The times, they are a changing
Faunal Changes in Georgia over the last 14,000 years

Virginia Museum of Natural History Paleontology Department
Fossil Teaching Kit 2GA

Teacher's Guide

This activity uses casts of fossils to examine changes in North America's fauna over the last 14,000 years. While the specimens are selected with Georgia's history in mind, in most cases the patterns seen here apply for any location in the eastern United States (in fact, most of the casts in this kits are replicas of specimens originally found in Virginia).

The casts are all either individual teeth or tooth rows from mammals. For paleontologists, fossil teeth are usually the most common fossil remains that are easily identified; complete skeletons of fossil animals are extremely rare.

The 11 specimens in the kit come from three different periods, and the casts are color-coded to represent these different times:

Dark brown — 14,000 years before present (YBP):
American mastodon (*Mammut americanum*) upper premolar
Woodland musk ox (*Bootherium bombifrons*) lower molar
Horse (*Equus* sp.) upper molar
Elk (*Cervus canadensis*) upper molar
White-tailed deer (*Odocoileus virginianus*) upper molar
Caribou (*Rangifer tarandus*) lower premolar

Light brown — 1,000 YBP:
Elk (*Cervus canadensis*) upper molar
White-tailed deer (*Odocoileus virginianus*) upper molar

Off-white — modern day:
White-tailed deer (*Odocoileus virginianus*) upper molar
Horse (*Equus* sp.) upper molar
Pig (*Sus scrofa*) upper molar

Two major events control the patterns seen in these fossils:

1) The end of the last glacial period at the end of the Ice Age approximately 10,000 years ago:

The end of the Ice Age saw the extinction of a large number of animals, including mastodons, the woodland musk ox, and all the New World species of horses. Your students may be familiar with other Ice Age species that went extinct at this time, including mammoths and sabertooth cats. While the ice sheet only reached south to New York, almost all of North America saw colder conditions than exist today. This can be seen by the presence of cold-weather species such as the woodland musk ox and caribou.

As the climate generally warmed after the end of the Ice Age other animals were able to move north, including opossum, fox squirrels, and armadillos. **Note**: this modest increase in temperatures since the end of the Ice Age should not be confused with the much more rapid increase in temperature that has occurred over the last 150 years, that are due primarily to human activities.

2) Arrival of large numbers of Europeans in North America approximately 400 years ago:

There were several significant faunal changes associated with the arrival of Europeans in North America. Due to hunting and habitat loss, some species that survived the end of the Ice Age were wiped out in eastern North America, including elk, bison, and passenger pigeons.

In addition, several domestic European species were introduced, including pigs and horses Note that native North America horses went extinct at the end of the Ice Age. Modern horses in North America are all descended from closely related European horses.

Optional advanced discussion points:

The Pleistocene Epoch is typically accepted as ending approximately 10,000 years ago, at the end of the last Ice Age. In trying to determine if a fossil deposit is Pleistocene, it is common to use the presence of "Pleistocene megafauna" (such as *Mammut* and *Bootherium*) as a determining marker.

While elk and caribou have both been found in Georgia, they have only been reported from the northern part of the state. Neither has been found in southern Georgia, or from the very extensive fossil mammal deposits of Florida.

A comparison of Georgia to other southeastern states is informative. As mentioned above, caribou and elk are known from northern Georgia, but not Florida. These two species are also found in states north of Georgia, including the Carolinas and Virginia. During the Pleistocene Epoch species found in Georgia are also found in Florida and the Carolinas (for example, the modern opossum *Didelphis* and the giant ground sloth *Eremotherium*), but are not known from Virginia or any states farther north. So during the Pleistocene the region from North Carolina to Georgia seems to be a transitional zone with a mix of warm-weather species (opossum, *Eremotherium*) and cold-weather species (elk, caribou, musk ox).

Some species were especially widespread during the Pleistocene and are found in many parts of North America, from northern Canada or Alaska to Florida. These include living species such as black bear (*Ursus americanus*), white-tailed deer (*Odocoileus virginianus*), and groundhog (*Marmota monax*) as well as extinct species such as mastodon (*Mammut americanum*), certain ground sloths (*Megalonyx jeffersonii*), and giant beaver (*Castoroides ohioensis*).

As an alternative for advanced students, you can provide the students with the list of species in the exercise, but withhold the identification cards and have the students use internet resources to identify their teeth. This will make the lab take longer, but more closely represents how professional paleontologists would approach these identifications.

Correlation with Next Generation Science Standards

Third Grade

3-LS3 Biological Evolution: Variation of Traits

Science and Engineering Practice

Analyzing and Interpreting Data: Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS3-1)

Constructing Explanations and Designing Solutions: Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2)

Disciplinary Core Idea

LS3.B: Variation of Traits: The environment also affects the traits that an organism develops. (3-LS3-2)

Crosscutting Concepts

Cause and Effect: Cause and effect relationships are routinely identified and used to explain change. (3-LS3-2)

3-LS4 Biological Evolution: Unity and Diversity

Science and Engineering Practice

Analyzing and Interpreting Data:

Construct an argument with evidence. (3-LS4-3)

Disciplinary Core Idea

LS4.D: Biodiversity and Humans: Populations live in a variety of habitats, and change in those habitats affects the organisms living there. (3-LS4-4)

Crosscutting Concepts

Cause and Effect: Cause and effect relationships are routinely identified and used to explain change. (3-LS4-2),(3-LS4-3)

Middle School LIfe Science

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Science and Engineering Practice

Engage in Argument from Evidence:

Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-LS2-4)

Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-LS2-5)

Disciplinary Core Idea

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1)

Middle School Earth and Space Science

MS-ESS1 Earth's Place in the Universe

Science and Engineering Practice

Constructing Explanations and Designing Solutions: Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (MS-ESS1-4)

Disciplinary Core Idea

ESS1.C: The History of Planet Earth

The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-4)

Crosscutting Concepts

Scientific Knowledge Assumes an Order and Consistency in Natural Systems: Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-ESS1-1),(MS-ESS1-2)

High School

HS-ESS2 Earth's Systems

Science and Engineering Practices

Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-ESS2-2)

Engaging in Argument from Evidence: Construct an oral and written argument or counter-arguments based on data and evidence. (HS-ESS2-7)

Scientific Knowledge is Based on Empirical Evidence: Science knowledge is based on empirical evidence. (HS-ESS2-3)Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-3)Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-3)

Disciplinary Core Idea

ESS2.A: Earth Materials and Systems: The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to `intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4)

ESS2.E Biogeology: The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7)

Crosscutting Concepts

Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7)

HS-LS4 Biological Evolution: Unity and Diversity

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information: Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-LS4-1)

Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2)
Engaging in Argument from Evidence: Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5)

Disciplinary Core Idea

LS4.C: Adaptation: Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-5),(HS-LS4-6) Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5)

Crosscutting Concepts

Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2),(HS-LS4-4),(HS-LS4-5),(HS-LS4-6)

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Teacher sample

Fossils are the remains of ancient organisms that have been preserved in rocks or sediments. Usually, only the hard parts of an organism's body, such as bones, teeth, and shells, are preserved. While fossils can tell us what past organisms looked like and how they are related to other organisms, there are many other things that paleontologists can learn from studying fossils. For example, it's possible to look at the whole community (or **assemblage**) of organisms in a particular place (**fauna**, for animals, and **flora**, for plants). If the flora or fauna changes over time, it can provide clues about how the environment has changed. Much of our knowledge of the Earth's past geography and climate comes from the study of fossil assemblages.

For this exercise you will be examining specimens of mammals that are known to have lived in Georgia during the last 14,000 years. In working with fossils, one of the challenges is that we are limited in the amount and type of data available to us. For example, when working with vertebrates such as mammals it's extremely rare to find an entire skeleton, or even a large part of one. The most common remains are individual teeth, so a paleontologist working on mammals needs to learn to identify them even from a single tooth.

In this exercise you will be identifying casts of individual teeth (or, in some cases, rows of teeth). Since real fossils are both fragile and rare, you'll be working with exact cast replicas of fossils; the original fossils are stored at the Virginia Museum of Natural History. You've also been provided with ID cards to help you identify your casts; the ID cards in most cases include photos of the original fossils. The following species are included in your sample:

American mastodon (*Mammut americanum*): This is an extinct relative to modern elephants. Mastodon fossils have been found from coast-to-coast, from as far north as Alaska and as far south as Mexico.

Woodland musk ox (*Bootherium bombifrons*): This is an extinct relative of the modern musk ox (*Ovibos moschatus*), a type of large goat. The modern musk ox only lives in arctic areas of Canada and Greenland.

Horse (*Equus* sp.): Wild horses live in grasslands in a variety of climates.

Elk (*Cervus canadensis*): Elk are large deer that today live mostly in mountainous parts of western United States and Canada.

White-tailed deer (*Odocoileus virginianus*): This is the same species of deer that is commonly seen in rural parts of Georgia today. Modern white-tailed deer are found from Canada to Central and South America, and in almost every state.

Caribou or reindeer (*Rangifer tarandus*): Caribou are a type of deer that today are found in Canada, Alaska, Greenland, and northern Europe.

Pig (*Sus scrofa*): Wild versions of the domestic pig were found across central Europe and Asia.

Another difficulty in working with changes in fossil assemblages over time is that the fossil record is not continuous. We usually only have fossils at a few discreet points in time. Because of this, your sample only includes specimens from three points in time: 14,000 years ago, 1,000 years ago, and modern day.

Purpose: To examine faunal changes over the last 14,000 years.

Materials: 11 casts replicas of mammal teeth
7 identification cards

Procedure:

1) Sort the teeth according to color. Each color represents a different age for when the animal was alive:

Dark brown = 14,000 years ago
Light brown = 1,000 years ago
White = modern day

2) Using the identification cards, determine the species for each tooth. The same species may occur in more than one time period.

3) Fill out the chart in the Results section, indicating which species were found in each time period.

Results:

	Time period		
Species	**14,000 years ago**	**1,000 years ago**	**Modern day**
Pig			X
Horse	X		X
Musk ox	X		
Mastodon	X		
Elk	X	X	
White-tailed deer	X	X	X
Caribou	X		

Discussion:

1) Which species were present in Georgia 14,000 years ago that were absent by 1,000 years ago?
Mastodon, musk ox, caribou and horse. Students may not include horse, since it appears again in the modern sample.

2) Which species were present 1,000 years ago, but are no longer present in Georgia?
Elk.

3) Which species only occur in modern day Georgia?
Pig.

4) Do any of the animals from 14,000 years ago suggest that the climate in Georgia was different then that it is today? Explain.
Musk oxen and caribou prefer colder climates than what is found in modern Georgia. Their presence suggests that the climate in Georgia was colder 14,000 years ago than it is today. Note that students may not be familiar with caribou and musk oxen, and may need to be told about their habits or allowed to do research to find out. It may help to point out that caribou is the North American name for reindeer; they are the same species.

5) What major event occurred in Georgia within the last 1,000 years that could explain the changes in fauna between 1,000 years ago and modern day? Explain.
The arrival of Europeans around 400 years ago caused big changes in the Georgia fauna. Some species, such as elk, were wiped out by hunting, and domestic species from Europe, such as pigs, were introduced to North America.

6) Horses show an unusual pattern that is different from all the other animals in this exercise. How can you explain this difference?
Horses were present in North America 14,000 years ago and are present here today, but were absent 1,000 years ago. Horses originally evolved in North America, but went extinct here at the end of the Ice Age. Then Europeans reintroduced them 400 years ago.

Students will probably be familiar with the introduction of horses by Europeans from their history classes, but will probably not know that horses originally evolved in North America. They may suggest that horses were forced out of Virginia by the change in climate (like caribou, etc.) but survived in other parts of North America. In discussion, you can point out to students that apparently there were no horses in North America at all between 10,000 years ago and 400 years ago.

7) Which of these species seem to be especially able to cope with changing conditions?
White-tailed deer are found in all three samples, so they survived both the warming climate at the end of the Ice Age and the arrival of Europeans.

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Caribou			

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