Looking a fossil horse in the mouth
Using teeth to examine fossil horses

Virginia Museum of Natural History Paleontology Department
Fossil Teaching Kit 1

Teacher's Guide

In this activity students will compare casts of teeth of two fossil horses from Virginia. There are two parts, which should be done in order. In Part 1, the students will determine the age of one of the fossil horses when it died. In Part 2, the students will estimate the height of each fossil horse based on the length of their teeth. Some of the discussion questions in Part 2 require the students to have access to the internet or to other resources.

As written, the exercise will require the students to take some measurements with a pair of calipers (included) or a ruler, and to solve some basic math problems. While they will not have to calculate any ratios, an understanding of them is helpful.

Each kit includes two casts, a handout that includes instructions and a labeled photo of the casts, and a pair of calipers.

Cast 1:

Upper molar from *Equus scotti*
Age: 14,000 years
Locality: Saltville, Smythe County, Virginia

Notes: *Equus scotti* is an extinct horse that was a close relative of modern horses. In fact, it's in the same genus as zebras and domestic horses, and it's about the same size. Horses originally evolved in North America and later spread to most other continents. At the end of the Ice Age all of the New World horses went extinct, including *E. scotti*, which was one of the last species in North America. Modern horses in North America are descended from domesticated European horses that were introduced to this continent in the last 400 years.

This cast is a replica of a specimen from Saltville, Virginia. This is a famous fossil locality that was mentioned by Thomas Jefferson in some of his writings. Many other Ice Age animals have been collected there, including mammoths, mastodons, musk ox and caribou.

Cast 2:

Palate from *Calippus regulus*, including several teeth
Age: 14 million years
Locality: Carmel Church Fossil Site, Caroline County, Virginia

Notes: Horses were very diverse during the Miocene Epoch (25 - 5 million years ago), with a large number of species on different branches of the horse family tree. Almost all of these branches are now extinct, even though they were very successful in the Miocene. *Calippus* is from one of branches that is now extinct, and was not ancestral to the living horses.

Calippus and its relatives were small, antelope-like horses that were only about 4 feet tall as adults. Like modern horses of the genus *Equus* they had grinding teeth that were well suited to eating grasses, but the teeth had a different enamel pattern than *Equus* (and, of course, *Calippus* teeth are much smaller than those of *Equus*).

This particular example of *Calippus* was not fully grown when it died. This is clear from the teeth; the 2nd and 3rd deciduous premolars (baby teeth) are still in place, and the 3rd molar had not yet erupted. Assuming *Calippus* grew at the same rate as *Equus*, this means it was about 2.5 years old when it died. Note that this is *not* the reason *Calippus* is so small; a 2.5-year-old horse has generally already reached its maximum adult size.

This cast is a replica of a specimen collected in 2001 from the Carmel Church Fossil Site. This site is mostly known for marine animals such as whales, sharks, and fish, but there have been several land animals found there as well.

Correlations to Virginia Standards of Learning

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

d) appropriate instruments are selected to measure linear distance, volume, mass, and temperature

e) appropriate metric measures are used to collect, record, and report data

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:

e) life cycles

Fifth Grade

5.1 The student will plan and conduct investigations in which:

b) estimations of length, mass, and volume are made

c) appropriate instruments are selected and used for making quantitative observations of length, mass, volume, and elapsed time

d) accurate measurements are made using basic tools (thermometer, meter stick, balance, graduated cylinder)

e) data are collected, recorded, and reported using the appropriate graphical representation (graphs, charts, diagrams)

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

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

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:

c) metric units (SI—International System of Units) are used
e) sources of experimental error are identified
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.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

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

d) graphing and arithmetic calculations are used as tools in data analysis
e) conclusions are formed based on recorded quantitative and qualitative data
f) sources of error inherent in experimental design are identified and discussed
l) alternative scientific explanations and models are recognized and analyzed
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

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Teacher's sample

In this lesson you will examine cast replicas of two fossil horses from Virginia. Your kit includes two casts replicas of fossils, a labeled photograph of your two casts that will help you identify each tooth and determine what measurements you need to take, and a pair of calipers.

Cast 1:

Upper molar from *Equus scotti*
Age: 14,000 years
Locality: Saltville, Smythe County, Virginia

Notes: *Equus scotti* is an extinct horse that was a close relative of modern horses. In fact, it's in the same genus as zebras and domestic horses, and it's about the same size. Horses originally evolved in North America and later spread to most other continents. At the end of the Ice Age most of the New World horses went extinct, including *E. scotti*, which was one of the last species in North America. Modern horses in North America are descended from domesticated European horses that were introduced to this continent in the last 400 years.

This cast is a replica of a specimen from Saltville, Virginia. This is a famous fossil locality that was mentioned by Thomas Jefferson in some of his writings. Many other Ice Age animals have been collected there, including mammoths, mastodons, musk ox and caribou.

Cast 2:

Palate (upper jaws) from *Calippus regulus*, including several teeth
Age: 14 million years
Locality: Carmel Church Fossil Site, Caroline County, Virginia

Notes: Horses were very diverse during the Miocene Epoch (25 - 5 million years ago), with a large number of species on different branches of the horse family tree. Almost all of these branches are now extinct, even though they were very successful in the Miocene. *Calippus* is from one of branches that is now extinct, and was not ancestral to the living horses.

This cast is a replica of a specimen collected in 2001 from the Carmel Church Fossil Site. This site is mostly known for marine animals such as whales, sharks, and fish, but there have been several land animals found there as well.

Part 1: How old was *Calippus* when it died?

Most mammals, including horses and people, have two sets of teeth. The first set, which grow in shortly after birth, are called **deciduous teeth** (sometimes, *baby teeth* or *milk teeth*). Eventually the deciduous teeth fall out and are replaced by the **permanent teeth**. In most animals there are more permanent teeth than deciduous teeth. For example, there are no deciduous molars.

When a tooth finally grows to the point that it extends beyond the gum line, it is said to have **erupted**. Only erupted teeth are involved in chewing food. An erupted tooth gets gradually ground down through chewing. In horses, an unerupted tooth has sharp points. After the tooth erupts the points start to grind down, and after enough time passes the surface of the tooth is almost flat.

Determine which teeth in *Calippus* have erupted, and which ones haven't. Use the diagram to help you identify each tooth.

	Heavy wear, light wear, or no wear?	Erupted? (Y/N)
3rd deciduous premolar	**H**	**Y**
4th deciduous premolar	**H**	**Y**
1st molar	**H**	**Y**
2nd molar	**L**	**Y**
3rd molar	**N**	**N**

Assuming *Calippus* grew at the same rate as modern horses, use the chart below to help you determine how old *Calippus* was when it died.

Approximate age when tooth erupts		
	Deciduous tooth	**Permanent tooth**
3rd premolar	2 weeks	2 - 3 years
4th premolar	2 weeks	2.5 - 3 years
1st molar	—	1 year
2nd molar	—	2 years
3rd molar	—	3 - 4 years

How old was *Calippus* when it died? Explain your answer.

Since the horse still had deciduous teeth, and since the 3rd molar had not yet erupted, it had to be less than 3 years old. Since the 2nd molar had erupted, it had to be at least 2

years old, but the 2nd molar was only lightly worn. Therefore, the horse was probably between 2 and 3 years old when it died.

Part 2: How big were fossil horses?

It can be difficult to determine the size of fossil organisms, especially if they're only known from incomplete remains. Even so, if a fossil organism has living relatives, it's sometimes possible to make a very rough estimate of body size.

With modern horses, a common measurement is the height of the horse at the shoulder. Like most domestic animals, domestic horses show a larger range of sizes than in most wild animals. The largest domestic horses, such as shire horses, can be over 200 cm tall, while the smallest domestic miniature horses are only about 85 cm tall.

Unfortunately, in order to measure height directly, we need a complete skeleton, and we very rarely find those as fossils. But if we take measurements of different body parts, we can set up ratios of one body part to another, which can allow us to make a rough estimate of the body size of our fossil animals.

For example, a modern horse breed called a percheron is approximately 174 cm tall, and the upper first molar has a length of approximately 28 mm. So we can set up the following ratio:

$$\frac{174\ \text{cm}}{28\ \text{mm}} = 6.2\ \frac{\text{cm}}{\text{mm}}$$

For high school and college students, you may want to only supply them with the percheron height and molar length measurements, and have them generate this equation themselves.

This allows us to set up the following equation:

$$H = L \times 6.2\ \frac{\text{cm}}{\text{mm}}$$

where H = horse shoulder height in cm, and L = length of the upper its molar in mm.

Again, older students should be able to generate this equation themselves.

Using your calipers, measure the length of the first molar in *Calippus* and in *Equus*. Use the included photograph to help you take the correct measurement.

Length of *Equus scotti* first molar: **Approximately 28-30 mm.**
Length of *Calippus regulus* first molar: **Approximately 18 mm.**

Length measurements may vary by several tenths of a millimeter, or only be to the nearest millimeter if using rulers or the included plastic calipers.

Then use the height equation above to estimate the height of *Calippus regulus* and *Equus scotti*.

Shoulder height of *Equus scotti*: **Approximately 174-186 cm.**
Shoulder height of *Calippus regulus*: **Approximately 112 cm.**

Height estimates may vary by +/- 2-3 cm.

Discussion:

1) Do you think your height estimates for each horse are very precise (do you think each horse was almost exactly as tall as your estimate)? What are some variables that might affect the height calculation?

They are probably not very precise. The height equation assumes that the body proportions of *Calippus* and *Equus* were exactly the same, but it's likely the proportions were somewhat different. There is also variation in body proportions between individuals of the same species, and between males and females of the same species. Some students may also notice that the length of the molar also changes slightly as it becomes more worn down.

This question, along with Question 2, may be a good time to review with students the difference between precision and accuracy.

2) Even if there is some uncertainty about the size of your fossil horses, can you say that *Equus* was definitely a much bigger horse than *Calippus*?

Even though there may be some uncertainty in the height measurements, *Equus* was clearly much larger than *Calippus*, probably a little less than twice as large.

3) How do the sizes of your two horses compare to breeds of horses that are alive today?

Students will have to use internet or other resources to answer this question. *Calippus* was about as tall as a Shetland pony. *Equus scotti* was the size of a large domestic horse, such as a Percheron or a Clydesdale.

4) Is it possible that *Calippus* was only small because it was a baby, and that when full grown it would have been as large as *Equus*? Explain your answer. (Hint: consider what you learned about *Calippus* in Part 1).

***Calippus* was not small because it was a baby. From Part 1, the eruption of the 1st and 2nd molars showed that *Calippus* was 2-3 years old, and was nearly full grown.**

5) Among modern domestic horse breeds, Clydesdales are much bigger than Shetland ponies, but they belong to the same species. Is it likely that *Calippus* and *Equus* belong to the same species? Explain your answer. (Hint: look closely at the patterns of ridges on the worn surfaces of the molars. Are they identical, or are there differences?)

Students should notice that, in addition to the size difference, *Calippus* and *Equus* have different patterns of enamel ridges on the molars. In particular, there is a loop of enamel on the inside of the tooth (called a protocone) that is much larger in *Equus*, and *Equus* has many small loops and turns in the enamel ridges that are not present in *Calippus*.

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4th deciduous premolar		
1st molar		
2nd molar		
3rd molar		

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Length of *Equus scotti* first molar:

Length of *Calippus regulus* first molar:

Then use the height equation above to estimate the height of *Calippus regulus* and *Equus scotti*.

Shoulder height of *Equus scotti*:

Shoulder height of *Calippus regulus*:

Discussion:

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