understand the details of evolutionary histories.

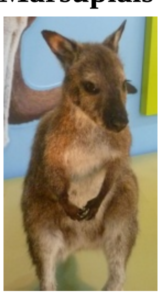
Fossils are preserved remains of ancient life, which means they can give direct evidence of an evolutionary history. Fossils can show that a certain species once lived in a different region than its present range or provide physical evidence of features possessed by a common ancestor of two lineages.

Before genetic evidence was available, scientists often used the shared physical characteristics of groups of organisms to determine how they might be related. For example, the different groups of animals (mammals, fish, amphibians, etc.) each share a set of features unique to the group. While anatomy often suggests the relationship of organisms, it may sometimes mislead. For example, some features that seem quite similar, such as the spines on cacti and other unrelated succulents, may have evolved independently (convergent evolution).

When scientists want to study how different species are related to each other, they sometimes use genetic clues to find out more about these relationships. Because DNA mutates (changes) over time, if two species have very similar sequences at a particular gene, then they are likely to be closely related. Therefore, the more similar the sequence, the more closely related the two species are.

Examples from the Academy of how fossils, comparative anatomy, and DNA show the evolution of species

Marsupials in the *Earthquake* exhibit



Marsupials are a distinct line of mammals that diverged from the placental mammals at least 125 million years ago. Unlike placental mammals, marsupials have a very short gestation period, after which they spend a long developmental period feeding off of milk from their mother (most often in a pouch). Newborn marsupials have well developed forelimbs to help them crawl to their mothers' pouch, but otherwise they are not fully developed and lack the ability to regulate their temperature.

Though Australia is associated with the diversity of marsupial species, the marsupial linage actually started much further north. The oldest fossil of any known marsupial was found in China and is estimated to be 125 million years old. Because there was still a connection between the continents in the North and South America, this marsupial line soon spread throughout the northern continents and into South America.

As marsupials went extinct in other parts of the world, those in South America survived and migrated across Antarctica into Australia, since South America was still connected to Antarctica and Australia long after other Gondwanan continents split off. DNA shows that Australian marsupials are related to those in the Americas. According to the DNA data, the South American monito del monte shares a common ancestor with the marsupials that now live in Australia. Fossil evidence of teeth found in Antartica also links the monito del monte to the lineage of marsupials that spread from Antactica to Australia. This extinct marsupial lived in Antarctica 70 to 55 million years ago.

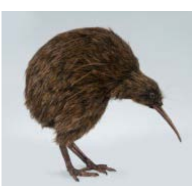
Plants of Gondwana in the *Earthquake* exhibit

Proteaceae is a family of flowering plants that has its origins in the Gondwanan supercontinent. The most distinguishing feature of many plants in the family is its “flower,” which is actually made of many small flowers densely packed together. The exhibit features three different examples from the Proteaceae family: the king protea from Africa, the red silky-oak from Australia, and the Chilean fire bush from South America.

DNA evidence links the African genus *Protea* to Gondwana and fossil pollen also shows that this genus was on the southern supercontinent. Today, *Protea* is native only to Africa, one of the first continents to break away from Gondwana. So, of the three flowers on display, the example from Africa is the most distantly related.

Flowers of South American plants in the family Proteaceae, such as the Chilean fire bush, are much like those of Australian species, providing an anatomical clue to their relationship. DNA confirms that they shared a common ancestor before South America, Antarctica and Australia separated. Fossil pollen from Antarctica also suggests that ancestors of Australian plants crossed Antarctica and spread to South America, when all three continents were joined.

Flightless Birds throughout the Academy



The flightless birds highlighted in the *Earthquake* exhibit are all ratites. Ratites, which include ostriches, rheas, emus and kiwis, are a group of birds that share flightless features. These features include: a smooth breastbone, which lacks the keel that anchors the wing muscles in flighted birds; no wishbone, since this structure is usually needed to strengthen the ribcage during flight; a large, heavy-boned body; fewer and smaller wing bones; and soft, plume-like feathers.

Flightless ostriches, rheas, emus and kiwis live on different continents, but they’re related through an ancestor that lived when the continents were one. Was that ancestor also flightless? Based only on physical evidence, one might expect that flightlessness arose in an ancestor common to all the ratites that share the anatomical features listed above. However, DNA evidence indicates that flightlessness evolved a number of different times as the ratite lineage diverged and were carried apart on the different Gondwanan continents.

The exact nature of the evolutionary relationships of the different ratites is still actively being studied. DNA evidence shows ostriches are more distant cousins to others in the group, making it, potentially, the oldest line of ratites. These genetic data also fit with the order that continents broke away from the supercontinent Gondwana - Africa was the first. Genetic data also place the South American tinamou into the ratite group. The tinamou birds are able to fly, further indicating that the common ancestor of the ratites had the ability to fly.

While ratites are one large group of flightless birds, the Academy features two others: the Galapagos cormorant (found in *Islands of Evolution*) and South African penguins (in *African Hall*). Their anatomical features resemble some of those found in the ratites but are an example of convergent evolution. Much like the ratites, the Galapagos cormorant has a smooth breastbone that lacks a large keel and also has less developed wing bones. On the other hand, a penguin still has a well developed breastbone as it uses the wing muscles to swim.

Finches in the *Islands of Evolution* exhibit

The Galápagos Islands are an archipelago consisting of sixteen volcanic islands located 600 miles west of Ecuador in the Pacific Ocean. They formed about 4 million years ago when a series of underwater volcanoes erupted, spewing up magma that cooled to form the cone-shaped islands. When the islands first formed they were devoid of life, but over time animal and plant species colonized them, allowing them to be a unique place to study the dispersal and evolution of species. A classic example of how species colonized and diversified once they arrive in the Galápagos is the finch. The geographic distribution, anatomical characteristics and, now, DNA all inform the understanding of how the different finch species of the islands evolved. Another example are the Galápagos mockingbirds, we have a related lesson all about the Galápagos mockingbirds: http://www.calacademy.org/teachers/resources/lessons/mapping-mockingbirds/.

Before your Visit

Tell your students that when they visit the California Academy of Sciences, they will see two exhibits that show how life has evolved on Earth. Make sure that they have an understanding of the process of evolution and some experience analyzing examples of speciation.

If students are unfamiliar with how DNA sequences might indicate how related two species are, make sure to introduce this concept before visiting the Academy.

At the Academy

Preparation

1. Make copies of the *Evidence of Evolution* scavenger hunt.

Introduction

- Explain that you will be visiting the *Earthquake* and *Islands of Evolution* exhibits to help discover the answer to how geology, fossils, DNA, and anatomy can provide evidence for how different species are related to one another.
- Review what students know about fossils, anatomy, and DNA.
- Pass out the hunt and go over the questions with your students and chaperones to make sure they understand what they will be doing.

- Let students know that some of the questions will require them to not just find an answer, but to spend time contemplating and discussing possible responses. A number of the questions do not have just one right answer.
- Point out that the Galapagos cormorant is a bit hidden in the exhibit. Students will find it in the area of the exhibit facing the windows, on the opposite side of the wall from "Underwater Diversity." If you have a visitor map or a chaperone guide, you can point out approximately where it can be found (near the green "E" on the map).

Procedure

1. This scavenger hunt is most easily completed in the order written; however, students can proceed in a different order or interrupt the sequence at any point for other activities.
2. For the recommended sequence, begin in the *Earthquake* exhibit. Allow some time for students to explore the other elements of the exhibit.
3. Allow time for students to explore, observe, and answer the questions on the scavenger hunt.
4. As students finish, encourage them to discuss what they found with each other. In particular, how would now answer the question at the beginning of the worksheet?

Back in the Classroom

Preparation

1. Print out the Teacher Answer Keys for your reference.
2. Prepare a simple t-chart to list the homologous and analogous features of flightless birds found at the Academy.
3. Next list the following table on the board

Name	Location	Living or Fossil
Monito del monte	South America	
Red-necked wallaby	Australia	
Woodburnodon casei	Antarctica	
Sinodelphys szalayi	Asia (China)	
Koala	Australia	

Procedure

1. Briefly reflect on the content in the *Earthquake* and *Islands of Evolution* exhibits.
2. Discuss what parts of the hunt were most difficult to complete. Allow students to share how they answered the questions, and provide answers where appropriate.
3. If you have previously discussed convergent evolution and homologous vs. analogous structures, you can use the information students gathered about the different flightless birds to make a list of which structures are analogous and which are homologous (see the Teacher Answer Key for some ideas). Or, use the information they collected to introduce this topic.
4. For their second task, break the students into groups and have them attempt to draw cladograms of the Gondwanan plants.

5. Lastly, as a class, discuss what evidence students collected or distinctly remember about the relationship of the different marsupial species from the *Earthquake exhibit.* Using the Teacher Background and the Scavenger Hunt Answer Key, fill in any missing information that they do not know.
6. Give the class time to work through the following:
   - Which two marsupials are most closely related? (*wallaby and koala)*
   - Which species do they think is most distant? (*S. szalayi*).
7. Help them draw a cladogram showing the evolutionary relationships among just these three species. (see the Teacher Answer Key)
8. Then have each group hypothesize where the remaining two species fit into the diagram. The exhibit does not present data to indicate whether the branching diagram looks more like the first or second answer on the Answer key. Discuss what type of evidence might help show how to figure out which is more accurate. (*Fossils of common ancestors; DNA from other Antarctic fossils would provide evidence but it is less likely that scientists will acquire this*).

References

Padilla, Michael, Ioannis Miaoulis, and Martha Cyr. *Focus on Life Science California (Teacher's Edition)* Pearson Prentice Hall, 2008.

Resources

New York Times *Antarctica yields first land mammal fossil*
http://www.nytimes.com/1982/03/21/us/antarctica-yields-first-land-mammal-fossil.html

Carnegie Museum of Natural History *Sinodelphys szalayi*
http://www.carnegiemnh.org/vp/sinodelphys.html

Evolution and the Nature of Science Institues http://www.indiana.edu/~ensiweb/evol.fs.html
This webpage has a great variety of lessons on different aspects of evolution

Understanding Evolution http://evolution.berkeley.edu/
A great resource for explaining evolution that includes a list of classroom resources.

Genetic Science Learning Center http://learn.genetics.utah.edu/content/variation/

Correlated California Content Standards

Grade Seven
Evolution

3.c. Students know how independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.

3.d. Students know how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.

Earth and Life History (Earth Sciences)

4.a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

Grades Nine through Twelve

Evolution

8.e. Students know how to analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction.

8.f. Students know how to use comparative embryology, DNA or protein sequence comparisons, and other independent sources of data to create a branching diagram (cladogram) that shows probable evolutionary relationships.

Investigation and Experimentation

1.d. Formulate explanations by using logic and evidence.

1.k. Recognize the cumulative nature of scientific evidence.