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

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

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 Virginia's history in mind, and most of the casts are based on original specimens from Virginia, in most cases the patterns seen here apply for any location in the eastern United States.

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 13 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
Opossum (*Didelphis virginiana*) palate

Off-white — modern day:
White-tailed deer (*Odocoileus virginianus*) upper molar
Opossum (*Didelphis virginiana*) palate
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, cold conditions (similar to modern Alaska) extended at least as far south as Virginia. This can be seen by the presence of cold-weather species such as the woodland musk ox and caribou. Other cold-weather animals, such as woolly mammoths are also known from Virginia at this time.

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.

The patterns for some of these animals will be somewhat different depending on your location. For example, 14,000 years ago opossums were already in Florida, which never got as cold as Virginia. Moreover, elk apparently never got as far south as Florida. But otherwise these trends will hold for any eastern state between New York and Georgia.

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.

There is some debate about the arrival time of opossum in Virginia. There are no published records of opossum being found with any uniquely Pleistocene animals such as mammoth or mastodon. Moreover, several Pleistocene cave deposits in western Virginia have been throughly examined, and there were no opossums identified from among the several thousand bones present. However, there are some reports of opossum from Virginia that are of unknown age.

Almost all of the records of Pleistocene mammals from Virginia come from sites in the Appalachian Mountains. It might be expected that these areas were the coldest parts of Virginia during the Pleistocene (as they are today), so that the fauna of these areas may not be representative of the entire state. It’s possible that the Piedmont and Coastal Plain regions had a warmer-climate fauna than the mountains.

A comparison of Virginia to other southeastern states is informative. For example, caribou and elk are known from the Carolinas and northern Georgia, but not Florida. The giant ground sloth *Eremotherium* has not been reported north of North Carolina, and its distribution may be similar to the opossum. This suggests that the region from North Carolina to Georgia was 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.

Correlations to Virginia Standards of Learning

Third Grade

3.1 The student will plan and conduct investigations in which:

a) predictions and observations are made
b) objects with similar characteristics are classified into at least two sets and two subsets
c) questions are developed to formulate hypotheses
g) data are gathered, charted, and graphed (line plot, picture graph, and bar graph)
j) inferences are made and conclusions drawn
k) natural events are sequenced chronologically

3.4 The student will investigate and understand that behavioral and physical adaptations allow animals to respond to life needs. Key concepts include:

a) methods of gathering and storing food, finding shelter, defending themselves, and rearing young

3.6 The student will investigate and understand that environments support a diversity of plants and animals that share limited resources. Key concepts include;

c) population and community

3.10 The student will investigate and understand that natural events and human influences can affect the survival of species. Key concepts include:

a) the interdependency of plants and animals

Fourth Grade

4.1 The student will plan and conduct investigations in which:

a) distinctions are made among observations, conclusions, inferences, and predictions
b) hypotheses are formulated based on cause-and-effect relationships
f) data are displayed using bar and basic line graphs
h) predictions are made based on data from picture graphs, bar graphs, and basic line graphs

4.5 The student will investigate and understand how plants and animals in an ecosystem interact with one another and the nonliving environment. Key concepts include:

b) organization of communities
d) habitats and niches
f) influence of human activity on ecosystems

Fifth Grade

5.1 The student will plan and conduct investigations in which:

a) rocks, minerals, and organisms are identified using a classification key
e) data are collected, recorded, and reported using the appropriate graphical representation (graphs, charts, diagrams)
f) predictions are made using patterns, and simple graphical data are extrapolated
h) an understanding of the nature of science is developed and reinforced

5.7 The student will investigate and understand how the Earth's surface is constantly changing. Key concepts include:

b) Earth history and fossil evidence
f) human impact

Sixth Grade

6.1 The student will plan and conduct investigations in which:

a) observations are made involving fine discrimination between similar objects and organisms
b) a classification system is developed based on multiple attributes
c) precise and approximate measurements are recorded
f) a method is devised to test the validity of predictions and inferences
h) data are collected, recorded, analyzed, and reported using appropriate metric measurements
i) data are organized and communicated through graphical representation (graphs, charts, and diagrams)
k) an understanding of the nature of science is developed and reinforced

Life Science

LS.1 The student will plan and conduct investigations in which:

d) models are constructed to illustrate and explain phenomena
i) interpretations from a set of data are evaluated and defended
j) an understanding of the nature of science is developed and reinforced

LS.5 The student will investigate and understand how organisms can be classified. Key concepts include:

c) the characteristics of the species

LS.10 The student will investigate and understand how organisms adapt to biotic and abiotic factors in an ecosystem. Key concepts include:

c) adaptations that enable organisms to survive within a specific ecosystem

LS.11 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time (daily, seasonal, and long term). Key concepts include:

b) factors that increase or decrease population size
c) eutrophication, climate changes, and catastrophic disturbances

LS.12 The student will investigate and understand the relationships between ecosystem dynamics and human activity. Key concepts include:

a) food production and harvest;
b) change in habitat size, quality, or structure;
c) change in species competition;
d) population disturbances and factors that threaten or enhance species survival

LS.14 The student will investigate and understand that organisms change over time. Key concepts include:

a) the relationships of mutation, adaptation, natural selection, and extinction
b) evidence of evolution of different species in the fossil record
c) how environmental influences, as well as genetic variation, can lead to diversity of organisms

Earth Science

ES.1 The student will plan and conduct investigations in which:

a) volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools

c) scales, diagrams, maps, charts, graphs, tables, and profiles are constructed and interpreted

e) a scientific viewpoint is constructed and defended (the nature of science)

ES.2 The student will demonstrate scientific reasoning and logic by:

b) recognizing that evidence is required to evaluate hypotheses and explanations

d) explaining that observation and logic are essential for reaching a conclusion

e) evaluating evidence for scientific theories

ES.10 The student will investigate and understand that many aspects of the history and evolution of the Earth and life can be inferred by studying rocks and fossils. Key concepts include:

a) traces and remains of ancient, often extinct, life are preserved by various means in many sedimentary rocks

d) rocks and fossils from many different geologic periods and epochs are found in Virginia

Biology

BIO.1 The student will plan and conduct investigations in which:

a) observations of living organisms are recorded in the lab and in the field;

b) hypotheses are formulated based on direct observations and information from scientific literature

e) conclusions are formed based on recorded quantitative and qualitative data

f) sources of error inherent in experimental design are identified and discussed

m) a scientific viewpoint is constructed and defended (the nature of science)

BIO.7 The student will investigate and understand bases for modern classification systems. Key concepts include:

a) structural similarities among organisms

b) fossil record interpretation

c) comparison of developmental stages in different organisms

BIO.8 The student will investigate and understand how populations change through time. Key concepts include:

a) evidence found in fossil records

b) how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations

BIO.9 The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include:

a) interactions within and among populations including carrying capacities, limiting factors, and growth curves

d) the effects of natural events and human activities on ecosystems

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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 Virginia 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 Virginia 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.

Opossum (*Didelphis virginiana*): Opossums are the only marsupial found in North America. They originally evolved in South America before moving north, and prefer warmer climates.

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: 13 casts replicas of mammal teeth
8 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		
Opossum		X	X
Elk	X	X	
White-tailed deer	X	X	X
Caribou	X		

Discussion:

1) Which species were present in Virginia 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 show up for the first time in Virginia 1,000 years ago?
Opossum.

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

4) Which species only occur in modern day Virginia?
Pig.

5) Do any of the animals from 14,000 years ago suggest that the climate in Virginia was different then that it is today? Explain.
Musk oxen and caribou prefer colder climates than what is found in modern Virginia. Their presence suggests that the climate in Virginia 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.

In addition, it seems that opossums only moved into Virginia after the end of the Ice Age, after the climate began to warm.

6) What major event occurred in Virginia 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 Virginia fauna. Some species, such as elk, were wiped out by hunting, and domestic species from Europe, such as pigs, were introduced to North America.

7) 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.

8) 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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