AMERICAN MUSEUM of NATURAL HISTORY

EDUCATOR'S GUIDE

PTEROSAURS

FLIGHT IN THE AGE OF DINOSAURS

INSIDE

- **Map of the Exhibition**
- **Essential Questions**
- **Teaching in the Exhibition**
- **Come Prepared Checklist**
- **Correlation to Standards**
- **Glossary**

ONLINE

- **Activities and Worksheets for Grades K-2, 3-5, 6-8, and 9-12**
- **Additional Resources**

amnh.org/pterosaurs/educators

The Museum gratefully acknowledges the Richard and Karen LeFrak Exhibition and Education Fund.

MAP of the Exhibition

Pterosaurs: Flight in the Age of Dinosaurs draws on the fossil record to create breathtaking portraits of these astonishing animals, the first vertebrates to take to the air.

Fossils, models, illustrations, videos, and interactive exhibits show how pterosaurs developed flight, diversified, and spread across the globe.

1 What Is a Pterosaur?

1a. Big and Small
1b. Intro Theater
1c. Fragile Fossils
1d. Evolution

2 From the Ground Up

2a. Life Cycle
2b. Locomotion on Land

3 Into the Air

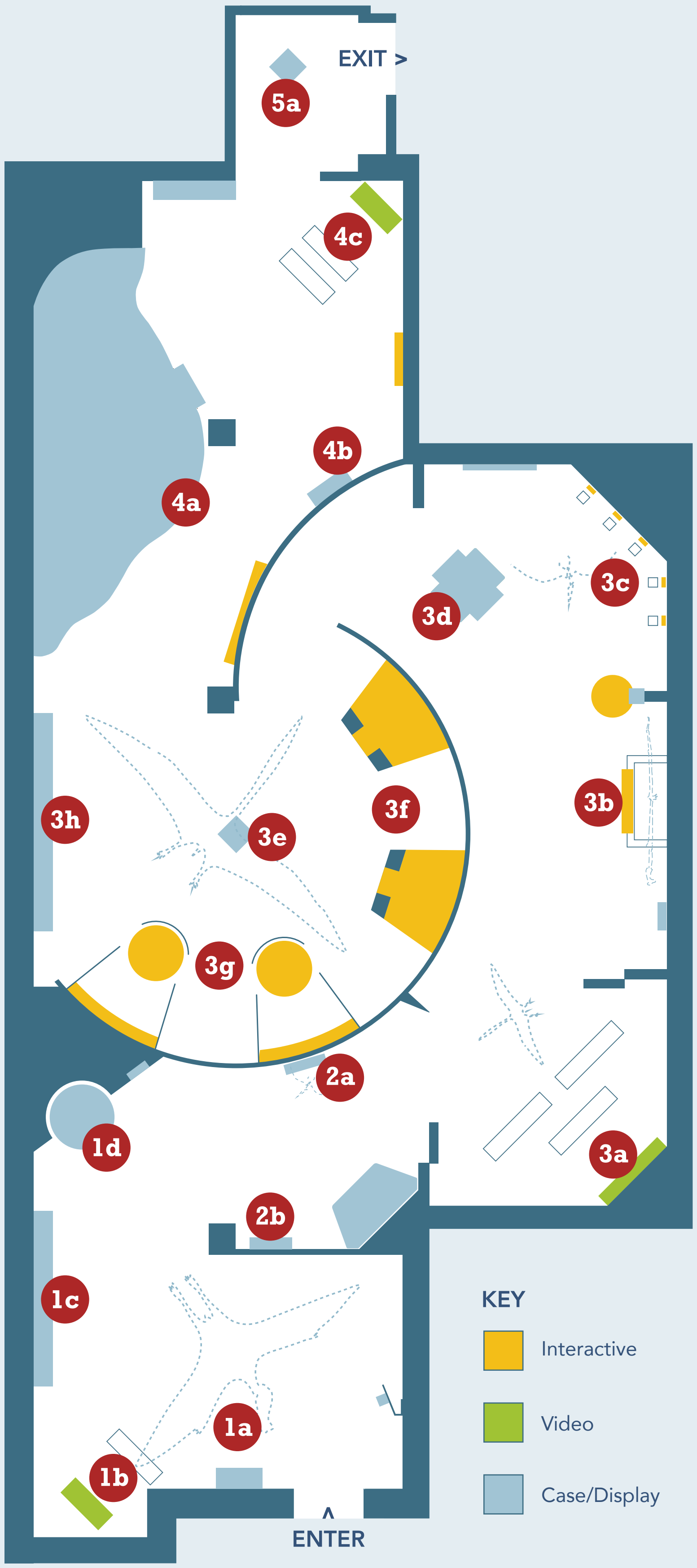
3a. Aerodynamics Theater
3b. Wing Structure
3c. iPad Interactives
3d. Skin Texture & Covering
3e. King of the Air
3f. Virtual Wind Tunnel
3g. Fly Like a Pterosaur
3h. Crests

4 A Watery World

4a. Diorama & Fossils
4b. Feeding
4c. Fossilization Theater

5 The Next Big Thing?

5a. Remains of a Giant

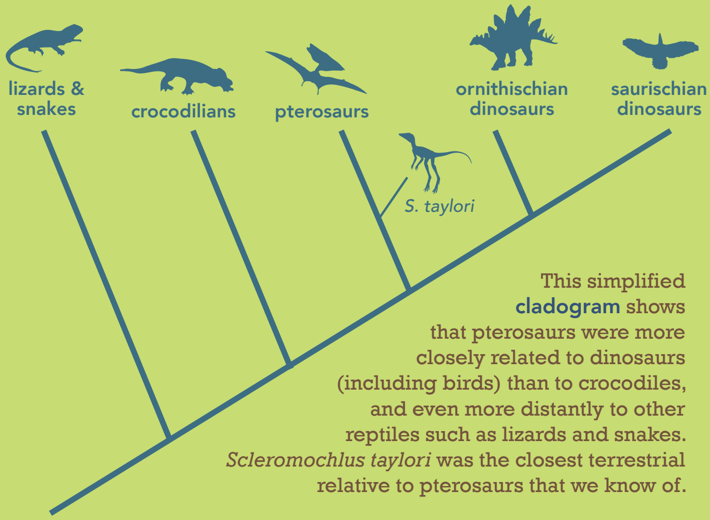


ESSENTIAL Questions

Use the Essential Questions below to connect the exhibition's themes to your curriculum. Identify key points that you'd like your students to learn. Bolded words are defined in the Glossary.

What were pterosaurs?

Pterosaurs were an extremely successful group of flying reptiles that first appeared more than 220 million years ago (mya). Not **dinosaurs**, they lived alongside them during the **Mesozoic Era**. Pterosaurs **evolved** from a land-dwelling reptile and flourished for more than 150 million years before becoming extinct. They flew well, and were the first and largest **vertebrates** ever to take to the air. Pterosaurs hatched from eggs with wings fully formed and could probably fly within a few days, so they likely fended for themselves from the start. When on the ground, they walked on all four limbs instead of hopping or running on two legs.



This simplified **cladogram** shows that pterosaurs were more closely related to dinosaurs (including birds) than to crocodiles, and even more distantly to other reptiles such as lizards and snakes. *Scleromochlus taylori* was the closest terrestrial relative to pterosaurs that we know of.

How do scientists use fossils to study pterosaurs?

To learn about long-extinct animals, **paleontologists** study their **fossil** remains. Fossils are rare, and pterosaur fossils especially so. Because pterosaurs were adapted for flight, their bones were extraordinarily thin and fragile. Their eggs had soft shells, like those of snakes and lizards, so not many have been preserved. And only a tiny fraction died in environments where fossils could form, mostly lagoons, where the body sank undisturbed and was quickly covered by very fine sediment. In order to describe a particular **species**, paleontologists often have to gather information from several specimens, or extrapolate from related pterosaurs that are better known. The animals also left tracks on the ground, and based on evidence from fossil **trackways**, paleontologists have learned how pterosaurs landed, walked, and stood.

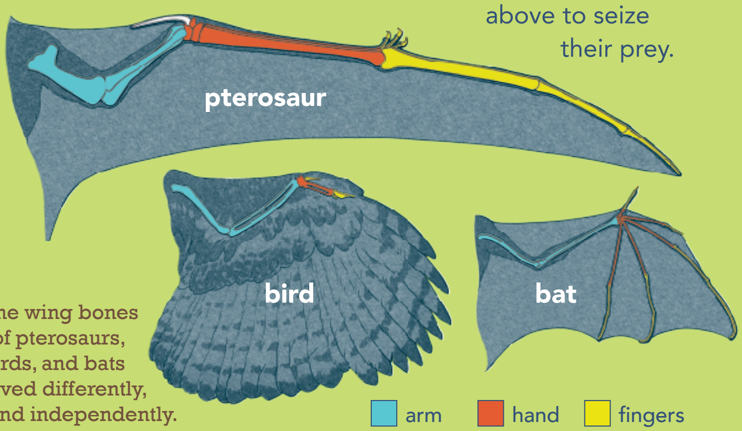
How diverse were pterosaurs?

Although the fossil record is incomplete, scientists think pterosaurs were abundant and diverse. Pterosaurs have been identified on every continent. So far, more than 150 species have been identified, and scientists estimate that thousands more species probably existed. All shared the same basic body plan, but species varied dramatically in size. Some had wingspans over 30 feet (three times that of a wandering albatross, the largest flying animal alive today), and others were smaller than a sparrow. While many early species had no head crests, some later ones, especially the giant pterosaurs of the Late Cretaceous, sported truly spectacular ones. Pterosaur fossils show a wide range of feeding **adaptations**, from daggerlike teeth clearly suited to stabbing prey or spearing fish to comblike teeth for straining seawater. Some pterosaurs had no teeth at all. Diverse and widespread, pterosaurs flourished for more than 150 million years.

The large, crushing teeth of *Dsungaripterus weii* could pulverize shellfish.

How did pterosaurs fly?

These were the first animals with backbones to truly fly — not just leaping or gliding or parachuting, but using their own muscles to generate **lift** and travel through the air. A number of adaptations made flight possible: a greatly elongated fourth finger of the hand that evolved to support a wing; flexible, hollow bones; and membranes between different parts of the body. Some pterosaurs had long thin wings and could soar like condors, while short stubby wings like a pigeon's made others acrobatic flyers. Tail fins on some species may have operated like rudders. Flight would have allowed pterosaurs to travel long distances, exploit new habitats, escape predators — and swoop down from above to seize their prey.



The wing bones of pterosaurs, birds, and bats evolved differently, and independently.

TEACHING in the Exhibition

1 What Is a Pterosaur?

1a. Big and Small: All pterosaurs shared the same basic body plan, but species differed widely. Students can observe the models of *Tropeognathus* and *Nemicolopterus*, compare the corresponding fossil casts, and note unique features.

Nemicolopterus crypticus had a wing span of just 10 inches (25 cm). Its name means "hidden flying forest-dweller."

1b. Intro Theater: In this video, experts dispel common myths and misconceptions about pterosaurs and explain basic facts. *(e.g. Pterosaurs are flying reptiles — not dinosaurs, which includes birds. Pterosaurs lived millions of years before humans evolved.)*

1c. Fragile Fossils: Everything we know about pterosaurs comes from fossils. Students can explore this section to learn about the process of fossilization and how pterosaur fossils were first discovered. They can also examine why pterosaur fossils are so rare. *(Pterosaurs had especially fragile bones that preserved poorly.)*

This fossil animal's long forelimbs perplexed early naturalists. In 1809, it was finally identified as a flying reptile and named *ptéro-dactyle*, meaning "wing finger."

1d. Evolution: From a land-dwelling reptilian ancestor, pterosaurs evolved into a spectacularly diverse group of flying species. Students can find pterosaurs on a 3-D tree of life. They can also observe the diversity of features, such as specialized jaws and crests or different shapes and sizes within the group.

2 From the Ground Up

2a. Life Cycle: Fossils of very young pterosaurs are exceptionally rare because their delicate bodies were easily destroyed. Students can explore recent discoveries that shed light on a pterosaur's first few days of life.

2b. Locomotion on Land: Pterosaurs were quadrupedal — they walked on all four limbs. Students can examine trackways from Utah and Morocco to see if they can identify impressions of the hands and feet and infer how these creatures moved on land.

Fossil tracks indicate that pterosaurs, like this *Dimorphodon macronyx*, walked on all four limbs, tucking up their wings like folded umbrellas.

3 Into the Air

3a. Aerodynamics Theater: This video introduces the basic principles of flight — lift, drag, weight, thrust, angle of attack, wing shape, and overall strength and stability — so students can go on to explore how pterosaurs flew.

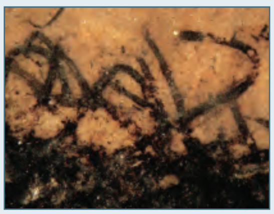
3b. Wing Structure: Although many animals can glide through the air, pterosaurs, birds, and bats are the only vertebrates to have evolved powered flight. This section will show how their bodies evolved differently — and independently — to make flight possible. Students can find the arm and hand bones and the impressions of wing and tail membranes in the *Rhamphorhynchus* fossil. Next, they can compare the wing bones of pterosaurs, birds, and bats to their own arms and hands, using the human arm illustration as a guide.

This remarkably well-preserved skeleton belonged to *Rhamphorhynchus muensteri*, a long-tailed, dagger-toothed pterosaur from the Late Jurassic. Wrinkles from its partly folded wings can still be seen.

Fossils show form, but not color. The colors of the pterosaurs in this exhibition are borrowed from living animals that scientists think live in similar ways.

3c. iPad Interactives: Stations give students an in-depth look at the anatomy and behavior of five species: *Pteranodon*, *Pterodaustro*, *Jeholopterus*, *Tupuxuara*, and *Dimorphodon*. They can also explore interactive maps, annotated fossils, and paleontologist interviews.

3d. Skin Texture & Covering: Unusual fossils, like those of *Rhamphorhynchus* and *Sordes*, enable scientists to understand more about small-scale structures like wing membranes and skin coverings. Students can investigate: What do these fossils show about pterosaur wings? *(Wing membranes can be stretched taut or folded up like a fan.)* What do fossils show about pterosaur skin coverings? *(Their bodies were covered with fibers that look like fur.)* From this fossil evidence, what can scientists infer about pterosaur metabolism? *(These animals were probably warm blooded.)*

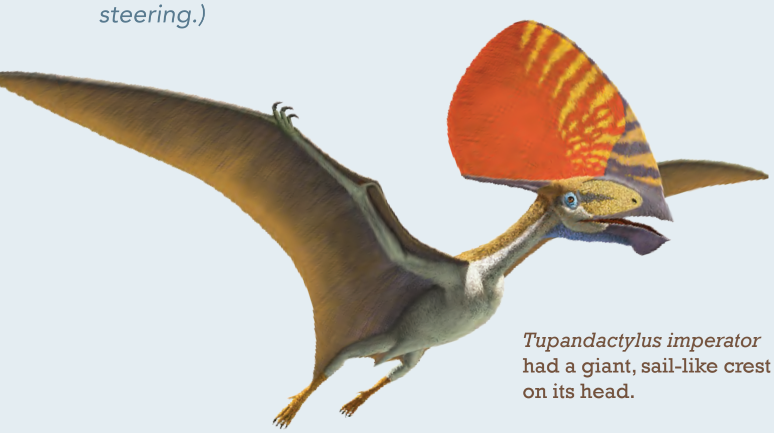

Fossils show that pterosaurs kept warm with a thick coat of fibers similar to fur.

3e. King of the Air: To learn how *Quetzalcoatlus* looked in life, researchers studied the fossils they found — parts of one wing — and compare them to the remains of smaller, closely related pterosaurs found nearby. Students can observe the largest pterosaur described so far.

3f. Virtual Wind Tunnel: Using their hands, students can experiment with the basic principles of flight: lift, weight, drag, and speed.

3g. Fly Like a Pterosaur: This full-body immersive experience challenges students to keep their pterosaur aloft and to target prey like fish or insects.

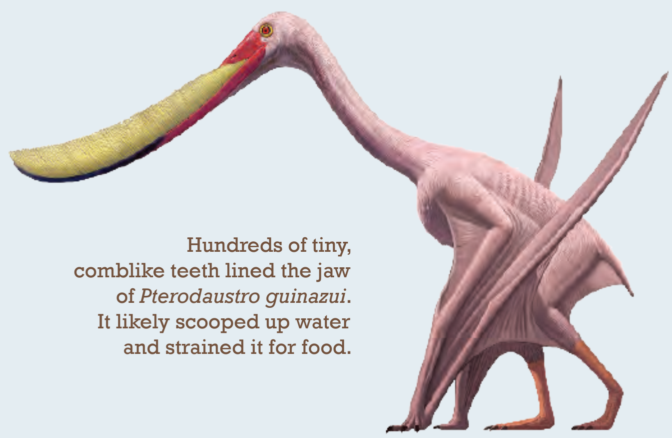
3h. Crests: While many pterosaurs had no head crests or very small ones, some crests were spectacular. Students can examine the different kinds of crests — blades that could stick up, back, or forward — and what they might have been used for. *(Probably for species recognition or sexual selection; other possibilities include cooling and steering.)*


Tupandactylus imperator had a giant, sail-like crest on its head.

4 A Watery World

4a. Diorama & Fossils: Based entirely on fossil evidence, this dramatic scene of a South American lagoon 110 million years ago depicts pterosaurs and many other ancient organisms. Students can look at the scene and see how many different species they can spot. They can also identify adaptations that helped *Thalassodromeus* survive in this environment. *(e.g. Its long blade-like jaws are streamlined for dipping into the water to snatch fish.)* Then they can examine fossils from the Romualdo Formation to explore how they formed and why these fossils are especially useful to scientists. *(They were not crushed flat like most pterosaur fossils but preserved in three dimensions, retaining more details.)*

4b. Feeding: Pterosaurs had an incredible diversity of feeding adaptations. Students can observe fossils, photos, and illustrations of pterosaurs and modern animals to learn about how and what they may have eaten. Then they can test their understanding with the matching game.


Hundreds of tiny, comblike teeth lined the jaw of *Pterodaustro guinazui*. It likely scooped up water and strained it for food.

4c. Fossilization Theater: This video discusses how fossils form, and why pterosaur fossils are so rare.

5 The Next Big Thing?

5a. Remains of a Giant: With each new discovery, our understanding of how these ancient reptiles lived will continue to change. Students can examine a neck vertebra fossil that paleontologists recently discovered in Romania. It belonged to an unknown species of pterosaur that was as big as *Quetzalcoatlus*, but much more massive!

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. Identify the key points that you'd like your students to learn.
- ☐ **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/pterosaurs/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.
  - Your students can use the worksheets to explore the exhibition on their own or in small groups.
  - Students, individually or in groups, can use the map to choose their own paths.

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

adaptation: a physical or behavioral characteristic that helps an organism survive in a particular environment

cladogram: a tree-like diagram that depicts how organisms are related to one another. Branching points represent where advanced features appeared and species diverged from common ancestors.

dinosaurs: a diverse group of animals that includes tens of thousands of extinct species, from *T. rex* to *Triceratops*, and all birds. A defining feature of dinosaurs is a hole in the hip socket that allows them to stand upright. All non-avian (non-bird) dinosaurs went extinct about 66 million years ago.

evolution: the process by which populations accumulate genetic changes over time that are passed on from ancestors to subsequent generations; descent with modification

fossil: traces or remains of ancient life — including bones, teeth, shells, leaf impressions, nests, and footprints — that are typically preserved in rocks

lift: the aerodynamic force generated by wings that opposes the weight of objects and keeps them in the air

Mesozoic Era: the time from 252 million to about 66 million years ago, which includes the Triassic, Jurassic, and Cretaceous periods. Early in the Mesozoic the first dinosaurs, pterosaurs, and mammals appeared, followed by the first birds and flowering plants.

paleontologist: a scientist who studies fossils

species: a basic unit of biological classification. Members of a species share ancestry and characteristics and can interbreed to produce fertile offspring.

trackway: a series of fossilized footprints. Trackways provide clues to the animal's size, speed, and behavior.

vertebrate: animal with a backbone

CREDITS

Pterosaurs: Flight in the Age of Dinosaurs was organized by the American Museum of Natural History, New York (amnh.org).

The Museum gratefully acknowledges the **Richard and Karen LeFrak Exhibition and Education Fund**.

Photo Credits

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