AMERICAN MUSEUM of NATURAL HISTORY

EDUCATOR'S GUIDE

DINOSAURS AMONG US

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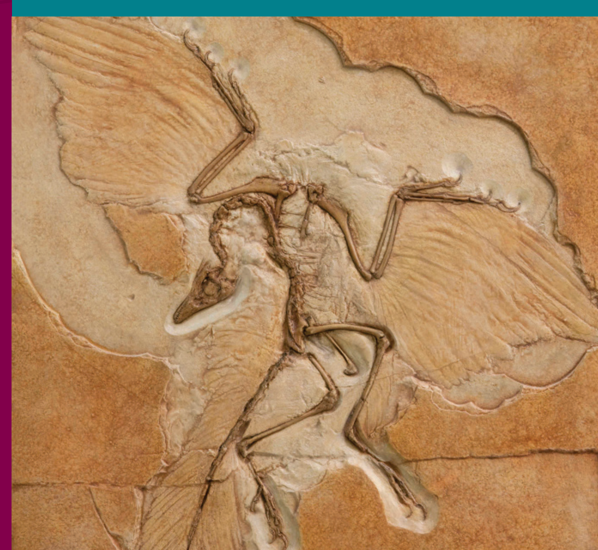

amnh.org/dinosaurs-among-us/educators

MAP of the Exhibition

Dinosaurs Among Us highlights the evolutionary connections between living dinosaurs—birds—and their extinct relatives.

This exhibition uses "extinct dinosaur" or "non-bird dinosaur" for extinct members of Dinosauria, and "bird" to mean all the descendants of the last common ancestor of living birds.

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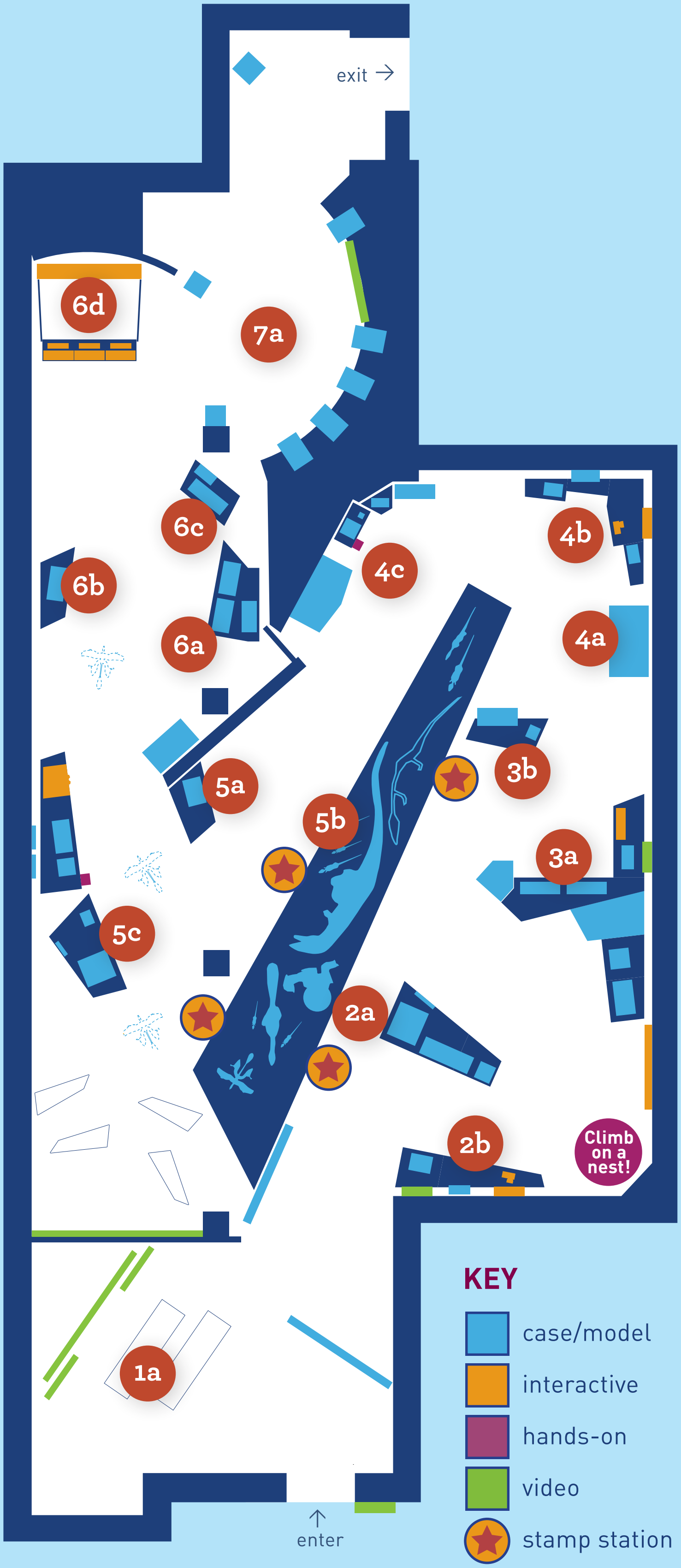
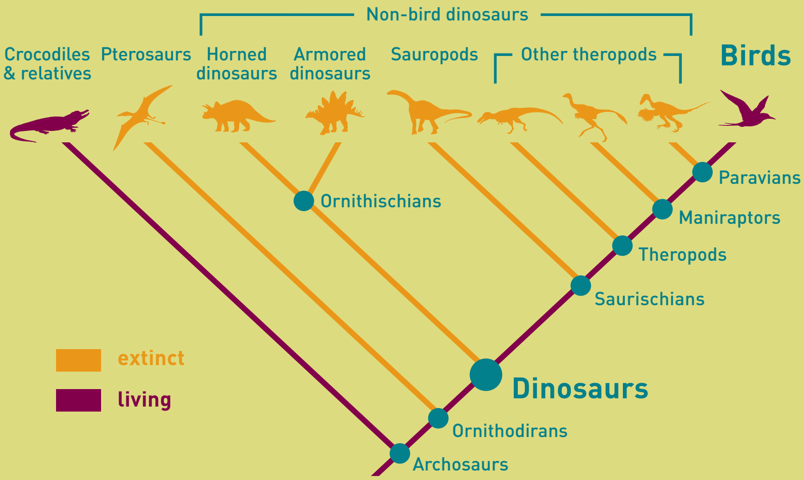


ESSENTIAL Questions

What are dinosaurs?

Dinosaurs are a group of animals that includes both birds, from hummingbirds to ostriches, and the non-bird dinosaurs like *T. rex* and *Stegosaurus*. A feature that distinguishes most dinosaurs from all other animals is a hole in the hip bone, which helps them to stand upright—unlike crocodiles, which are the closest living relatives of birds.



The group called Dinosauria includes the extinct dinosaurs and all their living descendants. All its members, including living birds, descended from the very first dinosaur—their common ancestor. That's why birds are a kind of dinosaur (just as humans are a kind of primate).

The earliest known dinosaur occurred over 228 million years ago (mya). Dinosaurs evolved into a very diverse group of animals with a vast array of physical features. There were small, feathered carnivorous dinosaurs such as *Xiaotingia*, and massive herbivorous dinosaurs like titanosaurs. The first bird, a kind of **theropod** dinosaur, appeared during the Jurassic Period (about 150 mya). This is the common ancestor of all birds. With perhaps as many as 18,000 species alive today, birds—the only living dinosaurs—now occupy every continent and almost every ecological niche.

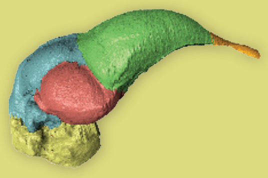
What is the evidence that birds are dinosaurs?

Birds have features and behaviors that are seen in non-bird dinosaur **fossils**:

- **Feathers:** Birds are the only living animals with feathers, which were once thought to have evolved specifically for flight. The discovery of more and more feathered non-flying dinosaurs disproved that theory. Feathers serve many functions besides flight, including locomotion, insulation, protection, and display.
- **Nests and eggs:** Nest-building, egg-laying, and brooding are regarded as quintessential bird traits, but evidence of these behaviors has been observed across groups of non-bird dinosaurs. Well-preserved fossils, like this one of the non-bird dinosaur *Citipati*, reveal that it demonstrated a behavior—parental care—common to nearly all living birds.

This rare fossil, known as Big Mama, preserves a moment in time. The *Citipati* died spreading its forearms to protect its eggs. Birds today assume the same position when brooding their eggs.

- **Internal organs:** Soft tissue, such as brains, is almost never preserved in the fossil record—but imprints sometimes are. Non-bird dinosaurs that were closely related to birds had particularly large brains that filled the entire braincase and left imprints on the inside of their skulls. Scientists are now using digital scans of fossil skulls to determine the size and shape of dinosaur brains, which contain important clues to how the animal functioned in the world. When scientists compare these findings to the brains of living birds, they find surprising similarities and intriguing differences.



Scientists use computed tomography (CT) scans of dinosaur skulls to create detailed, 3D reconstructions of their interiors. This one shows the space inside the skull of *Archaeopteryx*, an early bird.

The more comparisons we make between birds and their closest non-bird dinosaur relatives, the more connections we find.

How do scientists piece together the story of dinosaur evolution?

To understand the history of life on Earth, scientists look at evidence from both living and extinct species. To learn about ancient life, scientists collect and study fossils. They also study living birds and their reptilian relatives—their anatomy, genetics, and behavior—for insight into how they are related to each other. This process—comparative biology—is a powerful approach to understanding evolutionary history. Scientists organize and interpret all of this evidence in order to figure out the place of dinosaurs, including birds, on the tree of life.

TEACHING in the Exhibition

1. Introduction

1a. Transformation theater: This exhibition examines how one group of dinosaurs evolved into the array of living creatures we call birds. As students walk through this intro section, they can look at an artistic representation of dinosaur transformation over evolutionary time.

2. Nests, Eggs & Babies

2a. *Citipati*: Oviraptorid adults, with their eggs and young, look strikingly like modern birds attending their nests. Have students examine a cast of the amazing "Big Mama" fossil, which was found in Mongolia's Gobi desert. Fossils like this tell us not only what these extinct creatures looked like, but also how they behaved. Like shared physical traits, shared behaviors are clues to a common ancestry. Have students compare the model of *Citipati* nest to those of other archosaurs, including crocodiles and modern birds.

model of *Citipati* nest

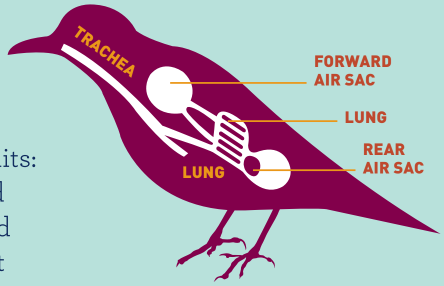
2b. Eggs: Watertight eggs allowed life to move from water onto land. The shells are substantial enough to contain food and water, yet porous enough to let oxygen in and carbon dioxide out—allowing the developing embryo to "breathe." Have students explore different kinds of terrestrial eggs. Make sure they examine a cast of "Baby Louie," a very rare fossil of an oviraptorid embryo.

a cast of the "Baby Louie" fossil

3. Brains, Lungs & Hearts

3a. Brains: Soft tissue doesn't usually fossilize, so scientists study skulls in order to infer characteristics of the brains of extinct animals. Have students examine a dozen endocasts to see what similarities and differences they reveal between the brains of non-bird dinosaurs and birds.

3b. Lungs and hearts: Birds and some of their reptilian relatives share similar internal traits: super-efficient lungs and powerful four-chambered hearts. This predicts that extinct non-bird dinosaurs had them, too. Have students look at the models and diagrams to see how these organs function.



When birds breathe, fresh air flows in one direction through the lung, moving from the rear air sac to the front air sac, before going back out the trachea. This allows birds to extract a high percentage of oxygen from the air.

4. Bones, Beaks & Claws

4a. *Khaan mckennai*: Known to paleontologists as "Sid and Nancy," these two fossils have exquisitely well-preserved skeletons. The two dinosaurs were buried when a sand dune collapsed on them about 75 million years ago. Have students look at them closely for characters that birds possess, such as the wishbone.

These animals belong to the group known as oviraptorids: fairly small, bird-like dinosaurs with toothless beaks and wishbones, as well as skulls filled with air pockets. Some have even been found sitting on eggs, the brooding posture typical of modern birds.

4b. Hollow bones, wishbones, and growth rings: Birds have wishbones and hollow bones, adaptations that help with flight. It turns out that many non-bird dinosaurs share these traits, even though they never left the ground! These discoveries indicate that structures that assist in flight did not necessarily evolve for that purpose. Have students examine these bones and use a digital microscope to compare and contrast solid and hollow bones.

4c. Feet and claws: Similarities between non-bird dinosaurs and birds are especially striking when it comes to legs, feet, and claws. Have students compare these features on models and fossil casts, and think about how they were used and what accounts for the similarities.

5. Feathers

5a. Feather array: Feathers come in different colors, sizes, architectures, and shapes, and serve many different functions—flight is just one. Have students compare and contrast the various modern and fossil feathers.

Feathers are light and airy but also are extremely sturdy. So feather fossils are not uncommon. This specimen is from a modern bird that lived around 50 million years ago.

5b. *Psittacosaurus, Archaeopteryx, Tianyulong,* and *Yutyrannus*: Many dinosaur species had feathers, some of which had unusual primitive structures. Students can explore the models of feathered dinosaurs from different branches of the dinosaur family tree.

Scientists identify feathery fibers extending off the tail of *Psittacosaurus*.

5c. Feathered fossils and casts: Scientists study the fossil feathers of extinct dinosaurs to understand the transition from non-bird dinosaurs to birds. Have students examine the fossils and casts on display for evidence of feathers.

6. Flight

***Microraptor* illustration**

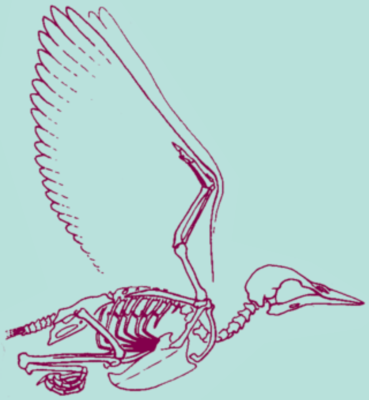
6a. *Microraptor, Confuciusornis,* and *Xiaotingia*: These animals range from an early bird to non-bird feathered dinosaurs, which may have had some aerial locomotion. The evolution of feathers was just the beginning—over millions of years, bodies became better adapted to move through air. Here students can observe fossil casts of feathers, and explore the different ways dinosaurs have used feathers to get around.

Simple, symmetrical feathers evolved before dinosaurs could fly. *Microraptor* is the first dinosaur ever found with asymmetrical feathers, which are adapted specifically for moving through the air.

symmetrical **asymmetrical**

6b. Wings: Wings capable of supporting true, powered flight evolved independently in three vertebrate groups: dinosaurs (more specifically, birds), bats, and pterosaurs (now extinct). Have students examine the casts of wings to compare the very different ways that flight evolved in these three groups.

6c. Extinct birds: Fully modern birds filled the skies by at least 70 million years ago. They possessed all the key adaptations for powered flight, including full-size wings, shoulders that permit a full range of flapping movements, and fused skeletal elements. Have students examine fossils and casts of birds and discuss the traits that make them "modern."



In advanced birds, the shoulder joint is able to rotate upward, allowing the wings to flap through a nearly 180 degree arc.

6d. "Will It Fly?" interactive: How do paleontologists figure out whether an extinct animal could have flown? They compare fossil skeletons to modern ones, study flight in living birds, and develop biomechanical models that may indicate the flight potential of extinct animals, which we can't examine directly. Students can use this interactive to "build" a feathered dinosaur and see if it will move through the air.

7. The New Age of Dinosaurs

Grey Heron

7a. Cladogram and bird array: The last 65 million years has seen an explosive diversification of birds; today they number perhaps 18,000 species. This final section celebrates this diversity and reveals behavioral glimpses of extant birds' theropod ancestry. Have students explore the array of birds shown here, as well as the cladogram (located near the "Will It Fly?" interactive) that illustrates how today, most scientists define birds not by features, but by shared ancestry and evolutionary relationships.

baby chicken

geese

Come Prepared Checklist

- [ ] **Plan your visit.** For information about reservations, transportation, and lunchrooms, visit amnh.org/plan-your-visit/school-or-camp-group-visit.
- [ ] **Read the Essential Questions** to see how themes in the exhibition connect to your curriculum.
- [ ] **Review the Teaching in the Exhibition** section for an advance look at what your class will encounter.
- [ ] **Download activities and student worksheets** at amnh.org/dinosaurs-among-us/educators. They are designed for use before, during, and after your visit.
- [ ] **Decide how your class will explore the exhibition:**
  - You and your chaperones can facilitate the visit using the Teaching in the Exhibition section.
  - Students can use the worksheets and/or maps to explore the exhibition on their own or in small groups.

Correlation to Standards

A Framework for K-12 Science Education

Science Practices • Asking questions • Developing and using models • Planning and carrying out investigations • Constructing explanations • Engaging in argument from evidence • Obtaining, evaluating, and communicating information

Crosscutting Concepts • Patterns • Cause and effect: Mechanism and explanation • Scale, proportion, and quantity • Systems and system models • Structure and function

Disciplinary Core Ideas • LS1: From Molecules to Organisms: Structures and Processes • LS2: Ecosystems: Interactions, Energy, and Dynamics • LS3: Heredity: Inheritance and Variation of Traits • LS4: Biological Evolution: Unity and Diversity

Glossary

brooding: sitting on eggs until they hatch

computed tomography (CT): a scanning process that combines many X-rays to produce a three-dimensional image

endocast: a cast or impression of the interior of a hollow object

extant: still in existence; not extinct

fossils: the remains of ancient organisms such as teeth, bone, wood, or shell; or evidence of activity such as footprints and burrows

primitive: original; the ancestral condition. Primitive traits precede **advanced** ones, which are more modified and less like the original condition.

theropod: a diverse group of fast-moving, bipedal, carnivorous dinosaurs. Birds are theropods.

What is natural selection?

Species diversify over time, a process called evolution. We know this from evidence preserved in the fossil record. Over time, cumulative mutations in an organism can result in new traits, which are inherited generation to generation. Some—downy feathers for warmth, for example, or upright stance for speed and endurance—help individuals survive in a changing environment. Individuals with the advantageous trait, or adaptation, will produce more offspring, until most or even all members of the species possess it. Called natural selection, this is an important mechanism of evolution.

CREDITS

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Photo Credits

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