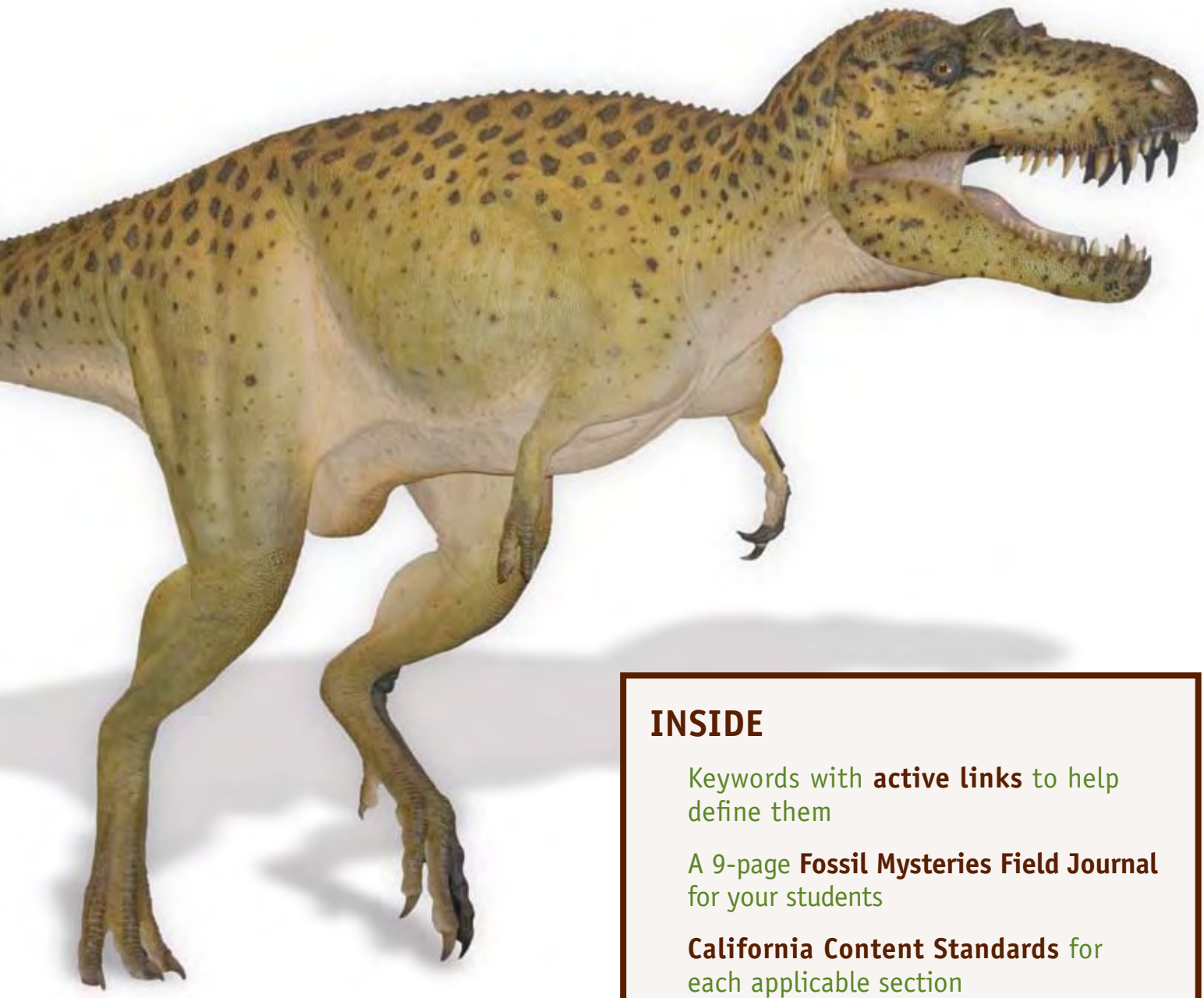
San Diego Natural History Museum

FOSSIL MYSTERIES

Teachers' Guide



INSIDE

Keywords with **active links** to help define them

A 9-page **Fossil Mysteries Field Journal** for your students

California Content Standards for each applicable section

Guide made possible through the generous support of the Ellen Browning Scripps Foundation and the Thursday Club Foundation.

contents

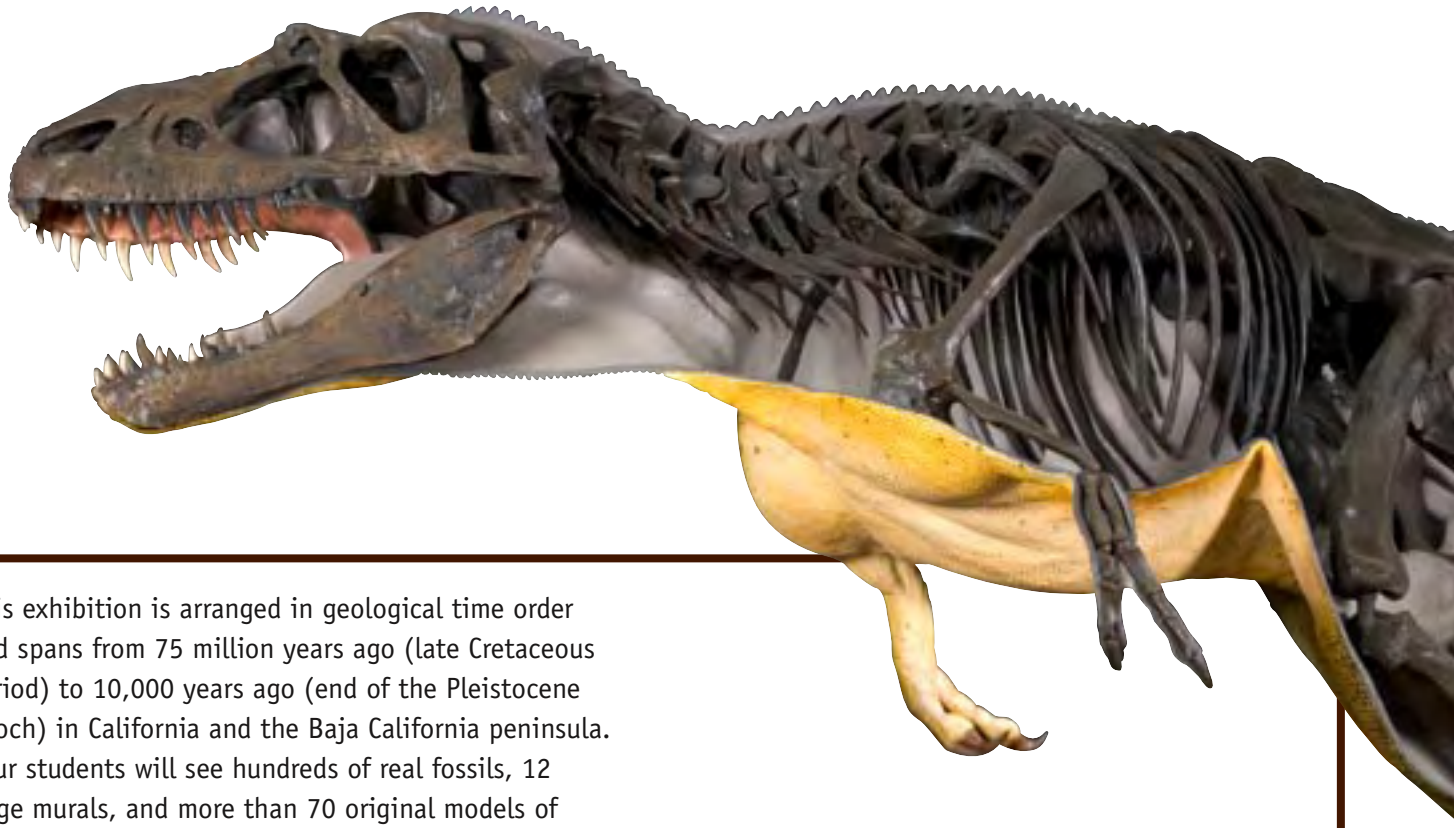
Dear Educator,

Welcome to *Fossil Mysteries*. This guide includes an exhibition overview, links (type that is bold, italic and brown), and curriculum to help make your Museum visit an engaging educational experience. Please accept our invitation to share your students' work with us for possible inclusion in future versions of this guide or for display at the Museum.

References to California Content Standards are included where appropriate.

If you have questions related to this guide please call the Museum Education Department at 619.255.0311 or email education@sdnhm.org.

About FOSSIL MYSTERIES



This exhibition is arranged in geological time order and spans from 75 million years ago (late Cretaceous Period) to 10,000 years ago (end of the Pleistocene Epoch) in California and the Baja California peninsula. Your students will see hundreds of real fossils, 12 large murals, and more than 70 original models of plants and animals including a dramatic walk-in diorama of an Eocene Epoch forest. Our interactive gallery map allows you to navigate the galleries before your visit:

http://www.sdnhm.org/exhibits/mystery/exh_map.html

http://www.sdnhm.org/exhibits/mystery/fg_glossary.html.

The specimens and exhibits you will see are the records of our region's distant past. They carry essential and relevant information about the ongoing forces of earth processes, evolution, extinction and ecology. A Museum visit will inspire your students to make meaningful connections to Earth and Life Science curriculum goals.

California State Science Content Standards

Grades 1–12 *Investigation and Experimentation*
K–4 *Life Science*
Grades 2, 4, 6, 7 *Earth Science*
Grade 6 *Ecology*
Grade 7 *Evolution*
Grades 9–12 *Ecology, Evolution*
Grades 9–12 *Dynamic Earth Processes*

Prepare KEY CONCEPTS

"The general idea of evolution is that the present arises from materials and forms of the past."

National Science Education Standards

Evolution

Biological evolution is the idea that all living creatures share common ancestors and have descended with modification from these ancestors. For example, mammoths and mastodons had a smaller, elephant-like common ancestor living 50 million years ago in Africa. As mammoths and mastodons diverged over time from their common ancestor and from each other, they acquired differences in skeletons and teeth. With these differences, they were able to occupy different niches in the environment. Their fossils serve as lenses through which we can see and study these changes.

Fossils offer testable evidence of evolutionary patterns, of lineages that belong to a grand "tree" of life. Branches of that tree are never found wildly out of place. We don't expect mammoths and mastodons to be found in rocks of the Mesozoic Era (248–65 million years ago)—thousands of fossil discoveries show that they evolved later, after the end of the Mesozoic.

Natural selection is the mechanism driving evolution. Natural selection requires:

- genetic variation in a population of organisms,
- a particular environment, in which some variable traits can be adaptive, and
- individuals with favorable variations reproducing more successfully than individuals lacking these variations.

During your visit, students can examine mammoth and mastodon fossil specimens and then compare them to the skull of a modern Asian elephant in the Sefton Atrium.

Earth Processes

Earth's crust moves: it grows, shrinks, and is reshaped in a recycling process called ***plate tectonics***. The crust is broken into large rigid plates that move, always in relation to each other. Plates travel toward, away from, against, and dive beneath each other.

Gravity is the main mechanism driving plate motion as dense cold oceanic plates are pulled toward the mantle. Hot buoyant rocks rise on the opposite edge of a plate and pour out along spreading boundaries.

Plate motion creates, destroys, and deforms Earth's surface. Earthquakes and volcanoes provide some of the contemporary evidence for this dynamic process. Rocks and fossils evince tectonic events of the past. In the Miocene gallery you will find fossil evidence of marine life unearthed at sites in today's Carrizo Badlands, far from the Gulf of California. A six-inch shark's tooth may seem out of place there, but 15 million years ago, as moving plates were stretching western North America, a long narrow basin formed and ocean waters flowed in to create a gulf as far north as Palm Springs. ***Carcharodon megalodon***, a 40-foot predatory shark, was right at home.

Extinction

Life on Earth is a delicately balanced system. Global large-scale extinctions happen when species can not adjust to major chemical, physical, or biological changes. Since life began, whole lineages of animals and plants have become extinct. More than 99% of all life that has ever existed is estimated to be extinct. This estimate is based upon our understanding of diversity within modern living systems and myriad extinct forms in the fossil record.

Paleontologists recognize several major periods of mass extinction. One such event occurred 65 million years ago. Dinosaurs, ***mosasaurs***, ***pterosaurs***, and ***ammonites***, represented in our Cretaceous (144–65 million years ago) gallery, as well as many species of plants, insects, birds and marine plankton all perished. Curiously, many other birds, insects, plants and mammals survived.

This disruption of life on the land and in the ocean coincided with the impact of a six-mile-wide asteroid near Chicxulub, Mexico. At the time of the impact, global atmospheric changes resulted from vast amounts of shattered rock and asteroid debris hurled into the stratosphere. Earth darkened and for months photosynthesis halted. Burning forests and vaporized rocks releasing carbon and sulphur dioxides brought global warming and acid rains. Plants and animals had little time to adapt and mass extinctions resulted.

Ask your students to suggest what adaptive features of some living things may have contributed to their continued viability.

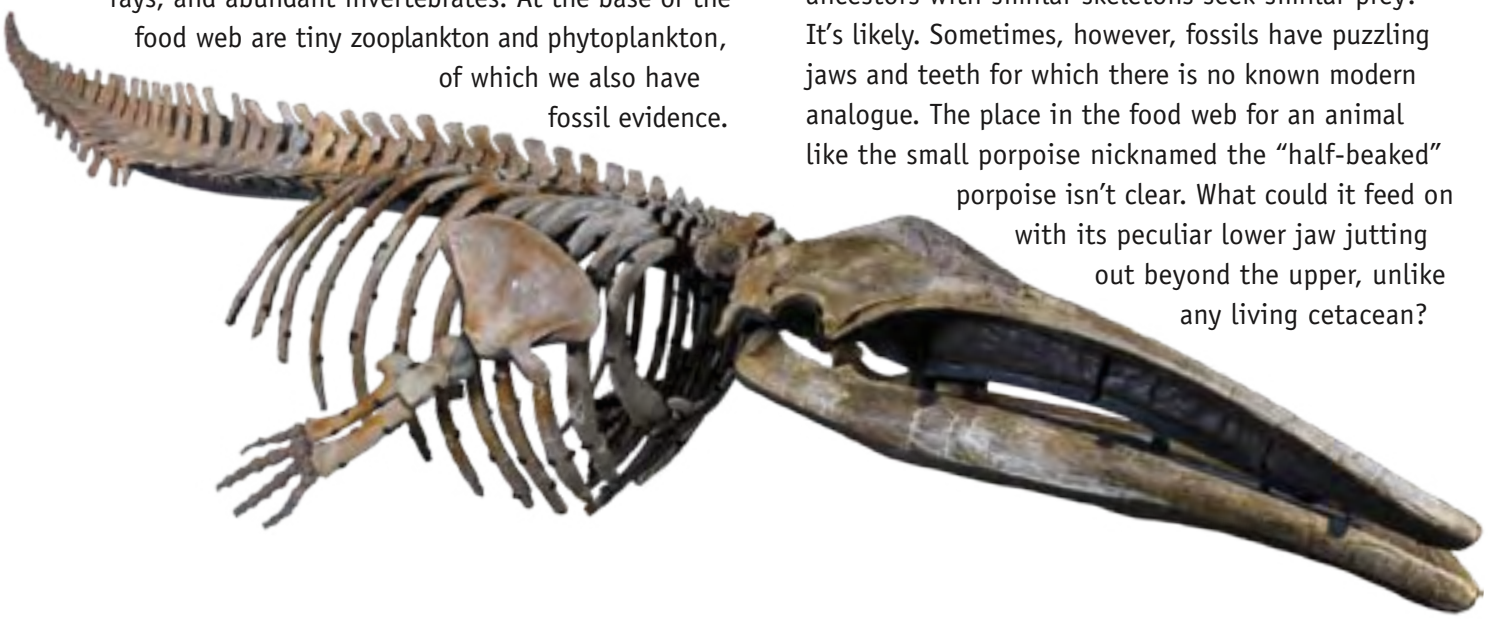
Ecology

Ecology is the study of how living things and their environment interact with one another. Understanding a community's food web is an essential thread of ecology because it illustrates connections between predators and their prey.

The Pliocene (5–1.8 million years ago) gallery's mural of a dynamic marine ecosystem is based on a rich ***fossil record*** that includes several species of toothed and baleen whales such as an ancestor of our present-day ***gray whale***, plus other animals such as ***sea cows*** and ***walruses***, flightless auks, fish, sharks, rays, and abundant invertebrates. At the base of the food web are tiny zooplankton and phytoplankton, of which we also have fossil evidence.

The large warm-blooded animals such as whales have enormous energy requirements and prodigious appetites. However, recognizing feeding habits in extinct communities is sometimes difficult. Paleontologists use knowledge of living ecosystems to help define the patterns that may have existed in ancient habitats like San Diego's Pliocene bay.

For example, all modern baleen whales filter water or mud to collect their prey. They are unusual examples of large animals that feed on some of the tiniest creatures within the food web. Did their ancestors with similar skeletons seek similar prey? It's likely. Sometimes, however, fossils have puzzling jaws and teeth for which there is no known modern analogue. The place in the food web for an animal like the small porpoise nicknamed the "half-beaked" porpoise isn't clear. What could it feed on with its peculiar lower jaw jutting out beyond the upper, unlike any living cetacean?



Explore MUSEUM ACTIVITIES

Learning how to enjoy a museum visit is an important academic skill. A good visit balances purpose and pleasure. The perfect time to prepare your students for any post-visit activities is before your visit. This allows your students to focus and to thoughtfully gather the information and ideas they will need later. The students should feel free to make independent inquiries and to reflect. It may be useful to provide your students with journals to record observations and inferences.

This section provides opening questions. We hope that you will discover many more lines of inquiry. If you would like to preview the exhibition to prepare for your class visit you may do so at anytime after you have registered. Contact the registrar for more details at 619.255.0210.

http://www.sdnhm.org/exhibits/mystery/exh_map.html

Evolution

How do fossils reveal the process of evolution?

Ask students to do a field survey and make a written record of San Diego's Eocene (55–34 million years ago) fauna using the models and fossils in the Eocene gallery. How many species can they find? Don't forget the invertebrates. Some of the animals are quite exotic and unfamiliar while others look very much like modern animals. Ask the students to organize their data into three categories: animals that have changed little and are still living in San Diego, animals that no longer live in San Diego and animals that are extinct. You may ask your students to pair each species with its preferred habitat. Ask students to determine whether observations or inferences are informing their choices.

The artists and scientists who created the Eocene diorama designed the models of these animals by employing both close study of the fossil evidence and knowledge of the physiology and behavior of living animals.

Ask the students to think about modern carnivores—dogs, cats, weasels and bears—and then ask them to take a second look at the Eocene, this time focusing on just the fossil jaws in the carnivore exhibit case. How are they similar to and how are they distinct from each other? Do they look like the jaws of modern carnivores?

Discussion:

Modern carnivores evolved from animals with jaws most like ***Tapocyon***, with upper and lower teeth for slicing (the carnassials) located in the middle of the jaw. *Hyaenodon*, in contrast, had slicing teeth in the rear of its jaw, a pattern not seen in today's carnivores.

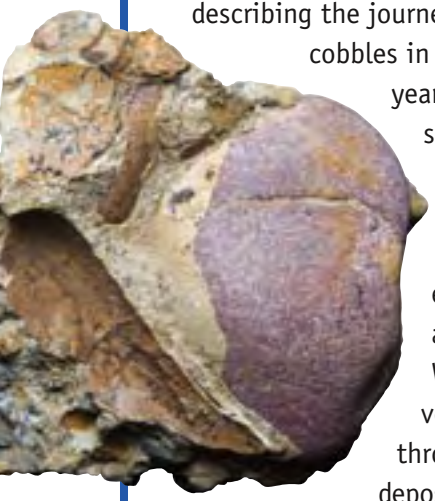
Fossils reveal the process of evolution by allowing us to see both changes and consistencies in life forms over great expanses of time.

California State Science Content Standards

K *Life*—2a
Grade 1 *Life*—2a, d; *Investigation and Experimentation*—4a, b
Grade 2 *Life*—2a, d; *Investigation and Experimentation*—4d, g; *Earth*—3d
Grade 3 *Life*—4a-d; *Investigation and Experimentation*—5e
Grade 4 *Investigation and Experimentation*—6a, f
Grade 5 *Investigation and Experimentation*—6h
Grade 6 *Investigation and Experimentation*—7a, e
Grade 7 *Evolution*—3a, c, e; *Earth Sciences*—4e
Grades 9–12 *Evolution*—8a, b, e

Earth Processes

How can the life story of a single rock reveal the movement of Earth's crust?



Ask your students to draw or write a narrative describing the journey of the ***red rhyolite*** cobbles in the Miocene (24–5 million years ago) gallery. How did smooth red rocks from Sonora, Mexico, get into San Diego's backyards? The rhyolite cobbles tell a story of eruption, erosion, deposition and continental movement. Worn away from ancient volcanoes, they tumbled through waterways and were deposited on coastal plains that rifted away from the mainland to form peninsular California. The Miocene gallery includes interactive displays, maps, and fossils to introduce and reinforce the concept of plate tectonics. Be sure to direct your students' attention to the western hemisphere on the Omni Globe located near the pendulum and watch closely for the formation of the Baja peninsula.

The movement of Earth's tectonic plates as they are destroyed and renewed in a continuing process is recorded in the geologic record.

California State Science Content Standards

Grade 1 *Investigation and Experimentation*—4a, b
Grade 2 *Investigation and Experimentation*—4d, g
Grade 3 *Investigation and Experimentation*—5e
Grade 4 *Investigation and Experimentation*—6a, f; *Earth*—5 a, c
Grade 5 *Investigation and Experimentation*—6h
Grade 6 *Investigation and Experimentation*—7a, e; *Plate Tectonics*—1a, e, f
Grade 7 *Earth Sciences*—4a
Grades 9–12 *Dynamic Earth Processes*—3a, b, c, f

Extinction

How does knowledge of past extinctions shape our ideas about endangered species? *Fossil Mysteries* will introduce your students to many prehistoric animals that may be unfamiliar, like the ***brontothere***. ***Sea cows***, ***camels***, and ***walruses*** may be more familiar, but students may be surprised to learn that these creatures lived here, far from their modern ranges, only a few million years ago.

Some extinctions are on a grand scale, involving many categories of animals and plants. Students may be familiar with the cosmic catastrophe that precipitated the Cretaceous extinctions, but many later extinctions and ***extirpations*** are also represented in the exhibition.

The Pleistocene (1.8 million–10,000 years ago) mass extinction of large mammals in North America is a much-studied event because it occurred within the last 13,000 years as the sea level rose and the climate here warmed and dried. Changes in landforms and climate affect vegetation zones. These external factors influence the success of a species. What are some other things that might determine a Late Pleistocene animal's success in a changing environment?

Ask your students to choose an animal from the Pleistocene gallery that is now extinct. What inferences can they make about the cause or causes of its extinction? Take a look at the ***pack rat midden*** and consider the rat as a survivor. How are its size, habitat, and food requirements different than those of an animal that became extinct such as the Dire Wolf? What about reproduction rates? How about the presence of humans in their world? When did humans enter North America?

Today only one large predator lives in our immediate region. Ask your students to consider the mountain lion's place in our changing environment.

An animal's size, diet, habitat range and reproduction patterns may influence its ability to survive in a changing environment.

California State Science Content Standards

Grade 3 *Investigation and Experimentation*—5d, e; *Life*—4a–d
Grade 4 *Investigation and Experimentation*—6a, f; *Life*—3b
Grade 6 *Ecology*—5e
Grade 7 *Evolution*—3e; *Earth Sciences*—4e
Grades 9–12 *Ecology*—6a, b; *Evolution*—8a, e

Ecology

What does fossil evidence of adaptation tell us about past habitats?

What can fossils reveal about the relationship between animals, plants, and their environments?

Ask students to take a mural walk through the Eocene (55–34 million years ago) gallery and to the Oligocene mural and Oligocene fossils. Ask your students to contrast the Eocene warm, wet forest habitat with the drier open spaces pictured in the Oligocene mural. Look carefully at the animals and their behaviors. Have them look carefully at the plants. What kinds of vegetation do they observe and what can they infer about the climate? Record observations in a field journal and make sketches. How have the landscapes changed?

Forest habitats favored which lifestyles? Open spaces with grass favored which lifestyles? What adaptations were favored to answer the challenges and opportunities in each? Take a look at the deer-leg interactive in the biomechanics gallery to see the features that enhance this animal's ability to run to escape predators. Take a look at the gibbon and fossil primate arms in the same area to see what adaptations allowed early primates to climb in the trees.

We can make inferences about the ancient habitats animals occupy from knowledge of their adaptations.

California State Science Content Standards

Grade 1 *Investigation and Experimentation*—4a, b; *Life*—2a, c, d
Grade 2 *Investigation and Experimentation*—4d, g; *Earth*—3d
Grade 3 *Life*—4 a–d; *Investigation and Experimentation*—5e
Grade 4 *Investigation and Experimentation*—6a, f; *Life*—2b, 3a, b
Grade 5 *Investigation and Experimentation*—6h
Grade 6 *Investigation and Experimentation*—7a, e
Grade 7 *Evolution*—3a, c, e; *Earth Sciences*—4e
Grades 9–12 *Evolution*—8a, b, e; *Ecology*—6a, b

Expand CLASSROOM ACTIVITIES

We want to hear from you. Please share your students' work with us. Contact the School Programs Manager at 619.255.0311 to submit student artwork, writing or photos.

Elementary & Middle School

Ask students to share what they have learned from the exhibition. What makes a fossil special? How can fossils be used like evidence in a crime-scene investigation to understand prehistory? How does the study of prehistory help us to understand Earth today? Can you think of any reasons why people might want to know and understand Earth processes? Think about the things you use and the natural resources used to make them. Think about California's earthquake history. How does studying geology and prehistory improve our lives and protect the environment?

California State Science Content Standards

Grade 2 *English Language Arts: Listening and Speaking*—2.1
Grade 3 *English Language Arts: Speaking Applications*—2.1
Grade 5 *English Language Arts: Analysis and Evaluation of Oral and Media Communications*—1.8
Grade 6 *Plate Tectonics*—1f; *Shaping Earth's Surface*—2d; *Resources*—6a–c
Grade 7 *English Language Arts: Research and Technology*—1.4

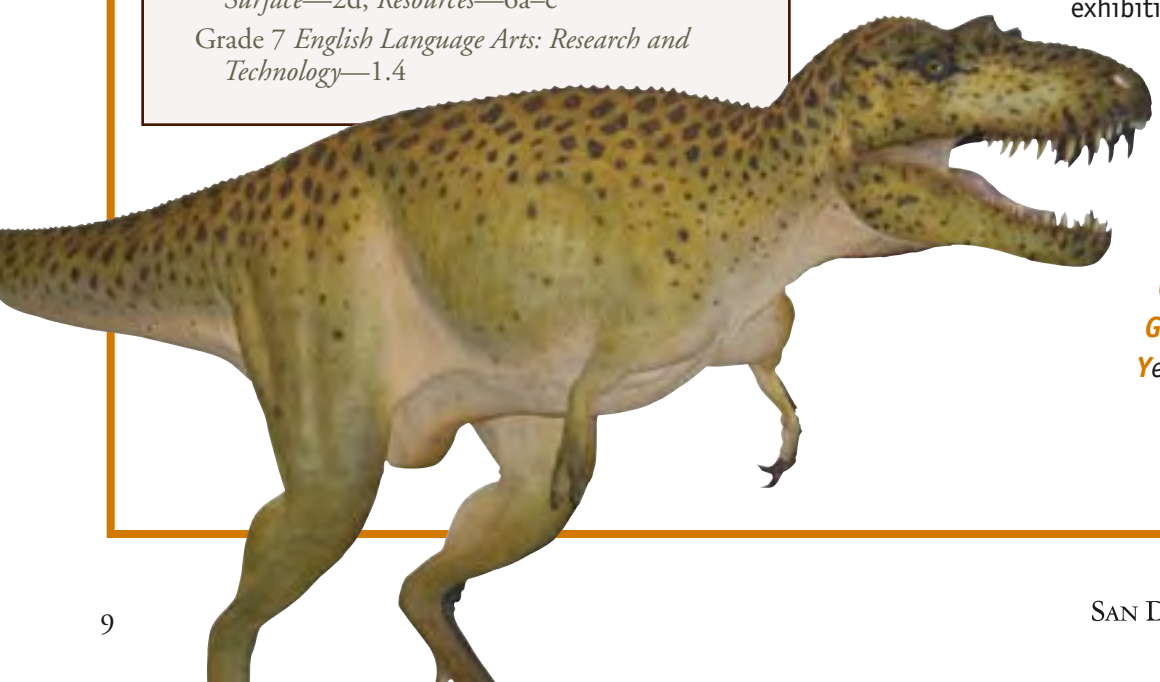
Create a classroom timeline mural for southern California. Visit ***http://www.sdnhm.org/exhibits/mystery/fg_timeline.html.*** Using linked poster boards or lengths of butcher paper, have teams create epoch panels. Students may use sketches of plants and animals made during the Museum visit to illustrate the final work. Visit ***http://www.sdnhm.org/exhibits/mystery/fieldguide.html*** for further reference.

California State Science Content Standards

K *Life*—2a
Grade 1 *Life*—2a, d; *Investigation and Experimentation*—4a, b
Grade 2 *Life*—2a, d; *Investigation and Experimentation*—4d, g; *Earth*—3d
Grade 3 *Life*—4a–d
Grade 7 *Evolution*—3a, c, e; *Earth Sciences*—4e

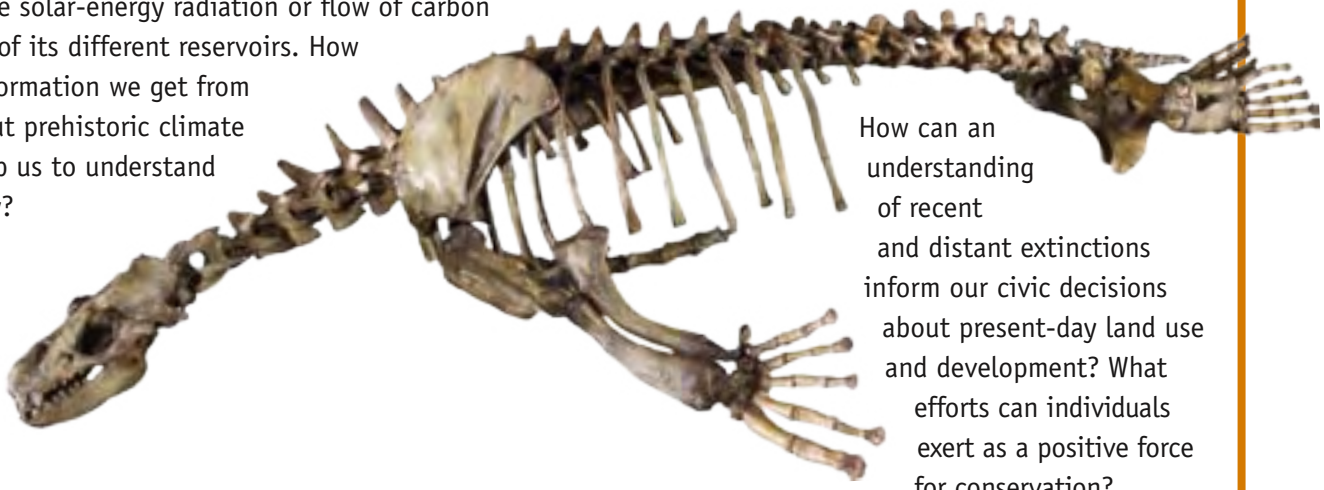
Write acrostic poems using the four "E"s of the exhibition; *evolution, ecology, extinction, earth processes.* Example:

Earth is an engine of
Cycles that can be
Observed in
Living and nonliving aspects.
Ocean, lithosphere, sky—
Graven in the fossil record
Years in millions are scored.



Middle & High School

Ask students to share what they have learned from the exhibition. How does knowledge about climate change and extinction patterns in the past inform us about life on Earth today? Research energy and biochemical cycles and then design a model to demonstrate solar-energy radiation or flow of carbon in and out of its different reservoirs. How can the information we get from fossils about prehistoric climate change help us to understand Earth today?



Helpful links:

http://www.planetguide.net

http://www.oceandrilling.org/Education/Educ.html

California State Science Content Standards

Grade 6 *Resources*—6a–c

Grade 7 *Investigation and Experimentation*—7b–d; *Earth Sciences*—4a, e

Grades 9–12 *Investigation and Experimentation*—m; *Ecology*—6b–f; *Energy in the Earth System*—4a–c, 5a–e, 6c; *Biochemical Cycles*—7a–d; *Structure and Composition of the Atmosphere*—8a–c

San Diego County has been identified as a "hotspot" of biodiversity.

Research what this means and then identify a threatened species of plant or animal in your area.

How can an understanding of recent and distant extinctions inform our civic decisions about present-day land use and development? What efforts can individuals exert as a positive force for conservation?

Helpful links:

http://www.sandiego.gov/planning/mscp/index.shtml

http://interwork.sdsu.edu/fire/resources/overview_bioderversity.htm

California State Science Content Standards

Grade 6 *Ecology*—5e

Grade 7 *Evolution*—3 a, e

Grade 9-12 *Science and Investigation*—m; *Ecology*—6b; *Energy in Earth's System*—6b

Glossary RESOURCES

Fossil Mysteries Glossary link

http://www.sdnhm.org/exhibits/mystery/fg_glossary.html

More reading

The Discovery of Evolution, David Young. Cambridge University Press and the Natural History Museum, London, 1992.

Evolution vs. Creationism, An Introduction, Eugenie C. Scott. University of California Press, Berkeley, 2004.

Future Evolution: An Illuminated History of Life to Come, Peter Ward. Henry Holt and Company, New York, 2001.

The Rise and Fall of San Diego, Patrick Abbott. Sunbelt Publications, San Diego, 1999.

Earth: An Intimate History, Richard Fortey. Alfred A. Knopf, New York, 2004.

Planet Ocean: A Story of Life, the Sea, and Dancing to the Fossil Record, Brad Matsen. Ten Speed Press, Berkeley, 1994.

Life History of a Fossil: An Introduction to Taphonomy and Paleoecology, Pat Shipman. Harvard University Press, Cambridge, 1981.

No Turning Back, Richard Ellis. Harper Collins, New York, 2004.

The Cretaceous World, Peter Skelton. Cambridge University Press, Cambridge, 2003.

T. rex and the Crater of Doom, Walter Alvarez. Princeton University Press, Princeton, 1997.

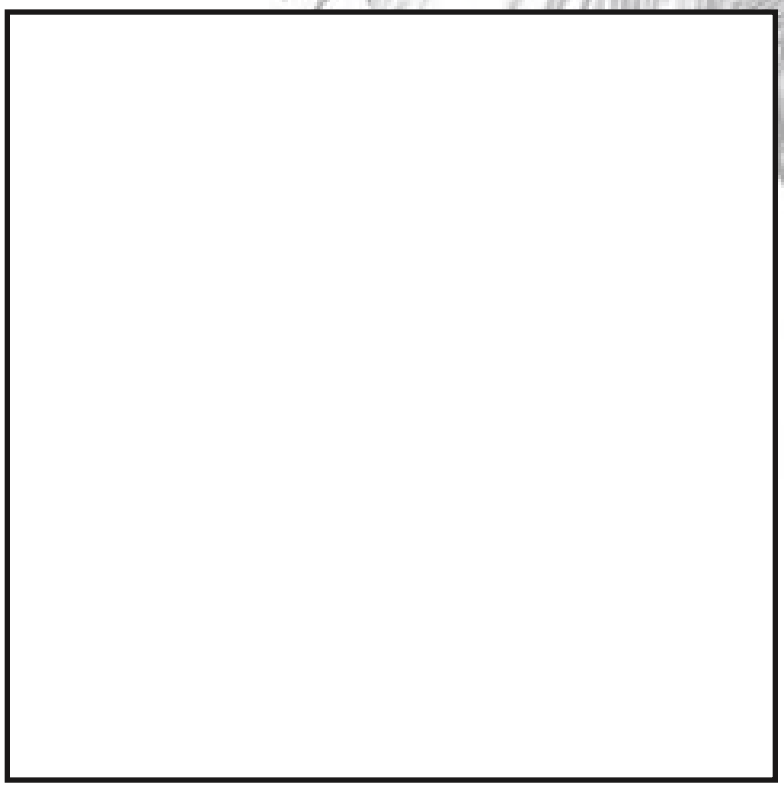
FOSSIL MYSTERIES
Field Journal

1. How many animals can you find in the Eocene rainforest? Fill the boxes below with drawings of the animals you see, one in each box:

Did you look above and below? Some animals are small and camouflaged.

2. On this page draw an Eocene animal in its habitat. Does it live in the trees, the water or the forest floor?

3. Take a good look at *Tapocyon*'s teeth. Draw them.
Do these teeth look like the teeth of modern carnivores?
Write the names of three modern animals that have similar teeth.

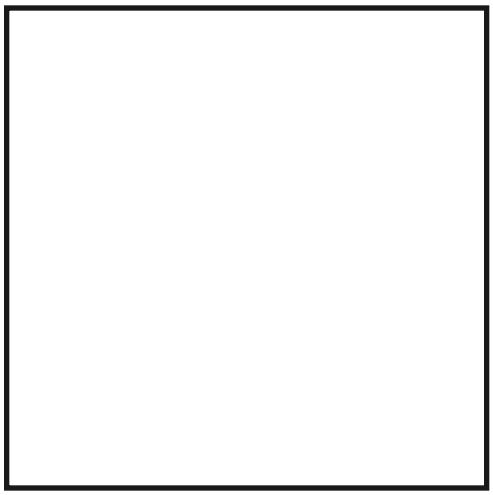
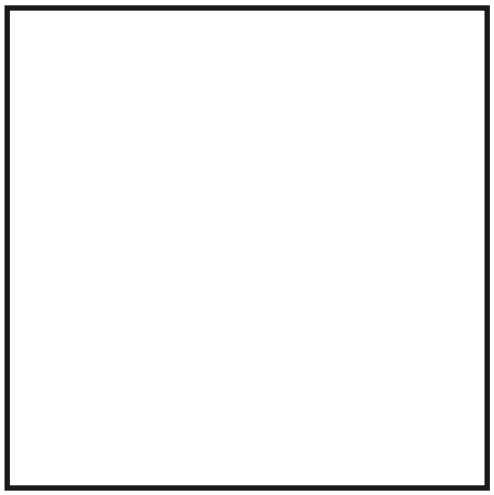
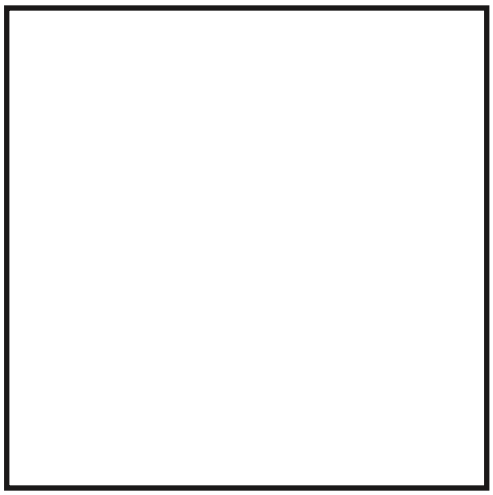


***Tapocyon*'s teeth**

_____, _____

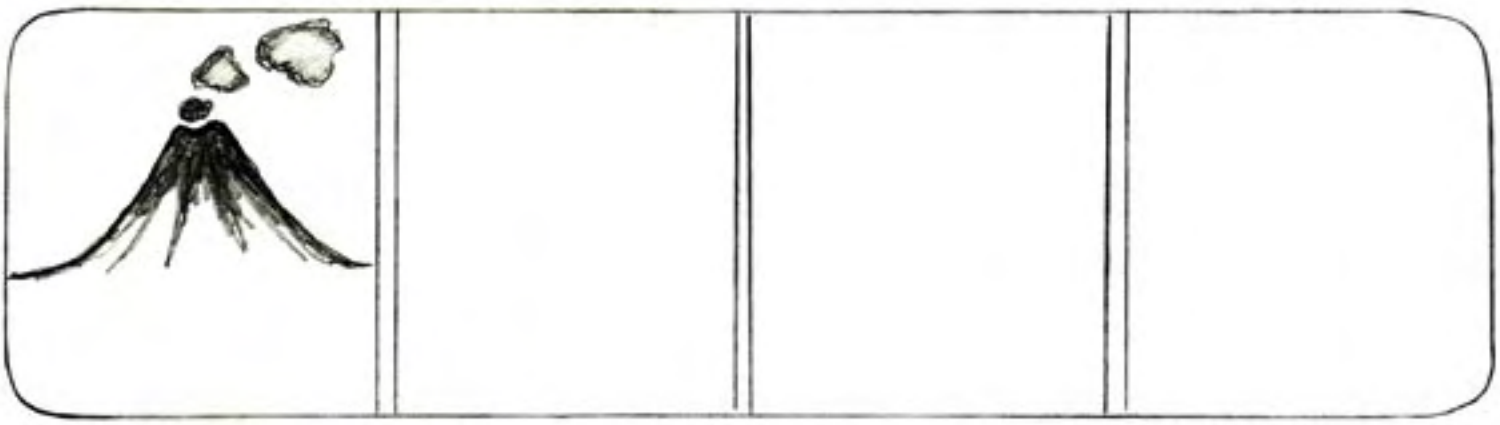
and _____ **have teeth like *Tapocyon*.**

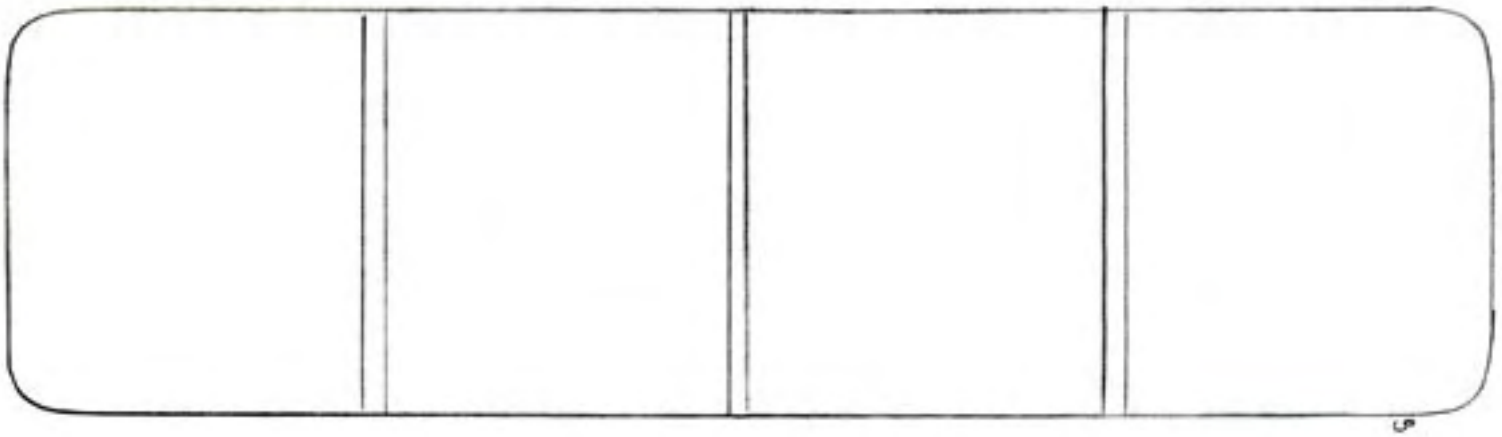
4. Find some other teeth and draw them.

Write four sentences comparing and contrasting the teeth you have drawn here to *Tapocyon*'s teeth.

5. How did the smooth red rocks (the rhyolites) travel from Sonora, Mexico, to San Diego's backyards?
Draw a comic strip to tell the story.





6. Choose an extinct animal from the Pleistocene gallery. What do you think are some reasons this animal became extinct?

I think the _____

became extinct because _____

_____

_____

_____

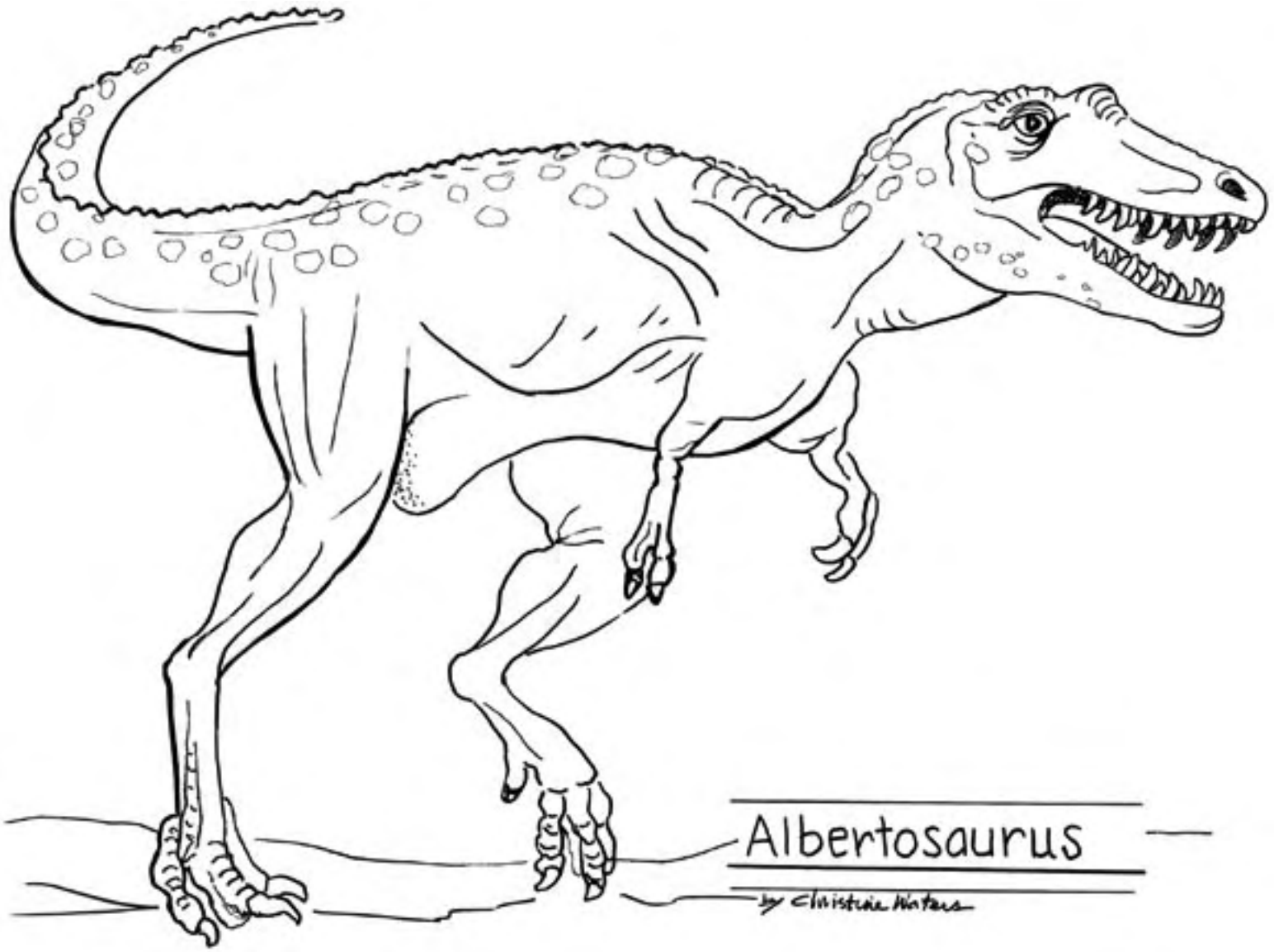
_____

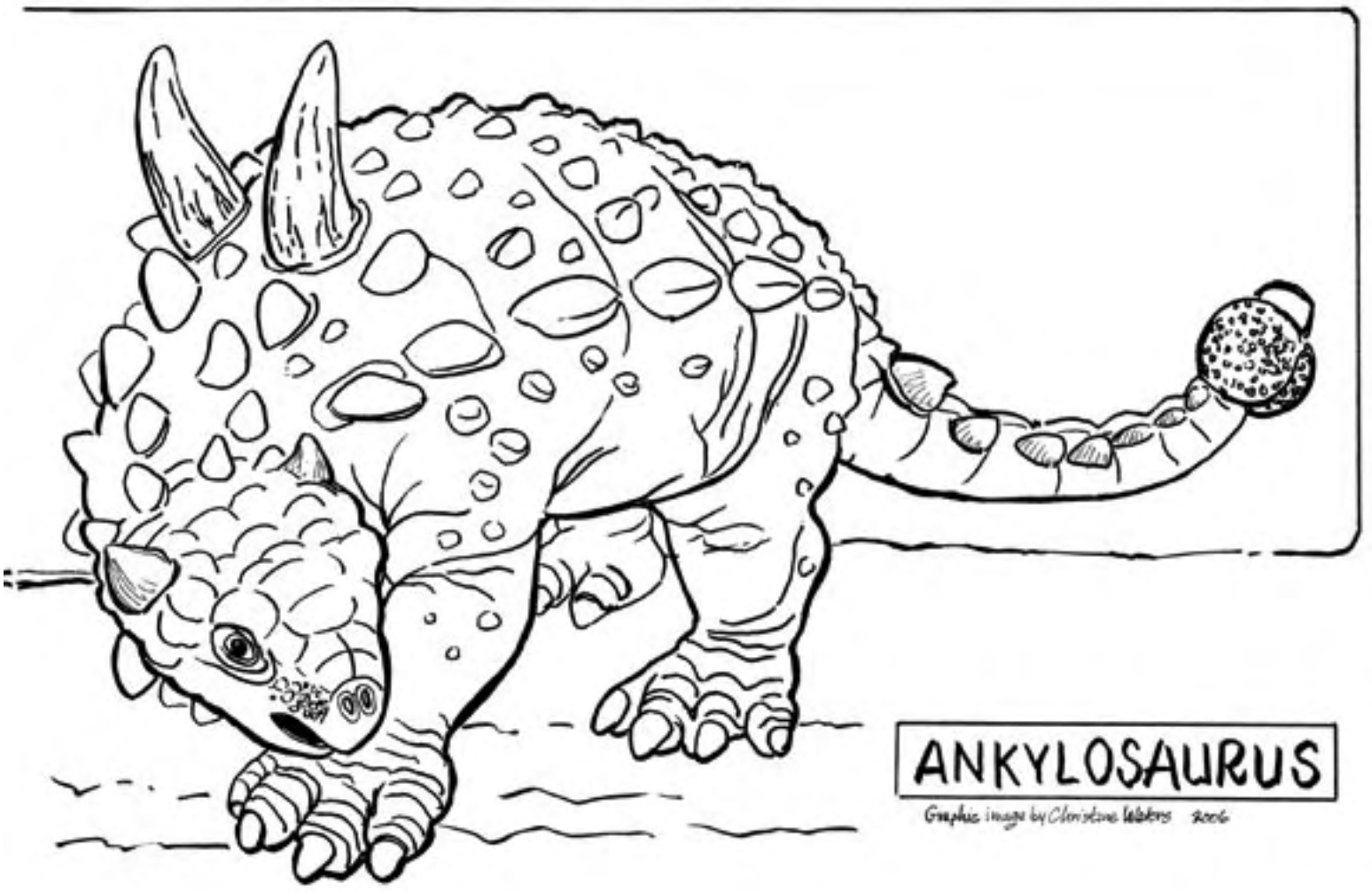
_____

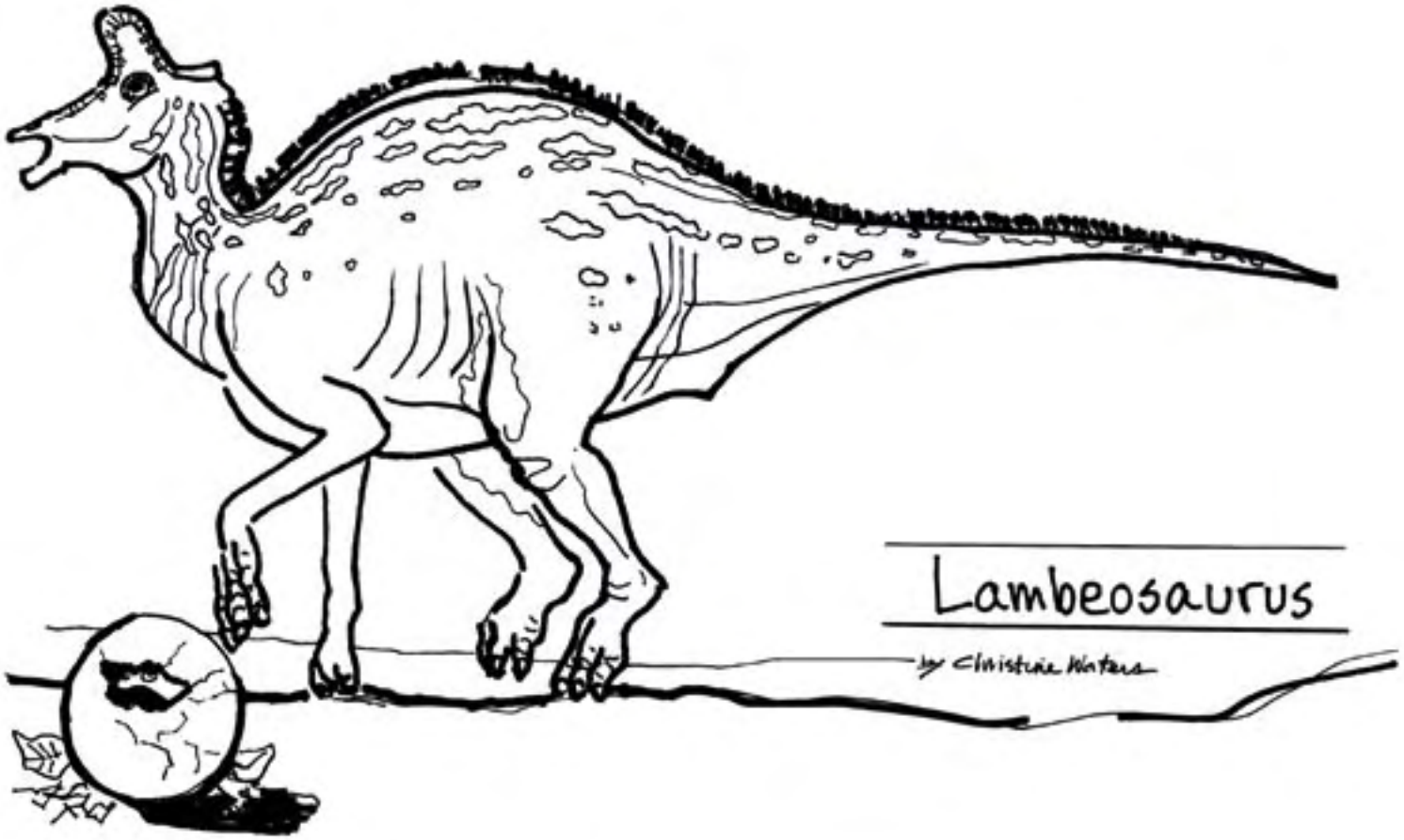
_____

_____

_____


Albertosaurus


ANKYLOSAURUS
Graphic image by Christine Walters 2006


Lambeosaurus
by Christine Waters

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