Feathered Dinosaurs and the Origin of Flight

SAN DIEGO NATURAL HISTORY MUSEUM

Teacher's Guide

Dear Educator,

Welcome to *Feathered Dinosaurs and the Origin of Flight.*

The enclosed materials have been designed to provide an educational and enjoyable experience for you and your students. This guide includes background information, vocabulary, student pre-visit materials, Museum visit worksheets, and post-visit activities, answers, and references. These materials are most appropriate for grades 3–6, but may be adjusted for other grade levels.

References to California Content Standards are included where appropriate. Words in boldface are in the glossary.

If you should have questions related to this guide please call the Museum Education Department at 619.255.0202 or email <cradford@sdnhm.org>

Exhibit Overview

From Liaoning, China's fossil beds of fine lake silt, come some of the most spectacular dinosaur/bird fossils ever discovered, and with them, new and revealing information about their relationships. These fossils—from feathered dinosaurs and birds to mummified lizards with color patterns—are brought to life through a series of dramatic life-size recreations by world-renowned sculptor Stephen Czerkas. Innovative tools help viewers to better see and understand the fossils, offering a new understanding of prehistoric life.

Through the use of fossils, photographs, diagrams, and models, this exhibition explores and seeks to answer the following questions:

• What is the relationship between dinosaurs and birds?
• Did birds evolve from dinosaurs?
• Are some dinosaurs actually birds?
• When did feathers first appear?
• Did flight originate from the trees down or the ground up?

Background

Earth Dynamics

Two hundred and fifty million years ago, the world's continents were clustered together in a super continent known as **Pangea**. Over the years, crustal movement has separated the continents, slowly moving them to their present positions.

As the land moves and changes, so does the climate. For instance, oceans tend toward moderate climate along coastal strips while interior areas tend toward more severe climates. Mountains often act as moisture barriers; one side of the mountain captures rainfall, while the opposite side receives little rain and is very dry.

Life forms are affected by changes in landforms and climate. Depending on their ability to **adapt** to change, plants and animals will either survive or become extinct.

Earth and Time

Geologists have developed a time scale dividing the history of the Earth into eons, eras, and shorter intervals of time. The **Mesozoic** ("middle life") Era began approximately 248 million years ago and ended approximately 65 million years ago. The Mesozoic Era is divided into three parts—the **Triassic**, **Jurassic**, and **Cretaceous** Periods—and is often called the Age of Reptiles. Dinosaurs appeared about 228 million years ago during the Triassic Period.

Early dinosaurs were mostly small predators. By the end of the Triassic Period, 206 million years ago, species of dinosaur had increased in size, and plant-eating dinosaurs had made their appearance. Since Pangea was still mostly intact, these early dinosaurs were able to migrate and disperse throughout the world.

It was during the Triassic Period that the last of the **synapsids** (mammal-like reptiles) disappeared. The first small, true mammals replaced the synapsids. In addition, the Triassic world was populated by assorted invertebrates, amphibians, fish, and other non-dinosaur reptiles such as crocodilians, turtles, and the sea-going *ichthyosaurs*.

During the Jurassic Period, 206-144 million years ago, dinosaurs became the ruling land animals. Some dinosaurs grew to be gigantic, while others remained rather small. Jurassic dinosaurs shared the Earth with various invertebrates, salamanders, fish, *ichthyosaurs*, *plesiosaurs*, small mammals, and ***archaeopteryx***—an early bird.

By the end of the Cretaceous Period, 144 to 75 million years ago, Earth's continents had moved to positions similar to those today. A circum-equatorial ocean—The Tethys Sea—created generally tropical conditions. The climate was mostly warm, but ranged from cool to hot with definite seasons. As the Cretaceous Period progressed, the climate became cooler and drier.

As Pangea separated, isolation of the continents contributed to the evolution of a wide variety of dinosaur types. Dinosaurs lived in deserts and polar regions. They grew both huge and small. Efficient plant-chewers and the most powerful meat-eaters appeared near the end of the Cretaceous Period.

Along with dinosaurs, other animal life diversified. There were many modern kinds of insects and other invertebrates, frogs, fish, turtles, lizards, snakes, small mammals, birds, and very large *pterosaurs*.

Extinction and Evolution

The **Theory of Evolution** states that all organisms descended from common ancestors and have changed over time. Organisms that adapt to changes in the environment survive and reproduce, while those that fail to adapt become extinct.

Convergent evolution refers to similarities in structure in distantly related groups that are due to environmental adaptations. For instance, if dinosaurs developed feathers for insulation but not flight, and birds developed feathers for flight but not insulation, the feathers would be an example of convergent evolution.

Throughout the Mesozoic Era, evolution and extinction were on-going processes. The periodic extinction of certain dinosaur species was matched by the evolution of new species. Thus, the dinosaur faunas of the Triassic, Jurassic, and Cretaceous Periods were quite different from each other. The extinctions at and near the end of the Cretaceous Period were especially significant because of their finality. The exact causes of these extinctions are not known, but there are many theories. Some of these include: eggshell thinning, rise of egg-stealing mammals, disease, asteroid impact, volcanic eruptions, and gradual climatic change.

As the Age of Reptiles ended, a new era began—the **Cenozoic**. Birds and mammals became the dominant vertebrate animals and filled niches left by the reptiles that once ruled.

Evolution of Feathers

Feathers may be considered glorified scales. They develop from structures in the skin, much like the development of scales in reptiles or hair in mammals.

The first feathers may have served as insulation for the animal. The function of feathers as an aid in flight developed secondarily. Colors and patterns in feathers may serve to attract a mate or act as camouflage.

Generally, there are two kinds of feathers. **Plumulaceous**, or fluffy feathers, are barbless and function as insulation, while **pennaceous** feathers are stiff and function in flight. **Proto**-feathers—early or pre-feathers—were more hair-like.

Archaeopteryx (ancient wing), was discovered in the 1860s in a limestone quarry near Solnhofen, Germany. The fossil clearly showed the impression of feathers. Scientists have dated the fossil at about 150 million years which places *Archaeopteryx* in the late Jurassic Period. For many years *Archaeopteryx* has been considered the first bird.

Wings and Flight

There are two major theories concerning the development of flight. One is the **arboreal** or trees-down approach. Here, it is believed that wings originated in? reptiles that climbed trees, perhaps in search of food. The so-called wing was then used to glide back down to the ground.

In the **terrestrial**, or ground-up theory, wings evolved in running reptiles to help the animal lunge after its prey.

With or without feathers, the structure of the skeletal anatomy should reveal whether an animal is a flying one or not. The key indications demonstrating flight are: the **coracoid** is at a near right angle to the scapula in the shoulder girdle; the **furcula**, or wishbone, is greater than that of *Archaeopteryx*; and the wrist bends sideways in the fashion of a bird.

The line between “feathered dinosaur” and “bird” is not entirely clear. Some specimens with feathers are dinosaurs and some are birds. It depends on whether or not the species in question had a flying ancestor. If so, then the animal is a flightless bird; if not, the animal is a feathered dinosaur.

How do Scientists Work?

The **Scientific Method** is an organized process for investigating natural phenomena. Random observations lead to the formation of questions about the how or why of something. A **hypothesis** or statement is then developed to provide a possible explanation or an answer to the question raised. Experiments are designed to test the hypothesis and gather data. From the information gathered, conclusions are drawn to prove or disprove the hypothesis.

In the case of paleontology, evidence comes from fossils. Two important factors are involved in this science: an ancient organism must have been fossilized (it is probable that many species did not fossilize) and the fossil must be discovered—an on-going process. These factors allow for speculation about what actually lived, how it lived, and how it was related to other organisms.

Glossary

Adaptation—any characteristic that helps an organism to survive and reproduce in the environment it inhabits
Archaeopteryx—fossil discovered in the 1860's with distinct feather impressions, first bird
Arboreal—living in or among trees, trees-down theory of flight
Aquatic—living in water
Barb—hair-like process attached to the rachis (central stem) of a feather
Barbule—projection on the barb of a feather that hooks the barbs together
Bipedal—walking on two feet
Calamus—hollow base of a feather
Cenozoic Era—followed Mesozoic Era, marked by rise of mammals and birds
Coracoid—bone in reptiles and birds that articulates with the scapula and the sternum
Cretaceous Period—final period of Mesozoic Era, 144–75 million years ago
Evolution—gradual change in a species over time
Furcula—"wishbone" of a bird
Homologous structure—structure that is similar in different organisms because the organisms are derived from a common ancestor (forelimb of a dinosaur compared with the wing of a bird)
Hooklet—small hook on a feather barbule
Hypothesis—possible explanation for a set of observations to answer a scientific question
Jurassic Period—second period of Mesozoic Era, 206–144 million years ago
Mesozoic Era—era in which dinosaurs emerged and developed, 248–65 million years ago
Metacarpal—part of hand between wrist and fingers
Mummified—preserved by drying
Pangea—super continent
Pennaceous—having the texture of a contour feather, as opposed to a down feather
Plumulaceous—having the texture of a down feather, fluffy
Proto—the earliest form of, such as proto-feathers
Pterosaur—extinct winged reptile
Pygostyle— in birds, the bone at the end of the spinal column formed by the fusion of several vertebrae
Quadrapedal—walking on four feet
Quill—lower part of feather shaft
Rachis—central stem of a feather
Scapula—bone that forms the shoulder blade
Scientific Method—organized system used to investigate natural phenomenon
Shaft—stem of a feather
Synapsid—mammal-like reptiles
Terrestrial—pertaining to earth, ground-up theory of flight
Triassic Period—first period of Mesozoic Era, 248–206 million years ago

Previst Activities

Greek and Latin Root Words

Language Arts Content Standards
Reading–Vocabulary Development—all grades

Scientific names may seem strange and impossible to pronounce. Often, these names describe the organism by using Greek or Latin words. These “root” words are found throughout the English language. Learning the meanings of these roots will help make more sense of scientific names as well as English in general.

Root words are often combined to make a compound word, so these words may be found at the beginning, middle, or end of a word.

• Create flash cards and practice learning these root words.

Root	Pronunciation	English translation
a, an		without
caudi	kaw dee	tail
comps	komp	elegant
crypto	kript	hidden
dactyl	dak til	finger
dein, *dino*		terrible
dromae	drom ee	running
gnathus	nay thus	jaw
Iguana		Iguana (a kind of lizard)
megalo		great, large
odon	oh don	tooth
onychos	on ik us	claw
ornis	orn is	bird
ori		mouth, a mountain
ovi		egg
pter	tair	wing
raptor		thief
rhynch	rink	snout, beak
saur		lizard
scans		climb
sino	sye nuh	Chinese
volan	vo lan	flying

• What do these names mean?
Iguan odon
Megalo saurus
Compso gnathus
Ptero saur
Pter an odon
Ovi raptor
Caudi pteryx
Ptero dactyl
Dromaeo saur
Pteo rhyn chus
Confucius ornis
Sino saur opteryx
Scans ori opteryx

Feathers
Science Content Standards
Life Science—grades 3, 6, 7

• Obtain some clean feathers. Craft stores are a good source.
Look for the:

shaft	the stem
quill	lower part of the shaft
rachis(RAY kis)	remainder of the shaft
barb	branches off the shaft (together form a vane on either side of the shaft)
barbule	extends from the barb
hooklet	found on ends of barbule

Scientific method
Science Content Standards
Investigation and Experimentation—all grades

Scientific Investigations follow a set of guidelines in a defined sequence.
a. Witnessing a phenomenon or occurrence may lead to a question “I wonder what would happen if I _____?“
b. Develop a hypothesis. “I think that if I do _____ , this will happen.”
c. Design an experiment to prove or disprove your hypothesis.
d. Observe the results of the experiment, collect, and interpret the data.
e. Draw conclusions based on your experiment and decide if your hypothesis was correct or not.

• Discuss the scientific investigation process.

• Arrange the following steps in sequence to illustrates the scientific method. Note: they are out of order.

a. Collect and interpret data

b. Design an experiment

c. Witness an occurrence

d. Develop a hypothesis

e. Draw conclusions

f. Pose a question

Geography
History/Social Studies Content Standards
Maps—grade 1, 2, 3, 4

Fossils are found all over the world. In this exhibition, locations of fossil discoveries are noted.
• Use a globe, world map, atlas, or other resource to locate:

Montana
Kansas
Connecticut
Inner Mongolia
England
China
Liaoning Province, China
Germany

Museum Visit Activity
Feathered Dinosaur Scavenger Hunt

The bold-face print is related to labels in the exhibit and provides clues where to look for the answers.

1. Early History of Dinosaurs and Birds
Two Legged Dinosaurs

a. The first skeleton of *Compsognathus* was found in 1859. The skeleton shows that *Compsognathus* walked on _____ feet.
two or four

b. Another word for this method of walking is _____

c. From the *Compsognathus* fossil, Thomas Huxley noted that birds might be related to _____.

2. Evolution of the Feather
Peacock

a. Feathers help an animal fly. Feathers are also used for _____

Pterorhynchus

b. *Pterorhynchus* had fluffy, or down-like feathers called _____ feathers.

3. The Origin of Flight and Flying Dromaesaurs
Diversity of Flight

a. *Pterosaurs*, _____, and _____ have arms that have developed into wings. **Dromaeosaur Without Feathers**

b. Name one skeletal feature that shows that an animal could fly.

_____

To Fly or not to Fly

c. Even if it had feathers, an animal that did not go through the process of flight can not be called a _____.

Scansoriopteryx

Scansoriopteryx means _____ _____. Study of this fossil

led to a belief that bird ancestors lived in _____.

4. Bird Diversity

A variety of bird fossils from the Mesozoic Era have been found, including *Archaeopteryx, Herperornis regalis*, and *Ichthyornis victor*.

Archaeopteryx lithographica

a. How was *Archaeopteryx* different from modern birds?

Herperornis regalis

b. *Herperornis* was a bird that could not fly. It was adapted for life in and near

the _____.

Ichthyornis victor

c. Ichthyornis appears to have been a _____ flyer.
strong weak

Bonus: What does its name mean?

5. Flightless Birds

Flying *Dromaeosaurs*

a. *Cryptovolans* had _____ feathers.
flight or fluffy

b. In this exhibit, *Dromaeosaurs* such as *Velociraptor* and *Deinonychus* are said

to be _____ instead of dinosaurs.

Post-visit Activities

Based upon your exhibit observations, answer the following questions. Give a reason for your answer.

1. Do you think birds are really dinosaurs?
2. Do you think some dinosaurs are actually birds?
3. Do you think flight originated from the trees down or the ground up?
4. What is the relationship between dinosaurs and birds?
5. Draw a picture of *Velociraptor* with feathers.

Answers to Museum Visit Scavenger Hunt
1. a. two b. bipedal c. dinosaurs
2. a. insulation, ornamentation b. proto-
3. a. bats, birds b. a wish bone, or furcula, shoulder girdle, sideways wrist, tail with bony rods. c. bird
4. a. teeth, clawed fingers b. water c. strong bonus. fish bird
5. a. flight b. flightless birds

Resources
www.dinosaur-museum.org/index.html
www.newscientist.com/news/print.jsp?id=ns99992002
www.ucmp.berkeley.edu/diaspids/birds/archaepteryx.html
www.enchantedlearning.com/subjects/dinosaurs
www.sciam.com/print
www.sdnhm.org/exhibits/feathered

Arnold, Caroline. *Dinosaurs with Feathers.* Clarion Books: New York, 2001. ISBN 0-618-00398-3

Czerkas, Sylvia J. *Feathered Dinosaurs and the Origin of Flight.* The Dinosaur Museum, 2002. ISBN 1-032075-01-1

Wenzel, Gregory. *Feathered Dinosaurs of China*. Charlesbridge Publishing, 2004.
ISBN 1570915628

Credits
The exhibition is organized and circulated by The Dinosaur Museum, Utah, in association with The Liaoning Fossil Administration Office, China.

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